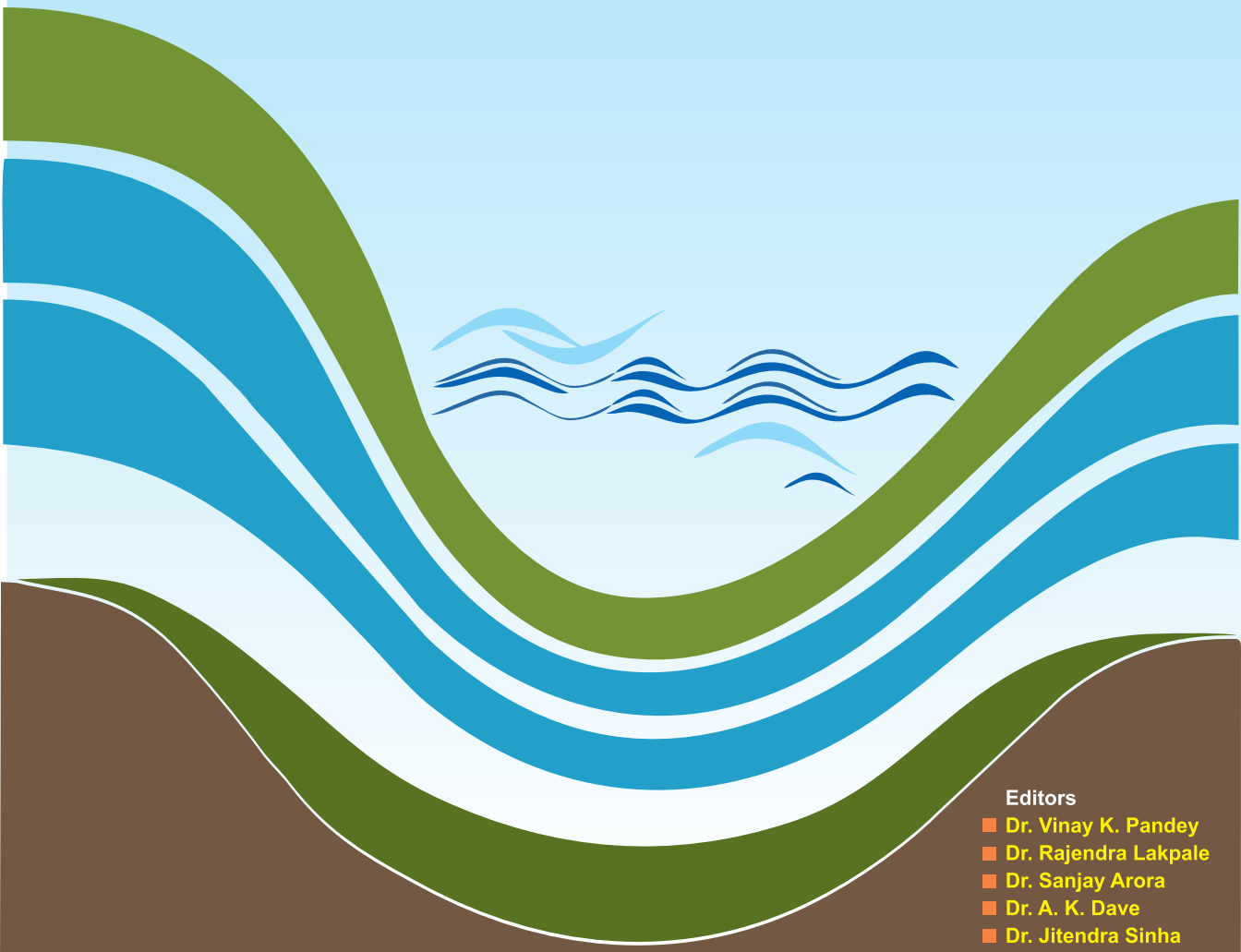
Land and Water Management for Food and Livelihood Security



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FOREWORD

On account of increasing population, the demand for food and employment is rising. We have no alternative, but to enhance our agricultural productivity and livelihood security by sustainable management of land and water resources. India faces challenges to increase its food production to the tune of 300 tons by the year 2020 in order to feed its ever-growing population. The country needs to produce 50% more food grain by the year 2020. Urgent action is needed to speed up agricultural development to meet the said requirements. Hence, scientists and planners need to realize the importance of sustainable land and water management for development of agriculture sector of the country. Therefore, it is necessary to invest in development of improved technologies as well as better management of available natural resource in order to achieve food and livelihood security.

It is a pleasure to know that 1st Asian Conference on "Water and Land Management for Food and Livelihood Security" is being organized by Indira Gandhi Krishi Vishwavidyalaya (IGKV) in collaboration with Soil Conservation Society of India, New Delhi during January 20-22, 2017 which aims to promote scientific exchanges and to share the latest developments in Integrated Water and Land Resources Management and Hydrologic Modeling, Geospatial Technology, River Basin Management and Inter- basin transfers & Resolving conflicts, Policy issues in Land and Water use, Water and Land productivity in Agriculture, Watershed Management, Groundwater Exploration, Recharge and Management, Water and Land Quality, Pollution and Remediation, Water and Land in relation to climate change and food & livelihood security.

To take stock of present situation arising out of pressure from all the corners to provide water, land, food and environmental security, it is essential, perhaps mandatory to have sound scientific and technical deliberations on the subject to identify cost effective, ecofriendly and sustainable technologies.

I congratulate the convener, organizing secretary and other colleagues who have done an excellent job in compiling information on specific themes in the form of technical publication. This compilation, I hope can serve as a useful reference for research scientists and others. I extend my heartiest wishes to the participating delegates for successful and result oriented deliberations.

(S.K. Patil)

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स्वामी विवेकानंद कृषि अभियांत्रिकी एवं प्राद्योगिकी महाविद्यालय एवं अनुसंधान केन्द्र
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PREFACE

Natural resources are the most precious gift of nature to the mankind. Conservation and judicious management of the major natural resources, such as land and water are of paramount importance for sustainable production. Management of these resources is the frontline of the struggle food security. Indicators show that resources like water, forests, and soil are under extreme pressure due to our current practices and their productivities are declining. Failure to manage these resources sustainably and equitably in many cases is leading to conflict and disaster. Proper management of water and therefore, has a key role to play in food and livelihood security.

For this reason, 1st Asian Conference on "Water and Land Management for Food and Livelihood Security" is being organized by Indira Gandhi Agricultural University (IGKV) in collaboration with Soil Conservation Society of India, New Delhi during January 20-22, 2017. An overwhelming response received from agricultural scientists, agricultural engineers/technologists and experts of others analogues areas of different parts of the country. Besides several invited papers from the leaders in the profession, about 200 contributory research papers have been received for presentation in the various technical sessions. There will be technical and poster sessions on Integrated Water and land resources management and hydrologic modeling, cropping systems, agricultural mechanization, agricultural processing and food security, Geospatial technology in land and water resources management, River basin management and Inter- basin transfers & resolving conflicts, Policy issues in land and water use, Water and land productivity in agriculture, Watershed Management, Groundwater Exploration, Recharge and management Water and land quality, Pollution and remediation, Water and land in relation to climate change and food & livelihood security, Water and land property right regimes.

The papers published in the technical publication entitled "Water and Land Management for Food and Livelihood Security" covering a vast spectrum of topics, will be of immense value towards adoption of emerging technologies and for furthering knowledge in the related major areas. I hope that the information contained in this publication serve as a ready-reckoner and be of interest to all the delegates and agricultural professionals. The publication committee has worked hard in compilation of technical papers and presents these in a uniform and concise form. However, there is always scope for improvement in any publication of this nature. Constructive suggestions are most welcome which will help us to improve such publication in future.

(Vinay K. Pandey)

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PERFORMANCE OF WATER MANAGEMENT TECHNOLOGIES IN INDIA- A COMPARISON ACROSS REGIONS OF INDIA

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Abstract

Recently conducted research study covering the overall water management research and technology transfer in India over the past 4 decades had shown that out of the 502 technologies released, only 110 technologies (22%) have successfully been transferred to farmers.The returns to water management technologies ranged from 15 to 25 % (average 21%) at research station level compared to 9-14% at farm level (average 10.8%). Among the technologies adopted by farmers, micro irrigation (drip and sprinkler) had the major share (65%).Hence, the gaps in technology transfer and technology performance need to be addressed. Revisiting the water management research agenda, piloting of location specific technology packages and initiating public private partnership in technology transfer and uptake will sustain the water management research and outreach in India.

Introduction

Despite the previous efforts to introduce agricultural water management technologies by the research centres around the country, we know that existing water use efficiency is still low at farm level and that national level evaluations of water management technologies are not available (P[i]alanisami *et al* 2012). A key question is thus whether we can learn from past efforts to improve water use efficiency to derive lessons for our new programs. Such an exercise will not only help improve the existing performance of the water management/research institutes, but also give direction for designing future water management research and outreach programs. Hence, this paper makes an initial assessment of the adoption of and returns to previous research efforts through detailed data analysis covering different regions of India.The major objective was to assess the success of the water management technologies and their outreach to benefit the farming community. More specifically, the aim was to: a) document the various types of water management technologies/practices that have been developed in different regions, b) analyse the financial feasibility of the water management technologies/practices, c) examine the spread and adoption of these technologies/practices by farming community, and d) suggest options to enhance the effectiveness of the water management research in India.

Data

The data relating to different water management technologies/practices were obtained from 34 water management research centre with the Directorate of Water Management (presently -Indian Institute of Water Management) under the Indian Council of Agricultural Research (ICAR) which implements All India Coordinated Research Program on Water Management throughout the country since 1970s. The data collected from individual centres included the basic details of the water management research centre, details of the technologies developed, year of start of the research and release of the technology/practices, crops covered, crop yield and cost (research cost and extension-dissemination costs) relating to each technology/practice. Time series data since the inception of the research centre were collected from project records as well as discussions with the project scientists. Economic surplus method was used to analyse the returns to water management research (for more details see, Palanisami et al 2015). In the case of

outreach/dissemination program, data from Farmer Participatory Action Research Program (FPARP) implemented by Ministry of Water Resources (MoWR), Government of India were used. The FPARP implemented during 2008-10 covered 5000 location water management trials in farmers' fields in 23 states. The study used the data available from 2512 locations. Technology evaluation was conducted one year after the introduction of the FPARP using a pre-tested questionnaire. The data for each farmer included the type of technology adopted by the farmer, implementing agency (Government department/ NGO/private agencies), cost of initiating the water management trials, water saving, yield increase and income. The constraints faced by the farmers in the adoption of the technology were also documented.

Analysis of Water Management Technologies from Research Centres

Economic studies that have estimated returns to research investment on the particular crop or livestock commodities, have usually found evidence of high returns, although returns do vary by commodity and over time. In India, many researchers have attempted to evaluate the returns to research investment in the agriculture and livestock sector. But, there is no clear evidence on returns to research investment on water management technologies in the country.The present analysis basically relied on the adopted technologies and two important indicators BCR and IRR. The BCR implies the returns derived per rupee of investment. Similarly, the IRR implies the rate at which the technology gives back the return. For more details of the analysis see, Palanisami et al. 2015.Adoption of different water saving technologies has resulted in significant water saving and increase in yield of crops. The water saving and increase in yield of crops varied across crops, technologies and regions. In southern region, the widely adopted technologies are irrigation scheduling, alternate furrow method of irrigation, drip irrigation, sprinkler and system of rice intensification. These technologies, by and large, have resulted in significant field level saving in water and increase in yield of crops. Overall, the returns to water management technologies ranged from 15 to 25 % (average 21%). Regionwise technology driven water saving, yield increase and IRR are given in Table 1.

Analysis of Water Management Technologies Adoptee by Farmers

It is important to see how the research station released water management technologies have really gone to the farmers. In this context, the key research findings from the Farmer Participatory Action Research Program (FPARP) were considered. FPARP has been initiated by the Ministry of Water Resources during 2008-09 and the first phase was implemented during 2009-10. A total of 5000 action research programs have been conducted throughout the country with the help of State Agricultural Universities, ICAR Institutes, ICRISAT, state water sector institutions like WALMIS and NGOs. Each farmer trial covered a minimum of one hectare and was implemented in a participatory mode. In all, 63 institutes in 23 states covering 2001 villages were involved in undertaking these 5000 action research trials. A total of 402 technologies/practices were in the field during the implementation phase including the 110 technologies from the research centres.

The performance of water saving technologies under FPARP was compared with the conventional method of irrigation in terms of percentage water saving and yield increase. It is observed that due to the FPARP interventions, there was an increase in water saving at farm level in various crops ranging from 8 to 27.5% As a whole, average water saving reported by farmers due to the water management technologies was about 15% which is about half of the water saving reported in the experimental station based technologies. Another measure of the effect of the FPARP was the yield of crops. In all the regions and crops, yield increase was reported which ranged from 2.3 to 18.3%. Looking at all the regions and crops, the average yield increase as a whole was about 10% which is about 38% of the yield increase reported under research station based technologies. The

financial rate of return of the technologies/practices adopted by the farmers under FPARP is comparatively low (most of them were in the range of 6-18 % with an average IRR of 10.8%) showing the poor performance of these technologies under varied agro- climatic and socio-economics conditions of the farmers (Table 1).

In sum, only 110 technologies/practices from the research stations were gone for field level adoption. This accounts for about 22% of the technologies/ practices released by the research stations and represents 28% of the 402 technologies/practices covered under the FPARP. The result highlights that still sizeable portion of the practices now being practiced by farmers are derived from traditional wisdom or variants of the technologies/practices already tested over years. Among the technologies that were successfully transferred, micro irrigation (drip and sprinkler) had the major share (65%) compared to gravity based surface irrigation technologies. Given the poor adoption rate of the research station technologies by farmers (22%) and their poor financial returns[ii] (only 55% of them had a financial rate of return of more than 10%), the success rate of the water management technologies is only about 12%(i.e., 22*0.55).Among the regions, the percent gap in water saving between research stations and farmers fields is comparatively lower(32%) in southern where as the percent gap in yield is lower in northern region (48%) (Figures 1-3). Regarding the global level technology adoption, the study done using Agricultural Resource Management Survey (ARMS) data collected over the past 10 years, had indicated that among the four key information technologies—yield monitors, variable-rate application technologies, guidance systems, and GPS maps—in the production of major field crops, yield monitoring has been used on over 40 percent of U.S. grain crop acres, and very few producers have adopted other technologies (Schimmelpfennig and Ebel 2011).

Constraints in Adopting the Technologies

The major constraints faced by the farmers besides timely water supplies, in adopting the technological interventions were high capital or initial cost of some of the technologies such as drip and sprinkler (Table 2). More than 30 per cent of the farmers had responded for the high initial cost. The other major constraints faced by the farmers were lack of labour supply followed by lack of technical skills and assured canal water release to adopt the recommended irrigation scheduling.

Recommendations

Based on the results, the following recommendations are made:

a) Given the vast number of technologies available with the research institutions in each region, water management research centres should give more emphasis on technology transfer to farmers than technology development. As still 78% of the practices in the farmers' fields are local wisdom based, future research should take the lead from these practices and validate them (bottom up approach).
b) Capacity building programs on these technologies can be inbuilt in the extension programs of the research stations and state agriculture departments in each region. Details of the additional costs and benefits associated with new technology should be explained to the farmers.
c) Convergence of the government programs in technology transfer should be made so that scaling up of the technologies will be much easier through involvement of different stakeholders such as government departments, NGOs, private sectors and farmers. As poor water control under canal systems is the major constraint in technology adoption, system improvement including improved water allocation norms should be given top priority by the concerned government departments.

d) Wherever possible, public- private partnership in technology promotion and uptake such as drip and sprinkler irrigation can be explored by initiating local skill development programs involving the drip manufacturers and suppliers.

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Table 1. Comparison of Research Station and Farmer based Technologies in Different Regions

Regions	Increase in water saving (%)			Increase in yield (%)			Internal rate of return (%)		
	Research station	FPARP	Gap (%)	Research station	FPARP	Gap (%)	Research station	FPARP	Gap (%)
South	26.58	18.12	31.84	24.75	8.03	67.5	22.3	10.4	53.1
West	38.34	11.98	68.75	24.63	10.79	56.2	25.0	10.8	56.6
North	30.95	12.23	60.49	20.86	10.72	48.6	19.1	11.4	40.0
East	29.40	15.29	48.00	19.93	8.60	56.8	15.5	9.3	40.3
Northeast	42.50	27.53	35.22	80.33	12.80	84.1	17.0	14.0	17.6
Average	32.73	14.85	54.61	26.21	9.72	62.9	20.9	10.8	48.5

Source: authors estimate from data analysis

Table 2. Constraints Faced by the Farmers in Adopting the Technologies (in %)

Region	Total no. of farmers	High capital/ initial cost	Too technical to adopt	Lack of skills	Maintenance problem	Need skilled labour	Not matching with local situation	others
South	670	29	20	12	20	15	2	2
West	310	31	23	12	3	19	9	3
North	400	20	5	19	29	18	5	4
East	450	23	33	21	3	12	3	5
Northeast	300	34	21	20	4	10	5	6

Figure 1. Water saving at research station and farm level (FPARP) due to water management technologies

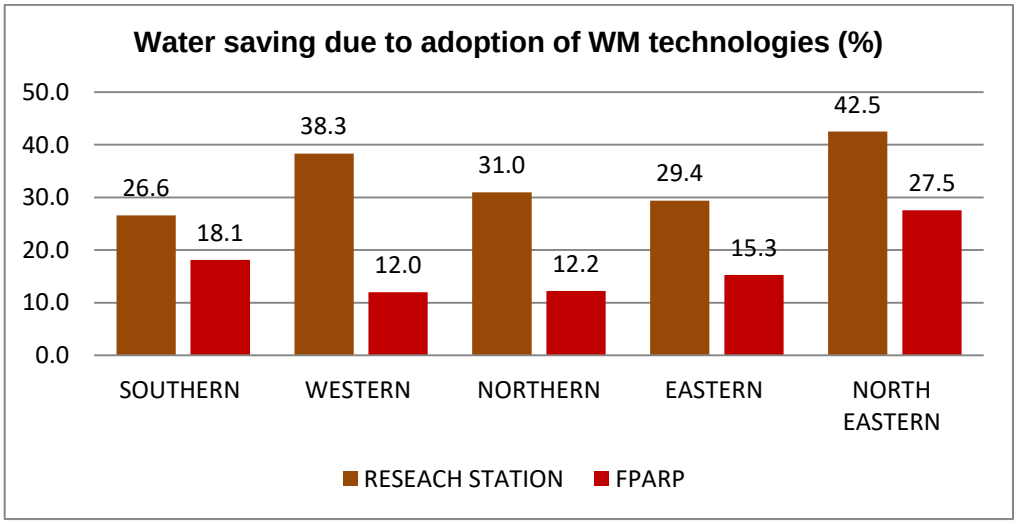


Figure 2. Yield increase at research station and farm level (FPARP) due to water management technologies

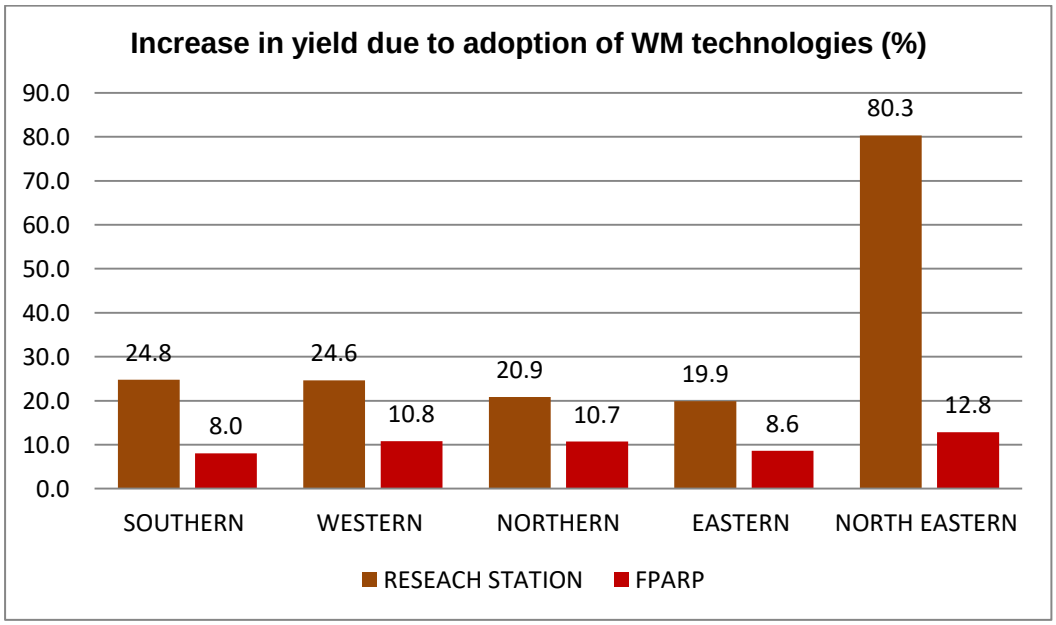
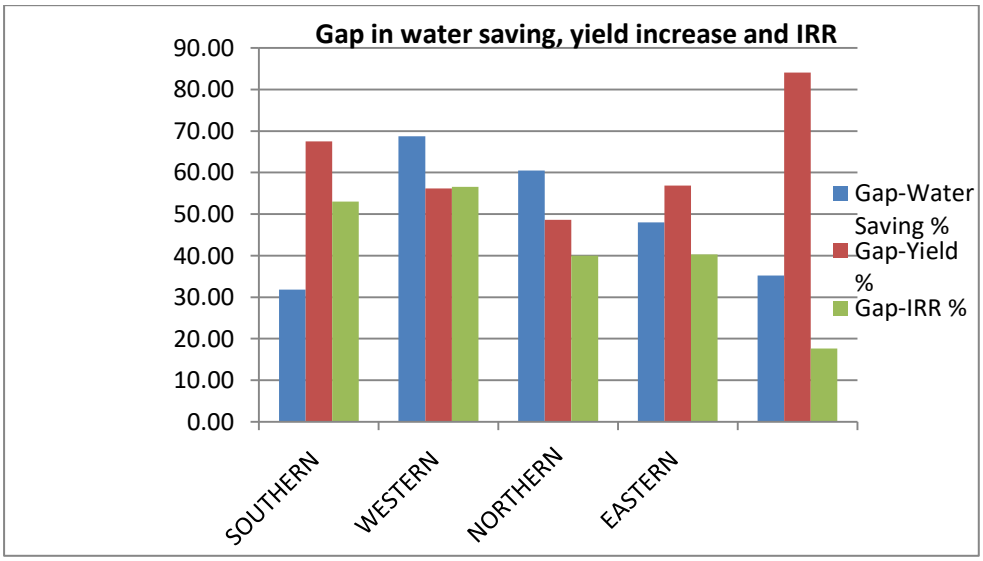


Figure 3. Gap in water saving, yield increase and IRR between research station and farm level



COMPREHENSIVE WATER RESOURCES DEVELOPMENT AND UTILIZATION IN AGRICULTURE THROUGH 'PMKSY'

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ABSTRACT

Agricultural sector is the largest consumer of water. The demand for water has been consistently increasing in non-agriculture sectors also including, municipal use and industry etc which can often be at the cost of agriculture. Though unparalled efforts have been made in the past in India for development of water resources but its utilization has rather been poor. Hon'ble Prime Minister of India launched PMKSY (Prime Minister Krishi Sinchai Yojna) with a clear vision of "water to each farm" and "per drop more crop". The scheme considers integrated planning for development of water resources (canal, surface storages and ground water) and making water available to each field. The task cut out in PMKSY involves improvement of engineering parameters e.g. lining of canals / improvement of structures / providing additional field channels but also application of a complex combination of field disciplines (agronomic / management / field measurement and hydro-sociological aspects) based on the specific situations. India, already stands first in area coverage under micro irrigation and is likely to surge ahead in its adoption in future in view of the positive push from the Government under PMKSY. Integration of micro irrigation with major irrigation projects, particularly in their tail end reaches, are likely to become a reality soon to bring at least 10 percent command under micro irrigation as envisaged under the scheme. The PMKSY also aims at enhancing water use efficiency in ground water utilization as well as in reuse of harvested rain water. Integration of micro irrigation with watershed projects particularly for utilization of harvested water too are likely to result in efficient utilization of available water resources in agriculture with significant savings of water required for extending the effective irrigation command area. The article presents different feasible technologies for on farm water management besides options for integrating large irrigation projects and water harvesting projects with micro irrigation projects.

Introduction

Water is prime requirement for all aspects of life. It is imperative to make certain that adequate supplies of water of good quality are maintained for all the needs of entire population, while preserving the hydrological and biological functions of ecosystems. Innovative technologies, including the improvements in the indigenous technologies, are needed to fully utilize limited water resources and to safeguard these resources against pollution. This involves not merely improvement of engineering parameters e.g. lining of canals / improvement of structures / providing additional field channels but also application of a complex combination of field disciplines (agronomic / management / field measurement and hydro-sociological aspects) to the irrigated agriculture sector. This process would also include restoration / rehabilitation / detailed diagnostic analysis and performance evaluation to identify / quantify design and execute the changes required.

Improving water use efficiency

The overall efficiency in most irrigation systems is low and in the range of 35 percent to 40 percent in surface water systems and 65-70 percent efficiency in ground water use. Being, major consumer of water, even a marginal improvement in the efficiency of water use in irrigation sector will result in saving of substantial quantity of water which

can be utilised either for extending irrigated area or for diverting the saving to other sectors of water use. Other major issues to be addressed in attempting to improve the efficiencies of irrigation water use include slow progress of irrigation infrastructure under construction, acute need for modernisation and rehabilitation of old irrigation systems and irrigation tanks, low reliability in timeliness and equity in irrigation water distribution, major shifts in cropping pattern, unsustained use of groundwater resources, unrealistic pricing of irrigation water and lack of awareness among farmers of the need for efficient use of water.Due to over draft, substantial ground water level declines are being witnessed both in hard rocks and alluvial areas. Ground water quality in coastal areas has also been affected by sea water intrusion due to excessive ground water development. Construction of check dams, percolation tanks, recharge wells, subsurface dykes, roof water harvesting and other innovative artificial recharge works and monitoring of the impact of these structures may help overcome the problem.

Ensuring Adequate and Timely Irrigation Water Supply

Disparities in the availability of water between head-reach and tail-end farms and between large and small farms should be obviated by adoption of an appropriate rotational water distribution system. There is a need for canal systems to respond quickly to flow changes. Computer technology is being recognised as a special tool for monitoring and analysing the data and development of decision support system (DSS). Special efforts by computer engineers and communication groups have helped in establishing Management Information System (MIS) for operation of reservoir and canals which helped in improvement in flood control, irrigation and hydropower. In future, from manual operation of canal system, shift to automatic regulation as precise discharge measurements and better communication facilities will be needed.

Conjunctive use of surface and ground water

Surface water and ground water are integral part of available water resources. However, planning for their use has generally been in isolation resulting in sub-optimal utilization. **.** For improved water use efficiency in canal irrigated command areas, optimal and efficient utilization of both ground and surface waters becomes imperative. Conjunctive use of surface water andgroundwater should be ensured from the planning stage of irrigation projects and should form an essential part of a project. Using surface water during monsoon period and using groundwater during non-monsoon period for irrigation of the same land mass is a form of conjunctive use. Large-scale development of private tube wells in the canal command areas can be viewed as informal practice of conjunctive use of surface and groundwater. There is a high emphasis in recent times on conjunctive use of canal water and groundwater to exploit the additional potential to augment canal supplies and also to control the water table rise.

Rational Pricing of Irrigation Water

At present there is no uniform set of principles in fixing the water rates. The water charges vary from State to State, project to project and crop to crop. The rates vary widely for the same crop in the same state depending on irrigation season, type of system etc. The water rates being charged at present are low and are not able to meet even the operation and maintenance costs of the irrigation projects. Water rates being abysmally low, enough funds are not generated for proper maintenance leading to poor quality of service. This is a vicious circle. Farmers on the other hand, who otherwise may not be averse to paying increased water charges refuse to do so unless the quality of services is first improved. It is imperative that the tariff structure is reviewed and revised with simultaneous improvement in the quality of services provided so as to restore the efficiencies.

Ensuring Environmental Protection

India's river systems typically originate in its mountain eco-systems, and flow towards the plains and are subject to siltation from sediment loads. They are also subject to significant net water withdrawals along their course, due to agricultural, industrial, and municipal use; as well as pollution from human and animal waste, agricultural runoffs, and industrial effluents. Excessive withdrawals of groundwater in excess of annual recharge, lead to rapidly falling water levels in many areas of the country in recent decades. Pollution of groundwater occurs due to leaching of stored hazardous wastes, leaching of industrial effluents and use of agricultural chemicals, like fertilizers and pesticides.

Participation of the Stakeholders in Water Management

In order to promote Participatory Irrigation Management (PIM), one time functional grant is given to the registered Water Users Associations. About 41,200 Water Users Associations covering an area of 8.68 million hectare have so far been formed all over the country. With the formation of Water Users Associations in various projects and enactment of legislation by various States, more and more irrigation projects are likely to be handed over to these associations for effective management. Under Restructured Command Area Development Programme more emphasis is being given to participatory approach. In the scheme farmers will have to contribute 10 percent cost of the works in the form of cash/labour involving construction and maintenance of field channels, field drains, reclamation of water logged areas, desilting and renovation of tanks etc. Such a provision is considered essential to ensure involvement of beneficiary farmers in the construction and maintenance of field channels and imbibe in them a sense of ownership of the assets created.

Adoption of Scientific Water Management Practices

Productivity of irrigated areas in India leaves much to be desired. The productivity in terms of yield per hector of almost all the crops are way behind the best productivity values achieved elsewhere in the world. In a positive sense, this shows that a great scope exists to achieve higher yields. It is well recognised that a major reason for this situation is unscientific practices of water management. The measures required include:

1. Efficient Conveyance and distribution network

Surface water reservoirs are common in irrigation systems and these are designed and operated to cater to crop water requirement throughout the year. It is essential, therefore, to check loss of water in reservoir due to i) Evaporation from the water surface , ii) Seepage from the base and iii) Reduction of storage capacity due to sedimentation. In India the water loss due to evaporation, seepage and mismanagement in the conveyance channels (for canals and its distributaries) is exceptionally high-nearly 60%. This loss can be reduced tremendously by taking several measures like lining of water courses, lining not only reduces seepage, but also minimizes weed infestation and reduces overall maintenance cost. The canal network consists of main canals, branch canals, distributaries, water courses and field channels which are termed according to their capacity and orientation with respect to the head-works. In India, the canals and branches up to minor distributaries are generally constructed and operated by the Government. The water courses fall under the jurisdiction of the individual cultivators.

2. Irrigation Scheduling based on GIS Modeling

The geographic Information system is used for calculating the crop water requirement before cultivation and helps in scheduling the irrigation need accordingly. Simulation Models are used for respective crops and the water demand at each season is calculated. Also another method used for similar purpose is real time Modeling for irrigation scheduling.

The aircraft containing Moisture Sensor along with GPS notes the moisture regime of the farm land and based on this, automated systems are activated. Historically India had adopted this approach more than a hundred year ago where 370 km long Ganga canal system was operated by British engineers by deploying men at each canal control to operate them such that constant depth is resulted. A humble beginning was proposed in the Bhadra canal system in southern India through a pilot study by CWC and Tungabhadra Board in early nineties. However this has not yielded any positive results during the operation of the canal. Operation of Narmada main canal of ambitious Sardar Sarovar Project in the state of The Majalgaon irrigation area, a part of the Jayakwadi scheme (240 000 ha) is one of the largest irrigation areas in Maharashtra which has adopted the concept of canal automation on a pilot basis with the assistance of World Bank.

3. Equity in water distribution:

Excepting Warabandi and to some extent Shejpali, in no other water distribution systems, in vogue, in India, the policy of water distribution to different fields in the command of an outlet is spelt out clearly. Even warabandi which is considered superior among other methods is not free from lacunae. However the system is gaining popularity as in warabandi the water is distributed properly, the watercourses are maintained by the beneficiaries themselves, in their own interest and the conflicts between them are minimum. Significant improvement however needs to be incorporated in this system of water distribution, particularly for achieving different kinds of equities in water distribution.

Keeping the basic structure of warabandi same, procedures are suggested for developing water distribution rosters to achieve time equity, volumetric equity, water requirement equity, and social equity in distribution of water to different fields in the command of a canal outlet. Water distribution schedules for achieving different criteria of equity for typical outlet command area were developed following the suggested procedures. A computer based model was developed for computing the allotted time to different beneficiaries.

4. Water conveyance network

Design of irrigation water distribution at farm level requires the consideration of three major elements 1. Cross-section, 2.Alignment, and 3. Longitudinal section. Standard procedures are available for determining cross section of earthen water courses under erodible as well as non-erodible conditions using Manning's or Chezy's formula. Determination of optimal alignment and Longitudinal sectioning are normally not given the due emphasis. The optimal alignment of water courses in a canal system would provide the minimal total length of water course connecting an outlet to the different fields in its command area. For this purpose the minimal spanning tree model, which is generally applied for laying telephone cables and other similar networks, could be adopted with certain modifications. This model minimizes the total length of connecting different points in space to a given point.

5. Precision land leveling

Unevenness in the soil surface adversely affects the uniform distribution of water in the fields. Now a day it is possible to do Precision land leveling on the fields, which seems to be leveled with naked eyes, with the help of Laser leveler

6. Conjunctive use of surface water and ground water

Integrated and coordinated development of surface and groundwater, known as conjunctive use. Conjunctive use mitigates the problems of high water table and salinity resulting from canal irrigation and facilitates the use of high salinity ground water by dilution

with canal water. Conjunctive use of surface and groundwater will not only increase the irrigation potential but also mitigate the problems of waterlogging and land degradation.

In-situ rainwater harvesting, also referred as water conservation method, includes activities in two broad categories, viz agronomic and engineering measures. The agronomic measures of water conservation includes practice like contour cultivation, mulching, deep tillage, contour farming and ridging. The engineering measures include practices such as bunding, graded bunding, conservation bench terrace system, bench terracing, contour trenches conservation ditches and broad bed and furrow system.

7. Measurement of water in the farm

Flow measurement structures are required in irrigation canals in order to facilitate the distribution of water through out the system and to keep account for seepage losses, etc. However, in the smaller channels the flow measurement structures or devices are closely associated with local water management practices of an irrigation command.

8. On-farm options

1. *Use of Water Efficient Crops:*
2. *Choice of irrigation method*
3. *Choice of cropping pattern:*
4. *Development of land drainage*:
5. *Use Of Micro Irrigation*

Considerable savings in water can be achieved by adoption of sprinkler, drip/micro-sprinkler irrigation systems in water scarcity areas, having conditions conducive to their application. Actual field studies indicated water saving of 25 to 33 per cent and increased yield up to 35 percent with sprinkler system compared with normal surface irrigation method. Further, 10-16 percent more area is available for crops as channels and ridges are not required. In sprinkler method as the water is sprayed, some loss in evaporation takes place. Sprinkler, therefore, should be avoided in zones of high wind. This loss of water is, however, eliminated in drip method in which water is directly trickled in to the soil near the root zone of the crop resulting in considerable saving and is particularly more suitable to row crops. 25 to 60 percent water is saved in drip method and increased yield up to 60 percent is obtained compared with conventional surface irrigation methods.

Micro-sprinklers are a combination of sprinkler and drip irrigation. Water is sprinkled or sprayed around the root zone of the trees with a small sprinkler which works under low pressure. This unit is fixed in a network of tubing but can be shifted from place to place around the area. Water is given only to the root zone area as in the case of drip irrigation but not to the entire ground surface as done in case of sprinkler irrigation method. This method is very much suited for tree/orchard crops.

Conclusion

Water is an essential resource for overall development of human settlements. A densely populated country like India has a large population dependent for their livelihood on agriculture. Irrigated agriculture has played a significant role in shaping the rural economy and rural development over the years. However, economy of water usage for agriculture is yet to get adequate attention in the agricultural and irrigation sectors and no concerted attempt was made to deal water in a comprehensive way. PMKSY aims at converging all efforts on water utilization in agriculture into one single scheme bringing several Ministries and Departments under one umbrella. Comprehensive district level planning to develop water resources through watershed development, renovation and upkeep of surface water

distribution systems and integration of large irrigation systems with micro irrigation, aimed in the scheme, are likely to achieve the goals of “water to each field” and “per drop more crop”.

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LANDUSE CHANGES ECOSYSTEM FUNCTIONS AND HOUSEHOLD WELFARE

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Introduction

The livelihoods of the people in developing economies are largely dependent on the ecosystem services from the natural resources around them. For instance, local communities in mangrove ecosystems collect fuel wood, fodder, honey, medicinal plants, timber and other products(Pattanaik*etal*.,2007;Hema,2013), and these forms a substantial part of their income. However, communities often fail to value the regulatory, cultural and supporting services of the ecosystems. The Millennium Ecosystem Assessment estimates conservatively that wet lands cover seven percent of the earth's surface and deliver 45 percent of the world's natural productivity and ecosystem services of which the benefits are estimated at $ 20trilliona year (www.MAweb.org).Even when the ecosystem services provided by wet lands are better understood- degradation and conversion of wetlands continues. Around 50per cent of the earth's wetlands have disappeared worldwide over the last hundred years through conversion to industrial, agricultural and residential developments (Costanza, *et al.,* 1997; Moirangleima, 2009). Wetlands in India are among the least protected ecosystems and are threatened and fast disappearing. (Mafumbo *et. al*. 2010; Kang, 2010; Deka *et. al.,* 2011; Mezgebe and Raju, 2011; Singh and Moirangleima, 2012). The dwindling status of wetlands of Kerala has also been highlighted by several researchers. The wetlands were regarded as "waste lands" by the public and policy makers. This negative image had resulted in under valuation of its potential, which together with the social and economic incentives for conversion lead to uncontrolled exploitation, conversion and degradation. For instance, the increasing demographic and developmental pressures on land in Kerala is leading to a situation of conversion of paddy lands (wetlands) for non agricultural uses. This widening supply demand gap in land resources result in surging land prices which act as an economic incentive for large scale conversion. Simultaneously, the communities who reside near to this wetland are denied of the ecosystem services, most prominent being the groundwater recharge .The level of water scarcity is reported to be getting worse, which is commonly attributed to climate change impacts. However, a large majority of residents relate it to the land use changes where the wetlands are converted. This paper tries to value the hydrological functions (water recharge) of wetlands measuring the relative level of water scarcity in neighboring regions of wetlands, under four different land use regimes. The paper compares the domestic water use pattern and estimates the economic costs of water scarcity.

The study area and Sample

The Kole Wetland Ecosystem

The study is conducted in the neighborhood human settlements of Kole wetlands (below mean sea level wetland ecosystem where paddy is grown construction bunds. This is a part of Vembanad Kole ecosystem) Geographically, Kole lands which spread in the two districts of Thrissur and Malappuram has been demarcated as southern Kole and Northern Kole. The area under the Kole ecosystem has been reported as 54625 ha (546.25km^2). Out of this, about 71.26 percent (38925ha) of the Kole lands comes under the Southern Kole (mainly in Thrissur District) while the remaining 28.74 percent (15700 ha) contributes to the Northern Kole (Malappuram). The land use changes in the ecosystem were assessed employing the advanced GIS and Remote Sensing software for spatial data and word processing and database management software for non-spatial data viz;

(a) ArcMap– this was used for displaying and subsequent processing and enhancement of the image. It was also used for the carving out the Kole lands extent from the whole imagery using the delineated boundary from Kerala Land Development Corporation (KLDC).

(b) ERDAS Imagine– This was used for the development of land use/ land cover classes and subsequently for change detection analysis of the study area.

(c) Microsoft word – forward processing purposes.

(d) Microsoft Excel– for database management purposes.

This part of the study was done with the help of experts during the year 2013. The land use changes, as reported in the study by Jeena (2011) (employing the same techniques) was compared with our results and thus the data pertains to the period from 1983 till 2013.

The primary data for the study was collected from the residents of the surrounding areas of the wetland system following a stratified random sampling technique. For this purpose the Kole ecosystem were stratified to four situations

I. Areas without any land use changes (remained as wetlands) (Situation I)

II. Areas which were kept as fallow lands (without cultivation of paddy) (Situation II)

III. Areas which was kept as fallow land for a while and the cultivation restarted and continuing (Situation III))

IV. Areas which were permanently converted as built up area/ garden lands (Situation IV)

Locations under these four situations were identified as indicated by the remote sensing/ GPS results as well as through ground truthing and consultation with Department of Agriculture, local people and *Kole* Development Authority.

The data was gathered from the respondent households residing within a distance of 1 5 0 0 mts from the Kole ecosystem. The number of sample respondents finally chosen for analysis, from each Situation was 103,106, 52 and 57respectively. The data was gathered through a structured pretested interview schedule developed for the purpose. Personal interview method was adopted for the data collection and the survey was conducted during December 2013 to May2014.

Results and Discussion

The land use classification (Table 1) scheme followed in this study are mixed cropped areas, paddy lands, built-up area, water body and waterlogged situations. Mixed crop category is composed of the garden land areas with coconut, arecanut, plantain and seasonal vegetables. Paddy lands are areas where the crop is grown. Built up area corresponds to land where permanent structures are

constructed. This area is irreversibly converted for the construction and allied activities and the wetland paddy cultivation is not possible any more. Ponds, small lakes and the like water sources are categorized as water bodies. Water logged area is the unused land inundated almost throughout the year.

Table 1: Land use/ land cover classification scheme

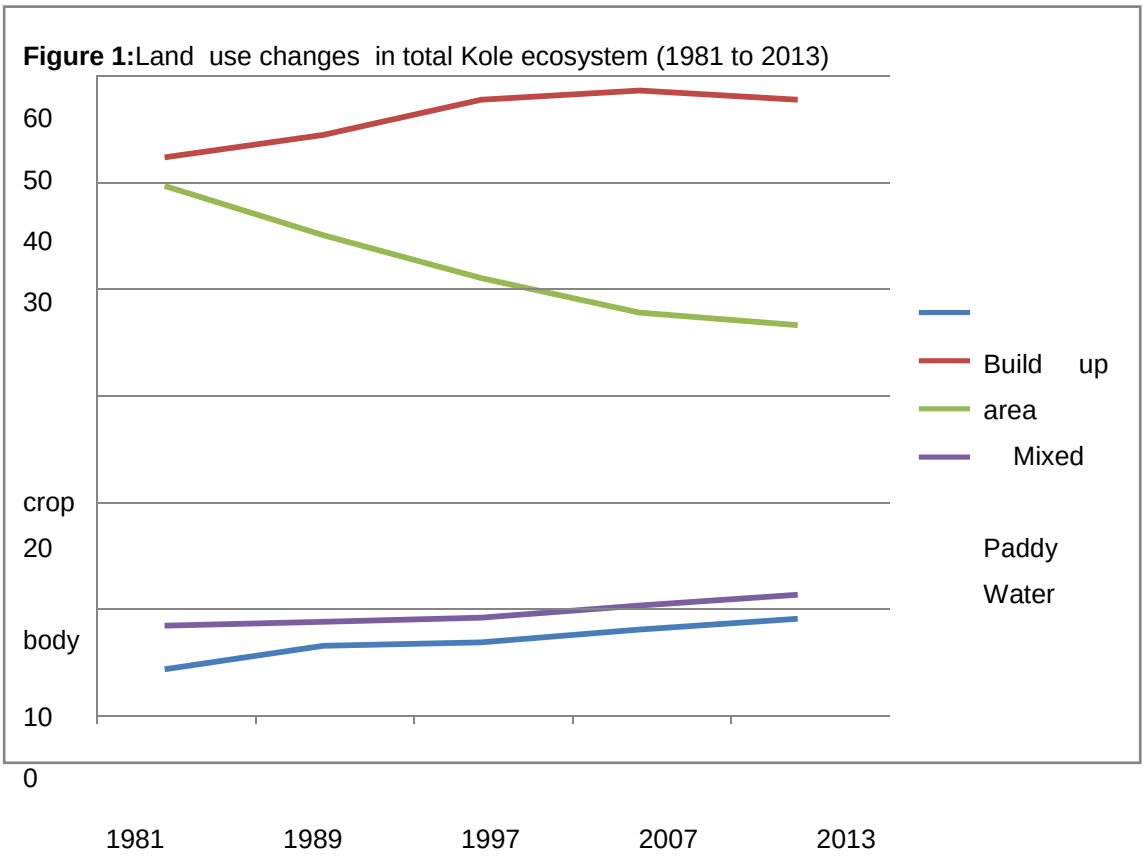
S. No.	Land Use/ Land Cover Categories
1	Mixed crop
2	Paddy
3	Built up land
4	Water body
5	Waterlogged

Table 2 and figure 1 to furnish the details of area under each land use category in the Kole ecosystem and table 3 describes the average annual growth rate, during the period under study.

Table 2: Land use changes in total Kole ecosystem (1981 to 2013)

Particulars	**1981**		**1989**		**1997**		**2007**		**2013**	
Total Kole ecosystem	Area ha	per cent to Total	Area ha	per cent to Total	Area ha	per cent to Total	Area Ha	per cent to Total	Area ha	per cent to Total
Built up Area	350	0.64	1544	2.83	1724	3.16	2388	4.37	2946	5.4
Mixed Crop	26572	48.64	27712	50.73	29528	54.06	30002	54.92	29516	54.06
Paddy	25113	45.97	22582	41.34	20382	37.31	18623	34.09	17968	32.91
Water Body	2558	4.68	2755	5.04	2751	5.04	2743	5.02	3616	6.62
Water logged	0	0	0	0	109	0.2	585	1.07	554	1.01
Waste Land	32	0.06	32	0.06	131	0.24	284	0.52	0	0
Grand Total	54625	100	54625	100	54625	100	54625	100	54600	100

Source: GIS data generated from the present study and data reported by Jeena 2011



The Built up Area

The built up area under Kole was reported as 350 ha (0.64 per cent of total Kole land area) in 1981 which has steadily increased to 2946 ha (5.4 per cent) in 2013.The proportion of built up area in S. Kole area is higher (69 per cent) obviously due to the faster pace of urbanization in Thrissur compared to Malappuram. During the gulf boom in the late seventies and eighties, Kerala state has witnessed changes in the economic structure as well as social status and perception of the people. It was the time when the peasants became the landlords, young generation was attracted to the opportunities in the gulf countries than, “fameless” agriculture activities. This might have influenced them to shift from less profitable and socially less acceptable agriculture to other activities. The course of conversion of Kole lands to the built up area was intense in the Southern Kole. During eighties, the rate of growth of built up area was 21.26 per cent while it was only 5.31 in the Northern Kole. We can see that these changes were in tune with the urbanization. With the progress in urbanization, the peripheral areas of Thrissur city were converted in order to meet the growing demand for land. Kole lands in the surrounding areas of Thrissur city has been widely converted to built up areas. Since the depth of the Northern Kole was high and the urbanization process in these areas was slow, the pace of building up in Northern Kole was comparatively less as compared to Southern Kole. The magnitude of increase in built

up area was highest during period I (Table1), which is in line with the period of paddy land decline. During the recent past (2007-13) the rate of increase registers a high 2.36 per cent. The share of Southern Kole in total built up area was reported high as 69.15 (242 ha) per cent in1981compared to the 30.85 per cent(108 ha) of Northern Kole. During the period 1981-2013 the share of S.Kole in the built up area increased drastically as it contributes 92 per cent of the total built up area In Northern Kole land area, too the rate of transformation was highest during 80s (5.31 per cent) and it was allow 0.38 per cent during 1997-2007 period. However, the latest trends reflected are mal picture, as the rate of increase has gained momentum at 2.04 per cent per annum. Since 1981, compared to Northern Kole lands, an alarmingly high rate of grow thin the built up area is shown in Southern Kole.

Agricultural Production Systems–Garden Land and Paddy Land

The agricultural activities in Kole ecosystem mainly constitute the production under garden land condition and paddy lands, together constituting 87 per cent of total area. In the Southern Kole these agro ecosystems together formed 86.45 per cent of Kole lands where as in Northern Kole they constituted 88.24 per cent. Mixed crops in garden land included the coconut, arecanut, banana and vegetables which are the usual components in the homestead system in Kerala, and it was 53 per cent of the southern Kole lands and 58 per cent of Northern Kole lands, higher than the paddy lands. Paddy lands averaged at 17968 ha of total Kole area (73 per cent in Southern Kole and 27 per cent in Northern Kole).

The mixed crop area is the garden lands. Slightly less than half of the total Kole area is garden lands, which are typical Kerala home gardens. Total mixed crop area in the Kole ecosystem was 26572 ha in 1981 and it has been increasing over the years. Southern Kole contributes about three fourth (19224ha) of the mixed crop area in the Kole ecosystem. Even though the southern Kole has an upper hand in the total mixed crop area, Northern Kole showed a more rapid increase in the mixed crop area. The annual rate of increase during Period I was 0.47 per cent, the rate of increase is more rapid in Southern Kole (0.55 per cent,) as against Northern Kole (0.25 per cent,). The rate of increase was highest during the Period II in the state and southern Kole ecosystem (0.71per cent and 0.64 per cent respectively), whereas it was highest during the period III(1.07per cent,) in Northern Kole. The eighties and nineties witnessed steady and fast shift from paddy cultivation due to social, economic and technical reasons. This must have prompted the conversion of substantial part of erstwhile paddy land to garden land. The pace of transformation naturally might have been influenced by the pace of urbanization as is reflected by the behavior in the Northern and Southern Kole. The garden lands, later on, are mainly used for residential purpose. By latter period of 90"s, technically possible paddy lands were converted. Since then sizeable part of these reclaimed lands were turned into built up area, thus registering a negative growth rate in garden and area in Southern Kole. In Northern Kole, where the urbanization is comparatively slow, the growth rate is still positive but has declined to a modest 0.16 per cent per annum indicating a negative trend in the near future. As a whole the growth rate is- 0.18 per cent. This supports our observation of conversion of garden land to built up area. Paddy cultivation in Kerala has been on cross roads. The area under rice in the state declined from 8.75 lakh ha in the TE 1972-73 to 2.06 in TE 2012-13 while the production declined from 13.4 LT to 5.33 LT during the same period. The rate of decline is more drastic towards the latter periods.

Total area under rice farming in the Kole ecosystem was 25113 hactares with 72.3 per cent in Southern Kole and rest in North Kole. Over a span of 22 years the area has declined to 17968 ha (28.45 per cent decline). The rate of decline was more rapid in Northern Kole (except during Period I) compared to Southern Kole (27.39 per cent) and was higher during the early periods than latter periods. In the Southern Kole lands, the pace of paddy land decline was rapid (-1.35 per annum) during eighties the magnitude of

which has gradually declined in the subsequent periods reaching-0.33 per cent latest. This is just half the rate of Northern Kole lands where the rate of decline is -0.58 per cent. During the field visits it is observed that in the northern Kole lands, the paddy fields are mainly reclaimed for mixed crops only. There are no mining activities for tile and brick clay as well as sand. But in the Southern Kole lands there are incidences of tile and brick clay mining and sand mining from underlying beds. There are about 35 tile making factories in the southern most part of the area as per the Department of Mining and Geology. Now clay mining and sand mining activities in Kole lands stand banned by law. However, there are a few illicit mining centers functioning now as per information from local people.

Water Body/Water Logged/Waste Lands

Area categorized as water body constitutes 6.62 per cent of total Kole area (2013), which along with water logged pact form 7.63 per cent currently. The extent of water bodies in Southern and Northern Kole lands was around 2558 ha during 1981 (4.68 per cent). The rate of increase was higher in Southern Kole land (2017 ha) than that of Northern Kole (1599 ha).

Water logged area, has registered an increase of 554 ha over the years. Waterlogged area is that part of the Kole ecosystem which was once used for agricultural purpose and presently agricultural activities are not there. These areas are submerged in the water. In the Northern Kole ecosystem, there is hardly any area in this category where as southern Kole ecosystem has109 ha of water logged area in 1997 which has increased more than five times to 585 ha during period III and then slightly declined to 554 ha in 2013. According to the respondents of the area, the cultivation was not taken up in this area, mainly due to the lack of interventions from the local bodies in building bund sand the absence of other supporting services. By waste land, we mean the area which is marshy in nature and cultivation is not possible due to practical difficulties. Though this area is termed as waste land, it has the features of wetlands.

Summing up, over a span of 32 years, a notable change in land use pattern has occurred in the Kole ecosystem. Major changes were visible in the areas under paddy land, garden land and built up area. The area under paddy land has drastically declined over the years, while the area of garden land and built up area have increased subsequently. The data shows an increasing trend on the water logged area in the Southern Kole ecosystem. As in the case of any other area of the state, the area under the study was also influenced by the changes in the tenant- peasant relationships and the changes in the structure of the family system. Shift from the joint family system to the„ nuclear" has increased demand for land for the housing purpose in parallel to the infrastructural and industrial demand for land. Absence of effective monitoring mechanism and loop holes in the existing regulations have made it possible to do any kind of alteration to the land. Moreover, Kole lands in the state have been dangerously polluted by urban sewage, hospital waste and pesticide residues (Hindu daily, 2 Feb 2015).

Water Resources for the households: Status and Scarcity

Ground water has been the main source of drinking and irrigation for majority of population in the world. In contrast to the neighboring states, the availability of annual replenishable ground water and extraction of potential ground water are low in Kerala. The net ground water availability in the state is 6229.03 MCM of which 59.25 per cent is utilized for irrigation and 44.74 per cent is for domestic and industrial purpose. The projected requirement by 2021 is 4270 Mm^3 in industrial sector and 3230 Mm^3 in domestic sector (Economic Review, 2014). There are growing numbers of reports on declining ground water status in Kerala. We trie to assess the level of water storage in the open dug wells of the respondent farmer households through direct measurement of the water level (from ground

level) and the diameter of the well. The details of the depth of the well as well as the water level during different seasons were gathered from the respondents. Based on this information, the volume of water in the well at different points of time was estimated and is presented in Table 4

Table.4 Average water volume in the study area (volume in litre)

Season	**Situations**			
	I	II	III	IV
June-September	31064	59612	44098	73269
October-December	24945	47019	33955	50556
January-February	17481	36307	26018	39931
March-May	8526	18351	11466	11357

The average storage in the wells varied considerably across seasons, in all the four situations. In situation I, the volume was a high 31064 litres/well during the monsoon season gradually declined to 8526 litreduring the summer months. The storage was higher (18351 litres) in the wells in Situation II, and Situation III (11466litres) during summer. The well capacity and storage level was the highest under Situation IV, during the period from June-February. But during summer the storage was lowest in Situation IV.

The extent of decline in water storage in the wells were estimated by subtracting the volume during each season (Oct-Dec, Jan-Feb and March-May) in comparison to that of the June- Sept levels, when it is the maximum (Table 5). Volume of water storage in the wells in Situation I, II and III was found to decline by an average 20 per cent during the post monsoon period (Oct-Dec), 40-44 per cent by Jan–Feb and 73 per cent during the peak summer. The condition in converted areas (Situation IV) is distinctly different, showing higher level of decline at 31per cent, 45.5 per cent and 84.5 per cent respectively. This was also reflected in the source wise analysis, where the dependence on external sources was found to be higher in these regions (Situation IV). This in directly underlines ground water recharge function of wet lands.

Table.5 Extent of decline in water storage (litre)

Season	**Situations**			
	I	II	III	IV
June- September	---	…..	…….	…..
October- December	6119(19.7)	12593(21)	10143(23)	22713(31)
January- February	13583(43.7)	23304(39)	18080(41)	33338(45.5)
March-May	22538(72.5)	41261(69)	32632(74)	61912(84.5)

Figures in the brackets shows percentage

Volume of Domestic Water use

Domestic water consumption is considered to be largely dependent upon the socioeconomic status and water availability. According to some estimates, the normal minimum available water per person per year is $1000m^3$, anything below which is considered as a water scarce situation. We have not come across any scientific study or data on per capita domestic consumption of fresh water per person in Kerala. Such data

could be helpful in water resource management as well as allocation. The data also assumes significance as there is a great imbalance in the demand and supply conditions.

The central groundwater commission, which monitors the groundwater level every quarter, check the water levels of1,000wells in the state and make an assessment on the per capita water consumption on its basis. It is calculated at 150 litres per person a day based on the water data taken in January, April, August and November, pre and post monsoon period. The household level average water consumption, in the present study was estimated by assessing the frequency of pumping and filling the over head tanks or/ and amount of water lifted/ gathered manually/ mechanically from own and external sources during normal periods as well as summer season (Table6). This information was primarily gathered from the women members of the households who manage the domestic water needs. The household level average consumption was estimated to be the lowest (627lit/day in situation IV to the highest 825 lit/day in Situation III). This variation is mainly on account of the difference in family size. The large Farmer households were consuming more water compared to the small farmers, except in Situation IV. Situation IV is the area of converted lands which are more near to the urban centers and the proportion of large farmer households are less. On a per capita basis the average consumption is estimated at 175 lit/day in Situation I, 170lit/day in Situation II, 190lit/ day in Situation III and the lowest 154 lit/day in the Situation IV. The household level consumption in converted areas was found to be 22 per cent lower than that in the areas near to wet lands. Generally the large farmer consumption was higher than the small farmers.

Table.6: Household water consumption in the study area (litre/day)

	Situation I			Situation II			Situation III			Situation IV		
	SF	LF	Avg	SF	LF	Avg	SF	LF	Avg	SF	LF	Avg
Water Use per house hold	672.3	963	814	693	868	781	629	1027	825	634	622	627
Per capita water use	158	196	175	173	166	170	146	233	190	143	164	154
Per cent age of External Dependence	26	22	24	23	24	24	26	24	25	37	39	38

However, the consumption status is much better than the situation in cities like Chennai. The estimated average per capita availability of water for the sample householdsin Chennai stands at 65.8 litres per day which is considered to be much lesser than the required per capita norm of 135 litres per day for the urban households (Venkatachalam, 2011).

The level of dependence on external sources during peak summer months was observed as one of the factor that influence the average consumption status. The proportion of the volume of water which was sourced from external sources was estimated based on the responses and was found to be around 24 per cent in the case of situations Ito III whereas it was as high as 38 per cent in Situation IV. Even then, it was quite different from the findings of Venkatachalam (2011) in Chennai city. There, out of the 293 sample households, 97 per cent collect water from ‘public sources’ viz, public taps and hand pumps. Out of 293 households, 237 households (78.5 per cent) utilize public taps and 56 households (18.5 per cent) depend on hand pumps for their water requirements. Another 7 households (2.3 per cent) depend on individual house connections; the remaining 2

households utilise water from their bore-well. Thus, a larger percentage of the households depend on public sources for their water needs.

Dependence on external water sources and household economic burden

According to the ministry of Home AffairsKerala is the state which has the least percentage of population having access to the safe drinking water. Kerala Water Authority (KWA) is the main agency for the construction, operation and maintenance of water supply schemes in Kerala. KWA has as significant role in the safe drinking water supply in Kerala both in rural and urban areas and the water supply schemes of KWA cover around 43 per cent of the total population of the state. Apart from the state funded schemes, KWA operates projects which are funded by external agencies and organizations. The JICA assisted Kerala Water Supply Project and The World Bank aided project *'Jalanidhi'* are the two major ones in this group. Despite this family managed and owned water supply mechanism which includes dug wells, tubewell/ borewells has a crucial role in the water supply of rural areas.

As per Economic Review (2014), the water supply schemes of KWA cover around 60 percent rural population through its 1193 water supply schemes whereas '*Jalanidhi*' meet the demand of 6.25 per cent rural population of the state.

Though government are expected to be the primary institution responsible for domestic water supply, the failure of the system resulting many alternate forms of water supply mechanism, both in rural and urban areas of Kerala. The role of welfare governments in ensuring potable drinking water is underlined in the water policies. Apart from the role of distributing water through public water supply mechanism, during peak summer months, Local Self-Governments arrange the water supply through private operators (either regularly or intermittently). This practice has been reported from across in India (Solo, 1999; Venketachalam, 2010). The market practices, policies and related aspects of these water markets are largely unmonitored.

The performance of public water supply program across the country has been criticized for many flaws, both quantitative and qualitative. Jalan *et. al*, 2006 reported presence of fecal matters in water collected from public inasmuch has 61 percent of sample households. Venketachalam (2011) in his study identified various problems associated with existing public sources of water supply in Chennai city, which include payment to rent seekers for ensuring steady supply. The studies on public water supply however is more skewed towards urban centres (Janakarajan, *et al.,* 2006; Mckenzie*et al.* 2009; Vidyanathan and Saravanam, 2006; Venketachalam and Vanathy, 2010; WHO, 2010). Though there are no systematic studies in the functioning, efficiency, adequacy and qualitative aspects of these programmes in Kerala, there are media reports and peoples responses on the poor performance of these systems.

Across the globe, the public economic burden for water supply is reported to be sizeable Water subsides provided through public utilities are estimated at about $656 billion or 0.6 per cent of global GDP in 2012. The share of water supply GSDP as a ratio to GSDP has shown as to increase over years, in India. It was only 0.2 per cent in 1970-71, which has risen to 0.13 per cent in 2010-11. In Kerala as per the prevailing water rates charged by government of Kerala (Appendix II) the price of water can be estimated as Rs.0.40 per litre (which covers only part of the distribution cost and does not include the resource cost).

Table7 Furnishes the estimates of household imputed expenditure on external water sources during the peak summer months. The estimated expenditure include the opportunity cost of collecting water and the imputed value of water under three scenarios *i.e.,* the supply through public taps, water supply through tanker lorries arranged by LSGs and water supply system operated by private water markets.

Table.7 Estimated expenditure on domestic water from external sources in the study area

Situation	External dependence (lit/day/ households)		Cost of fetching water		Expenditure on water resources (Rs/day/household)					
					Public taps (0.40/litre)		LSG tanker supply (0.21/litre)		Private Water markets (0.42/litre)	
	SF	LF	Time (mts/day)	Opportunity cost	SF	LF	SF	LF	SF	LF
I	174.8	211.86	8-12	5.64	69.92	84.74	36.7	44.5	73.42	88.98
II	159.4	208.32	8-12	5.64	63.76	83.3	33.47	43.75	66.95	84.49
III	163.54	246.48	8-12	5.64	65.42	98.6	34.34	51.76	68.69	103.52
IV	234.6	242.58	8-12	5.64	3.84	97.0	49.27	40.94	98.53	101.88

The imputed private expenditure incurred by the SF households averaged from Rs 36.70 (LSG supply) to Rs. 73.42 per day (Private markets), evidently due to the higher unit price in private water markets. The expenditure was highest under the situation IV, which was higher by 42 per cent compared to the situation I, II and III. The expenditure under situation I to III was found to be on par.

As expected, the expenditure incurred by LF households wasgenerally higher than SF households. Similar to the case of SF households, the LF households in situation I, II and III were incurring an average Rs 40.94 as against Rs102 in Situation IV, which was higher by 10 per cent.

On a monthly basis the expenditure was calculated and is presented in Table 8. The average monthly expenditure of SF households in situation I, II and III averaged Rs 2180 where as it was Rs 3000 in situation IV while depending on public taps. It was just half in the case of tanker water supply arrangements. However, the dependence on private markets resulted in an average expenditure of Rs. 2270. On an average, the SF households in situation IV incurred an amount ranging from Rs. 1620 to Rs. 3150 per month. This was approximate 6.04 per cent of their household income. The average monthly expenditure by LF, under situation IV was ranging from Rs 1710 to Rs 3240 (Situation IV).This was 5.13 per cent of the average household income.

Table.8: Total Expenditure on water resources during summer season (Rs/month per household)

	Publictaps		LSG tanker supply		Private Watermarkets	
	SF	LF	SF	LF	SF	LF
I	2280	2700	1290	1500	2370	2820
II	2100	2640	1170	1500	2190	2820
II	2160	3090	1230	1680	2250	3270
IV	3000	3060	1620	1710	3150	3240

Welfare Loss

The amount of welfare loss was estimated as the additional implicit expenditure incurred by the households in situation IV, compared to the average in the other three situations (I, II and III). The amount varies across the external source as well as holding size. Thus the average welfare loss for LF households is estimated as Rs 223/households/month and that by SF as Rs697/household/month. This include the imputed/actual market price of water and the opportunity cost of time spent for collecting water (Table 9)

The total number of households in Thrissur district (2011census) is reported as 7,59,200andthat in Malappuram is 7,93,000. Assuming that 50 per cent of households are directly benefited by the ground water recharge function of wetlands (either directly or indirectly) the number of benefited households are 7,76,100. The total welfare loss due to wetland conversion is estimated as Rs.69 crores per year, for Thrissur district and Rs59 crore for Malappuram district, which can be considered as the lowest bound, based on modest assumptions

Going by these estimates the welfare loss (on account of the ground water recharge) due to wet land conversion can be calculated as an average 56.98 per ha of wetland, it can be interpreted as the welfare gain due to avoided conversion. However, this can be considered as the lower bound of the value. The expenditure incurred by the Thrissur Corporation towards supply of water by tanker system is reported as an average 3 crores (for the past two years (2013-14 and 14-15) for three summer month (on alternate days only), which is only limited to forwards in the four zones. Wetland conservation, thus result in a savings of public expenditure towards water supply, which can be allocated for socially more desirable sectors. It is to be remembered that the price of water in these estimates do not include the resource cost

Table 9 Estimated welfare loss due to wet land conversion

Systems of water supply	Welfareloss(Rs/household/month)	
	SF	LF
Publictap	820	250
LSG tanker	390	150
Private watermarket	880	270
Average	697	223

The water recharging function of wetlands is reported as the most important ecosystem function by the wellers of Thrissur Corporation (Binil kumar, 2000). For this they were willing to pay an amount of Rs 240/household, based on which the value of Kole wetlands were estimated as Rs. 3,60,69,000. This is however based on the responses from the urban households of Thrissur Corporation, who were ready to pay for the conservation of Kole wetlands. Our estimate is based on the estimates of forgone benefits by the households on account of the conversion of wet lands and hence the ground water recharges function. These figures however reflect the economic value of these ecosystems which facilitate the planners to make scientific decision making.

Over the years the local communities value the regulatory, supporting and cultural services from these ecosystems more than the productive services. The ecosystem services (hydrological) from wet lands are perceived to be much higher than other benefits from wetlands (Aswathy, 2015; Hema, 2013; Binil kumar, 2000) and in the era of dwindling water resources the conservation of wetlands has gained more attention. Realizing this, the

approach towards water resource management has shifted more towards ecosystem conservation strategies alongwith consumption management.

Conclusion

The importance of water resource conservation in Kerala is being underlined by many researchers, owing to the reports of widening gap in demand and supply conditions. The study by NCAER project an increase of 64 per cent in the water demand in the state by 2031 over 2001. The increase in drinking water requirement is estimated at 29 per cent, irrigation by 81 per cent and ecosystem quality management at 156 per cent. But the water sources in the state shows continuous decline. The latest statistics of Central Meteorological Department shows a decline of 1.43 mm per annum (1951 to 2010) in the rainfall and water flow in the rivers of Kerala have been slowing down at an even faster rate (Central Water Commission, 1998-2009). The rapid changes in the land use pattern, conversion of water bodies and wetlands, sand mining from rivers and other exploitative activities have adversely affected the ground water recharge functions. This has lead to the water table decline/drying up of almost 48 per cent of open wells in the state. In Kerala 65 per cent of rural and 59 per cent of urban households depend on wells, for their water requirements. This situation highlight the importance of conservation of water bodies, in the state, for effective recharge of ground water and also to address the water quality issues, which is emphasized by several researchers (ChattopadhyayandNair,2015; Shaji, 2015; Sindhu,2015)

Chattopadhyay and Nair (2015) suggest the leadership and presence of Local Self Governments and MGNREGS workers towards achieving his goal. Such interventions are more effective through stakeholder awareness and participation. The information on the extent of water scarcity experienced by the residents around the wet lands, the economic burden due to the scarcity and their understanding of the linkage between wet lands and the hydrological aspects provide vital information towards achieving this goal.

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A MASTER PLAN FOR LAND AND RIVER MANAGEMENT IN INDIA

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ABSTRACT

Despite immensely balanced and superb overall disposition of land and river in greater parts of India, the country is facing serious problems in the form of annual visit of flood and related threats of ecological condition which is further aggravated by senseless deforestation. In the present paper the author has put forward a proposal for a proactive plan for preventing and recuperating the severe damage caused to the land and river system of the country. Proposals for massive river dredging and large scale plantation besides broadening the width of the river channel in possible flood zones have also been suggested. Besides, it has been contemplated that on both sides of the river bed, which forms the main channel for constant flow of water, shallow and sufficiently broad and flat zones in several steps to be dug out where extra water at the time of floods could be stored. Such a measure would not only alleviate frequent threatening of flood situations but would also provide fertile land for irrigation during normal condition.

INTRODUCTION

India is blessed with amiable geographical disposition, ideal proportion of land and river, congenial climatic and ecological condition throughout the year, and adequate rain in greater part of the country. Furthermore, supreme natural protection provided by the V-shaped southern boarder surrounded by oceans which is supplemented by presence of the mighty Himalayas in the north makes India an unique place in the world. It may be noted that originally a desert-like place, Israel, has now been turned green due to careful planning and indomitable will of its people. In comparison, our superbly bestowed country with all its natural advantages, each year faces floods and other natural calamities which too could have been avoided or reduced by careful planning and appropriate governance. In this paper certain measures of renovations have been put forward for alleviating the disastrous circumstances that our country faces almost each year.

Natural Disaster in India

While natural disaster in India like earthquake is restricted in certain areas, flood - caused by incessant rains on the contrary is more widespread. The situation is often aggravated by unprecedented melting of snow and glaciers in the Himalaya that intermittently floods large areas of northern and eastern parts of the country. The cause of undue melting of the Himalayan ice is due to increase of temperature which is to a great extent related to burning of coal in northern and eastern parts of the country situated nearer to the Himalayan belt. All these phenomena are further amplified by senseless deforestation in areas adjoining Himalayas and various other parts of the country. The rivers flowing from the north are already sufficiently silted up with sediments poured incessantly throughout the year which, in turn, is responsible for reduction of capacity of the basins, thereby, causing overflow of water bringing forth widespread flood.

Protection Measures for Rivers

Government's plan for cleaning Ganga and Yamuna rivers are now being persuaded in a vigorous manner. Cleaning of river does not mean to face lift it by clearing

up the floated garbage and waste. At the same time it is necessary to clear the sediments, silts, heavier dirt and waste materials that cause substantial reduction of volume of the rivers, an ominous sign indicative of impending floods. The plan for river linking should be implemented after thorough and careful consideration on all possible aspects of geographical, geo-political, regional needs and other problems. It must be ensured that the project would not relocate flood-like situation from one state or zone to another one neither water from one zone would be distributed to another making the donor area dry.

Dredging of Major Rivers

Dredging of major rivers like Brahmaputra, Ganga, Yamuna, Koshi etc is a colossal task not only in terms of money, appliances and man power but also in regard to time frame as the venture needs to be taken up as a virtually continuous project. These gigantic tasks can only be implemented by deploying large number of dredgers with participation of numerous civil engineers and experts of various branches. To reduce water content or for temporarily drying up of some parts of the rivers in order to achieve smooth progress of the project, additional deep and sufficiently broad (depending upon the local situation) canals running parallel to the rivers can be drawn. River water, particularly, during the summer and dry periods, can be diverted to the parallel canals so as to thoroughly clean and deepen the river bed for increasing its capacity.For controlling another major menace caused by erosion of banks, especially during the rainy season when extra water rushes out at great speed, broadening and deepening of the basins could be done for holding extra water. Additionally it would also be necessary to place large stone blocks in vulnerable points of the river banks for protection from incoming rush of water. Plantation of thick bushes with deep roots, which can firmly hold the soil, can substantially resist bank erosion. The use of vegetation as a bio-engineering tool at low cost for erosion control and slope stabilisation has been implemented for a long time (Hengchaovanich, 1999). In this regard vetiver grass has been found to be particularly useful as an unique bio-engineering tool for land stabilisation and erosion control (Truong, 1999).

Protection of Land

Protection of land is intimately associated with water and river management which needs systematic plantation in an extensive scale. The plantation in a meaningful manner would be beneficial to the country not only for river and land management, but also for improving economic condition of the people if suitable trees like mango, guava, apple and other varieties fruits are planted. Realising the importance of plantation poet Rabindranath Tagore initiated annual '*Briksharopan Utsav'* or tree plantation ceremony more than hundred years ago in Sreeniketan and Santiniketan for rural development. It may noted that when the poet's father Maharshi Devendranath Tagore first visited the barren zone of Birbhum District capped by lateritic soil, there was only one *Chatim* tree in that vast land now known as Santitiketan and Sreeniketan. Poet Tagore later formed his *Ashhram* there for imparting education following Indian traditional and converted a barren dry zone to a green terrain. This was implemented much before the example of converting dry desert-like zone to a green belt, as was done in Israel or the concept of tree plantation for protection of environment was mooted.

India has vast natural land with rich fertile top soil suitable for agriculture and plantation with supply of adequate water throughout the year, which does not require extra-ordinary efforts for cultivation. For production of diverse types of crops and farming, environment-friendly fertilizer, soil conditioner, compost and pesticide can be derived from the plentiful natural sources from local areas.

Landscape Designing For Flood Management

In our country enormous area covering states such as Assam, West Bengal, Bihar, Orissa, Andhra Pradesh, Tamil Nadu etc are annually affected by flood caused by incessant rains which is further aggravated owig to infrequent melting of snow in the Himalayas. Recently even a compapatively dry state Rajasthan was also flooded due to rain. An innovative plan for alleviating such catastrophic situation has been suggested by modifying or re-arranging the land situated on both sides of rivers covering vast plane surface as shown in Figure – 3. It has been contemplated that on both sides of the river bed, shallow and sufficiently broad and flat zones in several steps would be dug up for accumulation of extra amount of water at the time of floods. In normal condition these steps would be utilised for grazing and agricultural purposes. The first step shown in the figure, adjoining the river bed, would act as the space for accomodating extra water during the time when capacity of the river bed would be filled up due to mild rush of water. In case of more influx of water, the same may be accommodated in the platform situated above the river bed. The upper most platforms would be able to hold more water during severe type of flood. Such a measure would not only alleviate frequent threatening of flood situations but would also provide fertile land for irrigation during normal condition.

Remarks

Both river dredging and landscape designingprojects are long term colossus tasks which would require huge amount of money, manpower and other resources. Amongst the two assignments, river dredging project is already on the anvil which should be undertaken with utmost vigor and commitment. The landscape designing project, on the other hand, can be taken up expediently on experimental basis in a single major area as it is a new proposition and should be implemented on the basis of its merit to other river basins. Both the river projects guarantee extensive job opportunities with promise to turn the relevant zones environmentally and ecologically stable. The project would also be economically sound due to eradication of frequent menace of flood thereby saving huge amount of money spent for rehabilitation of flood victims and related expenditures incurred each year, such as, repair of houses, roads, bridges, railway lines, and river banks.

In flood affected rural sectors, it would be necessary to build raised platforms of sufficient height and area as shelter for human beings and cattle in convenient part of the village. The shelter should be well connected so that people can gather at the place during the time of flood. The raised ground should have additional space for landing of helicopter and some basic amenities for temporary stay, collection of rain water for drinking purposes etc. It would be necessary to distribute adequate number of boat or rubber dinghy to the affected people (Sen, 2005, 2007).

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Figures



Figure – 1. Severe flood inundating a vast area in India affecting normal life for several days.



Figure –2.Common situation of a village in India during flood.

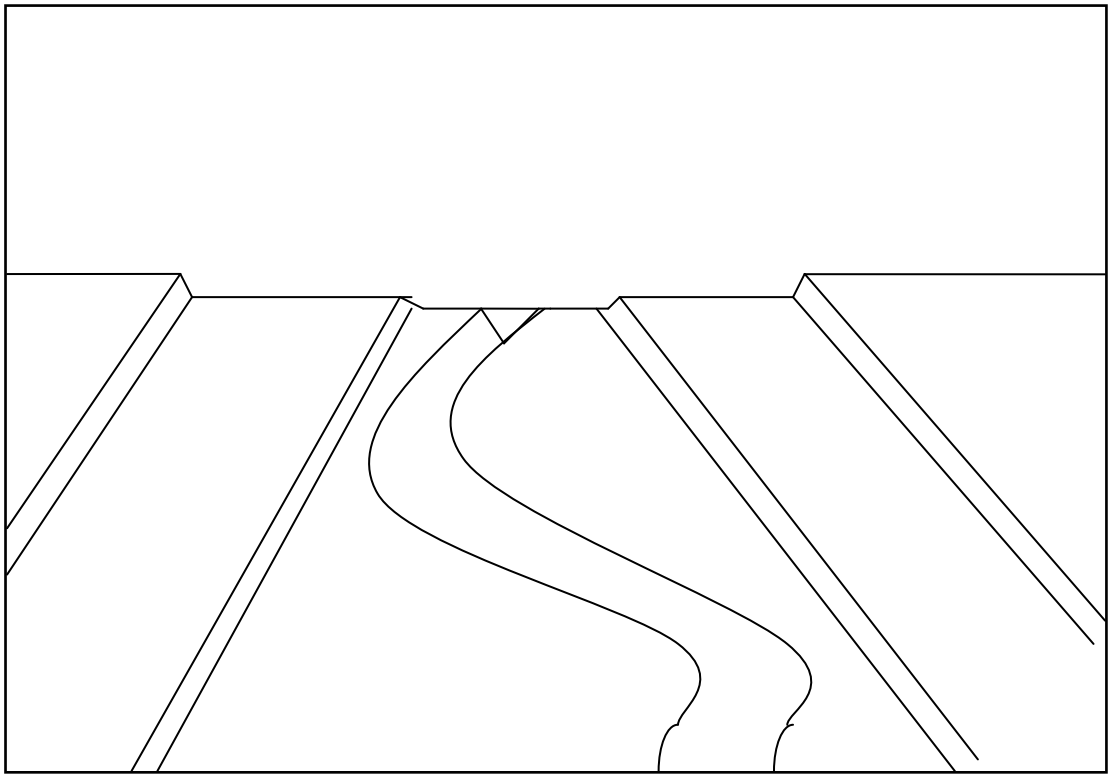


Figure - 3. Plan showing river bed or shallow canal-like depression with several flat shallow areas in steps. In both sides of the deeper central depression forming the river bed, shallow and broad flat zones in steps have been excavated which can be used for irrigation, as well as, for accumulation of excess water during the time of floods while through the river bed water would continuously flow.

INTER BASIN WATER TRANSFER VIS –A -VIS BRAHMAPUTRA RIVER WATER RESOURCES

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ABSTRACT

The Brahmaputra River has the highest volume of renewable water resources and the highest per capita water resources in the world. Therefore, there is an increasing interest among the policy planers for exploiting this vast unutilized water resource for sustaining the industrial and agricultural growth of India. The National Water Policy has a clause for inter-basin transfer. The sustainability of the Brahmaputra river water resources is therefore a critical question before the planers and the common people. To address the question of sustainability of Brahmaputra river water resources, a system dynamics model of the basin water system was conceptualized and built with 284 variables to represent five sectors, namely, population, irrigation, industry, basin water and sustainability sector. The model was tested both qualitatively and quantitatively. The model has been used for future scenario generation. The results suggest that water supply in the Brahmaputra basin remained more or less same whereas the consumption has been rising; therefore water availability status for the basin has been going down over the years. There is wide temporal variation over months. Flood storage reservoir to store excess water during high flood and augment flow during lean season will be required before implementing any in inter basin water transfer policy.

INTRODUCTION:

The importance of managing water resources in the most scientific manner had never assumed such urgency as it has become now. Engineers and planners with vision had been bringing the concerned and connected issue to the fore during the past few years. But importance of the topic failed to come to the fore owing to lack of proper assessment and vision. According to an assessment by Planning Commission, the population of India will be 13.5 billion by the year 2025 and by 2050 it will become 16.5 billion. For the food grain production to increase proportionately with population, more water will be required. Water will also be required for the daily use of the increased population and also to sustain industrial growth. As per an estimate, the average annual rainfall and snowfall over the entire country is around 4000 billion cubic meter from which only about 1869 billion cubic meter of surface water flow is available for use. Out of this, only about 690 billion cubic meters is utilized in agriculture, industry and in day to day use of the people. The rest flows to the sea. Rechargeable ground water put to use annually is around 432 billion cubic meters. Inevitably this vast volume of 1179 billion cubic meters flowing to the sea has to be the source of extra water requirement in future. But there are huge disparities from basin to basin and from region to region within the country. Two-thirds of the entire water resources of India are available in the Ganga-Brahmaputra basin. The rainfall in the Brahmaputra basin is nearly twice the rainfall in the Ganga basin. Therefore the gold mine of excess water for the entire country exists only in the Brahmaputra basin. The issue has become more prominent as per new National Water Policy 2002 where a clause for inter-basin transfer has been incorporated and the apex court has directed to complete inter linking of river basins by 2016. Accordingly National Water Development Agency has prepared feasibility report for Manas - Sonkosh- Tista link.

The problem before the planners is how to meet the demand for water for the rest of India while at the same time maintaining the unique ecosystem and ever-increasing local requirement for water. Environmental scientists and technocrats of Assam and opposed the idea on the ground that not enough studies have been made in this context. Therefore, it is appropriate that a comprehensive study of the Brahmaputra River water resources is made as early as possible. Apart from being backbone of Assam's economy, Brahmaputra River is also inseparably mixed with Assamese culture, folklore and way of life. Any decision to manipulate such a complex water resource system like Brahmaputra requires sound understanding of the regional water resource system and also how the system will react to a particular policy. Such an understanding may only be achieved by considering and exploring interactions among number of related social, economical and environmental factors. This is further complicated by the fact that all these factors occur dynamically over time. System dynamics theory is a promising option for studying the dynamics of such a large and complex system and analyze implication of different policies . The System dynamics technique can effectively incorporate individual system component within a system framework and comprehensively analyze their interaction which is very useful for providing holistic understanding of the regional concerns (sustainability of river system in this case) and relevant policy response. The System dynamics technique consist of dynamic simulation models which explicitly considers information feedback that govern the interactions in a system. Such models are capable of synthesizing component level knowledge into system behaviour simulation at an integrated level (Mahapatra et al 1994). Since the works on System Dynamics reported by Forrester (1961), the method has been applied to a number of water resources studies also. Notable among them are, river basin planning (Palmer et al., 1999), long term water resource planning and policy analysis (Simonovic and Fahmy, 1999), reservoir operation (Ahmad and Simonovic, 2000) and Sustainability analysis (Xu et al. 2002). This study is an extension of the SD's application for analysis Brahmaputra basin's water resources. Efforts have been made to develop a SD model f or water resources planning of the Brahmaputra River and use it as a policy tool after testing.

METHODS AND MATERIAL

The Brahmaputra River system:

The Brahmaputra covers a drainage area of 580,000 square km 50.5 percent of which lie in China, 33.6 percent in India, 8.1 percent in Bangladesh and 7.8 percent in Bhutan. Its basin in India is shared by Arunachal Pradesh (41.88%), Assam (36.33% i.e. 70634 Square km), Nagaland (5.57%), Meghalaya (6.10%), Sikkim(3.75%) and West Bengal (6.47%). The basin has a length of about 1540 km in East-West direction and maximum width of 682 km in North-South directions. The up stream portion of the basin lying in Tibet in China and Arunachal Pradesh in India comprises of mountain ranges and narrow valley. The Indian state of Assam falls in the middle stream and consists of hills, forest, tea garden and a valley having about 80 km width. Here the river has braided platform and multiple channel at most places and therefore the width of the river itself becomes 6 to 10 km in most places.

System Dynamics Model Development

The System Dynamics Model for the Brahmaputra river aims to address the dynamics of availability and consumption of water in the river basin. The water supply dynamics of any river basin depends on water supply and consumption. The water supply dynamics is influenced by external flow coming into the basin, tributary flowing into the basin, outflow from the basin, rainfall, evaporation, ground water in the river basin and its exchange with river water etc.), whereas the water consumption dynamic includes water

used in irrigation, consumed by population and industry. For conveniencein modeling the BrahmaputraRiver Basin water consumption has been split into 5 sectors , namely, population sector, irrigation sector , industrial sector, basin sector and sustainability sector.

The population sector has been explained through a causal loop diagram in Figure 1 which shows the causality of the population growth and water consumption. Accordingly in the river basin SD model these causalities has been incorporated through 3 sectors, namely, urban population water, rural population water and immigration population water In the urban population sub sector urban population and urban literate population has been considered as level variable and urban birth and death has been considered as rate variable. Experiences in India (e.g. Indian state of Kerala) show that literacy is the key factor for population control in developing countries and therefore literacy rate has been incorporated as multiplier for variables representing urban birth and urban life span. The same analogy has been followed for rural and immigration population. The multipliers from literacy rate has been determined against 'ratio of literacy rate actual to desired' from a relational graph. If the literacy rate actual equals literacy rate desired (ratio between them is 1), that condition will positively influence life span of and therefore the multiplier value would be maximum. Under similar condition the multiplier for rural births will be at its minimum. People immigrate to urban area as well as rural area. Therefore, in immigration population Sub sector, two additional rate variables to assess the immigration to rural and urban population have been incorporated. It has been assumed that immigration to urban area takes place due to industrial growth whereas immigration to rural area depends on availability of land, water and government policy towards immigration. These factors were taken into account through multipliers whose value has been assigned from relational graphs. For example, value for 'immigration rate to rural population multiplier from Land' was determined against 'Ratio of actual land population ratio to ideal' from a graph. If the 'Land Population ratio actual' is more than 'Land Population Ratio Ideal' than the ratio between them will be more than one and that condition will encourage immigration to rural population. Similarly the 'immigration rate to rural population multiplier from water' was determined from the 'Ratio of actual water population ratio to ideal' for the basin. Since in any democratic set up the elected representatives formulate policies of government, therefore, it is apparent that the ratio of elected representative from immigration population will determine its multiplier effect on rural population. More elected representative from immigrate population means there would be government policies that encourage immigration. Total population water consumption has been estimated using per capita consumption under each population category. Total waste water generated has also been determined from waste water generated per capita under each category.

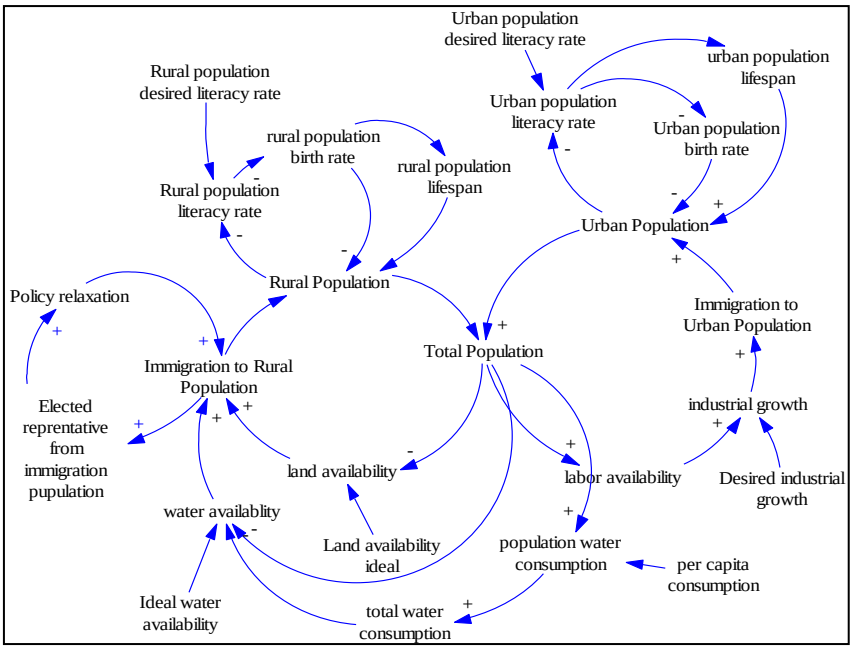


***Figure 1** : Population sector causal diagram*

Irrigation water accounts for more than 50 % of total water requirement in any river basin Figure 1 shows the dynamics of irrigation water consumption through a causal loop diagram. These causalities has been incorporated in River Basin SD model by 2 sectors, namely, 'Arable land' and 'Irrigated land'. In the arable land sector, arable land , waste land, forest land and urban Land (not shown in figure) have been taken as level variable. Forest conversion rate, urban creation rate and wasteland conversion rate have been considered as flows taking place to/from the arable land. Arable land gets converted to Irrigated land through arable land conversion and this conversion depends on water availability and actual utilization of irrigation water. Influence of water availability and actual utilization of irrigation water has been incorporated through multipliers from relational graph. Ratio of water available per capita actual to desired and ratio of irrigation potential created to irrigation potential utilized and , ratio of irrigated land to arable land (actual) to ratio of irrigated land to arable land (desired) are some factors used for estimating the multipliers. The water requirement for each crop has been estimated as per procedure outlined in Doorenbos & Pruittt (1977). Irrigation water has been estimated by incorporating efficiency of irrigation system.

The Industry Sector of the SD model has 2 sectors, namely, industrial working capital sub sector and industrial fixed capital sub sector. Agricultural processing, forest products, power production, petroleum refining, textiles and heavy industries are broad areas that have been considered for modeling. It has been observed that 'industrial fixed capital' inflow to any river basin depends on power availability, Infrastructure (Road, Railway and shipping) and law and order situation (not shown in figure). Accordingly influence of these factors has been incorporated in the model by introducing multipliers from each of these factors. Some of the variable used for estimating the multipliers are : number of police cases recorded (law and order), Power available per capita actual and power available per capita desirable (power availability), Ratio of power available per capita actual to desirable ,road length per square KM actual , road length per square KM desirable ,

railway track per square KM actual , railway track per square KM desirable and ratio of railway track per square KM actual to desirable (infrastructure). Working capital for industry depends on production and therefore in the model inflow to working capital has been assumed to be dependent upon actual production of each of the industry activity e.g. agricultural processing, forest products, power production, petroleum refining, textiles and heavy industries. Production multiplier estimated from relational graph of ratio of actual production to desired production has been incorporated in the model. The industrial water has been estimated by taking into account the actual production of each of these industries and the water required for per unit production of that industry. The total wastewater generated has also been estimated by taking into account the actual production of each of these industries and the waste water generated from per unit production.

The dynamics of water supply of river basin has been incorporated in Basin Sector. To introduce spatial dimension the river basin has been split into sections (0,1,2 etc). It has been shown in the diagram that rainfall and/or snow melt accumulates through tributary/external flow and joins the main river flow at different sections. The water stock in any particular section is the summation of ground water supply and river water supply of that section. Exchange between river water and ground water takes place through base flow and seepage. River water has been assumed to be exploited for consumptive uses (irrigation, population and industry), water storage in dams and diversion to some other site. Ground water has been assumed to be exploited for consumptive use only. Some fraction of consumptive use returns to ground water and river water. River water flow takes place from one section to the next and subsequently to the sea.

Test application of model

Using the causal relation explained in the earlier section , the system dynamics model for the Brhamaputra basin was made using STELLA, an object oriented simulation environment (High Performance System 1999). Stella makes it possible to develop a complex water resources model with less programming effort than using a traditional computer language and makes it easy for model expansion. It is a user-friendly programme that uses an iconographic interface to facilitate construction of dynamic system models. The essential features of the system are defined in terms of stocks (state variable), flows (in and out of the state variables), auxiliary variables (other algebraic or graphical relationship or fixed parameter) and information flows. Mathematically the system is geared towards formulating models as system of ordinary differential equations and solving them numerically. The user places the icon for each of the stocks in the modeling area and then connects them by flows of material or informational relationship. Next the user defines the functional relationship that corresponds to these flows.

Stocks represent a reservoir of material such as population, water, money etc. Material flows between stocks or into and out of undefined sources and sinks (represented by ‘clouds’ at the end of flow structures). Flows are affected by auxiliary variables, stocks and other flows through the use of information arrows. Auxiliary variables can take the form of constants, mathematical or graphical functions and data sets. Portion of larger model can be broken down into sectors which can be run independently or simultaneously to facilitate debugging. A sample flow diagram prepared in STELLA for rural population sub sector is shown in Figure 2.

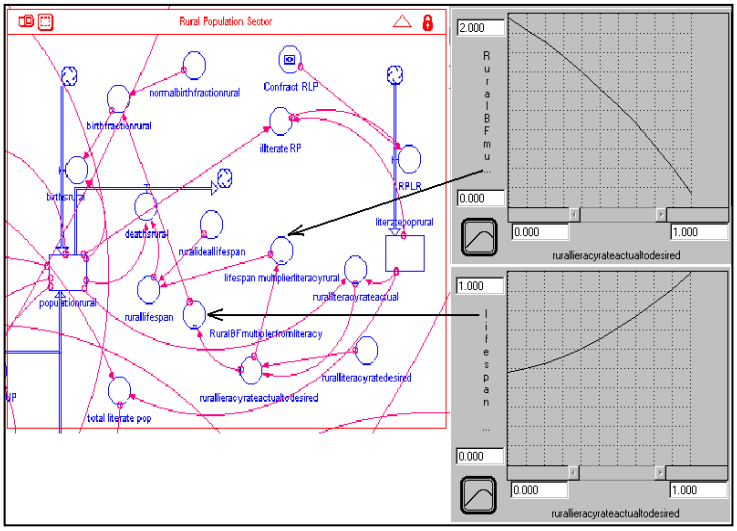


Figure 2:STELLA Flow Diagram ofRural Population Sub Sector

Model Application, Scenario Generation and Sustainability Assessment:

The model has been extensively tested and validated using historical data of the basin during the period from 1971 to 2001. A sample results of validation test on population have been shown in figure 3.

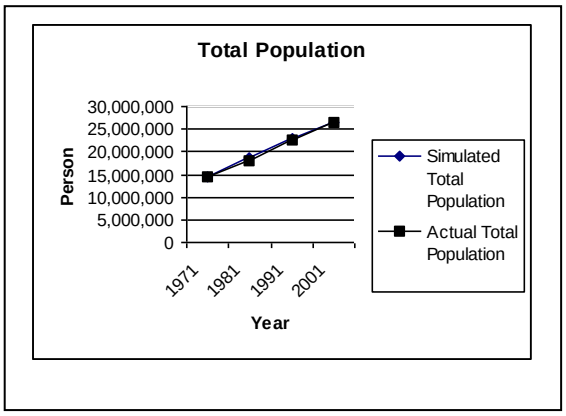


Figure 3: Total Population (Simulated Vs Actual)

After testing and validation some possible scenarios as described in Table 1 have been evaluated

Table 1: Scenario generated

Water Flow in River	Water Uses	Scenario
Maximum	Normal	A
Maximum	High	B
Mean	Normal	C
Mean	High	D
Minimum	Normal	E
Minimum	High	F

Maximum = Maximum recorded flow of the river
Minimum= Minimum recorded flow of the river
Mean =Mean value of recorded flow of the river
Normal =Rural population water requirement 20 lpcd, Urban population water requirement 100 lpcd, Immigration Population water requirement 15 lpcd, Floating Population water requirement 50 lpcd, Cropping Intensity 1.25

Sustainability assessment:

To assess sustainability in this study sustainability index (SI) as introduced by Xu et al, (2002) which is defined as the ratio of aggregated possible water deficit relative to the corresponding supply in the same region has been calculated. SI value greater than 0.2 correspond to low or no stress of water supply, which implies that water consumption is less than or equal to 80% of the water supply. SI value smaller than 0.2 reflect vulnerable condition and SI value zero or less indicate unsustainable

Population water consumption for the basin has been estimated by multiplying projected Population and per capita water consumption (a decision variable). Each of the projected Population from urban, rural and immigration Population has been considered and multiplied by the respective per capita consumption to estimate population water consumption. The normal per capita consumption for urban and rural population have taken from planning commission of India estimate (GOI, 1999) and that of immigration and floating population have been author's estimate. Some of the inputs considered for this sector are literacy rate, resources availability (land and water), industrial growth and government policy. Arable land in the basin gets converted to irrigated land. This conversion depends on water availability and government policy. Crops considered for estimating Irrigation water consumption have been Paddy, Jute and other Crop. The water required for irrigation has been estimated as per procedure after Doorenbos and Pruitt (1977) and adding for losses in conveyance. Industries considered for estimating Industrial Water Consumption have been : Agricultural Processing, Petroleum crude, Heavy industries, Forest Products, Power and Textiles. The actual production of these industries determined industrial working capital and industrial water consumption. Due to non-availability of local data, water requirement for selected industries as given by Leeden (1975) have been used for estimating industrial water consumption. The environmental water requirement has been considered to be 27% of available flow as estimated by Upali Amarsinghe (2004) for Brahmaputra Basin. Water per capita desirable value has been also taken from the same study.

RESULTS AND DISCUSSION

The results of the scenarios generated through simulation reveals that when simulated with minimum flow condition (Scenario E & F) , Brahmaputra River Basin appeared to be deficit in water as evident from the Sustainability Index (Figure 5). When simulated with Mean (Scenario C & D) and maximum flow (Scenario A and B) condition the river basin water status appeared to be sustainable till 2050. Further simulation revealed that the water status is unlikely to cross the benchmark sustainability index of 0.20 till 2125 after which the scenario turns to be unsustainable. Since huge differences in water availability could be observed between Minimum and Maximum Flow condition, water storage in dams to augment the lean season flow may be a possible policy option. Therefore some *efforts have been made to assess the pattern of seasonal water availability and consumption.*

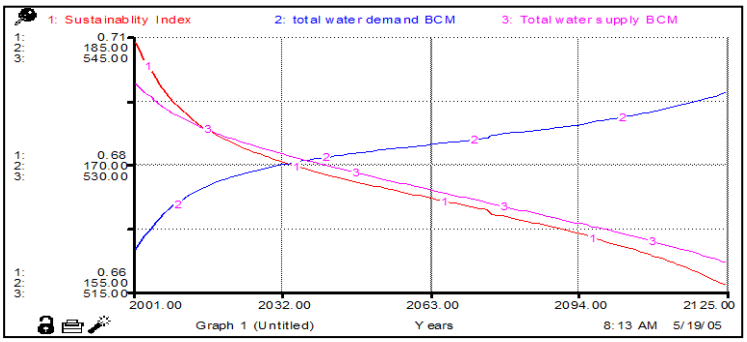


Figure 5: Sustainability Index of Brahmaputra Basin (2001-2125)

To assess seasonal water availability Monte Carlo technique has been used to simulate the time series data of discharge rate of Brahmaputra river and its tributaries and forecast discharge for the year 2025 and 2050 on weekly basis. These forecasted values of weekly/monthly average discharge rate along with average monthly rainfall and evaporation values have been used in the model to assess seasonal water availability. The population and industry water consumption have been assumed to be of constant rate through out the year. The irrigation water consumption dynamics have been assessed by using seasonal crop area, rainfall and evaporation records for the river basin.

Graphs in Figure 6 shows the comparative status of Sustainability Index for the Brahmaputra Basin during the year of 2025 and 2050. It has been clearly revealed that the Sustainability Index although remain mostly above 0.60 from March to November in both the years, the same has gone down drastically during January in 2050 and touched 0.00 during December 2050. It has been mentioned earlier that 0.20 has been considered as the benchmark for Sustainability Index and therefore water status for Brahmaputra Basin during 2050 is a matter of concern.

SUMMARY

Scarcity of fresh water in the face of increasing demand to sustain agricultural and industrial growth in India is a major concern for policy planers , scientists and water professionals. Brahmaputra is an important river system having highest amount of unutilized water resources. However growing demand for water in the basin requires an in depth study. This work is an attempt to study the Brahmaputra river water system through a system dynamicsmodel. The model has been tested with time series data of Brahmaputra basin for the period of 1971 to 2001. Test scenario generation using the model suggests

that water consumption pattern for Brahmaputra Basin has showed a rising trend during years 2025- 2050. The water availability in the River Basin has showed wide seasonal variation. The water supply remained more or less same whereas the consumption has been rising; therefore water availability status for the basin has been going down over the years. With the present consumption pattern the basin will face water scarcity during the lean season (December to February) before the year 2050. Flood storage reservoir to store excess water during high flood and augment flow during lean season may be an option.

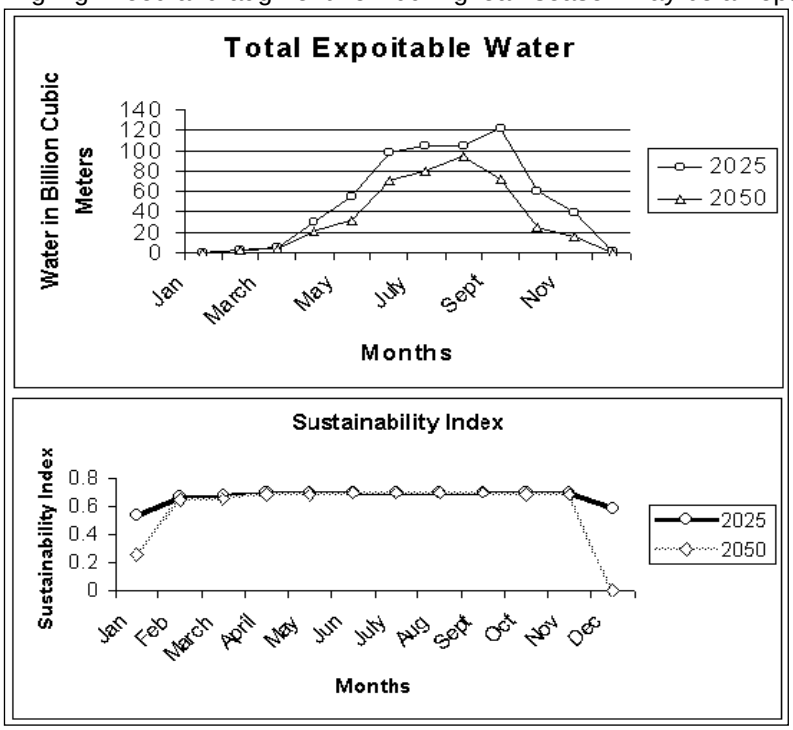


Figure 6 Comparative Status of seasonal water availability

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ARTIFICIAL RECHARGE OF GROUNDWATER: POTENTIALS AND LIMITS

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Abstract

Water stress is growing worldwide and groundwater continues to serve as the most reliable source of water supply for almost all kind of water demands. Groundwater also plays a crucial role in intensive agriculture practices for global food security. Our inevitable population growth has amplified the abstraction of groundwater several times higher than the natural recharge of the aquifers. Consequently, excessive groundwater withdrawal from aquifer systems has lowered the water tables significantly in many countries. The damage to the aquifers, in some cases, is irreversible. To deal with the situation, artificial recharge of groundwater is becoming increasingly important in most groundwater management plans, particularly in arid and semi-arid regions of the world. Artificial recharge of groundwater is principally achieved by diverting surface water into groundwater bodies in times of water surplus, which can be exploited during the times of water deficit. However, the effectiveness of these recharge structures depends on several factors such as rainfall pattern, availability of source water, topography, water storage capacity of geological formations, proper selection of the recharge technique, and adequate design of the structures. Although literature is rich in promoting and advocating the quantitative gains through these recharge structures, there has been little research on identifying the reasons for failure of these structures. There has also been relatively little work to link these failures to absence of procedure to be followed while considering such artificial recharge projects. Therefore, the key objective of this review paper is to understand the reasons for failure of these structures, and to develop scientific protocol for artificial recharge projects. The paper finally illustrates technical practice to be followed at all stages involved in the entire process of artificial recharge.

Keywords: Aquifer, Artificial Recharge, Ecology, Groundwater Management, Environment and Long-term Impact

Introduction

Water stress is growing worldwide and groundwater continues to serve as a most reliable source of water supply for almost all kind of demands arising from agriculture, industrial, recreational, and domestic users. In fact, groundwater resources dwarf surface water supplies (Burke, 20021). However, a rapid increase in the human population, particularly in arid and semi-arid regions of the world, has shown that the abstraction of groundwater is several times higher than the natural recharge of these aquifers. Consequently, excessive groundwater withdrawal from aquifer systems has significantly lowered the water table in many countries. Human intelligence can enhance the groundwater storage and water quality significantly in these dying aquifers (Gale et al., 20062) through artificial recharge interventions (CGWB, 19943). As a result, artificial recharge of groundwater aquifers is becoming increasingly common yet important in most of

the groundwater management plans.Artificial recharge of aquifers is to tailor scientific solutions in water stressed regions largely by storing water underground in times of water surplus, which can be exploited during the times of water deficit. Also, artificial recharge techniques are used in protection of: coastal aquifers from seawater intrusion (Ganesan and Thayumanavan, 20094), groundwater depleted regions from land subsidence, and base flow in the rivers and streams. Recharge of aquifers can also enhance water quality of contaminated wells through anthropogenic sources such as use of pesticides in agriculture, waste disposal and wastewater discharge. The concentration of geo-genic toxic elements like arsenic, fluoride, and iron can be diluted too through appropriate recharge of the aquifers. Moreover, the cost of groundwater pumping could be reduced significantly by raising groundwater table through artificial recharge.

The methods of increasing recharge are of two kinds (Meinzer, 19465): (1) indirect methods, in which increased recharge is accomplished by locating production wells as close as practicable to areas of rejected recharge or natural discharge and (2) direct methods, in which water from surface sources is conveyed to points from which it percolates into a body of groundwater. In principle, artificial recharge of groundwater is to direct either storm water runoff or treated municipal wastewater into aquifers through various engineering measures (Dillon et al., 20096) such as spreading (within channel, through a network of ditches and furrows, ponding over large area: by check dams and percolation tanks); recharge shafts (vertical and lateral); injection wells; induced recharge; improved land and water management (contour bunding, contour trenching, bench terracing, and gully plugging). These artificial recharge structures facilitate the storage and diversion of rainwater during peak season, like monsoon in India, and provide supply side management support during lean period. As groundwater abstraction is consistently increasing, artificial recharge projects have become priority projects for most of the nations, particularly for the countries located in arid and semi-arid regions of the world. Consequently, rise in artificial recharge techniques that divert polluted runoff into the aquifers, either through agricultural lands in rural areas or municipal waste and roof water in urban environments, finally become a potential source of groundwater contamination for these aquifers (Pitt et al., 19997). Similarly, there are definite quantitative gains (Sunaryo, 20018 and Rockstrom et al., 20019) through artificial recharge measures in upstream; however, the impact of these interventions on downstream water availability (Ngigi, 200310) cannot be underestimated.

Most of the literature on the subject is rich in documenting the success stories in terms of quantitative gains through these recharge structures, however, there has been little research to assess the impact of artificial recharge on qualitative aspects of groundwater. Also, there has also been relatively little work to link these interventions to ecologically acceptable changes in the catchments and aquifer parameters. Therefore, the key objective of this review paper is to understand the long-term impact of artificial recharge measures on groundwater quality, the catchments, and aquifer parameters. The paper argues that it is high time to rethink the approach of artificial recharge before making the practise common in all groundwater management plans.

Upstream interventions and downstream implications

Potential for rainwater harvesting depends on annual rainfall and pattern, topography, and water storage capacity of geological formations (Boers and Ben-Asher, 198211). On one hand, runoff lost through local hydrological unit, such as watershed, is considered as potential for rainwater harvesting. In contrast, it may be source water for surface withdrawals and groundwater recharge for downstream users. Hence, rainwater harvesting may cause substantial downstream impact if there has been either diversion or impounding of surface run off. As water always flow down the slope, human activity of upstream water users does affect the downstream users but not vice versa. However,

hydrological impact of any upstream water harvesting activity on downstream water availability is mostly overlooked. Therefore, it creates conflict between the upstream and downstream stakeholders, particularly in the basins with limited surplus water (Scott et al., 200512). To date, there is limited concern to assess the impact of upstream artificial recharge measures on downstream availability of both surface and groundwater.
It is therefore technically significant to look into the consequences of diverting or storing the water upstream and its resulting impact on downstream water resources and the community. In brief, if a site for artificial recharge of groundwater has been identified as an ultimate remedy through scientific considerations, technical investigations, and participatory process; it should ensure that it has no impact on the community in the downstream and its surrounding environment.

Impact of artificial recharge on aquifer parameters
Principally, artificial recharge is an activity that modifies natural path of water flowing systems. Then, the diverted water is allowed to enter into the groundwater bodies for their recharge. The process of artificial recharge, which is not natural, has direct impact on both quantity and quality parameters of the aquifer. The hydraulic conductivity and specific storage coefficient are directly affected. Similarly, the quality of diverted water has potential to change the existing water quality parameters of the aquifer.

Protocol for artificial recharge
Selection of feasible site
Artificial recharge of ground water is carried out mostly in areas where: groundwater levels are declining due to overexploitation, wells do not yield any water during lean period (CGWB, 200013), coastal aquifers need protection from seawater intrusion, concentration of toxic elements is higher than acceptable limits, groundwater depletion has caused land subsidence, or the cost of pumping has become too expensive.
Important factors governing the selection criteria of artificial recharge site include legal and social considerations, physical and chemical characteristics, and benefit/cost analyses. The rate at which an aquifer can be recharged depends on hydrogeology of the aquifer and its surrounding environment (Heath, 198414) which determines the ability of source water to percolate through the unsaturated zone and the capacity of the aquifer to store the source water. Physical and chemical characteristics such as transmission and storage capacity of the aquifer, overlying and underlying geological formations, topography (either allows or retards runoff), land use pattern, source water quantity and quality, and resulting water quality (O'Hare, et al. 1985) are central to the site selection.

All downstream problems, particularly riparian water rights, are the consequences of oversight in legal and social constraints while selecting the site. In the same way, the failure of many recharge structures is linked to the poor understanding of hydrogeology and its surrounding environment. All failures are mostly a result of illegitimate and unscientific consideration of the site. Groundwater recharge is a function of annual precipitation, hydrological characteristics, geology of the area, slopes, and nature of the soil (Igboekwe and Ruth, 201115), source water quality, selection of a suitable technique, and proper design of artificial recharge structure. Hence, the artificial recharge is a multidisciplinary work involving scientific and engineering expertise from various streams like civil and agricultural engineering, geology, geophysics, geochemistry, hydrology, soil science, and others. Therefore, all preliminary and reconnaissance survey of any artificial recharge site must be carried out by a team involving all experts of relevant disciples. Also, the involvement of all stakeholders' right from the process of site selection to completion of the project is essential. A detailed feasibility report on all technical and scientific aspects

including baseline study with clear recommendations should become mandatory for making a final decision of any recharge project.
On one hand, the feasibility report produced by multidisciplinary team can ensure a perfect and ideal site with a proper sense of accountability and transparency. On the other hand, conflict of interest in site selection or may be sometimes conflict of thoughts arising in the future can be avoided before the launch of such projects.

Source water apprehensions
As artificial recharge measures are carried out in areas where the natural recharge is slow and much below than the rate of abstraction, the availability of source water ensuring sufficient quantity (CGWB, 201316) and acceptable quality remains decisive (Bouwer, 199617). Oversight of quantitative aspects may create adverse conditions in downstream. While, polluted water of these rivers may deteriorate the existing groundwater quality of recharged aquifer. Moreover, surface water derived from the rivers, particularly in arid and semi-arid regions, carry significant sediment load which may result in clogging, if it is diverted directly into recharge structures. Artificial recharge in urban environments, where storm water remains source water, requires extra precautionary measures to deal with atmospheric deposition, road and roof surface accumulation, construction activity, industrial effluents, animal waste, litter and seepage from septic tanks. Diverting first-flood storm water to waste is a good practice but not enough to deal with the contaminants in subsequent storms. Likewise, runoff in rural areas is contaminated by pesticides, fertilisers, and faecal matter from livestock and humans. It is common practice in the world to divert such rural runoff directly into the aquifers without any pre-treatment which increases the risk of contamination of the aquifer.
Waste water as a source remains highly predictable in terms of its volume and discharge, however, it is considered to be of inferior quality (Murray and Tredoux, 199818). Thus, it requires rigorous treatment before considering for artificial recharge. Although wastewater as source can be used for all non-potable purposes, it is technically possible to treat reclaimed water and dilute with native groundwaterto the extent of potable water quality (Bouwer, 200219). However, it largely depends on the presence and nature of industries discharging wastes to sewers and the level of pre-treatment (Dillon and Pavelic, 199620). Here, the role of water resources engineers and water quality scientists becomes crucial for quantification and inspection of water quality parameters of source water. It becomes increasingly important because climate change can also result in increased intensity in precipitation, causing greater peak runoffs but less groundwater recharge. This impact of climate change, if not considered, may affect our present estimates on quantity and quality of source water. Nonetheless, quantitative and qualitative aspects of source water need to be documented in the detailed project report. Since these two features are dynamic in nature, their spatial and temporal variation should also be taken into account. All issues arising on effectiveness of artificial recharge schemes, in terms of both quantity and quality, can potentially be resolved by developing proper apprehensions of source water before commencement of the project.

Hydro-geological considerations
Storage of water within earth's crust is dependent upon geological processes that have produced voids capable of absorbing, transmitting, storing, and yielding water. In hydro-geological terms, they have been named as aquifers. Hence, a detailed hydro-geological assessment is required to understand the groundwater flow system of the aquifers to be recharged. There are misunderstandings in current hydro- geological considerations.For example, porosity is not a measure of ground-water storage capacity. Ground- water storage capacity is rather measured by the amount of water that the aquifer will yield by

gravity drainage and it is commonly known as specific yield. However, we would hardly find artificial recharge structures where the hydro- geological parameters like specific yield, infiltration rate, retention time, effective porosity, permeability and hydraulic conductivity were determined as a part of reconnaissance survey or a baseline study. Formations of sand, gravel, or highly fractured rocks; the presence of faulted zones; karst or sinkhole topography, the absence of barriers to the horizontal or vertical movement of groundwater are the indicators of feasible sites for artificial recharge. Similarly, the depth to water table can facilitate the selection of a good artificial recharge methodology. There are examples where storage capacity has been created for both natural and artificial recharge in an area underlain by Deccan basalts, in Maharashtra, India (Macdonald et al., 1995). As the aquifer parameters are crucial for design, the task of hydro-geologist becomes important in producing a comprehensive report on hydro-geological conditions and in calculating the rate at which the aquifer can be recharged. A detailed scientific investigation on hydro-geological conditions of the site and its surroundings can potentially avoid the failure of such schemes.

Selection of appropriate artificial recharge technique

As we have seen earlier, the artificial recharge methods include spreading (within channel, through a network of ditches and furrows, ponding over large area: by check dams and percolation tanks); recharge shafts (vertical and lateral); injection wells; induced recharge; improved land and water management (contour bunding, contour trenching, bench terracing, and gully plugging). However, their suitability to a particular situation varies widely. For example, spreading method can be used in a variety of forms where surface layer is a thick permeable weathered zone. In contrast, spreading method is not a viable option where surface layers are impermeable. Identification of a suitable method depends on physical conditions like soil type (infiltration capacity and distribution), source water (river, rainfall/storm, and wastewater), sub-surface storage capacity (geology, degree of confinement, permeability, groundwater flow, and quality). The proper design of any artificial recharge structure can ensure the success of the project without harming our environment. A technically sound design can contribute to the society and the environment substantially.

Conclusions

Groundwater has been consistently used for intensive agriculture for global food security, industries, and domestic demand; however, its over-exploitation in various countries has led to serious adverse environmental consequences. The damage, in some cases, is irreversible. Over- exploited regions in the world are increasing at an unprecedented rate. As a result, artificial recharge schemes have become a need of the time and moreover an opportunity in management plans. Frequent droughts in arid and semi-arid regions have imposed a threat to human survival. Therefore, most of these artificial recharge projects are planned and implemented in a very short time leaving several technical irregularities. On one hand, our challenge is to meet the demand; on the other hand, we need to protect our society, aquifers, ecology and the environment from permanent damage. All riparian issues of downstream habitants are a result of inappropriate site selection and lack of resource water understanding. In many catchments, lower reaches are now struggling for their survival because of intensive water harvesting in their upstream. Also, there are issues arising on failure of artificial recharge schemes, which may be linked to all non-scientific approach in finalizing these schemes. There has been a growing concern about diversion of poor quality source water into aquifers which invites adequate measures and policies to protect our groundwater bodies from such damages. Artificial recharge of poor source water quality can only be allowed for the aquifers being used for all non-potable uses. Otherwise, it poses a severe health risk when pre-treated

recharge water is used for potable water supplies. The practice of artificial recharge can be used for water security, but not on the cost of human health and the environment. Irrational diversion of surface water intothe aquifers has increasingly becoming a major concern for groundwater bodies. This is the high time, if not late, to rethink our approaches on artificial recharge. In fact, we require adopting a zero tolerance policy towards contamination of groundwater aquifers by absurd means of artificial recharge. We should not underestimate the damages to ecology and the environment of groundwater bodies through the instinctive recharge measures. In order to consider artificial recharge as a management option, the following protocol is suggested:

1. Description of magnitude of the problem and identification of the needs
2. Rationalization of artificial recharge as management option
3. Verification of source water
4. Feasibility report on hydro- geological considerations
5. Environmental impact assessment and people participation
6. Identification of feasible sites
7. Selection of appropriate recharge technique
8. Development of design and implementation
9. Mechanism for maintenance and monitoring

Technically, it requires a strict protocol to be followed right from selection of the site to execution of the project. The role of engineers and scientists becomes vital, accountable and more responsive at each stage of planning and execution. In brief, we require a good homework before manipulating our environment, which has not been completely understood by present stage of human intelligence.

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POLLUTION OF GROUND WATER DUE TO EXTENSIVE USE OF FERTILIZERS

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ABSTRACT

During the last four decades there have been many changes in the foot hill (Tarai - Bhabar) region of Western Himalayas including Nainital and Udham Singh Nagar districts in Uttarakhand state of India. Intensive use of nitrogenous fertilizers, has been on increase for better crop production. As a consequence in the last few years there have been reports of changes in ground water quality by the people inhabiting the area. Keeping in view the above, a study was conducted on the ground water quality of the area. The ground water samples from " Long Term Fertilizer Trial Fields " showed higher values for total alkalinity, chloride, total hardness, Ca and Mg hardness. This indicates that long-term uses of fertilizers lead to infiltration of nutrients like Ca and Mg to the ground water, which may ultimately lead to changes in chemical characteristics of water. The analysis of various forms of nitrogen, in ground water, from agricultural fields (Long and Short - Term Fertilizer Trials) revealed that nitrate content was high in ground water. However, in all cases values were quite low as compared to the maximum permissible limits of 45 mg/l. The data of present study indicate gradual accumulation of nitrogen in ground water but the levels are still relatively low. However, since nitrate percolation to ground water is a slow process, there is danger of high levels of NO_3 accumulation in ground water in the next few decades.

INTRODUCTION

Introduction of new high responding varieties, the necessity for higher economic yields and low fertilizer costs have resulted in the rapid increase in fertilizer consumption. This increase in the use of fertilizers has raised many questions concerning nutrient pollution of the surface and ground waters. When fertilizers are applied to agricultural lands, a portion usually leaches through the soil and to the water table. The primary fertilizers are compounds of nitrogen, phosphorus, and potassium. Phosphates and potassium fertilizers are readily adsorbed on soil particles and seldom constitute a pollution problem. But nitrogen in solution is only partially used by plants or adsorbed by the soils, and it is the primary fertilizer pollutant. A number of comprehensive reviews have been published concerning nitrate contamination in the environment and nitrate toxicity and health effects (Kaushik, 1963; Keeney, 1982; Narayana and Suresh, 1989; Kehew *et al*., 1996). There have been numerous studies related to nitrate contamination of ground water. A number of scientists have reported nitrate contamination of ground water, in different parts of the world, due to excessive use of fertilizers (Walker, 1973; Singh and Sekhon, 1976, 1977, 1978; Keeney, 1986, 1987; Pratt, 1984; Saxena and Mehra, 1991).The high probability of leaching, combined with large N inputs, results makes the irrigated agriculture a major potential source of nitrate to ground water (Pratt, 1984). Singh and Sekhon (1976, 1977, 1978) analysed water samples from Ludhiana and observed a significant positive correlation between amount of nitrogen fertilizer used and the nitrate concentration in ground water. They found that the amount of NO_3 contained in the soil profile down to 2.10 m depth reached the water table during rainy season. The projected geometric mean nitrate concentration was found to be 35.8 mg/l. Ramachandran *et al.* (1991) studied the nitrate

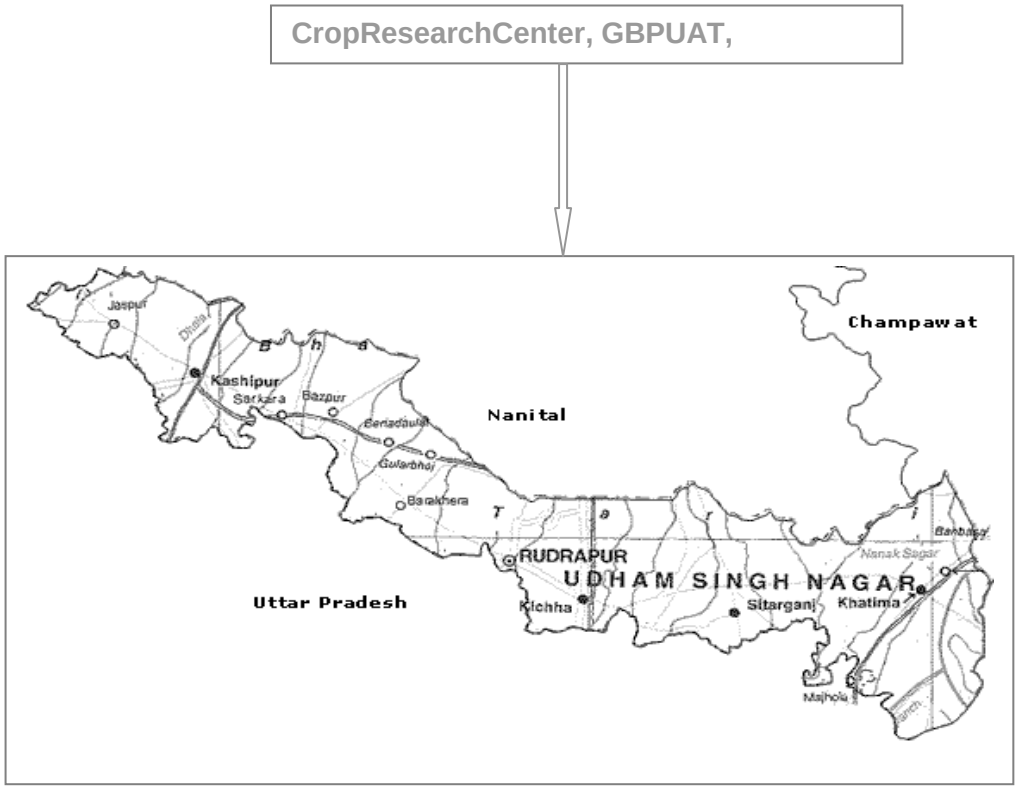
concentration in ground water of cultivated areas in North Madras. The study revealed that ground water quality was not affected by the application of inorganic nitrogen fertilizers. Saxena and Mehra (1991) found that ground water in the intensive farming belts of western U.P., Haryana and Punjab contain very high nitrate content (120 mg/l to 1310 mg/l) due to the rising trend in the consumption of nitrogen fertilizers. Kehew *et al*. (1996), in a study, concluded that nitrogen application coupled with shallow water table and permeable soil, make ground water contamination a virtual certainty. The results of the study confirm the common occurrence of nitrate-N at level higher than the drinking water standards of 10 ppm for both domestic and observation wells. The nitrate-N concentrations were found near zero in all wells screened below 30 m. Above this level the vertical distribution was quite variable.

Tarai region of Udham Singh Nagar district in Uttarakhand and adjoining district of Rampur, in the north - west Uttar Pradesh in India, is endowed with very fertile soils coupled with good rainfall. Due to this and other favourable agro - climatic conditions, the area has been under intensive agriculture for the last four decades or so. during this period there have been many changes in the area. Not only the dense forests have been cleared, there has been an unprecedented increase in urbanization, industrialization and agricultural activities. Many new industries such as Pulp and Paper Mills, Sugar factories, oil mills, rice mills, chemical factories, distillery etc. have come up. As a consequence in the last few years there have reports of changes in ground water quality by the people inhabiting the area. Considering the above, the present study was undertaken to assess the pollution level in this area, due to extensive use of fertilizers. This study was selected because of the fact that the drinking water in the region is largely drawn from the shallow aquifers and if polluted it might have adverse effects on the health of the inhabitants.

MATERIALS AND METHODS

Study Area

The study was conducted at the Crop Research Centre of the G.B.Pant University of Agriculture and Technology, Pantnagar located in the *Tarai* region of Udham Singh Nagar district of Uttarakhand in India. The farm area extends almost rectangular, measuring about 12 km east-west and almost 5 km north-south. The total University farm spread over an area of 57.5 km^2 and is located between 28^0 59' to 29^0 03' N latitude and 79^0 23' to 79^0 30' E longitude in the *Tarai* belt, as shown in Fig. 1. The climate of the area is subtropical temperate humid marked by extreme winter and very hot summer. The maximum temperature reaches occasionally beyond 46^0C. The annual rainfall ranges from 1140 to 1900 mm.



Collection of Water Samples and their Analysis

For the study of the water quality in the area under consideration the samples of water were collected in the sterilised plastic containers of 2 litre capacity from the agricultural farm lands, long term and short term fertilizer trials' field of Crop Research Centre (CRC), Pantnagar. The collected samples of the ground water were analyzed, for their physical and chemical characteristics, in the laboratory using the standard methodology.

RESULTS AND DISCUSSION

Physical Characteristics

The mean values of the physical characteristics of the ground water samples are indicated in Table 1.

Temperature : *Temperature* of the water samples collected from different places ranged from nearly 19^{o}C to 21.50^{o}C which was within the tolerance limit prescribed for the ground waters.

pH : The pH of the water samples collected from different places was nearly 7.5, and was with in the permissible limits.

Table 1. Mean values of physical characteristics of ground water in different polluted zones in *Tarai* region of Uttarakhand.

Zone	Temp. (^{0}C)	pH	Colour (H.U.)	Turbidity (NTU)	Elec. Con. (µmho)	TS (mg/l)	TDS (mg/l)	TSS (mg/l)
Agricultural Farm Land	18.92	7.53	11.67	6.83	346.67	486.67	166.67	320.0
Long Term Fertilizer Trial Field	21.50	7.53	13.50	2.77	929.40	650.00	513.00	137.0
Short Term Fertilizer Trial Field	20.20	7.48	10.00	3.28	720.00	358.00	280.00	78.0

Colour : Colour of the water samples was determined in terms of Hazen units The lowest and the highest mean values of colour intensity of ground water for agricultural areas varied within the ranges of 10 to 13.50 H.U. with highest in long term fertilizer trial field and minimum in the waters from the short term fertilizer trial fields. The values show the presence of chemical pollutants in the ground water as colour of the ground water is concerned.

Odour : The ground water samples were odourless.

Turbidity : The lowest and the highest mean values of turbidity of water samples collected from different places ranged from 2.77 to 6.83 NTU. Maximum permissible limit for turbidity as per International Standards of Drinking Water-WHO Geneva, 1963 is 25 NTU. Thus the turbidity ranged with in the permissible limits.

Electrical conductivity (EC): The electrical conductivity value reflects the salt content in the water sample. The mean electrical conductivity of the water samples varied from 346.66 µ mho at agricultural farm lands to 929.40 µ mho for long term fertilizer trial field. This indicates leaching of salts below into the ground water of the area.

Solids

Total solids (TS) : Total solid content of different samples varied from 358.0 mg/l to 650.0 mg/l. The highest value of the total solids was found in the ground water samples collected from the long-term fertilizer trial fields, whereas the lowest value was observed for the water from the short term fertilizer trial fields.

Total dissolved solids (TDS) : The total dissolved solids mainly consist of bicarbonates, carbonates, sulphates, chlorides, nitrates, and possibly phosphates of calcium, magnesium, sodium and potassium with traces of iron, manganese and other substances. The lowest and the highest mean values of total dissolved solid concentration varied from 166.67 mg/l to 513 mg/l for all the samples collected from different places of agricultural areas. The ground waters in the area under study may be used for human consumption without harmful physiological effect.

Total suspended solids (TSS) :The TSS value is generally used to evaluate the strength of domestic waste waters and to determine the efficiency of treatment unit. BIS has recommended the maximum permissible limit of TSS for drinking water as 30 mg/l. The lowest and the highest mean values of total suspended solid concentration varied from 78 mg/l to 320 mg/l. Since the values were above the safe permissible limits, the use of ground water from the agricultural fields for drinking purposes was not safe.

Chemical Characteristics

The chemical characteristics of the groundwater samples are summarized in Table 2. ***Dissolved Oxygen (DO) :*** The lowest and the highest mean values of DO concentration of different samples varied from 4.64 mg/l for long term fertilizer trial field to 8.20 in agricultural farm lands. The higher values in agricultural farm lands in comparison to the long term fertilizer trial fields may be due to higher and/or unbalanced fertilizer input.

Table 2. Mean values of different bio-chemical parameters of ground water in different polluted zones in *Tarai* region of Uttarakhand.

Zones	DO	COD	BOD	Total Alkali-nity	Acidity	Cl	Free CO_2	Hardness			Ca	Mg
								Total	Ca	Mg		
AFL	8.20	19.18	2.12	281.7	83.3	15.1	33.35	248.3	100.7	147.6	40.2	35.5
LTF	4.64	36.89	3.75	359.7	184.1	43.6	56.40	456.0	189.2	266.8	75.7	63.5
STF	7.62	31.38	3.20	297.6	231.2	41.2	63.60	310.0	124.0	186.4	49.4	45.6

Chemical Oxygen Demand (COD) :The lowest and the highest mean values of COD concentration of samples ranged from 19.18 mg/l for agricultural farm land to 36.89 mg/l for long term fertilizer trial field.

Biochemical Oxygen Demand (BOD) : The lowest and the highest mean values of the BOD of different samples varied from 2.12 mg/l for agricultural farm land to 3.75 mg/l for long term fertilizer trial field.

Total Alkalinity : The lowest and the highest values of total alkalinity for agricultural areas varied within the range of 281.7 to 359.7 mg/l for agricultural farm lands and long term fertilizer trial field, respectively. Under the present study the alkalinity of the ground water from the agricultural farm lands was more than the total hardness, indicating the presence of basic salts -Na and K in addition to those of Ca and Mg.

Acidity :Total acidity for the samples was found in the range of 83.3 mg/l to 231.2 mg/l. The lowest value of 83.3 mg/l was observed for the well water collected from agricultural farm, while the highest value of 231.2 mg/l was observed for the observation wells of short term fertilizer experiment field, CRC.

Free Carbon dioxide : The lowest and the highest mean values of free CO_2 for agricultural areas varied within the range of 33.35 to 63.60 mg/l , respectively, for agricultural farm land and short term fertilizer trial field.

Chloride : The lowest and the highest mean values of chloride for agricultural areas varied within the range of 15.10 to 43.60 mg/l , for agricultural farm land and short term fertilizer trial field, respectively.

Hardness

***Total hardness* :** The mean value of total hardness of the samples in terms of $CaCO_3$ was found to be in the range of 248.3 mg/l to 456.0 mg/l. The lowest value was found for the well water of agricultural farm land while the maximum value of 456.0 mg/l was observed for the sample collected from plot No. T5 of long term fertilizer experiment field, CRC.

***Calcium hardness* :**The mean value of Ca hardness of the samples ranged between 100.7 to 189.2 mg/l. The lowest value was found for the well water of agricultural farm while the maximum value of 189.2 mg/l was observed for the sample collected from plot No. T5 of long term fertilizer experiment field, CRC.

***Magnesium hardness* :** The lowest and the highest mean values of Mg hardness for agricultural areas varied within the ranges of 147.6 to 266.8 mg/l . The lowest value was found for the well water of agricultural farm while the maximum value was observed for the sample collected from plot No. T5 of long term fertilizer experiment field, CRC.

Calcium : Ca is an essential element and human body requires approximately 0.7 to 2.0 g of Ca per day as a food element. Ca deficiency is the most common nutritional lack in many parts of the world. However, waters with high Ca content are undesirable for household uses such as washing, bathing etc., because of the hardness requiring more soap and other cleaning agents. Ca is essential for plant growth and is desirable in water for irrigation up to some extent. Ca content is directly related to hardness. Ca content for the samples ranged between 40.2 mg/l and 75.7 mg/l. All the observed values were within the permissible limit of 200 mg/l set by BIS.

***Magnesium* :** Mg is one of the essential elements, which is relatively non-toxic for human beings. However, higher concentrations may cause unpleasant taste to water. At high concentrations, Mg salts have a laxative effect particularly where present as magnesium sulphate. Mg is essential for crop growth. Ca and Mg ions in irrigation water tend to keep soil permeable and in good tilth. For groundwater samples of the area, the maximum Mg content was 63.5 mg/l. This value was observed for same samples as in the case of total hardness.

Nitrogen : To study the presence of the nitrogen in ground water the water samples were analysed for various forms of nitrogen. The mean values of the various forms of nitrogen present in the samples are presented in Table 3. The currentpublic health standards for safe drinking water require that maximum contaminant level(MCL)should not exceed nitrate concentrations of 10 ppm as nitrate-N or 45 ppm as nitrate (10 ppm nitrate-N is same as 45 ppm nitrate).

Nitrate - N: Nitrate - N concentration for different samples from the agricultural farm were observed between 0.08 mg/l to 0.18 mg/l. The NO_3-N concentration for the samples of ground water collected from different plots of fields under short-term and long-term fertilizer experiment trials varied from 0.25 to 0.67 and 0.06 to 0.58 mg/l, respectively.

Nitrate: It has been reported in the literature that nitrate concentration above 20 mg/l may cause 'methamoglobinemia' in infants, a disease characterised by blood changes. The disease 'cyanosis' in which the haemoglobin apparently becomes incapable of transporting oxygen is also attributed to the high concentration of nitrates in the waters used for preparing feeding formulas. The maximum limit for nitrate in drinking water as per USPHS Drinking Water Standards is 45 mg/l as nitrate. Nitrate concentration for different samples of ground water was observed between 0.2544 mg/l to 2.5694 mg/l. The highest concentration of 2.5694 mg/l was observed for the samples of well no. 13 N of the long term fertilizer trial field of Crop Research Centre whereas the lowest concentration was observed in the ground water from well no. 11 N of the long term fertilizer trial field of Crop Research Centre, Pantnagar.

Table 3. Chemical characteristics of ground waters in terms of nitrogen in different pollution zones in *Tarai* belt of Uttarakhand.

Zone / Well Location	Well No.	NO_3-N	NO_3	Total N
Agricultural farm Land				
Pantnagar Farm	4A	0.08	0.3544	1.03
	5A	0.16	0.7088	1.16
	6A	0.18	0.5227	1.07
	8A	0.18	0.7974	1.06
Short-Term Fertilizer Trial Field				
CRC, Pantnagar	1N	0.41	1.8163	5.00
	2N	0.31	1.3733	6.20
	3N	0.25	1.1075	8.40
	4N	0.46	2.0378	4.50
	5N	0.67	2.0821	9.20
Long-Term Fertilizer Trial Field				
CRC, Pantnagar	11N	0.06	0.2561	4.48
	13N	0.58	2.5694	7.56
	14N	0.51	2.2593	3.64
	15N	0.12	0.5316	5.04
	16N	0.08	0.3544	5.60
	17N	0.33	1.4619	5.88
	18N	0.29	1.2847	4.20

Total nitrogen : Total nitrogen concentration in water samples varied from 1.03 mg/l to 9.2 mg/l. The highest value was observed for the sample collected from observation well located at the centre of the short term fertilizer experiment field. The total-nitrogen content, in case of short term fertilizer experiments, varied from 4.50 ppm to 9.20 ppm. No direct correlation could be found between the concentrations of nitrate in ground water. The total nitrogen content in case of long term fertilizer experimental field varied from 3.64 ppm to 7.56 ppm. The nitrogen concentration for all the ground water samples was found well within the prescribed limits of the nitrogen in ground water for human consumption.

CONCLUSION

A comparison of data on main physical properties of ground water from various regions reveal that ground water from long term fertilizers trial field of CRC, reflected some sort of chemical pollution in the form of higher values of total alkalinity, chloride, total hardness, Ca and Mg hardness. This indicates that long term uses of fertilizer lead to infiltration of nutrients like Ca and Mg to the ground water which may ultimately lead to changes in chemical characteristics of water. Comparison of mean values of various forms of nitrogen shows that nitrate content was high in ground water from the fertilizer trial areas. However, in all cases values were quite low as compared to the maximum permissible limit of 45 mg/l. Total nitrogen (inorganic and organic forms) in water was highest for agricultural areas. The high values of total nitrogen in ground water of agricultural areas clearly indicate percolation of nitrogenous fertilizers to the ground water but the levels are still relatively low. However, since nitrate percolation to ground water is a slow process, there is danger of high levels of NO_3 accumulation in ground water in the next few decades.

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TOWARDS EFFECTIVE ASSESSMENT AND MONITORING OF VULNERABILITY TO DROUGHT

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Abstract

The vulnerability to drought refers to a degree of exposure of an area to water deficit or shortage. It depends on regional physiographic features, climatic, hydrologic, environmental and socio-economic factors including regional developmental activities and ability to cope with drought. The vulnerability to drought varies with time and space. In this paper an attempt has been made to formulate a methodology for integrated assessment of vulnerability to drought in spatial and temporal scales using physiographic, meteorological, hydrologic, social and other factors. The physiographic factors are static physical features of basin including topography, slope, land use, soil type, soil depth, proximity to river reach, elevation zones and population density. The meteorological and hydrological factors are monthly rainfall departures from corresponding mean and soil moisture deficit. The spatial information of multiple factors has been categorized in various sub-classes and maps have been prepared using ArcGIS. A differential weighting scheme for various factors has been devised based on the level of significance of different sub-classes towards vulnerability to drought. The methodology has been applied in the Ken River Basin, located in the Bundelkhand region in central India. The Soil and Water Assessment Tool (SWAT) model has been applied to demarcate hydrologically homogeneous areas called HRUs in respect of land use, slope and soil type, and for the estimation of spatial and temporal distribution of soil moisture in the study basin. Using the soil moisture estimates from SWAT model, Soil Moisture Deficit Index (SMDI) has been computed. An Integrated Drought Vulnerability Index (IDVI) has been defined as the sum of weights of various factors scored by corresponding HRU (Hydrologic Response Unit) divided by the sum of the maximum weight value of each factor. The HRUs with higher value of IDVI represents the areas with high degree of vulnerability to drought and vice versa. The maps thus obtained were validated using the documented information and field surveys. The prepared map showed very good agreement with the physical field observations made in the study basin. The methodology presented in this paperputs forward a useful and reliable tool for quantitative assessment and demarcation of zones withdifferent degree of vulnerability to drought in time and space.The proposed methodology can be used for proactive as well as near real time assessment, monitoring and planning of response actions to cope with drought.

Keywords: Drought Vulnerability Index, SWAT Model, Soil Moisture Deficit Index, Rainfall Departure, Ken Basin in India

Introduction

Drought refers to relative deficit in precipitation over a given place for a certain period of time. The impact of droughts on agriculture, water availability, and regional social and economic activities depends on various regional climatic, physiographic, hydrologic, and socio-economicfactors(Alcamo et al. 2008;Pandey and Ramasastri 2002; Pandey et al. 2010;Vinit et al. 2015).Vulnerability refers to the degree of susceptibility to a hazard either

as the result of varying exposure to the hazard or because of variation in the ability to cope with its impact. Areas that have higher exposure and low coping capabilities would have highest risk from a given drought event and vice-versa. The degree of exposure to drought or water scarcity depends on climatic, hydrologic, environmental, socio-economic activities and physical characteristics like topography, land-use, soil type, soil depth, surface water storage andwater demandsin the region (Wilhelmi et al., 2002; Hamouda, 2009). Drought vulnerability thus depend upon on multiple factors such as topographic features, soil, land used, water resources development (irrigation supports), in-situ water conservation, utilizations of ground water, and regional water demand for domestic, industrial and agriculture activities etc.(Pandey et al. 2010; Jain et al. 2015). Thus, vulnerability to drought has dimensions of time and space (Downing and Bakker 2000; Wilhite 2000). The social vulnerability to drought is complex and it is reflected by society's capacity to anticipate, cope with and respond (Tsakiris and Pengalou 2009, and Iglesias et al. 2009b). Keeping in view the experiences and emerging lessons in development and implementation of drought management plans, Iglesias et al. (2009a) emphasized to adopt risk-based approaches for different levels of vulnerability to meet the challenges of coping with impacts of drought and water shortages. Also, Iglesias et al. (2009b) proposed methods for evaluating social vulnerability to drought using the natural resource structure, the economic capacity, the human and civic resources, and aspects of agricultural innovation etc. They weighted the above factors appropriately and computed final value of the vulnerability index. The severe drought events recently occurred all over the world have increased awareness of the harmful impacts they cause. Since drought, unlike other natural disasters, evolves in a long period of time, an effective reduction of related impacts is possible by implementing appropriate mitigation measures planned in advance (Rossi et al., 2007).The inspiration of concept for derivation of drought vulnerability mapwas originally taken from the 'DRASTIC' methodology for groundwater pollution assessment (Aller et al., 1987), Eastman et al. (1997) for food security mapping, and Thiruvengadachari and Gopalkrishna (1993) for drought mapping. Wilhelm and Wilhite (2002) and Wilhelmi et al.(2002) described drought vulnerability for the state of Nebrasks in U.S.A. using biophysical and social factors in spatial domain. Iglesias et al (2009b) presented guidelines to develop drought management plans using risk-based approach to mitigate the drought impact at different vulnerabilities.

Description of the Study Area

The Ken River basin located in central India between north latitudes 23^0 07' and 25^0 54' and east longitudes of 78^0 30' and 80^0 40'. The river Ken originates at an altitude of 550.0 m above mean sea level (msl) and drains a total basin area of 28,692 km^2 before it joins river Yamuna at an elevation of about 87.0 m above msl. The average elevation of the plain areas of the basin is about 328 m above msl. Fig. 1 shows the location map of the Ken Basin in India. The study basin belongs to the semi-arid and dry sub-humid climatic region of India with a single rainy season (June-September) followed by dry winter, and then a very dry summer. The average annual rainfall in the basin varies from 1250 mm near its origin to 800 mm near its confluence with Yamuna River with an estimated basin averaged annual rainfall of about 1165 mm (Pandey et al. 2008). The basin receives about 90% of its mean annual rainfall during south-west monsoon (June-September). The Upper reaches of river basin have hilly terrain covered with thick forests and undulating topography. The soil varies from mixed red and black soils to medium black soils. Northern most parts of the basin have patches of sandy loam soils also. The Location and Index Map of the Ken River Basin is shown in Fig. 1.

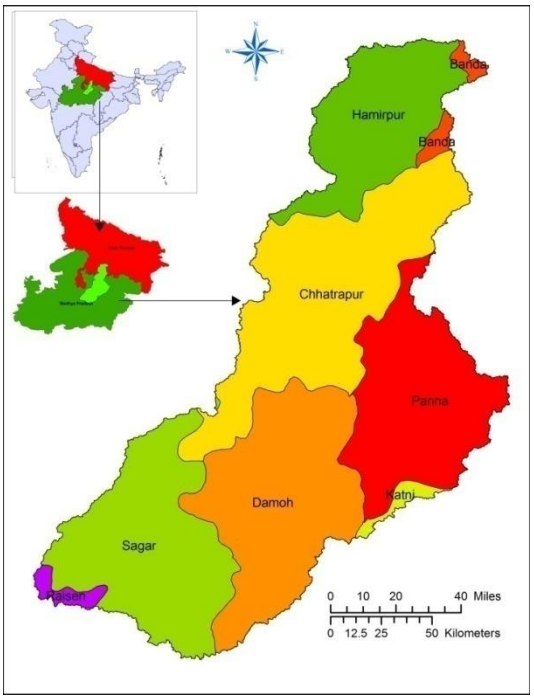


Fig. 1. Location and Index Map of the Ken River Basin

Description of Approach

The research is conducted in the Ken River Basin of India. It is understood that geographical location, physical characteristics of watershed, surface and ground water availability, variability of rainfall, regional climatic factors and socio-economic factors are responsible for water deficits and crop loss during drought in the study basin (District Statistical Handbook 1993 & 2007; Pandey et al., 2010 and Jain et al, 2015). During this study in the year 2006-2010, comprehensive field investigations were carried out in the Ken basin to monitor the onset and progression of droughts, quantification magnitude of drought severityand the extent of impact of drought on extent of area sown and crop yield. Fortunately, droughts occurred in the year 2006 and 2007 in the study basin (Pandey et al. 2010). It is hoped that the factual method for assessment of vulnerability to drought, which assimilate multiple factors in spatial and temporal domain using GIS, can be helpful to decision makers in visualizing the hazard and to disseminate the concept of vulnerability to stakeholders, natural resource managers, agricultural producers and others.

The agriculture sector is usually the first to get affected by drought because of its dependence on soil moisture which depletes rapidly during extended dry periods (Narsimhan and Srinivasan, 2005). Besides the deficiencies of rainfall, the depletion of soil moisture and reduction in stream flow play a vital role in the determination of onset and severity of drought event. Soil moisture and streamflow greatly depend upon the various physiographic factors such as type of soil, land use, topography, slope, geographic location of the basin and season. Spatial distribution of soil type, land use and land cover affect rate of infiltration, permeability, soil's moisture holding capacity and evapotranspiration (ET) of a region (Liu et al. 2008; Rose and Peters 2001; Gregory et al. 2006; Price et al. 2010). Spatial variability in precipitation and ET may also result from differences in topographic characteristics, such as aspect and elevation among watersheds. Further, topography of an area, land use and geomorphology affect stream flows (Vivoni et al. 2008; Tetzlaff et al.

2009; Price et al. 2011). Thus, the above discussed physiographic factors influence the availability of water and degree of water deficit/scarcity in a basin in space and time during drought. The measured values of soil moisture and streamflow are often not available in a basin at desired locations. Therefore, a distributed hydrologic model is preferred for soil moisture assessment. Also the areas with similar land-use, soil type and slope steepness behave in the same way in terms of their hydrologic response (Arnold et al., 1998).The Soil and Water Assessment Tool (SWAT) model (Neitsch et al., 2005) is capable to discretize the basin area into hydrological response units (HRUs) which have similar land use, soil type, and slope and provides estimates for soil moisture, evapotranspiration, surface runoff etc at the level of HRU. In view of the above, this study is taken up to assess vulnerability to drought in time and space domain in the Ken River basin in the Madhya Pradesh, India. The major purpose of this study is to devise a method for integration of various factors for spatial and temporal assessment of vulnerability to drought using a variable weighing scheme for various factors.

Analysis of Meteorological Drought in the Study Basin

India Meteorological Department (IMD) defines an area orregion to be drought affected if it receives less than 75% of its normal rainfall (Appa Rao, 1986). Accordingly in the present study, a year and a monsoon season (June-Sept) are considered as drought years and drought season respectively, if the total amount of rainfall over an area is deficient by 25% or more from corresponding mean values. Monthly rainfall data of 12 rain gauge stations for a period of 110 years from 1901-2011 (data missing for the year 2003) have been used in the analysis. In the present study, meteorological drought characteristics of the study basin have been assessed for monthly, seasonal and annual time scales. The meteorological droughts in a study basin are characterized on the basis of duration (period of rainfall deficit), severity (magnitude of rainfall deficiency), and frequency (drought recurrence).

Annual and seasonal rainfall departures with respect to corresponding mean values (RD-Mean) have been computed using the equation (Eq.1) for various stations in the Ken basin for the entire period of records starting from 1901 to 2011 to demarcate a year or season as wet year, normal year or drought year. Criterion used to demarcate wet and dry season or year is shown in Table 1.

$$RD - Mean(\%) = \frac{(x_i - \overline{x_i})}{\overline{x_i}} X100 \qquad \text{.....(Eq.1)}$$

Where, x_i represents the rainfall for a given month, season or a year and $\overline{x_i}$ represent the long term average for a corresponding month, season or year. The sample plots of annual and seasonal rainfall departures for Chattarpur and Sagar stations are shown in Fig. 2(a,b), respectively. As can be seen from Fig. 2(b), the basin experienced drought once in every five years on an average in later half of the past century. Major drought years identified from the rainfall departure analysis are 1905, 1913, 1918, 1941, 1965, 1966, 1987, 1989, 1991, 1992, 1993, 2002, 2006, 2007, 2009, 2010. The maximum annual rainfall deficit could be recorded as -50 % of annual mean in Sagar district. It is also evident from the analysis that the occurrences of annual droughts coincide with seasonal droughts. It is revealed that the deficiency of rainfall during monsoon season (June to Sept.) is primarily responsible for occurrence of drought and water stress in subsequent part of the year in the study area.

Table1. Criterion adopted to classify a year into different categories

Sr. No.	Rainfall Received in any year	Category
1	>125 % of Mean	Wet
2	125 % - 110% of Mean	Mild Wet
3	109%- 90% of Mean	Average
4	89% -75% of Mean	Mild Dry
5	74%- 65% of Mean	Moderate Drought
6	64%-50% of Mean	Severe Drought
7	<50% of Mean	Extreme Drought

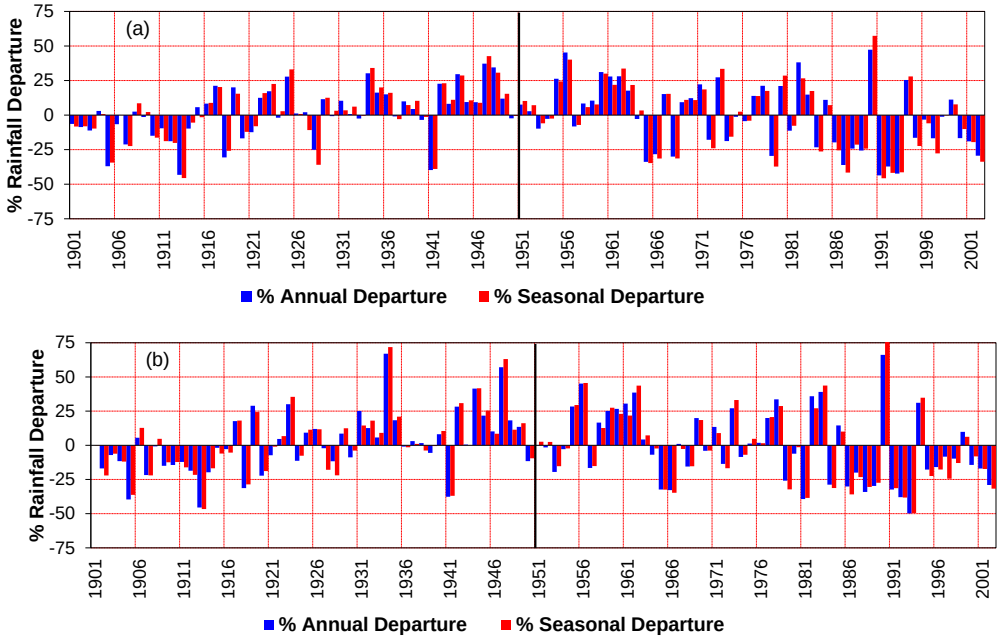


Fig.2: Plots of Annual and Seasonal Rainfall Departure for station (a) Chattarpur and (b) Sagar

Proposed Differential Weighting Scheme to Integrate Multiple Factors

In light of the discussions in the preceding sections, a differential weighting scheme is proposed as given in Table2 considering the relative importance of various factors on vulnerability to drought. In Table2, the choice of the range of weighted values for various factors is based on the assumption of relative degree of influence of a factor in overall vulnerability to drought. In the proposed scheme, the soil moisture deficit represented as Soil Moisture Deficit Index (SMDI, Narsimhan and Srinivasan, 2005) and rainfall deficiency in the form of rainfall departure are considered as the most influential factors and hence SMDI and rainfall departure have been assigned the highest weight range from 0 to 25 (Table 2). The land use and relative elevation have been considered moderately influential factors and hence assigned a range of numerical weight values vary from 0 to 10. It is assumed that the water demand and availability varies considerably with land use types and elevation zones, respectively. The slope, soil type, soil depth, distance from river reach and population density have been taken as relatively less influential factors and numerical weight values for these factors range from 0 to 5. This is termed as “differential weighing scheme” because different ranges of weights have been assigned to various groups of

factors. The weight value of 0 indicates that the sub-class of a given factor is causing least affect in vulnerable to drought. On the other hand, a higher weight value indicates that the sub-class is severely causing vulnerability to drought. For example, heavy (clay) soils have greater water holding capacity than sandy soils. Hence, sandy soils are assigned more weight value than heavy soils. Similarly, different weights have been assigned to various sub-classes of other factors too.

Different layers of spatial maps of physiographic, climatic and hydrologic factors are prepared using ArcGIS software and weights proposed in Table 2 are assigned to various sub-classes of factors. The weights assigned to various sub classes of factors are integrated using a simple scheme of addition of weight at corresponding HRU level. The composite weight value scored by selected HRU divided by the sum of maximum weight values of each factor represents Integrated Drought Vulnerability Index (IDVI). Thus, the IDVI has been defined as the ratio of sum of assigned weight value of each factor to the sum of the maximum weights of all selected spatial and temporal factors. Consequently, quantitative assessment of degree of vulnerability to drought for given HRU has been mathematically estimated using following equation (Eq. 2).

$$IDVI = \frac{\sum_{i=1}^{n} W_i}{\sum_{i=1}^{n} W_{i_{max}}} \quad \text{.....(Eq. 2)}$$

Where,

IDVI = Integrated Drought Vulnerability Index;
W_i = Weight scored by HRU for i^{th} factor
$W_{i_{max}}$ = Maximum weight of i^{th} factor
n = Number of factors under consideration

The appraisal of IDVI at HRU scale indicates that a geographic area, i.e. HRU, showing greater numeric value of IDVI is more vulnerable to drought than that of less value.

Table2. Weights assigned to various sub-classes of considered drought vulnerability factors

Sr.No.	Factors	Classification of drought vulnerability factors		Weights of different classes of factors
	(i)	(ii)		(iii)
1.	Land Use	Water Bodies (Areas under submergence)		-100
		Waste Land		0
		Range Land		2
		Pasture Land		4
		Forest		6
		Urban Land		8
		Agriculture		10
2.	Irrigation Support	Irrigated		-5
		Un-irrigated (rainfed)		5
3.	Elevation zones	Lower elevation zone	<140m	1
			140m-210m	2
			210m-280m	3
		Middle elevation zone	280m-350m	4
			350m-420m	5
			420m-490m	6

		Upper elevation zone	490m-560m	7
			560m-630m	8
			630m-700m	9
			>700m	10
4.	Slope	0-2%		1
		2%-5%		2
		5%-8%		3
		8%-12%		4
		>12%		5
5.	Distance from River Reach	Upto 1km		1
		1-3 km		2
		3-5km		3
		5-7 km		4
		>7km		5
6.	Soil Texture	Clay		1
		Loam		2
		Silt Loam		3
		Silt		4
		Sand		5
7.	Soil Depth (mm)	>=1000		1
		<1000 to >=800		2
		<800 to >=600		3
		<600 to >=400		4
		<400		5
8.	Population Density/Km^2	0-100	Low	1
		100-200	Moderate	2
		200-300	Medium	3
		300-400	High	4
		400-500	Very High	5
9.	Soil Moisture Deficit Index (SMDI)	>- 0.5	Near Normal	0
		-0.5 to -1	Dry Spell	5
		-1 to -2	Mild Drought	10
		-2 to -3	Moderate Drought	15
		-3 to -4	Severe Drought	20
		< -4.0	Extreme Drought	25
10.	Rainfall Departure	>−10%	Near Normal	0
		−10% to −15%	Dry Spell	5
		−15% to −25%	Mild Drought	10
		−25% to −35%	Moderate Drought	15
		−35% to −50%	Severe Drought	20
		<−50%	Extreme Drought	25

Multiple Factors Affecting Vulnerability to Drought

Vulnerability to drought depends on numerous factors including physiographic, meteorological, hydrological, agricultural, socio-economic and environmental factors. These factors can be categorized as:

(i) Static factors: which do not change with time. They change with space only. For example topography, land use, slope, soil type, soil depth, etc.

(ii) Semi static factors: which change with the phase of development like irrigation support, water resources development, storage schemes, cropping pattern, population density, etc. and

(iii) Dynamic factors: which change with space and time, for instant, rainfall, streamflow, soil moistureetc.

An integrated drought vulnerability index (Eq. 2) includes various factors such as meteorological, hydrological, agricultural, socio-economic and environmental factors. The integrated drought index is designed in an attempt to overcome some of the ambiguities in drought indices. It is unique because incorporates information from so many disparate types of drought information resources. The dynamic layers are depending on time and linked to time series data. Space-time or dynamic layers may be including: precipitations, evapotranspiration, mean temperature, groundwater levels, surface water storage, and environmental needs.

The physiographic factors considered in the present study are land use, slope, relative elevation of a place, distance from river reach, soil texture, soil depth, irrigation support, and population density. The areal extents of different sub-classes of physiographic factors present in the study area are given in column (iv) in Table 2. The significance of sub-classes of various physical factors is discussed in the following sections.

(i) Land Use: Land use is one of the important factors influencing vulnerability to drought. Landuse information is obtained by classifying Landsat ETM+ satellite data (NASA, 2003).Land use in the study basin is dominated by rainfed crop cultivation (about 53.8%) followed by forest (23.48%) and other uses including pasture, water bodies, waste and residential land (22.72%) etc. Among the various land uses, it is implicit that agriculture becomes the first sufferer due to water scarcity and drought compared to forest and other land uses because of its dependence on soil water. Therefore, agricultural lands are considered most vulnerable land use class to drought and assigned highest weight value. On the other hand, range land and waste land are least significant, and therefore, considered as less sensitive to water shortages and the less weight values have been assigned to these classes. The relative weights of vulnerability to different land uses are given in Table 2. The spatial distribution of land use in the basin is shown in Fig. 3. The area under water bodies is assigned negative weight value of -100 to mask them, since areas under water bodies are considered as non-vulnerable to drought.

(ii) Irrigation: Irrigation accessin a basin can be one of the key factors in the assessment of vulnerability to drought. There are very few minor and medium irrigation projects in the Ken river basin. The Bariyarpur command area, as shown in Fig.4, in the Ken River basin having irrigation command area of approximately 572 Km^2 is assigned negative weight value of -5 (Table2) to ascribe the irrigation command as area under low vulnerability zone, because the command areas are less exposed to short term water scarcity due to irrigation support. However, rest of the area under rainfed agriculture is assigned higher weight value of 5, because of its full dependence on rainfall.

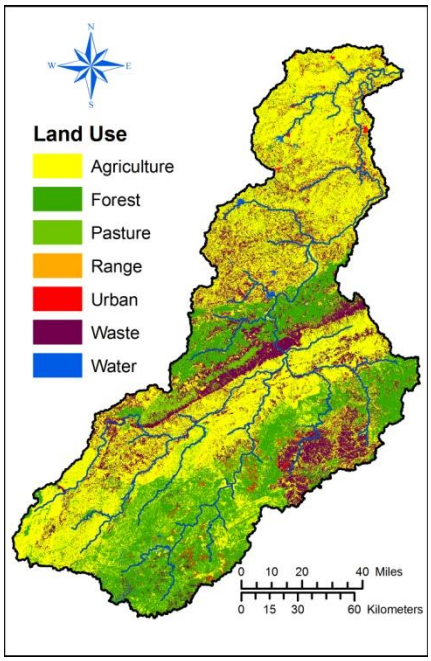


Fig. 3. Land Use Map of Ken River Basin

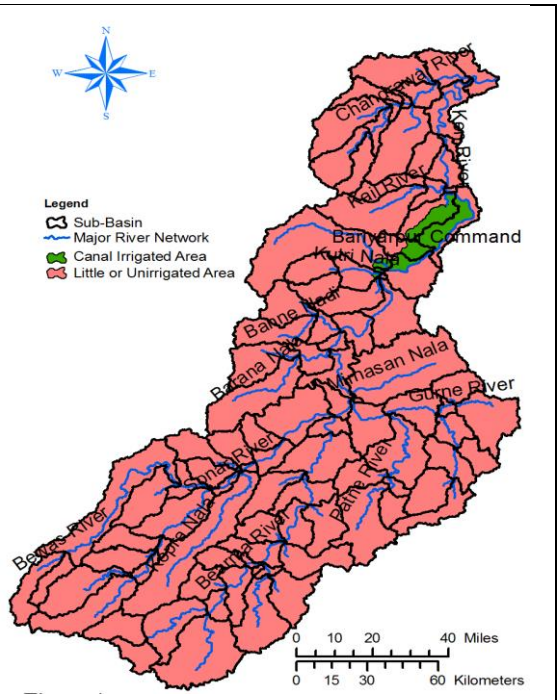


Fig.4. Bariyarpur Command Area Map

(iii) Slope: The slope map of the study basin is obtained from the elevation data obtained from SRTM (Jarvis et al., 2008) and the basin has been categorized into five slope classes viz. 0-2%, 2-5%, 5-8%, 8-12% and more than 12%. Spatial distribution of these slope classes in Ken basin is shown in Fig. 5. It is established from various studies that the soil moisture stay for relatively longer time in plain land areas followed by areas with mild and steep slopes. Hence, the areas with lesser slopes are considered least vulnerable to drought compared to moderate and higher slopes. In this case, slopes in the range from 0-2 % are categorized as least vulnerable to drought, followed by moderate and higher slopes. Thus, the relative weights assigned to each slope category are shown in Table 2.

(iv) **Elevation Zones:**Water availability greatly depends on elevation of the place in the basin. To indirectly account for the water availability at different elevations, Ken basin is divided into three elevation zones. These elevation zones are lower elevation zone (up to 280 m), middle elevation zone (280 m - 490 m) and upper elevation zone (more than 490 m). The upper elevation zone have mostly hilly and undulating topography with average slopes >6% and streams of 1st and 2nd order which are mostly ephemeral in nature. The upper reach areas do not sustain flow beyond October/ November and therefore have zero or lowest surface water availability during non-rainy season. The middle elevation zone encompass land areas with average slopes between 2-6% and streams of 3rd and 4th order having flow in streams upto December and January months and have moderate surface water availability. The lower elevation zone includes areas with average slopes <2% and stream flows are intermittent to perennial. Also, the lower sections of basin often get more time for water retention than upper and middle parts. Therefore, upper reaches of the basin may be considered more vulnerable followed by middle and lower reaches of the basin. The relative weights assigned according to vulnerability to water

scarcity of each elevation category are being given in Table 2. The elevation distribution of the study basin is shown in Fig. 6.

(v) **Distance from River Reach:** It is assumed that areas closer to river courses are less vulnerable to water scarcity because of more recharge potential and ground water availability relatively for longer period in comparison to areas distant from the river course. Accordingly, the basin area has been divided into five sub-classes depending upon the distance from the river course as shown in Fig.7. The area within one kilometer of the river boundary is considered as least vulnerable, while areas beyond 7 km distance are considered as highly vulnerable. The weights assigned to various categories according to distance from the river reach are given in Table 2.

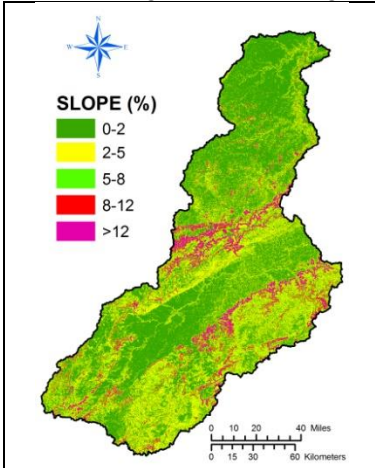


Fig. 5. Slope Map of the Ken Basin

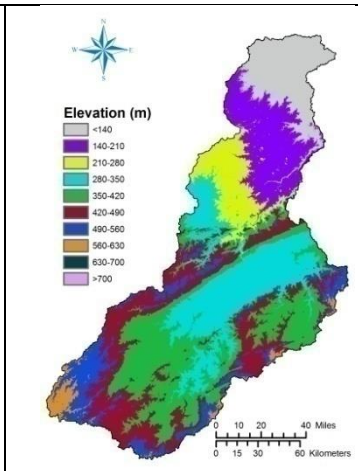


Fig. 6. Elevation zone in Ken River Basin

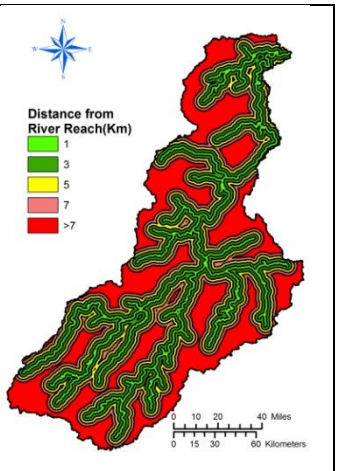


Fig. 7. Map showing the Distance from the River Reach

(vi) **Soil Type:** One of the main functions of soil is to store moisture and supply it to plants during non-rainy periods. The available moisture storage capacity of soil determines the time span for which particular type of soil could sustain dry spells in supplying moisture to plants for their survival. The soil map is digitized from hardcopy maps obtained from National Bureau of Soil Survey and Land Use Planning (NBSS&LUP) of the State of MP and UP and Soil Series of India (NBSS, 1994). Soils in the Ken River basin are classified into four major textural classes viza viz. clay, loam, silt and sand as shown in Fig.8. Out of which Clay soils are considered least vulnerable to drought because they retain more moisture compared to other types of soils (Blencowe et al., 1960). On the other hand gravely sandy loam soils hold least moisture and are most vulnerable to drought. Thus, soils having greater water holding capacity indicate low vulnerability to drought because root-zone has more available-water for plants. However, light soils have less available water for plants and signify high vulnerability to drought. Accordingly, areas with lighter soils are considered relatively more vulnerable than clayey soil areas.

(vii) **Soil Depth:** The soil depth largely controls total soil water storage for plants (McColley and Hodgkinson, 1970). Soils having more depth are capable to supply more water to plants and are considered as less vulnerable to drought and vice versa. Spatial distribution of soil depth in the study basin is shown in Fig. 9.

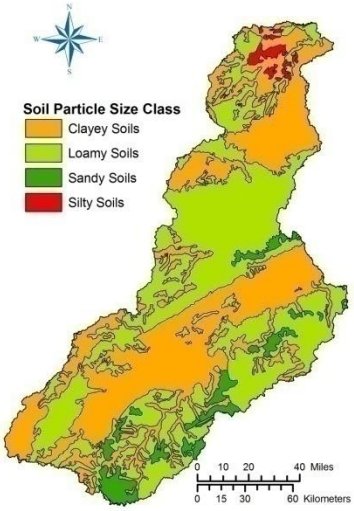


Fig. 8. Textural Classification of Soil type in Ken River Basin

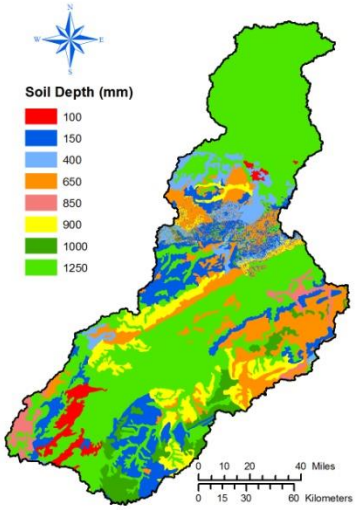


Fig. 9. Spatial Distribution of varying Soil Depth in Ken River Basin

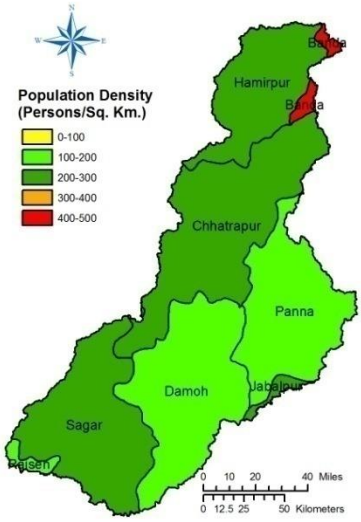


Fig.10. Population Density Map of Districts in Ken River Basin

Population Density: The pattern of water demand in an area is also affected by population density and it is considered as one of the important factors for water scarcities in lean periods (non-rainy season). In this study, areas with higher population density are considered to be more vulnerable than those with less population density. It is because the higher population density areas would have relatively more water demand and hence more susceptible to water scarcity during drought. Accordingly highly populated cities, towns and bigger villages are considered to be more vulnerable. The areas with less population and hence low water demand category are less vulnerable. Relative spatial distribution of population density in the study area is shown in Fig.10.

(viii) **Climatic and Hydrological Factors:** The rainfall deficiency is primary climatic factor responsible for happening of drought and subsequent relative water and soil moisture shortage are vital for crop growth. In order to assess vulnerability to drought in spatial and temporal domain, the percentage rainfall deficiency/excess with respect to mean value and the deficit of soil moisture in the form of SMDI are included as factors varying with time and space. Depending on the magnitude of SMDI and percentage deficiency of rainfall from mean during a given month, the values of weight from 0 to 25 are assigned as shown in Table 2. Positive values of SMDI represents either normal or wet condition, hence considered insignificant and has been assigned 0 weight, while SMDI below -4 is considered as critical soil moisture and poses serious threat to crop growth, is assigned weight value of 25. Similarly, rainfall deficiency up to 10 % with a weight value of 0 has been considered insignificant, whilst rainfall deficiency more than 50% with a weight value of 25 has been considered as severe rainfall deficiency.

Delineation of Hydrologic Response Units (HRUs) using SWAT-Model

The Soil and Water Assessment Tool (SWAT) model is a distributed hydrologic model developed to quantify runoff yield with reasonable accuracy in large ungauged basins. It provides continuous simulation of hydrological processes (evapotranspiration, surface runoff, percolation, return flow, soil moisture, groundwater flow, channel transmission losses, pond and reservoir storage, channel routing and field drainage) at the

level of Hydraulic Response Units(HRUs). The model can be run with a daily time step. SWAT divides the whole basin into sub-basins using topography. Each sub-basin is divided into hydrological response units (HRUs), which are unique combinations of soil, slope and land cover. Complete description of the SWAT model is available elsewhere (Neitsch et al., 2005). The SWAT model is preferred in this study because it provides distributed assessment of water balance components in time and space. Therefore, the desired assessment of soil moisture deficit could be obtained in time and space to quantify the distribution of vulnerability to drought in time and space in the Ken basin.

In this study SWAT model is calibrated to obtain estimates of different hydrological components at the level of HRUs of the Ken basin. For calibration of SWAT model, database on land use, soils, and weather is required. ArcGIS and Erdas imagine softwares are used as a pre-processor for preparation of database for use in the SWAT model. Using the spatial data on DEM, landuse and soil described earlier, entire area of the Ken basin is divided into 104 sub-watersheds, which are further segregated into 7942 HRUs. The available rainfall data of fourteen raingauge stations and temperature data of two temperature gauge stations for a period (1982-1997) and corresponding stream flow data at four gauging stations detailed in Table 3 are used for calibration and validation of the SWAT model. Available hydrological data is split into two groups of which data from 1982 to 1990 is used for calibration of the model parameters and data from 1991 to 1997 is used for model validation. The model's ability in simulating the stream flow is evaluated based on visual comparison and statistical criteria such as Nash-Sutcliffe Efficiency (NSE, Nash and Sutcliffe, 1970) and coefficient of determination (R^2).

Table 3: Location of gauge and discharge sites and data availability in Ken basin

Gauging Site	River on which Located	Drainage Area (sq.km.)	Elevation (m)	Length of flow data used
Garhakota	Sonar	5823.52	362	1984 to 1997
Gaisabad	Bearma	1335.72	291	1982 to 1997
Madla	Ken	20566.4	194	1982 to 1997
Banda	Ken	25302.6	92	1982 to 1997

Assessment of Soil Moisture Deficit Index (SMDI)

Soil moisture is an important hydrologic variable that controls various land surface processes. Although only a small percentage of total precipitation is stored in the soil, soil moisture reserve is critical for sustaining agriculture, pasture, and forestlands. It is good measure for agricultural drought monitoring. In spite of its importance to agriculture and drought monitoring, information about soil moisture is not widely available on a regional scale. This is partly because soil moisture is highly variable both spatially and temporally and is therefore difficult to measure on a large scale (Narasimhan et. al., 2005). However, SWAT model is capable of estimating soil moisture at sub-basin as well as HRU level. SWAT model estimated available soil water is used for computation of SMDI as described by Narasimhan and Srinivasan (2005). The SMDI can be calculated on an incremental basis as (Narasimhan and Srinivasan, 2005)

$$SMDI_j = 0.5\, SMDI_{j-1} + \frac{SD_j}{50} \qquad \text{.....(Eq.3)}$$

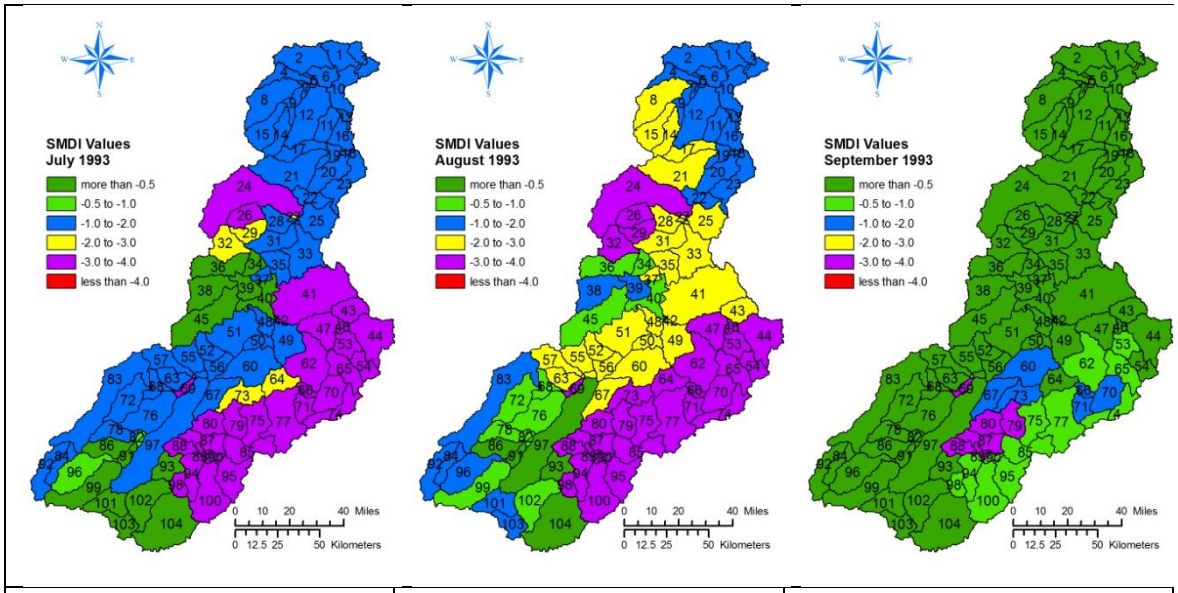
where, $SMDI_j$ represent the soil moisture deficit index for the given month and $SMDI_{j-1}$ represents soil moisture deficit during previous month. The complete algorithm for calculating SMDI at desired time step is available in Narsimhan and Srinivasan (2005).

SMDI during any month may range from - 4 to + 4 representing dry to wet conditions (Table 4). Using the equation (Eq. 3), SMDI is calculated for the entire period of record (1982 to 1997) for all sub-basins. The spatial distribution of SMDI computed during

the worst drought year 1993 identified previously, for the months of July, August and September are presented in Figs. 11(a-c). From Figs. 11(a-c) it is evident that during the months of July and August 1993, most part of the basin area was under mild to severe drought condition. However, due to good amount of rainfall during the month of September 1993, most part of the basin recovers from soil moisture deficit to normal soil moisture conditions.

Table 4. SMDI Classification

Class	SMDI	Condition
1	4.0 or more	Extremely Wet
2	3.0 to 3.99	Very Wet
3	2.0 to 2.99	Moderately Wet
4	1.0 to 1.99	Slightly Wet
5	0.5 to 0.99	Incipient Wet Spell
6	0.49 to -0.49	Near Normal
7	-0.5 to -0.99	Incipient Dry Spell
8	-1.0 to -1.99	Mild Drought
9	-2.0 to -2.99	Moderate Drought
10	-3.0 to -3.99	Severe Drought
11	-4.0 or less	Extreme Drought



(a) (b) (c)

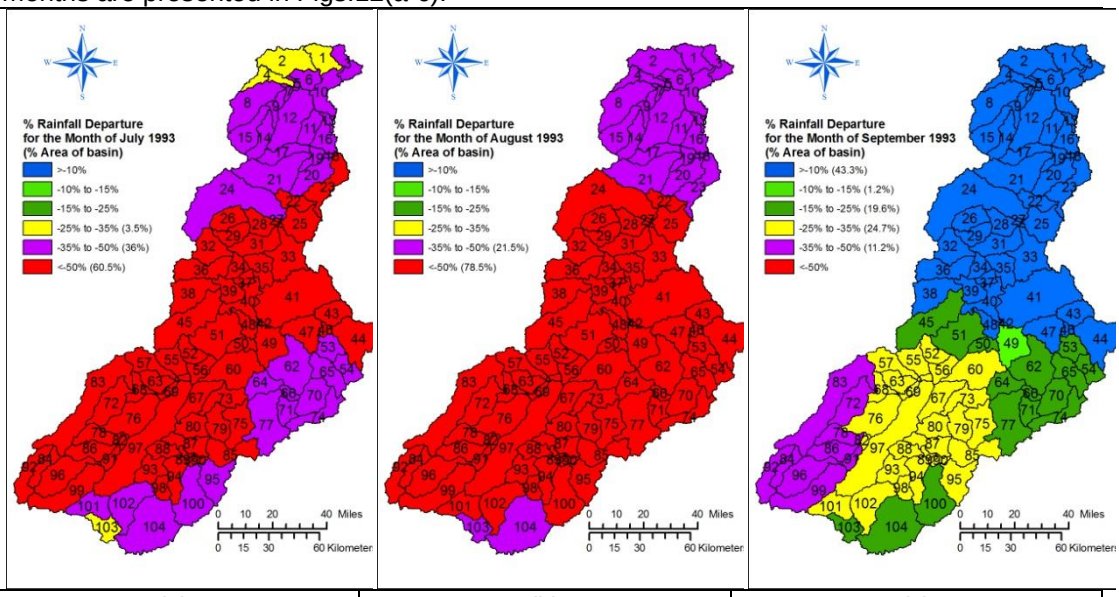
Fig. 11 SMDI Map of Ken River Basin for the Month of (a) July (b) August (c) September 1993

Assessment of Monthly Rainfall Departure

For the present study, monthly rainfall data of 12 raingauge stations for a period of 110 years from 1901-2011 (data missing for the year 2003) have been used to calculate the monthly rainfall values of 104 sub-basins. The monthly rainfall departure from long term mean of the corresponding month for all sub-basins has been calculated using the equation (Eq.1).

As described earlier, year 1993 was observed as worst drought year with maximum annual and Seasonal rainfall deficiency. The monthly rainfall departure for July, August and

September months of the year 1993 is used as the climatic factor in the study for assessment of vulnerability to drought. The spatial extents of rainfall departure during these months are presented in Figs.12(a-c).

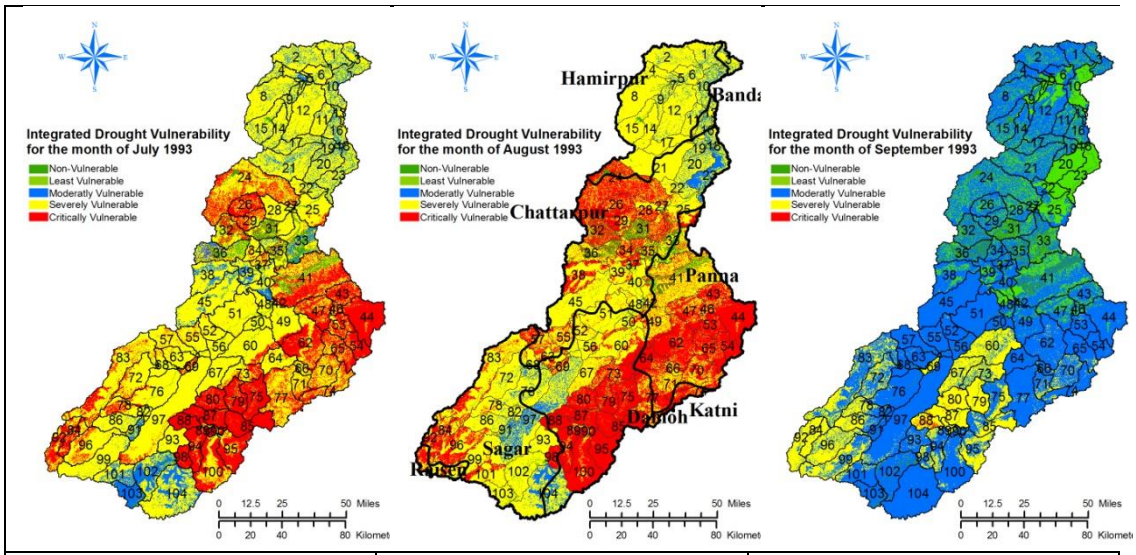


(a) (b) (c)

Fig. 12. Spatial Distribution of Rainfall Departure for the month of (a) July, (b) August and (c) September, 1993

Integration of Multiple Factors and Demarcated Zones Vulnerable to drought

To achieve integrated assessment of vulnerability to drought both in spatial and temporal domains, the maps of various physical factors (Fig. 4 to 10) have been combined with SMDI maps, Figs. 11(a-c) and rainfall departure maps Figs.12(a-c) for the months of July, August and September, 1993, using proposed weighing scheme (Table2). The resulting output maps of spatial distribution of vulnerability to drought during the months of July, August and September, 1993 are shown in Fig.13(a-c), respectively as illustration. Similar maps for other less drought vulnerable years are also generated (not shown here) for further analysis. The composite maps depicting IDVI values have been categorized into five classes i.e. Non-Vulnerable, Least Vulnerable, Moderately Vulnerable, Severely Vulnerable and Critically Vulnerable based on the values of IDVI. The limiting values of IDVI for above classes along with estimates of area under different vulnerability classes are also presented in Table 5.



(a) July, 1993	(b) August, 1993	(c) September, 1993

Fig.13 Integrated Vulnerability to drought for the months of (a) July, (b) August and (c) September during drought year 1993 using proposed differential weighing scheme

Table 5. Area demarcated with differential weighing scheme under different vulnerability classes using Rainfall Departure during July, August and September months of a Drought Year (1993)

	Values of IDVI	Vulnerability	Area under different vulnerability classes (km^2)					
			July 1993		August 1993		September 1993	
1	<=0	Non-Vulnerable	963.10	3.36	963.10	3.36	963.10	3.36
2	>0 to<=0.2	Least Vulnerable	0.00	0.00	0.00	0.00	4226.98	14.73
3	>0.2 to <=0.4	Moderately Vulnerable	2118.28	7.38	1467.31	5.11	18804.12	65.54
4	>0.4- <=0.7	Severely Vulnerable	18513.99	64.52	16559.87	57.71	4660.40	16.24
5	>0.7	Critically Vulnerable	7097.47	24.74	9702.56	33.82	38.23	0.13

Results and Discussions

From the resulting figures it is found that the application of proposed methodology clearly distinguishes the degree of vulnerability to drought during various months of a drought year (1993). For instance, the significant part of the basin areas were under severe and critical classes of vulnerability to drought during the July and August months of 1993. This is because the rainfall deficiency with respect to mean value in different sub-watersheds of Ken basin was ranging from -32 % to -61% and -45% to -56% for July and August months of 1993, respectively. However, there was good rainfall during the month of September, 1993, therefore, basin areas under critical and severe category reduced significantly (Fig.12(c)). This indicates that the method is sensitive to rainfall departures and identifies realistic distribution of vulnerability to drought in time and space.Table 5indicates that approx. 25.74%, 33.82% and 0.13% of the basin area was critically vulnerable to drought during the months of July, August and September in year 1993.

These critically vulnerable patches were located in western parts of Sagar district as well as northern parts of the Chattarpur district and South Eastern parts of Damoh and Panna Districts during these months (see Fig. 13). From the agricultural reports, it was found that, in the areas identified with critical and severe vulnerability throughout the rainy season, paddy crop yield was very low due to water stress during Kharif Season in 1993. These critical areas appears to be fully justified as city of Sagar is located in the western ridge areas with low surface and ground water availability plus very high municipal water demands. This corroborates favorably with the documented information of the region for the year 1993 i.e. (District Statistics Handbook, 1993& 2007). On the other hand, the areas which received good amount of rainfall during the month of September (Fig. 12(c)) have recovered from critical vulnerability and identified under moderate category of vulnerability to drought (Fig. 13(c)). These areas of basin fall in Hamirpur and Banda districts of Uttar Pradesh, wherein, the production loss to the Kharif crop was less than 30% of the average production. However, in Sagar and Damoh districts it was of the order of more than 60% (District Statistics Handbook, 1993). Also, the area covered by sub-basin no. 18, 20, 22, 23 and 25 that fall under canal command could recover fully from drought vulnerability due to irrigation support.

Integrated drought vulnerability index (IDVI) has been defined as the sum of weights of various factors scored by corresponding HRU divided by sum of the maximum weight value of each factor. Thus, the composite map showing spatial distribution of vulnerability to drought has been prepared. The HRUs with higher value of IDVI represents the areas with high degree of vulnerability to drought and vice versa. The maps thus obtained have been validated using the documented information and field surveys. It is believed that the proposed methodology may be used as a reliable tool for demarcation of zones vulnerable to drought.

The output maps from proposed differential weighing scheme were compare with that of uniform weighing scheme suggested by Pandey et al., 2010. It was found that, the maps generated using differential weighing scheme, present clear demarcation of the areas under moderate, severe and critical categories of vulnerability to drought compared to other one. It is therefore concluded that the uniform weighing scheme provides better assessment of vulnerability to drought. It is hoped that this method may provide more realistic assessment of vulnerability to drought and may help decision makers in planning for better drought mitigation strategies.

Summary and Conclusions

The paper illustrates a new method developed to assess vulnerability to drought in spatial and temporal scales using physiographic, climatic and hydrologic factors. The physiographic factors are static physical features of basin including topography, slope, land use, soil type, soil depth, proximity to river reach, elevation zones and population density. The climatic and hydrologic factors are dynamic in nature which changes with time and space. These factors are rainfall departure from corresponding mean and soil moisture deficit. Spatial information of different factors has been classified in various sub-classes and maps have been prepared using ArcGIS. A differential weighting scheme for various factors has been proposed based on the level of importance of various sub-classes on a contribution towards vulnerability to drought. The relevance of the method has been demonstrated for the Ken River Basinin India. The SWAT model has been applied to demarcate hydrologically homogeneous areas called HRUs in respect of land use, slope and soil type, and for estimation of spatial and temporal distribution of soil moisture in the study basin. Subsequently, Soil Moisture Deficit Index (SMDI) has been calculated using the available soil moisture estimates from SWAT model.

To obtain a composite map an integrated drought vulnerability index (IDVI) has been used. The IDVI is defined as the sum of weights of various factors scored by corresponding HRU divided by sum of the maximum weight value of each factor. The HRUs with higher value of IDVI represents the areas with high degree of vulnerability to drought and vice versa. The spatial and temporal assessment of IDVI has been validated using the documented information and field surveys. The prepared map showed very good agreement with the physical observations made in the study basin. It is hoped that the proposed methodology may be used as a reliable tool for demarcation of zones with different level of vulnerability to drought.

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AGRICULTURAL DROUGHT CHARACTERIZATION AND ITS IMPACT ON RAINFED CROP PRODUCTIVITY IN VIDARBHA REGION OF MAHARASHTRA STATE

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Abstract

Agricultural drought characterization and impact study on rainfed crop productivity was carried studied using climatic water balance method in six drought affected districts of Vidarbha region of Maharashtra state (India). Agricultural drought characterization study of thirty years period (1976-2005) in 32 talukas of drought affected districts indicated a very high tendency of occurrence of drought successively for two or more years at most of the talukas in all the districts. It also showed that, high intensity wide spread droughts occurred in the studied area at a frequency of 3 to 4 years. From the number of droughts of high severity (large, severe and disastrous category) which occurred during wide spread drought years at different talukas in each district, the most drought persistence areas (talukas) in respective district were identified.

The Spearman rank correlation coefficient values for different rainfed crops shows a positive correlation at maximum locations, which indicates that the drought index used for agricultural drought characterization had a better correlation with crop yield. On an average 20 to 40 percent reduction in yield of different rainfed crops was observed during high severity wide spread drought years at most of the talukas. Surplus water generated during drought years can be harvested if planned properly. The decadal variation of seasonal rainfall on district and taluka level clearly indicated a remarkable change in rainfall pattern of drought affected region during the current decade (1996-2005) over earlier two decades (1976-85 and 1986-95) which shows the visible impact of climate change in Vidarbha region. Hence in order to stabilize the crop productivity in dryland agriculture under changing rainfall pattern, it is necessary to give top priority for maximum in-situ rainwater conservation, creation of large water bodies through rainwater harvesting and conjunctive utilization of surface and subsurface water.

Key words: Agricultural drought, productivity, aridity index, correlation coefficient

Introduction

Drought is a major factor of uncertainty that continues to haunt Indian agriculture and economy. Maharashtra with its diverse climatic conditions and large cultivable area (84%) purely dependent on southwest monsoon, suffers too often from failure of the adequate monsoon rainfall and the consequent droughts. Droughts, resulting from scanty and ill-distributed rainfall, form one of the serious natural calamities, which frequently inflict one part or the other of the country. Agricultural drought is a situation when the rainfall and soil moisture are inadequate to meet the water requirement of crops for their healthy growth and maturity. Due to frequent droughts and adverse socio-economic constraints, per hectare yield in rainfed area is very low. Study of drought characteristics is one of the important aspects in the rainfed farming to establish suitable cropping pattern as well as in any water resource planning, management and allocation of irrigation water. Much of the studies refer to the meteorological drought analysis for a particular basin or a specific historical event without giving much emphasis to the quantitative and qualitative aspects of the drought. Drought is not a direct result of the shortage of rainfall alone, but is also something related to the soil and water need of a place. Hence, any drought analysis, which

is based on the rainfall criteria alone, is not adequate to explain drought conditions properly (Subrahmanyam and Sastri, 1969).Drought does not begin when rain ceases but rather only when plant roots can no longer obtain moisture in the needed amount. A better understanding of moisture status can be studied using water deficit parameters in comparison with reference evapotranspiration. Since water deficiency is the primary cause of all droughts, it can be employed as a rational parameter for the quantitative analysis of droughts. One of the most important methods to know the severity of drought is drought evaluation by means of an aridity index. In this study an attempt has been made to apply the aridity index for agricultural drought characterization and to find out its impact on dryland productivity in six drought affected districts in Vidarbha region of Maharashtra state.

Methodology

The weekly climatic data for Buldhana, Akola, Amravati, Yeotmal and Wardha district was collected from ARS, Buldhana, Agro-Meteorology Laboratory, Dr. PDKV, Akola, RRC, Amravati and ARS, Yeotmal and IMD, Pune for 30 years. Weekly rainfall data for 30 years (1976-2005) at different taluka places in above stated six districts was also collected. Soil data was obtained from reports of National Bureau of Soil Survey and Land Use Planning, Nagpur (Challa *et al.,* 1999). Climatic water balance component were determined by Thornthwaite and Mather water balance technique. Aridity index was calculated by using the procedure of Thornthwaite and Mather (1955 & 1957). Annual aridity index (Ia) was computed using following expression.

$$Ia = \frac{Deficit}{ETo} X 100$$

Drought years were determined at all the selected stations in each districts considering aridity index (Ia) deviation estimated on annual basis and categorizing the intensity of drought years using different ranges of standard deviation. The drought years were identified by using the classification suggested by Subramanyam and Sastri (1969).

Deviation of annual Ia from mean Ia	Drought intensity
> o to ½ σ	Moderate
½ σ to σ	Large
σ to 2 σ	Severe
> 2 σ	Disastrous

Drought characterization in drought affected districts was done by studying the spatial and temporal variation of water deficit during kharif season of the extensive drought years. Due to the discrete variation of two variables (i.e. yield and drought years), Spearman rank correlation was chosen as a measure of how well years ranked by drought index value are compared to years ranked by yield of the area. The years were sorted according to aridity index values and yield of the area separately and each year is given a rank value for the respective variable. The spearman rank equation correlates the two variables by comparing the difference of each set of rank values. Correlations between the drought years and yield of the year can range between -1 and 1(Chandel, 1965). The different years of study period identified by aridity index were arranged according to their severity from most severe to most wet years and were given rank. Similarly, the yield data of different kharif crops like sorghum, mung etc was arranged from lowest yield to highest yield and were given rank. These two variables were then compared for each station and rank correlation for that crop was estimated.

Results and Discussion

The different intensity droughts estimated at different district stations are schematically depicted in Figure 1. It is observed that agricultural droughts of different intensity occurred in the same year at all the stations during 1980, 1985, 1991, 1992, 1996 and 2002. However, severe to large intensity agricultural droughts occurred at maximum stations during 1980, 1984, 1986, 1991, 1996, 2002 and 2004. The interval of such droughts varies from 1 to a maximum of 5 years, having frequency of 3 to 4 years. It is observed that intensity of drought during 1980, 1986, 1991, 1996 and 2004 was of higher severity for maximum stations indicating severe consequences in terms of reduction in agricultural productivity and surface water availability.

From Fig. 1, it is also seen that, there is a tendency of occurrence of drought successively for three years at all the district places except for Yeotmal and such sequences are repeated during 1979 to 1981, 1984 to 1986, 1994 to1996 and 2002 to 2004 in the region. At Yeotmal a tendency of occurrence of drought successively for two yearsis observed during 1983-84 and 1991-92. The continuous prevalence of drought climatology in all the districts successively for two or more years can have serious consequences on water availability in general and productivity in particular.

Drought Spread Pattern

The areal extent of agricultural drought in different talukas of drought affected districts of Vidarbha region, total numbers of droughts of similar severity classes viz. moderate, large, severe and disastrous are grouped for every year and presented in Table 1. The data in the table indicates that the moderate droughts are highest followed by large, severe and disastrous droughts. The total number of talukas experiencing high severity droughts (large, severe and disastrous category) is totaled, which ultimately explains the years of high intensity wide spread drought year experienced in the region. It is also clear from the data that out of 32 taluka stations under study, the years during which more than 40 percent stations experienced the high intensity drought were marked as extensive drought years (1980, 1982, 1983, 1984, 1985, 1986, 1991, 1992, 1996, 2002 and 2004). The frequency of such high intensity wide spread drought was found to be varying from 1 to 5 years, however approximately it can be taken as 3 to 4 years.

In Buldhana district, high severity droughts were observed in 5 to 7 talukas during maximum wide spread drought year, hence those talukas which have experienced these drought maximum times can be considered most drought persistence area in the district. Such drought persistence talukas observed in the district are Khamgaon, Shegaon, Malkapur, Buldhana and Jalgaon- Jamod.

In Akola district, high severity droughts were observed in 3 to 4 talukas during maximum wide spread drought year, hence those talukas namely Akot, Telhara and Akola are considered as most drought persistence area in the district. Similarly, in Washim district the high severity droughts were observed in Mangrulpir, Washim talukas and hence both of them were considered as most drought persistence area in the district. In Amravati district, high severity droughts were observed maximum in 8 to 9 talukas during wide spread drought year, hence talukas which have experienced these drought maximum times namely Anjangaon, Daryapur, Achalpur, Amravati, Morshi, Warud, Chandur-Bazar and Chandur-Railway can be considered as most drought persistence area in the district. Similarly, in Yeotmal district the high severity droughts were observed in 4 talukas namely Digras, Yeotmal, Wani and Umarkhed out of 6 talukas considered and hence they can be viewed as most drought persistence area in the district. In Wardha district, the high severity droughts were observed in all the 3 talukas considered and hence Wardha, Arvi, Hinganghat talukas can be considered as most drought persistence area in the district.

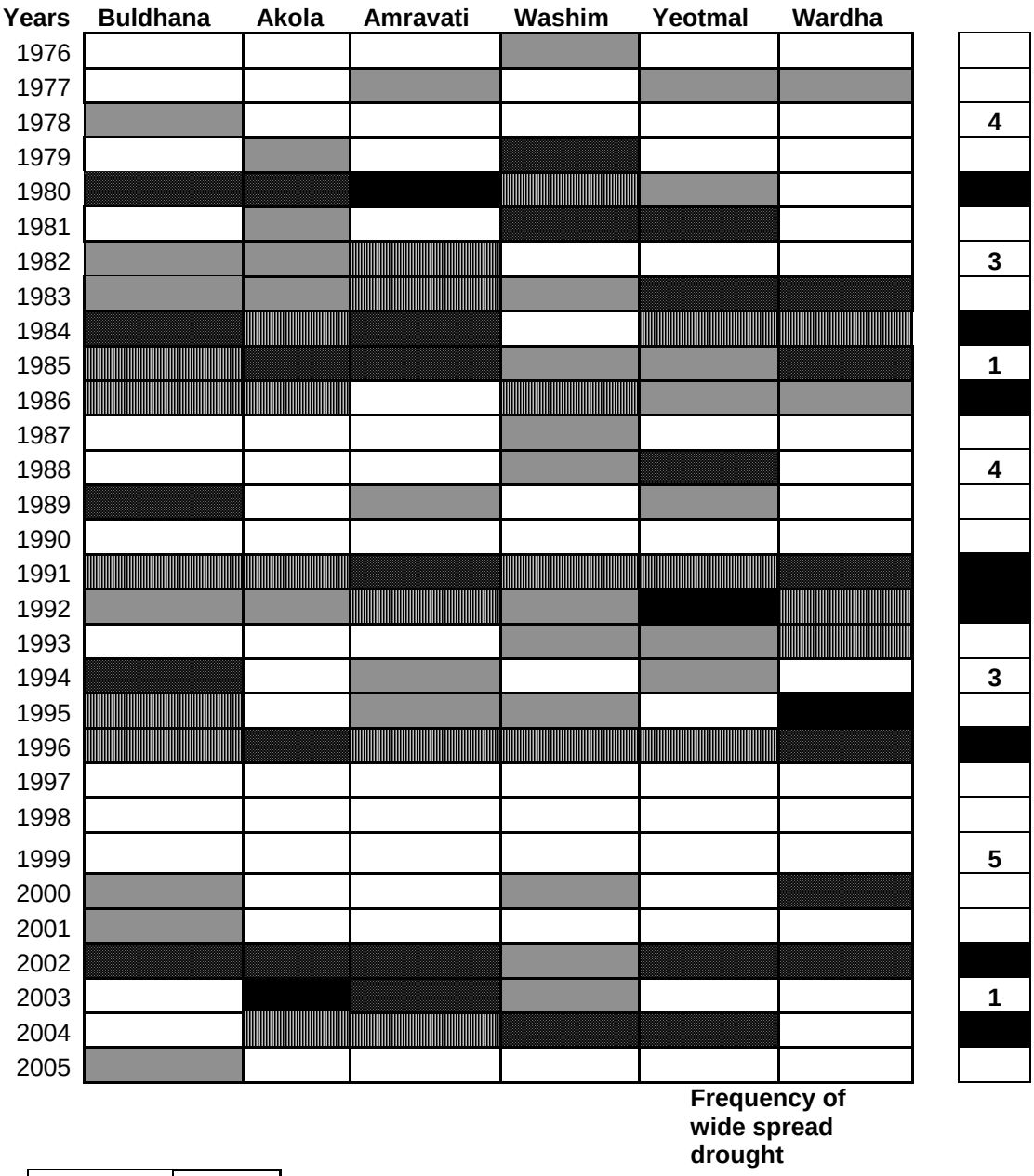


Fig. 1 : Schematic presentation of different intensity drought years in drought affected districts of Vidarbha

Table 1: Severity of drought during different years in six drought affected districts of Vidarbha

Year	Number of taluka stations under different drought severity				Total of L, S & D stations	Spatial extent of Severe drought (%)	Extensive severe drought years
	Moderate (M)	Large (L)	Severe (S)	Disastrous (D)			
1976	4	1	0	0	1	3.1	
1977	8	2	2	0	4	12.5	
1978	5	3	0	0	3	9.4	
1979	5	1	2	0	3	9.4	
1980	8	10	**6**	**1**	17	**53.1**	**1980**
1981	11	7	2	0	9	28.1	
1982	4	2	**10**	**2**	14	**43.8**	**1982**
1983	13	10	**6**	**0**	16	**50.0**	**1983**
1984	10	6	**8**	**1**	15	**46.9**	**1984**
1985	8	12	**7**	**1**	20	**62.5**	**1985**
1986	7	2	**13**	**5**	20	**62.5**	**1986**
1987	5	5	4	1	10	31.3	
1988	7	2	0	0	2	6.3	
1989	7	5	3	0	8	25.0	
1990	1	0	0	0	0	7.0	
1991	3	**8**	**18**	**1**	27	**84.4**	**1991**
1992	8	12	**9**	**1**	22	**68.8**	**1992**
1993	8	4	3	0	7	21.9	
1994	8	1	4	0	5	15.6	
1995	5	4	4	1	9	28.1	
1996	5	**13**	**10**	**0**	23	**71.9**	**1996**
1997	3	2	0	0	2	6.3	
1998	0	0	0	0	0	0.0	
1999	1	1	0	0	1	3.1	
2000	7	4	6	2	12	37.5	
2001	5	3	1	0	4	12.5	
2002	12	11	**4**	**0**	15	**46.9**	**2002**
2003	9	3	3	1	7	21.9	
2004	8	5	**7**	**1**	13	**40.6**	**2004**
2005	7	3	0	0	3	9.4	
Total	192	142	132	18	292	--	
%	**20.1**	**14.8**	**13.8**	**1.9**	**30.4**	**--**	

Dryland Crop Productivity

The taluka wise average yields of different rainfed crops as reported by State Agriculture Department were used for verifying the results obtained from the study. A considerable reduction in the yield of different dryland crops was observed during the widespread drought year's viz., 1984, 1986, 1991, 1996, 2002 and 2004 over normal years viz., 1987, 1990, 1997, 1998, 1999 and 2001 in the selected talukas of different drought affected districts. Percent reduction in the yield of mung, soybean, kharif sorghum, cotton and tur in different talukas of various drought affected districts is presented in Table 2. The

data reveal that there is considerable reduction in the yield of mung (19 to 46 %) and soybean (17 to 45 %) followed by jowar (18 to 36 %), tur (9 to 30%) and cotton (1 to 21%).

Table 2: Taluka wise percent reduction in yield of different dryland crops during wide spread drought years over normal years

District	Taluka	Mung	Soybean	K. Sorghum	Cotton	Tur
Buldhana	Jalgaon (J)	29.2	-17.7	28.3	17.0	16.2
	Chikhali	42.6	24.3	16.6	18.6	-6.0
	Buldhana	53.3	11.1	29.2	-13.6	15.6
	Mehakar	22.6	15.1	33.0	17.8	15.7
	Khamgaon	41.1	14.0	53.1	22.8	25.8
	Shegaon	49.6	53.3	58.4	27.6	10.4
	Malkapur	55.0	1.6	28.5	26.2	22.8
	Average	**41.9**	**18.5**	**35.9**	**16.9**	**14.5**
Akola	Akot	52.1	53.6	13.0	-27.3	26.0
	Telhara	60.6	NA	24.8	30.5	29.2
	Balapur	18.3	1.9	38.5	24.8	39.6
	Akola	38.6	-3.3	33.6	23.4	24.6
	Average	**45.5**	**17.4**	**27.1**	**16.8**	**29.9**
Washim	Washim	-2.7	14.5	39.8	30.7	8.7
	Mangrulpir	35.9	14.3	28.9	4.5	16.7
	Average	**18.7**	**14.4**	**34.3**	**19.3**	**13.2**
Yeotmal	Yeotmal	47.1	41.8	19.7	25.2	28.9
	Darwaha	47.2	55.0	16.5	8.5	20.2
	Digras	43.6	36.7	26.7	-12.4	14.5
	Pusad	34.8	55.7	19.2	-8.5	-10.2
	Umarkhed	5.6	33.2	-0.6	9.7	-6.7
	Wani	27.6	44.8	29.0	-7.3	2.1
	Average	**34.1**	**45.1**	**18.8**	**2.8**	**9.2**
Amravati	Dharni	NA	58.4	47.0	-3.1	2.0
	Chikhaldara	30.5	36.6	51.9	-4.9	28.2
	Amaravati	51.5	36.7	70.7	-28.5	2.3
	Chandur Rl	NA	26.9	24.7	6.2	4.9
	Morshi	62.4	19.3	23.6	14.5	9.9
	Warud	NA	17.9	12.6	11.1	17.1
	Darypur	39.0	35.4	31.9	-17.5	16.4
	Anjangaon	46.7	11.7	25.3	-3.3	0.5
	Achapur	10.4	40.2	36.7	10.3	8.6
	Chandur Bz	40.0	38.7	16.2	25.9	27.9
	Average	**40.0**	**33.4**	**37.8**	**1.1**	**9.1**
Wardha	Arvi	27.0	20.9	29.6	32.3	27.1
	Wardha	48.9	34.3	18.4	8.9	1.2
	Hinganghat	45.6	29.2	6.3	20.6	7.2
	Average	**40.5**	**28.0**	**18.2**	**21.2**	**11.6**

Data source : Office of the Joint Director of Agriculture, Nagpur.

Spearman Rank Correlation Coefficient

The Spearman rank correlation coefficient values for different crop in Table 3 shows a positive correlation at maximum locations, which indicates that the drought index used for agricultural drought characterization has a better correlation with crop yield.

Table 3: Spearman rank correlation between yield of different crops and drought severity at different taluka stations

District	Taluka	Spearman rank correlation values for different crops				
		Mung	Soybean	K. Sorghum	Cotton	Tur
Buldhana	Buldhana	0.31	0.33	0.32	0.10	0.31
	Chikhali	0.43	0.40	0.11	0.47	-0.07
	Khamgaon	0.29	0.05	0.54	0.27	0.13
	Malkapur	0.53	0.27	0.05	0.45	0.17
	Mehakar	0.18	0.29	0.28	0.23	0.06
	Shegaon	0.22	0.68	0.29	0.16	0.14
Akola	Akola	0.50	0.44	0.35	0.11	0.45
	Akot	0.70	0.82	0.58	0.79	0.79
	Balapur	0.52	0.20	0.45	0.51	0.24
	Telhara	0.73	0.64	0.64	0.66	0.63
	Akola CRS	0.60	NA	0.72	0.59	0.56
Washim	Washim	0.22	0.43	0.23	0.12	0.05
	Mangrulpir	0.26	0.18	0.22	0.05	0.19
Yeotmal	Yeotmal	0.24	0.26	0.05	0.22	0.18
	Darwaha	0.22	NA	-0.07	0.13	0.13
	Digras	0.15	NA	0.19	-0.10	0.44
	Pusad	0.52	0.25	0.35	0.01	0.12
	Wani	NA	0.14	0.19	-0.11	-0.22
Amravati	Chikhaldara	0.22	0.21	0.06	0.10	0.22
	Amaravati	0.57	0.29	0.014	-0.41	0.03
	Morshi	0.22	0.21	0.10	0.01	0.06
	Daryapur	0.17	0.10	0.20	-0.15	0.15
	Anjangaon	0.61	0.09	0.43	0.21	0.13
	Achalpur	0.22	0.36	-0.13	0.14	0.11
Wardha	Arvi	0.40	0.11	0.20	0.12	0.07
	Wardha	NA	0.50	-0.16	-0.18	0.08
	Hinganghat	NA	0.23	-0.24	0.14	-0.38

NA : Data not available

Hence, from the results of significant correlation between drought severity and crop yield on a very large extent of areas, it can be concluded that the aridity index is the most suitable index for quantifying drought impact on crop productivity.

Surplus Water

Surplus water generated (averaged values) during rainy season estimated by the climatological water balance study at taluka level in different drought affected districts (Table 4) clearly indicates that sizeable quantity of surplus water is available during normal years as compared to higher severity drought years. Similarly, the quantity of surplus water

generated during large and severe intensity drought years is also considerable. It will also give relief to dryland farmers to some extent if harvested in suitable farm pond or other types of water storage structures.

Table 4: Surplus water during normal and moderate drought years compared to large and severe drought years

District	Surplus water duringnormal and moderate drought years			Surplus water duringlarge and severe drought years		
	Seasonal rainfall, mm	Surplus water, mm	Percentage of surplus water	Seasonal rainfall, mm	Surplus water, mm	Percentage of surplus water
Buldhana	698.8	183.6	26.3	598.0	94.8	15.8
Akola	719.1	172.9	24.0	527.8	84.7	16.1
Amravati	792.1	201.8	25.5	661.8	119.3	18.0
Washim	843.7	357.4	42.4	674.8	226.5	33.6
Yeotmal	890.4	424.0	47.6	694.3	244.4	35.2
Wardha	872.9	327.6	37.5	621.8	163.6	26.2

Rainfall Variation

The decadal behavior of average seasonal rainfall distribution in different districts during monsoon season as presented in Table 5 reveals that in Buldhana and Akola districts seasonal rainfall increased while the same is reduced in Washim and Amravati districts and was nearly constant in Yeotmal and Wardha districts in second decade (1986-1995) than that of first decade (1976-1985). The seasonal rainfall in third decade (1996-2005) is reduced in Buldhana, Akola, Amravati, Yeotmal and Wardha districts while it was increased marginally in Washim district over that of second decade (1985-1996).

Table 5: Decadal behavior of average monsoon seasonal rainfall on district level basis in drought affected districts of Vidarbha (1976-2005)

District	**30 yr. seasonal mean, mm**	**Decadal mean seasonal rainfall, mm**			**Decadal mean seasonal rainfall as % of 30 yr. mean**		
		1976 - 1985	**1986 - 1995**	**1996 - 2005**	**1976 - 1985**	**1986 - 1995**	**1996 - 2005**
Buldhana	634.9 (35.5)*	620.6 (31.0)+	653.5 (42.5)+	630.5 (31.3)+	97.8	102.9	99.3
Akola	627.6 (31.8)	621.8 (29.4)	682.8 (36.9)	578.4 (23.6)	99.1	108.8	92.2
Amravati	764.4 (42.2)	823.2 (38.6)	773.2 (48.9)	696.8 (37.1)	107.7	101.2	91.2
Washim	767.7 (31.6)	787.3 (23.4)	747.5 (32.5)	768.1 (38.7)	102.5	97.4	100.1
Yeotmal	790.4 (33.5)	804.0 (34.0)	812.7 (35.7)	754.4 (30.4)	101.7	102.8	95.4
Wardha	836.9 (29.8)	879.6 (27.7)	872.5 (35.0)	758.7 (22.3)	105.1	104.3	90.7

* Figure in parenthesis is C.V.of 3o year seasonal rainfall.

+ Figure in parenthesis is C.V.of decadal seasonal (June to Sept.) rainfall

The percentages of decadal mean seasonal rainfall over that of 30 year mean seasonal rainfall (Table 5) indicates that in current decade all district except Washim shows considerable reduction in rainfall over the remaining two decades. During 1996-2005 (current) decade near about 21 taluka places shows 15 to 20 percent reduction in mean seasonal rainfall while individual year wise variation was quite high.

Hence from this typical characteristic feature of the droughts in the region, it can be concluded that the surplus water generated during normal or wettest rainfall years must be harvested at suitable sites by giving top priority to water resource development in the dryland area of drought affected districts.

Conclusions

Agricultural drought characterization of study area during thirty years period (1976-2005) in 32 talukas of drought affected districts indicated a very high tendency of occurrence of drought successively for two or more years at most of the talukas in all the districts. From the number of droughts of high severity viz., large, severe and disastrous category which occurred during wide spread drought years at different talukas in each district, the most drought persistence areas (talukas) in respective district were identified. The decadal variation of seasonal rainfall on district and taluka level clearly indicated a remarkable change in rainfall pattern of drought affected region during the current decade (1996-2005) over earlier two decades (1976-85 and 1986-95) which shows the visible impact of climate change in Vidarbha region. Hence in order to stabilize the crop productivity in dryland agriculture under the changing rainfall period, it is essential to give top priority for maximum in-situ rainwater conservation and for creation of large water bodies and encourage farmer's to go for rainwater harvesting and conjunctive utilization of surface and subsurface water.

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FARM POND TECHNOLOGY FOR CLIMATE RESILIENCE: POTENTIAL AND ECONOMIC VIABILITY IN DIFFERENT CROPPING SYSTEMS OF RAINFED AGRICULTURE

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Abstract

A long term study was done to assess the impact of farm pond technology on oil seed and cereal based cropping systems with vegetables (okra, tomato and carrot) in semi-arid alfisol of southern Telangana region. Two supplemental irrigation (SI) depths (30 and 50 mm) from farm pond with raingun system were studied for assessing the production potential and economic viability of the technology in these cropping systems. Cropping system using sole crop of groundnut or maize, later was found to be more profitable (3 times) with 50 mm SI in 2 critical growth stages having annualized net benefit (ANB) of Rs. 66627-68668 / ha, B:C ratio of 2.5 and economic productivity (EP) of Rs. 22 / m^3 under different capacities of farm pond (500-1500 m^3). In kharif with single filling of farm pond and deficit irrigation of 30 mm SI, maize+tomato was found to be more profitable (ANB-Rs. 1.12-1.56 lakhs/ha, B:C ratio-3.2-3.7 and EP-Rs. 24.8-34.9 / m^3) as compared to sole crop or with okra. During kharif and rabi with second filling of farm pond at SI depth of 30 mm, maize+tomato+carrot was the most profitable option (ANB-Rs. 1.72-2.04 lakhs/ha, B:C ratio-4.0-4.7 and EP-Rs. 25.9-30.8 / m^3) as compared to any combination of the crops. The study revealed that the best economical crop combination under deficit irrigation of 30 mm will make the rainfed agriculture more remunerative with on farm water availability and efficient use of surface water through farm ponds on custom hiring.

Key words: Farm pond, supplemental irrigation, economic productivity, cropping system, rainfed agriculture

Introduction

Food production for a growing world population would increase the global water demand. Rainfed agriculture constitutes 55% of total net cultivable area in the country and contributes to production of major coarse cereals, pulses and oil seeds. The environment of rainfed agriculture is enrolled with regular climate constraints like long dryspells, high intensity rainfall, high evaporation losses, soil degradation, etc. Moreover the annual average rainfall varies from less than 100 mm to 2500 mm in different rainfed agro-ecological regions of the country. Its distribution is erratic with CV varying from 30 to 80 % during crop growth period and it varies in both space and time. The present level of land productivity is about 1 t/ha in the country. Therefore, all the above vagaries of the climate necessitates for immediate measures towards adaption of rainwater harvesting technologies for climate resilience in rainfed agriculture to manage the drought (Critchley,1991). Rainwater harvesting technologies like check dams, drop spillways, gabion structures, percolation tanks, sunken pits, etc. have been implemented across the Indian states as a drought mitigation measure in the watershed programmes implemented by government of India. These technologies have resulted in the increase of recharge potential of shallow wells and tube wells. However, in the hard rock areas and long distances for access to water by the farmers in the watersheds, it is imperative for on-farm rainwater

harvesting through farm ponds is necessary for enhancing the field scale water productivity to basin level (Reddy et al, 2012).

Rainwater harvesting is the collection and storage of excess runoff generated from small scale farmers land, ephemeral streams and hill slopes in rainy season for productive purposes (Wang et al.,2011;Ngigi et al., 2005; Kahinda et al.,2007) . Enhancing the water productivity in rainfed areas using supplemental small-scale irrigation is an important tool to increase green water flows[4].Many researchers around the world mentioned that, the rainwater harvesting concept has become key component in production technology to enhance livelihoods of rainfed farmers and reduce the yield gap between irrigated and rainfed agriculture with water scarcity under changing climate conditions (Oweis and Hachum, 2005; Pandey et al.,2003).

The optimal design of rainwater storage structure, catchment command area ratio for giving supplemental irrigation to different cropping systems, depends on runoff potential of farm and the amount of water that is needed for supplemental irrigation at critical stages of rainy season crops and deficit irrigation to vegetable and rabi crops. A challenge in design and construction of on-farm water storage structures, such as farm ponds, is to minimize water losses (mainly due to seepage and evaporation) by way of lining(Ngigi et al ., 2005). Evaporation rate and water spread area directly relates to evaporation losses and it also depends on type of soil, climate and underlying formation material. The limited runoff collected in farm pond may not allow full irrigation in rainfed condition but it permits supplemental irrigation to mitigate long dryspells during critical stages of most rainfed crops. Excellent responses to supplemental irrigation have been reported from several locations in India(Gunnel and Krishnamurthy, 2006).The yield responses of crops to supplemental irrigation in different locations of India and indicated that one supplemental irrigation at the critical stages of crop growth considerably increased crop yields (Singh and Khan, 1999).

Government of India has introduced a specific programme under PMKSY (Pradhna Mantri Krishi Sinchayee Yojana) on farm pond technology to be widely implemented across the country in rainfed areas and proposes to construct 5 lakh farm pond in farmers' fields with a vision of *Har Khet me Paani* (water in every crop field). In Telangana, more than 60% agriculture fields are rainfed and endowed with water thirsty soils affecting the production, productivity and profitability of major rainfed production systems. In southern Telangana, both maize and groundnut are taken as major rainfed crops. Government of Telangana has given much importance to horticultural crops especially vegetables and fruits in recent years. But, there is no region-specific research for adoption of farm pond technology to the changing climate patterns in southern Telangana. Also, the information on catchment command area ratio, runoff coefficients for on farm rainwater harvesting on cropping system approach with net water availability, area could be supported with supplemental irrigation and different storage capacities of farm ponds are not available for the region. Therefore, a systematic methodology and economic assessment under prevailing cropping system approach is presented in the paper.

Material and Methods

Study area and climate

The field experiments were conducted from 2008 to 2015 in model rainwater harvesting through farm ponds in Gunegal Research Farm (GRF) of ICAR-Central Research Institute for Dryland Agricultural (CRIDA), which is located at 45 km away from Hyderabad, Telangana, India. The farm is located at 78°40' N and 17º2' E with mean sea level of 621 m. The daily climate data on rainfall, maximum and minimum temperature, solar radiation, relative humidity and wind speed were recorded from an automated weather station (AWS) installed at the farm. The average annual and seasonal rainfall of the study area is 701.87 and 478.05 mm, respectively. The average temperature of study area is 25.5

ºC with average minimum and maximum of 8.94 and 42.06 ºC, respectively. The land is relatively flat with a slope of 2 per cent or less and it has deep to moderately deep well drained red soils. Soil texture was sandy clay loam with Sand (70.96 %), Clay (22.32 %) and Silt (6.72 %) with soil depth varying from 50 to 100 cm.

Rainfall runoff relation in semi arid alfisols

A rainfall and runoff relation was developed by busing 7 years data of observations in the research farm on rainfall and runoff collected in the farm pond with different catchment areas varying from 1.5 to 14.5 ha. The water balance was worked out for both lined and unlined farm ponds considering the evaporation and seepage losses in unlined farm pond upto 2010 and only evaporation losses in lined farm pond with HDPE 500 micron geo-membrane sheet.

Cropping systems

The long term data generated through field experimentation has been used in the present analysis for cropping systems like groundnut (GN), okra (O), GN+O / tomato (T), carrot (C) in rabi and maize (M)+O / T and C in rabi. The experiments were conducted at the research farm with different crops and the yield data were obtained. During 2008-11, the groundnut based cropping system was tested and maize based cropping system was tested during 2012-15 under farm pond imposing different supplemental irrigation (SI) depths at two critical stages of the main crops and weekly scheduling of deficit irrigation of 30 mm for vegetables in the alfisols.

Farm pond technology

Three farm ponds having top dimensions of 17×17×3m, 20×20×3m, and 26×26×3m for the capacities of 500, 750 and 1500m^3, respectively (considering suitability to small farm of less than 1.0 ha, medium farm of 2-4.0 ha and large farm of more than 4.0 ha, respectively in rainfed areas) were considered in the present study with lining of HDPE 500 microns thick geo-membrane film. The structures were provided with inlet spill way, silt trap (1.5x1.5x1m) and rectangular outlet (1x1 m). The depth of maximum storage was of 3 m with side slopes of 1.5:1. On an average the evaporation losses were observed at 3 mm/day in kharif and 5 mm/day in rabi. The net water availability for critical irrigation in different farm ponds were calculated by reducing the evaporation losses up to the critical stage of the groundnut and maize. The yield data for rainfed as well as SI were considered for two irrigation depths of 30 and 50 mm. The details of SI, acreage and cropping systems under different capacities of farm ponds are given in Table-1. It was observed that, there is a chance of two fillings of farm ponds for three out of five years after lining in 2010. Similarly, there is a chance of single filling of the farm pond, four out of five years. It indicates that, the risk level is 20 % for single filling and 40 % for two fillings of farm ponds. Rabi crop was grown only after second filling of farm pond. In single filling, the water available is sufficient to provide two critical irrigations for groundnut and maize along with vegetables (tomato/okra) with 30 mm of irrigation depth weekly once.

Catchment-Command Area (CCA) Ratio

A 30 year seasonal rainfall data has been subjected to probability analysis by using Weibulls technique[9] as given below.

$$p\ (\%) = \frac{(m - 0.375)}{(n + 0.25)} \qquad \text{..... (1)}$$

p = probability % of m^{th} rank
m = rank of the observation

n = total number of observations

It is estimated that, the seasonal rainfall at 75 % probability of occurrence was 375 mm and taken as design rainfall[10] for Southern Telangana. The average runoff coefficients and runoff efficiency were taken as 0.07 (7%) and 0.75 (75%) (micro-catchments) respectively for the alfisols which have good drainage, infiltration meeting the hydrological group B conditions. The catchment areas for 500, 750 and 1500 m^3 capacities of farm ponds, are calculated by using the formula as given below:

$$Q = (A_{ca} \times RO_c \times RO_e \times R_d)/1000 \quad \text{----------(2)}$$

Where, Q = farm pond capacity, m^3

A_{ca} =catchment area, m^2

ROc = runoff coefficient, (fraction)

RO_e = runoff efficiency, (fraction)

Rd = design rainfall, mm

The CCA ratios were calculated under different farm pond capacities and cropping systems with different SI depths of 30 and 50 mm using equation 2 and the acreage as given in Table 1.

Farm pond construction and lining

The economics of farm pond construction involves earth excavation, slope stabilization, digging of field channels, silt trap, inlet and outlet structures along with bund formation. Beside the earth excavation for digging of farm pond, an extra of earth removal of 22%, 20% and 17% were added for 500, 750 and 1500 m^3, respectively. Based on the field experience of digging the farm pond using machinery with big bucket having capacity of 1 m^3 can cost Rs. 30/m^3 as per the recent market prices of hiring the machinery. Lining of farm pond with 500 micron HDPE black thick film is about Rs.100/m^2 plus labor charges for anchoring and laying of the film in the trench along the side bund of the farm pond. The costs of the lining were: Rs. 30000, Rs.41500 and Rs.70000 for 500, 750 and 1500 m^3, respectively. The life of the lining film is taken as 5 years. The costs of the earth excavation were: Rs. 18300, Rs. 27000 and Rs. 52650 for 500, 750 and 1500 m^3 capacities of farm ponds, respectively. These above fixed cost are annualized for 20 years of life of the structures by using the formula given below:

$$\text{Annualized cost} = \frac{p \times (r(1+r))^n}{(1+r)^n - 1} \quad (3)$$

Where,

P = loan amount, Rs

r = interest rate (9%)

n = amortization period, years.

Water Application system

The cost of the water application system was estimated using two rainguns with one full circle and one half circle at an operating head of 30 m with 50% over lapping in the spray pattern and the discharge rate of 150 lph. One full circle would cover an area of 1258 m^2 by Hidra model of raingun. The life of the system was taken as 15 years for the 5hp monoblock diesel pumpset , HDPE pipes with accessories for 1 ha irrigation at a time (50 HDPE pipes at 4kg/cm^2). It was assumed that the plot size of 100 x 100 m^2 for all calculations of irrigation cost. The system was operated on shifts immediately after meeting the irrigation depth criterion. The time of irrigation estimated for 30 and 50 mm depths were 2.5 hr and 4.2 hr, respectively. The total market price of the system was estimated as Rs 80,000/-. It is proposed to run the system on custom hiring basis with 100% benefit on annualized cost with 9% bank interest rate for loan repayment by the entrepreneur. The

annual operation and maintenance cost of the system was taken as 12% over the annualized cost of the system including transport, etc. It is presumed that the system will be in operation for 840 hrs in the field in a year taking care of kharif and rabi irrigation from the farm pond or any water source in a cluster of 5-6 villages. The unit irrigation cost of the system was arrived at Rs. 350/hr. The cost of SI at two critical stages of crop growth at different levels of irrigation depths of 30 mm and 50 mm of water application was worked out as Rs 1900/ha and Rs 3204/ha, respectively under the custom hiring module by using rainguns. It includes hiring charges of irrigation system and diesel cost with consumption of 0.5 l/hr of operation. On an average, the cost of the diesel is taken as Rs 60/litre.

Production economics

The selected crops GN, M, O, T and C were treated with 30 and 50 mm SI depths at 2 critical stages of the crop growth period. The average yields, costs of cultivation, market price are given in Table-2. In the present analysis, the cereal crop maize and oil seed crop, groundnut was taken as primary crops as commonly grown by the farmers of rainfed areas in southern Telangana. The economic analysis was carried out in the combination of vegetables (O and T) with single filling and carrot in rabi with second filling of the farm pond. The analysis into the systems like monocrop M, M+O, M+T, during kharif season and M+C, M+O+C, M+T+C during kharif and rabi season both spread over 2 seasons of the year, were carried out. Similarly, the second systems with oil seed crop, GN with the above combinations were tried in the experiment.

The sole crop of M and GN were experimented with both the SI depths of 30 and 50 mm at two critical stages (silking and tasseling, grain filling and development in M; flowering, peg initiation and pod development in GN). The combination of sole crop with vegetables like O and T were tested with 30 mm deficit irrigation from farm pond as vegetable requires minimum 5-7 irrigations during its growth period. In the rabi, C was grown with 7 irrigations of 30 mm from the farm pond. The analysis was considered for three different capacities of 500, 750 and 1500 m^3. Under rainfed conditions, the average yields of GN and M are 700 and 2800 kg/ha with a cost of cultivation of Rs. 23000 and 25000/ha, respectively. In addition to the GN seed yield, the haulm of the GN added a benefit of Rs. 12500/ha under rainfed and Rs. 19000/ha under SI. The B:C ratios were 1.41 and 1.71 for rainfed GN and M, respectively.

Economic productivity and B:C ratio of different cropping systems were estimated under different SI depths for all the three farm pond capacities. For estimating total water use for different cropping combinations, the effective rainfall at 75% probability of seasonal rainfall of 375 mm was considered by taking 57% of it as effective rainfall based on long term observations in the Alfisols. The SI depths applied for different crops as per Table-1 were also added to the effective rainfall for estimating economic productivity which is the ratio of annualized net benefit (Rs/ha) and total crop water use (m^3) by the system.

Results and Discussion

Rainfall and Runoff Relationship (RRR)

The relationship between rainfall and runoff in rainfed alfisols was developed using the regression analysis by using the data collected during experimental period and presented in Fig 1.From the all years of experimental data, it was observed that, there was a quadratic relation between rainfall and runoff with a coefficient of R^2= 0.82 in rainfed alfisols. Though the alfisols has high infiltration characteristics, the soils have the crust formation immediately after sowing having the runoff coefficient of 2 to12% depending upon the antecedent moisture conditions of the catchment area and the rainfall intensity and its duration.

Irrigation scheduling of different cropping systems

Under three different capacities of farm ponds with two levels of SI depths, an irrigation schedule was calculated based on the net water availability in the farm pond at the time of critical stages of sole crop and for different combinations of O, T in kharif and C in rabi and the results are presented in Table-1.

For sole oilseed based cropping system, the GN can be irrigated in 0.8 and 0.5 ha with the SI depths of 30 and 50 mm for 4 and 4.11 hrs of irrigation time, respectively with the designed rain gun irrigation system under the farm pond capacity of 500 m^3 with two critical irrigations. Similarly, for 750 m^3 capacity of farm pond, GN can be grown in 1.16 and 0.7 ha with 30 and 50 mm critical irrigation depths for 5.7 and 5.8 hrs, respectively. For 1500 m^3 capacity of farm pond, the areas under GN cultivation could be 2.23 and 1.34 ha with irrigation depths of 30 and 50 mm for 10.03 and 11.01 hrs of irrigation duration, respectively.

For the combination of GN and O, the areas under which GN could be irrigated with net available water are 0.25, 0.4 and 0.84 ha with 30 mm SI depth for the irrigation time of 1.25, 2.0 and 4.2 hrs under 500, 750 and 1500 m^3 farm pond capacities, respectively. The areas under O are 0.25, 0.3 and 0.5 ha with five irrigations for duration of 3.13, 3.75 and 6.25 hrs under 500, 750 and 1500 m^3 farm pond capacities, respectively in combination with GN.

For the combination of GN and T, the areas under which GN grown are 0.4, 0.5 and 0.84 ha with 30 mm SI depth for the irrigation time of 2.0, 2.5 and 4.2 hrs under 500, 750 and 1500 m^3 farm pond capacities, respectively. The areas under T are 0.1, 0.2 and 0.5 ha with six irrigations for duration of 1.5, 3.0 and 8.75 hrs under 500, 750 and 1500 m^3 farm pond capacities, respectively in combination with GN.

In rabi, C crop was grown in addition to the above combination of crops in kharif with the second filling of farm pond. The area under C are 0.2, 0.3 and 0.55 ha with 30 mm SI depth and seven irrigations with duration of 3.8, 5.7 and 10.9 hrs under 500, 750 and 1500 m^3 farm pond capacities, respectively. Except sole crop, the combination of crops are not possible with 50 mm level of irrigation depth under the farm ponds looking into the water requirements of vegetables like O and T in kharif and C in rabi and the evaporative demand in the rainfed areas.

Similar schedules were calculated for the M based cropping system with similar combination of vegetables like O, T in kharif and C in rabi (Table-1).

Catchment command area (CCA) ratio

The catchment areas estimated for alfisols with 7% average run-off coefficient are 2.55, 3.8 and 7.6 ha for 500, 750 and 1500 m^3 farm pond capacities, respectively. In both the cropping systems with GN and M as sole crops, the CCA ratio was found to be same with progressive increase with farm pond capacities from 500 to 1500 m^3. In 30 mm SI depth, both GN and M have the CCA ratio of 3.19-3.41 and it was 5.1-5.67 at 50 mm SI depth (Fig-2). In the GN-based cropping system, when C is planned in rabi after second filling of the farm pond, the minimum of CCA ratio was observed when both O/T in kharif and C in rabi are considered with 30 mm SI depth (Fig-2). It ranged from 2.13 to 2.28. The CCA ratio with sole GN under 50 mm SI depth is at par (5.1-5.67) with 30 mm SI depth with GN and vegetables (O/T) which indicates the benefit of deficit irrigation with 30 mm which may accrue more profits to a farmer under farm ponds of different capacities. The same holds true for the M based cropping system too. While comparing both the cropping systems, the CCA ratio in GN+O/T+C under 30 mm SI depth (CCA=2.13-2.28) is less than M based system (CCA=3.64-4.02) as evidenced by 71.43, 76, 76.19% increase in M based cropping system over the GN in farm pond capacities of 500, 750 and 1500 m^3, respectively (Fig-2).

The analysis of CCA ratio under different capacities of farm pond indicates that for low sloppy land (less than 5%) particularly in the alfisols, the run-off coefficients are less, however, the CCA values may further decrease with increase in run-off coefficients in the moderate to high sloppy lands in alfisols.

Production dynamics under different SI

Average yield of the GN obtained were 1200 and 875 kg/ha under different irrigation levels of 50 and 30 mm, respectively. The corresponding rainfed yield was 700 kg/ha with average seasonal rainfall of 436 mm. For M, average yields were 4600 and 3930 kg/ha under 50 and 30 mm critical SI depths, respectively. The rainfed M yield was 2800 kg/ha. The average yields of O with five irrigations were 8500 and 5950 kg/ha under 50 and 30 mm depths, respectively (Table-2). For T, the average yields were 40000 and 28000 kg/ha under 50 and 30 mm depths, respectively with six irrigations. The rabi C yields were 25000 and 17500 kg/ha under 50 and 30 mm depths of irrigation, respectively for seven irrigations.

SI showed a large potential to improve yield potential especially in semi-arid cropping systems with uneven rainfall variability and high intra seasonal dry spell occurrence(Pandey et al., 2003; Barron,J, 2004). Research results in Tigray(Araya et al., 2011) also showed that more than 80% of yield reduction and more than 50% of crop failure can be avoided when SI is employed during the critical growth stages of the crops. The importance of SI for different crops at critical growth stages is supported by various researchers in the world. In similar way SI was stated as one of the good crop water management options aimed to improve water availability and hence increase transpiration (Rackstorm and Barron, 2007). SI is a key strategy, still underused, for unlocking rainfed yield potential and water productivity(Rockstorm et al., 2010).

Economic assessment of farm pond technology

The economic analysis has been done for two situations, viz., single filling of farm pond with a risk of 20% (4 successful events out of 5 years) in kharif season and second filling of farm pond with a risk of 40% (3 successful events out of 5 years) in rabi season of semi-arid region of southern Telangana with major soil group of alfisols. With the single filling in the oil seed based cropping system, three combinations of taking GN as a sole crop with 30 and 50 mm SI depths at two critical stages and GN+O or GN+T with the vegetable in the kharif with the SI depth of 30 mm. Similarly, with the second filling of farm pond, the carrot crop was taken in addition to the above combinations in rabi season with 30 mm SI depth.

While comparing the annualized net benefit with single filling of farm pond in kharif season, it was observed that the net benefits with GN as a sole crop ranged from Rs. 11823 to 13506 per ha under the SI depth of 30 mm (Fig-3). However, there was an increase in the net benefit ranging from Rs. 21427 to 23168 per ha under the SI depth of 50 mm. Under the sole GN crop system, though the area increases (Table-1) with 30 mm SI depth, the response of crop yield is much more under 50 mm SI depth with less area giving increased net benefits. Under the cropping system of GN+O with 30 mm SI depth, the net benefits ranged from Rs. 24785 to 29399 per ha which is almost two times more than the net benefits with sole crop of GN. When tomato is taken instead of O, the net benefits ranged from Rs. 74451 to 128834 per ha which is five times more than the GN sole crop with the same SI depth of 30 mm. Also, when GN+T is compared with GN+O, the net benefits were increased by 2-5 times under different capacities of farm pond with the same SI depth. Therefore, under oil seed based cropping system, GN+T is the best option followed by GN+O in the kharif with the single filling of farm pond.

In both the kharif and rabi seasons with second filling of farm pond, the analysis was done for GN+C, GN+O+C, GN+T+C with the 30 mm SI depth and net benefits observed ranged from Rs. 71008 to 72936 per ha, Rs. 107043 to 110346 per ha and Rs. 141108 to 184940 per ha, respectively. It indicates that GN+T+C were the most profitable cropping system with two fillings of the farm pond followed by GN+O+C.

In the cereal based cropping system with M as sole crop, net benefits ranged from Rs. 59193 to 60876 per ha, Rs. 66627 to 68668 per ha under 30 and 50 mm SI depths, respectively (Fig-4). With the introduction of O in the cropping system, the net benefits ranged from Rs. 50729 to 54968 per ha under 30 mm SI depth which is less than the sole crop as M. The decreases in net benefits were observed due to reduction in the area under the crop as well as crop yield response to the SI.

With the second filling of farm pond, the net benefits ranged from Rs. 113720 to 115356 per ha, Rs. 126743 to 131719 per ha and Rs. 171616 to 204542 per ha for M+C, M+O+C and M+T+C, respectively. It indicates that M+T+C were the most profitable cropping system with two fillings of the farm pond followed by M+O+C with 30 mm SI depth.

In kharif season with single filling of farm pond, the GN (sole) based cropping system has B:C ratio ranging from 1.3 to 1.4, 1.47 to 1.53 under 30 and 50 mm SI depths, respectively (Fig-5). GN +O has the B:C ratio of 1.5, whereas GN+T has increasing ratio varying from 2.53 to 3.20 with 30 mm SI depth under different capacities of farm ponds. In rabi season with second filling of farm pond, the B:C ratio ranged from 2.86 to 2.95, 3.13 to 3.23 and 4.0 to 4.72 in GN+C, GN+O+C and GN+T+C, respectively indicating the option of T in kharif with GN and C in rabi under 30 mm SI depth has the maximum B:C ratio as compared to other cropping systems under three capacities of farm ponds (500 to 1500 m^3). However, in cereal based cropping system with M as sole crop, the B:C ratio ranged from 2.5 to 2.6 and 2.4 to 2.5 under 30 and 50 mm SI depths, respectively and it is two times more than the sole GN (Fig 5 and 6). M+O gave the least B:C ratio (1.9 to 2.1) as compared to M+T (3.2 to 3.7) under 30 mm SI depth (Fig-6). However, in both the kharif and rabi season with second filling of farm pond, the B:C ratio ranged between 3.4 to 4.7 with maximum in M+T+C(4.5 to 4.7) followed by M+C and M+O+C under different capacities of farm pond.

The economic productivity (EP) for different cropping systems were calculated by considering the total water used per ha by the system from the farm ponds along with effective rainfall of 2138 m^3 and the annualized net benefits, Rs/ha of the cropping systems under different farm pond capacities and SI depths of 30 and 50 mm. In GN based cropping system, the sole GN has the EP ranging from 4.32 to 4.93 Rs/m^3, 6.83 to 7.38 Rs/m^3, respectively under 30 and 50 mm SI depths (Fig-7). EP in GN+O declined from 6.94 to 5.85 Rs/m^3 as the capacity of farm ponds increased. GN+T had the maximum EP over GN+O and sole GN ranging from 16.4 to 28.4 Rs/m^3.

When both farming seasons are taken into account with C in rabi, GN+O/T in kharif with 30 mm SI depth, GN+T+C had the maximum EP ranging from 21.3 to 27.9 Rs/m^3 over the farm pond capacities of 500-1500m^3 followed by GN+O+C and GN+C with a declining trend as the farm pond capacity increases.

However, the other cropping systems with M under different capacities of farm ponds and SI depths, the EP increased 5 times more than that of sole GN based system (Fig-7 & 8) in kharif except in the case of M+O with 2-fold increase. The maximum EP with progressive increase from 24.8 to 34.9 Rs/m^3 was obtained in case of M+T in kharif with 30 mm SI depth (Fig-8). The EP was almost constant (23.51-23.84 Rs/m^3) in case of M+C with both cropping seasons under two fillings of farm pond, however, M+T+C had the maximum EP (25.9-30.8 Rs/m^3) as compared to M+O+C and M+C when both the seasons are considered.

Conclusion

Farm pond technology with different capacities and crop diversification will lead to reduce the yield gaps between irrigated and rainfed. Due to changing climate and rainfall patterns, principles of rainwater harvesting through farm ponds within the farmers fields has the potential of enhancing the economic productivity of different crops in the rainfed regions without exploiting the ground water in hard rock regions like southern Telangana. Among the selected cropping systems with combination of different vegetables in kharif and rabi under two SI depths of 30 and 50 mm, the maize based cropping system with vegetables particularly tomato in kharif and carrot in rabi was found to be more profitable with high economic returns to the farmers. SI depth of 50 mm was found to be more profitable in the sole crop of M and GN, however, SI depth of 30 mm is not sufficient to induce the crop response to the profitable yield in the soils like alfisols which are thirsty with low water holding capacity leading to underutilization of soil nutrients as per the requirement of the crop. But, in the case of crop diversification with vegetables, like O, T and C with 5-7 irrigations, 50 mm SI depth can't be supported with the limited water storage in the farm ponds upto 1500 m^3. Besides improving the economic productivity, farm pond contribute intangible benefits of controlling soil loss and the nutrients from the farmers' fields and the limitation is only the area loss for construction of farm pond within the farm field to an extent of less than or equal to 10% upto the capacity of 1500 m^3.

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Table-1. Command area under different combinations of cropping systems under differential rainfall and capacities of farm pond

Seasons	Storage/ SI depths	500 m^3 (CA=2.55)		750 m^3 (CA=3.8)		1500 m^3 (CA=7.6)		Storage/ SI depths	500 m^3		750 m^3		1500 m^3	
		30 mm	50 mm	30 mm	50 mm	30 mm	50 mm		30 mm	50 mm	30 mm	50 mm	30 mm	50 mm
	Cropping system (Oil seed based)							Cropping system (Cereal Based)						
Kharif	Acreage (ha)							Acreage (ha)						
	GN	0.8	0.5	1.16	0.7	2.23	1.34	Maize	0.8	0.5	1.16	0.7	2.23	1.34
	No of irrigation	2	2	2	2	2	2	No of irrigation	2	2	2	2	2	2
	Irrigation time (hrs)	4	4.11	5.7	5.8	10.03	11.01	Irrigation time (hrs)	4	4.11	5.7	5.8	10.03	11.01
	Acreage (ha)							Acreage (ha)						
	GN	0.25	*	0.4	-	0.84	-	Maize	0.3	-	0.4	-	0.84	-
	Okra	0.25	*	0.3	-	0.5	-	Okra	0.2	-	0.3	-	0.5	-
	No of irrigation							No of irrigation						
	GN	2	*	2	-	2	-	Maize	2	-	2	-	2	-
	Okra	5	-	5	-	5	-	Okra	5	-	5	-	5	-
	Irrigation time (hrs)							Irrigation time (hrs)						
	GN	1.25	-	2	-	4.2	-	maize	1.5	-	2	-	4.2	-
	Okra	3.125	-	3.75	-	6.25	-	Okra	2.5	-	3.75	-	6.25	-
	Acreage (ha)							Acreage (ha)						
	GN	0.4	-	0.5	-	0.84	-	Maize	0.4	-	0.5	-	0.84	-
	Tomato	0.1	-	0.2	-	0.5	-	Tomato	0.1	-	0.2	-	0.5	-
	No of irrigation							No of irrigation						
	GN	2	-	2	-	2	-	Maize	2	-	2	-	2	-
	Tomato	6	-	6	-	6	-	Tomato	6	-	6	-	6	-
	Irrigation time (hrs)							Irrigation time (hrs)						
	GN	2	-	2.5	-	4.2	-	Maize	2	-	2.5	-	4.2	-
	Tomato	1.5	-	3	-	8.75	-	Tomato	1.5	-	3	-	8.75	-
Rabi (Second Filling)	Carrot							Carrot						
	Acreage (ha)	0.2	-	0.3	-	0.55	-	Acreage (ha)	0.2	-	0.3	-	0.55	-
	No of irrigation	7	-	7	-	7	-	No of irrigation	7	-	7	-	7	-
	Irrigation time (hrs)	3.8	-	5.73	-	10.91	-	Irrigation time (hrs)	3.8	-	5.73	-	10.91	-

Table-2. Yield and cost details of different crops under different irrigation depths

Crops	Cost of cultivation (Rs/ha)	Present market price (Rs/kg)	Crop yield (kg/ha)		
			50 mm	30 mm	Rainfed
Groundnut	23000	40	1200	875	700
Maize	25000	23	4600	3930	2800
Okra	40600	20	8500	5950	-
Tomato	61000	15	40000	28000	-
Carrot	35600	20	25000	17500	-

Fig-1: Rainfall and runoff relationship in rainfed alfisols during experimental period

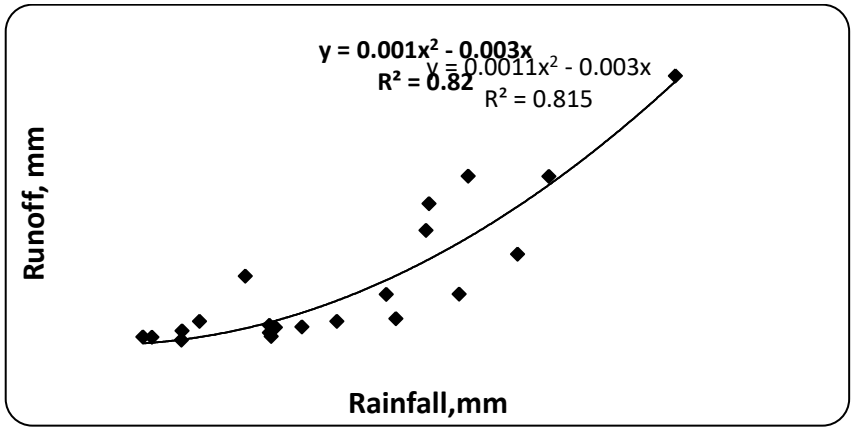


Fig-2. Catchment command area ratio for different cropping systems and pond capacities

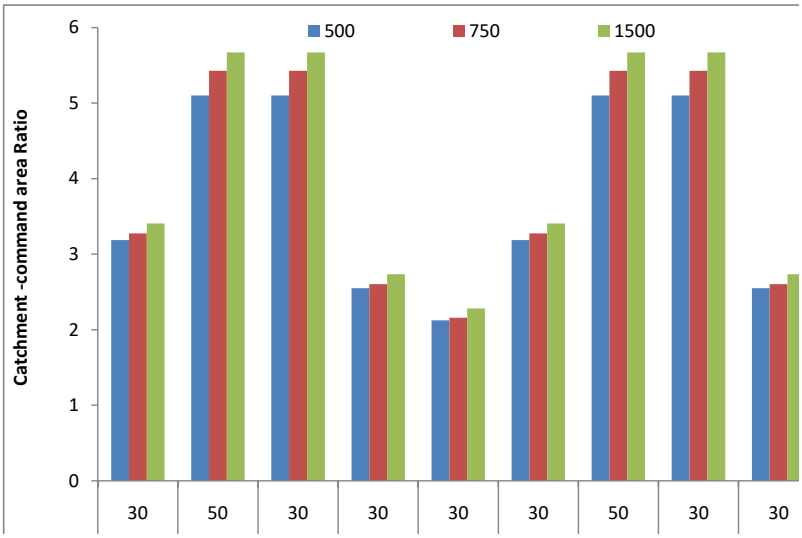


Fig-3. Annualized net benefits from oil seed based cropping system under different irrigation depths and pond capacities

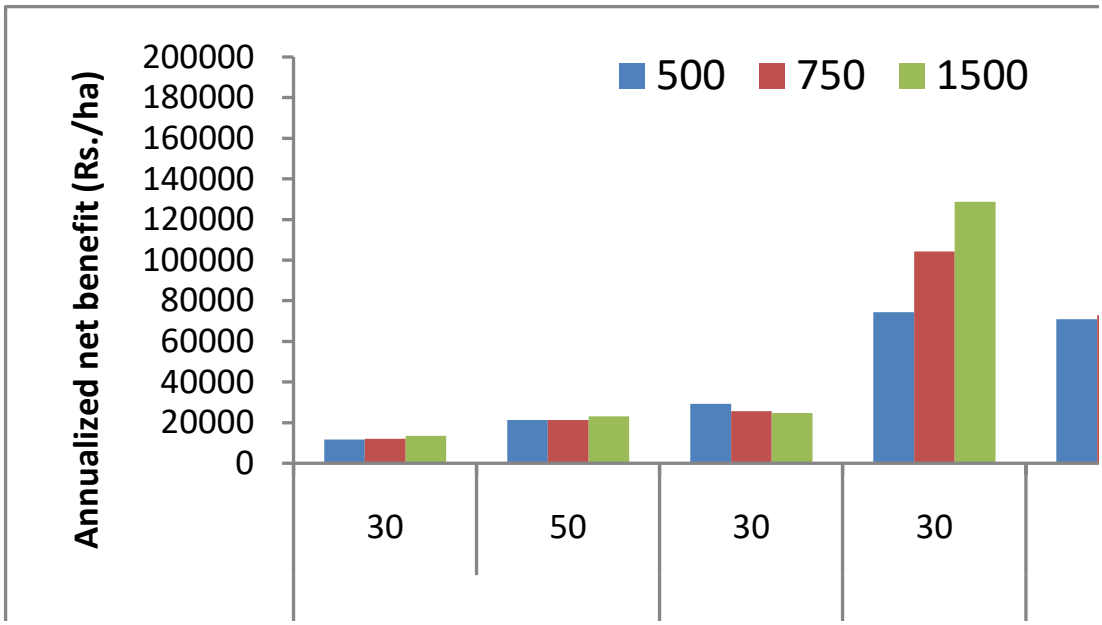


Fig-4. Annualized net benefits from cereal based cropping system under different irrigation depths and pond capacities

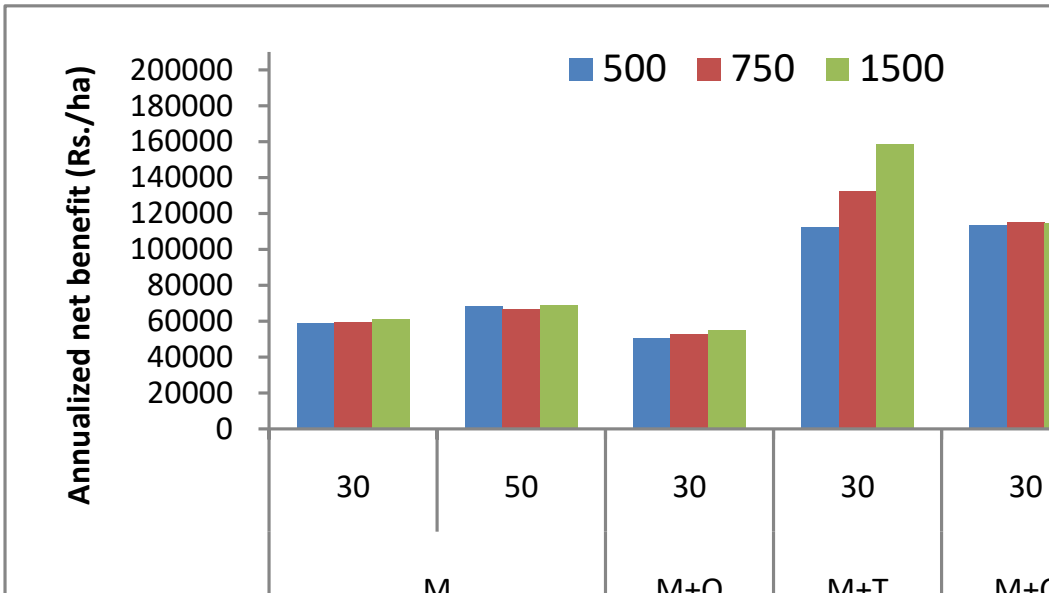


Fig-5. B:C ratio of oil seed based cropping system under different irrigation depths and pond capacities

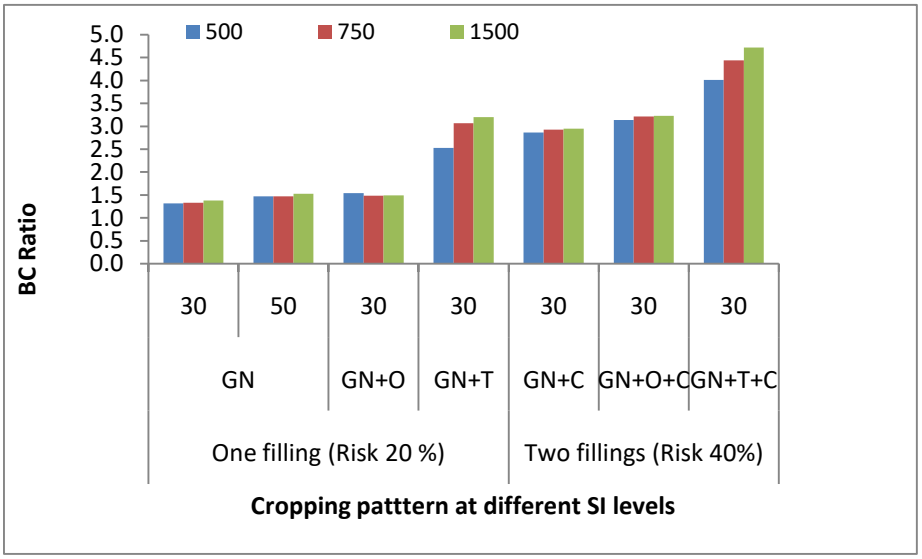


Fig-6. B:C ratio of cereal based cropping system under different irrigation depths and pond capacities

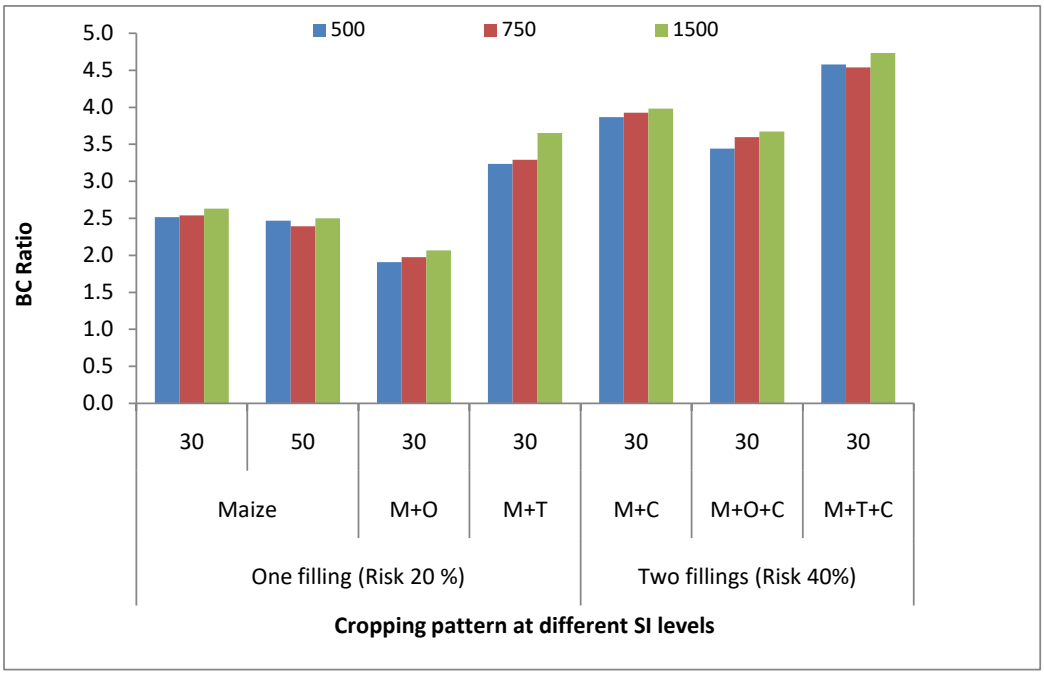


Fig-7. Economic productivity of oil seed based cropping system under different irrigation depths and pond capacities

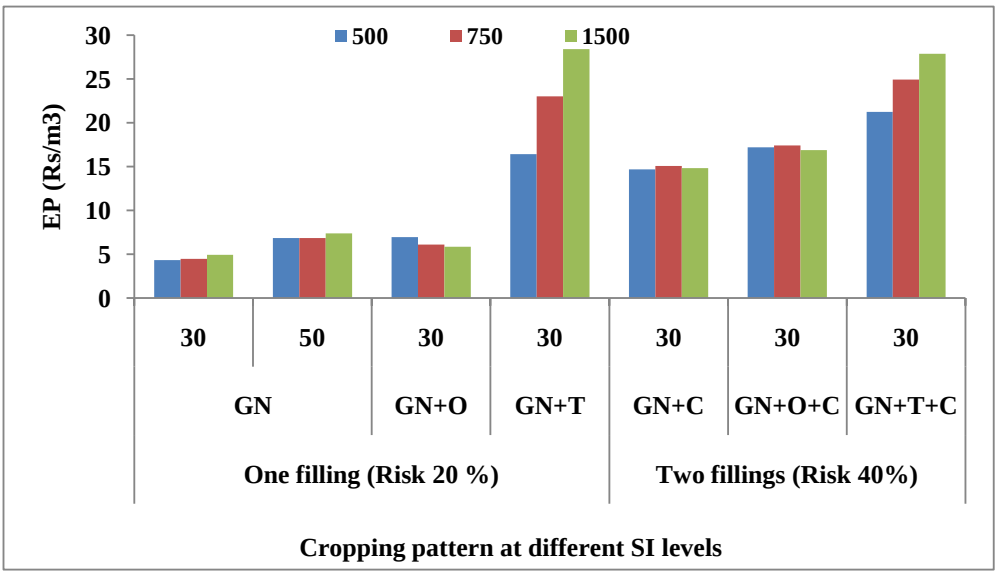
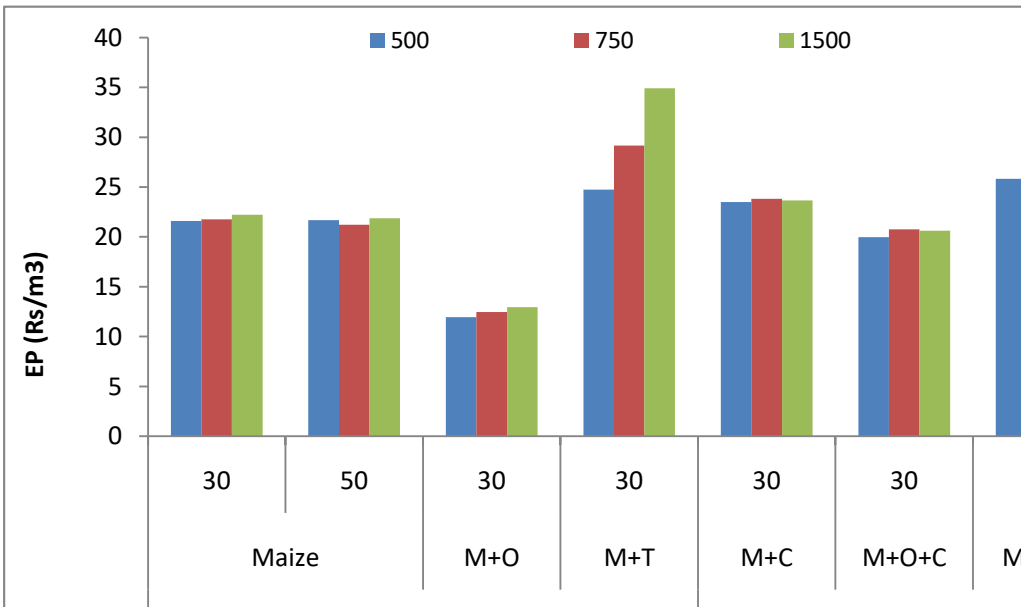


Fig-8. Economic productivity of cereal based cropping system under different irrigation depths and pond capacities



GLOBAL FOOD AND LIVELIHOOD SECURITY THROUGH RESOURCE EFFICIENT AGRICULTUREAL PRODUCTION AND POST PRODUCTION MANAGEMENT*

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Abstract

Food is a physiological necessity for human survival and performance and it is derived through agriculture which depends on natural resources like land, water, biodiversity and climate and as of now, these resources are dwindling and degrading along with climate change and environmental pollution. The need is to identify and/or develop food commodities which have higher nutritional and/or energy productivity and grow them following integrated and sustainable farming system and develop food recipes based on such identified commodities to have a nutritionally balanced healthy diet. Food processing technologies such as fortification, fermentation, extrusion, or hydro-thermal cooking may be used to prepare the diet. Such agricultural and post-production management would ensure global food and livelihood security of the present global population and that of the future generations employing better resources management technologies.

1. Introduction

Agriculture is the prime global source of human survival and their performance and the sustainable agriculture is one that produces enough biomass using natural resources like land, water, biodiversity and climate to meet the needs of present global population and at the same time maintains the soil health and its fertility for higher agricultural outputs to meet the requirements of the future generations. However, the management of natural resources are inherently complex and its involves ecological & hydrological cycles; plants & livestocks; geography & geology; and so on and all these being created and controlled by the Solar System and its energy. Appropriate engineering interventions in agriculture in the form of commodity & location specific tools, technology and machinery facilitates timely completion of various unit operations involved in production and post-production conservation and value addition to agricultural produces and thereby result into higher productivity on account of proper placement and enhanced inputs use efficiency and also reduce the drudgery of workers involved in farming and minimizes the cost of production and post-harvest losses which increases per capita food availability and this ensures food and nutritional security of the global population and thus help in alleviating hunger and promoting better health and happiness for one and all.

Agriculture traps and transforms solar energy into chemical energy in the form of harvested biomass of plant and livestock origin which is subsequently processed and utilized for food, feed, fibre, fuel and other necessities of life(Fig.1). Sustainable agriculture is one that produces enough biomass to meet the needs of the present global population and at the same time maintains the soil health and its fertility for higher agricultural productivity for the future generations. In other words, sustainable agriculture produces enough for the present population while retaining the soil health to produce required foods and other biomaterials for the future generations.

2. Livelihood

Agriculture, industry and services are the three major sources/sectors of livelihood for human beings on the planet earth (Table-1). Although, the human beings are the highest form of life and scientifically the most advanced species on the planet earth but need food for their survival and performance, because food is a physiological necessity and eating food is a source of pleasure and it, therefore, requires quantity, quality and variety. Food is produced through farming which needs farm, farmer and finance (inputs).

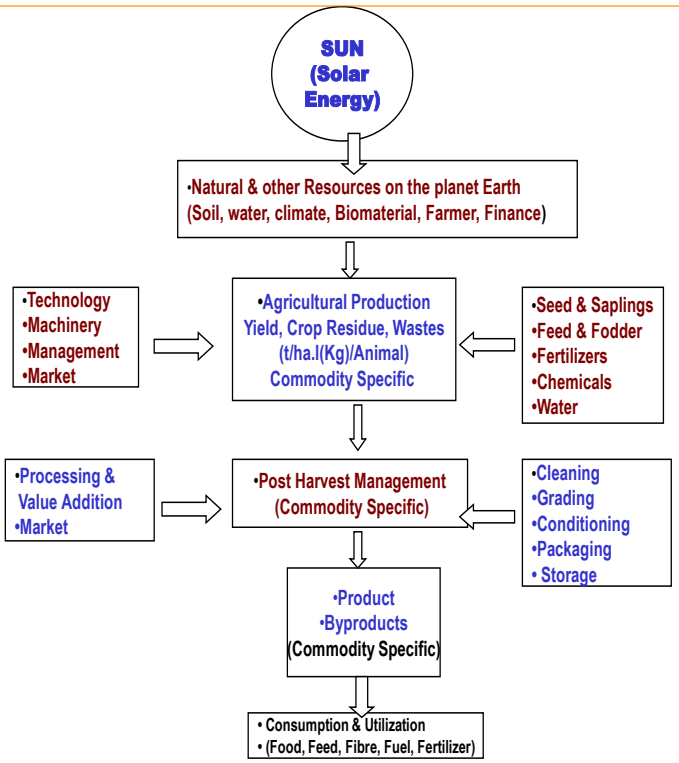


Fig-1: Agril Production to Consumption System

Table-1: The three major sources of livelihood in the World

Livelihood	A brief description	Remarks
• Agriculture	Agriculture includes raising of field crops, horticultural crops, livestocks such as animals, poultry, fishes & the capture of fishes from fresh water bodies and sea waters. Processing of harvested biomass, transport, marketing and utilization.	• Out of all the three major sources of livelihood, agriculture and allied activities are the most important & potent one because its output provides the basic necessities of life that are needed by each and every individual, rich or poor, for their survival & performance. • Farmer and his/her family can survive practicing agriculture but the people involved in industry and service cannot survive without agricultural produces, irrespective of their wealth & status.
• Industry	Automobile; electrical and electronics; information technology; textiles, infrastructure such as buildings, roads, bridges, culverts; pharmaceuticals, beauty aids, etc.	
• Services	Governance; management; health; education & research; judiciary; entertainment; medical; social & religious; and so on.	

The need is, therefore, to go for sustainable agriculture with appropriate natural resource management to have enough agricultural production for the present population and to meet the requirements of the future generations.

Agriculture not only supports life through food, cloth and shelter but also provides livelihood to about 65% of Indian people living in rural areas and contributes about 15 – 17% to the total GDP of India. Agriculture includes raising of field crops, horticulture, agro-forestry animal husbandry and fishery. The basic natural resources of agriculture are land, water, air, weather and biomaterials. The major inputs to agriculture are seeds, fertilizers and pesticides. All these are appropriately managed using energy, time, tools and skills for higher agricultural production and productivity on a sustainable basis.

3. Agricultural Production

The high achievements in agricultural production (Table-2) has lead to food self-sufficiency but it has put the natural resources under intense strain resulting in fast degradation and lowering of their production efficiency. The benefits of green and other revolutions are limited to a few areas only, thereby creating wide regional disparities in the productivity to different agro-ecological zones. Each agro-ecosystem should be treated as a unique case, and the land and water management practices should be linked to the local socio-economic and bio-physical environments and agriculture now should shifts to knowledge-based from resource-based technology in the quest to wipe off food and nutritional insecurity on permanent basis in India. In this context, conservation and/or sustainable agriculture offers an opportunity for higher sustainable productivity alongwith environmental upgradation and maintenance.

Table-2 Production of some of the major plant and livestock based food commodities in India during 1950-51 and 2014-15 (GOI, 2016)

Food commodities	Production in million tones (Mt) during 1950-51 and 2014-15		
	1950-51	1991-92	2014-15
Plant based Food Commodities			
Foog grains (Green Revolution)	51.0	168.0	255.0
Oil seeds (Yellow Revolution)	05.0	18.6	27.0
Horticulture (Golden Revolution)	06.5	96.6	256.5
Sugarcane (Sweet Revolution)	57.0	254.0	359.5
Cotton Jute & Mesta (Fibre Revolution)	1.0	03.4	8.2
Total	120.5	540.6	906.2
Livestock Based Food Commodities			
Milk (White Revolution)	20.0	56.0	146.3
Meat	1.5	4.0	6.0
Chicken	0.5	1.5	3.0
Fish (Blue Revolution)	1.0	4.2	9.6
Eggs	0.4	1.1	3.9
Total	23.4	66.8	159.2

4. Land, Water and Energy Scenario

4.1 Land

On the planet earth, oceans cover about 70% of the earth surface and 30% is the land area and out of this, approximately 10% comprises of deserts, tundras and mountains where no food can be grown. Only about 20% of the total global area is for agriculture and forestry. Since 1960, the world population has more than doubled but agricultural land has expanded by just 12% because, as of now, it is not advisable to fell more trees and grow foodgrains, on account of ecological balances.The option is to adopt sustainable agriculture and make use of latest agricultural tools and technology to grow more food from the present land resources and save whatever is produced and avoid wastage at household levels. In 1960, it took about 0.45ha of cropland to grow enough food for one person for one year but today, it takes just 0.20 ha on account of technology led higher agricultural productivity. Yet, hunger is widespread and the future looks uncertain. One of the reason for this is inequality in financial and physical access to food by each & every person of the world.Globally, the per capita cropland availability is about 0.23 ha. However, high-income countries cultivate more than twice the area per capita (0.37 ha) than low-income countries (0.17 ha). The population stability in high-income developed countries may ensure that their average per capita available of cropland will not significantly change until 2050. But in low-income and less developed countries, a person may be left with less than 0.1 ha by 2050. In such a situation, there is no option but to protect every field & furrow and maximize the yield using green sustainable technologies and inputs. Conservation/sustainable agriculture using organic inputs and biopesticidesare the answers for the future to maintain food, nutritional and social security of the people of the global village.

In India, mechanized mega-dairies and their demand of processed feed are putting additional pressure on land and at the same time, diversion of prime agricultural land for infrastructure, industry and urbanization continues un-checked. Between 1955 and 2000, more than 2.3 million hectares of agricultural land has been converted to support urban growth, in India. The pace of urbanization including that of Special Economic Zones (SEZs) are increasing every year, risking India's food security in the near future, though farmers are resisting acquisition of agricultural land, across the India. Globally about 70% of the total land area is used for agriculture. The top soil, also called skin of the earth, comprises of 05-20cm deep upper layers. This soil is a power-house of billions of microbes, fungi, earth-worm that transform rocks and plants residue into a moist fertile bed to grow crops. It takes about 1000 years to accumulate about 05cm of top soil layer but at present the world loses it 10-40 times faster than it can be replenished.Almost all the food, say about 99.7%, comes from cropland and it is now shrinking by more than 10 million hectares a year, due to soil erosion. Nearly 40% of soil used for agriculture around the world is classed as either degraded or seriously degraded, which signifies a loss of 70% of the topsoil. Topsoil is the thin layer of earth that supports plant life with nutrients. It is packed with micro-organisms that recycle organic material and enhance the soil ability to retain water. Loss of top soil on account of erosion leads to lower productivity. About 60% of washed away soil ends up in rivers, streams and lakes, triggering floods. Erosion also leads to more air pollutants and the blown-off soil carries about 20 organisms, spreading diseases such as anthrax and tuberculosis (Mazoomdar, 2013).Across India, about one mm of top soil is being lost each year, with a total loss of 5,340 Mt annually due to erosion. This amounts to a monetary loss of over Rs 10,000 millions/year. The rate of soil loss is about 16 tonnes/ha/year. Some present and future facts of the soil are given below:

- It is estimated that if the present day modern agriculture continue using chemical fertilizers and pesticides, it may take not more than 60 years (say by 2075 AD) to exhaust the earth's topsoil.

- About 250 million people in the developing world are directly affected by human-induced erosion and desertification.
- About 19.2 million km^2cropland was degraded by 1991.
- USA loses about 7.5 tonnes of top soil/ha/year.
- India loses about 16t of top soil/ha/year and in monetary term, it is about Rs 10,000 million/year.
- About 130 million hectares in India is seriously affected by soil erosion. It is about 40% of India's total geographical area.
- About one mm of top soil is washed away by a typical rainstorm. It amounts to 13t of top soil/ha. It takes about 20 years to get is replenished, naturally.

4.2 Water

It has been estimated that for about 7500 million people of the world, daily water requirement would be approximately 7500 billion m^3 to produce and consume 3000 kcal dietary energy/person/day. It amounts to per capita daily water requirement of about 1000m^3. At this rate of water use, by 2025, about 1.8 billion people would be living in absolute water scarcity and 65-70% of world population would face water stress (Mazoomdar, 2013)

A diet consisting of 80% plant and 20% livestock products would require about 1300 m^3 of water per person per year to produce it. While the world's population increased by 300% in the 20th Century, the use of water increased by a staggering 700%. By 2050, the water requirement would by 10-13 trillion m^3 per year, about 03-time to the present volume, to meet out the food demand. As of now, about 40% world food supply comes from irrigated lands and the availability of irrigation water is not sustainable. Hence, in future, the drip-irrigation, though costly, would help to overcome the water scarcity as it saves 30-35% water for the same output and also facilitates the use of fertilizers, enhancing its use efficiency. As of now, India uses about 80% of total water for agriculture whereas the global averages is 70%.

A shift in eating habit of the people toward meat also puts significance pressure on water. Food derived from plants consume less water than if derived from animals. Plants also have their hierarchy of water use efficiency. Potato, maize, onion and groundnut require less water but choice of water intensive crops like sugarcane or rice in arid regions, for higher profit, results unnatural water demand and drain aquifers. Judicious use of water for raising crops which have maximum nutrients productivity per unit of water (Table-3) need to be encouraged for food & nutritional security of the people. Potato, maize, groundnut, wheat and onion are some of the examples.

Table-3 Nutritional water productivity of some of the food commodities (Renault & Wallender, 2000)

Food commodity	Water input l/per kg produce	Productivity, kg/m^3	Nutritional water productivity			
			Energy, kcal/m^3	Protein, g/m^3	Fat, g/m^3	Calcium, mg/m^3
Wheat	1159	0.863	2279	74	9	279
Rice	1408	0.710	1989	49	5	132
Maize	710	1.408	3856	77	17	63
Potato	105	9.524	5626	150	9	543
Legumes	2860	0.350	1188	76	-	-
Groundnut	2547	0.393	2382	111	206	296
Soybean Oil	15240	0.660	547	0	62	0

Tomato	130	7.692	1416	65	11	200
Onion	147	6.826	2259	85	0	1673
Banana	499	2.004	432	11	0	29
Lemon	344	2.907	504	0	0	423
Beef	13500	0.074	102	10	7	3
Pork	4600	0.217	408	21	35	7
Poultry	4100	0.244	330	33	21	14
Egg	2700	0.370	519	41	36	166
Milk	790	1.266	659	40	38	1233
Butter	18000	0.056	404	1	45	11
• Maximum dietary energy per unit of water is produced by potato, maize, groundnut, wheat, onion, rice, tomato, legumes and others.						

4.3 Energy

The modern high-tech agriculture using chemical fertilizers and pesticides pushes the finite cropland to yield about three times its natural capacity. Fossil fuels like diesel to drive tractors, coal-fired electricity to run water-pumps, factories using energy to produce chemical fertilizers, pesticides and so on are leading towards high-energy intensive agriculture, and the fossil fuels are finite/limited and could be exhausted. Renewable energy based farming is long-lasting. The sun is the mother source of all energy on the planet earth including that of fossil fuels and also in the food. However, as of today, plants converts not more than 02-03% of total energy reaching to the earth surface, through photosynthesis. The energy productivity in production agriculture is given in Table-4. Energy derived from livestock proteins is a further fraction of that as only 5-15% of plant energy get converted into beef or chicken. Increasing energy input has not significantly increased agro-productivity since 1990s but farmers keep investing in energy (chemical fertilizer & pesticides) more to maintain the current productivity level.The Punjab State of India has 3.4 lakhs tractors, 14,000 combine harvesters and 2.4 lakhs diesel-run tubewells. Farming here needs an estimated 1000 million litres of diesel and even a single rupee increase in diesel price shoots the input cost up by Rs. 1000 million. The use of pesticides in the state is a serious energy crises and stark environmental degradation. Some Facts About Energy Used in Agriculture are:

- 01:12 is the raio of energy needed to produce a single calorie of edible plant material against a single calorie of beef.
- 120 Mt of diesel is ued globally in agriculture every year whereas in India it is 10 Mt.
- 18 Million water pumpsets are used in agricultural sector of India.
- 19-23% of India's power consumption goes to agriculture but due to high subsidy, it generates only 05-06% of the total revenue from all electrical utilities.
- 8.5 times more pesticides produced globally in 1999 than in 1960.
- 20 times more technical grade pesticides were produced in India in 1998 than in 1958.
- 05 times more fertilizers used globally in 2005 than in 1960.
- 17 times more fertilizers used in India in 2003 than in 1979.

Table 4: Energy Productivity in Production agriculture

Agricultural Commodity	Energy input MJ/ha (x)	Yield. Kg/ha (y)	Energy Productivity kg/MJ(y/x)
Cereals			
Paddy	13076	3125.2	0.239
Wheat	14657	2872.8	0.196
Maize	9956	2140.5	0.215
Sorghum	4745	949	0.2
Average value for cereals	10608.5	2271.9	0.2125
Pulses			
Green Gram	4315	509.17	0.118
Black Gram	3870	406.35	0.105
Bengal Gram	5464	1038.20	0.19
Chick pea	4890	1486.60	0.304
Average value for Pulses	4634.8	860.07	0.1793
Oil seed			
Mustard	8051	958.07	0.119
Ground Nut	5707	1739	0.305
Soybean	6382	1091.3	0.171
Sunflower	22945	1812.7	0.079
Average value for oil seeds	43085	5601	0.674
Fruits			
Banana	105137	38143	0.363
Mango	7329.05	8048	1.098
Litchi		6100	
Orange	60949.69	40000	0.656
Apple	101505	19447	0.23
Lemon	62977.9	35000	0.558
Mandarin	48838.2	30000	0.614
Average value for Fruits	79614.5	25738	0.44125
Vegetables			
Potato	31352	17321	0.55
Tomato	47647.12	57642.86	1.21
Cucumber	17969.54	35400	1.97
Cauliflower	1816.6	10700	5.89
Okra	327.75	4900	14.95
Average value for Vegetables	11165	10974	7.13
Cash crops			
Sugarcane	59192	61500	1.039
Cotton	9972	937.37	0.094
Tobacco	17393.08	1796.5	0.103

5. Agricultural Operations

Agricultural operations (Table-4) are carried out by farmers including women to produce biomass of plant and animal origin to meet the requirements of people and livestock. The goal in production agriculture is to get the highest productivity out of the limited land and water resources whereas the goal in post-production agriculture is to prevent post-harvest losses and produce value added products. For each operation, appropriate tools and machines are required to achieve timeliness in operation; enhanced inputs use efficiency, operator's comfort, and higher productivity, lower cost of cultivation and better quality products.

Table 4 – Various operations in production and post-production agriculture (Ali, 2005)

Production agriculture	Post-productoin agriculture
• Land development and leveling • Tillage and sowing • Irrigation and drainage • Intercultuer and plant protection • Harvesting and threshing	• Cleaning and grading • Drying and storage • Processing and value addition • Packaging and transport • Marketing and utilization

6. Tillage Technology

Tillage is a physical manipulation of soil to get an appropriate soil-titth which can provide favourable conditions for plant growth. It is now being realized that extensive tillage is neither ideal nor required as it causes formation of hard-pan, soil erosion and more energy and labour needs. Tillage is one of the most energy consuming unit operations in the conventional agriculture and it takes a lot of labour, time and fuel. All these lead to have a new appraisal of tillage concept.

The conventional tillage operations such a ploughing and harrowing, involve repeated soil disturbances making it vulnerable to soil erosion, loss of soil structure, etc. While shallow tillage helps in breaking dormancy of weed seeds by exposing seeds to light, deep tillage protects weed seeds by burying it deep in the soil horizon. One of the objectives of tillage is to control weeds and around 50% of the energy required for tillage is spent for weed control. Until herbicides became available in 1940s and beyond, tillage for weed control was an integral part of crop production. With the dramatic improvements being made in the field of herbicide technology, the necessity of soil manipulation for weed control has decreased. Herbicides to kill weeds are more effective and eliminate extra trips of tillage machinery over the field, which results in both a fuel (energy) and labour (time) saving.

Tillage includes all the operations and practices that are carried out for the purpose of modifying the physical character of soil so as to provide favourable conditions for plant growth. Different forms of tillage, and seeding/planting system are conventional, minimum, reduced, conservation, ridge and zero tillage and surface seeding and furrow irrigated raised bed planting system (FIRBPS).

6.1 Conventional Tillage

It is being followed by most of the farmers in the form of primary and secondary tillage operations using plough, harrows, cultivators, etc. It varies depending upon crop, soil and agro-climate condition. It uses more energy and the cost of operation is high. Now the trend is toward reduced tillage in India as well as in developed countries like USA. In conventional tillage, 35% is the fuel cost of the total energy used in crop production (Table-5).

Table 5: Break up of cost of cultivation using conventional tillage system

Component	% of total cost of cultivation
• Fuel	35
• Fertilizer	25
• Machine	20
• Chemical	10
• Seeds & other inputs	10

6.2 Minimum Tillage

It is the minimum amount of soil manipulation required for a good crop production or for meeting the tillage requirements under specific soil and climatic conditions. It eliminates excess tillage operations.

6.3 Reduced Tillage

It is the use of primary tillage in conjunction with special planting techniques to reduce or eliminate secondary tillage operations. Reduced tillage is defined as any combination of tillage operations, which do less tillage than all the operations used in conventional tillage. Reducing the number of operations may be accomplished by eliminating ploughing or one pass with a disk or it may be almost a no-till operations with only single disking or a pass with rotary tillage. The main advantages of reduced tillage are less soil erosion and saving in time and cost of operations.

6.4 Conservation Tillage

It is tillage system that leaves at least 30% of crop residue/stubbles on surface to control soil erosion and moisture loss. It is conducive to sustainable agriculture. In India, residue management is very important in rice-wheat cropping system because a large amount of crop residues are left on soil surface, especially where combines are used for crop harvesting (Fig.2)

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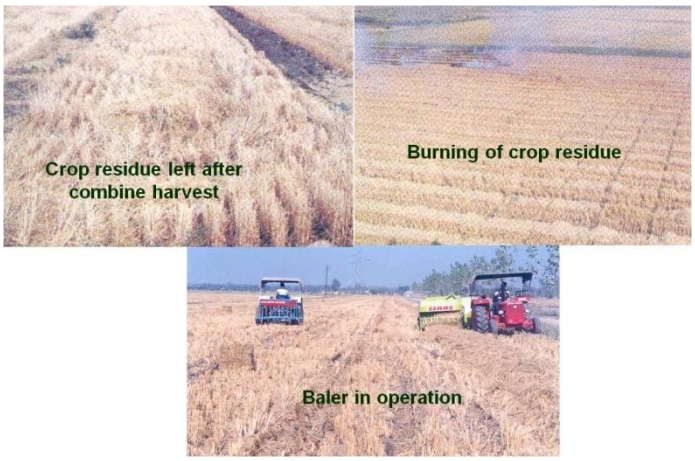


Fig.2 – Crop residue left in the field after combine harvesting

6.5 Zero Tillage

In zero tillage technology, crop seeds are shown in a single operation using specially designed tractor operated see-cum-fertilizer drill without any field preparation in

the presence of crop residues/stubbles at optimum to slightly wetter soil moisture regime. Zero-till drilling of wheat (Fig.3) has become very popular in Indo-Gangetic plains of India under rice-wheat cropping system.



Fig. 3 – Zero-till drilling of wheat

6.6 Rotary Tillage

In rotary tillage technology (RTT), soil is pulverized, seeds and fertilizers are placed and then soil surface is planked; all these three activities are done in a single operation. Soil is pulverized to a depth of 10cm and thus existing weeds and germinating weed seedlings get killed and incorporated into the soil along with crop residues resulting into increased organic matter content of the soil and at the same time it also reduces the air pollution as the straw burning is avoided.

6.7 Ridge Tillage

It is a form of conservation tillage that appears to overcome many of the soil micro-environmental, soil compaction and weed control problems associated with other conventional and un-tilled systems. In ridge tillage system, crop is planted on ridges formed during the previous growing seasons. During planting, the surface (5cm) of the ridge is scraped into the inter-row valleys. Seeds that were shed on the ridge in the previous season are thus moved to the valleys where seedlings can be destroyed by inter-row cultivation. At lay, when crop plants are at least 40cm tall, the truncated/scraped soil is excavated from the furrows and moved back to the ridge crests.

6.8 Night Tillage

A light requirement for some of the weed seeds to break its dormancy is widespread mechanism found in many weed species. This requirement can be satisfied even after a brief exposure to light, such as that resulting from significant reduction in weed density could be obtained as most of the weed seeds remained buried without exposing to light. Covering with an implement to prevent light reaching the soil at the point of cultivation may be sufficient to reduce weed emergence by up to 70%. However, not all weed species have light sensitive seeds. Daytime cultivation with a mould board plough increased weed seedling emergence by as much as 200% above the levels recorded following night time cultivation. The normal practice of cultivation of lands during day time was found to increase germination of burried seeds between 70-400% above the level recorded following night time cultivation. The enhancement of seed germination caused by day-time tillage is due to light that practical problems associated with night tillage under Indian conditions needs to be considered carefully.

7. FIRB Planting System

The furrow irrigated raisebed planting system (FIRBS) introduced in India in 1995, is a method where crops are sown on raised beds (Fig. 4). Generally 2-3 rows of wheat are sown on the top of the bed, 70cm wide, and irrigation is done through the furrows. The inter-row bed space is used to control weeds by mechanical weeding during the early vegetative growth of weeds. FIRB system of cultivation also helps in better input use efficiency.



Fig. 4 The furrow irrigated raisebed planting system (FIRBS)

8. Surface Seeding

It is the simplest no-tillage system being followed/promoted in areas like Eastern India, Nepal and Bangladesh; where wheat shown in lowland rice fields gets delayed considerably due to excess soil moisture. In this system, seeds of wheat, legumes and/or other crops are broadcasted on wet soil in standing rice crop, about a week before harvesting or on wet/muddy soil after harvest. This system is also called *Utera*or paira cropping.

9. Resource Conservation Measure

Resource conservation agriculture generally implies to the systems of cultivation with minimum tillage (Fig.5), in-situ management of crop residues (Fig.6); savings in water use (Fig.7) and that of inputs like seeds, fertilizers and pesticides. Minimum tillage is aimed at reducing the soil manipulation activities to a bare minimum that is necessary to facilitate favourable seedbed condition for satisfactory germination, plant establishment and crop growth. Excessive tillage can be minimized either by eliminating the operations which are not cost-effective or combining the tillage, seeding and fertilizer application in one pass operation (Ali, 2008). Zero tillage is however an extreme form of minimum tillage.

Laser Land Leveler



Fig. 5 Use of Laser Land Leveler and Zero-till-drill and Resultant Savings in Resources

- 30-50% saving in water and 5-10% higher yield
- Becoming popular among small and medium Farmers on custom-hire basis

map***Impact of Zero till drill Adaption***



Benefits

- **50 to 65% saving in time in land preparation and sowing.**
- **40-65% reduction in cost of operation**
- **Yield increase by 5%**
- **Saving in fuel by 30 %**

truthing***Potential***

- **Total wheat area =26 Mha**
- **If only 11Mha is sown by zero till, total saving expected is Rs.2200-3300 crore.**
- **Average Field capacity is 3ha/day (sowing time=20 days)**
- **Number of drills needed=0.18 million**
- **Funds needed = Rs. 360 crores**
- **Saving in cost of production =Rs.2200 crores**
- **Increase in wheat production= 2 Mt.**

Fig. 6 Straw Incorporation Tillage and Equipment for sowing





Sprinkler irrigation to save water (20-30%)



Fig. 7 Pressurised Irrigation System to Save Water and also to apply nutrients

experiments have shown that minimum tillage has improved soil conditions due to decomposition of plant residues in-situ, facilitated higher infiltration due to vegetative matter present on the top soil and passage formed by the decomposition of old roots, less compaction to soil by the reduced movement of tractor and heavy tillage equipment and less erosion compared to the conventional tillage. These stages are more visible in coarse and medium textured soils. Use of appropriate equipment and power source would save a considerable amount of energy and time and thereby reduction in cost of cultivation (Table-5).

10. Energy and Cost Effective Equipment

10.1 Direct Drilling Equipment

No-till drilling, strip till drilling and roto-till drilling of wheat after harvest of rice were compared with the conventional tillage sowing as practiced by farmers. The result showed that No-tillage drilling was the most time, energy and cost-effective for 70, 67& 66% respectively over the conventional practice. The roto-tillage seeding combined with full width shallow tillage in single pass operation was 60% energy efficient and 58% cost effective compared to the conventional practice. The strip tillage seeding although of single pass operation and found advantageous over conventional tillage seeding but for the intermittent strip tillage the operational energy and cost requirements were higher compared to the roto tillage and no tillage seeding.

• Low Tillage • Integrated Farming System • Crop cover and Rotation • Residue Incorporation • Interculture and Weed Control
Tools and Equipment are needed for timeliness in operation, placement of inputs and comforts to workers



Resource Conservation Measures and Equipment (Ali, 2005)

Resource Conservation Equipment & Technology	
• Laser land leveler	• 30-50% saving in water
• Rotavator	• 50% fuel saving & better quality seed bed
• Zero till drill/minimum till drill/ multipurpose tool bar/ raised bed planter	• 5-10% increase in yield and saving of Rs. 2000-3000/ha
• Pressurized irrigation	• 20-30% saving in water
• Rotary power weeder	• 20-30% saving in time and labour
• Vertical conveyor reaper/ combine	• Timely harvesting, more yield
• Multi-crop thresher	• 50% saving in labour and time and 54% saving in cost of threshing
• Straw combine	• Recovers 50% straw and also 70-100 kg grain/ha resulting into an average saving of Rs. 1250/ha
• Straw baler	• Makes bales and checks environmental pollution
• Straw cutter-cum-spreader	• Cuts and spreads the straw evenly and helps in sowing by zero till drill.
• Improved manual harvester for mango & kinnow	• No damage to fruit and higher capacity

Cultural practices to the direct drilling systems were developed in terms of frequency of irrigation and fertilizer applications. First irrigation of 40-50 mm was critical for all the direct seeding systems for initial establishment especially in no tillage seeding. The result show that in direct drilling system although the grain yields were found at par, the benefit-cost ratio were higher (15.2-23.4%) with savings in operational energy (8.4-14.7%) compared to the conventional practice.

10.2 Raised Bed Planter

Raised bed planter is used for planting of crops on raised beds. Making beds on tilled soil, planting of seeds, basal application of fertilizer and convering and dressing of planted beds are done in one operation. For planting of seeds on permanent beds the same machine is used for single operation and it adds the advantage of compared to those on fresh beds or flat sowings. Planting wheat on permanent beds was found to be energy efficient and cost effective by 41.6 and 44.3% respectively over the conventional flat sowing.

10.3 Water Harvesting and Utilization Structures and Machines

Water, the single most important feature of the planet earth, is the most threatened resource today. In rainfed areas, watershed management approach is used for water harvesting, conservation and its effective utilization through better irrigation devices and equipment and conservation of other natural resources for sustainable agricultural production and productivity.

10.4 Solarization

It is an effective non-hazardous technique of pest control including broad spectrum weeds, but its use is restricted to the region where the climate (clear sky and an intense solar radiation) is unsuitable and the land is free from crops 1-2 months. Solarization is a process of hydrothermal treatment of moist soil using transparent polyethylene film for disinfestations during summer months when atmospheric temperatures rises to $40^{o}C$ or more. Besides pest control, the polyethylene mulching also alters the soil chemical and biological properties. These changes usually bring about enhancement in crop growth and yield. Moreover, soil solarizaion also reduces the necessity for chemical applications to soil and the requirement of fertilizer. Its effect on some deadly soil-borne diseases and on-perennial and parasitic weeds is a big advantage. This technique could be profitably practices in nursery beds and high value crops. The cost of the treatment can be reduced by 50% through its reuse to solarize the other area of the fields in the same manner.

10.5 Miscellaneous Equipment

Besides tillage conservation tools and machine, there are equipments which help to conserve and save inputs like costly seeds, scarce water, and timely harvest the crop to save from weather and pests. Some of such equipment and machines are plastic mulch laying machine; incline plate and pneumatic planters; self propelled rice and vegetable transplanters, power weeder, high capacity multicrop thresher and grain combines (CIAE, 2003).

The integrated and Sustainable and/or conservation agriculture based on minimum tillage, soil cover and crop rotation alongwith an appropriate engineering intervention using required tools, technology and machinery, has tremendous potential for a sustainable agricultural production from the present dwindling and degrading natural resources like land, water, environment and biodiversity. India needs about 325 Mt of foodgrains and other food commodities of plant & livestock origin to feed an anticipated population of 1500 million people and their accompanying livestock by 2025 AD. The practice of conservation agriculture and integrated farming would enhance agricultural productivity and that of livestock on sustainable basis to meet the food and nutritional requirement of ever growing Indian population. Production of food commodities that have higher nutritional productivity per unit of land, water and energy would be desired in long-run to meet the food and health requirements of the ever growing national and global population with minimum degradation of the natural resources.

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HYDROLOGICAL AND SOCIO-ECONOMIC ASPECTS OF WATERSHED MANAGEMENT IN INDIA

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Abstract

Integrated watershed management is an effective preference to achieve optimal utilization of natural resource through practical planning. This is particularly important in the view of current scenario of climate change and agriculture. The integrated watershed management is basically a concept and approach to achieve the sustainable development of land and water resources with specific reference to agriculture and livelihood. Watershed development projects are designed with focus to dovetail the use of water, soil, forest and pasture resources with agricultural productivity. The moisture conservation and increasing irrigation potential through tank and aquifer based water harvesting are major activities of various watershed development projects. Water is a critical component in a host of environmental processes and economic, social, and political activities. However, in recent years, watershed management practices that were once praised for their broad benefits to society have become the focus of harsh criticisms for their adverse and unexpected environmental or socioeconomic impacts. Thus, policy makers and watershed managers needs to understand how different human activities affect watershed processes, and in turn how the variable nature of the hydrologic cycle affects humans' well-being. Watershed models provide efficient tools for integrated studies of the major hydrological and socioeconomic aspects of watersheds. The watershed modeling evolved from representing hydrologic processes to interdisciplinary studies. The interdisciplinary studies lead to decipher complexity and integration of environmental, social and economic functions to facilitate a holistic understanding of watersheds and associated human activities. The watershed Models essentially helps to quantify the different parameters of underlying processes involved in hydrological, ecological, environmental, hydro-geochemical and socioeconomic aspects of watersheds. Thus provide detailed and organized understanding of watershed subsystems function, which is essential to integrated water resources management and decision making.

Key words: Watershed management, Hydrological Models, Agriculture, Livelihood

Introduction

Soil and water both as natural resources play a critical role in variety of economic, social and environmental activities. The optimal management of these resources, with minimum adverse impact is essential for sustainable development. Watershed is a concept that represents land area usually contains a well-connected stream network, minimal spatial variability in hydrological parameters and well defined outlet or discharge point, where the representative area drains when rainfall occurs. Rainfall interaction with soil resulted into the soil erosion. The safe disposal of runoff without affecting region specific ecology including social and environmental aspect is extremely important. To attain these objectives, watershed management practice is the only option.Watershed management implies the judicious utilization of land and water resource for increased productivity with minimum depletion of natural resource base. The watershed management concept essentially adopts the soil and water conservation practices in the watershed for

implementing resource conservation technologies (RCTs). The major goal of RCT adaptation is to maintain land capability in different aspect such as soil fertility, water resource, drainage, flood protection, reduction in sediment loss, maintaining ecology for increase productivity for human consumption. RCTs adaptation with recommended management practices (RMPs) of crops and livestock holds the key of sustainable productivity particularly in rainfed areas. Srinivasa Rao et al 2015, prescribed in details to achieve the livelihood security in Indian rainfed farming. This includes bridging the yield gaps in prevailing crops amid biotic and abiotic stresses coupled with RMPs to realize the potential. These are indeed required to implement on watershed basis as it provide avenues to integrate many enterprises in a unit. The watershed management and multiple use concept, involves integration of various livelihood enterprises to meet the food, fibre, fuel and fodder requirement of the inhabitants. Central Research Institute for Dryland Agriculture (CRIDA) is pioneer in conducting research on watershed development and management. Srinivasa Rao et al 2014 enlisted those outcomes in form of doable farming technologies specific to 10 agro-climatic regions of India that form basis for various watershed management activities.

The multiple use management is either resource based or area based. In resource based multiple use represents various alternative use of one or more natural resources e.g. national horticulture mission or bamboo mission; whereas area based represents mixes of products and facilities in a particular area such integrated watershed development program (IWDP) and other watershed development program. Area based watershed management program are more frequent in Indian rural settings which forms almost 70% of country population. While planning area based watershed management program, it is important to consider the physical, biologic, economic and social factor. Singh (2003) compiled various products obtainable from management of multiple resource of the watershed (Table 1). Rao and Gopinath, 2016, Location-specific rainfed technologies are available to cope with different drought situations based on extensive research done at ICAR-CRIDA on to conservation of soil & rainwater and to drought proofing to address the problem .in rainfed agriculture of India. They further enlisted the key technologies that can be implemented as watershed management activities include in-situ moisture conservation, rainwater harvesting and recycling, resilient crops and cropping systems including contingency crop plans, foliar sprays, and integrated farming systems.

Watershed is a manageable hydrological unit and is assumed that the different hydrological parameters do not vary significantly in spatial dimension. The watershed essentially drains the runoff resulted from rainfall to a common point. Thus considering this definition the watershed size can be varied from few hectares to many square kilometers. However, for land water management for agricultural intensification point of view, 500 to 1000 hectares are most suited. Several watershed management programs are running in Indian for this size of watershed. However, the new guidelines for implementation of watershed management as suggested by NRAA, National Rainfed Area Authority (2011), encourages to club 10-20 such watershed and follow cluster approach in order to reduce the administrative cost.

Table 1. Various product obtainable from multiple resource management of watershed (Singh 2003)

Resource	Products
Water	Irrigation, Municipal and industrial water, recreation
Timber	Timber, pulp, wood, fuel wood, recreation
Forage	Livestock, wildlife, recreation
Wildlife	Consumption, recreation
Minerals	Different minerals

Extent of soil erosion problem

More than 80% of world's agricultural land suffers from moderate to severe soil erosion (Pimentel and Kounang, 1998). The mean annual soil erosion rate on cropland is approx. 30 Mg ha^{-1}, while reported values vary from 0.5 to 400 Mg ha^{-1} yr^{-1} (Pimentel and Kounang, 1998). Soil erosion rates, caused by water, are highest in agro-ecosystems located in hilly or mountainous regions of Asia, Africa and Southern America, especially in less developed countries. In the hillocks of high rainfall area, erosion can be controlled by planting crops along the contour and by managing land use in such a way that soil disturbing activities should be less during the period of erosive rains. In India, it is estimated that water erosion causes damage on 113.3 million ha threatening the productivity and the fertility of the soil (Tirkey et al., 2013). In order to restore the productivity of the soil and to prevent further damage, planning, conservation and management of the catchments are inevitable. Hence, gauging stations are needed to record the runoff and sediment yield. In cases of unguaged areas, runoff and soil loss estimation methods like SCS curve number method and Revised Universal Soil Loss Equation (RUSLE) can be adopted.

Status of Groundwater utilization

The rapid industrialization, population growth, climate change and agricultural activities resulted in over-utilization of the fresh water resources leading to reduction of groundwater level in many parts of India (Kadam *et al.,* 2012). The scarcity of water in India is a well known fact in spite of higher average annual rainfall of 1,170 mm compared to the global average of 800 mm (Jasrotia, 2009). India is the largest user of groundwater for irrigation in the world and the drawn amount of groundwater is estimated to be 210 billion cubic meters/year compared to 105 billion cubic meters in China and 100 billion cubic meters in US (Shankar et al, 2011). According to the 2005-06 Agricultural Census, 60.4 percent of the net irrigated area is irrigated using groundwater. According to the CGWB, 15 percent of the administrative blocks are over-exploited and are growing at a rate of 5.5 percent per annum. The most substantial decline in groundwater level is observed in north western India over a period of 30 years (1980 to 2010). In many parts of Gujarat and Rajasthan, groundwater level fell more than 16 meters (Sekhri, 2012). A decline of 1 to 4 meters was observed in states like Telangana and Andhra Pradesh. The depletion of groundwater resources has increased the cost of pumping, caused seawater intrusion in coastal areas and has raised questions about sustainable groundwater supply as well as environmental sustainability (Rejani *et al.,* 2009). Hence, optimal groundwater management and recharging of aquifers are very essential.

Watershed development in India

The government of India has identified the watershed management as a part of approach to improve agricultural production and alleviate poverty in rainfed regions. The watershed management program are implemented in India since the 1970s. These programs majorly aim to restore degraded watersheds in rainfed regions to increase their carrying capacity by rainwater harvesting, reduction in soil erosion and thus improving soil nutrient and carbon content in order to produce higher agricultural yields and other benefits. As the majority of India's rural poor live in these regions and are dependent on natural resources for their livelihoods and sustenance, improvements in agricultural translates into improvement in human welfare vis a vis improving national food security (Ahmad *et al.,* 2011; GOI, 2011; Kerr, 2002).

The major focuses of watershed management program practiced in India are however, on rainfed regions. This is particularly important as these areas represent 60 percent of arable land in India and producing 50% of country's agricultural output that supports 40 percent of the nation's population (Planning Commission, 2012). Despite of

these, the rainfed region of the county are characterized by low productivity, fragment land holding, vulnerability due to both geographical and climatic conditions, and also poor land and water management. This results into the lower productivity of rainfed areas in which crop productivity is almost one third of national average. There are several agro-climatic zones of rainfed area at different geographical elevation ranging from sea shore to hill and mountain. The brief historical development in watershed management programs in India is presented in Table 2.

Table 2. Historical development of watershed management program

Year	Program/policy/guidelines
1973	Drought prone area program (DPAP)
1977	Desert development program (DDP)
1989	Integrated watershed development program(IWDP); Integrated afforestation and eco development scheme
1991	National watershed development project for rainfed area (NWDPRA)
1993	Indo-German watershed development program.
1999	Watershed development fumd
2003	Hariyali guidelines
2005	Mahatma Gandhi national rural employment guarantee scheme (MGNREGS)
2006	National rainfed area authority
2009	Integrated watershed management program
2011	Common guidelines for watershed development.

Integrated watershed management

In present context, apart from issue resource conservation and productivity, climate resilience becomes an important aspect in integrated watershed management. The vertical of climate resilience in integrated watershed management includes practice, intervention and implementation of knowledge based optimal utilization of resources. This implies efficient integration and management of natural resource, diversified farming system and allied enterprises to ensure food, nutrition and livelihood security. This developed model indeed helps in addressing the challenging task of attaining livelihood security, sustaining food production, nutritional security and environmental protection particularly in dryland regions of India. The integrated watershed development program address the holistic development by integrating different modules that includes (i) Water resource development and management module; (ii) Integrated farming system module; (iii) Farm mechanization module and (iv) Livestock sustenance module. The objectives of integration of these modules are to achieve livelihood sustenance with desired level of climate resilience. Figure 1 to 4 represent typical framework for implementing different modules of integrated watershed management in the field.

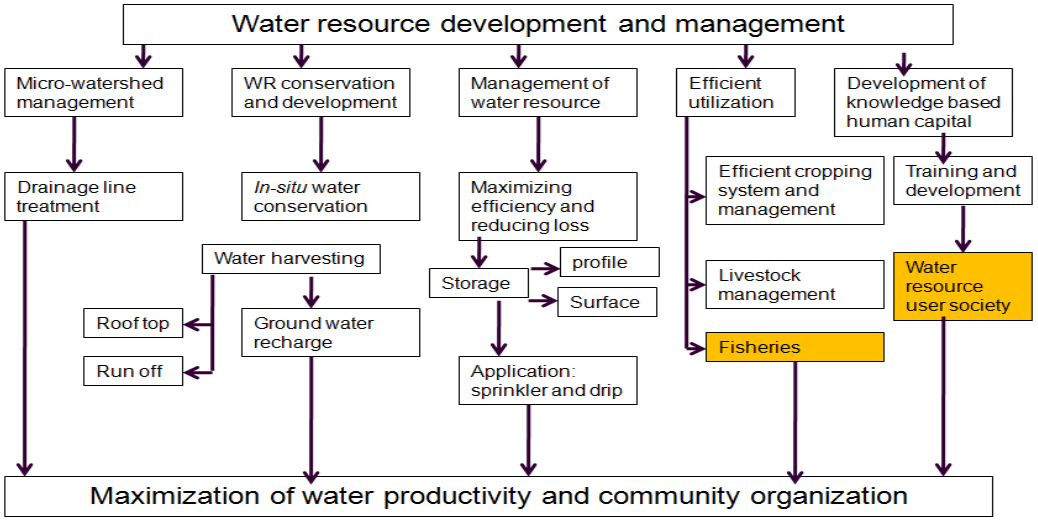


Figure 1.Water resource development and management module

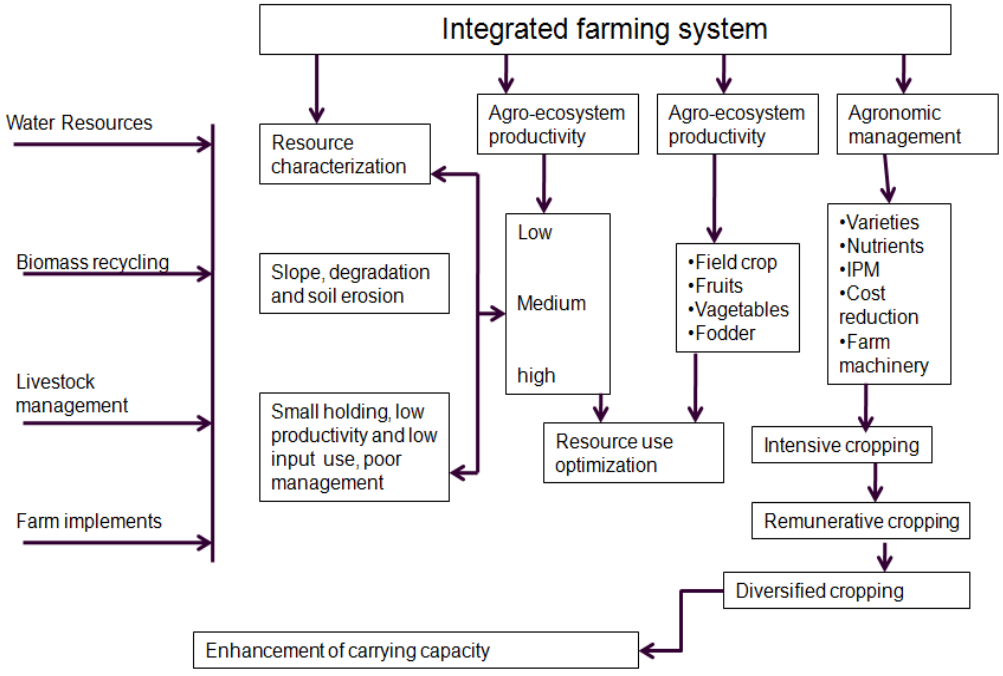


Figure 2.Integrated Farming module

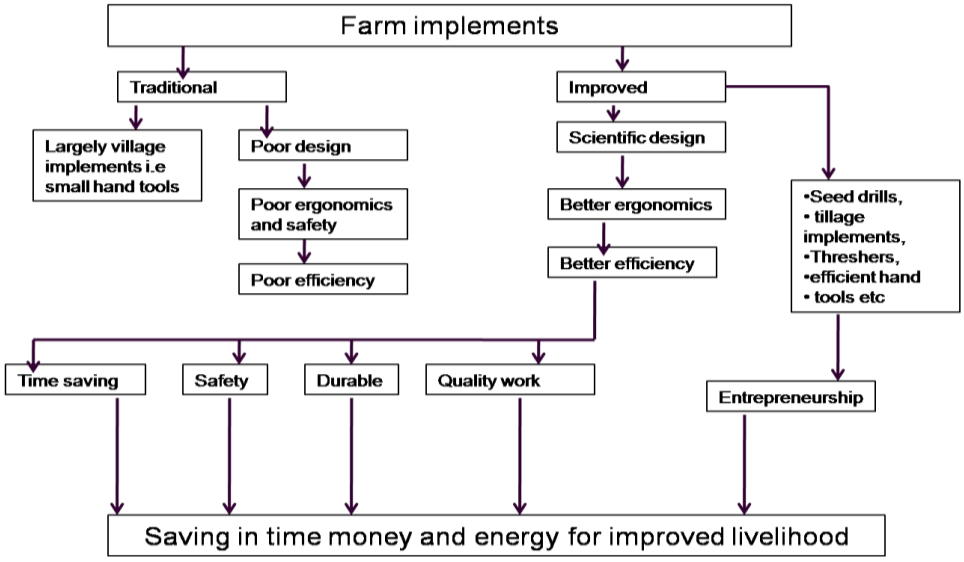


Figure 3.Farm mechanization module

Livestock sustenance module

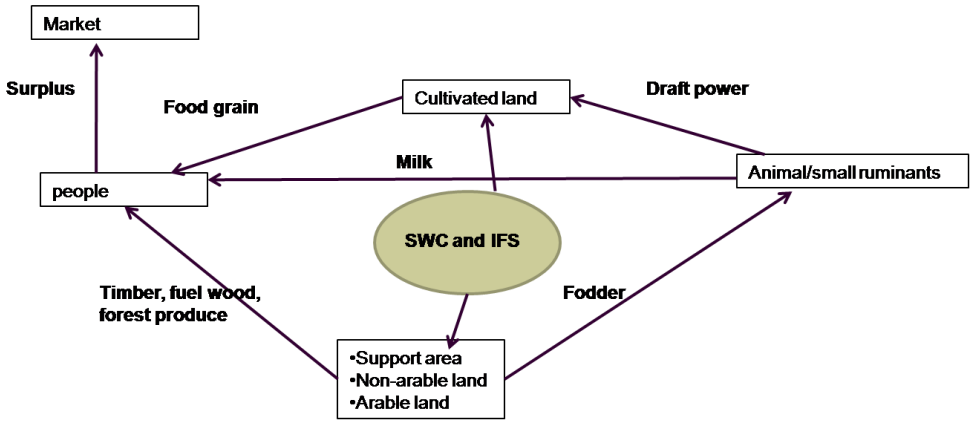


Figure 4.Livestock sustenance module

Hydrological modeling for watershed management

Models representing the hydrological process confined in a watershed are called hydrological modeling of watershed. The various hydrological processes are defined in the series of mathematical equations pertinent to the specific watershed characteristics. These models are mathematical representations of watershed processes and also affected socioeconomic and environmental systems. Thus this become a fundamental and integrated element to alter diverse natural processes. These models help in getting insights on various aspects of watershed. These aspect includes hydrological, ecological, biological, environmental, hydrogeochemical, and socioeconomic aspects of watersheds (Singh and Woolhiser, 2002). These aspect are extremely required to develop system dynamics of specific watershed understand the watershed function (Lund and Ferreira, 1996 Lund and Palmer, 1997), which is essential to integrated water resources management and decision making (Madani and Marino, 2009). The general structure of hydrological modeling is presented in Fig. 2. The hydrological models mainly attempts water balance modeling of various hydrological components. The relative interaction among various components of hydrologic cycle is described in the Figure 5.

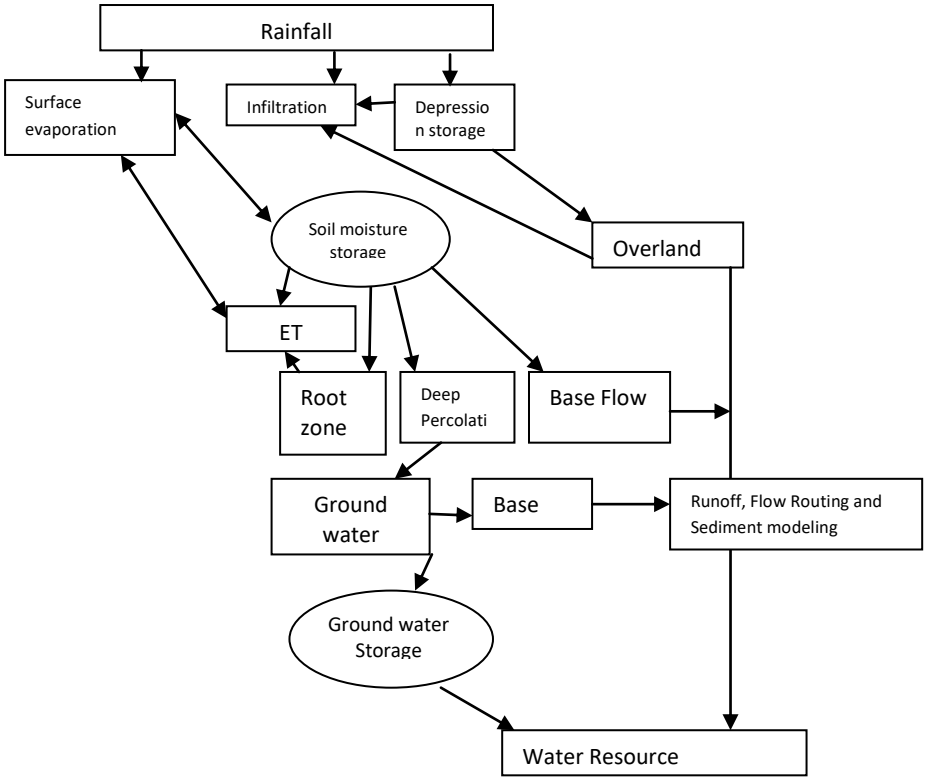


Fig. 5 Flowchart for typical hydrological modeling

Types of hydrological model

The different components of hydrologic cycle are represented conceptually in simplified form of hydrological models. These are developed to understand the hydrological process for prediction and estimation of hydrological parameters. The hydrological modeling, essentially a set of mathematical formulae can be classified in to two broad groups.

- ***Stochastic Models or black box models*.** These models are developed based on observed data and using mathematical and statistical concepts to link a certain input and model output. The underlying hydrological processes are defined by location specific coefficients. Commonly used techniques are regression, transfer functions, neural networks (Kumar et al 2002 and 2009) and system identification. These models are known as stochastic hydrology models. These models have limited applicability.
- ***Process-Based Models***. These models represent the physical processes observed and mathematical relationship are derived based on physical interaction among the factors. Typically, such models contain representations of surface runoff, subsurface flow, evapotranspiration, and channel flow in separately and form as a parameters for water or energy balance and thus are more complicated. These models are also known as deterministic hydrology models. Deterministic hydrology models can be subdivided into single-event models and continuous simulation models.
- ***Simulation models:*** Simulation models consist of surface water models, groundwater models (flow and transport), composite models containing both (surface and groundwater) and agricultural hydro-salinity models. These models utilize simulation and optimization approach. Simulation models take physical parameters and engineered designs or management plans as inputs and generate detailed predictions of outcomes. Simulation is widely applied in the detailed design phase of projects for quantitative performance and impact analysis of a limited number of alternative designs.

Synthesis of watershed modeling

Watershed modeling for management includes development of models to analysis "what if" scenario for various options. In the past, water resource professionals have been developed, attempted and evaluated several hydrological models to solve various watershed management problem, yet watershed management models are still in evolving phase. Since hydrological processes involved in watersheds are highly complex and non-linear in nature, there is difficulty in developing model to address watershed problem in terms of approach, application and reliable understanding of the management problem. Initially during 60's, watershed modeling efforts were limited to quantitative computation of individual hydrologic processes (Singh and Woolhiser, 2002). Various components of the hydrologic cycle, such as surface runoff, infiltration, groundwater flow, and evapotranspiration, were modeled separately due to, but a lack of data and computing capability hindered more integrated analysis (Freeze and Harlan, 1969; Chen *et al.,* 1982). Next paradigm shift in watershed management modeling was to develop simulation model to develop decision support system (DSS). These support systems were developed primarily to assess the effect on watershed response to a specific activity and accordingly to suggest the development and management options. The main criteria in these DSS were to select a treatment and its relative effect on runoff and soil loss.

It is extremely important for policy planners and watershed managers to have firsthand understanding and knowledge of how various human activities affects watershed processes and also and to know how the dynamic nature of the hydrologic cycle affects life. Integrated watershed modeling, aims to provide efficient tools for integrated studies of the major physical, socioeconomic, and cultural aspects of watersheds. There is a paradigm shift from rainfall-runoff modeling of watershed to the integrated watershed modeling. However, watershed modeling is still evolving in terms of approach, application, and ability to provide users with a comprehensive and reliable understanding of problems at a reasonable cost and within a specified timeframe. Watershed management decision making

is a complex process and several factors needs to be looked in while balancing biophysical and socio-economical concerns. Now a day the public is actively participating in environmental decisions through public debates, and so there is a need for efficient technology transfer from public agencies to stakeholders. Application of information technology thus has a profound influence on watershed management over the past decade. Advances in data acquisition through remote sensing, data utilization through geographic information systems (GIS), and data sharing through the Internet have provided watershed managers access to more information for management decisions.

Integrated modeling for watershed management

The integrated model links biophysical modeling with village scale socio-economic and cultural models (Fig. 6). This approach is necessary to develop a holistic understanding of interactions between land, water, and people and draw appropriate conclusions as to the causes of differences in the resilience of households and the communities. The hydrologic models provide an assessment of the availability of surface and groundwater resources for watershed development under different climate scenarios. The crop models simulate yields as well as water use and recharge which feed back into the next season hydrology. Water availability and crop productivity are the main links between the biophysical and socio-economic models (Merritt *et al.,* 2011). This information in addition to survey data detailing access to land, water and common pool resources as well as network and demographic data is input to the socio-economic and cultural models which simulate the response of social and economic indicators for groups differentiated on social (e.g. gender, caste) or economic (e.g. landless, landholders) characteristics or cultural differences (with respect to its demographics, status of its social groups (tribes), sectoral shifts etc.). Issues of equity needs to be assessed by analysing trade-offs within and between villages. Two options exist in how to link the biophysical models to the socio-economic and cultural models: (a) full integration where the socio-economic and cultural models are dynamically updated with information from scenarios arise from crop and hydrology models, or (b) outputs from the biophysical models are used as inputs to the socio-economic and cultural models. The nature of the integration will depend on the structure of the socio-economic and cultural models, i.e. how responsive they are and the complexity, scale and linkages of the groundwater, surface water and crop models developed by project partners.

Socio-economic and cultural models

Optimization methods or socio-economic and cultural models are geared obtain alternatives based on selecting values for decision variables that provide the best value of an objective function, subject to a set of mathematical constraints. Some advantages of optimization models are that they can help to screen a large number of potential alternatives, generate new alternatives that otherwise may have been overlooked, and provide an intuitive means of trade-off analysis. Also, optimization results need to be interpreted carefully, as the “optimal” outcomes may be overly optimistic and not achievable in practice (Mirchi et al., 2009). These process based models have been used in a wide range of studies, including rainfall-runoff prediction, flood mitigation design, water supply development, safety assessment of water infrastructure, land use planning, irrigation planning, hydropower operations, and surface and groundwater quality protection.

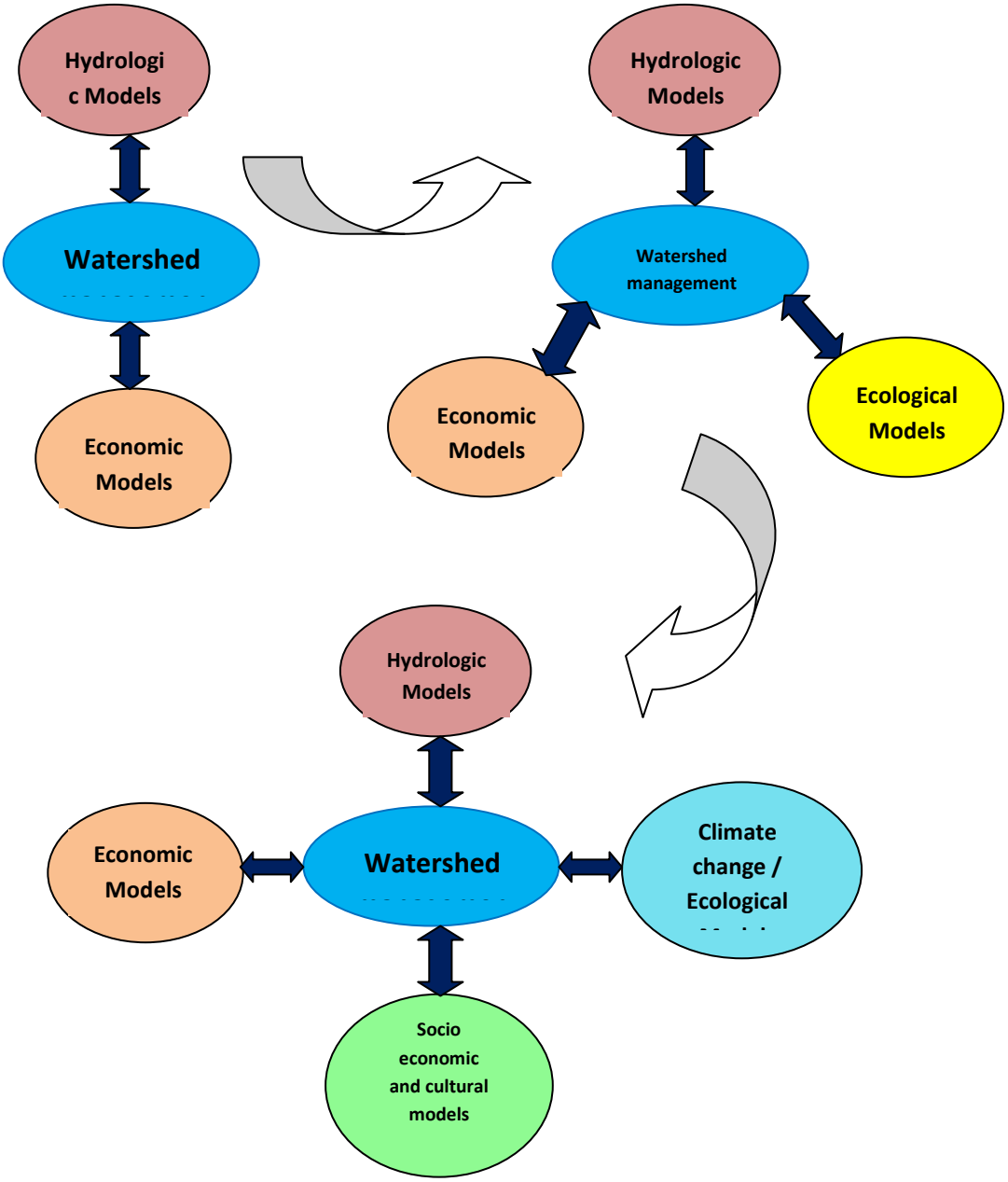


Fig 6 Evolution of watershed modeling

Integration of hydrologic and socio- economic watershed models

Integration of hydrologic and socio- economic watershed models form the hydro economic models, often based on optimization methods, possess the advantage of facilitating economic studies by maximizing or minimizing some specified economic objective function subject to a series of constraints. Hydro economic models have been applied to analyze water resources management practices and its potential economic and environmental impacts, (i) to address trade-offs and interactions among various stakeholder groups; (ii) to evaluate long term drought management and flood mitigation plans; (iii) to improve water resources operation policies and strategies; (iv) to suggest climate change adaptation strategies; and (v) to improve water quality and quantity for ecosystems.

Harou *et al.,* 2009 describe hydro-economic watershed models as solution-oriented tools that foster formulation of new strategies to promote water-use efficiency and transparency of decision making, thus contributing to integrated water resources management. However, maximizing the economic value of water use serves as the only driver of decisions in hydro-economic models as economic valuation of many social and environmental objectives remains difficult. Integrated modeling of watershed-scale hydrological, environmental, and economic aspects of water use often requires simplified representation of natural processes (Heinz *et al.,* 2007). Thus, water resources management decisions which are solely based on hydro-economic models may not be comprehensive and a holistic model and approach are required for integrated water resources management.

Multi-objective decision making models

Watershed planning and management decisions almost always consider multiple goals, many of which are conflicting. Often it is impossible to aggregate the goals into a single criterion or performance measure in the alternative ranking and selection process (Makowski *et. al.* 1996). Thus, multi-criteria (or multi-objective) decision support methods are widely applied for water policy planning and evaluation, strategic watershed planning and management, and infrastructure development (Hajkowicz and Collins, 2007). Multiple criteria analysis techniques have aided water resources practitioners to select decision or design alternatives in such areas as river basin planning and development, water resources development, land use management, groundwater/surface water allocation, watershed restoration, and water resources quality.

Conflict resolution models

The multitude of watershed planning and management objectives inevitably leads to conflicts among watershed stakeholders, or interest groups. In many cases, however, different stakeholder groups share common interests (e.g., a homeowner along a river may be primarily concerned about flood risk reduction but may also value the riverine ecosystem), or they may be able to reach compromise agreements (e.g., development of one portion of the floodplain may be offset by enhancing wetlands in another portion). Conflict resolution models essentially seek to promote compromise through holistic understanding of technical, socioeconomic, political, and environmental aspects of the problem (Lund and Palmer, 1997).

Future directions in watershed modeling

Despite the complexity and uncertainty of various watershed processes, many engineering-based models have been successfully calibrated, verified, and applied by decision makers. Our ability to model hydrologic processes with greater accuracy, and at finer spatial and temporal resolution, will continue to improve with (i) increased use of remotely sensed data (e.g., satellite observations); (ii) increased computational capacity;

and (iii) improvements in GIS and database management systems. However, computational capacity, data availability, and model complexity will not increase at the same rate, and thus there is always a danger of two types of "modeling error": (1) Developing an overly complex model that cannot be properly calibrated and verified using available data, or (2) Developing a model that fails to make proper use of available, high-quality data. While future watershed process models may suffer from either of these two kinds of error, it is likely that integrated watershed management models will suffer primarily from the first kind. Determining "the best" set of watershed management practices is complicated by a host of regional and global-scale socioeconomic, cultural, political, climatic, and biogeochemical factors. Even setting the global-scale issues aside, our ability to account for and predict dynamic, interactive socioeconomic, policy and cultural aspects of watershed systems is still questionable. To do this reliably, fundamental advances in economics and other social sciences may be required. However, even as planning and management model complexity outpaces observational data, proper recognition and accounting of uncertainty in predicted socioeconomic, policy and cultural outcomes will be critical to determining areas where improved understanding of human systems is most needed. Increased experience with integrated models, and analysis and documentation of this experience, will also further enhance the understanding of the role of models in watershed planning, management, and decision making.

Conclusions

Natural and anthropogenic processes within watersheds are complex, dynamic, and spatially variable. Previous experiences of unsuccessful or unsustainable watershed planning and management practices manifest how a lack of understanding of watershed subsystems can cause environmental disasters as well as socioeconomic problems affecting humans' well- being. Watershed modeling has become a commonplace tool for water resources system design, planning, and management at an affordable cost and within a reasonable timeframe. The computer revolution in the mid 1960's and continuous growth in computational capacities, along with other advances in data collection and management, has allowed watershed models to evolve from describing only physical processes to describing the interaction of social, economic, cultural and environmental systems objectives in support of decision making. The gradual shift from merely employing engineering-based simulation models to applying integrated hydro-economic models, and more recently multi-criteria/multi-objective decision making and conflict resolution models, is an indicator of promising changes in the traditional paradigm for the application of watershed models. More holistic understanding of watershed systems, consideration of multiple stakeholder values, objectives and behavior, and improved abilities to predict and plan for future impacts are likely to lead to more sustainable watershed planning and management decisions.

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LAND AND WATER MANAGEMENT TECHNIQUES FOR POVERTY REDUCTION IN SMALL AND MARGINAL FARMERS

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India has made impressive growth on the agricultural front during the last four decades. The policysupport, production strategies, public investment in infrastructure, research andextension for crop, livestock and fisheries have significantly helped to increase foodproduction and its availability. Poverty has been significantly reduced during this period because of manifold increase in food grain production. Poverty rates have fallendramatically throughout much of this region, and the absolute number of poor hasdeclined in East Asia despite continued, rapid population growth. But still millions of rural people are living in rainfed agriculture dominated areas and are still below poverty line. Poverty rates are stillhigh in many of these areas; productivity growth is slow; and many such areas aredeclining as a result of natural resource degradation, including soil erosion, soil fertilitydepletion, overgrazing and deforestation. Similarly with intensive agriculture, the agriculture growth is decreasing in high intensive agriculture areas because of over use of natural resources like soil and water. Among various approaches, low external input agriculture, organicagriculture and biotechnology are being considered as the technologies which may play role in poverty reduction of small and marginal farmers.In green revolution, the main factors causing this growth in productivity were increased use ofirrigation, widespread adoption of higher-yielding varieties and increased use ofchemical inputs, especially inorganic fertilizer. The impacts of the Green Revolution and the associated rural development, althoughwidespread, did not reach all rural areas or all farmers. The rural poor are increasingly concentrated in rainfed areas.Less-favoured areas withoutaccess to irrigation or reliable rainfall benefited much less from the improved rice andwheat varieties that were introduced during the first phase of the Green Revolution (upto the early 1980s), widening the gap between less-favoured and more favoured areas. Although the impacts of the Green Revolution in India have been overwhelminglypositive, the rate of productivity increase has slowed, especially in intensive ricecultivation, but also in intensive wheat production. Even inlong-term experiments in which input use is controlled, there is evidence of decliningproductivity in intensive wheat and rice systems.Degradation of the natural resource base in these systems contributes to slowproductivity growth and, in some cases, declining productivity.Three key factors contributing to poverty in farm sector may be small and scattered landholdings, lack of irrigation facilities and more recently climate change. These three factors have resulted in low profitability as well as high risk factor in agriculture.

Land and water management technology options toreduce poverty in small and marginal farmers:

Low input agriculture: It involve limiting the use of external inputs such as inorganicfertilizers and pesticides and relying more on local and naturally available resourcesand a combination of traditional and improved methods to manage soil fertility, water,pests and other agronomic needs. The particular methods used include a wide range oftechnologies, such as water harvesting; soil and water conservation measures;minimum or zero tillage; the application of manure and compost; the incorporation ofcrop residues; the transfer of biomass and mulching; the use of leguminous cover crops,shrubs, or trees in improved fallows or intercropping systems; the use of crop rotationto manage soil fertility

and pests; and integrated pest management (IPM). Theecological principles underlying these technologies involve providing favourable soilconditions for plant growth by managing soil organic matter and enhancing soilbiological activity; optimizing plant nutrient availability through biological nitrogenfixation, nutrient recycling and the limited use of inorganic fertilizers; minimizinglosses by managing microclimates and water to prevent erosion; minimizing pest anddisease problems through IPM; and exploiting complementarities in the use of geneticresources by combining these in farming systems with a high degree of genetic diversity.There are many promising technologies that show a potential to reduce naturalresource and environmental degradation, maintain or increase productivity andcontribute to improved household livelihoods. The potential of such technologiesdepends greatly on the biophysical, socio-economic and institutional context and onthe capacities and constraints of individual farm households.

Efficient use of fertilizers: Soil test based fertilizer applicationhas been observed that soil test based fertilizer application has improved profitability of even marginal farmers. Govt. of India is giving stress on soil health cards and it is expected that in next three years all famers of India shall get their soils tested.Use of leaf colour chart for nitrogen application has been recommended in many crops and in many regions and it has been very successful in increasing crop yields and improving profitability particularly in rice-wheat cropping system. Similarly skipping of phosphatic fertilizer for kharif crops when it has been applied to rabi crops in a crop rotation has resulted in lowering the cost of fertilizer application in many situations without sacrificing on yield. Incorporation of crop residues and use of biofertilizers has resulted in improvement of soil health and use of low inputs in agriculture. The use of N for at All India level was 128.9 kg./ha. in irrigated area against76.4 kg./ha. in un-irrigated area, so there is potential to increase fertilizer use in Indian agriculture if irrigation facilities are expanded.

Judicious use of irrigation water: As poverty is concentrated in rainfed regions, so if we are able to horizontally expand the irrigation network by using present available irrigation water resources in efficient manner, it may help in reducing poverty. For efficient use of irrigation water, micro irrigation systems may prove beneficial but they are costly and need financial assistance from government. Use of underground pipelines for conveyance of water isalso useful for reducing water losses. In-situ moisture conservation practices like mulching have been found to be very useful for efficient utilization of limited available water. Similarly laser leveling of land has been widely adopted by the farmers. It not only results in efficient use of water but also improves productivity. Some techniques like soil matric potential based irrigation application in rice using tensiometerhave potential to improve irrigation water efficiency but these are difficult to adopt.

Integrated Farming System: It offers significant and increasing opportunities to many farmers for improving the productivity and sustainability of their farming systems,while earning higher incomes. Significant numbers of farmers have recently begun toadopt integrated farming system, and many are able to increase their profits as a result. In addition to these, creation of rural seed banks, custom hiring of agricultural machinery and self-marketing are the techniques which have great potential to improve the livelihood of rural people. Use of ICT in extension services has been growing with penetration of mobile telephony in rural India, and there is potential to use these techniques in advising the farmers in efficient use of land and water resources for improving their livelihoods. Still there are researchable and policy issues like lack of recommendations for crop production with low input, need to test and refine indigenous land and water management techniques, provision of high cost implements like laser levelers under custom hiring for efficient land and water management etc.

APPLICATION OF VISUAL MODFLOW IN GROUNDWATER FLOW MODELLINGINUPPER SEONATHBASIN CHHATTISGARH

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Abstract

Groundwater is one of the major available fresh water in our country. Due to its over exploitation, fulfilling the demands for domestic, agricultural and industrial purpose, groundwater level is falling very rapidly day by day especially during summer season in arid and semi-arid regions, leading to water scarcity problems. The present paper covers study and analysis of groundwater flow inUpper Seonathbasin, a sub basin of Mahanadi river inChhattisgarh by developing a groundwater flow model. Study area extend from 20°16'N to 22°41'N latitude80°25'E to82°35'E longitude comprises of two district of Chhattisgarh namely Durg andRajnandgaon having a total geographical spread of 7292 sq.km. From the fieldobservation it was found that there is a considerable rate of change in water table, especially during the summer season in the past years. This fluctuation in water tableis generally caused due to land use/land cover change, over exploitation inunscientific manner. Therefore it becomes necessary to study the groundwater beforeits exploitation so that a proper balance is maintained between the recharge andextraction. In this study Groundwater flow simulation model has been developed using Visual MODFLOW package.Simulation results help in fetching information about the hydraulic head, drawdown,flow direction etc. The graphs and maps generated using the Visual MODFLOWtoolhelps us in predicting the groundwater flow condition.

Keywords*:* Groundwater Model, MODFLOW, Upper SeonathBasin, Ground water flow, GIS

Introduction

Groundwater is a major source of fresh water and is an important part of hydrological cycle. Freshwater resources are critically important in economy, biologically and ecologically. Water is essential requirement for all living organisms. For any country water play very important role in his social economic and cultural progress. The demand of water is increasing in earth for sustaining life and environments one good thing is that water is a natural renewable resources. So therefore the proper management required for protection of natural resources which are scientific too. Groundwater models are very useful for managing the water for upcoming demands. Groundwater modelling is a scientific tool for study and analysis the complex system. There are manytypes for preparingthe groundwater models for any system, among them the best is Numerical modelling which provides accurate and real-time prediction of groundwater resources.

Numerical Model

A computer model, using finite difference, finite element or other method, with an approximate solution of the governing flow and/or transport equations. Numerical models are typically used to represent more complex systems. A numerical model uses numerical methods to solve the governing equations of groundwater flow and/orcontaminant transport.Visual MODFLOWis a modular three dimensional finite difference based groundwater simulation system. It is primarily written by McDonald and G. Harbaugh of United States Geological Survey (1988). The model is capable of modelling time-dependent

flow as well as heat and mass transport problems. Several similar studies have been investigated to perform groundwater modelling in Upper Seonathbasin are:Tripathi et al. (2009) conducted a study for groundwater assessment of a small watershed using Visual MODFLOW. The analysis was performed to know the impact of different flow and contaminant properties on hydraulic head, dispersion and chemical reaction in small groundwater basin. He had been performed for the Kurdihnalawatershed adjoining the Patan block of Durg district in Chhattisgarh.Thangarajan and Ranghaswami (2003) have made an attempt to estimate the amount of groundwater for the Gunder river basin, using Visual MODFLOW. The model, when applied to the study area, shows the permissible error of ±10 to 20%. For better modelling results the error should be minimized. The results showed that the flow direction was more or less coincided with the general slope and there was an inflow and outflow across to western and eastern boundaries.Shah et al., (2010) has also conducted a study on assessment and management of ground water in Upper Mahanadi Basin using same modelling technique. Sekhar (2005) has adopted an integrated groundwater modelling approach for better assessment of water balance components. The model study shows that impact of pumping results in regional ground water flows influencing the hydro-geologic regime in the recharge zone of the sub basin. MODFLOW is calibrated assuming specified transmisivities for each of the zones obtained from several pump tests in the region.Due to the fluctuation in the availability of groundwater level in pre monsoon and post monsoon in Upper Seonathbasin, therefore the purpose of this study is assessment of groundwater that will permit the appropriate tools & techniques for interdisciplinary prospects to enhanced management of groundwater condition and water resources systems during pre-monsoon and post monsoon periods to be systematically evaluated with existing information for Upper Seonathsub basin. The main objectives of study are, a steady state groundwater flow simulation using Visual MODFLOW software and its calibration, provide an over view of groundwater occurrences of seonath basin in different season and assessment of the exiting groundwater resources of the seonath basin for effective planning and management.

Materials and Methods

Study AreaCharacterization

The study area focused is Upper Seonathsub-basin which is sub basin of Mahanadi basin and it is located at upstream of Durg, the two districts of Chhattisgarh State namely Durg and Rajnandgaon are covered in this basin. Location of study area20’16”N to 22’41”N latitude80’25”E to 82’35”E longitude the catchment area this basin cover two district which include 13 blocks 6 from Durg district and 7 from Rajnandgaon district, and the total study area 7292 sq.km. The Seonath river basin is originated from two rivers i.e. Kharkhahariver and Tandula river and divided into 16 catchments. The area selected for the study is the Upper Seonathsub-basin and is situated inside the Seonath basin of well-known Mahanadi river basin in Chhattisgarh. Entire study area of Upper Seonathsub-basin falls within the state of Chhattisgarh. The mean annual rainfall in the basin varies from 1005 mm to 1255 mm. Climate region under consideration is characterized by general dryness, excluding during southwest rainy season. The hot season is from March to May. The southwest monsoon generally sets in over this region during the second week of June and rainfall activity continuous till second week of October. The second half of October and entire month of November constitutes the post monsoon season.

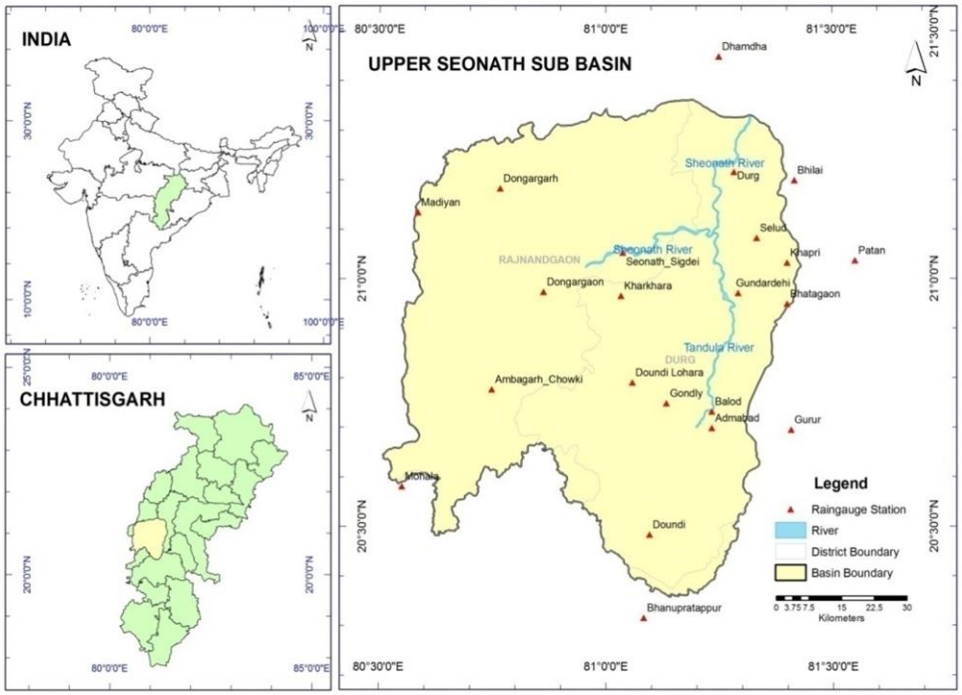


Figure 1.Location map of Upper Seonathbaisn (Source: Rajput, *et al.* 2014)

Total geographical area of Upper Seonathsub basin is 7292 sq.km out of which agricultural land occupies about 62.16% of total geographical area, built up area occupies 3.92% of total area, forest occupies20.14% of total area, and Tree clad occupies 3.60% of total area which has minimum area in Upper Seonathsub basin, waste land occupies 6.47% of total area, water bodies occupies is about 3.70% of total geographical area Thus it can be concluded that agricultural area covers maximum area where as tree clad and water bodies cover very less or minimum area.

Governing equation of groundwater flow modeling

A model that simulates groundwater flow is the simplified representation of the sub surface aquifer system, which may be used to predict aquifer response to various input/output stresses. Groundwater flow in three dimensions in a porous medium of constant density can be expressed by the following partial differential equation.

MODFLOW is a modular three dimensional finite difference groundwater model developed by U. S. Geological Survey to simulate saturated flow through a layered porous media. The Partial Differential Equation solved is for h(x, y, z, and t)the governing three dimensional flow equation used by MODFLOW combines Darcy's law and the principal of conservation of mass.

$$\frac{\partial}{\partial x}\left(Kxx\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(Kyy\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial z}\left(Kzz\frac{\partial h}{\partial x}\right)-W=Ss\frac{\partial h}{\partial t}$$

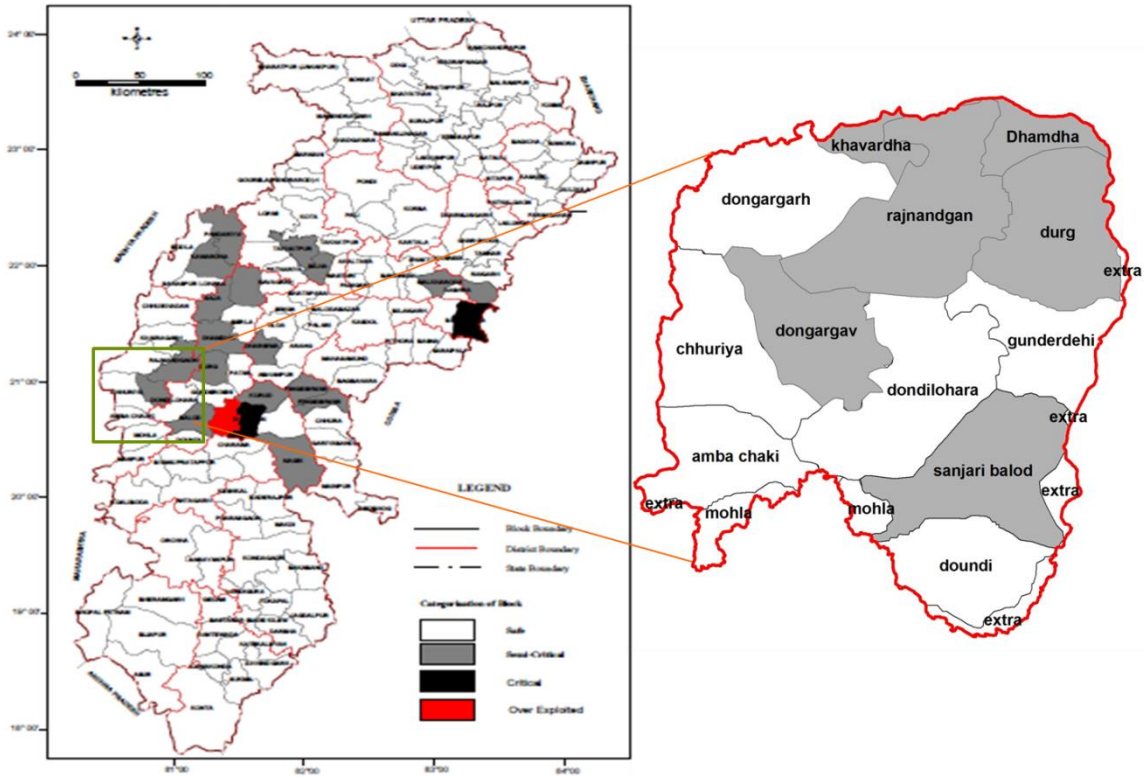


Figure 2. Site selection based on Dynamic Groundwater Resources of Chhattisgarh, 2011

Where K_{xx},K_{yy}, and $K_{zz}$are hydraulic conductivity along the x, y and z direction, *h* represents the potential head, *W* is the volumetric flux per unit volume being pumped, S_s is the specific storage of the porous material and t is time. This equation describes ground-water flow under non-equilibrium conditions in a heterogeneous and anisotropic medium and provided the principal axes of hydraulic conductivity are aligned with the coordinate directions.

The VISUAL MODFLOW software developed by McDonald and Harbough. In this programme, using the block centered finite difference approach to solve and approximation to the groundwater flow equation simulates groundwater flow.For groundwater flow modelling various data hydrological metrological and toposheets are collected from respective departments or observed and measured in study area. Alltoposheets are georeferenced and digitalized, the hydrological behavior of a watershed may be understood by the digital elevation model (DEM), it is based on various information's including elevation/altitude, drainage and basin boundaries is delineated in GIS.Various other morphological parameter of the watershed such as watershed boundary, drainage map of the Upper Seonathbasin, area of the watershed which is required for the model, were also extracted using digital elevation model. The river, observation wells and pumping wells are also digitized which directly used as a input data for Visual MODFLOW after competitions of input data preparation work for model, import the all required input parameters for model like grid, watershed boundary, location of observation well and river etc. Those inputs are in

the form of shape file from GIS or excel sheets are feded to form boundary condition of the model. All observed parameter head, recharge and aquifer property such as hydraulic conductivity, specific yield, total porosity, transmissivity and specific storage are defined in model.

The model is developed to simulate the existing hydrological system and the processes that control the ground water flow. The ground water flow equation with the specification of flow and initial head conditions at the boundaries constitutes a mathematical representation of the aquifer system. Recharge and pumping well has been deliberate for the study area and assigned in model. The observation wells head values and village wise draft value for well has been assigned in the model. The aquifer parameters including hydraulic conductivity [K (m/day)], specific yield (Sy), and specific storage [S (L-1)] were assigned layer wise for each layer. Boundary conditions evapo-transpiration, recharge, river, constant head were also assigned in the model (Sinha et al. 2016).

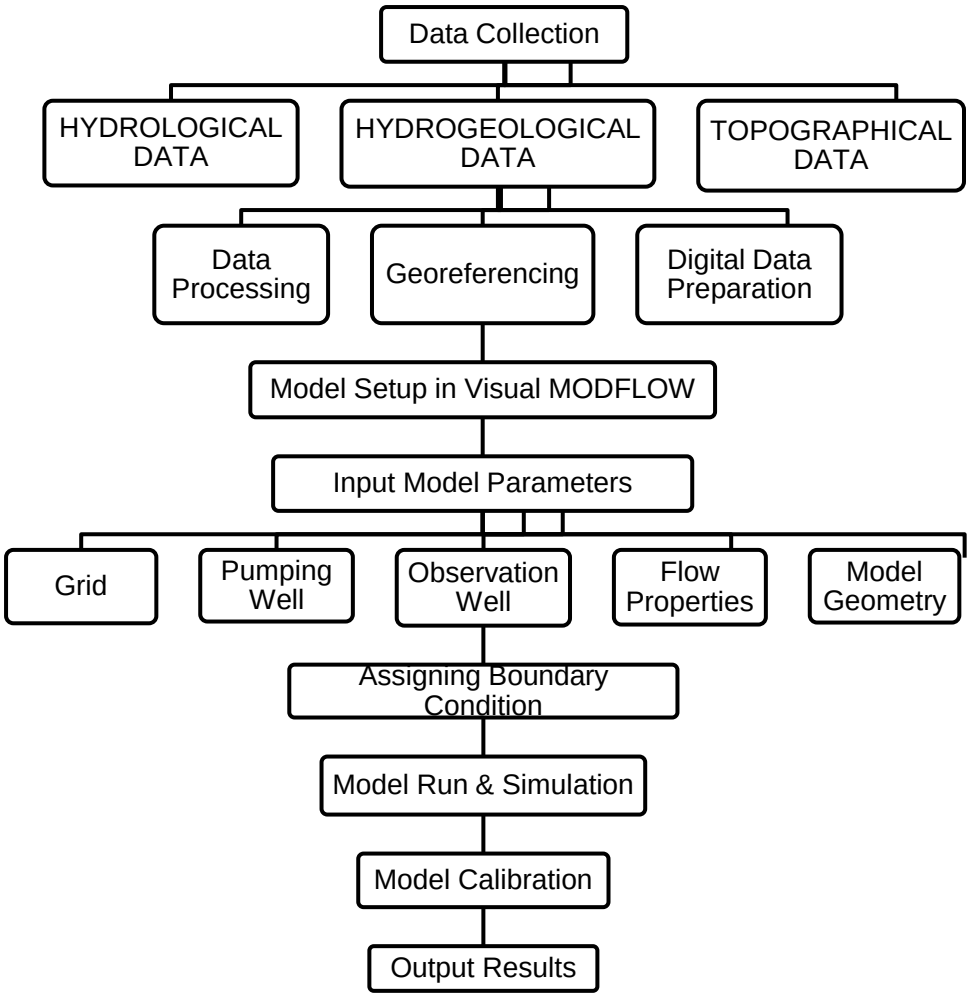


Figure 3. Flow chart of the methodology

Result and Discussion

Simulation and Calibration

Initially the model has been simulated in steady state for period of five year for both pre and post monsoon. Alldata, such as constant head, recharge, evapo-transpiration have been enteredseason wise sothat transient state run may carried out season wise. In initial simulation the model results as most of the area are dry due to pumping data. Hence it has been corrected by adjusting the values of hydraulic conductivity.

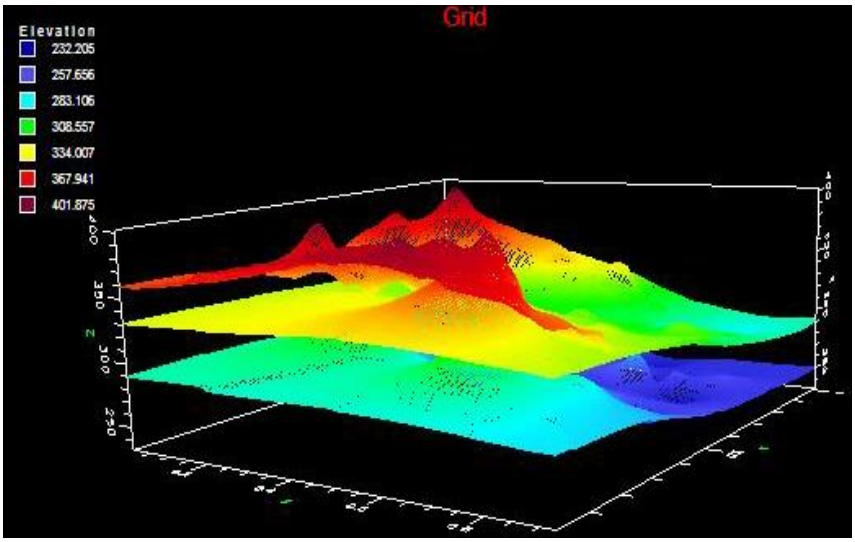


Figure 4.3-D preview of layer in grid elevation of model.

Regional flow pattern of Groundwater

The flow direction and velocity vector obtained for different period indicates (Fig.5&6) thatmajority of the flow direction is in North East direction. This is route of the groundwatermovement from the upper higher altitude to lower altitude. It has been also observed that there is less flow pattern in layer one during pre-monsoon and water table during this season is very low in high built-up areas and they are also controlling the flow patterns. The Fig.7 shows in Upper Seonathbasin the red color contour reveals the drawdown of the study area for first layer, which varies from location to location and block. And the blue color contour shows in the study area map are head equipotential for the value of 331.7745 m. the color shading shows the head equipotential in particular location which minimum and maximum values are from 350m to 366m.Few heads of the observation sites located near theconstant head boundary i.e. reservoirs and channel has not shown any change with time and equipotential head near this structure shows negative depth i.e. -20m.maximum equipotential head is 60 m near the high abstract locations.In Fig. 6 post monsoon season result shows shallow water table depth for whole basin and flow direction have no effect due of pumping.

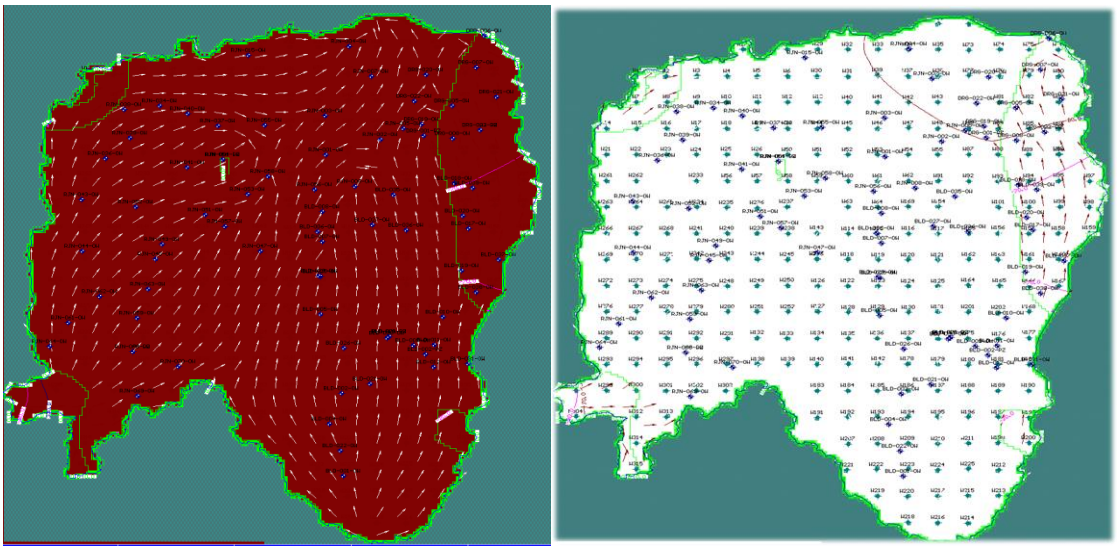


Figure 5.Velocity vector with recharge for Upper Seonathbasin in first and second layer in pre monsoon.

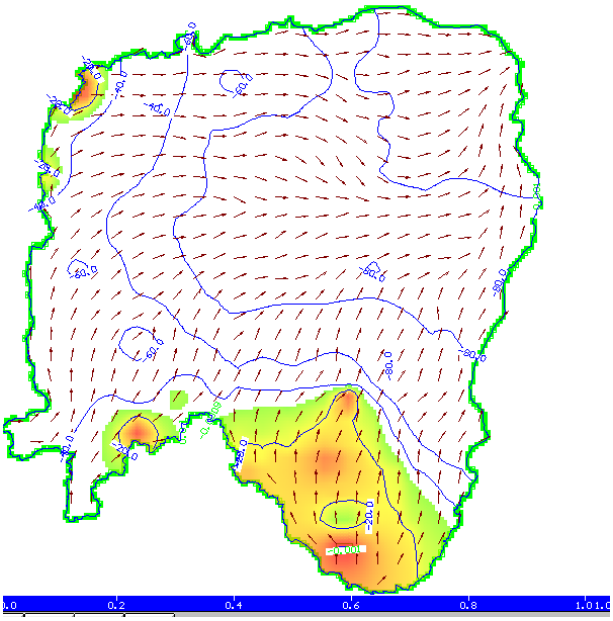


Fig. 6Velocity vector with recharge for Upper Seonathbas in in first layer in post monsoon.

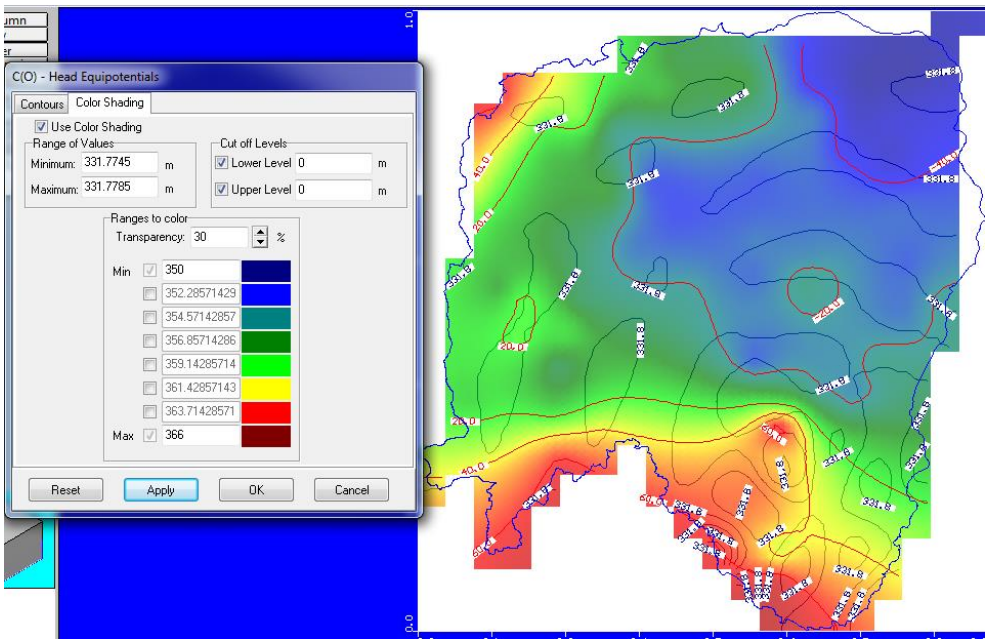


Figure 7.Drawdown contour and equipotential contour

Flow Budget from the model output

Results of flow budget (Fig.8) indicate that an amount of 1200000 m3 per day has beenpumped on the pre monsoon from the constant available effective storage of the aquifer. The recharge from the stream and storage support the inflow of water in the area. Constant head is insufficient for constant abstraction by 20000m3 per day. The inflowoutflow to the system is also balanced till the month of June-July. After start of monsoon i.e. June-July, situation reversed after increase in recharge to the system. Inspection of drawdown inindividual pumping wells indicated influence ofthe wells is very limited and rarelyinterfering the other wells.

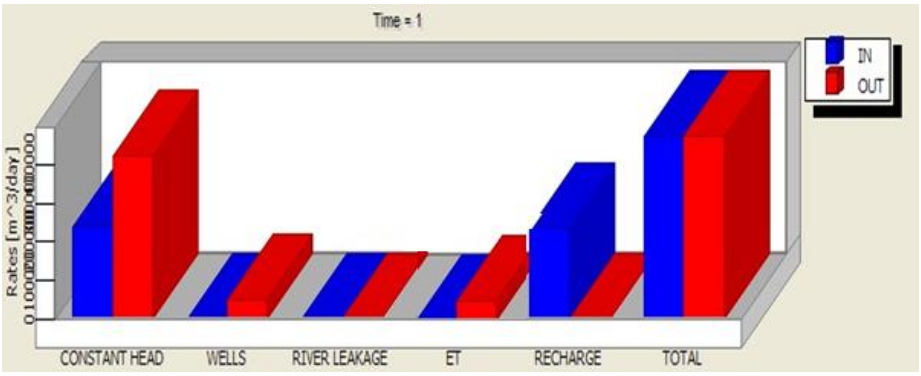


Figure 8.Comparison Graph between Input and Output

Model Calibration

The observation well used during model has been implemented for calibration. In model, calculated heads and observed heads have been analyzed and calibrated. Majority

of the heads falls in 95per cent confidence level (Fig.9). Same simulation has been carried out for pre and post monsoon. The calculated and observed heads have been plotted for all the stress period. It is found that behavior of heads is changing with seasonal change in the water table.

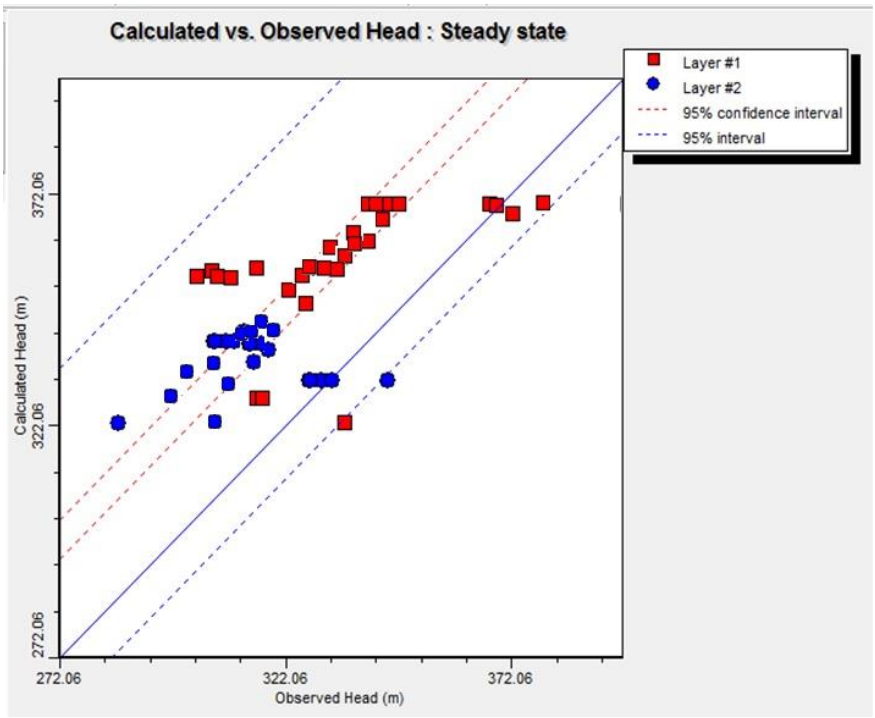


Figure 9. Calibration of model for head in the study area

Conclusion

Groundwater resources are very useful and important in sustaining people's lives in Upper Seonathbasin. However, the intensive use of groundwater has reduces this resource and also caused problems for future and present.Land use change is pointed out as affectingthe recharging capacity inUpper Seonathbasin. The recharging capacity has decreased due to urbanization, hence natural recharge quantity are less in this areas which leadsusually low water level depth for this region. Extensive use of groundwater in the Upper Seonathregion started primarily for public water supply. But, at present, private usage of groundwater has become more significant, mostly by the industrial sector and agriculture in summer season is a cause of high drawdown in the study area and issue of low water table depth. From the results it can be concluded that in Upper Seonath catchmentgroundwater preservation by reasonable exploitation has to be employed and the use of groundwater abstraction rate at less than 500,000 m3/day were advised, so that the adverse impacts on ground water such as ground water contamination and drawdown of ground water level can be minimized. This study reveals a very valuable results for planner, manager and stakeholders to sustainable use of groundwater resources in Upper Seonath Basin.

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ASSESSMENT OF GROUND WATER QUALITY FROM INDUSTRIAL AREA LOTE M.I.D.C.MAHARASHTRA

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Abstract

The assessment of ground water quality of industrial area from Lote M.I.D.C. analyzed, it is utilized for drinking and domestic purpose and hence it is need to assess the quality of ground water. The several factories drain their liquid wastes to the nearby river. The samples of water were collected from wells situated around the industrial area at one month interval throughout the year. The parameters viz., pH, EC, Na^+, Cl^-, Ca^{2+}, Mg^{2+}, HCO_3, SAR and RSC were estimated to assess the impact of industrial wastes on ground water. The results show that the present study most of the water samples below permissible limit of drinking water quality.

Key Words: Water Pollution, Factory waste, Water quality.

Introduction

Water is an important life supporting material and required for all biotic communities. Water is a factor of production in virtually all enterprises, including agriculture, industry and the service sector. The society depends on water for domestic needs, irrigation, sanitation, and disposal of waste. Normally water is never pure in the chemical sense (Agale*et al*., 2013). In water impurities are in very low amounts, but due to rapid industrialization, over population, indiscriminate use of chemicals causing water pollution and exploitation of ground water disturbs the state of equilibrium of aquifer (Ramesh *et al*., 2014). The effluents or waste from industries, sometimes percolate through subsoil and reached the ground water table forming contaminated pool, which disturb the natural ground water quality by changing its chemical composition. Contaminated water when used for irrigation purpose affects the soil quality and crop health. The physico-chemical analysis of soil and ground water reveal the impact of industrial waste on soil health and pollution of ground water.

Material and Methods

The study area includes parts of Lote M.I.D.C. (Maharashtra Industrial Development Corporation) in Ratnagiri district. The Ratnagiri district is geographically situated in latitude of 16.58^0 to 16.98^0 N and 73.18^0 to 73.30^0 E longitudes. In that area, soil is generally lateritic soil and monsoon season (June to October), winter (November to February) and summer (March to May) are occur. The region receives very high rainfall (above 3000 mm annually). Month of May is generally the hottest, with a mean maximum temperature of around 33^0 -35^0C. During rainy season, humidity is as high as 90 to 98 per cent. It is least in winter afternoon, when it may come down to about 60 per cent.Twenty water samples were collected at one month interval for one year (April 2014 to March 2015) from the wells, which were situated around the industrial area and evaluated the seasonal variation of ground water. Twenty water samples were collected every month. These water samples were collected in clean plastic and transparent bottles from the well. The samples were stored in refrigerator at 4^0C or added two to three drops.

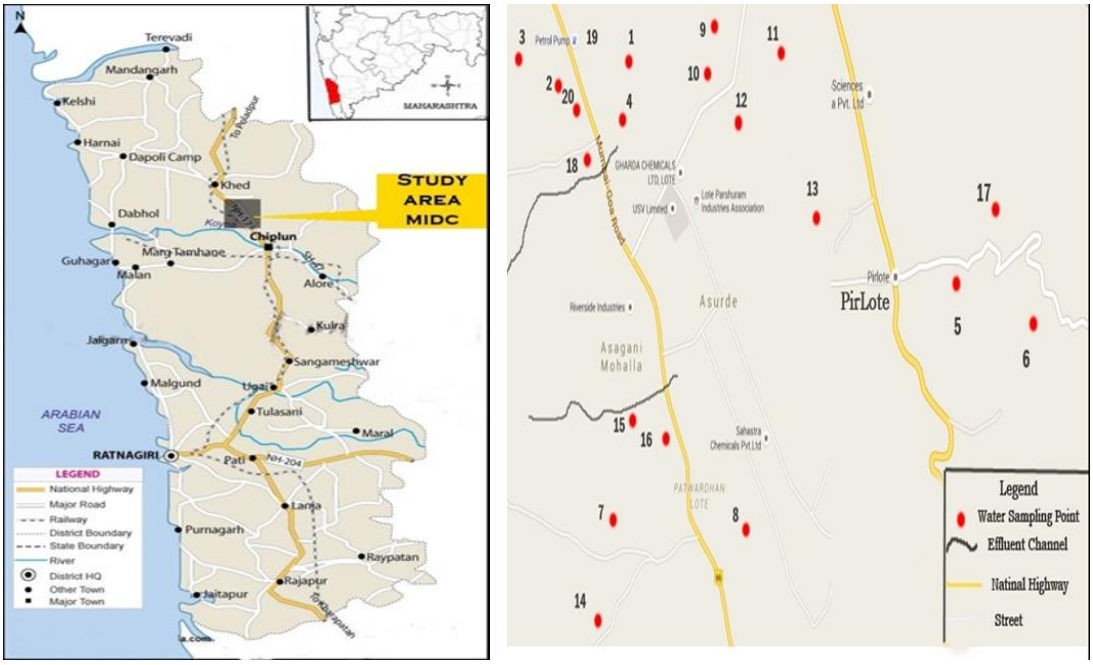


Fig1-Location of study area (MIDC) and water sampling points

Results and Discussion

The ground water at industrial area Lote MIDC, Maharashtra showed change in physico-chemical characteristic during throughout year (April, 2014 to March, 2015). The result of water quality status is depicted in table.

1. pH

The pH is a measure of acidity or alkalinity of water. It is known to be related to the availability of macro and micronutrient for plants (Ladwani*et al*., 2012). In present study, the pH of water at different seasons varied from 6.04 to 6.15, 5.50 to 6.06 and 5.56 to 5.97 with a mean value of 6.08, 5.77 and 5.89 in summer, monsoon and winter seasons, respectively. However, laterite soil is acidic in nature and hence ground water is also acidic nature. In that area during monsoon season certain chemical and metals are percolating through rain water and accumulated in ground water, hence water had low pH value (Walakira, 2011) and it could be due to discharge industrial effluents, which are acidic and mix in the well water (Sunil *et al*., 2011).

2. Electrical conductivity

The electrical conductivity is the ability of a substance to conduct electricity. The conductivity of water is a more or less linear function of the concentration of dissolved ions (Kumar *et al*., 2012). The electrical conductivity of water were varied from 0.124 to 0.183 dSm^{-1} with a mean value of 0.150, 0.135 to 0.202 dSm^{-1} with an average value of 0.166 dSm^{-1} and 0.164 to 0.196 dSm^{-1} with a mean value of 0.185 dSm^{-1} during summer, monsoon and winter seasons, respectively. Hence all the samples collected from wells belonging excellent and good water categories throughout year. The electrical conductivity increased during monsoon and winter season due to increase in number of ions which is

supported by salinity value (Ramesh *et al*., 2014) and lower duringsummer due to increased rate of precipitation (Katariae*t al*., 1994).

3. Carbonate and Bicarbonate

The carbonate concentration was not found in any water samples in study period. The bicarbonate concentration in water during summer season varied from 71.38 to 101.68 mg L^{-1} with an average value of 84.74 mg L^{-1}, while during monsoon season ranged from 53.69 to 82.97 mg L-1 and its mean value of 68.69 mg L^{-1}. In winter season varied from 70.77 to 89.69 mg L^{-1} with a mean value of 80.84 mg L^{-1}. The concentration of bicarbonate is lower during monsoon season due to dilution effect of rain water (Prasath*et al*., 2013). The data showed that bicarbonate concentration in groundwater samples was below the maximum permissible limit.

4. Chlorides

Chlorides are found in ground water through natural and anthropogenic sources, such as weathering of rocks and leaching of inorganic fertilizers, dumps or landfills, industrial effluents etc. (Yadav*et al*., 2014).The seasonal variation of chloride concentration in ground water during summer, monsoon and winter season varied from 190.77 to 208.50, 189.35 to 212.05 and 195.74 to 216.31mg L^{-1} with an average value of 199.99, 198.43 and 207.22 mg L^{-1}, respectively found below permissible limit for drinking purpose. The chloride concentration is lower in monsoon season as compared to summer and winter season might due to evaporation, dilution effect and anthropogenic influences as chloride readily transported through soil (Rao*et al*., 2013).

5. Sodium

Sodium is highly soluble chemical element, which is naturally found in ground water. The sodium concentration of ground water was in the range from 12.01 to 23.78, 6.21 to 13.80 and 11.60 to 11.98 ppm with a mean value of 18.79, 9.34 and 11.81 ppm during summer, monsoon and winter season, respectively.

During summer season maximum sodium concentration in ground water due to low water level and high evaporation losses (Yadav*et al*., 2014). In present study, the ground water samples contain sodium concentration below the maximum permissible limit.

6. Calcium

The calcium concentration in ground water ranged from 34.27 to 40.97, 16.03 to 42.28 and 24.65 to 27.25 mg L^{-1} with a mean value of 37.77, 30.70 and 26.15 mg L^{-1} during summer, monsoon and winter season, respectively. The data showed that ground water samples were below the maximum permissible limit of calcium concentration in ground water.The calcium concentration is higher in ground water during summer season as compared to monsoon and winter seasons, there was continuous decreased during winter season. During summer season, higher calcium concentration in ground water was observed due to industries pollution, low water level and high evaporation (Deshmukh, 2014).

7. Magnesium

The variation of magnesium concentration in ground water varied from 5.11 to 12.65 mg L^{-1} with a mean value of 9.57 mg L^{-1} during summer, 3.77 to 16.29 mg L^{-1} with an average value of 8.83 mg L^{-1} in monsoon and 4.50 to 6.93 mg L^{-1} with an average value of 5.32 mg L^{-1} in winter season, respectively. In present study, the ground water samples were below the maximum permissible limit of calcium concentration in ground water as drinking purpose. During summer season higher magnesium concentration in ground water

may be due to polluting industries situated near the water sources, low water level and high evaporation (Deshmukh, 2014).

Table 1. - Physico-chemical status of ground water from Lote MIDC during April, 2014 to March, 2015

Parameter	Summer	Monsoon	Winter	Mean
pH	6.08	5.77	5.89	**5.91**
EC (dSm^{-1})	0.150	0.166	0.185	**0.167**
Bicarbonate (mg L^{-1})	84.74	68.69	80.84	**78.09**
Chloride (mg L^{-1})	199.99	198.43	207.32	**201.91**
Sodium (ppm)	18.79	9.34	11.81	**13.31**
Calcium (mg L^{-1})	37.77	30.70	26.15	**31.54**
Magnesium (mg L^{-1})	9.57	8.83	5.32	**7.90**
SAR	0.88	0.54	0.76	**0.73**
RSC	0.58	0.48	0.70	**0.571**

Table 2. Month-wise periodical changes in physico-chemical status of ground water during April, 2014 to March, 2015

Parameter	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March
pH	6.06	6.15	6.06	5.50	5.94	5.67	5.66	5.97	6.12	5.56	5.89	6.04
EC (dSm^{-1})	0.124	0.143	0.150	0.195	0.202	0.135	0.150	0.196	0.189	0.191	0.164	0.183
Bicarbonate (mg L^{-1})	71.38	81.15	82.97	53.69	63.45	74.41	68.93	70.77	84.18	78.70	89.69	101.68
Chloride (mg L^{-1})	200.69	208.50	212.05	189.35	199.29	193.61	197.87	216.31	209.92	214.89	195.74	190.77
Sodium (ppm)	20.54	23.78	13.80	10.90	7.54	6.21	8.26	11.98	11.93	11.60	11.75	12.01
Calcium (mg L^{-1})	40.97	38.08	42.28	40.88	29.06	25.25	16.03	24.65	25.65	27.25	27.05	34.27
Magnesium (mg L^{-1})	12.65	10.94	16.29	12.77	6.81	4.50	3.77	4.62	4.50	5.23	6.93	5.11
SAR	0.868	1.086	0.678	0.456	0.503	0.394	0.683	0.814	0.792	0.709	0.717	0.696
RSC	0.240	0.530	0.494	0.063	0.386	0.621	0.624	0.567	0.776	0.626	0.819	0.964

8. Sodium Adsorption Ratio

The Seasonal variation in Sodium Adsorption Ratio of ground water from 0.696 to 1.086 with a mean value of 0.883 in summer, while 0.543 was an average value found in monsoon and it ranged between 0.394 to 0.678 and it ranged from 0.709 to 0.814 with a mean value 0.758 during winter season. The Sodium Adsorption Ratio of all the ground water samples found to be less than 10, which shown low sodium hazard making it suitable for irrigation in almost all type of soil. The sodium Adsorption Ratio is lower during monsoon season due to less amounts of sodium salts present in ground water (Bhadra*et al.*, 2012).

9. Residual Sodium Carbonate

The Residual Sodium Carbonate in ground water ranged from 0.240 to 0.964, 0.063 to 0.624 and 0.567 to 0.819 with a mean value of 0.58, 0.44 and 0.70 during summer, monsoon and winter season, respectively. During the study, the RSC values clearly indicated that the ground water is not having any residual sodium carbonate hazard. Residual Sodium Carbonate value is lower during monsoon season as compared to summer and winter season in ground water.

Conclusion

An assessment of the environment risk due to water pollution especially industrial wastes are the particular importance for agricultural and non-agricultural areas because that are directly affected to water quality, which also further effect on soil health and human health. For going research, that water is safe for irrigation purpose. But however, long term studies about contamination of ground water need to be examined.

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EFFICIENT LAND AND WATER RESOURCE PLANNING OF A MICRO WATERSHED USING GEOSPATIAL TECHNIQUES

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Abstract

False colour composite (FCC) of IRS-P6 LISS IV geocoded data was interpreted in conjunction with survey of India (SOI) toposheet on 1:50000 scale to extract information on existing land use/ land cover, slope, aspect and physiography for characterization and mapping of soils in the Village Dabo of Block and District Mungeli (Chhattisgarh). The revenue maps of 1:4000 scale was digitized and converted to vector shape file with attributes of field details like owners name & caste and coverage area, perimeter etc. This revenue map was overlapped to the FCC of mosaic satellite data for retrieving the true land characterization of the project area. Two farming situations were characterized and mapped as per the local names of the agro climatic zone viz. Matasi and Dorsa comprising of 52.3% and 47.7% area respectively. The village was classified into nine land use classes and found that the total agricultural land comprising of harvested fields, lowland paddy, midland paddy and soybean crop covering a total area of 250.46 ha. Total of 420 farm fields were digitized and converted to vector layer and micro level land and water resources management plan was developed for the same. Total five new small ponds and two check dam were proposed as per the best identified site for harnessing of runoff and recharging of ground water.

Keywords: *Cadastral mapping, farming situations, geospatial, GIS, remote sensing*

Introduction

Agriculture continues to play a major role in the country with the well known fact that India lives in villages and would continue to do so. But rapid urbanization and consequent haphazard growth of cities has resulted in neglecting of villages. With clear understanding of the soil type, fertility and other parameters related to agricultural yield, farmers can achieve better agricultural productivity. For sustainable agricultural development cultivable land information plays vital role. With detailed and reliable information, it is easier to implement better agricultural practices. Nearly about 75 percent people are living in rural areas and are still dependent on Agriculture. Cadastral or revenue map have traditionally dealt with land ownership and land use at the level of the individual land owner or occupier. They operate in the context of national laws and land use policies with regional and local planning inputs. In many countries this includes considerable involvement with land consolidation projects designed to improve the efficiency of agriculture and/or to implement rural or urban development. Land resource information at the village level has become essential under the present scenario of the farmers' agitation for not parting with the fertile agricultural land which is the back bone of food security. For any agricultural planning and development, an inventory of natural resources is a prerequisite. Soil is part of the land which is a non-renewable natural resource. Soil is the base for every production system but most of the crop production system and knowledge on their properties, extent and spatial distribution is extremely important. Therefore, it is imperative to maintain soil resources to sustain the ecosystem (Beckett and Webster, 1971; Gessler, 1996). In this context, characterization and mapping of different types of soils and their interpretation attains greater importance for micro level planning (Sahu *et al*., 2014).

We are well aware that most of the problems exist at the field level which can be tackled only by formulating and adopting rational, site-specific and viable land-use options suitable for each and every parcel of land at village or watershed level. Any other macro-level planning will not have the desired effect in solving the problems faced by our farmers. To address the issues at farm or field level, we need a detailed site-specific data base covering each and every plot or parcel and survey number occurring in each village. Detailed natural resource information at larger scales (1:4,000 to 1:10,000) can only provide such basic information for optimal utilization of natural resources. Accurate baseline information and methods to evaluate the quantity and quality of resources is a prerequisite for mapping and characterization of soils (Laake, 2000).The region has several hot spots of rural poverty, as most farmers in the region are small holders with diverse farming systems, which are highly risk prone. In addition, these farmers have poor access to support services such as extension, the agricultural Land information, knowledge, technology and financial credit. The new Agricultural Land Information System brings sustainable revolution by empowering the resource to poor farmers with up-to date knowledge and information about agricultural land and technologies, best practices, crop information, soil-moisture conditions and the environment etc.

The traditional methods of cadastral level planning, gathering information was expensive and time consuming due to large number of observations. However, advances in computer and information technology have introduced new group of tools, methods, instruments and systems. Rapid developments in new technologies such as Remote Sensing (RS), Global Positioning System (GPS) and Geographical Information System (GIS) provide new approaches to meet the demand of resource planning and successfully used in studying the various aspects in spatial and temporal domain (Shrestha 2006, Yeung and Lo 2002). The field of remote sensing and GIS has become exciting and glamorous with rapidly expanding opportunities (Patra 2011). Most of the problems exist at the field level which can be tackled only by formulating and adopting rational, site-specific and suitable land-use options for each and every parcel of land at village or watershed level. For addressing such type of problem the pilot study in Dabo village, Mungeli district in the state of Chhattisgarh was carried out to develop cadastral level agricultural resource information system using remote sensing and GIS techniques for identifying the problems and potentials and to conserve and manage them at farm level for improving their productivity.

Materials and Methods

Study Area

Village dabo is situated in Block and District Mungeli of Chhattisgarh State and lies between 81^{o}35'0''E to 81^{o}36'15''E longitude and 21^{o}05'12''E to 22^{o}06'45''E latitude with and average altitude of 298 m above mean sea level (Fig. 1). The village lies within the hydrological boundary of Tesua watershed with an average rainfall of 924 mm with hot and arid climate. Dabo micro-watershed is covered by topographic map No. 64F/12 of 1:50,000 scale having 10 m contour interval. This topographic map was collected from Survey of India, Raipur, Chhattisgarh for use in this study.

Cadastral/ Revenue data

Initially the cadastral map of the Dabo village at 1:4000 scale has been collected from Land Record Department (LRD) Mungeli. The satellite imagery of the study area has been rectified by selecting ground control points from SOI toposheet 64F/12 at 1:50000 scale using ERDAS IMAGINE 9.2 and ArcGIS 10.

Remote sensing data

The cloud free digital data of the study area were obtained from National Remote Sensing Centre (NRSC), Hyderabad in Compact Disc (CD). LISS IV sensor path 102, row 57. Scene of IRS-P6 satellite with date of pass 10th October 2014was used for the study to prepare the land use/cover maps of the Dabo micro watershed. The satellite data were in four electromagnetic spectral bands (band 2: 0.45-0.52 μm, band 3: 0.52-0.59 μm, band 4: 0.62-0.68 μm and band 5: 0.77-0.86 μm). Its sensor provided the data of 5.8 m x 5.8 m spatial resolution.

Table 1: Details of satellite image used in the study

Toposheet no.	Satellite	Sensor	Resolution (m)	Path	Row	Date of Pass
64F/12	IRS-P6	LISS-IV	5.8	102	57	10/10/2014

Hardware and Software Used

Geoinformatics Laboratory of Department of Soil and Water Engineering at R. H. Richariya Rice Research laboratory, IGKV, Raipur was utilized for the Hardware and Software requirement of the study. All the required software, ArcGIS 10 for digital data analysis, ERDAS IMAGINE 9.2 for image processing, large size colour scanner for scanning the topographic maps were used in the study.

Assessment of availability and utilization trends of surface and groundwater, crop water requirement and surface runoff calculation by SCS curve number method. Various thematic maps were prepared by using Survey of India toposheets (1:50000 scale), IRS P6 LISS IV satellite data dated 10th October 2014 and other hydrological & meteorological information's, ERDAS IMAGINE software was used for image rectification, enhancement and classification operations. IRS P6 LISS IV satellite data has been used to classify land use/land cover. On Screen interpretation has been used to extract thematic layers. Interpretation was made in conjunction with the topographical map and also supported by adequate ground actual data for accurate output. Required thematic layers - hydrology (drainage), DEM, Soils, Slope, Land use / Land cover have been derived from the image. Arc GIS 10.0 software has been used to integrate the individual layers to generate suitable land use models and to develop a cadastral level management plan. Methodology has been applied to classify the land use categories and recommendations were suggested appropriately.

Results and discussion

Soil

The study area comprises silty clay (262.93 ha), clay loam (95.49 ha) and silty clay loam (37.76 ha) as shown in Fig. 3. The soil textural class of silty clay dominates the village comprising of 66.32% followed by clay loam and silty clay loam with 24.14% and 9.5% respectively.

Land use pattern

The area is characterized under Chhattisgarh plains Agro climatic zone. Cropped area related data of *kharif* and *rabi* seasons were available and collected from the Department of Senior Agricultural Development Officer, Mungeli block. The data were analysed to depict land use pattern of the watershed according to the percentage of cropped area of that village. Based on image characteristics, the nine major land use/ land cover identified (Fig. 4) are midland paddy (79.41 ha), soybean (81.64 ha), lowland paddy (32.53 ha), harvested field (56.88 ha), barren land (10.39 ha) and current fallow (76.27 ha). Other land use were delineated as settlements, water bodies and plantation with 51.16 ha,

2.21 ha and 5.94 ha area respectively. On analyzing the present land use/ land cover pattern it can be clearly identified that nearly than 22% of land is still unused and has to be brought under cultivation by adopting suitable and sustainable land and water resource management plan.

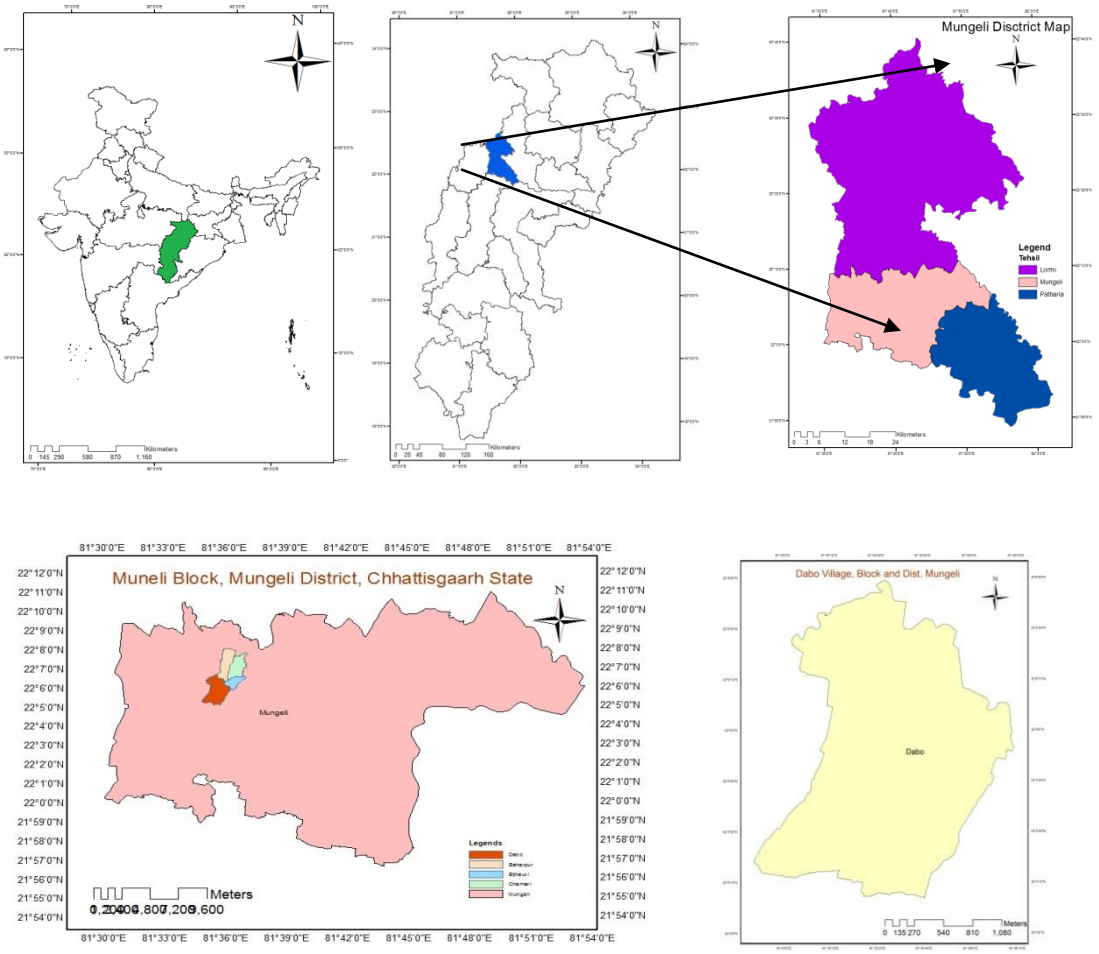


Fig. 1 - Location map of the study area

Irrigation

Data related to irrigated area through distributaries of canal and tubewell under *kharif* and *rabi* season were available and collected from the Department of water resources, district Mungeli Govt. of Chhattisgarh and Senior Agricultural Development officer, Mungeli block of Mungeli district.

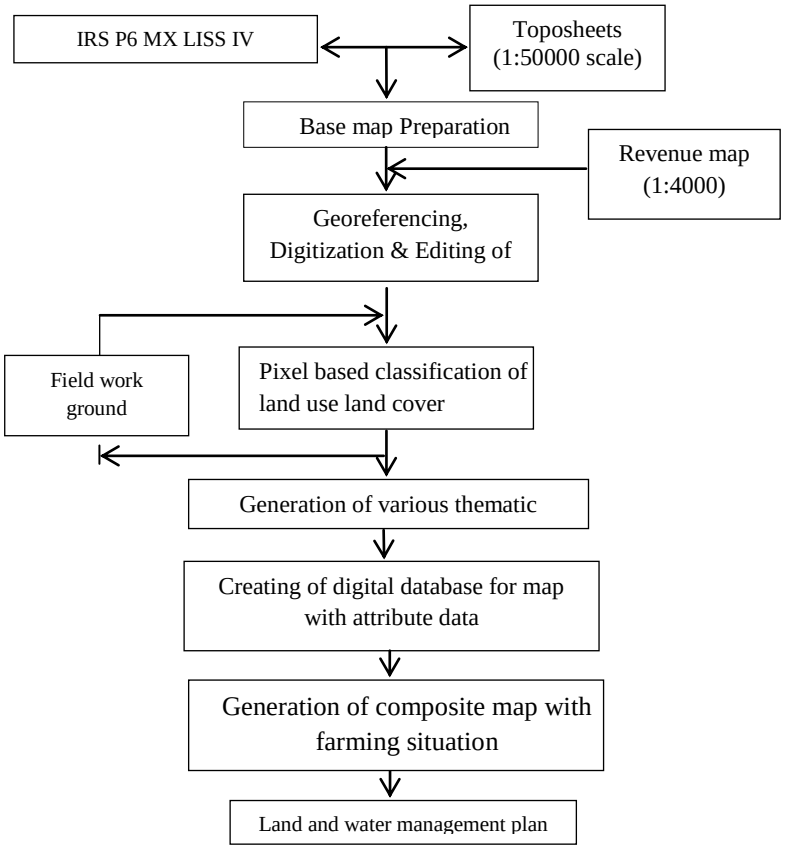


Fig. 2 – Flow chart of the methodology

DEM and Slope

Digital Elevation Model (DEM) was generated using the contour map along with the field surveys done using global positioning system (GPS). The elevation of the project area was found to be in the range of 295 – 301 m above mean sea level. The slope map was generated by the classifying the relief in four classes. Four slope classes viz (a) flat (0.2 - 1% slope) covering an area of 63 ha (b) moderately flat (1.1 - 2 % slope) covering an area of 202 ha, (b) moderate gently slope (2.1 - 3 % slope) covering an area of 107 ha and (c) gentle slope (3.1 – 3.8 % slope) covering an area of 24 ha has been derived (Fig. 5). The slope map played the major role in delineating the farming situations for preparation of site specific management plan.

Farming situations

Based on the visual interpretation and field survey, two farming situations (Fig. 6) viz. *matasi and dorsa* were identified and characterized based on soil morphology, land use, land cover, drainage, slope and aspect. As per the local names of the agro climatic zone viz. *Matasi* and *Dorsa* comprising of 52.3% and 47.7% area respectively consists of Inceptisol and Alfisol soil taxonomy.

Land and water resource management

The integration of physiography, soil, land use, land cover, slope and cadastral maps under GIS environment has brought out the two farming situations of Dabo village of Mungeli District, which leads to identify the areas for alternate land use, resource development and conservation. The cadastral map digitized showed that 420 number of farm fields was available in the village (Fig. 7). Total of 48 number of farm fields covering an area of 45.65 ha is under current fallow under *matasi* farming situation and similarly 43 number of farm fields covering an area of 29.48 ha under *dorsa* farming situation lays under current fallow. Total 91 number of farm fields covering 75.13 ha land is left fallow and can be brought under cultivation by proper land management practices. For bringing this 75.13 ha of land under cultivation additional water resources is required. Five farm ponds and two check dams at appropriate sites were suggested with its approximate command area. These water resources will definitely help in increasing the production and productivity of the moderately fertile farming situations (Fig. 8). The details of total field and farming situation is presented in table 2

Table 2 – Fields under different farming situation in village Dabo

		Matasi		*Dorsa*	
	Classes	No of Fields	Area ha	No of Fields	Area ha
1	Plantation	2	1.14	3	2.25
2	Settlement	25	31.49	14	20.3
3	Midland Paddy	43	42.54	47	35.48
4	Water body	2	0.5	2	1.5
5	Soybean	32	47.12	27	38.71
6	Barren land	12	8.1	11	2.94
7	Current Fallow	48	45.65	43	29.48
8	Harvested Field	21	18.29	23	36.36
9	Lowland Paddy	27	11.36	38	23.27
	Total	212	206.2	208	190.3

Conclusions

The good and fertile land is very limited in the form of *dorsa* and *kanhar* farming situations. More than 52 % of the land was occupied by poor to moderately fertile farming situation of *matasi,* which is also characterised by their low soil depth and poor infiltration capability leading to poor production potentiality of the farming situations. In order to make sustainable management plan, due emphasis was given to utilize each farming situation and to enhance its potential be adopting necessary measures. In this context, actual numbers of field laying vacant as current fallow was identified and proposed for cultivation with the additional water resources development plan. Excavated farm ponds were proposed by intercepting the natural drainage line of the region in the *matais and dorsa* farming situations. The stored water will act as life saving and supplemental irrigation to the *kharif* crops and will help in supporting the *rabi* relay crops. Check dams and farm pond was proposed to check and store the excess runoff water. Thus, an operational strategy for land and water conservation structures could be planned based upon geospatial technologies and could be blessing for tribal dominant agro climatic zone with limited resources for development of sustainable site specific management plan.

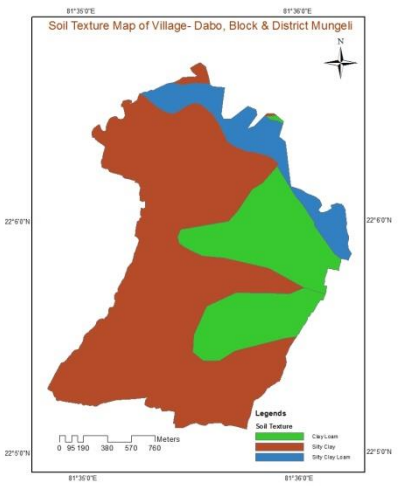


Fig. 3 – Soil Map

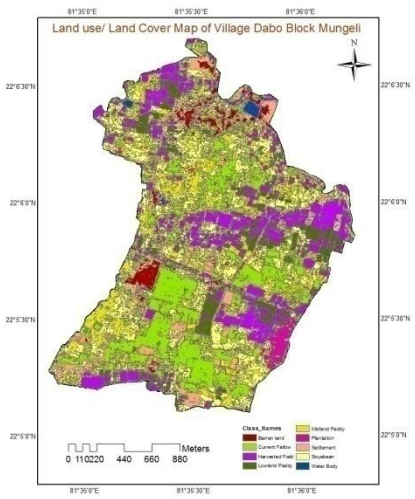


Fig. 4 – Land use land Class

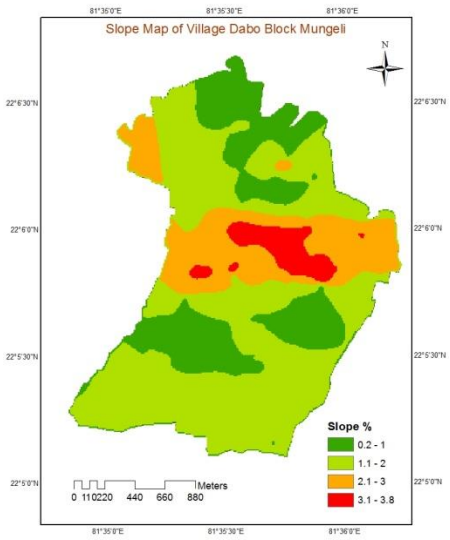


Fig. 5 – Slope Map

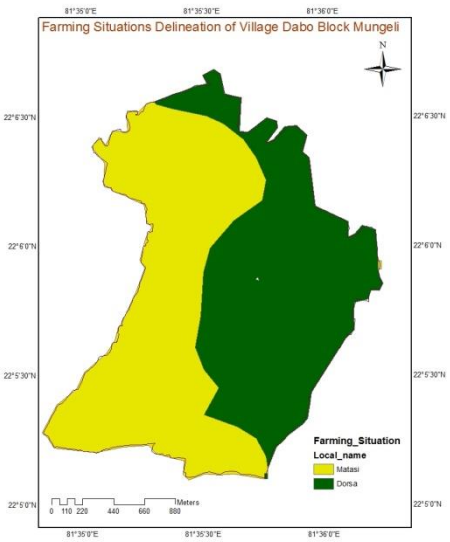


Fig. 6 – Farming situations map

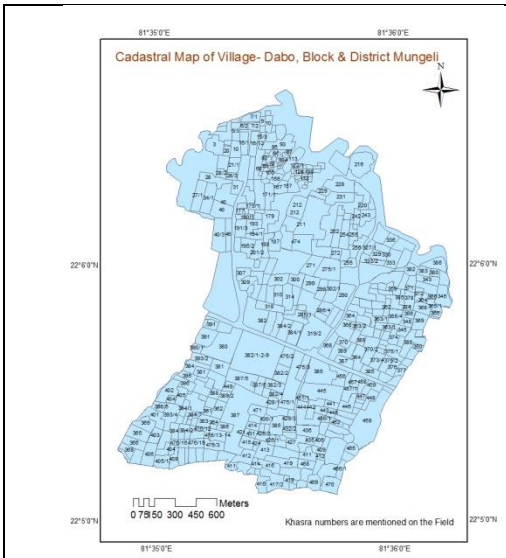


Fig. 7 – Cadastral Map

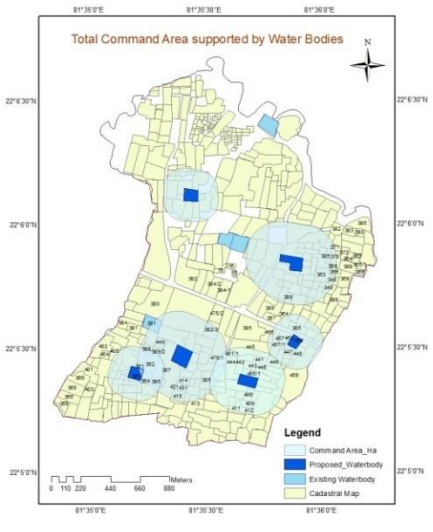


Fig. 8 – Land and water resources plan

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ASSESSMENT OF WATER REQUIREMENTS OF VEGETABLE CROPS FOR CHHATTISGARH STATE OF INDIA USING CROPWAT MODEL AND GIS TECHNIQUE

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Abstract

Water is a vital component of vegetable crop production. Adequate water supply is essential to maximize both quality and quantity of vegetable produce. However, water has to be applied at the correct time, in sufficient quantity, but without waste and in an environment friendly manner. The amount of water required to supplement crop water needs usually depends on the water requirement of the plants, local climate and soil conditions. Crop water needs can be estimated using CROPWAT model. CROPWAT is a computer program for irrigation planning and management, developed by the Land and Water Development Division of FAO (FAO, 1992). Its basic functions include the calculation of reference evapotranspiration, crop water requirements, and irrigation scheduling. Through a daily water balance, the user can simulate various water supply conditions and estimate yield as well as irrigation and rainfall efficiencies. In the cultivation of important vegetable crops viz. tomato, brinjal, pepper, onion and cucurbits, water management is of prime importance to harness optimum productivity. To explore this option, analysis of water requirement is essential at the crop level for daily or decadal basis. The objective of the study was to apply CROPWAT model to compute water requirement of commercially important vegetable crops of Chhattisgarh and compute in GIS environment for generation of different maps with respect to the season. The methodology was applied to the whole state of Chhattisgarh comprising of three different agro-climatic zones i.e. Northern hills, Chhattisgarh plains and Bastar plateau. Tomato, brinjal, pepper, onion and cucurbits were considered as test crop. The water requirement of different selected locations of the three agro-climatic zones of Chhattisgarh was used as a representative of the different agro-climatic zones. The highest water requirement (818 mm) was computed for brinjal for Raipur, whereas the lowest (663 mm) was computed for Jashpur. The crop water requirement for tomato was computed highest (546 mm) in Raipur and lowest (424 mm) in Pendra. The crop water requirement for Pepper was highest (544 mm) in Raipur while lowest (424 mm) both in Kanker and Pendra. With regard to onion, crop water requirement was computed highest (558 mm) in Raipur and lowest (447 mm) in Jashpur. Whereas, in case of cucurbits, crop water requirement was computed highest (499 mm) at Raipur and lowest (370 mm) at Pendra.

Keywords: *Crop water requirement, CROPWAT, GIS, Vegetable crops*

Introduction

Water resources and its management are a serious environmental problem worldwide and a major threat to the sustainability of agriculture and economic development. Water is important for plant growth and food production. The primary objective of irrigation is to apply water to maintain crop evapotranspiration (ETA) when precipitation is insufficient. The finite total amount of available water is crucial for the economy, health and welfare of a very large part of the developing world. Hess (2005) defined crop water requirements as the

total water needed for evapotranspiration, from planting to harvest for a given crop in a specific climate regime, when adequate soil water is maintained by rainfall and/or irrigation so that it does not limit plant growth and crop yield. FAO (1992), Smith et al. (1991) and Smith (1992) reported that CROPWAT is meant as a practical tool to help agrometeorologists, agronomists and irrigation engineers to carry out standard calculations for evapotranspiration and crop water use studies, and more specifically the design and management of irrigation schemes. It allows the development of recommendations for improved irrigation practices, the planning of irrigation schedules under varying water supply conditions, and the assessment of production under rainfed conditions or deficit irrigation. Plants use water for cooling purposes and the driving force of this process is prevailing weather conditions. Different crops have different water use requirements, under the same weather conditions. Adequate irrigation design, good irrigation management and scheduling have long been recognized as keys to increasing vegetable production on a sustainable basis. Scheduling irrigation according to crop water needs minimises the chances of under or over watering. Consequently, there is less crop failure and leaching of fertilizers beyond the root-zone, and more profit for growers. This approach underpins the long-term viability of an efficient and sustainable production system for the irrigated vegetable industry. Weather data has been used for estimating crop water requirements for many years, and is a handy management tool when it is used in conjunction with scheduling methods. Accurate prediction of agricultural water consumption is required for better management of water resources. Most predictions are based on biophysical components and estimates of crop water requirements. The accuracy of the estimates depends on knowledge of soil properties, climatic variability, and irrigated cropping patterns. Satellite imagery combined with crop models is currently widely used to estimate irrigation water requirements at a regional scale (Heinemann *etal.,* 2002). Including farmers' practices and choices can improve the accuracy of such estimates (Maton *et al.,* 2005).

Materials And Methods

The Climatic situation and Soils of Chhattisgarh state:

The state of Chhattisgarh is endowed with varied agro-ecological conditions. It is divided into three agro-climatic zones (ACZs). The districts that come in each agro-climatic zone (ACZ) are presented in Table 1. Seven stations were taken under for study area to represent the three agro-climatic zones presented with latitude and longitude (Table 2).

Table 1: Agro-climatic zones of Chhattisgarh

Agro-climatic Zones	Districts
Chhattisgarh Plains	Raipur, Durg, Rajnandgaon, Bilaspur, Dhamtari, Mahasamund, Korba, Raigarh, Kabirdham (Kawardha), Janjgir (Champa), Kanker, Mungeli, Bemetara, Balod, Gariyaband and Balodabazar (16)
Bastar Plateau	Bastar, Dantewada, Bijapur, Narayanpur, Kondagaon and Sukama (6)
Northern Hills	Surguja, Jashpur, Koria (Baikunthpur), Surajpur and Balrampur (5)

Table 2: Latitude and longitude of different station of Chhattisgarh under study

Station	Latitude	Longitude
A: Northern Hills		
1. Ambikapur	23° 10' N	83° 15' E
2. Jashpur	22° 53' N	84° 12' E
B: Chhattisgarh plains		
1. Raipur	22° 15' N	81° 41' E
2. Kanker	20° 15' N	81° 32' E
3. Raigarh	21° 90' N	83° 40' E
4. Pendra(Dist.–Bilaspur)	22° 76' N	81° 95' E
A: Bastar plateau		
1. Jagdalpur	19° 05' N	82° 04' E

There is a considerable soil variability spread over the three-agro-climatic zones of Chhattisgarh. The soil type of Chhattisgarh plains varies from lateritic to heavy clay soils through sandy loam and clay loam.

General features of climate

The climate of Chhattisgarh state, in general, is sub-humid type with an average rainfall of about 1400 mm. The day time temperatures during peak summer season are usually very high in the entire area varying from 43^{o}C at Raigarh to 38^{o}C at Jagdalpur in the second-fortnight of May. At Raipur, the day time temperatures are consistently high (above 40^{o}C) right from the second fortnight of April to first week of June. The monsoon sets in around 10th June in the southern most part of Bastar district and finally extends over the entire area by 25th June. Rainfall during July and August is high (about 350-400 mm) at all places. It is assured and stable till mid September. The average annual rainfall of Chhattisgarh plain is 1422 mm distributed over 64 rainy days; 1452 mm in Bastar plateau distributed over 72 days and 1539 mm in Northern hills distributed over 80 days. Barring Bastar plateau, the spatial variability of annual rainfall is large within districts of the other two agro-climatic regions. For example, in Chhattisgarh plains highest annual rainfall of 1639 mm is received in Raigarh distributed in 73 days. The lowest annual rainfall is received in Rajnandgaon district (1215 mm) distributed over 64 rainy days. Similarly, in the Northern hills the highest annual rainfall of 1727 mm distributed over 92 rainy days is received at Jashpur district.

The winter conditions set in by mid November when the average minimum temperature reaches around 15^{o}C. The atmospheric humidity is usually low (maximum humidity around 30-40 per cent) during summer months (March-May). However, right from second fortnight of May, the humidity slowly starts building up and as soon as the monsoon sets in, it reaches a peak value of over 90 per cent. The high humidity conditions persist till end of October in most of the places. During July and August, the average bright hours of sunshine are around 2-3 hours/day. During active monsoon season, the bright sunshine hours become zero continuously for more than 10 days. As regards evaporation rates, peak rates of evaporation exist during the summer months.

Five vegetable crops were considered in the analysis viz., tomato, brinjal, peppers, onion and cucurbits. The crop water requirements of different selected locations of the three

agro-climatic zones of Chhattisgarh were used as a representative of the different agro-climatic zones of Chhattisgarh i.e. Northern hills, Chhattisgarh plains and Bastar plateau.

The CROPWAT Model analysis:

CROPWAT is a computer program that uses the FAO Penman-Monteith model to calculate reference evapotranspiration (ETo), crop water requirements (ETm) and crop irrigation requirements (FAO 1992). The program allows for the development of irrigation schedules under various management and water supply conditions and to evaluate rainfed production, drought effects and efficiency of irrigation practices (FAO 2002).

Data requirements for CROPWAT (based on FAO 2003 and FAO 2006)

The average climatic data from 1971 to 2000 were used as climatic input of CROPWAT model. The climatic data are maximum and minimum temperatures (C), mean daily relative humidity (in %), daily sunshine (in hours), wind speed and rainfall. The crop parameters included water stress coefficient (Ks), length of the growing season, critical depletion level, and yield response factor (Ky). The soil data include total available soil water content and the maximum infiltration rate for runoff estimates in addition to the initial soil water content at the start of the season (FAO 1998; 2003). Assessment of the impact on yield of various levels of water supply is simulated by setting the dates and the application depths of the water from rain or irrigation. Through the soil moisture content and evapotranspiration rates, the soil water balance is determined on a daily basis. Output tables enable the assessment of the effects on yield reduction, for the various growth stages and efficiencies in water supply (FAO 2003).

Estimation of Crop water requirement

The crop ET (ETc) was estimated by FAO Penman-Monteith equation (FAO, 1998) Hess (2005) and Smith et al., (1991)

$ET_O = ETc = KC\ (ETo)$ ……(1)

Where Kc is the crop coefficient and the reference crop ETo (mm/day) is as defined in equation (3) below as:

$$ET_O = 0.408\ \Delta(R_n - G) + \gamma[900/(T + 273)]\ u_2\ (e_s - e_a) / \Delta + \gamma\ (1 + 0.34\ u_2)$$ ……(2)

Where ETo = reference evapotranspiration (mm day^{-1})

R_n = net radiation at the crop surface (MJ $m^{-2}day^{-1}$)

G = soil heat flux density (MJ $m^{-2}day^{-1}$),

T = mean daily air temperature at 2 m height [°C],

u_2= wind speed at 2 m height (ms^{-1}),

e_s = saturation vapour pressure (kPa),

e_a = actual vapour pressure (kPa),

$e_s - e_a$ = saturation vapour pressure deficit (kPa),

D =slope vapour pressure curve (kPa $°C^{-1}$),

g =psychrometricconstant (kPa $°C^{-1}$).

Irrigation frequency was calculated using the relationship discussed by Michael (1999).

$$\text{Irrigationfrequency (days)} = \frac{\text{Field capacity of Soil – Moisture content before irrigation}}{\text{Daily consumptive use}}$$

$F = d_g / C_u$ ……(3)

Where F= irrigation frequency (days),

d_g= gross depth of application (mm), and

C_u= consumptive use (mm/day).

The CROPWAT programme developed for the FAO Penman-Monteith method (FAO, 2005) was utilized for estimating the crop water requirement of vegetable crops. Toensure the integrity of computations, the weather measurements were made at 2 m (or converted to that height) above an extensive surface of green grass, shading the ground. The climatic data used for the calculations were obtained from a different meteorological station located in three different zones of Chhattisgarh.

Results and Discussion

Crop water requirement of vegetable crops for different locations of the Chhattisgarh state:

The methodology was applied to the whole state of Chhattisgarh. Five vegetable crops were considered in the analysis viz., tomato, brinjal, peppers, onion and cucurbits. The crop water requirements of different selected locations of the three agro-climatic zones of Chhattisgarh were used as a representative of the different agro-climatic zones of Chhattisgarh i.e. Northern hills, Chhattisgarh plains and Bastar plateau. Crop water requirements (CWR) and irrigation requirement (IR): The CWR module includes calculations, producing the irrigation water requirement of the crop through CROPWAT model on total growing season. Irrigation requirement is different between the crop evapotranspiration under standard conditions (ETc) and the effective rainfall. A summary of the results, which explains the different CWR and IR calculation for selected crops, is showed in the tables (3 to 7). For assessing the crop water requirement CROPWAT model was used. The model predicted crop water requirement throughout the year from the date of planting of vegetable crops, predicted from date of sowing/planting to end of crop season.

An investigation of the crop water requirements in three zones of Chhattisgarh, seven major stations was under study which covering five major vegetables crops viz., tomato, brinjal, peppers, onion and cucurbits grown in each of the station was undertaken. The crop water requirement of different vegetables crops varies in different areas. Despite the fact that the bulk of Chhattisgarh's agriculture is rainfed, an attempt was made to assess the crop water requirements of the crops in the respective station. This was as a result of the desperate attempts some farmers across the country make to use the water resources at their disposal to grow crops, especially the high value market vegetables crops. The following are the findings of this study for each of the station that were selected for CROPWAT analysis.

Table 3: Crop water requirement, Effective rainfall and Irrigation requirement of different vegetable crops for Jagdalpur station of Bastar Plateau Zone.

S. No.	Name of crop	WR/ETc (mm)	Effective rainfall (mm)	Irrigation requirement (mm)
1	Tomato	497.8	1056.6	3.2
2	Brinjal	724.1	1060.9	324.5
3	Peppers	480.4	1026.1	28.7
4	Onion	487.8	56	431.8
5	Cucurbits	440.7	1013.2	8.2

In Bastar plateau, Jagdalpur station was taken for irrigation requirement of different vegetable crops. The CROPWAT model predicted maximum irrigation requirement for Onion (431.8 mm) and minimum for Tomato (3.2 mm). The effective rainfall was varied from 56 to 1060.9 mm. The crop water requirement of Brinjal was fund higher (724.1 mm) and minimum for Cucurbits (440.1 mm). The higher irrigation requirement was found for onion crop, which is due to minimum received of effective rainfall during span of cropping season.

Tomato and Cucurbits required minimum irrigation, which is due to received of higher effective rainfall during the span of cropping season (Table 3).

Table 4: Crop water requirement, Effective rainfall and Irrigation requirement of different vegetable crops for Raipur station of Chhattisgarh Plains Zone.

S. No.	Name of crop	WR/ETc(mm)	Effective rainfall (mm)	Irrigation requirement (mm)
1	Tomato	546.3	975.9	80.0
2	Brinjal	818.3	1016.9	406.70
3	Peppers	543.7	975.9	87.1
4	Onion	558.2	54.6	503.60
5	Cucurbits	499.0	970.3	51.60

The area under observation of Chhattisgarh plains covers maximum station to analyze the irrigation requirement for vegetables crop (Table 4). The data predicted for Raipur station, the effective rainfall received ranged from 54.6 to 1016.9 mm for different vegetable crops. However, irrigation requirements of onion crop (503.6 mm) computed maximum followed by Brinjal crop (406.7 mm) and minimum irrigation requirement was computed for Cucurbits crop (51.6 mm) followed by Tomato crop (80.0 mm) and Peppers crop (87.1 mm). In case of crop water requirement, Brinjal crop requires higher value (818.3 mm) and cucurbits require minimum crop water requirement value (499.0 mm).

Table 5: Crop water requirement, Effective rainfall and Irrigation requirement of different vegetable crops for Kanker station of Chhattisgarh Plains Zone

S. No.	Name of crop	WR/ETc(mm)	Effective rainfall (mm)	Irrigation requirement (mm)
1	Tomato	438.4	868.9	40.6
2	Brinjal	669.9	843.1	378.5
3	Peppers	424.4	839.9	67.8
4	Onion	478.6	8.6	470.0
5	Cucurbits	384.8	835.7	37.4

The minimum irrigation requirement was computed for Cucurbits (37.4 mm) followed by Tomato (40.6 mm) and the maximum irrigation requirement for onion crop (470.0 mm) was computed due to crop season with minimum receipt of effective rainfall (Table 5). The crop water requirement of Brinjal was computed maximum (669.9 mm) and minimum for Cucurbits crop (384.8 mm).

Table 6: Crop water requirement, Effective rainfall and Irrigation requirement of different vegetable crops for Raigarh station of Chhattisgarh Plains Zone

S. No.	Name of crop	WR/ETc(mm)	Effective rainfall (mm)	Irrigation requirement (mm)
1	Tomato	442.8	1104.0	84.8
2	Brinjal	708.9	1085.1	448.5
3	Peppers	443.3	1104.0	97.7
4	Onion	518.3	3.6	514.7
5	Cucurbits	388.4	1082.7	73.2

The data computed for irrigation requirement, onion crop was found higher value (514.7 mm) and followed by Brinjal (448.5 mm). The minimum irrigation requirement predicted for Cucurbits (73.2 mm) and Tomato (84.8 mm). The crop water requirement was computed maximum (708.9 mm) for Brinjal crop while minimum (388.4 mm) for Cucurbits crop (Table 6).

Table 7: Crop water requirement, Effective rainfall and Irrigation requirement of different vegetable crops for Pendra station of Chhattisgarh Plains Zone

S. No.	Name of crop	WR/ETc (mm)	Effective rainfall (mm)	Irrigation requirement (mm)
1	Tomato	424.2	904.6	54.1
2	Brinjal	670.3	893.5	384.5
3	Peppers	424.6	904.6	63.7
4	Onion	495.6	22.9	472.7
5	Cucurbits	370.0	871.7	49.9

The maximum irrigation requirement was predicted for onion (472.7 mm) crop and minimum for Cucurbits (49.9 mm) among the vegetables (Table 6). While the data run in CROPWAT model and computed for crop water requirement, the maximum (670.3 mm) value was computed for Brinjal crop and minimum for Cucurbits (370.0 mm).

Table 8: Crop water requirement, Effective rainfall and Irrigation requirement of different vegetable crops for Ambikapur station of Northern Hills Zone

S. No.	Name of crop	WR/ETc(mm)	Effective rainfall (mm)	Irrigation requirement (mm)
1	Tomato	496.9	908.5	38.7
2	Brinjal	718.1	924.8	327.8
3	Peppers	476.9	868.6	65.8
4	Onion	496.6	67.2	429.4
5	Cucurbits	438.4	861.7	40.2

The data computed for Ambikapur station of Northern hills region, Onion (429.4 mm) crop required maximum irrigation requirement because of duration of cropping season (Table 8). The minimum irrigation requirement was computed for Tomato (38.7 mm) followed by Cucurbits (40.2 mm) at same station due to effective rainfall received in this region and crop season. The maximum (718.1 mm) crop water requirement was computed for Brinjal crop while minimum (438.4 mm) for Cucurbits.

Table 9: Crop water requirement, Effective rainfall and Irrigation requirement of different vegetable crops for Jashpur station of Northern Hills Zone

S. No.	Name of crop	WR/ETc(mm)	Effective rainfall (mm)	Irrigation requirement (mm)
1	Tomato	465.4	1162.7	27.3
2	Brinjal	662.7	1177.6	296.5
3	Peppers	462.2	1162.7	36.3
4	Onion	446.6	68.5	376.1
5	Cucurbits	413.2	1120	30.6

Maximum irrigation requirement was computed for onion crop (376.1 mm) and minimum for tomato crop (27.3 mm). The crop maximum crop water requirement was computed for Brinjal crop (662.7 mm) and minimum for Cucurbits crop (413.2). The date presented in table 9.

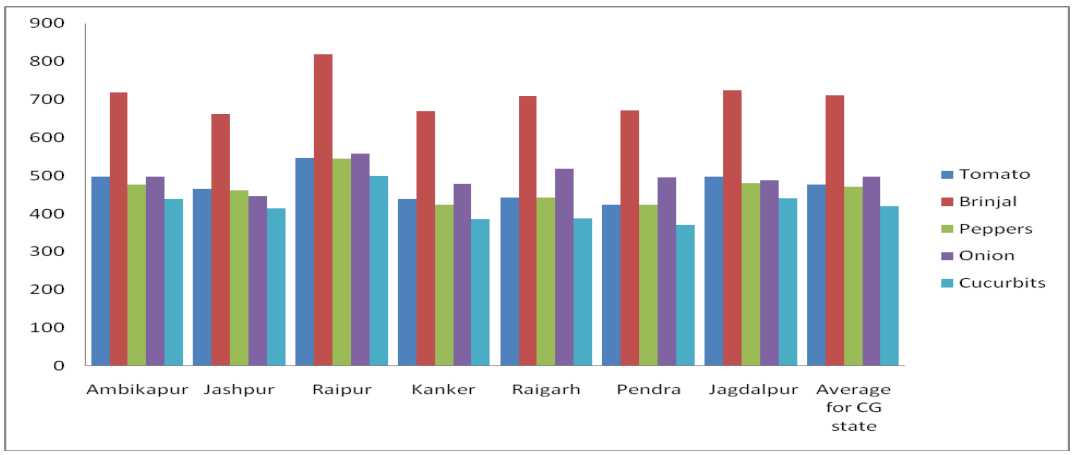
Crop water requirement of different vegetable crops generated through CROPWAT model and depicted in map with the help of GIS:

The ETc/crop water requirements of different selected locations of the three agroclimatic zones of Chhattisgarh were used as a representative of the different agroclimatic zones of Chhattisgarh i.e. Northern hills, Chhattisgarh plains and Bastar plateau (Plate 1). Crop water requirement of different vegetable crops (viz.:tomato, brinjal, peppers, onion and cucurbits.), three agroclimatic zones of the Chhattisgarh state have been depicted using geographical information system (GIS) on the basis of crop water requirement computed by CROPWAT model (Plate 1). The map generated through GIS software and data have been classified in four classes that were by default range provided by software.

The crop water requirement of different vegetables crops varies in different areas. Among vegetables crops, Brinjal crop needs about 818.3 mm of water in Raipur while it is 662.7 mm in Jashpur (fig. 2). For Tomato, crop water requirement was highest (546.3 mm) in Raipur, whereas it was lowest (424.4 mm) in Pendra of same region i.e. Chhattigarh plains (fig. 1). Similarly, for Pepper the crop water requirement was highest (543.7 mm) in Raipur while lowest (424.0 mm) in Pendra (fig. 3). In case of Onion, crop water requirement is highest (558.2 mm) in Raipur and lowest (446.6 mm) in Jashpur (fig. 4). For the Cucurbits, the crop water requirement of Raipur station was maximum (499.0 mm) and minimum at station Pendra (370.0 mm) (fig. 5).

From this investigation, it can readily be seen that, for a given crop type, crop water requirements were location specific owing to the marked variability in the agro-ecological characteristics of the study district. Seasonal vegetable crops (tomato, brinjal, peppers, onion and cucurbits) had different amounts of crop water requirement as per rainfall received during the season at different location. This finding corroborates result found by Kia (2013) and Husam (2011). The information obtained from this analysis will enhance understanding of crop water requirements which will consequently help improve the productivity of horticulture crops. The much longed-for attainment of stability in fruit crop production, reduction in poverty and general enhancement of horticulture productivity which are all Chhattisgarh's concern, may be achieved through policies based on these findings.

Plate 1: Evapotranspiration (ETc) / Crop water requirement (mm) of different vegetables crops for different centre and Chhattisgarh.



Conclusion

Results and analysis conclude the effect of climate on crop water requirement of vegetable crops different region of Chhattisgarh. There are rise in crop water requirement (ETc) as compare irrigation requirement (ETo) has been seen in this study. All vegetable crops (Tomato, Brinjal, Peppers, Onion and Cucurbits) shows rise in crop water requirement in all station of Chhattisgarh as compared to Effective rainfall.

It has been concluded from the results and analysis that in future years crop water requirement will increase in the study area. The reason for this may be due to climate change in future years, decreasing trend in average rainfall of the study area. Results of this study will be useful for policy makers and planners of water resources for the future planning of projects and suggest water saving techniques to satisfy increasing crop water requirement. These findings may also help achieve the potential for increased vegetable crop production in the arid and semi-arid areas of the country. There has been a growing need to quantify water use by various consumers with a view to apportioning the available water resources for use by the competing socio-economic sectors of the country. This calls for the formulation of appropriate policies to guide the use of the available water resources.

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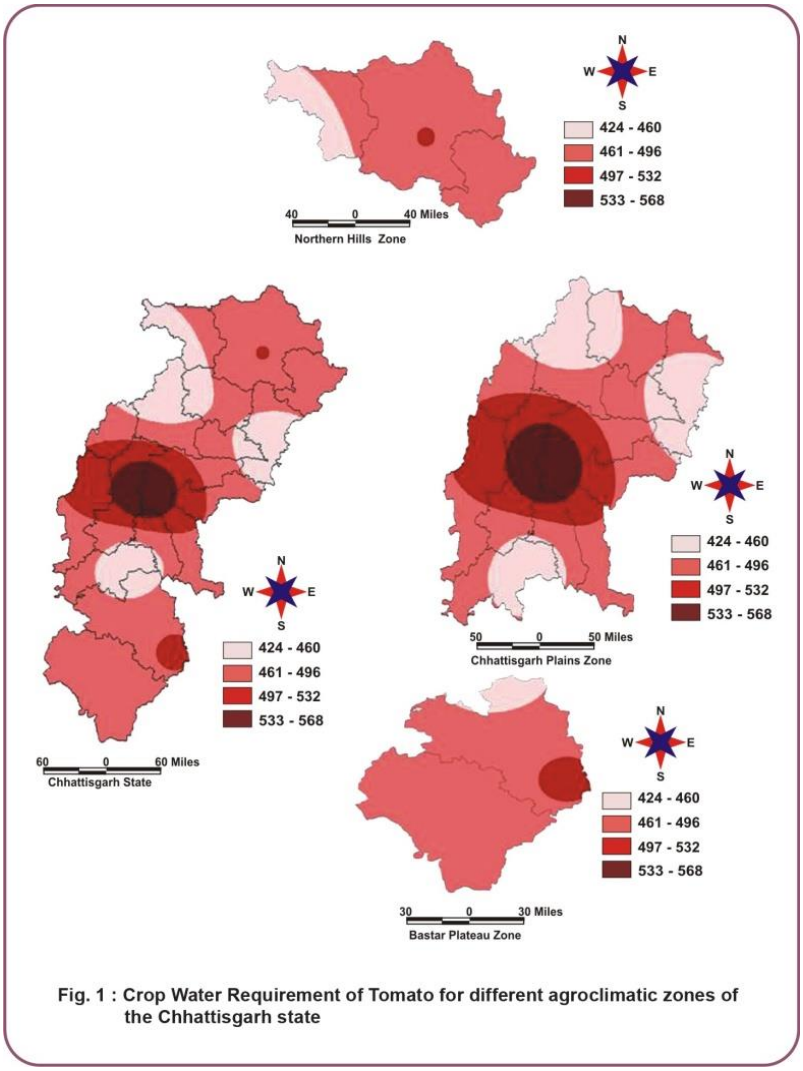


Fig. 1 : Crop Water Requirement of Tomato for different agroclimatic zones of the Chhattisgarh state

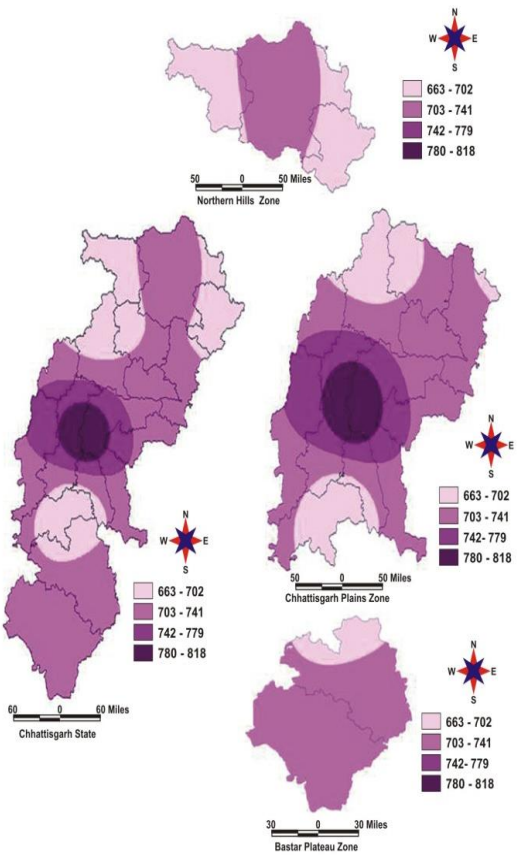


Fig. 2 : Crop Water Requirement of Brinjal for different agroclimatic zones of the Chhattisgarh state

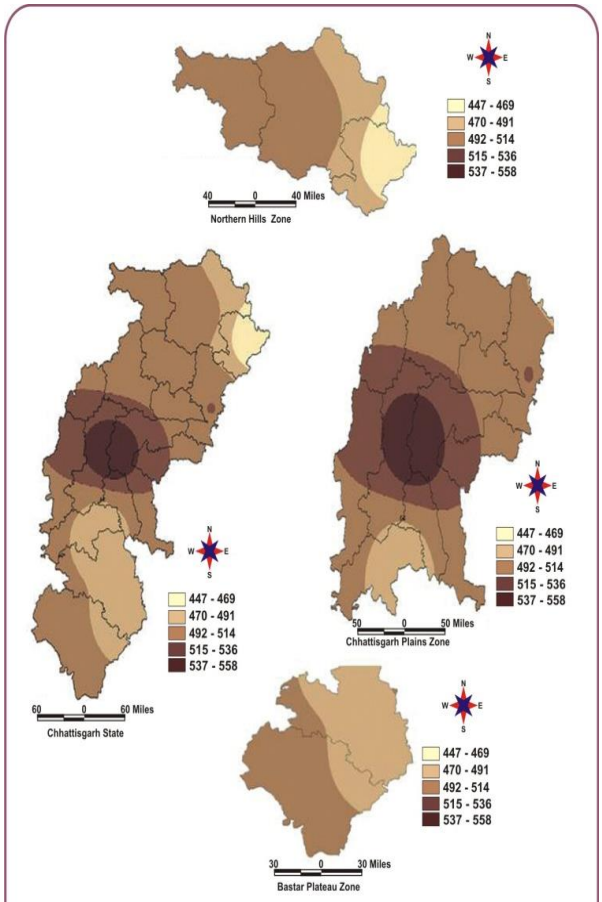


Fig. 4 : Crop Water Requirement of Onion for different agroclimatic zones of the Chhattisgarh state

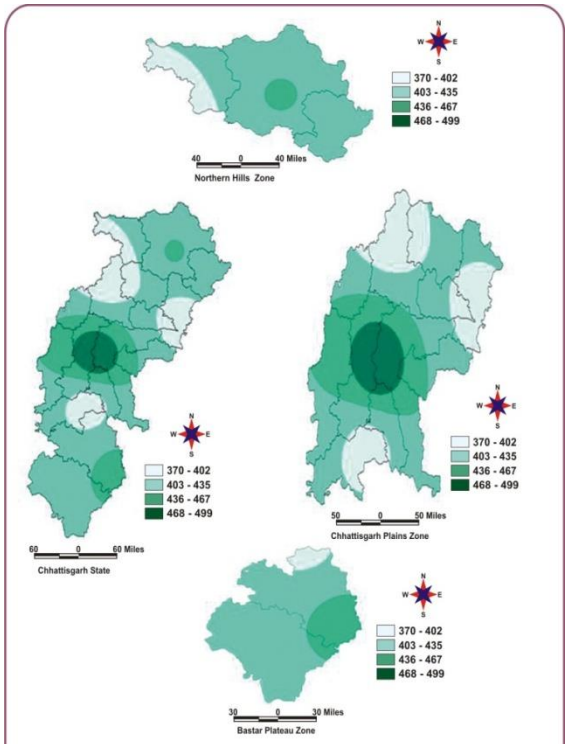


Fig. 5 : Crop Water Requirement of Cucurbits for different agroclimatic zones of the Chhattisgarh state

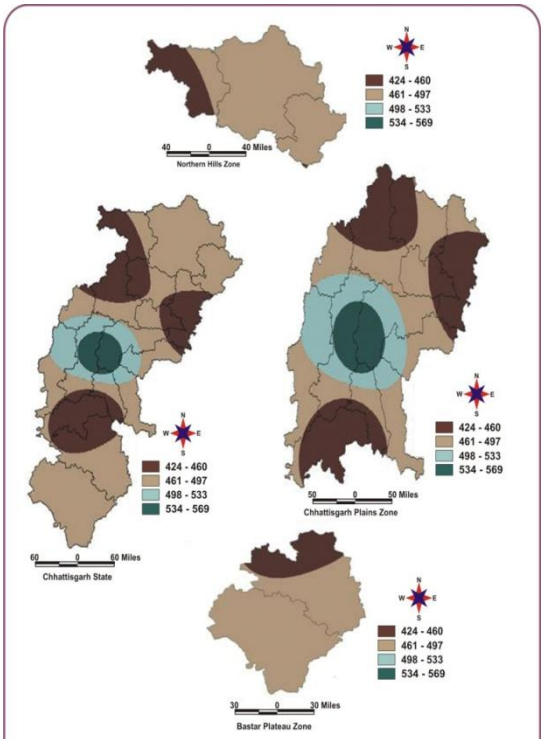


Fig. 3 : Crop Water Requirement of Pepper for different agroclimatic zones of the Chhattisgarh state

SPATIAL & TEMPORAL RAINFALL VARIATIONS IN DIFFERENT DISTRICTS OF CHHATTISGARH STATE

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Abstract

In Chhattisgarh state more than 90% of annual rainfall received during south-west monsoon (June-September). Mostly rice is cultivated in rain fed conditions, but the monsoon usually withdraws by mid September. As a consequence, the Annual rainfall analysis is showed decreasing trend in districts Kabirdham, Durg, Bastar from 1951-2000, whereas the increasing trend in districts Bilaspur, Durg and Janjgir Champa from 2001-2013. The variation of rainfall in recent years suggests for developing strategies for better water management practice for agricultural crops. The erratic distribution of rainfall, though the quantum of rainfall is high in these regions. These factors were discussed in detail with reference to alleviate the critical water scarcity situation in rain fed crop by improving need based planning like rain water harvesting technology, studies on micro regional climate variations and their causes need to be ascertained, Agricultural planner's & Policy maker's of prevention from drought,Spatial Identification of crop pattern & types of crops in different field in Chhattisgarh state.

Key Words: Rainfall Analysis, Rainfall Variation, Time Trend Series.

Introduction

The country is divided into 127 agro climatic zones according to frequency and quantum of rainfall & temperature in a region. The erratic behavior, uneven distribution and uncertainty of rainfall are responsible for creating drought and subsequently decreased production or crop failure under worst conditions. Chhattisgarh state situated in eastern part of India, has three *Agro climatic zones viz. Chhattisgarh plains, Bastar plateau* and *Northern hills region* (Baghel .S.S. and Sastri. A.S.R.A.S. 1992). Its climate is of dry sub humid type. The average annual rainfall is about 1400 mm which is largely contributed by south west monsoon receiving (about 90 percent rainfall during the period from June-September). The onset of monsoon is around 10th June in the southernmost tip of Bastar district and extends over the entire area by 25th June. The monsoon starts withdrawing from northern parts from mid September and by 25th September it is completely withdrawn from the entire area.

Material and Methods

The present study is confined to Chhattisgarh, a newly created state which came in to existence on November 1, 2000 as a result of bifurcation of the state of Madhya Pradesh. Chhattisgarh state, situated in eastern India, is located 17°41'N and 24°45'N latitudes 79°30'E and 84°15'E longitudes. It is surrounded in the west by Madhya Pradesh and Maharashtra, in the north by Madhya Pradesh, in the east by Orissa and Jharkhand (the new state separated from Bihar) and in the south by Andhra Pradesh. Chhattisgarh state spreading over a geographical area of 13.60 million hectares.The Monthly time series data base of each undivided station (districts) are in table 1. The monthly rainfall data for long term records

(1951-2013) were obtained from the Department of Agro meteorology, IGKV, Raipur which maintains a data bank as a part of its activity.

Table 1.The monthly rainfall data for long term records (1951-2013).

S.N.	Station	Data Base
Chhattisgarh plain zone		
1	Undivided Raipur	1951 – 2013
2	Raigarh	1951 – 2013
3	Korba	1951 – 2013
4	Undivided Bilaspur	1951 – 2013
5	Janjgir- Champa	1951 – 2013
6	Kabirdham	1951 – 2013
7	Rajnandgaon	1951 – 2013
8	Undivided Durg	1951 -2013
9	Mahasamund	1951 – 2013
10	Dhamtari	1951 – 2013
11	Kanker	1951 – 2013
Northen hill zone		
12	Jashpur	1971 – 2013
13	Korea	1974 – 2013
14	Undivided Surguja	1951 – 2013
Bastar plateau zone		
15	Bastar	1951 – 2013
16	Undivided Dantewada	1951 – 2013

Rainfall analysis: Here we discuss about two ways, which are,

1.Spatial variability

The basic data of rainfall i.e. i) Annual rainfall ii) Seasonal rainfall

2.Temporal variability

For analysis of temporal variability of rainfall at different districts, the monthly and annual rainfall data of 16 districts having long term records have been considered. For temporal analysis of rainfall, the time trend equations for each station for the entire database were analyzed. The *time trend equations* are regression equation where the X-values are years like (Raghavendra,V.K.1974)

Y=a+bx

Where,Y = Annual rainfall X = Years a = Intercept b = Slope

The slope indicates the trend of the rainfall over the study period.Either it is increasing or decreasing trend in mm/year.

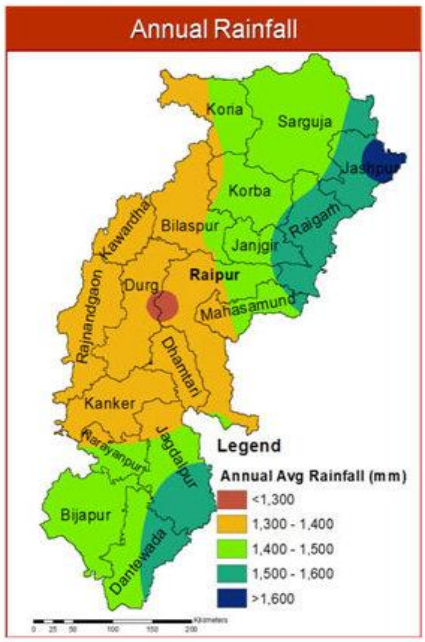


Fig.1 Annual average Rainfall of Chhattisagarh.

Results And Discussion

1.Rainfall characteristics

1.1 Annual Rainfall

The lowest rainfall is received in kabirdham district (1013.4mm) followed by Mahasamund (1104.7mm). The highest annual rainfall is in Jashpur (1594.0mm) followed by Bastar (1447.6 mm). The annual rainfall decreased from east to west. The annual rainfall in the eastern part of the state varies from 1300-1600mm. This covers Raigarh, Korba, Janjgir, Bastar, Dantewada and Surguja Districts.

1.2 Seasonal Rainfall

The lowest seasonal rainfall is received in Kabirdham (880.1 mm). The highest seasonal rainfall is in Jashpur (1351.8mm) followed by Raigarh (1211.0 mm) Korba (1194.5mm). The seasonal rainfall also follows the same trend of annual rainfall that is decreasing from both east to west and north to south.The districts with higher rainfall are in the east, which are Raigarh, and Jashpur having greater than 1200 mm. The lower rainfall districts are Kanker, Durg and Kabirdham in west. The middle part of state receives rainfall in between 1100-1200mm.

2. Rainfall variability

The district wise coefficient of variation of annual rainfall was also computed. There is a considerable spatial variability in the distribution of coefficient of variation in different districts of Chhattisgarh. The lowest coefficient of variation (%) of annual rainfall was observed in Bastar (17%) districts followed by Dantewada (20%) and Bilaspur (20.2%) districts. The highest coefficient of variation (%) of annual rainfall were observed in Mahasamund district (38.8%) followed by Rajnandgaon (32.4%) and Raigarh (30.9%) districts In remaining districts the coefficient of variation ranged from 20 to30 %.

2.1 Monthly rainfall variations during monsoon season.

In June, the average rainfall varied from 151.3mm (Min.:At Kabirdham) to 276.6mm (Max.:At Jashpur). Thus, the average rainfall during this month's decreasing from east to

west. The lowest coefficient of variation was observed at Bastar (46.2%) and the highest was in Raigarh (69.1%) district.

In July, the minimum average rainfall occurs at Kabirdham district with 289.5 mm and the maximum average rainfall was in Jashpur with 438.9mm. This month rainfall also follows the same trends of June rainfall that is decreasing from east to west. The lowest coefficient of variation (in %) for this month was observed at Bilaspur (29.2%) while, the highest was in Mahasamund (49.8%) followed by Kanker (46.4%) districts. The coefficient of variation of rainfall of this month is less when compared to June month.

In August, the maximum average rainfall was observed at Dantewada (413.1mm) followed by Raigarh (399.4mm) district. The minimum average rainfall in August was observed at Kabirdham (262.3mm). While the highest coefficient of variation (%) for this month was observed at Mahasamund (52.4%) and the lowest was in Bilaspur (29.2%) district.

In September, the minimum average rainfall was observed at Kabirdham (177.1mm) followed by Mahasamund (183.3mm).While the maximum was in Jashpur (264.9mm) district. The lowest coefficient of variation of rainfall was observed at Bastar (42.6%) and the highest coefficient of variation of rainfall was observed in Mahasamund (72.8%) districts.

With the above analysis, it was clear that the rainfall during monsoon months decreased from east to west in Chhattisgarh. The coefficient of variation of rainfall was high in month receiving maximum rainfall i.e July and August in Mahasamund district. The maximum amount of rainfall during monsoon month was received at Jashpur (1351.8mm) whereas, minimum was observed in Kawardha (880.1mm) district.

3. Rainfall trend equation

3.1 Rainfall trend based on annual rainfall (1951- 2000& 2001-2013)

In order to find out the districts where the rainfall variability was more pronounced, the decadal variability of annual rainfall in the sixteen district where long term rainfall records are available was analyzed and the time trend equations for 1951-2000 and recent decade at each station are table 2.

In Chhattisgarh plain zone: At Raipur, the rainfall was in decreasing trend with 3.89mm per year during the 1951-2000. In decade of 2001-2013, the trend of decadal rainfall is statically increasing. At Raigarh, during the period (1951-2000) the rainfall is increasing, where as the rainfall is decreasing with 6.94 mm/year in the recent decade i.e. 2001-2013. At Korba, during the period (1951-2000) there was increasing trend of rainfall, but from (2001-2013) there was decreasing in trend. At Bilaspur district, decreasing trends in rainfall in 1951-2000 with 1.07 mm/year was observed, but increasing trend with 11.04 mm/year rainfall during 2001-2013 were observed. At Janjgir Champa district, during the period of 1951-2000 decreasing trend of rainfall was observed, but the rainfall is in increasing trend in 2001-2013. At Kabirdham, the decreasing trend in rainfall was observed in the 1951-2000, but increasing trend in recent decade of 2001-2013 was found. At Rajnandgaon, the decreasing trend of rainfall in the 1951-2000, but increasing trend in recent decade of 2001-2013 were observed. At Durg, the decreasing trend of rainfall in during 1951-2000, but increasing trend in decade 2001-2013. At Mahasamund district, there was decreasing trends in rainfall during 1951-2000 with 22.06 mm/year, but increasing trend in 2001-2013 with 0.79 mm / year rainfall. At Dhamtari district, during 1951-2000, there was trend of decreasing rainfall, but increasing trend in recent 2001-2013 were found. At Kanker district, there was a decreasing trends in rainfall during 1951-2000, but increasing trend in 2001-2013.

In Northen hill zones: At Jashpur there was an increasing trend with 0.56 mm/year rainfall in 1971-2000, but decreasing trend with 45.69 mm/year in 2001-2013. At Surguja district, there was a decreasing trends with 0.026 mm/year rainfall in 1951-2000, also rainfall is in decreasing trend in 2001-2013. At Korea district; there was a decade with decreasing trends rainfall in 1974-2000, but increasing trend in 2001-2013. In Bastar Plateau zone: At Bastar district there was decreasing trends in rainfall in 1951-2000, also decreasing trend in 2001-2013. At Dantewada district, there was decreasing trends rainfall in 1951-2000, also decreasing trend in 2001-2013.

From the decadal analysis, it is clear that the rainfall trends have no relation either among the decades (temporal scale) or among the stations (spatial scale). Thus, it can be inferred that there were no patterns of rainfall trends, either spatial (or) temporal, in Chhattisgarh state. However it was observed that the rainfall trend in most of the districts of Chhattisgarh plain is increasing during recent decade, whereas the same for Northern hills and Bastar Plateau zone it is decreasing in recent decade.

3.2. Rainfall variability based on seasonal rainfall (1951-2000 & 2001-13)

The time trend equation for seasonal rainfall (June-september) for each station were worked out and are shown in table 3. In Chhattisgarh plain zone: At Raipur, the seasonal rainfall was in decreasing trend during the period 1951-2000. In recent decade of 2001-2013, the trend of seasonal rainfall was increasing trend. At Raigarh,the during 1951-2000, there was a decreasing rainfall trend with 39 mm/year(high) in seasonal rainfall,also seasonal rainfall is decreasing in recent decade of 2001-2013. At Korba, during 1951-2000 there was an increasing trend of seasonal rainfall, but from 2001-2013 there was a decreasing trend in seasonal rainfall with 20.24 mm/year was observed .At Bilaspur district, there was a decreasing trend in seasonal rainfall during 1951-2000 with 1.43 mm/year, which is further decreasing during 2001-2013 with 3.13 mm / year. At Janjgir Champa district, during 1951-2000, there was trend of decreasing seasonal rainfall with 1.38 mm/year, which is further decreasing during 2001-2013 with 2.867 mm/year rainfall. At Kabirdham, the decreasing trend in seasonal rainfall in the period 1951-2000 was observed, which is further decreasing trend in recent decade of 2001-2013 with 1.22 mm/year. At Rajnandgaon, the decreasing trend of rainfall in the 1951-2000, which is further decreasing trend in decade 2001-2013 with 0.453 mm/year rainfall. At Durg, the decreasing trend of seasonal rainfall in the decade 1951-2000, but the same is found increasing trend in decade 2001-2013. At Mahasamund district, there was a period with decreasing seasonal rainfall trends in 1951-2000, but the same is increasing trend in 2001-2013. At Dhamtari district, during 1951-2000, there was trend of decreasing seasonal rainfall, which is further decreasing trend with 1.46 mm/year in 2001-2013. At Kanker district, there was a period (1951-2000) with decreasing trends in seasonal rainfall, but the same is found in increasing trend in 2001-2013.

In Northen Hill zone: At Jashpur there was a period with decreasing trends of seasonal rainfall with 0.011mm/year in 1971-2000, which is further found decreasing during 2001-2013. At Surguja district, there was a period with decreasing trends with 0.648 mm/year during 1951-2000, which again found decreasing with 21.29 mm/year rainfall in 2001-2013. At Korea district, there was a period with decreasing trends in seasonal rainfall during 1974-2000, which started increasing during 2001-2013.

In Bastar Plateau zone: At Bastar district, there was a period with decreasing trends in seasonal rainfall in 1951-2000, which is again found decreasing trend in 2001-2013. At Dantewada district, there was a period with decreasing trends with 1.631 mm/year rainfall in 1951-2000 which continues to decrease in 2001-2013.

3.3 Rainfall fluctuations

For examining the trends in term of Rainfall fluctuation for all the districts based on the entire data base was computed. The Rainfall fluctuations in all the districts for the period 1951-2013, were studied as shown in fig. The results of Rainfall fluctuation are follows: At Raipur, the rainfall was decreasing @ 3.89mm per year during 1951-2000. At Raigarh, during 1951-2000, there was trend of decreasing rainfall, which is again decreasing @6.94 mm /year rainfall in decade of 2001-

2013. At Korba, during 1951-2000 there was an increasing trend of rainfall, but from 2001-2013, it was decreasing. At Bilaspur district, there was a decreasing trends in rainfall in 1951-2000 with 1.07 mm/year, but increasing trend with 11.04 mm / year rainfall in 2001-2013. At Janjgir Champa district, during 1951-2000, there was trend of decreasing rainfall, but increasing trend in 2001-2013. At Kabirdham, the decreasing trend in rainfall during 1951-2000, but increasing trend in decade of 2001-2013. At Rajnandgaon, the decreasing trend of rainfall during 1951-2000, but increasing trend in decade 2001-2013. At Durg, the decreasing trend of rainfall during 1951-2000, but increasing trend in decade 2001-2013. At Mahasamund district, there was a decreasing trend in rainfall during 1951-2000 @ 22.06 mm/year, but increasing trend in 2001-2013 with 0.79 mm/year rainfall. At Dhamtari district, during 1951-2000, there was trend of decreasing rainfall, but increasing trend in 2001-2013. At Kanker district, there was a decreasing trend in rainfall in 1951-2000, but increasing trend in 2001-2013.

In Northen Hill zones: At Jashpur there was a decade with increasing trends with 0.56 mm/year rainfall in 1971-2000, but decreasing trend with 45.69 mm/year in 2001-2013. At Surguja district, there was a decade with decreasing trends with 0.026 mm/year rainfall in 1951-2000, also decreasing trend in 2001-2013. At Korea District; there was a period with decreasing trends rainfall in 1974-2000, but increasing trend in 2001-2013.

Stations	Period	Annual Rainfall		
Chhattisgarh plain zone				
		Trend line equation	Signaure	R^2
Raipur	1951 - 2000 2001– 2013	y = -3.839x + 1345 y = 17.06x + 1074	Decrease Increase	R^2 = 0.031 R^2 = 0.101
Raigarh	1951 - 2000 2001– 2013	y = -19.09x + 1856 y = -6.949x + 1325	Decrease Decrease	R^2 = 0.381 R^2 = 0.011
Korba	1951– 2000 2001 - 2013	y = 1.170x + 1377 y = -12.46x + 1317	Increase Decrease	R^2 = 0.003 R^2 = 0.026
Bilaspur	1951 - 2000 2001 - 2013	y = -1.076x + 12 y = 11.04x + 1104	Decrease Increase	R^2 = 0.003 R^2 = 0.044
Janjgir champa	1951 - 2000 2001 - 2013	y = -1.626x + 1318 y = 8.852x + 1168	Decrease Increase	R^2 = 0.008 R^2 = 0.041
Kabirdham	1951 - 2000 2001 - 2013	y = -5.003x + 1173 y = 16.77x + 767.8	Decrease Increase	R^2 = 0.064 R^2 = 0.121
Rajnandgaon	1951 -	y = -8.714x + 1542	Decrease	R^2 = 0.084

	2000 2001 - 2013	y = 1.931x + 1100	Increase	R^2 = 0.000
Durg	1951 - 2000 2001 - 2013	y = -5.584x + 1255 y = 14.94x + 999.2	Decrease Increase	R^2 = 0.063 R^2 = 0.057
Mahasamund	1951 - 2000 2001 - 2013	y= -22.06x+1613 y = 0.179x + 1309	Decrease Increase	R^2 = 0.525 R^2 =6E-06
Dhamtari	1951 - 2000 2001 - 2013	y = -7.142x + 1307 y = 7.891x + 1084	Decrease Increase	R^2 = 0.120 R^2 = 0.018
Kanker	1951 - 2000 2001 - 2013	y = -7.828x + 1414 y = 5.118x + 1071	Decrease Increase	R^2 = 0.157 R^2 = 0.002
Northen hill zone				
Jashpur	1971 - 2000 2001 - 2013	y = 0.561x + 1666 y =-45.69x +1727	Increase Decrease	R^2 = 0.000 R^2 = 0.177
Korea	1974 - 2000 2001 - 2013	y = -1.251x + 1208 y = 1.673x + 1251	Decrease Increase	R^2 = 0.001 R^2 = 0.000
Surguja	1951 - 2000 2001– 2013	y = -0.026x + 1396 y = -21.29x + 1076	Decrease Decrease	R^2= 1E-06 R^2 = 0.108
Bastar plateau zone				
Bastar	1951 - 2000 2001 - 2013	y = -4.428x + 1569 y = -6.012x + 1456.	Decrease Decrease	R^2 = 0.067 R^2 = 0.008
Dantewada	1951 - 2000 2001 - 2013	y = -4.282x + 1409. y = -7.314x + 1333	Decrease Decrease	R^2 = 0.083 R^2 = 0.009

Table 2: Time trend equations of annual rainfall during the period 1951-2000 and 2001-2013 for different districts of Chhattisgarh.

Station	Data	Seasonal		
Chhattisgarh plain zone				
		Trend equation	Signature	R^2
Raipur	1951 – 2000 2001 - 2013	y= - 4.305x + 1193 y = 21.89x + 910.9	Decrease Increase	R^2 = 0.041 R^2 = 0.196
Raigarh	1951 - 2000 2001 - 2013	y = -19.46x + 1716 y = -15.90x + 1288	Decrease Decrease	R^2 = 0.436 R^2 = 0.087
Korba	1951 - 2000 2001 - 2013	y = 1.355x + 1170 y = -20.24x + 1295	Increase Decrease	R^2 = 0.004 R^2 = 0.077
Bilaspur	1951 - 2000 2001 - 2013	y = -1.434x + 1101 y = -3.131x + 1049	Decrease Decrease	R^2 = 0.008 R^2 = 0.006
Janjgir champa	1951 - 2000 2001 - 2013	y = -1.389x + 1193 y = -2.867x + 1145	Decrease Decrease	R^2 = 0.006 R^2 = 0.004
Kabirdham	1951 - 2000 2001 - 2013	y = -5.853x + 1049 y = -1.228x + 812.4	Decrease Decrease	R^2 = 0.096 R^2 = 0.000
Rajnandgaon	1951 - 2000 2001 - 2013	y = -9.034x + 1396 y = -0.453x + 1018	Decrease Decrease	R^2 = 0.112 R^2 =6E-05
Durg	1951 - 2000 2001 - 2013	y = -4.940x + 1107 .y = 7.523x + 973.9	Decrease Increase	R^2 = 0.065 R^2 = 0.019
Mahasamund	1951 - 2000 2001 - 2013	y = -18.90x + 1427 y = 0.312x + 1222	Decrease Increase	R^2 = 0.502 R^2= 2E-05
Dhamtari	1951 - 2000 2001 - 2013	y = -5.563x + 1145 y =-1.461x + 1033	Decrease Decrease	R^2 = 0.090 R^2 = 0.000
Kanker	1951 - 2000 2001 - 2013	y = -4.922x + 1192 y = 5.118x + 1071	Decrease Increase	R^2 = 0.065 R^2 = 0.002
Northen hill zone				
Jashpur	1971 - 2000 2001 - 2013	y = -0.011x + 1407 y = -39.49x + 1499	Decrease Decrease	R^2 =1E-07 R^2 = 0.186
Korea	1974 - 2000 2001 - 2013	y = -3.583x + 1147 y = -5.867x + 1208	Decrease Decrease	R^2 = 0.009 R^2 = 0.005
Surguja	1951 - 2000 2001 - 2013	y = -0.648x + 1246 y = -21.29x + 1076	Decrease Decrease	R^2 = 0.000 R^2 = 0.108
Bastar plateau zone				
Bastar	1951 - 2000 2001 - 2013	y = -4.429x + 1279 y = -4.429x + 1279	Decrease Decrease	R^2 = 0.096 R^2 = 0.096
Dantewada	1951 - 2000 2001 - 2013	y = -1.631x + 1205 y = 3.603x + 1201	Decrease Increase	R^2= 0.013 R^2= 0.002

Table 3: Time trend equations of seasonal rainfall during the period 1951-2000 & 2001-2013 for different districts of Chhattisgarh.

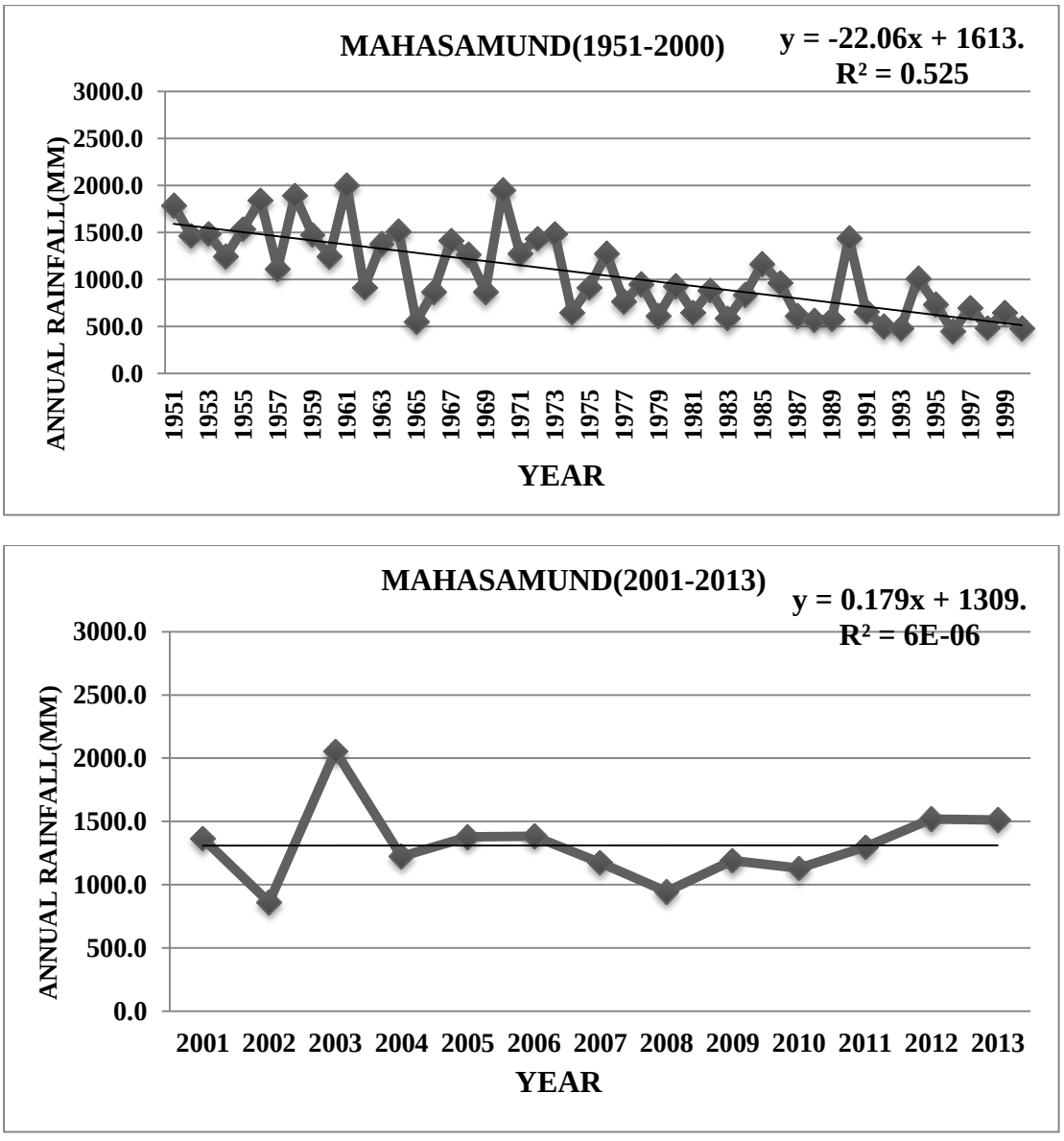


Fig. 2: Rainfall Trend Series of Mahasamund Districts from 1951- 2013.

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REMOTE SENSING AND GIS BASED CATCHMENT AREA TREATMENT PLAN FOR SOIL CONSERVATION MEASURES

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Abstract

The fast growing development and ignorance of catchment area treatment plan during and after implementation of water resource project accelerating rate of sedimentation and disturbing the ecological balance in reservoirs and watersheds. The scientifically developed catchment area treatment plan identifies environmentally stressed areas, necessity and intensity of mechanical and biological measures to arrest further soil erosion and selection of spatial distributed locations of appropriate soil conservation measures. The Saaty's analytical hierarchal process (AHP) based multi-criteria decision making tool based on nine spatially distributed erosion hazard parameters (EHPs) was applied for identification of priority sub-watersheds. Various thematic layers such as geology, land use, soil, slope, drainage, geomorphology in weighted overlay technique (WOT) with decision rules were used to identify suitable sites for mechanical structures and areas for agronomic and biological measures of soil conservation. The Kodar reservoir is situated on river Kodar, a tributary of river Mahanadi in Chhattisgarh state of India has been selected for the study and divided in sixty seven sub-watersheds where nine EHPs were estimated and participated in Saaty's AHP tool for identification of priority sub-watersheds. From the analysis, 117 km^2 area of Kodar catchment can be put for intensify soil conservation measures because of high and very high priorities. The CAT plan for Kodar catchment consists of 37 gully plugs, 22 nala plugs, 21 boulder bunds and 6 check dams under mechanical measures with 101.61 ha land for afforestation, 114.86 ha for agro-forestry and 11.41 ha land for development of grazing land under biological measures. Under Panchayati rules in India, the gram panchayats are considered the administrative units for implementation of various conservation works and the areas of various agronomic and biological measures and mechanical structures suggested for different gram panchayats will be helpful for local administration to work in better way.

Key words: *analytical hierarchal process (AHP); CAT plan; geomorphology; prioritization; soil loss*

Introduction

The soil erosion in catchment areas and the subsequent deposition in rivers, lakes and reservoirs are of great concern for two reasons. Firstly, rich fertile soil is eroded from the catchment areas. Secondly, there is a reduction in reservoir capacity as well as degradation of downstream water quality. Soil being one of the potential resources of a watershed demands proper conservation and management and it could only be possible if its degree of degradation is assessed properly. The catchments and watersheds have been identified as the planning units for administrative purpose to conserve soil and water resources in CAT plan (FAO, 1985; 1987; Honore, 1999; Khan, 1999). The catchment area treatment plan pertains to preparation of a management plan for treatment of erosion prone area of the catchment through agronomic, bioligical and mechanical measures. A well

designed CAT plan should not only control the sedimentation of the reservoir but also provide a life support system to the local population through their active involvement in soil conservation and livelihood works (Jaiswal et al, 2014a). The development of CAT plan for a watershed or catchment essentially comprises the prioritization of erosion prone sub-watersheds or areas, selection of suitable conservation measures, implementation and impact assessment (Jaiswal et al, 2012).

The prioritization of watershed helps in taking up soil conservation measures on the priority basis. Jain and Goel (2002) suggested an index based approach based on surface factor including soil type, vegetation, slope and various catchment properties such as drainage density, form factor, etc for watershed prioritization. Panda et al. (2005) and Shinde et al. (2010) described soil conservation planning methods on the basis of the quantified soil erosion rate in different catchments. The soil erosion rate was determined as a function of land topography, soil texture, land use/land cover, rainfall erosivity and crop management and practice in the watershed using the Universal Soil Loss Equation (for Indian conditions), remote sensing imagery, and GIS. Khan et al. (2001) used sediment yield index (SYI) for priority watershed delineation with the objective of selecting watersheds to undertake soil and water conservation measures using remote sensing and Geographical Information System (GIS) techniques. Vittala et al. (2004), Chopra et al. (2005), Hlaing et al (2008), Sharma et al. (2010), Akram et. Al, 2009, Mishra and Nagarajan (2010) and several others used geomorphological characteristics such as stream order, stream length, stream frequency, drainage density, texture ratio, farm factor, circulatory ratio, elongation ratio, bifurcation ratio and compactness ratio for prioritization of sub-watersheds in different watersheds in India. The remote sensing and Geographical System (GIS) have been found very useful in the field of CAT development and prioritization of sub-watersheds by coupling spatial information on various soil erosion parameters and natural resource conservation. The remotely sensed data has the advantage of providing synoptic view and large area coverage, which impart knowledge about conditions of the earth surface that change over the period of time. GIS has held in making a number of useful suggestions for the development of the watershed. It allows variety of manipulation including map measurement; map overlay transformation, graphic design and database management etc. Shrimali et al. (2001) presented mapping, monitoring and prioritizing the areas based on their susceptibility to degradation using remote sensing and GIS. Remote sensing and Geographic Information Systems are effective tools for inventory, monitoring and management of spatially distributed resources. Recent studies revealed that remote sensing and GIS techniques are of great use in characterization and prioritization of watershed areas (Pandey et al., 2007; Yoshino and Ishioka, 2005; Chowdhary et al., 2004; Sharma et al., 2001; Khan et al., 2001; Sidhu et al., 1998).

An effective CAT plan of a water resources project is a key factor to make the project eco-friendly and sustainable. Tyagi and Joshi (1994) developed catchment area treatment plan for Himalayan region and suggested contour bunding, graded bunding, bench terracing, strip cropping and mixed cropping for soil conservation. Pandey et al. (2007) divided Karso watershed of Hazaribagh, Jharkhand (India) into 200 × 200 m grid cells and average annual sediment yields were estimated for each cell of the watershed to identify the critically prone areas of watershed for development of CAT plan. In the present study, based on prioritization results of Saaty's analytical hierarchical process (AHP), spatial distribution of agronomic and biological measures and site specific mechanical measures were identified for Kodar reservoir catchment in Chhattisgarh state of India.

Study Area

The Kodar reservoir is constructed across river Kodar, a tributary of river Mahanadi. The dam is constructed on Raipur – Sambalpur national highway at a distance of 65 km

from Raipur near village Kowajhar in Mahasamund district. The base map showing location of Kodar reservoir has been given in Fig 1. The catchment area of the river up to dam site is 317.17 km2. and mean annual rainfall in the catchment area is about 1433.1 mm. The dead storage capacity and gross storage capacity of reservoir are 11.33 Mm3 and 160.35 Mm3 respectively. The Kodar dam is an earthen dam of 2363 m length, height of 23.32 m and waste weir of 183m long to pass designed flood and head regulators on both the flanks to feed the canal system. Two canals of length 23.30 km (Left Bank Canal) and 10.60 km (Right Bank Canal) are envisaged from the sluices located on left and right flanks of the earthen dam to provide irrigation to 16,066 ha and 7,406 ha respectively. The topography of the catchment area of Kodar reservoir is undulating, soil is loamy type and most of area is under agriculture from where soil loss is more due to lack of conservation measures.

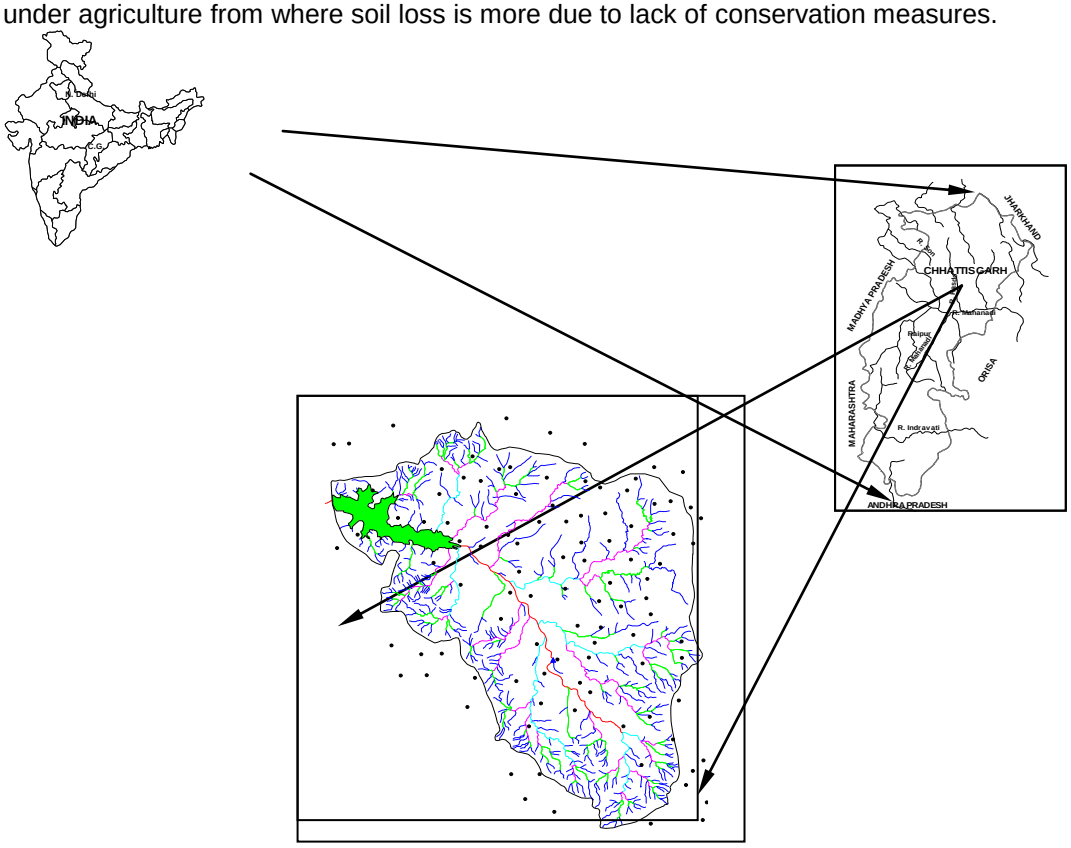


Fig. 1.Base map of Kodar reservoir in Chhattisgarh (India).

Methodology

The methodology for preparation of management plan based on scientific inputs and knowledge base consist of prioritization of sub-watersheds based on multiple erosion hazard parameters under Saaty's AHP decision support tool and devise areas suitable for soil conservation measures based on weighted overlay technique in GIS environment.

Identification of priority sub-watersheds

The Saaty's AHP has been applied which is a structured technique to deal with complex decision by building a hierarchy (ranking) among decision elements and then making comparisons between each pair in each cluster (matrix). This gives a weighting for

each element within a cluster (or level of the hierarchy) and also a consistency ratio (useful for checking the consistency of the data). The AHP helps capture both subjective and objective evaluation measures, providing a useful mechanism for checking the consistency of the evaluation measures and alternatives suggested by the team thus reducing bias in decision making. The AHP is very useful when the decision-making process is complex, for instance, by being unstructured. Indeed, when the decision cycle involves taking into account a variety of multiple criteria which rating is based on a multiple-value choice, AHP splits the overall problem to solve into as many evaluations of lesser importance, while keeping at the same time their part in the global decision. The steps for applying AHP include decomposing, weighing, evaluating and selection. In the present study, nine spatially distributed erosion hazard parameters including soil based on topography, geomorphology, soil loss and yield criterions were used and weigh in AHP for determination of relative hazard ultimately provided priority sub-watersheds. The details regarding AHP based prioritization can be seen in different literature (Ranjan, 2013; Jaiswal et al 2014b)

Development of Catchment Area Treatment Plan

The drainage line treatment is very important and most relevant aspect in CAT plan for arresting the soil erosion and checking the velocity of runoff, harnessing the rainwater lost through drains and impounding them through various soil and water conservation measures would result in improving the water resources of an area. The soil and water conservation measures required in CAT plan can be classified in to three broad groups as, mechanical measures, agronomic measures and biological measures being described below:

The mechanical measures of soil and water conservation include various engineering techniques and structures constructed across the direction of the flow of rainwater with the objective of division of long slopes in to a series of shorter ones in order to reduce the velocity of runoff water thereby reduce the soil and water losses. The important mechanical measures are check dams, gully plugs, boulder bunds, percolation tanks, farm ponds, bench terracing, contour bunding, graded bunding, land levelling etc. The agronomic measures of soil and water conservation help in reducing the impact of raindrops through interception and thus reduce splash erosion. These practices also help in increasing infiltration rate and thereby reduce runoff and overland flow. The contour farming, strip cropping, vegetative barriers, grassed waterways, mulching etc are some of important agronomic measures. The biological measures are preferred in catchment area treatment plan as they are eco- friendly, sustainable and cost effective. The underlying principle here is that soil erodes only if it is bare and expose to erosive forces and if the soil can be kept under a permanent or near-permanent cover of vegetation, then little or no erosion will occur. The agroforestry, grazing management, affroestation, reforestation etc .are some of the important biological measure in CAT plan.

The CAT plan was prepared by weighted overlaying technique of spatially distributed maps using ARC GIS software. The land use map obtained from digital image analysis of LISS IV RS data, soil, geology, geomorphology, slope and sub-watershed themes were built as raster features, whereas streams and roads were built as line features. All the thematic maps were overlaid in GIS environment by giving suitable weights and appropriate conservation measures along with sites for mechanical measures have been identified using the criterions given in Table 1. The slope, land use and soil map were joined spatially and all combinations were examined for suitability of various agronomic and biological measures considering different combination of soil and slope for agriculture land. After this a separate column has been added and suitable conservation measures given in the column. The map generated from this column can be used for identification of areas for

agronomic measures for agricultural land and biological measures for barren and open forest.

Table 1. Criteria adopted in suggesting soil and water conservation measures

Structure	Slope (%)	Drainage	Soil	Land use/ Land cover	Geomorphological land form	Advantage
Bench Terracing	6-10%	_	Shallow Soil not having permeability	Agriculture Field	Steep slope, low rainfall	Uniform impounding of water, Reduced the existing steep slope to mild slope.
Contour Farming	2-10%	_	Alluvial and black deep lateritic soils	Agriculture Field	Area where runoff is 10% of precipitation lower point of natural Depressions	Prevention of soil erosion, increased supply of moisture to the plant, control flash floods
Strip Cropping	< 3	_	All type	Agriculture Field	Gently sloping land	Shortening length of slope , reducing velocity of runoff,
Land leveling	any slope	_	Non Shallow Soil		Agricultural Land with rainfall	Reduce the velocity of water, reduced the chance of soil erosion
Check dam	more than 3%	3rd order & higher stream	Sandy Gravel zone	waste land on either bank, forest land	Buried pediment	Surface water harvesting life irrigation, Drinking water facility, partially recharges structure.
Vegetative barriers	Perpendicular to the dominant slope less than 10%	_	All type	Agriculture Land	On crop land fields where water or wind erosion is a problem, or where water to be needs conserved.	Facilitate benching of sloping topography, reduced surface runoff, divert runoff to a stable outlet, provide wildlife habitat
Farm Pond	1-2%	_	Semi Pervious to impervious, All soil	Single crop area	Area where runoff is 10% of precipitation lower point of natural depressions.	Life saving irrigation , drinking water for live stock horticulture development recharge to ground water

			except in light textured soils			
Boulder Bund	2-3%	1st to 3nd	severe soil erosion semi pervious to pervious	Single crop area	Buried pediment (M),Buried pediment (S),Buried pediplain, pediment	Soil conservation runoff retardant, delay recharge of water, Recharge to ground water.
Gully Plug	2-3%	1st to 2nd	Soil erosion	Forest and waste land	pediment, Buried pediment (S)	Soil conservation runoff retardant structure's soil moisture, recharge to ground water.
Percolation tank	2-3 %	3rd to 4th	Semi pervious to pervious	waste land	Buried pediment fractured and weathered rock zone	Induced artificial drinking water, well in downstream.
Contour Bund	1-6%	_	All type except deep clayey soils	Agricultural land	steep slope, low rainfall	Reduced soil loss, increase infiltration time, reduced velocity of flow
Graded Bunding	0.1-0.4%	_	Clay soil even with lesser rainfall	Agricultural land	on crop land fields where water or wind erosion is a problem as where water to be needs conserved	Acts primarily as drainage channels for reducing and regulating the excess runoff water and draining the same with a mild and non erosive velocity.

Analysis of Results

Assessment of Priority Sub-watersheds

For prioritization purposes, the whole Kodar catchment has been divided into sixty seven sub-watersheds with area ranging from 0.05 sq. km. to 13.05 sq. km. In the present study, spatial distribution of all selected EHPs including soil loss using USLE/RUSLE model, sediment production rate, sediment yield, sediment transport index or sediment transport index, slope, drainage density, channel frequency, form factor and circulatory ratio for all 67 sub-watersheds in Kodar reservoir catchment have been computed and converted to its normalized value. Considering the relative importance of each parameter on others, the priority matrix and subsequently the weights for each parameters using Saaty's AHP have been computed. The soil loss being the most important parameter got weight of 0.33 while circulatory ratio attained minimum weight of 0.02 in Satty's AHP decision tool (NIH, 2013). The final priority for each watershed was determined as a product of multiplication of priority weights and normalized values of all parameters for categorization in various groups including very high, high, moderate, low and very low priority groups. The sub-watershed map and its priority of Kodar catchment has been given in Fig. 2 and areas under different priorities in Table 2.

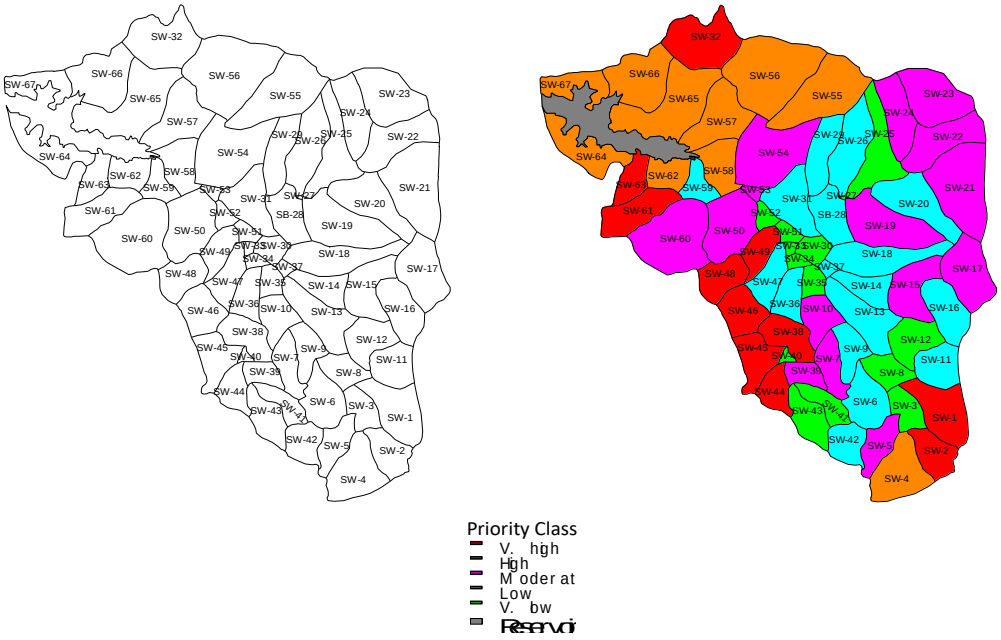


Fig. 2.Sub division of watershed and priority sub-watersheds in Kodar reservoir catchment

Table 2. Sub-watersheds under different priorities in Kodar catchment

S.N.	Priority Class	Rang of priorit	Watershed	No. of watershed	Total (sq. m)
1.	V. low	Less than 0.17	SW-3, SW-8, SW-12, SW-25, SW-27,SW-30, SW-33, SW-34, SW-35, SW-40, SW-41, SW-43, SW-51 and SW-52	14	29.00
2.	Low	0.20 to 0.17	SW-6, SW-9, SW-11, SW-13, SW-14, SW-16, SW-18, SW-20, SW-26, SW-28, SW-29, SW-31, SW-36, SW-37, SW-42, SW-47 and SW-59	17	72.11
3.	Modera	0.25 to 0.20	SW-5, SW-7, SW-10, SW-15, SW-17, SW-19, SW-21, SW-22, SW-23, SW-24, SW-39, SW-50, SW-53, SW-54 and SW-60	15	88.75
4.	High	0.30 to 0.25	SW-4, SW-55, SW-56, SW-57, SW-58, SW-62, SW-64, SW-65, SW-66 and SW-67	10	70.03
5.	V. high	Up to 0.30	SW-1, SW-2, SW -32, SW-38, SW-44, SW-45, SW -46, SW-48, SW-49, SW -61 and SW-63	11	47.81
6.	Total area				307.71

CAT Plan

The CAT plan for the Kodar catchment has been designed by crossing of landuse, soil, slope and geomorphology maps. The standard guidelines have been used for demarcation of areas suitable for agronomic and biological measure. The spatial join of tables was used to determine suitable areas under different gram panchayats in the study area. The mechanical measures in the catchment have also been suggested including check dams, gully plug, nala plugs and boulder bunds considering suitable criterions on drainage lines. The map showing CAT plan of the study area consisting of suitable areas for agronomic and biological soil conservation measures and location of mechanical measures have been given in Fig. 3. The CAT plan suggests 101.61 ha land for afforestation, 114.86 ha for agro-forestry and 11.41 ha land for development of grazing land with 37 gully plugs, 22 nala plugs, 21 boulder bunds and 6 check dams in Kodar catchment. The agronomic measures should be used in all agriculture fields. The gram panchayat wise suggested areas for soil conservation measures will be useful for local administration for implementation of CAT plan.

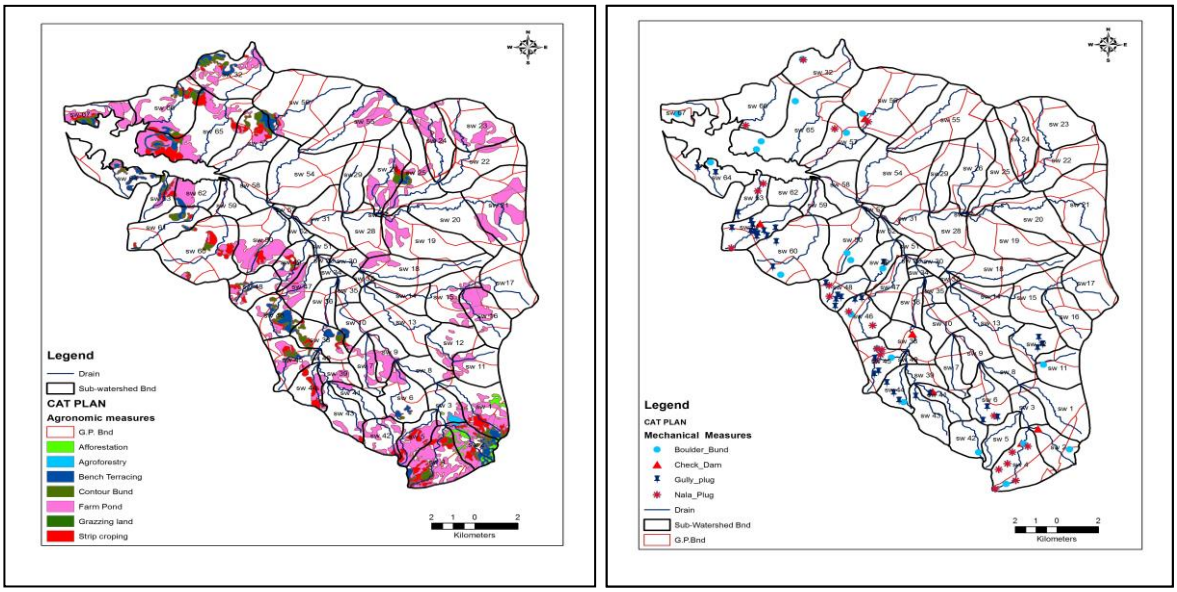


Fig. 3. Areas for agronomic and biological measures and sites for mechanical structure

Conclusions

For development of CAT plan for environmentally stressed areas in Kodar reservoir, various thematic layers such as geology, land use, soil, slope, drainage, geomorphology have been used for selection of soil and water conservation measures in sub-watersheds of Kodar reservoir catchments. It may be concluded that nearly 41 sq. km area in Kodar catchment is suitable for farm ponds. The CAT plan suggests 101.61 ha land can be used for afforestation, 114.86 ha for agro-forestry and 11.41 ha land for development of grazing land which will be beneficial for rural population for their additional income and environmental health of the watershed. The mechanical measure under the CAT plan of Kodar reservoir catchment includes 37 gully plugs, 22 nala plugs, 21 boulder bunds and 6 check dams. Gram panchayats break up of agronomic, biological and mechanical measures have been provided in the study will be useful for administrative authority to take up these measures systematically. The design of check dams provided in the report will be helpful to implement agencies for cost estimation and construction. It is recommended that the participation of local governance, rural development organizations and local people should be ensured in the implementation of CAT plan. The awareness regarding agronomic and biological measures should be developed among the farmers by local level awareness program.

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MORPHOMETRIC ANALYSIS OF A SEONATH RIVER OF CHHATTISGARH USING REMOTE SENSING ANDGEOGRAPHICAL INFORMATION SYSTEM (GIS) TECHNIQUE

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Abstract

The delineation of drainage system is importance in understanding hydrological system of an area, water resource management and it's planning in an effective manner. Remote sensing, Geographical Information System has proved to be an efficient tool in delineation of drainage pattern and water resources management and it's planning. The study has demonstrated the potential use of remotely sensed data and Geographical Information Systems (GIS) in evaluation of linear, relief and areal morphometric parameters of Seonath river. Strahler's method of stream ordering is the most commonly used method has been followed for the present study. The Seonath river covers an area of about 30868 sq km and is 7th order drainage basin with mainly dendritic drainage pattern. The numbers of lower order streams are more than the higher order streams and the bifurcation ratio of the study area was low value. The low values of bifurcation ratio indicate that the drainage of the basin has sufferedless structural disturbances and drainage pattern has been distorted. The basin has low drainage density of 0.49km^{-1} and is elongated in shape. Stream length decreases with the order increases and the length of overland flow values of the basin was 0.25.

Keywords: Morphometric, Surface drainage networks, GIS, Linear aspects, Relief aspects, Arial aspects.

Introduction

Morphometric analysis is refers as the quantitative evaluation of form characteristics of the earth surface and any landform unit. Drainage network architecture in a basin is an expression of the surface water hydrological characteristics, and it is function of the climate, geology and relief of the basin (Odi Reddy *et al.,* 2004; Pakhmode, *et al.,* 2003). The composition of the stream system of a drainage basin is expressed quantitatively with stream order, drainage density, bifurcation ration and stream length ratio (Horton, 1945). Morphometric characteristics of watershed were employed for characterizing watersheds (Nag, 1998; Vittala*et al.,* 2004), for prioritization of micro watersheds for developments (Nookaratnam*et al.,* 2005), Horton's law of stream lengths suggested that a geometric relationship existed between the numbers of stream segments in successive stream orders. The generation of adequate data on the hydrographic conditions is difficult especially for large drainage basins. In recent years, application of Remote sensing data and Geographical Information System (GIS) tools have been successfully explored to generate adequate data on the spatial variations in drainage characteristics which provide an insight into hydrologic conditions, for the watershed management (Das and Mukherjee, 2005; Vittala*et al.,* 2004). Application of remote sensing provides a reliable source for the preparationof various thematic layers for morphometric analysis. Many workers have carried out morphometric analysis using remote sensing and geographic information system (GIS) techniques includes Vittala*et al.,* (2004),Chopra *et al.,*

(2005), Narendra and Nageswararao (2006), Ozdemir and Bird (2009), Thomas *et al.,* (2011), Chitra*et al.,* (2011), Zende and Nagrajan (2011), and Magesh*et al.,* (2012).As the main objectives of this work was to carried out to detailed morphometric analysis of Seonath river of Chhattisgarh and discusses their feature and characteristic with the help of different morphometric parameter viz., streams order, streams number, streams length, mean streams length, bifurcation ratios, elongation ration, circularity ratio, shape factor, drainage density, stream frequency, texture ratio, relief ratio, length of overland flow, constant channel maintenance, etc. using the remote sensing and GIS. Morphological studies of Seonath rivers are very important to study the behavior of a river, its aggradations/degradation, shifting of the river course, erosion of river bank etc. and to plan remedial measure for erosion and other related problems. The value of drainage morphometric parameters were calculated in the aspects of linear aspect, areal aspect, and relief aspect.

Materials and Methods

Description of Study area

The study area of Seonath river was selected for research work. The river originates near village Markaskasa of Maharashtra State near Chhattisgarh Border. It flows initially from West to East the North-East, North and finally again South-east. The catchment area of this sub-basin is about 30868 Km^2 and it joins river Mahanadi near Seorinarayan a town in District Bilaspur. Its main tributaries are Tandula, Kharun, Amner, Surhi, Hamp, Arpa etc. It is the longest tributary of the Mahanadi basin and drains. This is located between latitude $20^0$16' N to 22^0 41' N and Longitude $80^0$25' E to $82^0$35' E (fig.1).

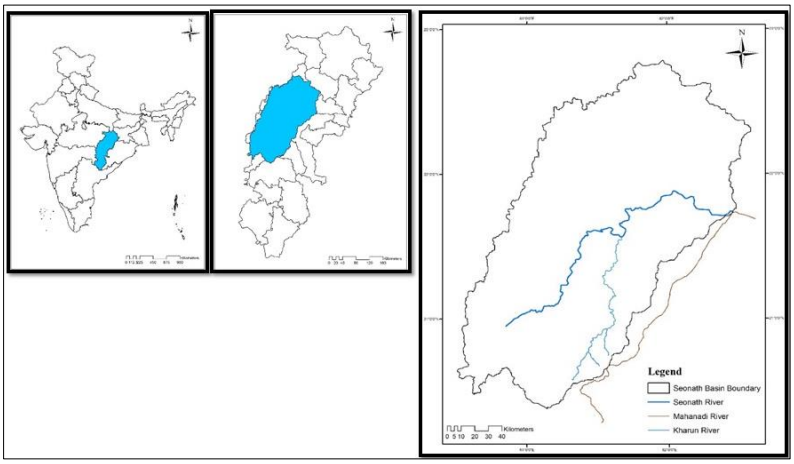
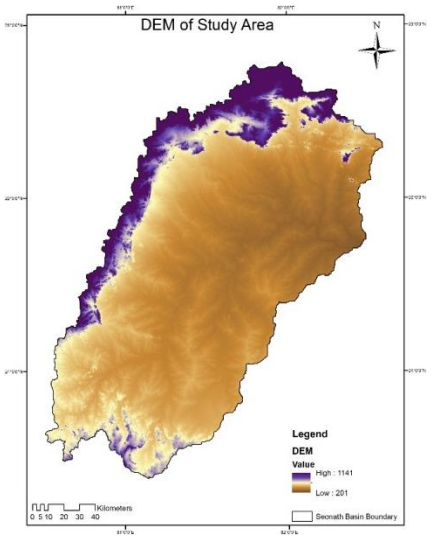


Fig. 1. Location Map of Study Area

Database and Methodology

Topographical maps were rectified/referenced geographically and mosaiced and entire study area was delineated in GIS environment with the help of Arc-GIS 10 software assigning Universal Transverse Mercator (UTM), World Geodetic System (WGS dating from 1984). SRTM(30m) data was used in this study to extract drainage network and analysis of Morphometric parameters. Hydrology tool under Spatial Analyst Tools in ArcGIS10 software was used to extract drainage channels, and other parameters. The automated method for

delineating streams followed a series of steps i.e. DEM, fill, flow accumulation, stream order and drainage network. Map creation, Scanning, Georeferencing, Spatial data and Topology creation are the steps involved in the morphometric analysis of Seonath river. The various morphometric parameters were computed using standard methodology (Table 1).



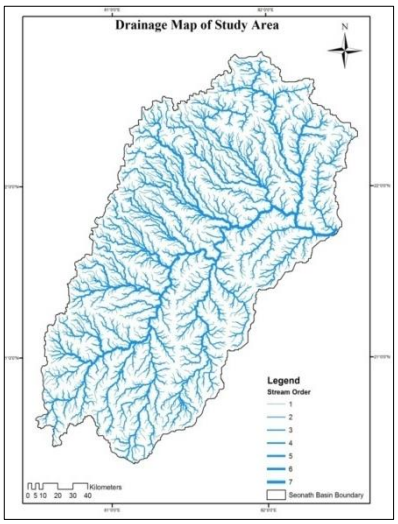


Fig. 2.DEM Map of Study Area **Fig. 3. Drainage Map of Study Area**

Table 1 Empirical relationships used in analysis of morpho-metric parameters and formula

Morphometric parameter	Formula	Reference
Linear Aspects		
Stream order	Hierarchial rank	Strahler (1964)
Stream length (L_u)	Length of stream	Horton (1945)
Mean stream length (L_{sm})	$L_{sm} = L_u/N_u$ where, L_{sm} = mean stream length L_u = Total stream length of order 'u' N_u = Total no. of stream segments of order 'u'	Strahler, 1964)
Stream length ratio(L_{ur})	$L_{ur} = L_u / L_{u-1}$ where, L_{ur} = stream length ratio L_u = mean of stream length of order 'u' L_{u-1} = mean of stream length of its next lower order	Horton (1945)
Bifurcation ratio (R_b)	$R_b = N_u / N_{u+1}$ R_b = Bifurcation ratio N_u = Total no. of stream segments of order 'u' N_{u+1} = no. of stream segments of the next higherorder	Schumn (1956)
Mean bifurcation ratio(R_{bm})	R_{bm} = Average of bifurcation ratios of all orders	Strahler (1957)
Length of overland flow (L_g)	$Lg = 1/2D_d$ where, L_g = Length of overland flow D_d = Drainage density	Horton (1945)
Basin length (L_b)	$L_b = 1.321A^{0.568}$ where, A= Area of the basin	Nookaratnam (2005)

Basin Perimeter (P)	Outer boundary of drainage basin measured in kilometers. (GIS software analysis)	Schumn(1956)
Areal Aspects		
Drainage density (D_d)	$D_d = L_u / A$ where, D_d = Drainage density L_u = Total stream length of all orders A = Area of basin (km^2)	Horton (1945)
Basin Area (A)	Area from which water drains to a common stream.(GIS software analysis)	Strahler (1964)
Stream frequency (F_s)	$F_s = N_u / A$ where F_s = Stream frequency N_u = Total no. of streams of all orders A = Area of basin (km^2)	Horton (1932)
Texture ratio (R_t)	$R_t = N_u / p$ where, R_t = Texture ratio N_u = Total no. of streams of all orders P = Perimeter (km)	Horton (1945)
Infiltration Number (I_f)	$D_d \times F_s$ Where, D_d= Drainage density (Km/Km^2) and F_s = Drainage frequency.	Zavoiance(1985)
Form factor (R_f)	$R_f = A/L_b^2$ where, A = Area of basin (km^2) L_b^2 = Square of basin length	Horton (1932)
Shape factor (B_s)	$B_s = L_b^2/A$ where, L_b = Square of basin length A= Area of basin (km^2)	Nookaratnam (2005)
Circulatory ratio (R_c)	$R_c = 4 \times \pi \times A / P^2$ where, R_c = circulatory ratio A = Area of basin (km^2) P = Square of the perimeter (km)	Miller (1953)
Elongation ratio (R_e)	$R_e = (4 \times A / \pi)^{0.5} / L_b$ where, Re = Elongation Ratio A = Area of basin (km^2) L_b = Basin length	Schumn (1956)
Compactness constant (C_c)	$C_c = 0.2821P/A^{0.5}$ where, A = Area of basin (km^2) P = Perimeter (km)	Horton (1945)
Constant channel maintenance(C)	$C = 1 / D_d$ where, D_dDrainage density	Schumn (1956)
ReliefAspects		
Ruggedness Number (R_n)	$R_n = D_d * (H /1000)$ R_n= Ruggedness number where, D_dDrainage density and Basin relief (m)	Strahler (1956)
Relief Ratio	$R_{hl} = H / L_b$ R_{hl} =Relief ratio where, Basin relief (m) and	Schumn (1956)

Results and Discussions

Morphometric characteristics

A drainage basin, which is defined as the area receiving water from rainfall in a particular set of channels, is the most convenient unit for the study of geomorphology and

hydrology. The parameters considered for assessing the morphological parameters are linear aspects, relief aspects and areal aspects.

Stream order

Stream order reflects a change in the physical characteristics of the soil (Bhagwat *et al.,* 2011).The stream order and the total number of stream segments in each order for the basin are shown in Table 2. Based on the Strahler (1964) system of stream ordering, the basin has been designated as a seventh order basin in Fig. 3.The calculated result matched with Strahler (1964), it was observed that the maximum frequency is in the case of first order streams and number of streams gradually decreases as the stream order increases. The presence of large number of streams in the basin indicates that the topography is still undergoing erosion, and at the same time, less number of streams indicates mature topography.

Stream Number (Nu)

The total of order wise stream segments is called stream number. Horton (1945) states that the numbers of stream segments of each order form an inverse geometric sequence with order number. When two channel of different order join then the higher order is obtained. Stream number was found out by using ArcGIS10. Total no of 6486 streams were identified in the study area, out of which 1498 was found to be in first order, 863 was in second order, 457 was in third order, 216 was in fourth order, 147 was in fifth order, 147 was in sixth order and 60 was in seventh order respectively (Table 2).The higher amount of stream order indicates lesser permeability and infiltration (Strahler, 1964).

Bifurcation ratio (R_b)

The bifurcation ratio is dimensionless property, defined as ratio of number of streams in N^{th} order to $(N+1)^{th}$ order (Horton, 1945). It is an important parameter to describing stages of a river development. Strahler, 1957 demonstrated that bifurcation shows a small range of variation for different regions or for different environment except where the powerful geological control dominates. Bifurcation ratio though varies from one order to the next order but tend to be constant for the entire basin which is the basis for Horton's law of stream number. Strahler (1957) and Schumn (1956) recommended the use of weighted bifurcation ratio because drainage basin is an evolving system and each order of streams develops into the higher order as a result of drainage development process which results in the variation in bifurcation ratio depending upon the stages of development. Bifurcation ratio is an important characteristic feature of drainage basin as it controls the rate of discharge after a sudden heavy rainfall. Potential flood damage increases as the value of bifurcation ratio increases (McCullagh, 1978).From the Table 2, clearly the bifurcation ratio values for the Seonath river vary from 1.5 to 2.5 with the mean bifurcation ratio of 1.97 and the highest R_b was in stream order 6^{th}.Weighted mean bifurcation ratio was2.0 of the steady area. The value of the weighted mean bifurcation ratio was observed that very close to the mean value of bifurcation ratio (Table 2).

Table 2:Stream Order, Streams Number, and Bifurcation Ratios in Seonath River

S_u	N_u	R_b	N_{u-r}	R_b*N_{u-r}	R_{bwm}
1	3245				
2	1498	2.2	4743	10274.4	
3	863	1.7	2361	4098.2	
4	457	1.9	1320	2492.7	
5	216	2.1	673	1423.9	2.0
6	147	1.5	363	533.4	
7	60	2.5	207	507.1	
Total	6486	11.8	9667	19329.7	
Mean	926.6	1.97*			

S_u: Stream order, Nu: Number of Streams
R_b: Bifurcation ratios, Rbm: Mean bifurcation ratio*,
N_{u-r}: Number of stream used in the ratio,
R_{bwm}: Weighted mean bifurcation ratio

Stream Length (L_u)

The length of the stream channel is a dimensional property, which reveals the size of the component of drainage lines. It is the total length of stream in a particular order. It is the most significant hydrological feature of the basin as it reveals surface runoff characteristics. The total stream lengths of the Seonath river was found to be various orders, which havecomputed with the help of Survey of India topographical sheets and ArcGIS 10software tool. The stream length of different order wise was computed based on the law proposed by Horton (1945). The stream length of study area varies from 7592.5 km to 96 km(Table 3.).In the present work, results show that the total length of stream segments is more in case of first order streams and decreases with the increase in the stream order.

Ratio of stream length and stream order for different stream order has been calculated for the steady area and highest value for Lu/Su was found in the 7^{th} stream order whereas lowest was found in the 1^{st} stream order(Table 2.).

Mean Stream Length (L_{sm})

Mean Stream length is a dimensional property revealing the characteristic size of components of a drainage network and its contributing watershed surfaces (Strahler, 1964). It is computed by dividing the total length of stream of an order by total number of segments in the order (Table 3).

Stream Length Ratio (L_{ur})

Horton, 1945, states that the stream length ratio is the ratio of the mean (L_u) of segments of order (S_o) to mean length of segments of the next lower order (L_{u-1}), which tends to be constant throughout the successive orders of a basin. The stream length ratio has important relationship with surface flow and discharge and erosion stage of the basin (Horton, 1945). The value of L_{ur} was vary from 0.85 to 1.12 attributable to differences in slope and topographic conditions.

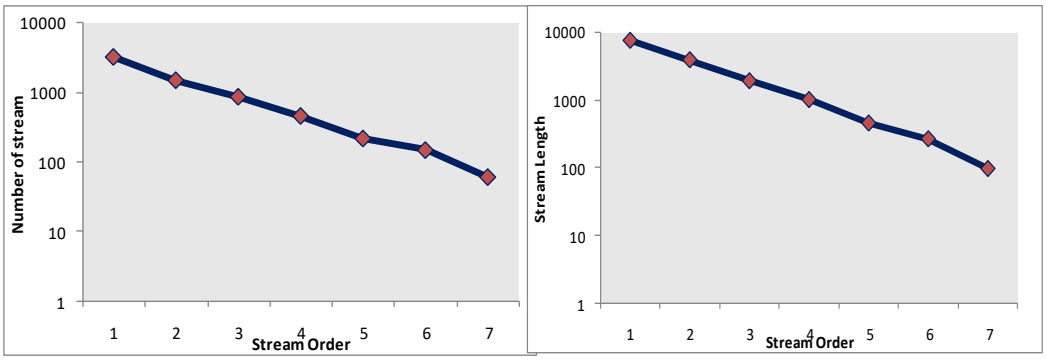
Table 3: Stream Length, and Stream Length Ratio in Seonath River

S_u	L_u	N_u	L_u/S_u	L_{ur}	L_{ur-r}	$L_{ur}*(L_{ur-r})$	L_{uwm}
1	7592.50	3245.0	2.34				
2	3917.15	1498.0	2.61	1.12	11509.65	12863.22	
3	1911.35	863.0	2.21	0.85	5828.50	4936.61	
4	1007.56	457.0	2.20	1.00	2918.91	2905.67	1.01
5	453.15	216.0	2.10	0.95	1460.71	1389.95	
6	264.66	147.0	1.80	0.86	717.82	616.03	
7	96.01	60.0	1.60	0.89	360.67	320.55	
Total	15242.4	6486.0	14.87	5.66	22796.26	23032.04	
Mean				0.94*			

Su: Stream Order, Lu: Stream Length
L_{ur}: Stream Length ratio, L_{urm}: Mean Stream Length ratio*
L_{ur-r}: Stream Length used in the ratio,
L_{uwm}: Weighted mean Length ratio Stream.

Length of overland flow (L_g)

This term refers to the length of the runoff the rain water on the ground surface before it gets concentrated into definite stream channels (Horton, 1945).Length of overland flow is one of the most important independent variables affecting both hydrologic and physiographic development of drainage basins (Horton, 1932). This factor relates inversely to the average slope of the channel and is quite synonymous with the length of sheet flow to a large degree.



(a) (b)

Fig. 4:(a) Relation of logarithm of number of streams versus stream order (b) Relation of logarithm of Length of Stream versus Stream Order

Table 4: Morphometric analysis of the study area

Morphometric parameters	Seonath River
Basin Area (sq. Km)	30868.48
Total Number of Stream (Nu)	6486.00
Perimeter(P), (Km.)	1066.78
Basin Length (L_b), (Km.)	465.56
Elongation Ratio (Re)	0.43
Texture Ratio (R_t)	6.08
Mean Bifurcation Ratio (R_{bm})	1.97
Drainage density (D), (Km/Km^2)	0.49
Stream frequency(F_s)	0.21
Infiltration number (I_f)	0.10
Form factor(R_f)	0.14
Circulatory ratio(R_c)	0.34
Length of overland flow (L_g), (Km.)	0.25
Constant channel maintenance(C)	2.03
Compactness constant (C_c)	1.71
Shape factor (B_s)	7.02
Ruggedness Number	464.16
Basin Relief (H), (m.)	940
Relief Ratio (R_h)	2.02

The length of overland flow (L_g) approximately equals to half of the reciprocal of drainage density (Horton, 1945).Overland flow is significantly affected by infiltration/percolation through the soil that vary in time and space (Schmid, 1997 and Kanth, 2012). The length of overland flow of the Seonath river is 0.25kilometers, (Table 1).Higher the values of Length of overland flow lower will be the relief and lower the values higher will be the relief.

Area (A)

The rate of runoff of any drainage basin depends on its area and physiography. The drainage basin area is a dimensional parameter and it is denoted by A. Larger the area, smaller is the runoff and vice versa.

Perimeter (P)

Length boundary of a basin is known as the perimeter of the basin and it is denoted by P. The factors that are dependent on the basin parameter are elongation ratio and circulatory ratio. Perimeters of study area were derived from GIS software that automatically gives the perimeter of the polygon.

Drainage density (D_d)

The drainage density determines the time travel by water (Schumn, 1956). The measurement of D_d is a useful numerical measure of landscape dissection and runoff potential (Chorley*et al.,* 1957). Drainage density expresses the closeness of spacing of channels, thus providing a quantitative measure of the average length of stream channel for the whole basin. Drainage density is calculated as the total length of the stream of all orders divided by the area of the basin(Horton, 1932), which is a measure of the wetness of the basin. It indexes together many characteristics of the catchments such as soil, lithology (Kelson and Wells, 1989), land-use (Montgomery and Dietrich, 1994), slope, climate

(Moglen *et al.,* 1998), vegetation andthe catchments response to rainfall. A high drainage density reflects a highly dissected drainage basin with a relatively rapid hydrological response to rainfall events, while a low drainage density means a poorly drained basin with a slow hydrologic response(Melton, 1957).The drainage density of the Seonath river was found to be 0.49 km/km^2 respectively indicating low drainage density.

Stream frequency (F_s)

Drainage frequency is the measure of the topographic feature. Stream frequency factor is the ratio of total number of streams in a basin to the basin area (Horton, 1945). The stream frequency (F_s) of the whole basin is 0.21as shown in Table 1. The low values of stream frequency indicate that the basin possesses low relief and the almost flat topography. The stream frequency shows positive correlation with the drainage density (Hajam*et al.,* 2013). Lesser the drainage density and stream frequency in a basin, the runoff is slower, and therefore, flooding is less likely in basins with a low to moderate drainage density and stream frequency (Carlston, 1963).

Texture ratio (R_t)

It is the total number of stream segment of all orders per perimeter of that area (Horton, 1945). Horton recognized infiltration capacity as the single important factor which influences Texture ratio (R_t) and considered the drainage texture to include drainage density and drainage frequency. Table 1 show that in Texture ratio (R_t) of the study area was found to be 6.08.

Infiltration number (I_f)

Infiltration number plays a significant role in observing the infiltration characteristics of the basin. It is inversely proportional to the infiltration capacity of the basin. The infiltration number of the Seonath River was 0.10 very low. It indicates that runoff will be low and the infiltration capacity high.

Circularity ratio (R_c)

Miller (1953) introduced circularity ratio to describe nature of the basin. It is ratio of the area of the basin to the area of circle having the same circumference as the perimeter of the basin (Miller, 1953). It is influenced by the length and frequency of streams, geological structures, land use/land cover, climate, relief and slope of the basin. High circularity ratio reflects rapid discharge from the basin and basins of low circularity ratio have high channel storage and low sediment yield–delivery ratio (Singh, 1992). The Circularity ratio of the study area was found to be 0.34indicates that the drainage basin is more or less elongated and is characterized by medium to low relief.

Form factor ratio (R_f)

Basin shape can be indexed by simple dimensionless ratios of the basic measurements of area, perimeter and length (Thornbury, 1969).It is defined as the ratio of basin area to square of the basin length (Horton, 1932). The form factor ratio value of the basin was low, 0.14 that represents elongated shape. The drainage basin has flatter peaks of flow for longer duration that is easier to manage than of the circular basins (Singh, 1998).

Elongation ratio (R_e)

Elongation ratio is the ratio of the diameter of a circle of the same area as that of the basin to the maximum length of the basin (Schumn, 1956).Elongation ratio (R_e) is a significant index in the analysis of basin shape which helps to give an idea about the hydrological character of a drainage basin. Singh and Singh (1997) said that the circular basin appear more efficient in the discharge of run-off than that of the elongated basin. The

value of R_e in the study area was found to be0.43 which indicate that basin is elongated. Values near to 1.0 are typical of regions of very low relief (Strahler, 1964).

Compactness constant (C_c)

The C_c is independent of size of basin and dependent only on the shape. The compactness coefficient for study area was found to be 1.71.

Constant of channel maintenance (C)

Schumn (1956) used the inverse of drainage density as a property termed as constant of channel maintenance. Similar to the drainage density, constant of channel maintenance depends on the basin relative relief, lithology, climate, etc. It decreases with increasing erodibility (Schumn, 1956). Constant of channel maintenance (C) value for Seonath river was found to be 2.03 shown in Table 1. Higher values suggest more area is required to produce surface flow which implies that part of water may get lost by evaporation, percolation etc.; lower value indicates less chances of percolation/infiltration and hence more surface runoff (Bhagwat *et al.,* 2011).

Ruggedness Number (Rn)

Strahler's (1968) ruggedness number is the product of the basin relief and the drainage density and usefully combines slope steepness with its length. Extremely high values of ruggedness number occur when slopes of the basin are not only steeper but long, as well. The Ruggedness Number of the Seonath river was 0.464 to be indicate that low value of ruggedness and basin implies that area is less prone to soil erosion and have intrinsic structural complexity in association with relief and drainage density.

Relief Ratio

Difference in the elevation between the highest point of a watershed and the lowest point on the valley floor is known as the total relief of the river basin. The relief ratio may be defined as the ratio between the total relief of a basin and the longest dimension of the basin parallel to the main drainage line (Schumn, 1956).The possibility of a close correlation between relief ratio and hydrologic characteristics of a basin suggested by Schumn who found that sediments loose per unit area is closely correlated with relief ratios. In the study area, the value of relief ratio was 2.02 (Table 4).

Conclusion

The quantitative analysis of morphometric parameters is found to be of immense utility in river basin evaluation, watershed prioritization for soil and water conservation, and natural resources management at micro level. The integrated Remote Sensing and GISbased approach is more appropriate and useful than conventional methods. The detailed quantitative morphometric analysis at the river basin enables to understand the relationships among the different aspects of the drainage patterns and their influence on landform processes, drainage, and land erosion properties. The drainage density and stream frequency are the decisive factor for the morphometric classification of drainage basins. These are controllers the runoff pattern, sediment yield and other hydrological parameters of the drainage basin. The value of drainage density is 0.49 km^{-1} i.e below $1km^{-1}$, which shows that low drainage density nature of basin. The low values of bifurcation ratio indicate that the drainage of the basin has sufferedless structural disturbances and drainage pattern has been distorted. Thus, the morphometric parameters evaluated using GIS tools helps in better understanding the nature of landforms and their processes, drainage pattern demarcations for basin area planning and management.

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MODELING REFERENCE CROP EVAPO-TRANSPIRATION USING WATER LEVEL DEPLETION IN CONVENTIONAL PLASTIC JARS

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Abstract

Estimation of reference crop evapotranspiration (ET_o) in remote areas considering the depletion of water level in conventional plastic jars has been addressed in the present study. Knowledge about ET_o and crop coefficient (K_c) is absolutely necessary for estimating crop evapotranspiration (ET_c). Neither the farmer is adequately trained to estimate ET_o nor he has any access to collect the same from nearby crop weather observatory. Still the farmer is very often blamed for injudicious use of irrigation water. In the present study, a regression model has been developed through analysis of the rate of evaporation from regular size plastic jars placed at the close proximity of the evaporation pan and ET_o values recorded by class A pan evaporimeter in the crop weather observatory. Daily ETo value measured by class A pan evaporimeter was found to bear a polynomial relationship with evaporation rate of the plastic jar. Performance of the model so developed was tested using statistical tools like root mean squared error (RMSE), percent deviation (PD) and scatter plots. Further, the performance of the model was also verified by installing the plastic jars near a crop field at 100 m distance and in a fallow land at 400 m distance away from the observatory. In both the cases, the predicted ET_o values were found to be in close agreement with the actual ET_o recorded by pan evaporimeter in the observatory.

Keywords: *Reference crop evapotranspiration; class A pan evaporimeter; water level depletion; Plastic jar*

Introduction

Water, a natural resource base for agricultural crop production, is gradually becoming scarcer due to the increasing demand of the growing population and industrialization inter-linked with large scale urbanization. Report reveals that the global water consumption is getting almost doubled in every 20 years.Irrigated agriculture is being practiced over 300 million hectares of land across the globe today and it covers about 20% of the total cultivable area (FAO, 2010). Literature also specifies that the irrigation efficiency is as low as 50 – 60% in many cases (Michael, 1978). In addition to increasing pressure on the resource from various sectors, injudicious use of the water in agriculture has pushed many regions of the globe into the crisis of water scarcity. Many more countries including India are likely to be under water scarcity zones by 2050. Furthermore, due to higher dependency on the groundwater, the water table irrespective of location across the world is declining at an alarming rate than ever before. Thus, it has become imperative to develop effective water management practices in agriculture for conserving the natural resource without affecting the crop production. Timely application of irrigation water to the crops in precise amount is now considered as the most essential part of effective water management in agriculture. A wrong approach in this respect may lead to either excess or less amount of irrigation than the requirement which is no way beneficial. However, proper scheduling of irrigation is not a concern of the farmer in many of the developing countries including India. As pricing of irrigation water is not yet enforced in the country, the farmers get tempted to use more and more water, either from surface or sub-surface sources,

injudiciously. Consequently, fertile lands in irrigated tracts are gradually converted to either waterlogged or salt affected areas or both. Apart from this, the socio-economic factor also plays a substantial role in this direction. More than 80% of the farmers in India belong to small and marginal categories and they are not financially sound enough to afford installation of micro-irrigation systems. The other option left before us for judicious use of irrigation water is educating the farmer about estimation of ET_c and proper irrigation scheduling for various types of crops. With advent of time, several methods (Holland and Steyn, 1975; Monteith, 1981; Shuttle worth, 1993) and models (FAO, 1998) have been developed so far to estimate ET_o, the basic parameter in calculation of consumptive use of crops. These methods require a number of weather parameters which are unlikely to be available easily to the farmers. On the other hand, there is no such user-friendly tool or instrument available with the farmer to determine daily ETo values. Hence, a simple but approximate method for estimating daily ET_o values by the farmers using depletion of water level in conventional plastic jars kept near the crop field or in the open space accessible to the farmer has been envisaged in the present study. The plastic jars locally available in remote areas have been used in the study to estimate ET_c of crops using the depletion of water level in them.

Materials & Methods

The Experiment was carried out in the agricultural farm of Orissa University of Agriculture and Technology (OUAT), Bhubaneswar, Odisha during summer season of 2013. The site is located at 20^0 15' N latitude and 85^0 52' E longitude at an elevation of 25.9 m above mean sea level. The average climate experienced in the experimental site is moist sub-humid. The mean annual temperature is 27.4 °C. Summers (March to June) are hot and humid with temperature in the range of 30 – 45 ^{0}C. Maximum temperature during peak summer (May and June) often exceeds 40 °C. Winter lasts for only about ten weeks with seasonal lows dipping to 15–18 °C in December and January. January, the coldest month, has temperatures varying from 15–28 °C. Rains brought by the Bay of Bengal branch of the south west summer monsoon lash Bhubaneswar between June and September (rainy season) supplying 80% of the mean annual rainfall (1,542 mm). The highest monthly rainfall total of 330 mm occurs during August. Rice is the predominant crop grown extensively in the state during monsoon season. Maize, oilseeds, pulses and vegetables are the other major crops grown in specific pockets during the year.

Theoretical considerations

Evaporation pan provides a measurement of the reference crop evapotranspiration from a specific open water surface integrating the effects of radiation, wind, temperature and humidity. The governing equation for the estimation of crop water requirement is expressed as:

$$ET_c = k_c \times ET_o \quad (1)$$

where, k_c = crop coefficient, fraction; ETo = reference crop evapotranspiration, mm d^{-1}.

The ETo is further derived by the following equation (Eq. 2)

$$ET_o = K_p \times E_{pan} \quad (2)$$

where, Kp = pan coefficient, fraction and E_{pan} = Pan evaporation rate, mm d^{-1}.

The pan coefficient takes care of the aerodynamic functions prevailing in the locality of the site where the pan is installed. It depends on the factors like the pan material and aerodynamic functions.

Installation of Plastic Jars

Three number of candy jars made of plastic material cylindrical in shape each of 10.5 cm diameter were procured from the local market for installing at different points in the experimental site. The height of each jar was made 15 cm by cutting and removing the top cap portion. These jars are numbered 1, 2 and 3 for avoiding confusion. While the jar -1 was installed at the close proximity of the Class A pan evaporimeter in the crop weather observatory, the jar-2 was installed near a crop field at a distance of 100 m from the pan evaporimeter and the jar-3 was located in a fallow field without any standing crop nearby at 400 m away from the pan evaporimeter. Attempt was made to simulate the installation procedure of evaporation pan through placing the jars on wooden platforms. The dimension of each platform was 15 x 15 x 10 cm with intermittent openings in order to allow free movement of air below. Initial water level maintained in each jar was 12 cm. Depletion of water level in the jars as well as the evaporation pan was taken every day in the morning at 8.30 A.M. The recommended practice of addition or removal of water from the evaporation pan was also followed in case the jars on daily basis. Thus, the observations were recorded for two months from 1st March to 30th April 2013.

Statistical Analysis

Root mean square error

The root mean squared error (RMSE) has been used for estimation of the degree of error associated with model prediction. It is expressed as:

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(P-A)^2} \quad (3)$$

where, N= Number of data pairs; P=Predicted value of evaporation; A=Actual pan evaporation

Percent deviation

Deviation of the predicted values of evaporation from the actual values in percentage has been studied by using percent deviation. It is expressed in percentage as:

$$Percentdeviation = \left[\frac{(\text{measured value} - \text{true value})}{(\text{true value})}\right] \times 100 \quad (4)$$

Results and Discussion

Observed data on depletion of water level in jar-1 and ET_o values from Class A pan evaporimeter obtained on daily basis for a period of two months were put to regression analysis. Relationship functions between them were derived using Microsoft Excel software. Very close relationship between the variables was established under 2nd degree polynomial function as evidenced from the co-efficient of determination (R^2=0.8484) value. The relationship between ET_o and depletion of water level in jar-1 is expressed as follows:

$$ET_o = -0.0133\ ({D_w}^2) + 1.0508(D_w) + 0.4664 \quad (5)$$

where, D_w = depletion of water level in the jar, mm.

It implies that the ET_o value increases with increase in the depletion of water level in the jar. However, the the ET_o value under no depletion of water level in the jar is negligible.

Model validation

Before applying the model for simulating ETo values at different places, an attempt has been made to validate the model at various locations.

Plastic jar at close proximity of the pan (Jar-1)

Validation of the regression model so developed has been attempted through scatter plots, RMSE and per cent deviation between daily ET_o values predicted by the model and the actual ET_o values recorded by the pan evaporimeter. Here, the daily depletion of water level in the jar-1 at the close proximity of the pan evaporimeter on the respective days has been used to model ET_o values. The scatter plot of modeled ET_o values and the actual values recorded by pan evaporimeter depicts a close agreement between them (Fig. 1). It also indicates that in majority of the cases the modeled values of ET_o are lying uniformly around 1:1 line.

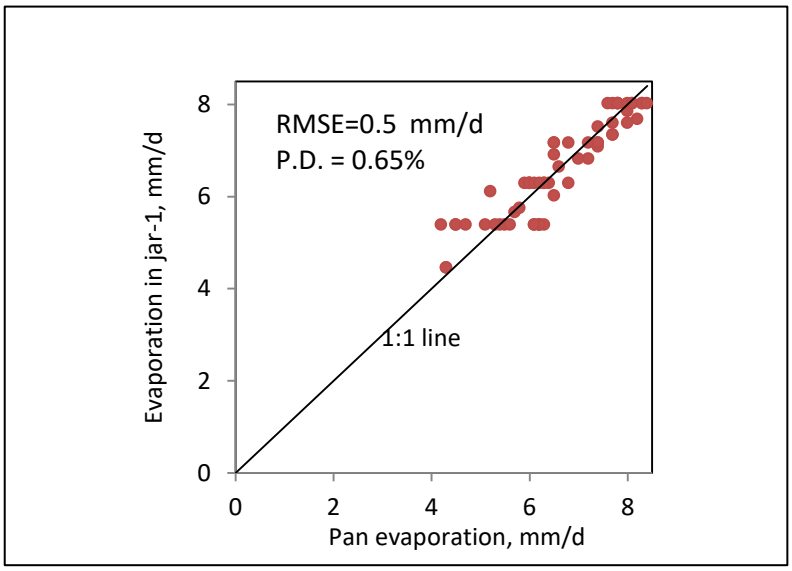


Fig. 1 Scatter plot of ET_o by jar 1 and pan ET_o

Furthermore, the RMSE between the modeled and measured ET_o values was also found to be considerably small in magnitude (0.5 mm d^{-1}) indicating the performance of the model. High degree of prediction efficiency of the model is confirmed through minimal values of percent deviation, which is only of 0.65%. Thus, it is established that the ET_o values of a locality can be simulated using the depletion of water level in plastic jars in lieu of class A pan evaporimeter.

Plastic jar at 400 m distance in a fallow land (Jar-3)

The jar – 3 was installed at a distance of 400 m from the class A pan evaporimeter in a fallow land. Depletion of water level in this jar in each day was used in the developed model to predict ET_o values. Predicted values of ET_owere matched with the corresponding values predicted by Jar-1. The closeness between the data pairs was compared using scatter plots, RMSE and percent deviation. The scatter plot of ET_o values predicted taking depletion of water level in jar-1 and jar-3 is illustrated in Fig.2. In this case, the ET_o values predicted based on the depletion of water level in Jar-1 is assumed to be the actual values of ET_o. It may be seen from Fig. 2 that the model slightly overestimates the ET_o values for most of the days in case of water level depletion in jar-3 as compared to jar-1 (1:1 line). Further, the RMSE between the data pairs

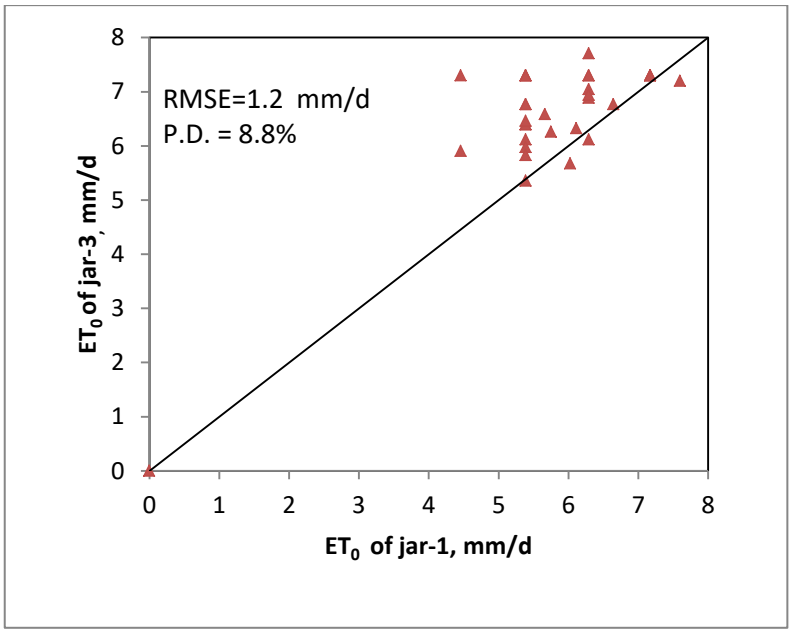


Fig. 2 Scatter plot of ETo in jar-1 (Actual) and ETo in jar-3 (predicted)

was computed and found to be 1.2 mm/day indicating a minimal but acceptable error. However, the degree of overestimation is observed to be within acceptable range as evidenced from the percent deviation of 8.80% only. It implies that a minimal error of about 10% in estimation of ET_o is expected when the plastic jar is located at a distance of 400 m from the pan evaporimeter and this much of error is acceptable in estimation of crop water requirement. The variation in the ET_ovalues at a distance of 400 m from the pan may be attributed to the factors like elevation of the location as compared to that of the pan which has not been taken into account in the present study.

Plastic jar at 100 m distance adjacent to crop field (Jar-2)

In this case, the plastic jar was kept at a distance of 100 m from the class A pan evaporimeter adjacent to a crop field. Daily depletion of water level in the jar was recorded and compared with the ET_o value obtained from the jar-1. Similar procedure was followed to find the closeness of the variables through scatter plot (Fig.3). The RMSE of the predicted ET_o by Jar-2 is found to be 0.4 mm/d which seems to be very low as far as the daily ET_o is concerned. Further, the percent deviation of the predicted values of ET_o from the actual is estimated to be 5.99% only. It indicates that the variable is slightly underestimated when the jar is placed near crop field and in the leeward side of the wind and the error in estimation is well within the acceptable range.

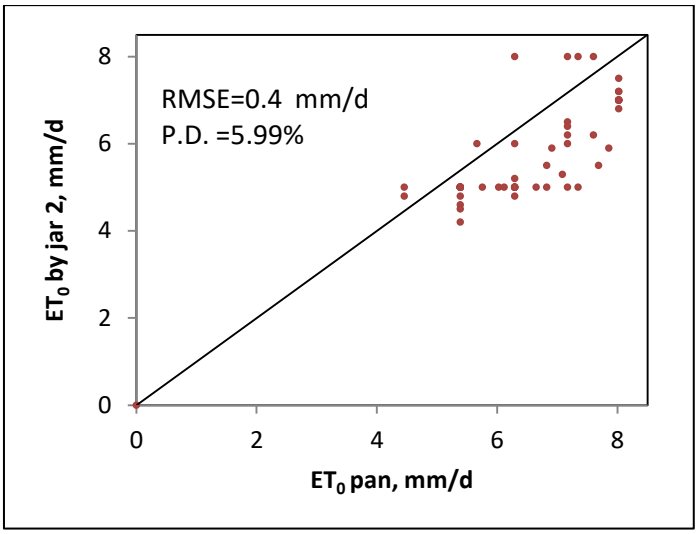


Fig. 3 Scatter plot of predicted ET_o by jar-2 and actual ET_o by pan

Conclusion

The results from the experiment reveal that the depletion of water level in plastic jar bears a polynomial relation with the ET_o measured by Class A pan evaporimeter. It is also observed that the location of the plastic jar with respect to distance from the pan as well as obstructions in between have some effect on the ET_o values. This has been evidenced through slight overestimation of ET_o when the distance is 400 m from the pan and slight underestimation when the jar is placed at a 100 m distance adjacent to a crop field. Hence, when this plastic jar is placed at a distance of 100 m near a crop field or at a distance of 400 m or in a fallow land, the depletion level in them can be used to estimate the ET_o values with acceptable error. However, for farther distances from the pan evaporimeter, care must be taken to check the validity of the model before application.

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PERFORMANCE OF POWER TILLER FOR *BIASI* OPERATION IN CHHATTISGARH

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Abstract

The study was aimed at investigating the Biasi operation of 13hp power tiller attached cultivator with different cage wheel in broadcasted field. Tests were conducted in standing crop in wet field with 73cm diameter with 30^o, 45^o and 60^o lug angle of cage wheel. It was evaluated that increasing lug angle of cage wheel with reduce the performance and increase the plant mortality. Cage wheel of 30^o lug angle was plant mortality 14.29% while 18.21% and 23.72% of 45^o and 60^o lug angle of cage wheel respectively. It was also evaluated thattime required to cover a hectare of land for Biasi operation with cage wheel 30^o,45^o and 60^o lug angle was recorded as 7.63, 8.96, and 9.87 h respectively. Weeding efficiency was also higher in 30^o lug angle cage wheel with 84% while 79% and 71% of 45^o and 60^o respectively. It was also revealed that less fuel consumption, less sinkage and higher puddling index, less wheel slippage, less sticking of soil was in 30^o lug angle of cage wheel.

Keywords- Cage wheel, lug angle, plant mortality, weeding efficiency, time of operation.

1. Introduction

Paddy is the principal crop and the central plains of Chhattisgarh are known as rice bowl of central India, about 80% people are engaged in agriculture. Biasi cultivation constitutes 80 percent of the rice area of Chhattisgarh. *"Biasi* is a local term used for wet ploughing or intercultural operation, carried out in the standing rice crop (Shrivastava et al.1987 and Anonymous, 1996). Beausani (Biasi) increased rice yield of long duration varieties by 9-40% compared to non Beausani cultivation Ghose et al. (1960).Biasi ploughing was done 45 days after sowing of rice with small wooden plough (Biasi Plough) in 10 cm standing water and at about 30 cm height of crop and after Biasi operation plants get re-established faster while the weeds retard their growth Patra and Gite (1980). Weed control in broadcasted crop was difficult and in such crop, the weeds are removed with manual labor once only, due to this, the weeding is not effective and the operation gets delayed resulting in non timeliness and loss of yield Rajput (1987). Then mechanization is needed to replace the labor which is not available or is very expensive. Hence, the design, development, manufacture and popularization of appropriate machines, especially the two-wheel tractor or power tiller, have received much attention in these countries during the last two decades. Power tiller is walking tractor mostly used for rotary cultivation in puddle soil. For wetland paddy cultivation, the power tiller can puddle the fields with rotavator and cage wheels much more uniformly and would give atleast 8 times higher output in a day than bullock operated puddling. The cage wheel, in particular, provides a floating effect to the power tiller in wet paddy fields, in addition to puddling the soil. The current market for power tillers in India is estimated at 56,000 numbers during 2013-14. The market for power tillers in India is

mainly concentrated in the eastern and southern parts of the country owing to the small land holdings per farmer in these regions and high cultivation of rice crops. Overall power tiller density is 2.21 per thousand hectare of net sown area.Shrivastava and Shrivastava (1990) concluded that under rainfed condition broadcast Biasi method of rice cultivation is followed and is proving as the most important constraint in adoption of high yielding technology and raising rice production in this region. Anonymous (2008) reported that the 2-row improved Biasi rice cultivator gave higher work rate and reduced plant mortality compared to the traditional practice.

2. Material and Methods

This study was conducted on A 13 hp power tiller was used for Biasi operation on a standing rice crop on wet land field attached five tynes cultivator with cage wheel with different angle and diameter. Two research field of IGKV research farm was taken of different soil for Biasi operation. The size of each plot was 20×14 m^2, three replications were taken for each cage wheel. Cage wheels were fitted to a power tiller with five curvature tines with "C" shape was used for Biasi operation. Cage wheels were tested for Biasi operation on standing crop at 8-10 cm depth of water. Specification of power tiller and physical properties of field soil are given below in Table 1 and Table 2.

Table 1 Specification of VST Shakti 130 DI Power Tiller

S.N.	Particulars	Technical Details
1	Horsepower	13.0 HP@2400rpm.
2	Length * Width * Height	2320 mm x 810 mm x 1300 mm
3	Combustion chamber	Direct injection DI
4	Displacement (cc)	673.4
5	Fuel	High Speed Diesel
6	Fuel Tank Capacity (L)	11
7	Oil Sump capacity (L)	2.4
8	Compression ratio	18:1
9	Maximum torqe ($kgrpm^{-1}$)	4.2/ 1900
10	Specific Fuel Cons ($ghp^{-1}h^{-1}$)	192
11	Governor System	Mechanical Centrifugal Type.
12	Cooling System	Condenser Type Thermo Siphon cooling System
13	Starting System	Hand Cranking
14	Total weight of power tiller (kg)	485
15	Gears	Forward – 6 Reverse – 2

Table 2 Physical properties of soil at the time of sowing

S. No.	Property	Enceptisols (Matasi) Soil	Vertisol (Kanhar) Soil
1.	Colour	Light yellow	Dark Brown/Black
2.	Mechanical composition (%) Sand, Silt, Clay	17.9,29.4,39.6	19.0, 32.8, 48.2
3.	Texture	Clay loam	Clay
4.	Bulk density of unpuddled soil (g cm^{-3})	1.73	1.3-1.4

2.1 Bulk density of soil

Undisturbed soil cores were collected by driving with a iron hammer 10 cm diameter metal cylinder into the depth in plot. Bulk density was calculated based on volumes, calculated from the length and diameter of section and dry weights of the soil samples. Bulk density (gcc^{-1}) measured with the help of the following formula (Mari et al 2011).

$$\text{Bulk density (gm/cc)} = \frac{\text{Weight of soil (gm)}}{\text{Volume of core cutter (CC)}} = \frac{\text{gm}}{\pi r^2 h}$$

2.2 Wheel slip

A simple method of determining the amount of wheel slip is to make a mark on the power tiller drive cage wheel with coloured tapes and the distance of power tiller moves forward is measured. forward speed of the power tiller and the wheel rotational speed are used to compute the wheel slip from the following formula.

Wheel slip, $s = 1 - Va / Vt$

where

Va = actual speed of a power tiller (ms^{-1})
= reel rev. (rps) x reel dia. (m) × π

Vt = theoritical velocity of the test wheel (ms^{-1})
= wheel rev. (rps) x wheel dia. (m) x π

2.3 Puddling Index

It is the ratio between volume of settled soil and total volume of sample. For determining the puddling index the samples of soil-water suspension was taken by immersing a glass tube to a depth of about 100 millimetres. The sample was taken from a number of points and was collected in measuring cylinders. These were kept undisturbed for 48 hours to allow the soil to settle. The volume of settled soil was noted for computing the puddling index, and it is given by formula (Baboo, 1976):

Puddling Index = $Vs/V \times 100$

Where

Vs = volume of settled soil, and
V = total volume of sample.

2.4 Operational Speed

In test plot .two poles of 20m apart are place approximately in the middle of the test run. The speed will be calculated from the time required for the machine to travel the distance (20m) between the assumed line connecting two poles opposite sides. A stop watch or other accurate time piece should be used to record the time for machine.

2.5 Fuel Consumption

The following simple method was used for measuring fuel consumption. The tank was filled to full capacity before and after the test .Amount of refueling after the test was the fuel consumption for the test. When filling of the tank, carefully attention should be keep the horizontal and not to leave empty space in the tank.

2.6 Effective Field Capacity

The time lost in every event such as turning, adjustment, refueling, change gear and machine trouble was recorded .For calculating field capacity, the time consumed for real work and that lost for other activities which is depend on field and crop condition should be used.

$$C = A/Tp+Tt$$

Where

C = Effective field capacity (ha/hr)
A = Area covered (ha)
Tp = Productive time (hr)
Tt = Non –Productive time (hr)

2.7 Theoretical Field Capacity

It is the rate of field coverage of the implement based on 100 percent of time at the rated speed and covering 100 percent of its rated width**.**

$$\text{Theoretical field capacity (ha/h)} = \frac{\text{Speed (km/h)} \times \text{Width of implement (m)}}{10}$$

2.8 Field Efficiency

This gives an indication of the time lost in the field and the failure to utilize the full working width of the machine .it is calculated from the following formula.

$$\text{Field efficiency (\%)} = \frac{\text{Effective field capacity}}{\text{Theoretical field capacity}} \times 100$$

2.9 Cone index

To determine cone index, a cone penetrometer (model BL, 250 EC, Baker Mercer type C10, LC = 0.002 mm), having 2.618 cm diameter of cone base with cone angle of 20°, was used. Cone penetrometer was calibrated with known weights and the relationship between applied load and dial gauge deflection was established (Bhadoria, 1995).

2.10 Plant Mortality

Number of plants per square meter was counted from each of the three one meter quadrates before and after treatment and average values were calculated. The plant mortality or plant loss was calculated using following formula:

$$\text{Plant mortality (\%)} = \frac{P1 - P2}{P1} \times 100$$

Where,

P1 = Number of plants/m^2 counted before Biasi.

P2 = Number of plants/m^2 counted after Biasi.

2.11 Weeding Efficiency

Total number of weeds lying in each observational quadrate (1 sq. m size) of each plot was counted before and after each treatment. The weeding efficiency was calculated using the following formula:

$$\text{Weeding efficiency } (\%) = \frac{W1 - W2}{W1} \times 100$$

Where,

W1 = Number of weeds per square meter counted before Biasi.

W2 = Number of weeds per square meter counted after Biasi.



Fig1. Different view of *Biasi* operation

3. Result and Discussion

3.1 Puddling index

Puddling index of cage wheel C2 (23.89%) was found significantly higher than that of C1(19.47%) ,C3(17.56%),C4 (14.07%) and C5 (16.23%) in matasi soil of research field while in black soil highest was also in C2 (27.38%) than that of C1(21.67%) ,C3(18.96%),C4 (15.74%) and C5 (19.29%). During puddling soil undergoes two type of deformations first due to normal stress due to compressive force and second because of tangential stress causing shear. Higher puddling index in C2 because of angular orientation of lug angle 45 which creates a cycloid action of lug on soil thereby increase the churning of soil and water mixture. Increase of puddling index in P2 was due to increase in level of puddling because of more soil manipulation by the implement which is in agreement with the results reported Behera et al.(2007).

3.2 Cone Index

Cone index was measured to study characteristics of puddled soil and its effect on performance of power tiller cage wheel. It was observed that soil strength reduced as increasing the lug angle of cage wheel increase at same level of Biasi.Cone index was highest in C1 (263kPa) while followed by C2 (232.17kPa) , C3(205.39kPa),C4 (243.09kPa),and C5(210.65kPa) cage wheel in Black soil. In matasi soil cone index was C1 (209.84kPa), C2(251.91kPa),C3(224.79kPa), C4(229.67kPa) and C5 (192.16kPa).cone index was observed less in matasi soil as compared to black soil.

3.3 Wheel slip

It was observed that minimum slip was in C2 (11.56%) cage wheel due to less sinking and sticking of soil on lug plate followed by cage wheel C3 (14.27)%, C1 (16.45%),C4 (21.02%) and C5(19.67%). Due to smaller diameter and high draft higher slippage was found in cage wheel C4 in Matasi soil.

3.4 Performance parameter

The effect of different lug angle and diameter of cage wheel on performance parameter for Biasi operation is given in (Table 3) and (Table 5).The time required to cover a hectare of land for Biasi operation with cage wheel C2, C1 and C3 was recorded as 7.14h, 8.33h and 9.51h respectively. Biasi operation was done on matasi soil where highest field efficiency was found in C2 cage wheel with 84% while 79%, 71%, 63% and 72% of C1, C3, C4 and C5 cage wheel respectively. It was observed that in 45º lug angle interaction of soil was less causes less sinkage and sticking of soil, while due to lower diameter of wheel C4 cage wheel was highest time taking operation as well as more blocking of soil on lug plates Fig.1. Working speed of C1 cage wheel with 30º was higher than all cage wheels but due to sticking of soil and large depth of Biasi, performance was less as compared to C2. Due to incorporation of plants and weed C4 cage wheel was blocked cause high plant mortality and low traficability.Due to smaller diameter C4 cage wheel was highest time taking operation while high traction, low sinkage and sticking cage wheel C2. Highest weeding efficiency was observed in C2 cage wheel with 45º lug angle (Table 4).

3.5 Crop Parameters

Power tiller was performed by different cage wheel on standing plant on leveled water. It was observed that minimum plant mortality in C2 cage wheel of 45 lug angle with 11-13% which followed by C1, C3, C4 and C5 with 18.29%, 23.72%, 26.54% and 22.61% respectively in matasi soil. While in black soil also plant mortality was minimum in C1 (17.23%) cage wheel and followed by C3,C2,C5 and C4 with 19.37%,21.46%,20.72% and 24.67% respectively shown in Table(4) and Table (6).

3.6 Yield Performance

Different lug angle and different diameter of cage wheel was tested and compare with the other Biasi methods where it was found that power tiller cage wheel C2 45º lug angle and 73cm diameter yield 32.61 qha^{-1},while Trifal Biasi plough 28.70qha^{-1} and traditional 25.89 qha^{-1}. Power tiller Biasi operation gives more than 17% and Trifal Biasi plough gives 21% more than Traditional Biasi system as shown in Table (7).

Table 3 Performance of Power Tiller attached with different Cage Wheel in matasi soil

S.N.	Particular	C1 30º dia73 cm	C2 45º dia 73 cm	C3 60º dia 73 cm	C4 30º dia 68 cm	C5 30º dia 78 cm
1.	Average. time of operation (hha^{-1})	8.33	7.14	7.69	8.33	10.00
2.	Field capacity (ha/h)	0.14	0.12	0.16	0.09	0.10
3.	Field efficiency (%)	79	84	71	63	72
4.	Working speed kmh^{-1}	1.33	1.28	1.22	0.81	0.92
5.	Fuel consumption lha^{-1}	9.10	8.67	10.92	13.18	9.79
6.	Slippage (%)	16.45	11.56	14.27	19.67	21.02
7.	Puddling index (%)	19.47	23.89	17.56	14.07	16.23
8.	Soil sticking in cage wheel (cm)	6.2	3.5	6.5	7.4	5.4
9.	Sinkage (cm)	17	14	12	19	14
10.	Depth of ploughing (cm)	16	15	12	11	18
11.	Cone index (kPa)	263	232.17	205.39	243.09	210.65

Table 4. Biasi operations in matasi soil under different power tiller cage wheel

S.No	Particcular	C1	C2	C3	C4	C5
1	Plant population	252	210	187	219	242
2	Plant height (mm)	230	220	215	235	205
3	Plant mortality (%)	18.29	14.29	23.72	26.54	22.61
4	Weeding efficiency (%)	79	84	71	69	78

Table 5. Performance of Power Tiller attached with different Cage Wheel in black soil

S.No	Particular	C1	C2	C3	C4	C5
1	Average. time of operation (hha^{-1})	9.09	7.14	9.52	11.30	10.11

2	field capacity (hah^{-1})	0.11	0.14	0.17	0.13	0.14
3	Field efficiency (%)	70.00	69.30	60.69	70.4	72.59
4	Working speed (kmh^{-1})	1.08	1.35	1.15	0.83	0.90
5	Fuel consumption ($litha^{-1}$)	9.99	8.74	13.56	15.70	14.55
6	Slippage (%)	17.61	13.57	15.89	20.73	18.24
7	Puddling index (%)	21.68	27.38	18.96	15.74	19.29
8	Soil sticking in cage wheel (mm	20	20	30	40	30
9	Sinkage (mm)	40	40	60	60	40
10	Depth of ploughing (mm)	80	100	130	140	110
11	Cone Index (kPa)	209.84	251.91	224.79	229.67	192.16

Table 6. Biasi operations in black soil under different power tiller cage wheel

S.No	Particular	C1	C2	C3	C4	C5
1	Plant population	342	363	331	353	368
2	Plant height mm	235	240	245	245	235
3	Plant mortality %	17.23	21.46	19.37	24.67	20.72
4	Weeding efficiency %	76	78	64	61	71

Table 7 Effect of different Biasi implements/ploughs on rice yield (qha^{-1})

Biasi Plough	Yield qha^{-1}	yield increase% *	B:C ratio
Traditional (Control)	25.89	--	1.65
Trifal Biasi plough	28.70	21	2.11
Power Tiller operated 5 tines Biasi plough	32.61	17	2.62

* As compared to using traditional Biasi plough ** - significant

Conclusion

On the basis of less sticking, less slippage and easy to incorporate the weeds and higher field capacity with less fuel consumption, observed in cage wheel C2. It was concluded from the research that power tiller cage wheel of 45º lug angle with tines is best suitable for Biasi operation for higher production and as timely operation and high efficiency.

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INFLUENCE OF ANIMAL DRAWN PUDDLING EQUIPMENTS AND ITS INTENSITY ON SOIL PHYSICAL CONDITION AND YIELD OF MECHANIZED TRANSPLANTED RICE (*ORYZA SATIVA* L.)

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Abstract

Puddling destroys soil aggregates and thus changes physical properties of soil. During puddling operation the soil is rigorously manipulated, soil structure is thoroughly disturbed and air filled pore volume is drastically reduced. Puddling equipment and level of puddling influence the physical properties of soil. The changes are due to specific soil texture, structure, type of clay mineral and organic matter content which jointly influence. Puddling brings about significant changes in soil physical properties and many times proves to be advantageous or disadvantageous. Mostly puddling is performed by tractor or animal drawn puddling equipments. In Chhattisgarh, a rice mono cropping area (4 million hectare) puddling is usually performed by animal drawn implements which include indigenous plough and wooden planker due to small land holdings. A very small percentage of farmers have started using animal drawn puddlers for puddling operation. Lots of research work has been carried out by researchers on evaluation of mechanical transplanters in a field prepared by tractor drawn puddling equipments. The same with animal drawn equipments has not been carried out so far. With this background a study was conducted to find out the varying intensities of puddling equipments on soil physical condition and yield of rice with different level of puddling under animal farming system. Five different animal drawn puddling equipments (lugged wheel puddler, zigzag puddler, rotary blade puddler, disc harrow cum puddler and indigenous plough) with two level of puddling intensity (two and three passes) were used for development of puddle bed and subsequently rice transplanting was done by transplanting by self propelled rice transplanter. Results revealed that, depth of puddling increased with increase in puddling intensity from two to three passes. There was no significant differences in depth of puddling between treatments. However, lowest puddling depth was obtained in pudddling with indigenous plough. The highest (48.39%) amount of soil dispersion with lowest (12.5%) wet sieving fraction was obtained in puddling with rotary blade puddler with three passes. Bulk density increased with increased level of puddling. The percolation rate, shear strength and penetration index decreased with increase level of puddling from two to three passes for all the puddling equipments. Rotary blade puddler with three passes gave best result (minimum percolation rate 0.31 mm/h after 24 hours of puddling and decreased penetration index values upto 100 mm of soil depth was higher). The highest grain yield (48.79 q/ha) was obtained in rotary blade puddler with three passes which was at par with treatment in which disc harrow cum puddler was performed for puddling operation.

Keywords: Rice; Animal drawn puddler; Puddling intensity; Soil physical Properties; Rice yield

Introduction

Rice is the most consumed cereal grain in the world, constituting the dietary staple food for more than half of the planet's human population. India is the largest grower of rice in terms of area (44 million hectare) with annual production of 141.134 million tonnes (fao, 2008). Rice is usually grown by transplanting seedlings under wetland conditions. The most common method of land preparation for wetland rice to obtain soft soil bed for transplanting of rice seedlings is puddling. Puddling of soil generally refers to breaking down of soil aggregates at near saturation in to ultimate soil particles. Puddling creates a favourable physico-chemical and microbiological environment for better crop growth. However, excess puddling is detrimental to subsequent crop in a wetland and dryland crop rotation (kar, 1995). The degree of puddling depends on tillage implement and intensity of puddling. Mostly puddling is performed by tractor or animal drawn puddling equipments. An ideal puddled soil condition is required for satisfactory performance of mechanical rice transplanters and the performance of transplanted seedlings for their establishment, growth and yield. In Chhattisgarh, a rice mono cropping area (4 million hectare) puddling is usually performed by animal drawn implements which include indigenous plough and wooden planker due to small land holdings. The field performances of these implements are quite low and those often requires more number of passes to achieve required degree of puddle. A very small percentage of farmers have started using animal drawn puddlers for puddling operation. Similarly, transplanting of rice is mostly done by hand in random fashion using root wash seedlings. Nearly 25-30 labour days are required for transplanting one hectare of rice (Singh et. al., 1985). Rice transplanting by self-propelled rice transplanter could provide timeliness in operation with savings in cost of operation and minimizing human drudgery. For efficient working of self propelled rice transplanter, besides mat type seedlings a suitable puddle bed condition with shallow depth of puddle and low strength of soil with differential consistency are the prerequisites.

Lot of research work has been carried out in different places on tractor, power tiller and animal drawn puddling equipment. Similarly the performance of manually operated rice transplanter, self propelled rice transplanter and hand transplanting has been evaluated and compared. It has been observed that evaluation of self propelled rice transplanter and hand transplanting is mostly carried out on the field prepared by tractor drawn puddling equipment. However, in some extent hand transplanting is also done on the fields prepared by animal drawn puddling equipment. It gives an impression that research work on self propelled rice transplanter has not been carried out so far on the fields prepared by animal drawn puddling implements. Due to this reason, researchers working on self propelled rice transplanter have not adequately specified the suitable puddling equipment and optimal puddle soil bed condition for mechanical transplanting of rice under animal farming system. Therefore, the research on development of puddle bed for mechanized transplanting of rice under animal farming system is very much essential in the areas where animal farming is still practiced. In view of above perspectives, a study was conducted to compare the intensities of puddling on physical properties of soil, yield attributes and yield of rice.

Material and Methods

The study was conducted at the research farm of Indira Gandhi Agricultural University, Raipur (CG), India in a silty clay loam soil (Sand : Silt : Clay :: 21 : 51 : 28) during the rainy

season of 2008 and 2009. To maintain the uniformity in field condition, initially one dry cross ploughing by animal drawn mould board plough was done and the field was flooded for 24 hours to saturation. To develop puddle bed five types of animal drawn puddlers viz. lugged wheel puddler, zigzag puddler, rotary blade puddler, disc harrow cum puddler and indigenous plough (farmers practice) with two level of intensity – two and three passes were used Field experiment was conducted following randomized block design having a each plot size of 40 x 10 m^2. The details of designed treatments are given below-

Main Treatments

T_1:	Lugged wheel puddler (two pass)	T_2:	Lugged wheel puddler (three pass)
T_3:	Zigzag puddler (two pass)	T_4:	Zigzag puddler (three pass)
T_5:	Rotary blade puddler (two pass)	T_6:	Rotary blade puddler (three pass)
T_7:	Disc harrow cum puddler (two pass)	T_8:	Disc harrow cum puddler (three pass)
T_9:	Indigenous plough (two pass)	T_{10}:	Indigenous plough (three pass)

Measurement Techniques

Performance of the different puddling methods was assessed on the basis of depth of puddling, amount of soil dispersion, percolation rate of water, wet sieving fraction, bulk density and penetration index.

The depth of puddling was measured by using a dial gauge penetrometer having a base plate of 5 x 5 cm^2 in place of cone as suggested by Taneja and Patnaik (1962). Firstly the deflection in the dial gauge was noted by applying 9 kg load. After puddling operation the penetrometer was forced gently in to the soil to record the same deflection was achieved at 9 kg load. The corresponding depth was measured by 30 cm scale.

The amount of soil dispersion was determined by following relationship (Dave *et al.* 2003).

$$\mathbf{Di = \{(Vs/dw) \div (V)\} \times (ds) \times 100}$$

where, Di = Puddling index or amount of dispersion, %

Vs = Volume of settled soil after 24 h, cc

V = Total volume of sample, cc

ds = Depth of soil puddle, cm

dw = Depth of water during sampling, cm

Percolation rate of water was measured by using infiltrometer rings of two sizes (diameter = 600 and 300 mm and length = 300 mm each) which were installed in the puddle field to depth of 200 mm. The stilling well was placed at the centre being inserted to 50 mm depth. The space within the rings was filled with water to the specified mark. A linear scale was fixed within the stilling well to measure the depth of standing water. The set up was covered with by shed structure to prevent falling of rainwater. The fall in depth of standing water with respect to time (after 12 h, 24 h, 36 h and 48 h of puddling operation) was measured.

The wet sieving fractions were determined by using standard wet sieve method. Wet sieving of puddle soil samples were done to measure the size and amount of water stable aggregates retains on standard sieves: 2 mm, 1 mm, 0.5 mm, 0.25 mm and 0.125 mm. The bulk density (0 – 150 mm depth) for all the treatments were recorded at five stages, viz. just after puddling, 15, 30, 45 and 60 days after puddling.

Penetration index of the puddled field was measured by cone penetrometer. The average cone penetrometer resistance over a depth range of 0-15 cm has been termed as cone/penetration index (ASAE Standard 313.2, 1995).

Transplanting of rice seedlings (Variety: Danteshwari) was done by using 8 row self propelled rice transplanter after 24 hours of puddling operation. Recommended agronomic practices were followed for rice cultivation. To determine the grain yield sample harvesting was done manually, threshed by use of plot thresher and grain yield was measured at 14% moisture content (wet basis). The results of the study were analyzed using the standard statistical package. The data were compared pair wise with the help of critical difference (CD) at 5% level.

Results and Discussion

Effect of puddling intensity on depth of puddling and weed density

In general, depth of puddling increased with increase level of puddling from two to three passes. The maximum depth of puddling (13.25 cm) was obtained in T_6 while the lowest puddling depth (9.26 cm) was obtained in T_9. Results revealed that puddling helps in reduction of weed density. The performance of puddling was also assessed by counting the number of weeds per m^2 regerminated after 10 days of puddling and thereby regermination of weeds in per cent was calculated. It was found that the lowest value (21.41%) of regermination of weeds was in treatment T_6 while the highest (44.73%) was in T_9. Increase in level of puddling decreased the regermination of weeds (Table 1).

Effect of puddling intensity on amount of soil dispersion

The data on soil dispersion are presented in Table 1 shows that it was influenced significantly due to different puddling treatments. It was observed that the soil dispersion increased significantly with increase level of puddling from two to three passes. The maximum amount of soil dispersion (48.39%) was found in puddling by rotary blade puddler (T_6) which was at par with zigzag puddler (T_4), disc harrow cum puddler (T_8) and lugged wheel puddler (T_2) but significantly superior to the indigenous plough (T_{10}). However, treatments T_8, T_2 and T_5 were also found statistically at par to each other which shows that puddling by rotary blade puddler with two passes of operation may be sufficient to develop puddle bed for mechanized transplanting of rice seedlings as compared to puddling operation performed by disc harrow cum puddler and lugged wheel puddler with three passes. The lowest puddling index was in indigenous plough (24.67%), this may be due to that it performed only scratching action on soil.

Effect of puddling intensity on water stable aggregates

Wet sieving fraction in percentage of different puddling treatment was determined and compared with unpuddled soil. The mean values of total percent of aggregate by weight of soil sample retained on all sieves are given in Table 2. In general, it was observed that different tested puddling treatments reduced soil aggregates significantly. The results revealed that highest percentage of wet sieving fraction was recorded in puddling by indigenous plough with two passes (T_9), which was significantly higher than rest of the puddling treatments except T_{10} as both were statistically similar to each other. Treatments T_{10} & T_1, T_1, T_7 & T_2 and T_2, T_8 & T_3 gave no significant variation on wet sieving fraction. The lowest percentage of wet sieving fraction (12.25%) was observed in treatment rotary blade puddler with three passes (T_6) followed by T_4, T_5, T_3 and T_8 and those were statistically at par to each other but significantly differed to the rest

of the puddling treatments. This may be attributed to the fact that better puddling with higher amount of dispersion of soil resulted in reduced wet sieving fraction.

Effect of puddling on penetration index

Penetration index was measured to study the strength characteristics of puddled soil and its subsequent effect on performance of mechanical transplanters. Cone penetrometer resistance (CPR) of puddle profile was measured from 0 to 150 mm depth at an increment of 25 mm. The average of cone penetrometer resistance of puddled soil for the depth range of 0 – 150 mm was termed as penetration index and the mean values was presented in Table 2. The mean values showed that it decreased as the puddling level increased from two to three passes. The data on penetration index from Table 1 revealed that it influenced significantly due to the different puddling treatments. The highest value of penetration index (144.52 kPa) was obtained in T_9 which was significantly higher to the rest of puddling treatments. However, no significant difference on penetration index was noticed between treatments T_{10}, T_7, T_1 and T_2. The lowest penetration index (116.40 kPa) was obtained in T_6 which was statistically similar to the treatments T_8, T_5 and T_4. It showed that two passes of puddling operation by rotary blade puddler gave similar penetration index as obtained in three passes of zigzag puddler and disc harrow cum puddler. Results also revealed that penetration index decreases with level of puddling from two to three pass.

Effect of puddling intensity on percolation rate

The effect of different puddling equipment and their number of passes on percolation rate was measured after 12, 24, 36 and 48 hours of puddling operation. The average values of percolation rate and percent decrease in percolation rate over saturated unpuddled soil are given in Table 2. It was found that after 12 h of settlement the percent reduction of percolation rates in different treatments were lower compared to the corresponding values after 24 and 36 h. Further percent reduction values of percolation rate after 36 h of settlement were at par to those after 24 h. Therefore average percolation rate as measured after 24 h of puddling operation was considered appropriate as within this period the process of settlement of suspended soil particles was assumed to be almost over for the purpose. The results revealed that the percolation rate decreased with increase in level of puddling from two to three passes for all the puddling equipment used in the study. Minimum percolation rate (0.31 mm/h) was recorded in puddling by rotary blade puddler with three passes (T_6) at 24 hours after puddling. Statistically similar percolation loss was observed in T_6, T_5, T_4 and T_2, which shows that the puddling by rotary blade puddler with two passes is sufficient to reduce the percolation rate as compare to three passes of rotary blade puddler, zigzag puddler and lugged wheel puddler. The reduced percolation rate obtained in three passes of puddling may be due to that higher amount of dispersed soil settled.

Effect of puddling intensity on bulk density

Bulk density (0 – 150 mm depth) for all the treatments were recorded at five stages, viz. just after puddling, 15, 30, 45 and 60 days after puddling are given in Table 3. The mean value of bulk density for saturated unpuddled soil was recorded as 1.47 g/cc.

In general, percentage decrease of bulk density of puddled soil was observed over saturated unpuddled soil due to puddling with different equipments at all stages except at 60

DAP. Percentage increase in the mean value of bulk density was maximum (7.6%) in puddling by rotary blade puddler with three passes at 60 DAP. The percent decrease values of bulk density at just after puddling starts increasing at 15, 30, 45 and 60 DAP in all the treatments. It means the value of bulk density increased at 15, 30, 45 and 60 days interval compared to the initial value of bulk density just after puddling. It can be stated form the result that puddling helps in decreasing the bulk density of soil and it has shown an increasing trend with the relative age of soil. This may be due to the settling of soil particles and consolidation of the soil layer. Similar findings were also reported by Kumar et al. (2007). The effect of puddling treatments showed significant changes in the values of bulk density just after puddling. The variation in bulk density was found significant with maximum value of 0.980 g/cc in T_9 and minimum of 0.917 g/cc in T_6. In this stage, it was found that three passes of puddling operations significantly reduced the values of bulk density of soil as compared to two passes of puddling operation. At 15 DAP, higher bulk density (1.279 g/cc) was recorded in T_6 which was statistically at par with T_5 but significantly superior over rest of the treatments. In case of 30 DAP, maximum bulk density was obtained in T_6 (1.386 g/cc). No significant variation on value of bulk density was observed in treatments T_6, T_5, T_4 and T_8 due to different puddling method. Lowest bulk density was obtained in treatment T_9 (1.283 g/cc). Similar trend was also observed in 45 DAP. At 60 DAP, an increase in bulk density was observed over bulk density of saturated puddled soil and it followed the similar trend as observed in 15 DAP. This indicated that the bulk density increase with respect to time due to reduction in moisture content which causes the shrinkage of soil leading to compaction. Similar results were also observed by Choudhary and Varshney (2008).

Effect of puddling intensity on yield attributes and grain yield

The shallow minimum dry friable tillage followed by water submergence and puddling have facilitated the development of soft and partly impermeable puddle profile which likely helped for higher nitrogen assimilation rate contributing for higher number of tillers (Table 4) and increased panicle production. The increased effective tillers and subsequent higher growth of crops due to puddling in T_6 and T_4 may be attributed to the favourable soil condition during the growth period supporting better and more vigorous root growth. The highest grain yield (53.18 q/ha) was obtained in T_6 where three passes of rotary blade puddler for puddling operation was performed.

Conclusions

1. The increase in number of passes of puddling increased the amount of soil dispersion and depth of puddling and decreased the values of percolation rate of water, bulk density, penetration index and wet sieving fraction.
2. The rotary blade puddler with three passes gave highest soil dispersion and minimum value of wet sieving fraction with percolation rate of water.
3. Increase in level of puddling increased the grain yield. However, highest grain yield was obtained in rotary blade puddler with three passes.

On this basis, puddle bed prepared by animal drawn rotary blade puddler with three passes proved to be ideal for efficient performance of mechanical transplanter i.e. self propelled rice transplanter.

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Table 1. ***Effect of puddling treatments on depth of puddling, weed density, soil dispersion, wet sieve fraction and penetration index***

Treatments	Depth of puddling, (cm)	Regermination of weeds, (%)	Amount of soil dispersion, (%)	Wet sieve fraction (%)	Penetration Index (kPa)
T_1	10.69	40.14	36.33	24.08	134.22
T_2	12.33	37.82	45.11	20.74	127.62
T_3	11.68	38.63	39.75	15.86	125.71
T_4	12.94	29.94	46.66	13.93	120.14
T_5	11.32	35.28	42.27	14.69	122.21
T_6	13.25	21.41	48.39	12.25	116.40
T_7	12.65	41.09	40.38	21.43	131.14
T_8	13.15	33.74	45.57	16.37	123.84
T_9	9.26	44.73	24.67	31.66	144.52
T_{10}	10.10	42.16	29.52	26.78	135.08
CD (0.05)	-	-	3.41	4.90	8.47

Table 2. ***Effect on percolation rate of water due to different puddling equipment***

Treatments	Percolation rate of water at different period of settlement (mm/h)			
	12 hrs	24 hrs	36 hrs	48 hrs
T_1	0.41 (19.60)	0.39 (23.52)	0.38 (25.49)	0.38 (25.49)
T_2	0.39 (23.52)	0.36 (29.41)	0.35 (31.37)	0.34 (33.33)
T_3	0.40 (21.56)	0.37 (27.45)	0.35 (31.37)	0.35 (31.37)
T_4	0.38 (25.49)	0.35 (31.37)	0.34 (33.33)	0.34 (33.33)
T_5	0.37 (27.45)	0.34 (33.33)	0.33 (35.29)	0.32 (37.25)
T_6	0.34 (33.33)	0.31 (39.21)	0.30 (41.17)	0.30 (41.17)
T_7	0.43 (15.68)	0.41 (19.60)	0.39 (23.52)	0.38 (25.49)
T_8	0.41 (19.60)	0.39 (23.52)	0.38 (25.49)	0.37 (27.45)
T_9	0.48 (5.88)	0.44 (13.72)	0.42 (17.64)	0.41 (19.60)
T_{10}	0.47 (7.84)	0.42 (17.64)	0.40 (21.56)	0.40 (21.56)
CD (0.05)	0.051	0.046	0.073	0.053

*Average percolation rate of saturated unpuddled soil = 0.51 mm/h

*Figure in parenthesis show percent reduction of percolation rate after different period of settlement compared to the saturated unpuddled soil.

Table 3. ***Bulk density as influenced by different puddling equipment***

Treatments	Bulk density (g/cc)				
	Just after puddling	15 DAP	30 DAP	45 DAP	60 DAP
T_1	0.961	1.206	1.331	1.333	1.439
T_2	0.953	1.218	1.333	1.334	1.452
T_3	0.941	1.228	1.342	1.346	1.478
T_4	0.932	1.234	1.353	1.356	1.497
T_5	0.928	1.248	1.368	1.378	1.531
T_6	0.917	1.279	1.386	1.394	1.549
T_7	0.966	1.226	1.343	1.346	1.476
T_8	0.949	1.229	1.349	1.350	1.491
T_9	0.980	1.188	1.283	1.322	1.432
T_{10}	0.968	1.204	1.311	1.324	1.443
CD (0.05)	0.0158	0.0442	0.0498	0.0375	0.0374

Table 4. ***Effect of puddling treatments on yield attributes and yield***

Treat-ments	Plant hills popu-lation/m^2	No. of tillers/ plant hill	No. of effective tillers /plant hill	Panicles length (cm)	No. of grains/ panicle	Test weight (g)	Grain yield (q/ha)	Harvest index (%)
T_1	36.33	20.33	11.73	21.90	92.60	22.70	42.15	43.87
T_2	37.66	21.06	12.26	22.10	96.80	23.70	45.73	44.24
T_3	37.66	20.00	12.53	22.70	102.40	22.10	47.48	44.55
T_4	39.86	24.20	14.33	23.30	113.00	24.40	51.63	45.29
T_5	38.00	20.26	12.80	23.06	105.20	23.30	48.32	44.84
T_6	41.06	23.13	15.06	23.60	113.40	24.80	53.18	45.44
T_7	36.73	19.66	12.13	22.00	92.80	22.60	44.56	44.16
T_8	39.26	23.26	14.00	23.10	111.40	24.20	49.00	45.05
T_9	35.33	17.93	11.33	20.36	78.60	22.50	34.47	43.41
T_{10}	35.73	18.66	11.46	21.35	83.60	21.60	38.52	43.77

SOIL RESOURCE MANAGEMENT UNDER DIVERSIFIED RICE-BASED CROPPING SYSTEMS AND INCREASING FARM MECHANIZATION IN ASSAM

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Abstract

The agricultural scenario of Assam, dominated by winter rice, is at a crossroad with intensive diversification of second crop and increasing farm mechanization comprising few of the major issues. Sustenance and effective management of soil resources hold key to success and long-term stability of such endeavor. This is more crucial in the backdrop of increasing micronutrient deficiency in soils of different districts of the state, and gradual rise in productivity of winter rice. The diversification of suitable succeeding crop vis-à-vis soil resource management would be determined by efficient crop residue and nutrient management practices, and farm mechanization.

Keywords: crop diversification, soil resource management, farm mechanization

Sustainability of agricultural systems has become an important issue in developing countries, including India in the backdrop of increasing demand for food for an ever increasing population. In spite of higher productivity of small and marginal farm units, which constitute 83.5% of total holding in the country with a share of more than one third of the total cultivated area, the income is not adequate in terms of per hectare value output and comparable to that in most of the south eastern and eastern countries like China (Vyas, 2011). Low fertilizer use efficiency emanating from low and indiscriminate fertilizer use, and ignoring the secondary and micronutrient are critical in realizing the potential yield of crops (Ayappan and Chand, 2011), and contribute significantly to the low productivity of the small and marginal farms. Harnessing of soil over many decades has resulted in exhaustion of the intensive agricultural production systems and steady decline in productivity has been noticed in long-term experiments in Asia (Bhandari *et al,* 2002; Ladha *et al*, 2003; Manna *et al*, 2005)**.**

The State of Assam with a geographical area of 78,438 sq. km i.e. about 2.4 percent of the country's total geographical area forms the core of the North Eastern Region of India and is comprised of the Brahmaputra valley, the Barak valley and the Hill range. The agricultural scenario of the state, largely dominated by small and medium farmers with low resource availability, had changed from subsistence nature (Barah, 2006) to steady growth rate in rice yield (Pegu and Hazarika, 2016). Winter rice, the major crop of the state, is cultivated under lowland and medium land situation over an area of about 1.749 million hectares. Lowland rainfed rice ecosystems are managed with low inputs (Dobermann and White, 1996) and are usually characterized by medium to high clay content. The soil type largely determines the management

of physical environment through tillage (Mambani *et al,* 1990), and nutrient transformation and availability (Fageria *et al,* 2011).

The routine and time-bound operations during cultivation have become difficult owing to shortage of agricultural labour (Phukan, 1990) against ever increasing wage. The government of Assam is emphasizing on increasing cropping intensity through double cropping, especially in rice growing areas (Hazarika, 2011; Anonymous, 2012a). Farm mechanization holds key to higher cropping intensity and the use of farm machinery during the past decade has increased at an enviable growth rate, both at national and state level. The increase in the number of tractor is two-fold and that of power tiller by three times during 1990 to 2000 in India (Alam, 2012). In Assam, 3349 tractors and 9308 power tillers had been distributed through subsidy under various schemes during 2006-07 to 2009-10 (Anonymous, 2012b and 2012c) with farm power availability of 0.66 hp/ha as against national average of 0.80 hp/ha, and thus a phenomenal growth is anticipated in the coming years.

Soil resource management under rice-based crop diversification

The cropping pattern of a region has important implications for its agricultural growth in general and livelihood of the farmers. India has the largest national area of rice cropping (FAO, 2015), much of which is multi-cropped and cropping patterns are very diverse. These varied cropping systems occur across a varied environment (e.g., weather, soils, topography) and the 'outputs' of agriculture (e.g., crop yield, water use, nutrient leaching) vary widely. Rice-based agriculture system has failed to provide required household income-security (Barah, 2006), possibly because diversification was adopted as a mechanism to cope with limits imposed by flood (Mandal and Bezbaruah, 2013). Though very low crop diversification with a gradual shift from cereals to vegetables and fruit crops in Assam was reported (Deka *et al*, 2013), significant differences in intensity and rate of diversification among the districts were observed (De and Bodosa, 2014).

Crop residue management

The crop residues of rice mono-cropped areas are left in the field after harvest till the next crop. There is ample scope for buildup of the soil fertility through *in situ* utilization of the stubbles which is a good source of sulphur (Dobermann and Fairhust, 2002), and contains almost all the K and about one-third of the N, P, and S removed from the soil by the rice crop (IRRI, 1984). Incorporation of rice stubble was implicated for yellowing of wheat at early growth stage, which was possibly due to immobilization of nitrogen and other effects of decomposition of high C:N ratio biomass (Annual Report, 1996). Spraying cellulose degrading microbe culture with glyphosate significantly enhanced decomposition of crop residues in winter rice (Borah *et al*, 2016b; Borah *et al*, 2016c) and direct seeded autumn rice (Borah *et al*, 2016a). The effects of such residue management practices on status and dynamics of available nutrients in soil and on crop growth need to be evaluated. Further, such developed technology should be compatible with mechanized harvesting and/or seed sowing or crop establishment.

Crop establishment

Higher moisture retention capacity of soil and profile distribution following rice stubble mulch or deep tillage significantly increased yield of wheat and mustard compared to no tillage, minimum or moderate tillage (Hussain, 1993). Field pea, with 4 cm irrigation once, as relay crop

performed better with residual effect of organic manures applied to winter rice (Annual Report, 2011). Harvesting winter rice at a height of 40 cm from soil surface followed by conventional tillage significantly increased growth, yield and nutrient uptake in linseed (*Linum usitassimum* L.) and available nutrients in soil in comparison to complete removal of stubbles (Borah, 2011). The residual soil moisture, in most of the winter rice growing areas had been exploited for succeeding crop establishment, but the same may pose as major hurdle for operation of farm machinery.

Nutrient and water management

Decline in yields had been observed in rice-based cropping systems in Asia and reasons ascribed to this phenomenon are quality and quantity of soil organic carbon and its impact on nutrient supply (Bhandari *et al*, 2002; Ladha *et al*, 2003**).** Several workers have studied the composition and losses of soil organic carbon, particularly carbon and nitrogen, under intensive cropping and continuous cultivation (Dalal and Mayer, 1986; Dawe *et al*, 2000; Swarup *et al*, 2000). Wide variation in soil organic matter fractions in rice-based cropping systems under similar physographic units was reported (Das, 2012) due to difference in climate and management practices. Higher soil quality index (SQI) was recorded for new alluvium rice soils compared to that in old alluvium soils, while among the cropping systems it was higher in rice-toria followed by rice-vegetables (Baruah, 2013).

The usual farmers' practice for growing crops like potato, mustard and pea after rice showed negative net return compared to recommended practice for specific cropping systems (Anonymous, 2008). The approach to nutrient management is of significance as the alternate wetting and drying following puddling to facilitate rice cultivation affects the soil nutrient dynamics and growth and yield of succeeding crop (Wade *et al* 1998, De Dutta 1986). Mixing of chemical fertilizer with organic manure could reduce half of the recommended doses of nutrients in chilli (*Capsicum annum* L.) under rice-fallow medium land (Uddin, 2012). Application of chemical fertilizers in optimum doses had also been profitable for cultivation of linseed as relay cropping (Kalita, 1999) and as a succeeding crop (Borah, 2011) to winter rice. However, addition of farmyard manure enabled fifty per cent reduction in the recommended dose of fertilizer and realization of maximum yield and monetary benefit in niger (Gogoi, 2006). Long-term application of recommended doses of fertilizer (RDF) with organic manure increased all but non-exchangeable forms of potassium (Chanu, 2015), and different forms of nitrogen (Miranda, 2015) in soil under rice-rice cropping sequence. While the macronutrients did not show significant variations (Fanai, 2014), low available boron content of soil was reported for rice-rice than that of rice-rapeseed or rice-vegetable cropping systems (Nath, 2013). About more than 20 per cent of the analysed soil samples showed deficient levels of available boron and zinc in more than 18 districts of the state. Long-term use of herbicide and nutrient management practices in rice-rice sequence did not have any effect on soil physical properties except water holding capacity of soil, which increased with organic manure addition for partial N-fertilizer substitution (Goswami, 2013).

Soil biochemical properties are the indicators of soil quality. The properties include both general biochemical parameters (i.e. microbial biomass carbon, dehydrogenase activity and N mineralization potential) and specific biochemical properties (i.e. the activity of hydrolytic enzymes, such as phosphatase, urease *etc*. In general, the physical and physiochemical parameters are of little use as they alter only when soil undergo a really drastic change (Filip, 2002). On the contrary, biological and biochemical parameters are sensitive to the slight

modifications that the soils can undergo in the presence of any degrading agent (Nannipieri *et al*, 1990; Yakovchenko *et al*, 1996). Higher total population of bacteria than fungi in soils under rice-based cropping system compared to tea-ecosystem was reported (Das, 2012), but the soil microbial biomass carbon (MBC) differed with changing climate and crop management. The population of *Azotobacter*, *Azospirillum*, and PSB decreased significantly in soil due to application of herbicides with or without rotation in rice-rice cropping, however the effect was significant only with sole chemical fertilizer than with addition of organic manure for partial N-fertilizer replacement (Goswami, 2013). Continuous application of organic manure in transplanted rice-rice sequence was shown to affect significantly the activity of acid phosphatase and urease (Goswami, 2013), dehydrogenase (Goswami, 2013; Debbarma, 2015) in soil.

Soil resource management with increasing farm mechanization

Due to promotional effort from Government the farm power availability has increased to 1.52 Hp per /ha against a national average of 2.25 HP/ha (Yassing *et al*, 2016). This availability is likely to increase in future because of ongoing promotional effort. It is interesting to note amongst the various unit operations land preparation has the highest mechanization index (0.80) in Assam. This means mechanization effort in the state of Assam is mostly concentrated in the area of land preparation. An analysis of the number of tillage machinery in the state has revealed that there has been considerable jump in rotary tillage implement (i.e. rotavator, power tiller rotary) etc. Study conducted under AICRP on FIM, AAU, Jorhat centre revealed that there is 25% reduction in bulk density immediately after rotavator use which is not very healthy for the soil. There is likely to be modification of soil structure and aggregation in medium textured soil of Assam which is a matter of concern. A crop wise best tillage practice needs to be worked out for long term sustainability of the land. Wind erosion from cultivated land is very limited in Assam. The credit goes to the Assamese farmers because they leave a blanket of straw over the crop land after rice harvest which prevents wind erosion. With government effort for increasing double cropping in rainfed rice fallow (RRF) land, effective mechanical straw management technique needs to be developed having provision for straw incorporation. Tractor operated paddy straw chopper (Singh *et al*, 2011) will be good mechanical option. To ensure availability of sufficient soil moisture for subsequent crop and decomposition of straw, mechanization is required for harvesting of paddy. It is better if such harvester is capable of operating in land having some amount of standing water. This will facilitate land preparation and decomposition of straw. The choice of crop for farmer will also increase. Zero tillage seed placement through tractor and power tiller operated zero till seed drill has been successfully tested in Assam (Technical Bulletin, 2015). For successful operation of such a seed drill some of the crop residue must be left in the fields. It was found that when crop residue of 20-40 cm height is left on the field, an amount of 3-4 tonnes of organic matter are returned to the soil. This helps in maintaining soil fertility and improves crop growth Raised bed planting of pulse have been approved as recommended practice for kharif pulse cultivation in Assam (Annual Report, 2015). This may further be promoted for other crop. With increased use of tractor for cultivation, research should be conducted in the field of control traffic farming to reduce soil compaction. Present mechanized farming systems allow machines to run at random over the land, compacting around 75% of the area within one season and at least the whole area by the second season. Soils don't recover quickly, taking as much as a few years. A proper Control Traffic Farming (CTF) system on the

other hand can reduce tracking to just 15% and this is always in the same place. As a result farmers may go for little or no tillage because soil structure does not need to be repaired. The permanent traffic lanes are normally parallel to each other and this is the most efficient way of achieving CTF. The permanent traffic lanes may be cropped or non-cropped depending on a wide range of variables and local constraints. While doing PFT and FLD of raised bed planter for pulses in Assam, it was noticed that a lot of manpower is required for performing subsequent operation like weeding and spraying. Land preparation is also required for growing a subsequent crop. In this context CTF with pulse as a crop in the cropping pattern appeared to be a viable option (Annual Report, 2016). Experiment at AAU revealed a highest B:C ratio i.e. 4.20 in black gram planted with raised bed planter and where weed control was done using a tractor drawn cultivator with tyne rearrangement and spraying was done using a tractor drawn boom sprayer. Soil compaction in rice land is already reported in Assam (Annual Report, 2015). Dry seeding of rice in non puddled soil will not only maintain soil structure but also reduce cost of tillage for subsequent crop. Five techniques for direct seeding for winter rice cultivation were compared at AAU during 2015 and 2016 to test the feasibility of DSR seed drill (Annual Report 2016). Among the treatments, mechanical seed placement by DSR seed drill and power tiller operated zero till seed resulted in highest benefit cost ratio followed by drum seeder. There was no significant yield reduction due to direct seeding as compared to traditional practice of transplanting**.**

Conclusion

The approach to crop diversification in rice-fallow needs special attention with respect to crop residue management, crop establishment and nutrient management in the succeeding crop. Effective and careful integration of farm machinery in all aspects including harvesting is required. Though not discussed, the effects of local and regional variations in rainfall intensity and pattern, and temperature need due consideration.

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MECHANICAL *IN-SITU* MOISTURE CONSERVATION MEASURES TO MITIGATE PROLONGED DRY SPELL EFFECT

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Abstract

Rain-fed agriculture occupies 67 percent net sources area, contributing 44 percent of food grains and supporting 40 percent of the population. In view of growing demand for food grains in the country there is a need to increase the productivity of rain-fed areas from current 1 tha^{-1} to 2 tha^{-1} in next decades. Further, effect of climate change and erratic rainfall pattern it is dire essential to conserve the water and utilize for sustenance of crop and increase water productivity. In view of the uncertainty of rain and mitigate drought two year experiment on in-situ moisture conservation technologies was conducted at Regional Agricultural Research Station, ANGRAU, Tirupati. The experiments were designed with moisture conservation techniques like vertical tillage up to 50cm (ramana etal.,2015) and basin listing(muthamil selvan etal.,), Vertical tillage was administered during primary tillage with sub-soiler and basin listing in between rows during seeding with basin-lister in the groundnut (Dharani variety)crop. During the first year the crop could not experience any dry spells and there was no significant effect of treatments on the yield attributes. During second year of experiment, one month dry spell experienced by the crop at 30th day of planting and after dry spell there was good rain occurrence of 32mm. The results indicated that treatment of vertical tillage up to 60cm at 2m apart registered 125.6 per cent yield (1243.6kg ha^{-1})increase and 22.3 per cent yield (674.0kg ha^{-1}) was observed over control plot (un treated) yield(551.0 kg ha^{-1}). This clearly indicates that deep layer moisture conservation through vertical tillage is more effective in mitigating one month dry spell effect of shallow rooted groundnut crop. The technology was approved for large scale adoption in the rain-fed districts of Andhra Pradesh.

Key words: *drought mitigation; in-situ moisture conservation; vertical tillage; basin-listing*

Introduction

Mechanical manipulation (tillage) is very important operations in ensuring the better crop productivity, especially in rain-fed agriculture scenario, but these are most neglected operations in India. Though the primary tillage implements are available, farmer with somehow complete mind-set is getting compromised with cultivator-tilling (designed for inter cultural operation for tilling 5-10cm depth) for primary and secondary tillage. The poorly practiced tillage operations, over years and influence of weathering action on soil crust aid in forming hard pan(compacted soil) just below(10-15cm) so called tillage depth, thereby limiting the root growth and rain water entry in to the soil strata and way-out rainwater from the field, which fails in conserving moisture in deep layers in-turn, fails to support crop during *dry spells* of farming. In addition change in climate, raining pattern i.e., less number of occurrences with greater intensities, prolonged

dryspells without moisture conserving practices allowing water to go out of the field and affecting the normal returns.

To overcome the emerging difficulties and insuring crop against prolonged dry spells during sensitive stages of crop, available moisture conservation methods one time ***sub-soiling*** (vertical tillage) (Ramana *etal.,*2015) in a year to the depth of 40-60 cm with single standard sub-soiler or deep layer moisture conservation and ***basin listing,*** shallow layer moisture conservation(Muthamil Selvan,*etal.*,2012) between rows i.e., near root zone were experimented. The main objective of the study was to verify the effect of ***shallow and deep layer conservation*** methods on farmer preferred rain-fed crop groundnut.

Materials and Methods

The experiment was designed in the fields of Regional Agricultural Research Station, Tirupati. The field was divided in to three parts and the following treatments were administered. Vertical tillage (sub-soiling) was administered to break open the hard pan to ensure vertical cut so as to maximize rain water entry in to the deep layers of the experimental fields (to ensure deep layer moisture conservation), with minimum disturbance on the surface soil. The field was sub-soiled with single standard Sub-Soiler to the depth up to 50 cm at 2 m interval after which regular tillage implement was used to plough and rotavator was used as secondary tillage operation and field was leveled. Similarly T_2 field was prepared by using plough after which rotovator was used and taken up the secondary tillage operation. Later the field was levelled and artificially (manually) formed basins (not continuous) were created in between crop rows at every 2m to retain rain water near root zone (to ensure shallow layer moisture conservation). The control plot T_3 was just prepared by using plough after which rotovator was used and taken up the secondary tillage operation. Later the field was levelled and seeding was done. All the experiments were sown on same day and field with same type of soil.

The morphological attributes and drought tolerant traits were recorded and yield parameters were recorded at harvest using ten randomly selected and tagged plants in each net plot and average data is presented. Mean plant height was measured from the ground level to the apex of the main axis and expressed in cm/plant. The mean number of branches/plant was worked out from the same selected ten plants and was expressed as number of ranches/plant. Leaf area was recorded by using leaf area meter (LICOR Model 3100) and the average was expressed as leaf area/plant in cm^2 .The relative water content was recorded as per the procedure of Barrs and Weatherley (1962). For root sampling ten random plants in each treatment were selected and boundaries were defined based on the area occupied by each plant. Roots in the soil layers were carefully removed by digging to a depth of 40 cm (soil was too hard to dig after that) and washed with fresh water to remove adhering soil. Root length was measured using a standard scale from the ground level to the tip of the root. Thus harvested roots were oven dried at 80^0 C for 48 hr and dry weights were recorded using sensitive electronic balance and expressed in g/plant. The number of pods from the randomly selected ten plants in each treatment was counted and the average was expressed as number of pods/plant. A lot of seeds were drawn at random from each treatment and weighed. Number of seeds constituting the sample was counted and from these values 100 seed weight was computed. Harvested plants were allowed for drying and weighed (g/plant).It was also calculated for a net plot area and it was computed to hectare and expressed as kg/ha.



Fig. 1 Tractor with Sub-soiler Basins formed and with water after arainy day

Results and Discussion

During the year 2012-13 the rainfall was well distributed throughout the crop duration and significant differences were not observed among all the morphological and drought tolerant traits and yield attributes. Hence the data was not presented. However during the year 2013-14, the crop sown after initial rains of monsoon and after one month (about 27 days) suffered with severe terminal moisture stress one month in August 2014 (before flowering) for 30 days due to failure mid rains. The data on morphological parameters, drought tolerant traits and yield attributes showed significant variability between conventionally tilled plot and sub-soiled plot (Table 1) and detailed results are presented here. Morphological characters though the plant height is genetically controlled, soil moisture plays critical role in its regulation. Plant height was significantly higher by in sub-soiled treatment compared to conventional tillage treatment where as the effect was not so significant in basin listed plot. Similarly, the leaf area/plant which is an active photosynthetic surface and prime source to feed sink was significantly higher by 27.4% and 20.1% in sub-soil tillage and basin listed treatments respectively compared to control plots at 57thday after sowing (Table.1). These results clearly demonstrate the magnitude of response of sub-soil tillage treatment in sustaining plant growth and leaf area by maintaining higher tissue water status. Similar results of increased biomass (26.7%) due to sub-soil tillage was reported in maize compared to conventional tillage (Hongguangcai et al. 2104) Drought tolerant traits Maintenance of plant water status is more important for cellular functions, which is a prerequisite for any crop to perform under drought. Rekika et al.(2000) reported that enhanced RWC under moisture stress conditions helped the plants to perform the physiological processes like stomatal conductance, photosynthesis, biochemical metabolism to continue more effectively. Root system plays an important role under drought conditions. The nature and extent of root traits, viz. root length and root dry weights are considered to be major factors affecting plant response to water stress. Soil tillage treatment recorded significantly higher root length (74.3%) and (49.4%) in sub-soiled and basin listed plots respectively compared to conventional tillage treatment (Table 2). It implies that due to the breaking of plough pan through sub-soiler, plants extended root system to

deeper layers and maintained water uptake and plant water balance under moisture stress conditions. Hence the plants could maintain higher plant growth, green leaf area and thus maintained higher morphological and physiological activities.

Table.1 Morphological parameters of the groundnut crop of the experiment on 57th day

Method	S.No.	Plant ht (cm)	No of branches	No of pegs	No of pods	Root length	Root fresh weight (g)	No of nodules
Basin listing	1	26	5	6	13	26	1.219	50
	2	25	5	7	11	30	1.350	125
	3	23	5	3	4	30	1.950	
	4	22	5	5	8	25	1.494	
	5	23	5	5	10	26	1.468	
Leaf Area: 2297.67 Sq.cm								
Subsoiling	1	34	6	8	12	26	0.932	75
	2	30	5	9	16	34	1.399	115
	3	34.4	5	1	8	16	0.956	
	4	27	5	4	10	26	1.469	
	5	26	5	8	10	25	1.235	
Leaf Area: 2419.99 Sq.cm								
Control	1	30	5	1	8	16.9	0.717	30
	2	23.5	5	4	4	20	1.048	39
	3	25	5	2	7	17	0.726	
	4	33	5	9	2	22.4	1.653	
	5	19.5	5	2	7	16.5	1.206	
Leaf Area: 1899.39 Sq.cm								

Table 2 Effect of subsoiler and basin lister on drought mitigation of groundnut (Dharani)

Method	Plant ht.		Root length		Plant population		No of filled pods		Pod yield/ m^2		Shelling %		Pod yield/ha	
Control	28.20	**b**	7.86	**c**	10.50	**c**	5.37	**c**	58.27	**c**	58.8	**b**	551.0	**c**
Basin lister	31.62	**a**	11.75	**b**	14.65	**b**	12.65	**b**	68.65	**b**	68.8	**a**	674.0	**b**
Subsoiling	31.92	**a**	13.70	**a**	26.75	**a**	18.62	**a**	124.3	**a**	70.6	**a**	1243.0	**a**
% increase by basin lister	12.1		49.49		39.5		137.4		17.81		17.01		22.3	
% increase by subsoiling	13.19		74.30		154.7		246.7		113.3		20.15		125.6	

Yield and its attributes Yield is a complex polygenic trait which is highly influenced by the environment. The stress factors especially drought affect plant growth and development and causes a sharp decrease of plant productivity (Sudhakar et al.2006). In the present investigation also number of plants per square metre area has come down after the 30day dry spell drastically reduced the population in the control as well as in the basin listed plots due to stress and root-rot instance (root-rot flare up in dry spell followed by heavy down pour). However such negative effect was counteracted with the mechanical intervention of tillage with sub-soiling up to 50 cm. From the data, it is clearly evident that sub-soiling was responsible for significant increase in number of pods/plant by 250.4%, and pod yield by 113.5% compared to conventionally tilled treatment. Similarly mediocre benefit was resulted through basin listed plot of pods/plant higher by 137.3%, and pod yield by 17.8% over conventionally tilled treatment. Such yield advantage due to sub-soiling can be ascertained to enhanced soil water storage capacity due to breakup of plough pan and their by entry of rain water into the deeper layers of field. It may also be due to reduction in bulk density at root zone. Improved water uptake by plants in sub-soil treatment owing to increased depth of the sub-soil tillage, promoted root penetration and mitigated the instances of root-rot. It is important to note that vertical-cuts aids rain and irrigated water entry in to a deeper layers beyond hard surface so as to minimize lateral flowing rain water and to percolate in to the same field where the rain occurred, which propels in-situ moisture conservation. Such beneficiary effect due to sub-soiling was proliferated specially where crop exposed to moisture stress condition for over a month during 2014. The present investigation exhibits more advantage of deep layer moisture conservation (sub-soil tillage) over the shallow layer (basin listing) moisture conservation for groundnut crop grown under rain-fed condition and can be used as a potential option for drought mitigation.

Conclusions

The two in-situ moisture conservation methods sub-soiling up to 40-60cm(deep layer moisture conservation) and Basin listing (shallow layer moisture conservation) are tested for suitability in the rain-fed groundnut crop. The mechanical intervention of tillage with sub-soiling up to 50 cm was exceptionally effective in mitigating the effect of prolonged dry spell in groundnut crop and pod yield registered by 113.5% increase, compared to conventionally tilled plot yield. Similarly mediocre benefit was resulted through basin listed plot with pod yield increase by 17.8% over control plot.

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CROP & WATER PRODUCTIVITY ASSESSMENT IN CANAL COMMAND AREA THROUGH WATER USERS ASSOCIATION

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Abstract

In irrigated agriculture, profitability from irrigation system for raising/ growing various crops is largely depending upon proper planning for optimum utilization of irrigation water, operation& maintenance of irrigation system, efficient on-farm water management practices and proper marketing of the produces. There is enough scope to make farming more profitable if high value crops and modern methods of irrigation are selected. Despite this, demand and supply has to be throughly studied before products are sent to the market. Water productivity may be regarded as an indicator realizing optimal harvest from the best performed irrigation system. A correction in achieving high value of water productivity is possible if sound planning is done and the field performance is maximized. Water productivity also gives a sense how to grout market attractive crops, keeping all related systems in dynamic form.Irrigation Engineers are constant trying to supply irrigation water to each farmers of command area those who need water by making all efforts. Finally, after completion of season, they are having only water release data normally at head regulator of dam site and some times at block or at beat level. They are also having data of how much total water released during one season for all the crops, how much area is irrigated for each crop & total for all crops. However no data is available for individual crop that consumed water. With this data, we can calculate area irrigated by unit of water i.e. duty achieved in Ha/Mcft or Ha/Mcum of water but economic status point, this is not sufficient. At least for this, we required crop productivity data for all irrigated crops in each project area.The cropped area, crop production and crop productivity data are worked out and forecasting by Director of Agriculture for each crop grown in respective states are based on crop cutting survey carried out by Department irrespective of command area and irrigation sources, hence, Irrigation Engineers can not use this data to calculating water productivity in his project. Hence, project-wise crop productivity data is required and for this, neither irrigation department nor agriculture department is collecting project-wise crop productivity data. By this way only lacking of crop productivity data, we can not workout water productivity for individual project. Therefore, efforts has been made to worked out strategy for this by which irrigation authority can assess crop productivity data to be fill up in prescribed format by farmers through participatory approach with the help of Agriculture Extension Officers / VLWs or WALMI with minimum efforts. The developed strategy has been successfully implemented in Uben Irrigation Project as a trial base during the year 2009-10 to 2013-14 and results are presented in this paper.

Introduction

Up till now we have heard about crop productivity (kg/ha.), animal milk productivity (liters/animal), mileage of vehicle (km/liter of petrol or diesel), labor efficiency (works/hour or day) but nobody is seriously thinking about water productivity i.e. agricultural production in terms of rupees over applied unit of water. More precisely it can be said that net profit Rs./unit of water

application. Water use efficiency is different than water productivity. Efficiency concept in any system is based on a resources of output obtained from a given unit of input. But in water productivity we are counting output in terms of rupees rather thanquantity, whereas, in WUE we are considering quantity produced by unit volume of water. High irrigation efficiency means maximum productivity of water and therefore our main focus should be on higher net profit by agricultural production from unit volume of applied water. In nutshell, we can say that water productivity is a broad concept and it covers all other efficiency in water resources management because higher net return is only possible when farmers able to produce good quality, high quantity with less amount of water which reflects upon agro-technology also used by farmers, market price and water application techniques.

A theoretical calculation of water productivity of important irrigated crops is given in ***Table-1***. The crop water requirements are considered at farm gate. However, water productivity given in ***Table-1*** is depends on ***farmers skill***, ***soil type***, ***seasonal variations***, ***marketing price*** etc. If water is a constraint, farmers can choose the low water consuming crops like cumin, coriander to get maximum return over applied water.

Table-1 Water productivity of important irrigated crops of Gujarat on the bases of theoretical data.

Sr. No	Name of Crop	CWR at FG (mm)	Quantity of CWR at HR with 50% PE (M^3/Ha)	Crop Yield (Kg/Ha)	WR at HR for 1 Kg Yield (M^3)	Price as per APMC (Rs/Kg)	Water Productivity at HR (Rs/M^3)
1	***2***	***3***	***4***	***5***	***6=4/5***	***7***	***8 = 7/6***
1	Wheat	500	10000	4000	2.5	14.00	5.60
2	Mustard	350	7000	1500	4.7	25.00	5.32
3	Gram	300	6000	2000	3.0	20.00	6.67
4	Cumin	300	6000	800	3.5	120.00	16.00
5	Coriander	400	8000	1500	5.3	45.00	8.49
6	Maize (R)	400	8000	4000	2.0	10.00	5.00
7	Paddy	1200	24000	4000	6.0	10.00	1.67
8	Sugarcane	1500	30000	100000	0.3	02.50	8.33
9	Potato	400	8000	24000	0.3	05.00	16.67
10	Castor	650	13000	2000	6.5	35.00	5.38
11	Cotton	650	13000	2000	6.5	45.00	6.92
12	H.W.Bajri	500	10000	3000	3.0	10.00	3.33

CWR = Crop Water Requirement, FG = Farm Gate, PE = Project Efficiency, HR = Head Regulator

METHODOLOGY FOR CROP PRODUCTIVITY DATA ASSESSMENT BY FARMERS IN CANAL COMMAND AREA

To find out easy, simple and workable reliable strategy for assessing crop productivity in canal command area the detailed discussion was held with the Department of Agriculture, Project Engineers and also progressive farmers of the command area. As a out cum of this the following strategy was developed by WALMI:

1. Select randomly at least three farmers (Head, Middle & Tail reach) from each minor of irrigation project ***(Figure-1)*** and make them fully aware about this assessment.
2. Handover the **Form-A** to selected farmers well in advance i.e. before sowing.
3. Monitor and verify that the farmers are filling information properly or not.
4. Consult VLW/Agriculture Extension Officer if required in crop yield survey and collect the ***Form-A***from all farmers after crop cutting.
5. Calculate the crop productivity for individual crops on the bases of farmers data fill up in the ***Form-A*****.**
6. ***Form-A*** is also contains other data on Agro-technology adopted by farmers and it will helps to judge the crop productivity data.
7. Here we are collecting data from entire area viz. head reach middle reach & tail command and therefore, the collected data are highly useful to comparing water productivity in different parts of command area which can be useful to further improvement in next coming season.

CASE STUDY FOR WATER PRODUCTIVITY IN UBEN IRRIGATION PROJECT

Uben Irrigation Project is a World Bank Aided Project situated near village Bhatgam of Bhesan Taluka in Junagadh District of Gujarat State. Total CCA of the project is 2500 Ha, which is already developed with fully lined distribution system extending up to 8 Ha. Block to serve entire command. In the entire command area, the measuring devices viz., ramp flume, proportional flow divider and other efficient structures are provided for implementing the Rotational Water Supply (RWS) system. Committees such as farmers committee, chak and sub-chak level committee for introduction of RWS were formed initially but now entire command has been hand over to 11 WUAs and recently they have also formed federation of 11 WUAs.

The Brief Salient Feature of Uben Irrigation Project is as under

1.	Total C.C.A.		:	2500	Ha.
2.	Total No. of Farmers		:	1200	Nos.
3.	Gross Storage at FRL		:	16.20	Mcm.
4.	Dead Storage at OSL		:	0.60	Mcm.
5.	Live Storage at F.R.L.		:	15.60	Mcm.
6.	Evaporation & Seepage losses		:	5.71	Mcm.
7.	Design Cropping intensity:	Kharif	:	94.50	%
		Rabi	:	15.00	%
8.	Principle Crops:	Kharif	:	Groundnut	
		Rabi	:	Wheat	

The irrigation was started from Kharif 1986 and thereafter, strictly RWS system was enforced and water has been released as per pre-determined canal operation plan. After continuous efforts made by Irrigation Department and WALMI, farmers co-operation were achieved for adopting canal operation plan and RWS system.

During the year 2009-10, 2010-11,2011-12& 2013-14 the developed strategy was followed in Uben Irrigation Project by involving farmers to assess the crop productivity in canal command area. In each minor, 3 farmers were selected from had reach, middle reach and tail reach. All the selected farmers and LLFs have been trained at project site by arranging farmers meeting by WALMI Faculty with the co-ordination of project engineers. Entire methodology was followed and constant monitoring was done by project engineer. At the end of season, **Form-A** were collected from each farmer and analyzed by project engineer with the help of WALMI Faculty. The detailed of selected farmers and results obtained are given in ***Table.2A, 2B & 2C*** for the year **2013-14**. Whereas summary of results obtained in 4 years are given in ***Table.3***.

General Observations & Conclusion

1. All the farmers have taken very keen interest to follow this strategy for assessing crop productivity.
2. Now farmers are understand the value of drop of water after adopting this strategy.
3. The higher crop productivity is found in canal command area than district average crop productivity in which irrigation project is located. It shows the importance and needfulness of assessment of crop productivity in canal command rather dam use of district crop productivity data to workout water productivity.
4. Data presented in ***Table-2A*** indicates that there is no heterogeneity in crop productivity from head reach to tail reach farmers within the minor & between the minors.
5. Data of cropping pattern & crop productivity given in ***Table-3*** indicate that the farmers are switched over from mono cropping to diversified cropping pattern.
6. Marginal increase in water productivity has been noticed in the year 2009-10 TO 2011-12 whereas in the year 2013-14 two time water productivity has been observed as compared to earlier year and it may be due to crop productivity, marketing price and higher duty (more efficient water use)
7. Now farmers are well aware to adopt this strategy and without any burden to Govt. Machinery, the valuable information can be generated with a participatory approach.
8. Water productivity obtained during the year 2009-10, 2010-11 & 2011-12 ***(Table.3)*** are considerably higher than the theoretical water productivity given in ***Table.1***, which indicates the how efficiently farmers are applying water and advance Agro-Technology.
9. This strategy should be adopt in all the irrigation projects for comparison & further improvements.

Form-A

Specimen Format for collection of data from farmers to assess crop productivity in canal command area.

Sr. No.	Particulars	Information to be fill-up by Farmers/WRD		
A	***Project Information***			
1	Name of irrigation project			
2	Name of Division / Sub Div. / Minor No.			
B	***Farmer's Information***			
1	Name of Farmers			
2	Name of Village / Taluka / District			
3	Survey No. of Farm			
4	Cultivated Area of Survey No. (Ha.)			
C	***Crop Information***			
1	Year / Season			
2	Name of crop / variety			
3	Crop area (Ha.)			
4	Date of sowing / Method of sowing			
5	Whether Seed treatment given ? (Yes / No)			
6	Seed rate (Kg/ha.)			
7	Fertilizer applied	Name of fertilizer	Date of application	Quantity of fertilizer
	a. Organic fertilizer / FYM			
	b. Chemical fertilizer			
8	Irrigation by Canal Water • Outlet flow rate : LPS	No. of Irrigation	Date of Irrigation	Time Taken in hours
		1		
		2		
		3		
		4		
		5		
9	Irrigation by other sources • Name of source : _____ • Flow rate : LPS	No. of Irrigation	Date of Irrigation	Time Taken in hours
		1		
		2		
10	Date of crop cutting			
11	Yield Kg/Crop area			
12	Yield Kg/Ha			
13	Date of visit & place with signature of LLFs / VLW			
14	Signature of Farmer			

Table-2
Table-2A: Crop Productivity of major crops grown in Rabi 2013-14 in Uben Project.

Sr. No.	Water Course No	Survey No.	Name of Farmer	Crop productivity (Kg./Ha.)			
				Wheat	Cotton	Garlik	Dhana
1.	LB -M1	129 p	Hasamukh Kadava , Bavapipaliya	5625	--	-	-
2	LB -M1	117/1	Nitesh Arajanbhai, Bavapipaliya	6000	-	-	-
3	LB -M1	138/ 1	Gandu Bhana , Bavapipaliya	6250	-	-	-
4	LB -M2	16	Mansukh Velaji , Bavapipaliya	5500	-	-	-
5	LB -M2	66	Hira Soma, Bavapipaliya	5625	-	-	-
6	LB -M2	49	Ramesh Gandu, Bavapipaliya	5250	-	-	-
7	LB -M3	47/1/1	Bhikha Hira, Bavapipaliya	6250	-	-	-
8	LB -M3	74 / 4	Pankaj Mohanbhai ,Arab Timbadi	-	-	-	2500
9	LB -M3	88/1	Jagadish Hira, Arab Timbadi	6125	-	-	-
10	LB -M4	14 / 2	Ashok Vashram, Arab Timbadi	6250	-	-	-
11	LB -M4	66 / 2	Aravind Mulaji, Arab Timbadi	6250	-	-	-
12	LB -M4	7/ 1/2	Hitesh Vallabh, Arab Timbadi	6250	-	-	-
13	LB -M5	193/2	Kanti Govind, Arab Timbadi	6250	-	-	-
14	LB -M5	298	Daya Ruda, Arab Timbadi	-	-	3750	-
15	LB -M5	211 / 1	Mukesh Mohan, Arab Timbadi	6250	-	-	-
16	LB -M6	234/1	Gopal Kala , Arab Timbadi	5625	-	-	-
17	LB -M6	286	Nilesh Mohan, Arab Timbadi	6000	-	-	-
18	LB -M6	264/4	Prabhaben Bachu, Arab Timbadi	6250	-	-	-
19	LB -M7	273 / 3	Ramanik Jamanadas, Pipalava	6250	-	-	2500
20	LB -M7	228 /1	Raiya Haradas, Pipalava	-	4500	-	-
21	LB -M7	173 / 1	Bachu Amba, Pipalava	5625	-	-	-
22	LB -M8	44 /3	Gandalal Ranchhod, Akala	6000	-	-	-
23	LB -M8	209 /5	Premaji Laxman, Akala	-	-	-	2250
24	LB -M8	68 / 1	Parsotam Jeram, Akala	-	4750	-	-
25	LB -M9	24 p	Subhas Bavanji, Akala	-	4750	-	-
26	LB -M9	74	Bhanu Gordhan, Akala	-	4375	-	2125
27	LB - M9	57	Trikam Harasukh, Akala	-	-	-	2500
28	LB -M10	94 /3	Hari Manji, Ishapur	6000	-	-	-
29	LB -M10	63 / 2	Nanduben Popat, Ishapur	-	-	-	2375
30	LB -M10	14 / 1	Paresh Jivaraj, Kathrota	6250	-	-	-

31	RB -M1	105 / 1	Ranjanben Bipin, Arab Timbadi	5625	-	-	-
32	RB -M1	36	Bhikha Jivaraj, Pipalava	5000	-	-	-
33	RB -M1	14 / 2	Ramesh Bhikhu, Pipalava	5375	-	-	-
			Average	5910	4594	3750	2375
			District Average	**4314**	**2151**	**N.A**	**N.A**

Table-2B: Value of Agriculture Production in Uben Irrigation Project for Rabi : 2013-14.

Sr. No.	Name of Crop	Total Area (Ha.)	Productivity (Kg./Ha.)	Total production (Kg.)	Price Rs./Kg. As per APMC	Total value (Rs.)
1	**2**	**3**	**4**	**5**	**6**	**7=5x6**
1	Wheat	334	5910	1973940	14.00	27635160
2	Cotton	385	4594	1768690	45.00	79591050
3	Garlik	45	3750	168750	18.00	3037500
4	Dhana	110	2375	261250	75.00	19593750
5	Onion	32	25000	800000	3.50	2800000
6	Bajari	25	2500	62500	12.00	750000
					Total.....	**133407460**

Table-2C: Water Productivity at head regulator of dam site for Rabi : 2013-14

Water Utilization in M^3		Total Water Utilization (M^3)	Value of Total Agricultural production (Rs.)	Water productivity (Rs./M^3)
Canal Water at HR	Approximately well water @ 20% of Canal water			
4746000	949200	5695200	133407460	**23.42**

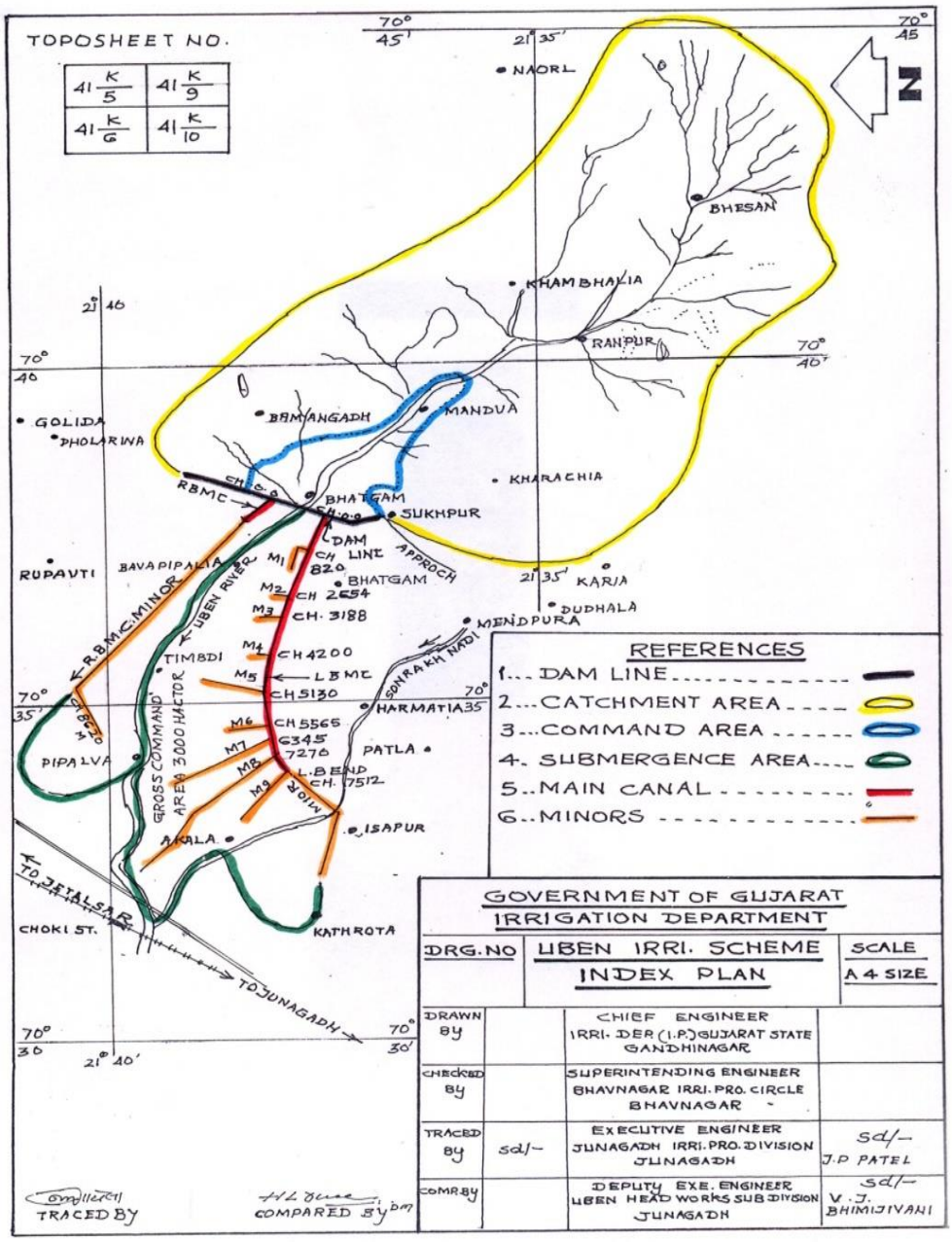
Table-3

The comparative water utilization, cropping pattern and crop productivity of Uben Irrigation Project.

Sr. No.	Particulars	Year			
		2009-2010	2010-2011	2011-2012	2013-14
1	Canal Water Utilization				
a.	Water released at HR (Mcft)	190.00	206.52	219.55	167.58
b.	Total Ha. Watering	8380	7495	6568	5417
c.	Duty achieved at HR (Ha/Mcft = b/a)	44.11	36.29	29.92	32.32
d.	Delta at HR for one watering in mm (2832/c)	64	78	95	88

2	Cropping Pattern (Area in Ha. with crop productivity Kg/Ha)	**Area**	**Yield**	**Area**	**Yield**	**Area**	**Yield**	**Area**	**Yield**
a.	Wheat	1000	4614	661	4792	616	5197	334	5910
b.	Cotton	-	-	120	2812	66	3250	385	4594
c.	Castor	-	-	-	-	33	4375	-	-
d.	Garlic	-	-	-	-	33	9400	45	3750
e.	Onion	-	-	83	17500	24	26667	32	25000
f.	Fodder	-	-	61	43750	-	-	-	-
g.	Dhana	560	1362	-	-	49	1765	110	2375
h.	Tal (Sesamum)	-	-	76	1250	-	-	-	-
	Total Area Irrigated	1560	-	1001	-	821	-	906	-
3	Total Value of Agril. Production in Rupees.	69822000		69566394		76341118		133407460	
4	Total Water utilization in M^3 (Canal + Well)	6466800		6432800		6590020		5695200	
5	Water Productivity at HR (Rs. / M^3 of Water)	10.80		10.81		11.58		23.42	

FIGURE – 1


TOPOSHEET NO.
41 K/5
41 K/9
41 K/6
41 K/10
70° 45'
21° 35'
NAORL
BHESAN
KHAMBHALIA
RANPUR
21° 40'
70° 40'
GOLIDA
PHOLARWA
BAMANGADH
MANDUA
KHARACHIA
RBMC
BHATGAM
SUKHPUR
DAM
CH LINE
APPROCH
820
BHATGAM
RUPAVTI
BAVAPIPALIA
UBEN RIVER
M1
M2 CH 2654
M3 CH. 3188
KARJA
DUDHALA
MENDPURA
R.B.M.C. MINOR
M4 CH 4200
M5 L.B.M.C.
CH 5130
SONRAKH NADI
TIMBDI
HARMATIA
M6 CH 5565
6345
7276
PATLA
PIPALVA
M7
M8
L.BEND
CH. 7512
M9
MINOR
GROSS COMMAND AREA 3000 HECTOR
ISAPUR
AKALA
TO JETALSAR
CHOKI ST.
KATHROTA
TO JUNAGADH
21° 40'
70° 30'
N
REFERENCES
1... DAM LINE
2... CATCHMENT AREA
3... COMMAND AREA
4. SUBMERGENCE AREA
5.. MAIN CANAL
6.. MINORS
GOVERNMENT OF GUJARAT
IRRIGATION DEPARTMENT
DRG. NO
UBEN IRRI. SCHEME
INDEX PLAN
SCALE
A 4 SIZE
DRAWN BY
CHIEF ENGINEER
IRRI. DEP (I.P.) GUJARAT STATE
GANDHINAGAR
CHECKED BY
SUPERINTENDING ENGINEER
BHAVNAGAR IRRI. PRO. CIRCLE
BHAVNAGAR
TRACED BY
sd/-
EXECUTIVE ENGINEER
JUNAGADH IRRI. PRO. DIVISION
JUNAGADH
sd/-
J.P PATEL
COMP. BY
DEPUTY EXE. ENGINEER
UBEN HEAD WORKS SUB DIVISION
JUNAGADH
sd/-
V. J. BHIMJIYANI
TRACED BY
COMPARED BY

WATER USE EFFICIENCY: A CASE STUDY OF SAURASHTRA IRRIGATION PROJECTS OF GUJARAT STATE

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Introduction

Efficiency concept in any system is based on a measure of output obtained from a given unit of input. In agriculture, efficient water utilization reflects how efficiently water is stored, distributed and used in crop production. The *design of the irrigation system,* the *degree of land preparation* and the *skill and care of the irrigator* are the principle factors influencing water use efficiency. In a well designed irrigation system, on-farm efficiencies in surface methods of irrigation ranges from 60 to 70 percent and in sprinkler irrigation, 70 to 80 per cent. The common cause of loss of water in the field in surface methods of irrigation is by deep percolation below crop root zone and in sprinkler irrigation by the evaporation of the spray and interception of the applied water on the crop foliage most of which is lost by evaporation subsequently. Loss of runoff at the end of irrigation borders, furrow and field channels may also occur sometimes. Most of the Irrigation Projects throughout the world functioning on the principle of gravity flow operate with 25 to 40 percent efficiency. Thus, perhaps one third of the water that is released in to canal system at their Head works is actually beneficially used by crops for evapotranspiration. Major reasons for low efficiency are:

- Inadequate design of the project
- Lack of maintenance
- Inadequate management
- Lack of co-ordination
- Water allocation on area basis
- Inadequate knowledge of users about irrigation scheduling

Water use efficiency is becoming one of the key issues facing irrigation farmers and water managers in India. With increasing demand on water resources, it is becoming more important to manage these resources effectively. Generally, it is seen inefficient water use as a threat to water resource sustainability. To maintain access to water, there will be more pressure on farmers and water system managers to demonstrate that they are using water effectively and efficiently. There are many benefits to improving Water Use Efficiency including both environmental and economic. **"Evaluation is therefore an essential aid to policy"** : In order to know the performance of an existing system may be improved, it is first necessary to know how well or poorly it is performing in its existing state. Also, in order to know how effective technological and managerial improvements are, it is necessary to know how much better the system performed after the improvements were made.

Methodology

To work out actual WUE, the measurement of water diverted from HR, CR, Outlet and how much water stored in the root zone is essential. Practically no such mechanism is available in majority of the irrigation projects in our country and therefore, it is very difficult to workout WUE those prescribed by scientist in theory. Majority of the irrigation projects authority having accurate and reliable recorded data on water release at Head Regulator in different season. Moreover from the same released water they are also record available for how much area under different crops are irrigated in particular season and also in single watering. By this way duty Ha/Mcft. can be worked out easily at Head Regulator point of irrigation project. Under these circumstances in order to assess how much amount of water (depth of irrigation water) applied by farmers on their fields, the study was under taken by WALMI Faculty with the help of field irrigation engineers of different projects in Saurashtra (water scarce area) region of Gujarat State in current Rabi season i.e. Rabi 2015-16. Considering soil type & topography, following two pockets were selected for this study. The location of irrigation projects are depicted in ***Fig. 1***

A. Soils having uneven topography,shallow depth & medium to heavy texture.

1. Nyari-II Project, Dist. Rajkot.
2. Aji-II Project, Dist. Rajkot.

B. Soils having uniform slope, fiat topography and heavy texture.

1. Machhu-II Project, Dist. Morbi.
2. Demi-I Project, Dist. Morbi.
3. Bhadar Project, Dist. Rajkot.

Necessary information and data were collected and also recorded by taking actual reading / measurement during study period for all the irrigation projects. Simultaneously three sites were also selected where well irrigation is practiced for comparing with canal irrigation. At each project site some small area (Nos. of borders) were earmarked and actual time required for irrigating the same area were recorded. Based on design flow rate of outlet and actual functioning flow of outlet given by field engineers the average flow rate was considered for calculating the amount of water diverted from outlet head for irrigating the selected area. Based on these data, depth of irrigation water applied at outlet head by farmers in different sites were workout and given in ***Table-1*** for medium texture soil, ***Table-2*** for heavy texture soil &***Table-3*** for well/tubewell irrigation with other relevant information.

Result and Discussion

The data given in ***Table-1*** reflects that the depth of irrigation water applied by farmers is ranging from 83 to 90 mm. at outlet head. If we consider 80 % field efficiency the actual depth of irrigation applied by the farmers is arround 70 mm. at field. Considering soil topography and texture the applied depth of irrigation is nearer to scientific depth of irrigation(60 to 65mm). It indicates that the farmers are not wasting water on their farm during irrigation. The data given in ***Table-2*** shows some more depth of irrigation (90 to 100 mm) than the earlier case and this is due

to soil topography and heavy texture soils. The depth of irrigation water (40 to 80 mm) applied in well irrigation is very close to scientific depth of irrigation which can be easily shown from data presented in ***Table-3.*** Comparing all the sites, no too much deviation are observed in depth of irrigation water applied by farmers on their field. Marginal deviation may be due to of farmers skil & involvement, land preparation for irrigation and moisture status in the root-zone prior to irrigation. The duty achieved by field engineers was reported ranging from 16-20 Ha/Mcft In single watering. If we calculate average duty 18 Ha/Mcft i.e. irrigation depth at head regular is about 157 mm. Out of 157 mm. irrigation depth released at HR, 80 mm reached at farmers field and this indicate about 50 % Project efficiency or you can say WUE.

Observations

1. Saurashtra's farmers are very hard worker and habituated with water scarce situation. They are very expert for land preparation for irrigation very scientifically which resulted in efficient irrigation.
2. Farmers are well aware about value of water and most of the farmers are doing cultivation themselves and remain present in the field during irrigation period even also in night period.
3. Farmers also knows about irrigation cut off point. When water reaches upto point of 70-80 length of border they stopped water flow and divert in next border which avoid excess runoff or stagnation of water at tail portion of border / field.
4. Crops like cotton, farmers are applying water in alternate furrow for irrigating more crop area from less water which gives very high WUE.
5. Overall results shows that farmers are preparing very long border (***as long as field length***) due to shortage of labour or to minimise labour cost. Further WUE can be increased by reducing length of border to avoid high recession in initial stage of border.
6. This is only observations / measurement on the basis of one watering but it should be repeated even next two to three irrigations for over all seasonal WUE and irrigation performance.
7. By making crop cutting experiment or by crop yield data collecting from the farmers, the water productivity can be easily worked out which is the ultimate goal of irrigation development.

Fig. 1 : Location of the Irrigation Projects of Case Studies

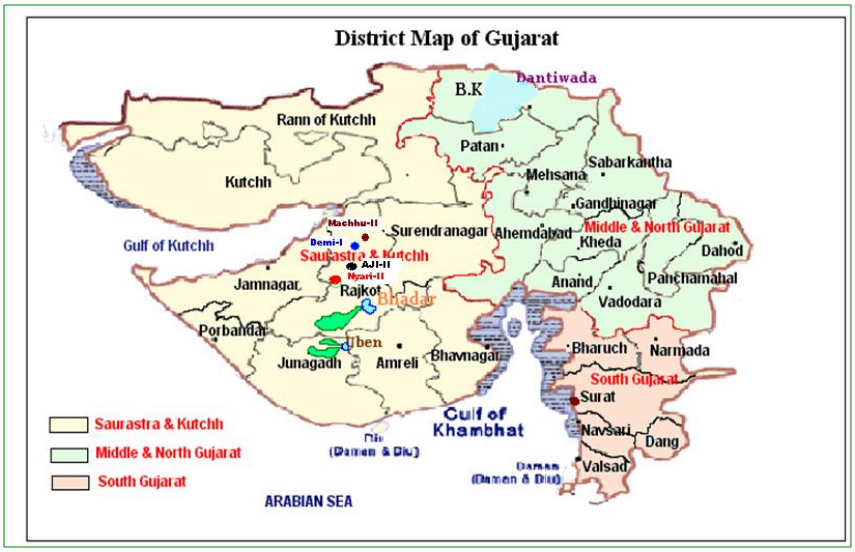


Table – 1 : Irrigation Performance in Medium to Heavy Texture Soils

Scheme	Nyari – II	Nyary – II	Aji - II
Canal	D1R	D1R	Minor - 5
Outlet / WC	Ch. 3370 / WC -5	Ch. 3370 / WC – 1	WC - 3
Discharge	1.375 Cusecs = 38.94 lps	0.75 Cusec = 21.24 lps	1.125 Cusecs = 31.86 lps
Farmer's Name	Dharamshi Pipalia, Metoda	Rajesh Vekaria, Metoda	Bechar Parmar, Baghi
Survey No.	96 paiky	52 paiky	66 paiky
Soil Type	Sandy Clay	Sandy Clay	Sandy Clay
Irri. Period	0-22-44 (H-M-S)= 1364 Sec	1-19-0 (H-M-S)=4740 Sec	0-27-50 (H-M-S)=1670 Sec
Irri. Area	134 m x 4.8 m = 643 M2	115 m x 10 m = 1150 M2	128 m x 4.6 m = 589 M2
Irri. Method	Long Border	Long Border	Long Border
Crop	Wheat	Wheat	Wheat
Delta at outlet	**83 mm**	**88 mm**	**90 mm**

Table – 2 : Irrigation Performance in Heavy Texture Soils

Scheme	Bhadar	Demi - I	Machchhu - II
Canal	M1R (Section – 1)	Main canal	D1L
Outlet / WC	2 / WC - 1	D.O.	M8R / WC - 1
Discharge	0.875 Cusec = 24.78 lps	0.50 Cusec= 14.16 lps	0.88 Cusec=24.92 lps
Farmer's Name	Vaghaji Gondalia, Vadasada	Sajibhai Chaudhary , Tankara	Prabhulal Thoriya , Bagathala
Survey No.	33	670 paiky	393
Soil Type	Silty Clay	Silty Clay	Black Cotton
Irri. Period	1-15-20 (H-M-S)= 4520 Sec	1-7-30 (H-M=S) = 4050 Sec	1-44-24(H-M-S) = 6264 Sec
Irri. Area	105 m x11.4 m=1197 M2	128 mx5m =640 M2	267m x 5.80 m=1549 M2
Irri. Method	Long Border	Broad Furrow	Broad Furrow
Crop	Dhana (Coriender)	Cotton	Castor (Divela)
Delta at outlet	**94 mm**	**90 mm**	**100 mm**

Table – 3 : Irrigation Performance in Well / Tubewell Irrigation

Scheme	Irri. By WELL	Irri. By WELL	Irrigation By BORE
Canal	Bhadar command	Out of UBEN Command	Out off UBEN command
Outlet / WC	5 HP / 15' -20'	5 Hp / 55'– 60' deep	20 Hp / 700' – 800'
Discharge	0.40 Cusec = 11.33 lps	0.35 Cusecs= 9.91 lps	0.60 Cusecs = 17 lps
Farmer's Name	Bhagavanji Gondalia, Varasada	Kanji Gordhan Rabadia , Akala	Keshu Rupapara , Akala
Survey No.	33 paiky	102 / 3	NA
Soil Type	Sandy Clay	Sandy Clay	Sandy Clay
Irri. Period	8 hrs. Reported by Farmers = 28800 Sec	9 Hours Reported by Farmer = 32400 Sec	16 Hours Reported by Farmer = 57600 Sec
Irri. Area	135 m x 30 m =4050 M2	8000 M2	16800 M2
Irri. Method	Long Border	Alternate Furrow	Long Narrow Border
Crop	Wheat	Cotton	Dhana (Coriendre)
Delta at outlet	**81 mm**	**40 mm**	**58 mm**

USER FRIENDLY COMPUTER SOFTWARE FOR THE DESIGN OF DRIP IRRIGATION SYSTEM

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Abstract

Drip irrigation is a system in which water is supplied directly to plant roots with a pressure and flow rate to meet the crop water requirement. Drip irrigation systems are in extensive use around the world since its acceptance for easy control of the applied water volume and thus to irrigation management. These systems are compatible for a wide range of crop variety, soil type, climate and land surface despite of few potential constrains. Drip systems are simple and pretty forgiving of errors in design and installation, there are some guidelines that if followed, will make for a much better drip system. Appropriate design of drip irrigation systems helped the farmers to bring more area under irrigation.Drip irrigation systems offer the potential for efficient irrigation of high value crops and have proven feasible from engineering and agronomic standpoints. However, little information is available in this region regarding the optimum design of these systems. The objective of this study was to develop a computerized programme for design of drip irrigation systems for different horticultural crops. In order to design economical system of drip irrigation, a computer software has been developed in the Department of Soil and Water Engineering, Faculty of Agricultural Engineering, IGKV, Raipur with objective to facilitate the students, officials of Department of Agriculture/Horticulture Government of Chhattisgarh, NGOs and farmers for easily designing the drip irrigation system. User friendly computer software was developed to design drip irrigation system for different locations for horticultural crops. This computer program was named "Drip Irrigation System Design (DISD) software" and written using visual basic (Version 6.0). The method of complete enumeration was used to find the optimum sizes and numbers of main line, sub-main lateral pipelines, drippers along with water requirement of different crops and pump size. The software provides useful information in the design and optimization of drip irrigation systems for small areas. The DISD software requires only few data and it can calculate large number of data output for the design of drip system for small as well as large area of land. The developed DISD software tested and found to be satisfactorily. The DISD software can be used for designing the drip irrigation systems for almost all the horticultural crops grown in the different locations of the Chhattisgarh state. The Department of Soil and Water Engineering, IGKV, Raipur has been accepted to this software and ready to distribute for use.

Introduction

Agricultural irrigation is highly important in crop production everywhere in the world. In India, where the economy is mainly base on agriculture and the climatic conditions are isotropic and are not able to make full use of agricultural resources. The main reason is the lack of rains and scarify of land reservoir water. So, efficient water management plays an important role in the irrigated agricultural cropping systems. The demand for new water saving techniques in irrigation

is increasing rapidly right now. In order to produce-more crop per drop, growers in (semi) arid regions currently explore irrigation technique. In the modern drip irrigation systems, the most significant advantage is that water is supplied near the root zone of the plants drip by drip due to which a large quantity of water is saved, at the present era, the farmers have been using irrigation technique in India through the manual control in which the farmers irrigate the land at the regular intervals. This process sometimes consumes more water or sometimes the water reaches late due to which the crops get dried. This problem can be perfectly rectified if farmers use Drip Irrigation System Design (DISD).

This paper focused on the design of drip irrigation system for small as well as large area of land. However, this software is easily installed on a computers and small information was required by the operator. This software was developed in the Visual Basic 6.0. Visual basic program is a computer language in visual basic studio. There have been a number of reports on the success of software development using Visual Basic. Visual Basic has been used widely by researchers to develop various applications including drip irrigation system design (Narayanan *et al.*, 2002; Kumar and Pande, 2009; Laosiritaworn and Bunjongjit, 2010; Bombale *et al.*, 2011).It is a tool for software development from Microsoft. The advantages of visual basic are for example, visual basic is an advance object oriented programing, it use less code for writing and it support for Microsoft Window. Moreover, there have been a number of reports on the success of software development using Visual Basic. The software also provide warning if the process is out of control. Visual basic has been used widely by researchers to develop various applications. This software helps operators in quantity control division to install drip system in the field and analyze size of different component of drip system and calculate area, water requirement of crops etc. Due to the previously advantages and also a number of successful reported Visual basic studio was chosen as a development tool for the DISD software. This software is capable to provide useful information in the design and optimization of drip irrigation systems for small areas.

Methodology

In drip irrigation system small diameter plastic pipes are used. Numbers of emission points are provided at regular intervals for applying water to the plant near the roots. The diameter of plastic pipes is decision making process based on numerous factors. These factors are hydraulic principles, emitter flow characteristics, row length, elevation, energy cost and some criteria of water application uniformity. The relationship between these factor is rather complex. The design of drip system is essentially a decision regarding emitters, laterals, manifolds, sub-main, main and required pumping unit. The design criteria and formulae for the drip system of irrigation were selected as suggested by Howell *et al.* (1983), Karmeli *et al.* (1985) and Michael (2008). Various factors such as economic, topographic (location, elevation, field boundary, shape/slope, area, location of pumping unit etc.), soil (type, soil moisture holding capacity, depth and intake rate), water supply (quantity, quality, temporal variation) and crop factors (crop, row-to-row and plant-to-plant spacing) were consisted while developing the DISD software for designing the drip system of irrigation.

Input Parameters Required for DISD -

Appropriate design of Micro Irrigation System is very essential to obtain proper performance and benefits. The software is a user-friendly interactive computer program

executable directly on Window system. The “Input Parameters Required for DISD” is designed for operator use. DISD software requires a few inputs for the design of drip irrigation system. As we are aiming at a precise quantity and uniform application of water for each and every plant, collection of data is a prerequisite for designing of an efficient Micro Irrigation System. The input parameters are listed below:

- Length of Plot (m)
- Pan Evaporation (mm/day)
- Pump Discharge (lps)
- Head (m)
- Length of Lateral (m)
- Length of Sub-main (m)
- Length of Main (m)
- Slope (%)

Design criterion for drip irrigation system -

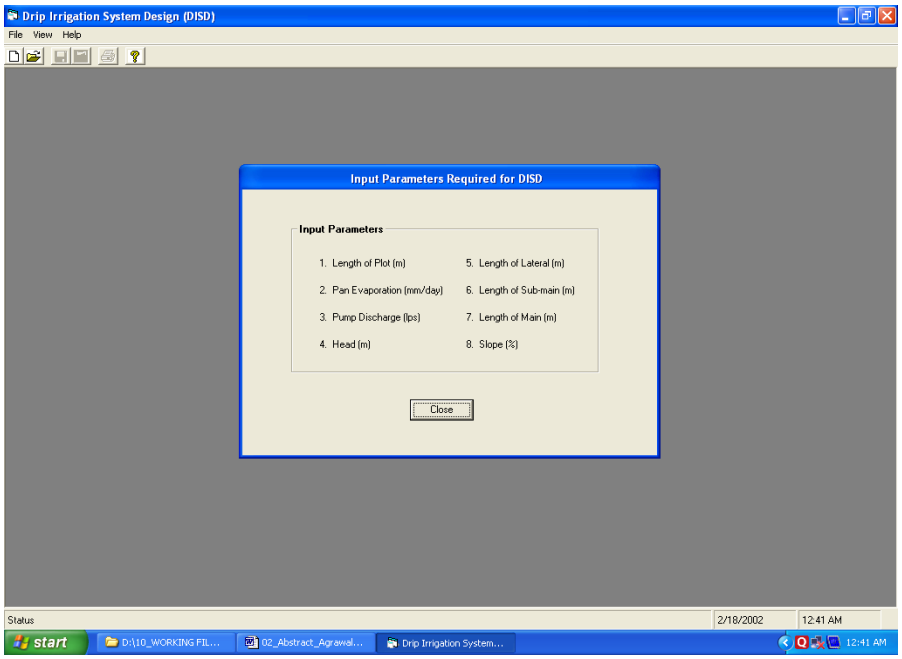
It is necessary to design a suitable and economically viable system to deliver a predefined amount of water at the root zone of each plant at regular intervals. This is to ensure that the plants do not suffer from stress or strain of less and over watering. Totally customized, efficient and long-life system ensures saving in water, early maturity and a bountiful harvest, season after season, year after year. Apart from all this, savings in labour and fertilizer costs.

Prime objectives of design should be,

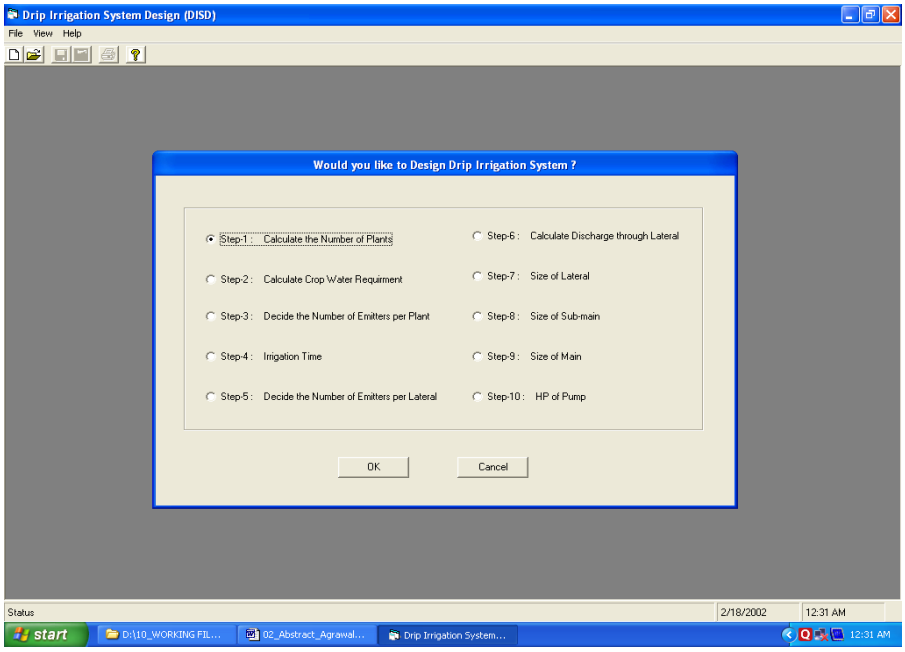
1. To achieve higher water application and conveyance efficiency.
2. To optimize both initial as well as operation cost.
3. To design the system for long term and high performance.
4. To satisfy and fulfillments and requirements of the farmer.

Effective design should be reflected in its operation as far as flow variation is concerned. There should be minimum variation in emission of drippers. Overall irrigation efficiency should be more than 90 %. The design of drip irrigation differs from crop to crop, plot to plot, soil to soil and climatic conditions. In general, following steps are involved in design of drip irrigation system.

Step-1: Calculate the Number of Plants.
Step-2: Calculate Crop Water Requirement.
Step-3: Decide the Number of Emitters per Plant.
Step-4: Irrigation Time.
Step-5: Decide the Number of Emitters per Lateral.
Step-6: Calculate Discharge through Lateral.
Step-7: Size of Lateral.
Step-8: Size of Sub-main.
Step-9: Size of Main.
Step-10: HP of Pump.



Input parameters required for DISD



Steps involved in design of drip irrigation system

Step-1: Calculate the Number of Plants –

A command area map giving systems layout is necessary to plan and design a drip irrigation system. It may not be necessary to have a detailed contour plan but it is helpful if a plan showing the highest and lowest points along with well location is given in the scheme. This enables proper design of main line and laterals to suit the spacing and number of plants. The recommended spacing and population of some of the important plants/crops like, fruits, vegetables and spices are calculated in the DISD software. DISD software calculates row to row spacing and plant to plant spacing and also calculates the number of plants / crops in per hectare, per acre and per row.

Step-2: Calculate Crop Water Requirement –

While designing the drip irrigation system, highest water required for the plant throughout its lifecycle is considered for calculation of water requirement. While calculating peak water requirement, peak rate of evapo-transpiration is taken into consideration. For peak water requirement for various crops pan evaporation data is collected from nearest weather station. Actual water requirement may vary depending upon soil type, agro-climatic conditions, crop variety etc. Other factor like, crop factor (Kc) and canopy factor (Kp) is given in table in DISD software.

Step-3: Decide the Number of Emitters per Plant –

The design, number of emitters required for plant and their discharge are important factors in designing a drip irrigation system. Various emitters are designed for controlled release of water to the plants. It is necessary for manufactures of drip system to state optimum operating pressure and discharge and the emitter is so selected that application rate equals to the absorption rate of soil so that no water stagnation takes place on the surface of the soil. The number of emitters is based on the volume of wetting for each plant. Generally, 30-70 percent of the area is wetted dependent upon plant spacing, nature & development of root zone. The number of emitters required per plant is estimated as the ratio of rate of irrigation requirement to the emitter discharge. If single emitter is provided, it must be placed 15-30 cm. from the base of the plant. In this software average discharge of emitters are given, choose any of discharge for the calculation of numbers of emitters per plant.

Step-4: Irrigation Time–

Drippers should be selected such that it should emit enough water to fulfill water requirement within predefined time. Irrigation time is the ratio of crop water requirement in liters to discharge of single emitter in liter per hour.

Step-5: Decide the Number of Emitters per Lateral –

It depends on the length of lateral and spacing between two plants in a row. In this software, for calculating number of emitters per lateral, information regarding dimension of plot is very important. After knowing of plot area, the software calculates number of laterals, lateral spacing, number of emitters per lateral and emitter spacing. To provide nearly uniform pressure

at each emitter, the lateral should be of sufficient diameter to avoid excess friction losses. The water delivered in the supply line is released through emitters spaced along the supply line.

Step-6: Calculate Discharge through Lateral –

After finalizing number of emitters per plant, number of laterals and approximate value of pump discharge, we have to decide the discharge through single lateral and numbers of lateral operated in the system. This information is useful in deciding the number of manifolds and the valves required for layout.

Step-7: Size of Lateral –

The design of lateral pipe involves selection of required pipe size for a given length which can carry the required quantity of water to the plant. This is the most important component of the system as large amount of pipe per unit of land is required and the pipe cost is such that system is economically viable. In designing the lateral, the discharge and operating pressure at emitters are required to be known and accordingly, the allowable head can be determined by the Hazen-Williams formula formula.

The allowable pressure drop in laterals depends upon the operating pressure required at emitters. The pressure head of emitter of any lateral should be calculated based on discharge requirement of each emitter. Pressure variation along the lateral line should not exceed 10% of the design lateral pressure. Laterals are available in various sizes of 12 mm, 16 mm, 20 mm etc. Design the layout of the system considering maximum lateral running length so as to obtain higher uniformity. In this software, reduction factor for multiple outlet pipeline friction loss computations are given in table form.

Energy/Head Losses

Energy losses occur in the pipeline due to friction and elevation changes. The most commonly used equation in irrigation calculations is the Hazen-Williams formula:

$$H_f = K \times (Q / C)^{1.852} \times D^{-4.87} \times (L + Le) \times F$$

Where:

H_f = frictional head loss (m)

$K = 1.526 \times 10^4$

Q = pipeline discharge (lps)

C = friction coefficient for pipe sections (140)

D = inside diameter (mm)

L = pipeline length (m)

Le = equivalent length of pipe and accessories

F = reduction factor

Step-8: Size of Sub-main –

After finalizing drippers and laterals or in-lines, we have to decide the no of sections, for the entire area, so that irrigation cycle can be completed in the available time for operation. Design of sub-main for the particular section is based on both capacity and uniformity. Sub-main

size should be large enough to deliver the required amount of water to irrigate subsequent part of the field.

To design the sub-mainline, the pressure required at proximate end of laterals and the maximum friction loss at that point should be determined. Sometimes, two or more laterals simultaneously operate from the sub-main and these have to be properly accounted for in the design. The head loss through pipe should be calculated by Hazen-Williams formula. The allowable pressure drop in sub-main line and laterals depend upon the operating pressure required at emitters. The pressure difference between the proximate and distant point along the supply line should not exceed 20% which will keep the variation of discharge within 10% of its value at the first emitter. DISD software calculates –

1. Sub-main pipe discharge,
2. Number of Sub-main pipe,
3. Number of laterals per Sub-main,
4. Head loss in Sub-main,
5. Variations in head,
6. Size of Sub-main pipe.

If the allowable variations are more than 20% then sizes of sub-main is not acceptable and again repeat the process until the allowable variations are less than 20%.

Step-9: Size of Main –

After finalizing drippers, laterals/in-lines and sub-main sizes and locations, we have to connect all the sub-mains to the water source using the main line. Size of mainline is decided by considering the quantity of water flowing through it. It's very important to decide how many sub-mains are to be operated at one time, and based on that the flow through the mainline is calculated and size of mainline is designed for that flow.

After deciding the length of main pipe, reduction coefficient and selecting the size main, DISD software calculates head loss through main and variations in head. If the allowable variations are more than 20% then size of main is not acceptable and again repeat the process until the allowable variations are less than 20%. The head loss through pipe should be calculated by Hazen-Williams formula.

Step-10: HP of Pump –

Size of pump depends upon the flow of water required and total pressure required at the pump to operate the irrigation system efficiently. While designing the system from drippers to mainline, we have finalized the system flow. The pump should have the capacity to deliver this flow. However, the additional head loss on account of diversion of flow from the main, sub-main, laterals into the emitters has to be separately added while estimating the total head for purpose of calculating hp of the pump set. The required total head of pump is the sum of all the following heads –

$$H = H_{main} + H_{Sub\text{-}main} + H_{Static} + H_{Local}$$

Where,

H = Total head (m)

H_{main} = Head loss in main (m)

$H_{Sub\text{-}main}$ = Head loss in sub-main (m)
H_{Static} = Static head (m)
H_{Local} = Other head loss (m)

Now flow (discharge) and total head of pump is finalized, then calculate the approximate HP of pump using following formula –

HP of Pump = (Q x H) / (75 x E)

Where,

Q = Discharge (lps)
H = Total Head (m)
E = Efficiency of Pump (0.60)

Results and Discussion

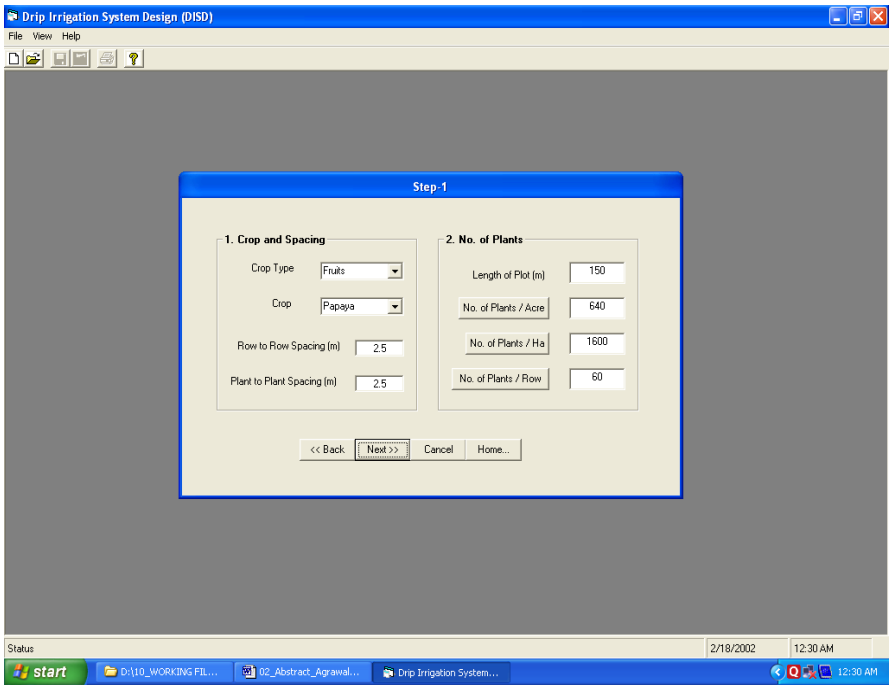
Model for a scheme of drip irrigation system

Design a drip irrigation system for 2.25 ha of an orchard planted with Papaya. The tree spacing are 2.5 m x 2.5 m. The available data are as below:

1. Land Size : 150 x 150 m
2. Maximum Evaporation : 11.0 mm/day
3. Available Discharge : 3.0 lps
4. Static Head : 9.5 m
5. Land Slope : 0.3 %

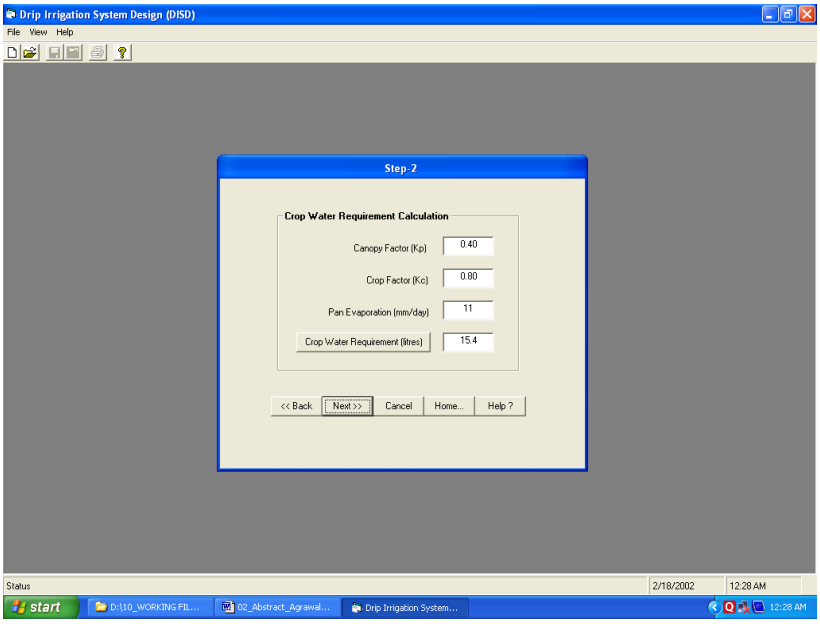
Step-1: Calculate the Number of Plants -

First select crop type fruit and crop papaya. The row to row and plant to plant spacing 2.5 x 2.5 m is already given in software. Only putting the value of length of plot 150m, software calculates the number of plant per acre is 640, number of plant per hectare is 1600 and number of plant per row is 60.



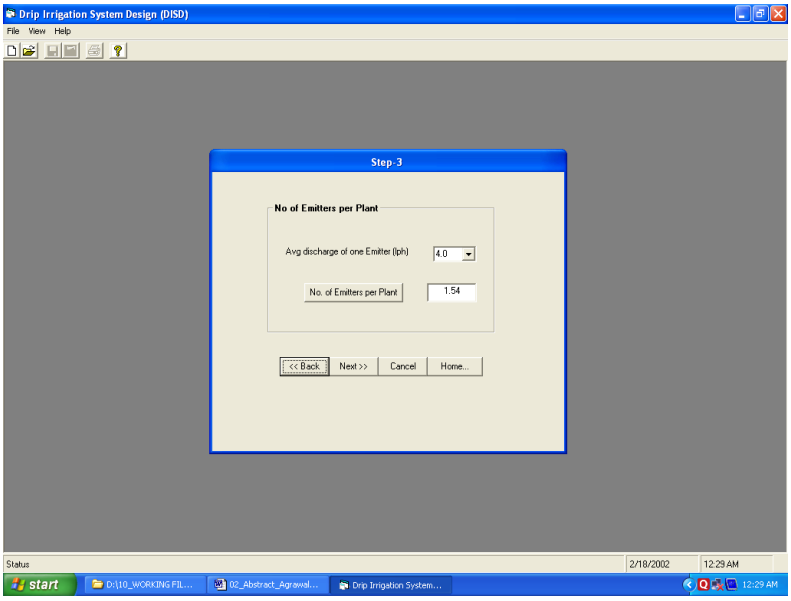
Step-2: Calculate Crop Water Requirement -

Putting the value of canopy factor (Kp) 0.40, crop factor (Kc) 0.80 and maximum evaporation 11 mm /day, software calculates the crop water requirement 15.4 liter/day/plant.



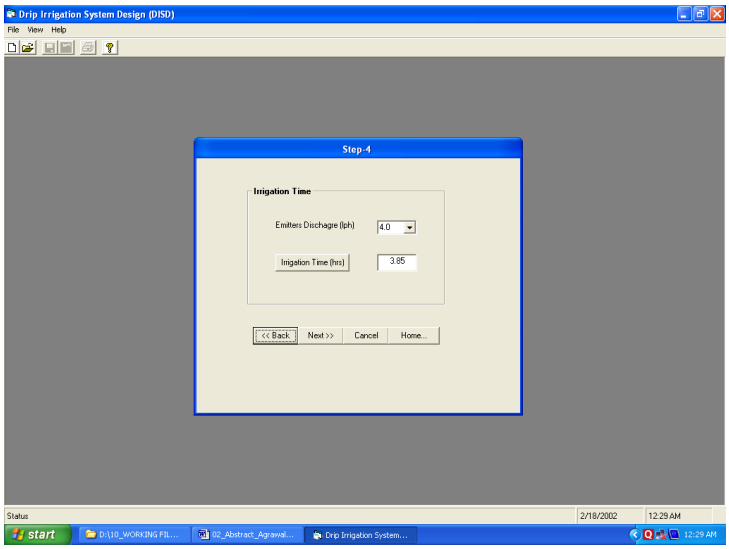
Step-3: Decide the Number of Emitters per Plant -

After deciding the number of plants and crop water requirement, select average discharge of one emitter 4.0 lph then DISD software calculates the number of emitters per plant 1.54 but it is taken as 1.0.



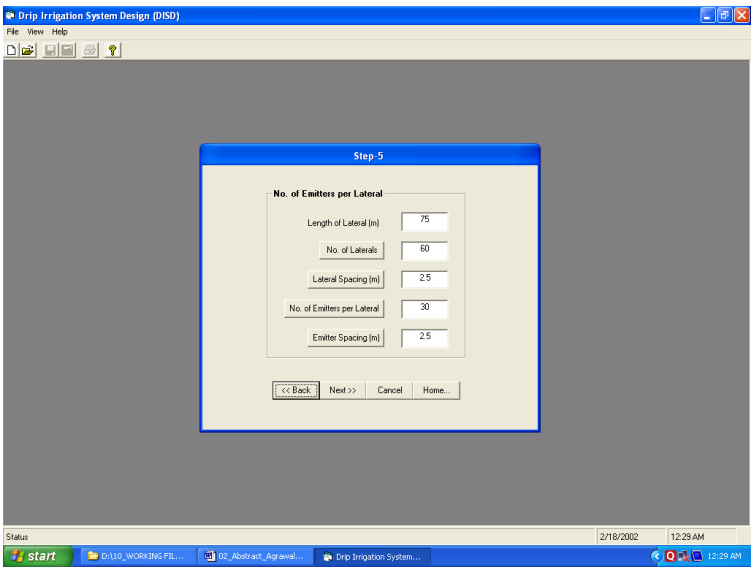
Step-4: Irrigation Time -

After finalizing the number of emitters per plants, select average discharge of one emitter 4.0 lph then DISD software calculates the time of operation is 3.85 hours.



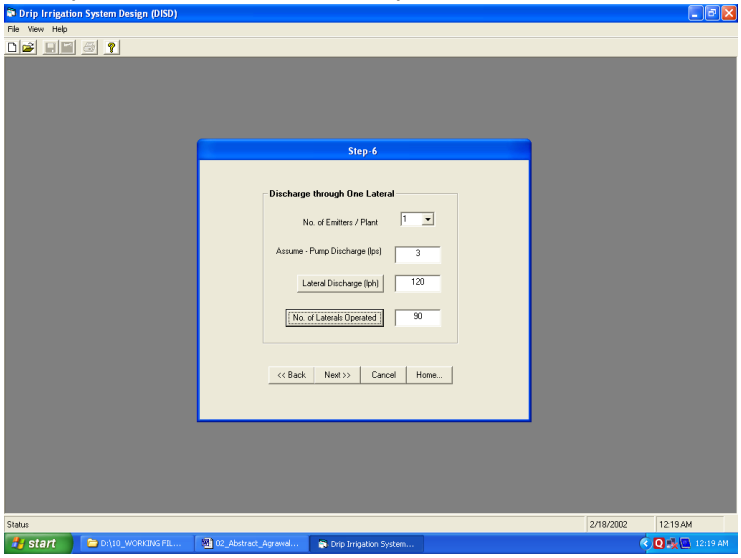
Step-5: Decide the Number of Emitters per Lateral –

For deciding the number of emitters per lateral the length of lateral is taken as 75 m because the installation of sub-main pipe is the center of the plot. However, the length of plot is 150 m. After putting the value of length of lateral 75 m, software calculates number of laterals is 60, laterals spacing 2.5 m, number of emitters per laterals is 30 and spacing between the successive emitters is 2.5 m.



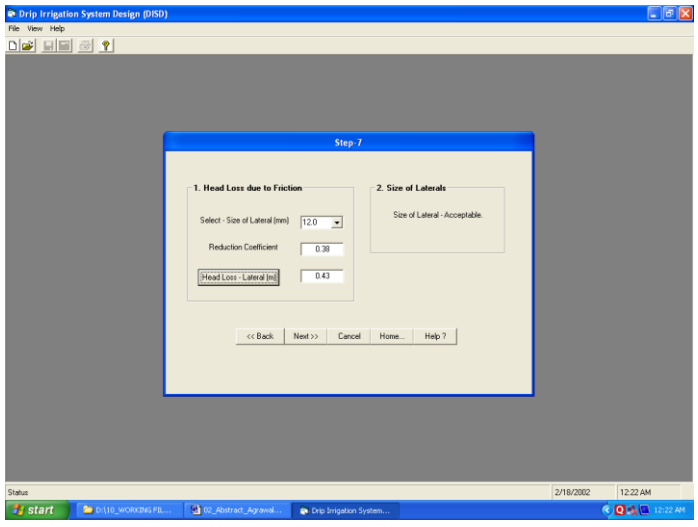
Step-6: Calculate Discharge through Lateral -

After finalizing the number of emitters per laterals, select the number of emitters per plant is 1.0 and available discharge of pump is 3.0 lps then DISD software calculates the discharge through single lateral is 120 lph and number of laterals operated at a time is 90.



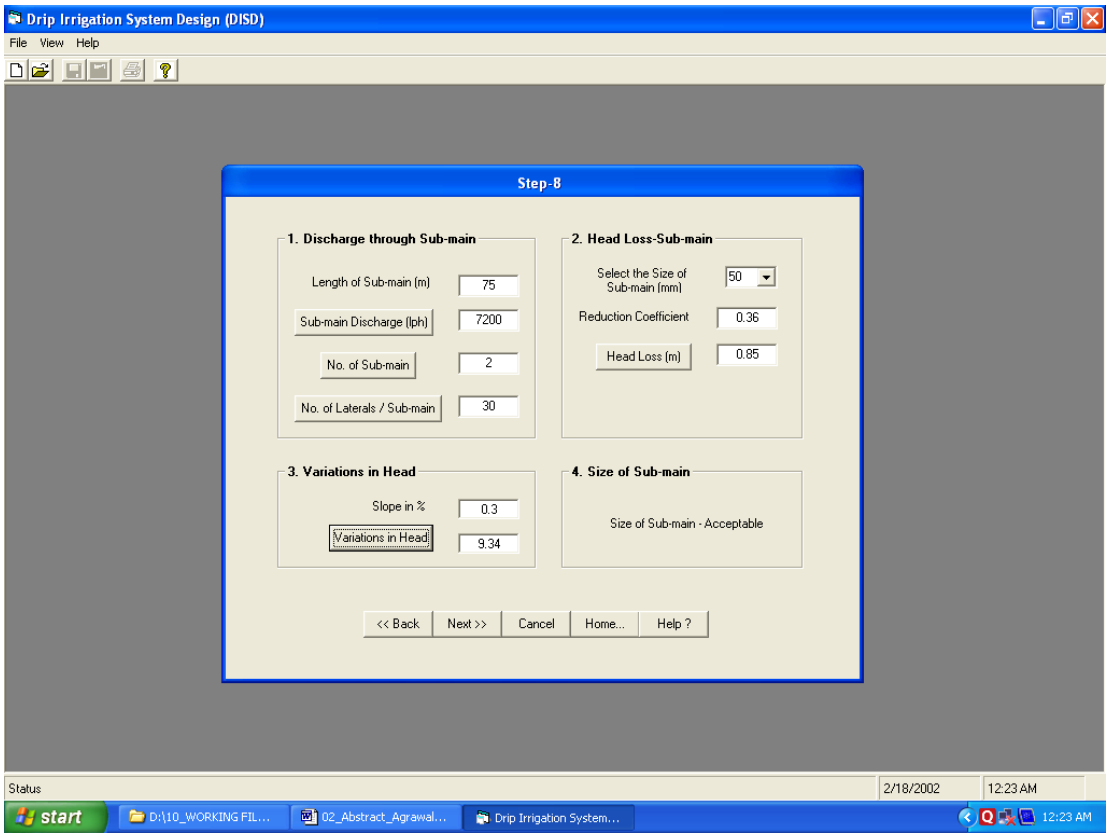
Step-7: Size of Lateral -

The pressure head of emitter of any lateral should be calculated based on discharge requirement of each emitter. The permissible head loss due to friction by taking into account 10% head variation will be 1.0 m. The Hazen-Williams formula is used for determining the size of laterals. After finalizing the discharge through single lateral, select the size of lateral is12 mm, reduction coefficient given in table is 0.38, then DISD software calculates the head loss through lateral is 0.43 m. Hence, the size of lateral is acceptable because the head loss is less than 1.0 m or within the permissible limit.



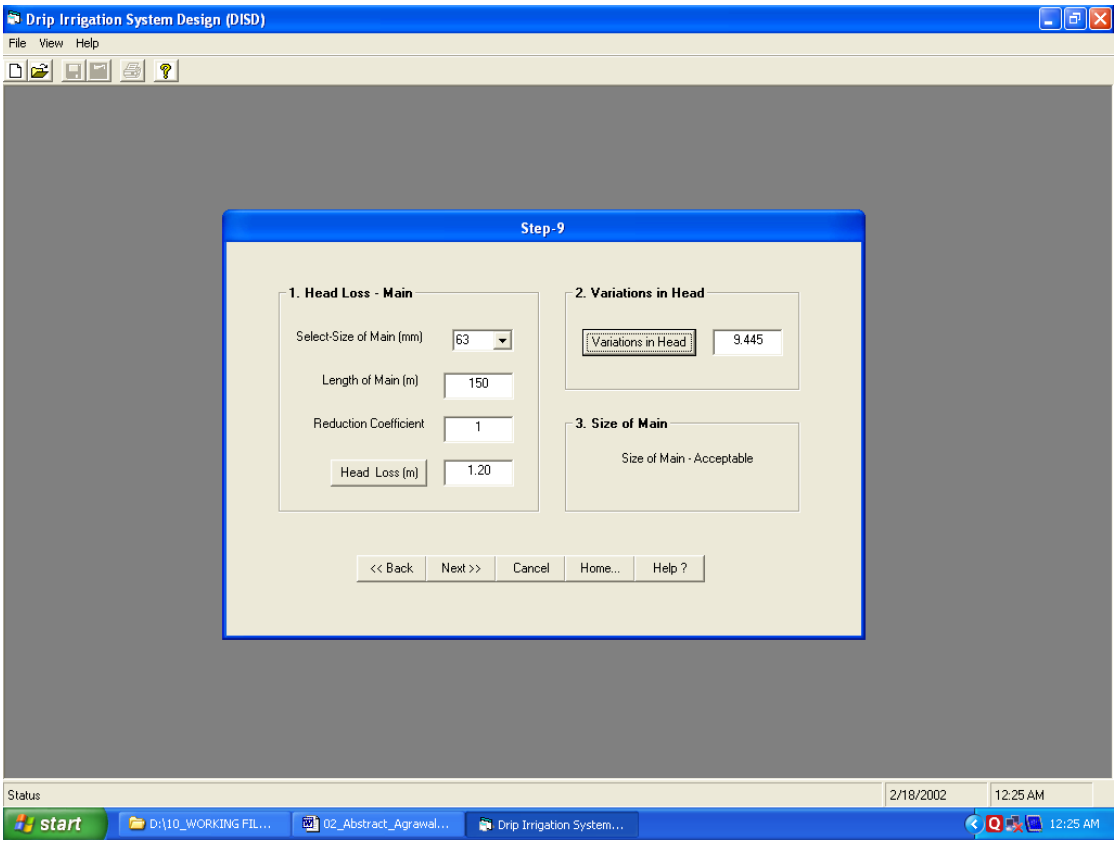
Step-8: Size of Sub-main –

After finalizing drippers and laterals, we have to decide the length of sub-main. The length of plot is 150 m, so, the total length of sub-main required is 150 m. In this plot 2 sub-mains of 75 m each are placed at the centre of the field and laterals are laid along both sides of the sub-main, for 75 m lengths. After putting the value of length of sub-main is 75 m, DISD software calculates the sub-main discharge is 7200 lph, no of sections / sub-mains is 2 and number of laterals per sub-main is 30. For finalizing the head loss through sub-main, select the size of sub-main is 50 mm, reduction coefficient given in table is 0.36, and then DISD software calculates the head loss through sub-main is 0.85 m. Then putting the value of slope is 0.3, software calculates the variation in head is 9.34% and the allowable variations in head is 20%, hence, the size of sub-main is acceptable.



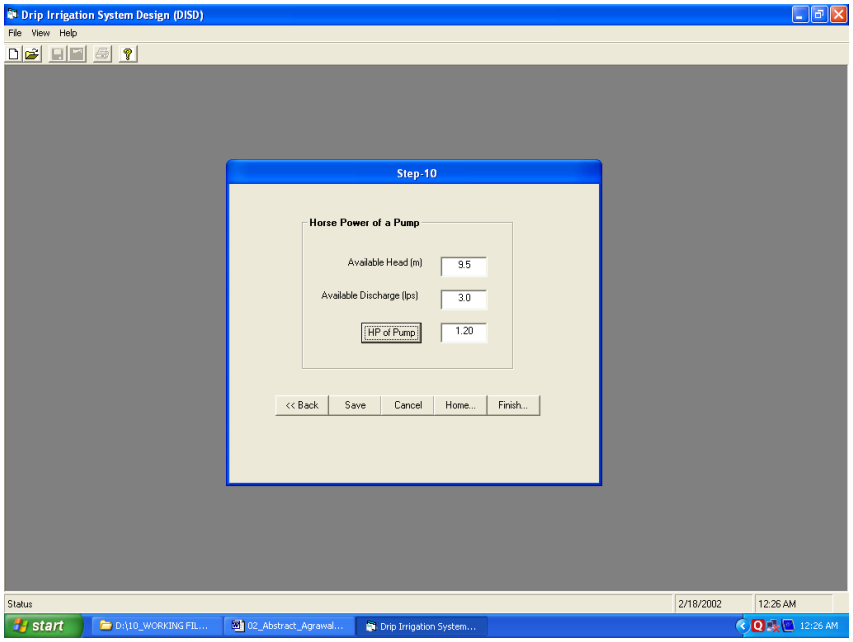
Step-9: Size of Main -

It's very important to decide how many sub-mains are to be operated at one time, and based on that the flow through the mainline is calculated and size of mainline is designed for that flow. Here one sub-main is operated at one time. Hence discharge through mainline is same as the discharge through a sub-main i.e. 7200 lph. After selecting the size of main is 63 mm and putting the value of length of main is 150 m and reduction coefficient given in table is 1.0, then DISD software calculates the head loss through main is 1.20 m and variations in head is 9.445 %. This variations in head is less than allowable variations in head (20%), hence, size of main is acceptable.

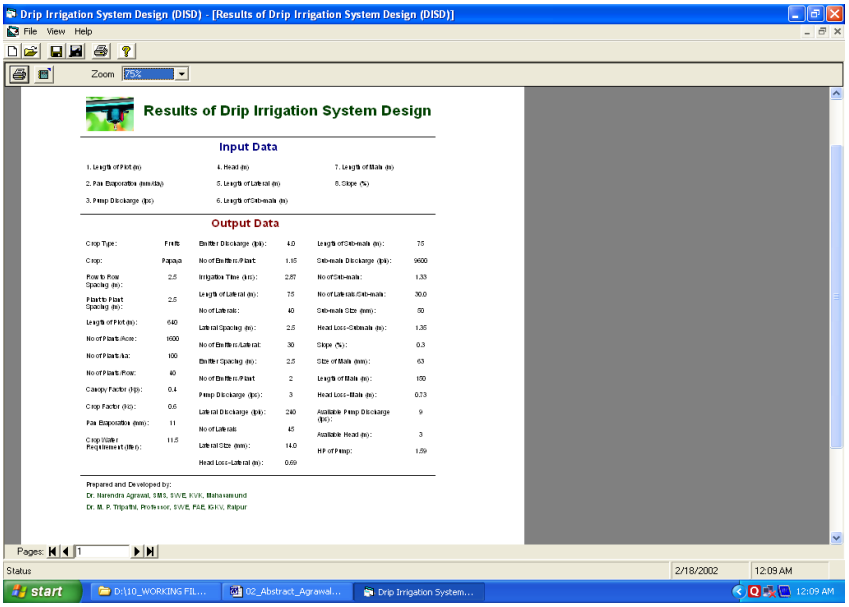


Step-10: HP of Pump -

The HP of pump set required is based upon design discharge and total operating head. The total head is the sum of total static head and friction losses in the system. Putting the value of available head is 9.5 m and available discharge is 3.0 lps, then software calculates the horse power of pump is 1.20.



Results of drip irrigation system design (DISD) –



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EFFECT OF FERTIGATION ON PRODUCTIVITY AND ECONOMICS OF SOYBEAN *(GLYCINE MAX* L.) UNDER *VERTISOLS*

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Abstract

A field experiment was conducted during kharif 2015 under All India Coordinated Research Project on soybean at College of Agriculture, IGKV, Raipur to find out the effect of fertigation on critical stages for increasing the productivity and water use efficiency of soybean under Vertisols. Results revealed that fertigation applied at flowering (50% RDF as basal + 50 % RDF through fertigation) stage recorded maximum and significantly higher pods per plant, seed yield (2,808 kg ha^{-1}), net return (83,740 kg ha^{-1}), B:C ratio (4.20), total uptake and balance of nitrogen, phosphorus and potassium in soil over other fertigation schedules, irrigation with different critical stages of soybean and flat sowing (RDF as basal) treatments. However, branches per plant, seed index, straw yield and harvest index were not influenced due to fertigation levels, irrigation and flat sowing.

Introduction

Soybean [*Glycine max* (L.) Merill] is popular as 'golden bean' and become the miracle crop of 21st century. It serves the dual purpose for being grown both as an oilseed crop as well as pulse crop (Thakare *et al*., 2006). It is an excellent health food containing 40 to 44% good quality protein, 20% cholesterol free oil, 20% carbohydrates and 0.69% phosphorus. It also fixes atmospheric nitrogen (45 to 60 kg ha^{-1}) through root nodules and add about 0.5 to 1.5 ton organic matter ha^{-1} through leaf fall (Kanase *et al*., 2006). Soybean is important rainfed leguminous crops of India. The uncertain on-set of monsoon and its non-uniform distribution over crop growth period is one among the major limiting factors for optimizing the productivity of soybean. The aberration in temporal and spatial distribution makes the crop vulnerable to moisture stress/drought. The moisture stress at critical growth stages often leads to its lower productivity. Water stress decreased the ratio of main stem grain yield to total plant grain yield of soybean. Sinaki *et al*. (2007) found that biological yield of soybean under moderate and severe drought stresses was decreased by 20.7 and 31.2 per cent, respectively over control. All the physiological processes of plant are directly and indirectly influenced by water status of plant. Water is essential for cell turgidity, which is related to photosynthesis, growth of cell tissues and organs (Reddi and Reddy, 1995). Timely irrigation enhanced the yield attributes and yield (Dhindwal *et al*., 2006). In this respect, fertigation (application of fertilizers with the irrigation water), is proposed as a means to increase efficient use of water and fertilizers, increase yield, protect environment and sustain irrigated agriculture. Fertigation is directly related with improved irrigation systems and water management. Thus the distribution of chemicals in the irrigation water will likely place these chemicals in the desired location, the root zone. This reduces water

and fertilizer application (Clark *et al*., 1991). With a drip-fertigation system uptake of N, P and K are substantially improved. Hence, present investigation was carried out to find out the effect offertigation for increasing the productivity, soil health and nutrient uptake of soybean under*Vertisols*

Material and Methods

The field investigation to study the effect of fertigation on soybean (*Glycine max* L. Merr.) under field condition was undertaken during *kharif* 2015 at research and instructional farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur. The soil of experimental field was medium black, well drained, clayey in texture (*Vertisols*) with neutral pH (7.12), low in available nitrogen (218 kg ha^{1}), medium in available phosphorus (13.45 kg ha^{1}) and high in available potassium (331 kg ha^{1}). The experiment was laid out in a Randomized Block Design. There were three replications and seven treatments under study. The treatments were F1- Fertigation at flowering (50% RDF as basal+50 % RDF through fertigation), F2-Fertigation at pod initiation (50% RDF as basal+50 % RDF through fertigation), F3-Fertigation at seed filling (50% RDF as basal+50 % RDF through fertigation), F4- Irrigation at flowering (RDF as basal). F5– Irrigation at pod initiation (RDF as basal), F6– Irrigation at seed filling (RDF as basal), F7– Flat sowing (RDF as basal). Where RDF is 25:60:40 (N, P2O5, K2O kg ha^{-1}) and S- 20 kg ha^{-1}. Fertilizers were applied through urea, single super phosphate, muraite of potash and for fertigation required quantity of fertilizer dissolved with water for 24 hours and applied at different critical growth stages of soybean as per treatments. The soybean variety JS 97-52 was used as a test crop and the seeds were sown @ 75 kg per ha. The observations in respect of branches $plant^{1}$, pods $plant^{1}$, seed index (g), seed yield (kg ha^{-1}), straw yield (kg ha^{-1}) at harvest stage of crop and harvest index (%), net returns (Rs ha^{-1}), B:C ratio, analysis of available and uptake of N, P and K (kg ha^{-1}) were determined by after harvest of soybean crop were recorded respectively.

Results and Discussion

Growth and yield attribute

Different fertigation levels had significant impact on yield attributes, namely pods $plant^{1}$ whereas, branches $plant^{1}$ and seed index (g) were not influenced due to fertigation levels (Table 1). Significantly highest number of pods $plant^{1}$ (78.8) at harvest was obtained when fertigation at flowering (50% RDF as basal + 50 % RDF through fertigation) stages, respectively over other treatments. The more number of pods per plant, under above treatment could be ascribed to the better nutritional environment for plant growth at active vegetative stage as a result improvement in root growth, which ultimately increased the dry matter. The results confirm the findings of Kumrawat *et al*. (1997). The increase in the rate of biosynthesis of various plant metabolites and physiological processes in the plant system might have led to increase the rate of pod formation as a result of adequate supply of water at critical stages of the crop. The results are in corroboration with the findings of Pradhan *et al*. (2012).The lowest number of pods $plant^{1}$ on flat sowing (RDF as basal). The reduction in number of pods $plant^{1}$ might be due to less development of seeds under stress conditions. These results are in accordance with the finding of Ali *et al*. (2009).

Yield and Economics

Significantly maximum seed yield (2,808 kg ha^{-1}) were recorded when crop was obtained with fertigation at of lowering (50% RDF as basal + 50 % RDF through fertigation) over rest of the treatments (Table 1). It might be due to prolonged availability of nutrients during the growth, flowering and fruiting period from fertigation over basal application which might have improved the fruit set and retention. Similar results have also been reported by Shanker *et al*., (2002) and fertigation with more readily available form which resulted in higher availability of all the three major nutrients (NPK) in the soil solution leading to higher uptake and better translocation of assimilates from could be explained by easy access of resources like source to sink. Similar result was obtained by Prasad *et al*. (2009).The difference in the seed yield among different fertigation treatments might be accounted for the differences in pods per plant, and seed index. These results are in line with the findings of Ali *et al.* (2009) and Pradhan *et al.* (2012). No significant influence was observed due tofertigation treatments on straw yield and harvest index. These results corroborated the findings of Pradhan *et al.* (2012). The lowest seed yield was obtained with flat sowing (RDF as basal). Significantly higher net returns (Rs 83,740 ha^{-1}) and B:C (4.20) ratio were recorded with fertigation at flowering (50% RDF as basal + 50 % RDF through fertigation) and lowest net returns (Rs 72,225 ha^{-1}) were recorded with Flat sowing (RDF as basal) (Table 1).The magnitude of increased net returns over no fertigation. This might be due to no moisture stress at crop growth critical stages resulted higher yield. On the contrary in control, which experienced severe water stress resulted in lower values of yield attributes and lower yield. These results corroborate the findings of Ali *et al.* (2009). The benefit: cost (B: C) ratio followed a similar trend to that of net returns except of F6- Irrigation at seed filling (RDF as basal) and F7- Flat sowing (RDF as basal) (Table 1). Less input cost and higher economical yield may be result in increase the B:C ratio. Similar results were also reported by Shivakumar *et al*. (2008).

Nutrient uptake

Nitrogen, phosphorus and potassium uptake was significantly influenced by the different fertigation treatment. Fertigation at flowering (50% RDF as basal + 50 % RDF through fertigation) significantly increased the N and K uptake, which was at par with Irrigation at flowering (RDF as basal) with K uptake (Table 2). However, P uptake was increased with Irrigation at flowering (RDF as basal) which was at par with Fertigation at flowering (50% RDF as basal + 50 % RDF through fertigation). The increase in nutrient uptake by Fertigation at flowering (50% RDF as basal + 50 % RDF through fertigation) may be due to increased availability of nutrients to the plants. It also improves the soil environment, which enhances profuse root system resulting in better absorption of moisture and nutrients. Thus, it resulted in higher biomass production. These results corroborated the findings of Meena *et al*. (2006). Applied phosphorous improved the nutrient uptake because of its significant role in regulating the photosynthesis, root development and enhanced microbial activities. The high level of phosphorous resulted in the maximum uptake of NPK due to close association of N and P in the process of metabolism in plant cells.

Post harvest N, P, K status and N, P, K balance

Available N, in post-harvest soil increased significantly with Fertigation at flowering (50% RDF as basal + 50 % RDF through fertigation) in soil. Fertigation at flowering (50% RDF as basal + 50 % RDF through fertigation) enhanced the biological immobilization and mineralization of the nutrient to soybean in adequate amount and remained in soil in considerable quantity after meeting the nitrogen requirement of soybean, that eventually improved the post harvest N fertility in soil. Minimum values of residual nitrogen with application of Flat sowing (RDF as basal). A maximum net gain of 14.00 kg N kg ha^{1} was recorded with fertigation at flowering (50% RDF as basal + 50 % RDF through fertigation) over other treatments (Table 2).

The post-harvest available P content of the soil indicated a significant and progressive increase with different levels of fertigation (Table 2). The highest available P of 15.53 kg ha^{1} was recorded at Fertigation at flowering (50% RDF as basal + 50 % RDF through fertigation) and minimum 12.10 kg ha^{-1} with Irrigation at seed filling (RDF as basal). It was due to addition of adequate amount of P through higher level of fertilizer, besides supplying proportionate amount to soybean, considerable amount of unutilized P left in the soil. The maximum net gain over initial P status 2.08 kg N kg ha^{1} was recorded with Fertigation at flowering (50% RDF as basal + 50 % RDF through fertigation) over other treatments and negative indicating with F5- Irrigation at pod initiation (RDF as basal) and F6- Irrigation at seed filling (RDF as basal) the significance of balanced nutrition for soil health sustainability. Appreciable variation in post-harvest P availability was also observed in different treatments. Results corroborate the findings of Govindan and Thrimurugan (2005).

Maximum K status of 343 kg ha^{1} in post-harvest soil was observed under Fertigation at flowering (50% RDF as basal + 50 % RDF through fertigation) and minimum 325 kg ha^{1} was observed when Flat sowing (RDF as basal) applied (Table 2). Fertigation at flowering (50% RDF as basal + 50 % RDF through fertigation) assured the availability of K to the soybean in adequate amount and left out in the soil after crop uptake to fulfil the requirement. In turn that ultimately enhanced the post-harvest status of K nutrient in soil. The maximum net gain over initial K status 12 kg ha^{1} was observed with Fertigation at flowering (50% RDF as basal + 50 % RDF through fertigation) over other treatments and F5- Irrigation at pod initiation (RDF as basal), F6- Irrigation at seed filling (RDF as basal) and F7- Flat sowing (RDF as basal) treatments showed negative, indicating that application of balanced nutrients is essential to sustain soil health. Appreciable variation in post harvest K availability was also noticed in fertigation at different critical stages and treatments. This might be due to increased availability of native K owing to improved physical and biological properties of soil.

Table 1: Effect of fertigation on productivity and economics of soybean

Treatments	Branches plant^{1}	Pods plant^{1}	Seed index (g)	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest Index (%)	Net returns (Rs ha^{-1})	B:C ratio
F1- Fertigation at flowering (50% RDF as basal + 50 % RDF through fertigation)	4.8	78.8	12.3	2,808	3,592	43.88	83,740	4.20
F2- Fertigation at pod initiation (50% RDF as basal + 50 % RDF through fertigation)	4.6	75.6	12.3	2,646	3,455	43.37	77,841	3.90
F3- Fertigation at seed filling (50% RDF as basal + 50 % RDF through fertigation)	4.5	74.6	12.1	2,635	3,423	43.50	77,431	3.88
F4- Irrigation at flowering (RDF as basal)	4.7	77.3	12.3	2,696	3,725	42.03	80,219	4.06
F5- Irrigation at pod initiation (RDF as basal)	4.2	76.4	12.1	2,582.	3,384	43.29	75,718	3.83
F6- Irrigation at seed filling (RDF as basal)	4.1	75.5	12.0	2,561	3,046	45.99	74,477	3.77
F7- Flat sowing (RDF as basal)	3.8	71.2	12.0	2,454	3,282	42.79	72,225	3.88
SEm±	**0.21**	**1.41**	**0.231**	**40.21**	**132.064**	**1.162**	**4,429**	**0.221**
CD (P=0.05)	**NS**	**4.21**	**NS**	**125.3**	**NS**	**NS**	**1,422**	**0.071**

Table 2: Effect of fertigation on nutrient uptake, nutrient balance of soybean

Treatment	Nutrient uptake (kg ha^{-1})			Available nutrient after harvest (kg ha^{-1})			Actual difference of initial and final (kg ha^{-1})		
	N	P	K	N	P	K	N	P	K
F1- Fertigation at flowering (50% RDF asbasal + 50 % RDF through fertigation)	208.98	32.04	118.65	197.98	15.53	343	14	2.08	12
F2- Fertigation at pod initiation (50% RDFas basal + 50 % RDF through fertigation)	197.27	30.57	112.99	183.27	14.46	339	11	1.01	8
F3- Fertigation at seed filling (50% RDF asbasal + 50 % RDF through fertigation)	196.40	30.35	112.23	184.4	13.75	340	13	0.30	9
F4- Irrigation at flowering (RDF as basal)	202.14	32.25	118.61	187.14	14.65	333	10	1.20	2
F5- Irrigation at pod initiation (RDF asbasal)	192.60	29.90	110.47	174.6	13.33	328	7	-0.12	-3
F6- Irrigation at seed filling (RDF as basal)	189.37	27.98	104.31	172.39	12.10	327	8	-1.35	-4
F7- Flat sowing (RDF as basal)	183.39	28.77	106.11	160.39	13.74	325	2	0.29	-6
SEm±	**8.74**	**2.29**	**7.46**						
CD (P=0.05)	**2.81**	**0.74**	**2.39**						

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HYDRAULIC PERFORMANCE AND ECONOMIC ANALYSIS OF DRIP IRRIGATION SYSTEM FOR CHERRY TOMATO (*PIMPINELIFOLIUM, L.*)

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Abstract

The experiment was laid out at Faculty of Agricultural Engineering Indira Gandhi Krishi Vishwavidyalya, Raipur with 12 treatments i.e. four irrigation level (100, 80, 60% and control) and three types of mulches (BPM, PSM and WM) having three replications. Furrow irrigation with and without mulch was treated as control. The effect of black plastic mulch (BPM), paddy straw mulch (PSM) and without mulch (WM) with four level of irrigation (100% CWR, 80% CWR and 60% CWR) on Soil temperature, moisture level, yield, quantify the economics through drip irrigation system of Cherry tomato was studied. Hydraulic parameter of drip irrigation system was studied for 4 lph emitter at 1.5, 1.2, 0.9 and 0.7 kg/cm^2 pressure. The soil moisture depletion at 12 and 20 cm depth of the soil was evaluated by using time domain reflectometer. The soil temperature was recorded at 7:30AM and 2:00 PM under different mulches conditions. Emitter flow variation, Statistical uniformity coefficient, Distribution efficiency and Application efficiency was found excellent at 1.5, 1.2 and 0.9 kg/cm^2 operating pressure. It is found that at 7:30 AM and 2.00 PM the average soil temperature under BPM was higher as compared to other at 5 cm and 10cm. Similarly maximum soil moisture and minimum soil depletion was found under BPM than under PSM and WM at 12 and 20 cm soil depth. The higher yield, income and benefit cost was recorded under 80% CWR drip irrigation system with BPM. The water saved with 80% of CWR - BPM treatment can be used for cultivating an additional area of 0.25 ha.

Keyword: *Hydraulic performance of Drip Irrigation, Soil moisture & temperature, Yield of Cherry Tomato, Economics cost.*

Water is one of the primary inputs in agricultural production. Water for agricultural use is becoming scare, both in quantity and quality, not only in the traditionally prone arid and semi arid zones, Agriculture represent the major user worldwide, and a general perception that agricultural water use is often wasteful and has less value than other uses is widespread. Irrigation water is supplied to the plants/crops to replenish root-zone moisture storage when natural rainfall is poorly or inadequately distributed. However, it is nearly impossible and economically unfeasible for traditional flood irrigation methods to apply the same amount of water to all plants within a field, which results in reduced crop yields (Bralts, et al. 1987). Moreover, the traditional flood irrigation methods waste huge amount of water as deep percolation.

Drip irrigation is a very efficient method of supplying water to plants. In drip irrigation water is supplied to the soil surface directly at the plant root zone, drop by drop. Drip irrigation supplies water close to the soil surface, reducing the chance of evaporation. This slow rate of

water flow allows time for the water to soak into the soil resulting in less likelihood of runoff. Another advantage is that the water goes right where it is needed, at the plant roots, rather than sprayed all over the plant. Not wetting the plant leaves can also reduce plant disease problems that accompany high moisture levels on plants. Since the water is supplied only to the root zone of plants, open unplanted areas between the plants are not watered resulting in a saving of water and not wasted on growing weeds.

Mulch is a layer of material applied to the surface of an area of soil. Mulches can be derived from either organic or inorganic materials. They are applied to the soil surface, around trees, paths, flower beds, to prevent soil erosion on slopes, and in production areas for flower and vegetable crops. Mulching with drip irrigation system is an effective method of manipulating crop growing environment to increase yield and improve product quality by conserving soil moisture, ameliorating soil temperature, reducing soil erosion, improving soil structure and enhancing organic matter content, salinity and weed control etc, beneficial response of lands to mulch includes early production, more yield and reduced insect and disease problems.. Mulching does not perform instant miracles, but it encourages better plant growth and development.

Cherry tomatoes are small tomatoes. These small tomatoes often have a sweeter taste than full-size tomatoes and offer several nutritional benefits. A serving of five cherry tomatoes contains 20 calories, the majority of which comes from carbohydrates – 80 percent. Twenty percent of the calories in a serving come from protein, and none comes from fat as cherry tomatoes do not have any fat. The carbohydrates in cherry tomatoes help meet your energy needs. The Institute of Medicine suggests consuming 130g of crabs each day.

Materials and Methods

Experimental Site

Field experiments were carried out during the year 2014-15 at Faculty of Agricultural Engineering, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.), located in the central part of Chhattisgarh at Longitude 81.36^0 E, Latitude 21.16^0 N and at an Altitude of 289.56 meters above the mean sea level.

Experimental Design and Treatments

The experiments were laid out in a Split Plot Design (SPD) having three replications (Figure 1). In this experiment, the main plot treatment at different levels of irrigation and sub plot treatment at different type of mulches (black plastic mulch, paddy straw and without mulch) were utilized. Cherry tomato was planted utilizing four levels of irrigation, in which three level of irrigation were provided by drip system (60% of CWR, 80% of CWR and 100% of CWR) and fourth level of irrigation was provided by furrow irrigation. Both the treatment was randomized to check the effect of different irrigation levels and different type of mulches. Drip irrigation system consists of drip tubing placed in each row of plant. During the treatment, irrigation levels were maintained by use of control valve in each row. During irrigation, water pressure in the system was maintained at 1.2 kg/cm^2. The cherry tomato plants were spaced at 1m x 1m and the black polythene mulch and straw mulches applied during the study period.

Emitter flow variation (Q_{var})

Emitter flow variation (Q_{var}) was calculated as follows:

$$Q_{var} = 100\left[1 - \frac{Q_{min}}{Q_{max}}\right] \quad \text{----------} \quad (1)$$

Where,

Q_{var} = emitter flow variation in percentage

Q_{min} = minimum emitter discharge rate in the system, l/h

Q_{max} = average or design emitter discharge rate, l/h

General criteria for Q_{var} values are 10% or less (desirable) and 10 to 20% acceptable and greater than 25%, not acceptable.

Statistical uniformity coefficient (U_S)

Statistical uniformity coefficient given by the equation (Bralts, et al. 1987).

$$U_s = 100(1 - V_q) = \left(1 - \frac{S_q}{q_a}\right) \quad \text{----------} \quad (2)$$

Where,

U_S = Statistical uniformity coefficient (%)

V = Coefficient of variation emitter flow

S_q = Standard deviation of emitter flow

q_a = mean emitter flow

Drip Irrigation Efficiency

Distribution efficiency

The distribution efficiency determines how uniformly irrigation water can be distributed through a drip irrigation system into the field. It can be determined from the emitter flow variation along a lateral line (or sub main) in a drip irrigation system layout in the field and can be expressed by the equation,

$$E_d = 100\left[1 - \frac{\Delta q_a}{q_m}\right] \quad \text{----------} \quad (3)$$

Where

E_d = distribution efficiency %

q_m = mean emitter flow rate, l/h

q_a = average absolute deviation of each emitter flow from the mean emitter flow

Application efficiency

The application efficiency is defined as the ratio of water required in the root zone to the total amount of water applied. It shows how well irrigation water is applied that is, what percentage of water applied is stored in the root zone as required and is available for plant use.

Therefore, application efficiency can be expressed as,

$$E_a = \frac{Q_{min}}{Q_{avg}} \times 100 \quad \text{----------} \quad (4)$$

(Source: “Principal of Drip Irrigation System” by M. S. Mane, B. L. Ayare, S. S. Magar).

Measurement of Soil Temperature

Temperature of soil was taken during the experiment with the help of digital soil thermometer. Soil temperature was taken at 5 and 10 cm depth by inserting sensor rod of digital soil thermometer below the soil surface. Soil temperature was taken from the plot covered with different mulches as black polythene mulch (25µ), use plastic mulch, paddy straw mulch and without mulch. Observation was recorded to know the effect of different mulches on soil temperature which indirectly affect the crop production. The daily records of soil temperature were taken at 7:30 am and 2:00 pm.

Soil Moisture Measurement

Moisture of soil was taken during the experiment with the help of Time Domain Reflectometer. Soil moisture was taken at 12 and 20 cm depth by inserting sensor rod of digital time domain reflectometer below the soil surface. Soil moisture was taken from the plot covered with different mulches as black polythene mulch (25µ), used plastic mulch, paddy straw mulch and without mulch. Observation was recorded to know the effect of different mulches on soil moisture which indirectly affect the crop production.

Soil moisture depletion (mm)

$$= \frac{(\text{F. C.} - \text{M. C.}) \times \text{Root zone depth} \times \text{B. D.}}{100} \quad ---------- (5)$$

Where,

F.C. = Field capacity (%)**,**

M.C. **=** Moisture content (%)**,**

B.D. = Bulk density (g/cc).

Fruit yield

Total yield per plant was calculated by weighing the fruits after harvesting.

Economics

The total cost of cherry tomato production including cost of seed, nursery preparation, ploughing, FYM application, preparation of beds for seedlings, drip irrigation system, mulches, transplanting, crop protection measures, and fertilizer and harvesting was measured. The total income from produce over one hectare area was considered to workout net seasonal income and benefit cost ratio. The useful life of the drip irrigation system was considered to be 8 year.

Results and Discussion

Evaluate the hydraulic performance under the discharge of drip irrigation with different discharge, coefficient of variation and uniformity coefficient were recorded and are presented in the form of tables.

Emitter flow variation (Q_{var})

Emitters flow variation, (Q_{var}) of drip irrigation system was estimated by formula different operating pressures and are given in Table 1. The emitter flow variation 5% for was found minimum at 1.5 kg/cm² operating pressure and maximum 32.7% at 0.7 kg/cm² operating pressure.

From the observed data it is clear that the emitter flow variation mostly depends on the performance of emitter under the field condition, if the ratio between minimum and maximum discharge value is more then it will give low emitter flow variation which will come under desirable range. All these calculated emitter flow variation data at different pressure are presented in Fig.2. The results are in conformity with the findings of Yeeshu Kumar Desshmukh (2012).

Uniformity coefficient (Us)

Uniformity coefficient of 4lph emitter at different operating pressure are1.5 kg/cm^2, 1.2 kg/cm^2, 0.9 kg/cm^2, and 0.7 kg/cm^2 are presented in Table 4.7. The average uniformity coefficient observed at 1.5 kg/cm^2 operating pressure was 97.94. The average uniformity coefficient observed at 1.2 kg/cm^2 operating pressure was 97.43 percent respectively. The average

uniformity coefficient observed at 0.9 kg/cm^2 operating pressure was 96.29 percent respectively. The average uniformity coefficient observed at 0.7 kg/cm^2 operating pressure was 94.20 percent respectively**.** Thus for a particular spacing uniformity coefficient increases as the operating pressure increases for all emission devices.

Distribution efficiency (E_d)

The distribution efficiency, (E_d) of drip irrigation system was estimated for 4 lph drippers under different operating pressure, which is presented in Table 4.8. The distribution efficiency 97.9% at 1.5 kg/cm^2 operating pressure, distribution efficiency 97.4 % at 1.2 kg/cm^2 operating pressure, distribution efficiency 96.3 % at 0.9 kg/cm² operating pressure and distribution efficiency 94.22 % at 0.7 kg/cm^2 operating pressure. The distribution efficiency was found minimum at 0.7 kg/cm^2 operating pressure and maximum at 1.5 kg/cm^2 operating pressure. Thus for a particular spacing distribution efficiency increases as per the operating pressure for all emission devices. Fig.4. is presenting the distribution efficiency at different operating pressure in the form of bar diagram.

Application efficiency (E_a)

The application efficiency, (E_a**)** of drip irrigation system was estimated for different operating pressure which is presented in Table 4.

The drip irrigation system was operated at 0.7, 0.9. 1.2 and 1.5 kg/cm^2 operating pressure. The application efficiency 95.3% at 1.5 kg/cm^2 operating pressure, application efficiency 94.0% at 1.2 kg/cm^2 operating pressure, application efficiency 93.6% at 0.9 kg/cm^2 operating pressure and application efficiency 89.5% at 0.7 kg/cm^2 operating pressure. The application efficiency 95.3% was found maximum at 1.5 kg/cm^2 operating pressure and minimum 89.5 % at 0.7 kg/cm^2 operating pressure. Thus for a particular spacing application efficiency increases as per the operating pressure for all emission devices. Fig.5 is presenting the application efficiency at different operating pressure in the form of bar diagram.

Effect of different type of mulches on soil temperature

Soil temperature was recorded at 7:30 AM and 2:00 PM from 1 January to 5 March. The weekly average of daily recorded soil temperature at 5 and 10 cm depth is presented in Table 4. From table it can be seen that at 7:30 AM the average soil temperature at 10cm depth is higher as compared to 5 cm depth under all three type of mulches. At the same time soil temperature has been found maximum under black plastic mulch followed by paddy straw mulch and without mulch at 5 and 10 cm depth. The result revealed that during forenoon soil temperature decreases with decreasing depth. Increasing and decreasing trend of soil temperature under black plastic mulch depends on daily atmospheric temperature. Similar trend follows in the case of paddy straw and without mulch. It was found that at 7:30 AM the average soil temperature under BPM is 1.31 and 2.39°C higher than under PSM and WM at 5 cm depth respectively. Similarly, at 10 cm depth soil temperature under BPM is 1.52 and 2.83°C higher than under PSM and WM respectively. At the same time the average soil temperature under PSM is 1.08 and 1.31 ºC higher than under WM at 5 and 10 cm depth respectively.

Based on the recorded data at 2:00 PM the average soil temperature at 10cm depth is lower compared to 5 cm depth under all four types of mulches. At the same time soil temperature

has been found maximum under black plastic mulch followed by without mulch and paddy straw mulch at 5 and 10 cm depth.

The result revealed that at afternoon soil temperature decreases with increasing depth at 2:00 PM the average soil.

Temperature under BPM is 4.01 and 4.14ºC higher than under WM and PSM at 5 cm depth respectively. Similarly at 10 cm depth soil temperature under BPM are 3.26 and 3.38 ºC more than under WM and PSM respectively.

The result revealed that soil temperature variation is low under paddy straw mulch and high under without mulch at 5 and 10 cm depth. The results are in conformity with the findings of Yeeshu Kumar Deshmukh (2012)

Effect of different irrigation levels and mulches on soil moisture content and soil moisture depletion

Average soil moisture content and soil moisture depletion with different levels of irrigation (100, 80, 60% of CWR and control) and mulches were measured at 12 cm and 20 cm soil depth and is presented in Table 6. At 12 cm below the surface moisture content (27.3, 25.7, 22.86 and 19.91%) and soil moisture depletion (1.13, 2.31, 4.57 and 6.91mm) was observed under BPM respectively. At the same depth soil moisture content (25.4, 23.67, 20.78 and 17.76%) and soil moisture depletion (2.55, 3.93, 6.23 and 8.64mm) was observed under PSM respectively. Soil moisture content (21.92, 18.52, 16.29 and 14.78%) and soil moisture depletion (3.89, 5.35, 6.30 and 6.95mm) was observed under WM at 12 cm depth respectively. Similarly at 20 cm below the surface moisture content (25.6, 23.90, 20.10 and 17.19%) and soil moisture depletion (2.61, 3.14, 6.77 and 9.14mm) was observed under BPM respectively. At the same depth soil moisture content (23.8, 21.14, 18.36 and 15.38%) and soil moisture depletion (3.82, 5.94, 8.16 and 10.54mm) was observed under PSM respectively. Soil moisture content (23.97, 21.8, 18.84 and 15.98%) and soil moisture depletion (3.69, 5.4, 8.18 and 10.06mm) was observed under WM at 20 cm depth respectively.

From table it can be seen that maximum soil moisture content and minimum soil moisture depletion were found under the main plot 100 % of CWR with BPM at 12 and 20 cm depth of soil. Similarly minimum soil moisture content and maximum soil moisture depletion were found under control irrigation WM at 12 and 20 cm depth of soil. Soil moisture content for different level of irrigation and mulches at 12 and 20 cm depth is presented in Fig.8.

Fruit Yield

It is apparent from the Table 7 that the yield per plot recorded was significantly influenced by different irrigation levels and mulches. The variation in fruit yield per plot differs significantly due to interaction effect which is presented in Table 4.21. Significantly maximum yield per plot was recorded under the treatments T_2 (16.02kg) and it was followed by T_1 (15.08 kg), T_3 (13.43kg) and T_4 (11.66 kg) respectively. Due to effect of different type of mulches, significantly maximum yield per plot was recorded under the treatment M_1 (18.54 kg) followed by M_2 (13.43 kg) and M_3 (10.18 kg) respectively. Due to interaction effect, maximum yield per plot was recorded by T_2M_1 (21.21kg) and it was followed with T_1M_1 (20 kg) and T_3M_1 (17.513kg) respectively. Minimum yield per plot (8.78kg) was recorded under the treatment T_4M_3.

The present investigation revealed that various irrigation levels, different mulches and

their interaction were effective in the variation of fruit yield per plot. Drip irrigation with 80% of CWR produced significantly more marketable fruit yield per plot as compared to other irrigation level and minimum under furrow irrigation. Drip irrigation provides appropriate moisture at field capacity and better root development which facilitate luxuriant growth of plant due to better nutrient uptake resulting better fruit growth and development ultimately higher yield. The results are in close agreement with the findings of Singh *et al*. (2009), Sharma, U. (2010), Sahoo et al. (2010) and Deshmukh, Y. K. (2012).

Economics of drip irrigation system for cherry tomato under different levels of irrigation and mulches

Economics of drip irrigation system for cherry tomato is presented in Table 8, it is evident that higher cost of cultivation Rs. 136656.2/ha was estimated under treatment T_2M_1 i.e. drip irrigation with black plastic mulch followed by treatment T_1M_1 (Rs.136256.2) and T_3M_1 (Rs. 135655.2) whereas the lowest cost of cultivation Rs. 83142.2/ha was calculated under treatment T_4M_3.

The maximum net income Rs. 181953/ha was estimated under the treatment T_2M_1 (80% of CWR through drip irrigation with BPM) followed by T_1M_1 (Rs.159561.7/ha) and T_3M_1 (Rs. 120044.7/ha). The lowest net income Rs. 25770.3/ha was found under treatment T_4M_3 i.e. furrow irrigation without mulch. Data regarding benefit cost ratio (B/C) shows that the higher benefit cost 2.16 was obtained under the treatment T_2M_1 i.e. 80% of CWR through drip irrigation with BPM followed by T_2M_2 (2.04), T_1M_1 (2.02), T_1M_2 (1.99) and T_3M_1 (1.77) while the lowest B/C ratio 1.28 was recorded under treatment T_3M_3 i.e. 60% CWR through drip irrigation without mulch. The net income and benefit cost ratio are directly related to cost increased and yield obtained in the treatment.

Conclusions

Performance of drip irrigation system was found good and needs to be operated at 1.0-1.2 kg/cm^2 pressure. In the production of cherry tomato use of 80% of crop water requirement through drip irrigation system with black plastic mulch would be more effective for increasing yield and yield attributing characters of crop.100% and 80% crop water requirement in drip irrigation system save up to 43.5 % and 55.2% water respectively in comparatively with furrow irrigation. Water equivalent to 20% of crop water requirement saved in 80% crop water requirement can be used to produce additional 2.56 tones of cherry tomato under the same arrangements.

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Table 1: Emitter flow variation under different operating pressure

Operating pressure	1.5 kg/cm^2	1.2 kg/cm^2	0.9 kg/cm^2	0.7 kg/cm^2
Emitter flow variation	5	10	15	32.7
Classification	Desirable	Desirable	Acceptable	Non-Acceptable

Table 2: Uniformity coefficient under different operating pressure

Operating pressure	1.5 kg/cm^2	1.2 kg/cm^2	0.9 kg/cm^2	0.7 kg/cm^2
Uniformity coefficient(%)	97.94	97.43	96.29	94.20
Classification	Excellent	Excellent	Excellent	Excellent

Table 3: Distribution Efficiency under different operating pressure

Operating Pressure	1.5 kg/cm^2	1.2 kg/cm^2	0.9 kg/cm^2	0.7 kg/cm^2
Distribution efficiency (%)	97.9	97.4	96.3	94.2

Table 4: Application Efficiency under different operating pressure

Operating Pressure	1.5 kg/cm^2	1.2 kg/cm^2	0.9 kg/cm^2	0.7 kg/cm^2
Application efficiency(%)	95.3	94.0	93.6	89.5

Table 5: Weekly average of daily recorded soil temperature under different type of mulches

S. No	Black plastic mulch				Paddy straw mulch				Without mulch			
	7.30 am		2.00pm		7.30am		2.00pm		7.30am		2.00pm	
	5 Cm	10 Cm	5 Cm	10 Cm	5 Cm	10 Cm	5 cm	10 cm	5 cm	10 cm	5 Cm	10 Cm
1	14.57	16.5	23.46	21.64	13.07	15.6	19.38	17.7	12.52	13.8	17.56	16.5
2.	15.08	16.7	24.02	21.88	14.64	15.79	20.32	19.8	13.94	14.58	17.93	16.97
3.	15.97	18.44	25	22.76	14.38	16.5	23.5	22.5	13.44	15.87	20	19
4.	16.97	19.47	27	24.33	15.75	17.33	23.57	22.57	14.90	16.55	22.7	21.11
5.	16.45	19.35	26.91	25.11	15.78	17.82	22.72	21.41	14.67	16.6	23.72	21.72
6.	17.17	19.75	26.67	25.15	16.28	18.27	23.19	21.41	15.07	16.78	24.1	23.14
7.	18.65	20.57	28.2	26.2	16.69	18.64	23.31	22.07	14.88	16.82	25.9	23.75
8.	21.63	23.6	31.75	28.95	19.72	21.78	25.42	23.92	18.01	20.04	28.47	26.97
9.	20.61	22.18	29.22	27.01	19.31	21.22	23.63	22.15	18.25	20.07	25.71	24.54
Mean	17.46	19.62	26.91	24.78	16.15	18.10	22.77	21.40	15.07	16.79	22.90	21.52

Table 6: Soil moisture content and soil moisture depletion under different treatments

Mulches	Irrigation level	12 cm depth		20 cm depth	
		M.C. (%)	S.M.D. (%)	M.C. (%)	S.M.D. (%)
Black Plastic mulch	100 % CWR	27.3	1.13	25.6	2.61
	80% CWR	25.7	2.31	23.90	3.14
	60% CWR	22.86	4.57	20.10	6.77
	CONTROL	19.91	6.91	17.19	9.14
Paddy Straw Mulch	100 % CWR	25.4	2.55	23.8	3.82
	80% CWR	23.67	3.93	21.14	5.94
	60% CWR	20.78	6.23	18.36	8.16
	CONTROL	17.76	8.64	15.38	10.54
Without Mulch	100 % CWR	21.2	5.90	23.97	3.69
	80% CWR	19.57	7.20	21.8	5.4
	60% CWR	17.84	8.58	18.84	8.18
	CONTROL	14.32	11.38	15.98	10.06

Table 7: Fruit yield cherry tomato influenced by different levels of irrigation and mulches

Main plot treatment (Irrigation Level)	
Treatment	Yield per plot,(kg)
T_1	15.08
T_2	16.02
T_3	13.43
T_4	11.66
SE(m)	0.084
CD	0.290
Sub plot treatment(Mulches)	
M_1	18.54
M_2	13.43
M_3	10.18
SE(m)	0.091
CD	0.273

Table 8: Economics of drip irrigation system for cherry tomato under different levels of irrigation and mulches

Treatment	Cost of cultivation	Total cost	Gross Income	Benefit cost ratio
T_1M_1	123627.2	143380.8	290000	2.02
$T_1 M_2$	72027.2	92180.75	170000	1.85
$T_1 M_3$	70487.2	90240.75	141900	1.57
T_2M_1	124027.2	143780.8	307140	2.13
$T_2 M_2$	72427.2	91780.75	190470	2.07
$T_2 M_3$	70547.2	90300.75	150000	1.66
T_3M_1	123027.2	142780.5	250000	1.75
T_3M_2	71627.2	91380.75	150600	1.648
$T_3 M_3$	70027.2	89780.75	117140	1.30
T_4M_1	78827.2	78827.2	155000	1.96
$T_4 M_2$	72327.2	88254.7	128090	1.45
$T_4 M_3$	70627.2	86759.7	102300	1.17

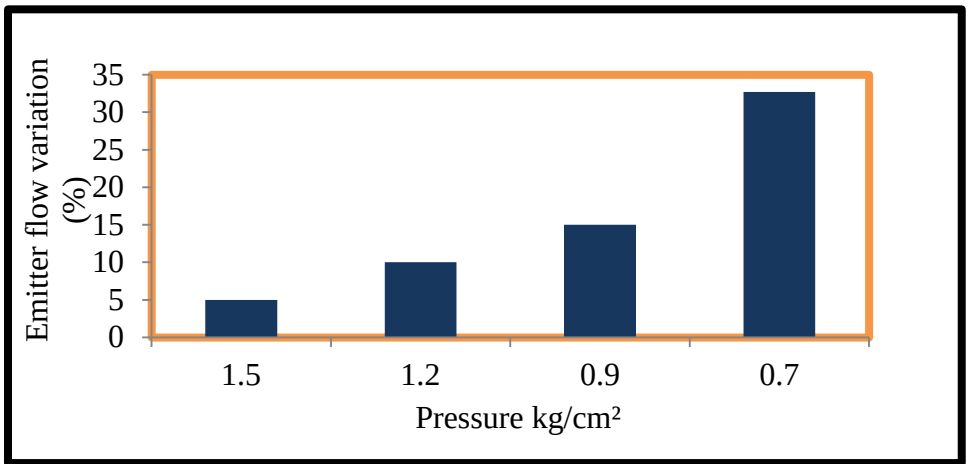


Fig. 2: Emitter flow variation under different operating pressure

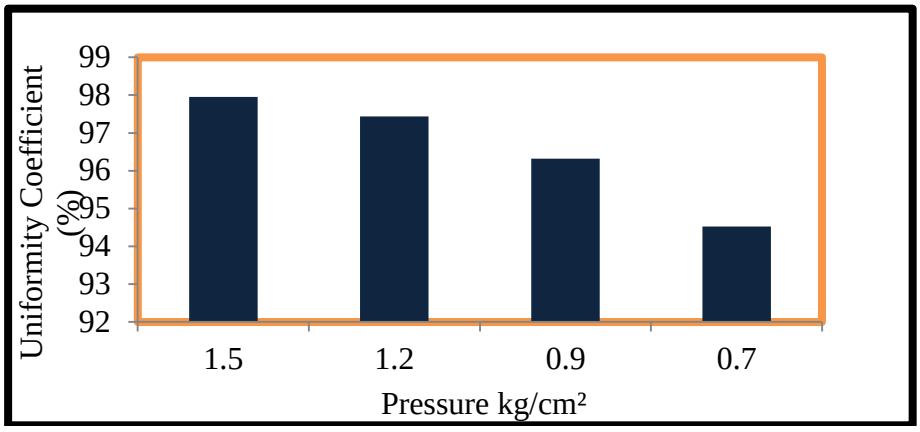


Fig. 3: Uniformity coefficient under variable operating pressure

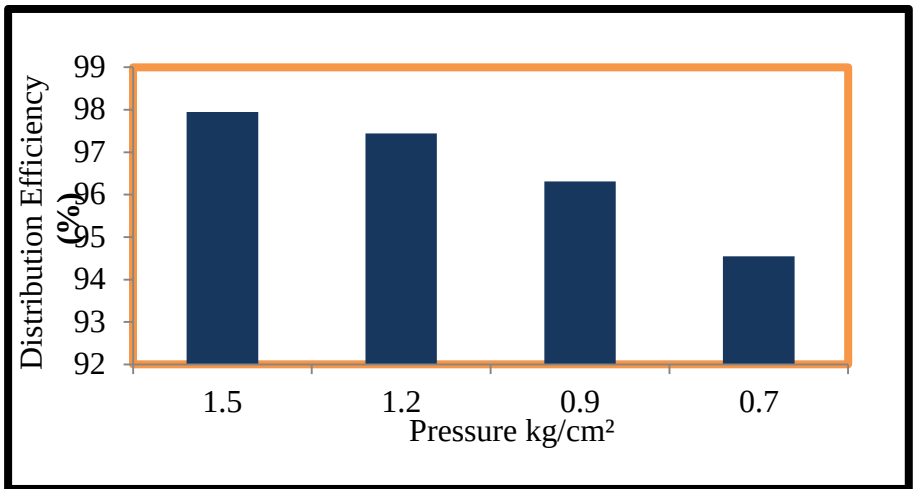


Fig. 4: Distribution efficiency under different operating pressure

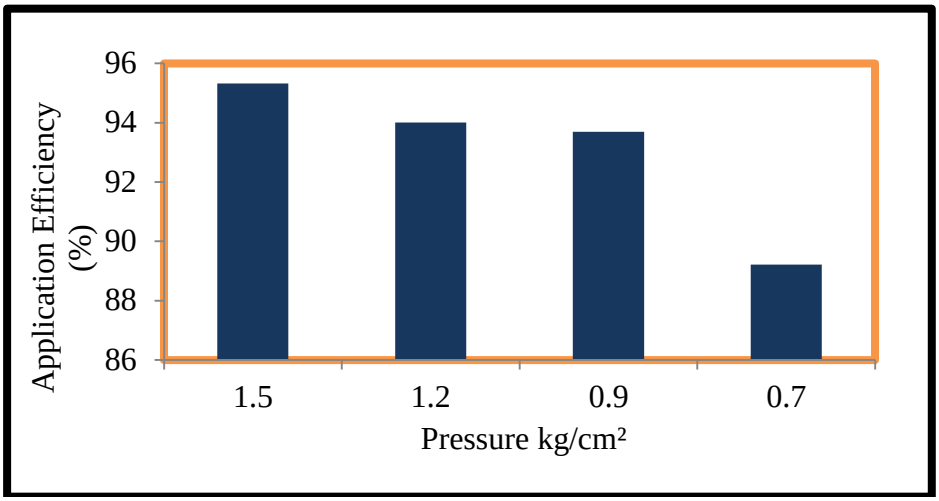


Fig. 5: Application efficiency under different operating pressure

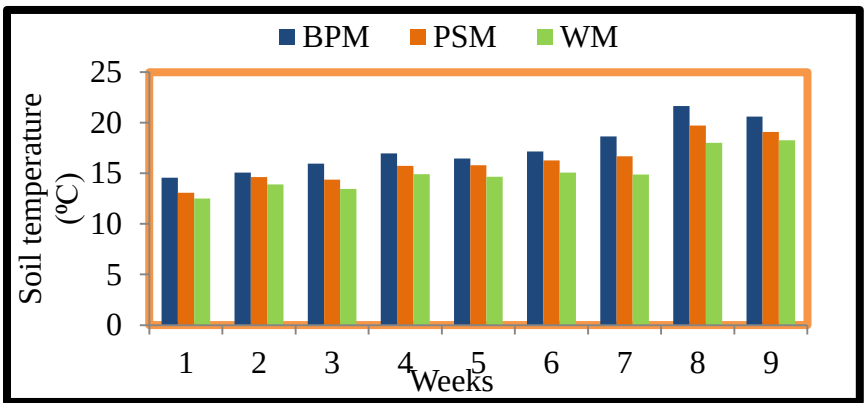


Fig. 6: Average weekly soil temperature at 7:30 AM in 5 cm depth

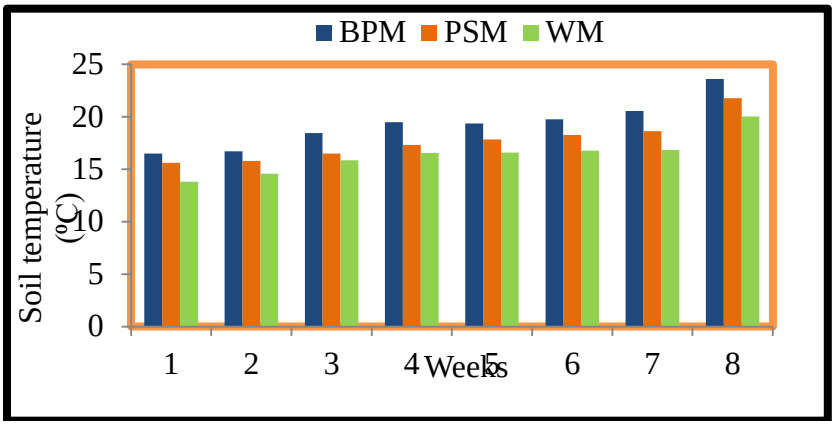


Fig.7: Average weekly soil temperature at 7:30 AM in 10 cm depths

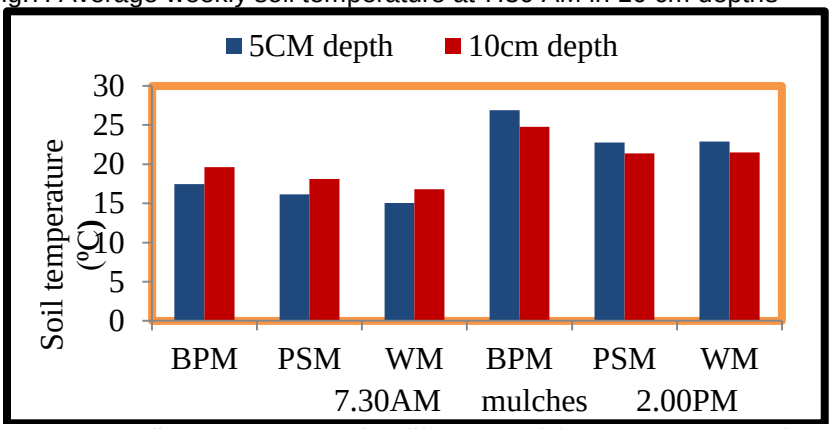


Fig.8: Mean soil temperature under different mulches at 7:30 AM and 2:00PM at 5cm and 10 cm depth

ANALYSIS OF DRAINAGE MORPHOMETRY AND MICRO-WATERSHED PRIORITIZATION IN SARDHA WATERSHED, MUNGELI, CHHATTISGARH THROUGH RS AND GIS TECHNOLOGY

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Abstract

The development of new advanced techniques in Spatial Information such as remote sensing and GIS are effectively used for the extraction of information about spatial features. DEM (Digital Elevation Model) is one of the important sources in extraction of drainage network and is useful for determining the quantitative description of catchment geometry i.e. morphometric analysis. Morphometric analysis has been commonly applied to prioritization of watersheds. The quantitative analysis of drainage system is an important aspect of characterization of watersheds. Using watershed as a basic unit in morphometric analysis is the most logical choice because all hydrologic and geomorphic processes occur within the watershed. The present study makes an attempt to prioritize six inaccessible micro-watersheds of Maniari river catchment of Mungeli district, Chhattisgarhon morphometric analysis, using remote sensing and GIS perspective. These have been classified into three priority categories as high, medium and low for conservation and management. Two micro-watersheds viz., 4G3F4n1 and 4G3F4n6 qualify for high priority watersheds and are likely to be subjected to maximum soil erosion and susceptible to natural hazards. Micro-watersheds 4G3F4n4 and 4G3F4n5 have been categorized as under medium priority watersheds and 4G3F4n2 and 4G3F4n3 as low priority category. Watersheds categorized as high priority have been proposed for conservation treatments.

Keywords: Watershed prioritization, Morphometric analysis, Micro-watershed, RS, GIS

1. Introduction

Watershed is an ideal unit for management and sustain-able development of natural resources (Patel *et al*. 2012). It is a natural hydrological entity which allows surface runoff to a defined channel, drain, stream or river at a particular point (Chopra *et al*. 2005). Watershed management is the process of formulation carrying out a course of action that involves modification in the natural system of watershed to achieve specified objectives (Johnson *et al*. 2002). It further implies appropriate use of land and water resources of a watershed for optimum production with minimum hazard to natural resources (Osborne and Wiley 1988; Kessler *et al*. 1992). Morphometric analysis helps in better understanding of drainage morphometry on landforms and catchment characteristics (Sreedevi *et al.* 2009).

Catchments are geographical drainage areas of the land surface that contribute flow to outlet point. Study of Catchment characteristics plays an important role in the hydrological

response of the catchment. The accurate delineation of the catchment boundaries is the first important step in the determination of stream flow path and its contributing area. Remote sensing and GIS are effective tools in extraction of spatial information particularly for the delineation of catchment boundaries (Ahmed *et al*. 2010; Bertolo, 2000). In recent years the use of GIS (Geographic Information System) has become increasingly popular and has facilitated much of the work of hydrologists in the scientific study and management of water resources. The use of DEMs (Digital Elevation Models) in particular has made watershed delineation a relatively smooth procedure. DEM provide good terrain representation from which the watersheds can be derived automatically using GIS technology. The techniques for automated watershed delineation have been available since mideighties and have been implemented in various GIS systems and custom applications (Garbrecht and Martz, 1999). The present study involves the application of geospatial technique to delineate the catchment boundary and evaluation of morphometric parameters derived from DEM. The morphometric parameters include basic parameters and derived parameters. The basic parameters are catchment area, perimeter, basin length, maximum and minimum elevations and slope. The derived parameters for Prioritization considered are linear (Stream order, Stream length, Stream length ratio and Bifurcation ratio) and areal (Drainage density, Stream frequency, Texture ratio, Elongation ratio, Circularity ratio and Form factor). The main aim of the present study is to delineate and analyze all the morphometric features derived from DEM and to establish the superiority and easiness of remote sensing and GIS techniques in deriving the morphometric features.

2. Study Area

Sardha Small watershed is situated in Lormi block of Mungeli district and located between 21^0 11'0" to 21020'0" N latitudes and $81^0$37'0" to $81^0$49'0" E longitudes (Fig 1). It falls in SOI topographical map no. 64 F/12(1:50,000). The Sardha watershed covers geographical area of 80.59 Km^2. The general elevation of the area ranges from 264 to 337 m above mean sea level (MSL).

3. Materials and Methods

The base map for morphometric analysis of the Maniari River was prepared from Survey of India topographical maps no. 64 F/12 (1: 50,000). The hard copy of topographic map was scanned using a wide format scanner and exported in ERDAS IMAGINE 2011 where it was georefernced. After georeferencing onscreen digitization process was carried out using ARC GIS 10 to extract stream network. The designation of the stream order is the first step in morphometric analysis of a drainage basin, which is based on the hierarchy ranking of streams proposed by Strahler (1964). Sardha sub-watershed is divided into six micro-watersheds, (Fig.1) digitized from topographic map, were designated as 4G3F4n1 to 4G3F4n6. Computation of basin parameters required for morphometric analysis, ordering, lengths, area etc. were estimated using GIS technique, which were later used to calculate other parameters like drainage density, stream frequency, bifurcation ratio, drainage texture, length of overland flow, form factor, circularity ratio, elongation ratio and basin shape for each micro-watersheds. These parameters were evaluated with the help of standard mathematical equations as mentioned in table 1. Prioritization of micro-watersheds was carried out by assigning weight factors to all the computed morphometric parameter. ThevDEM is the digital representation of the topographic surface. DEM was prepared

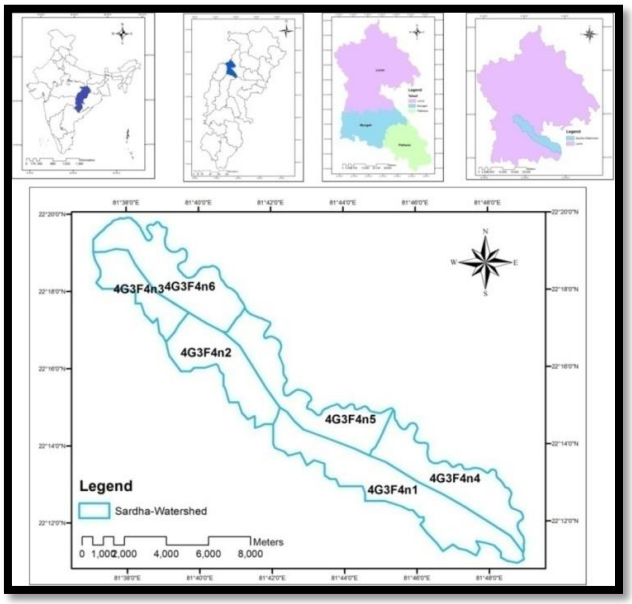


Figure 1: Layout of the study area

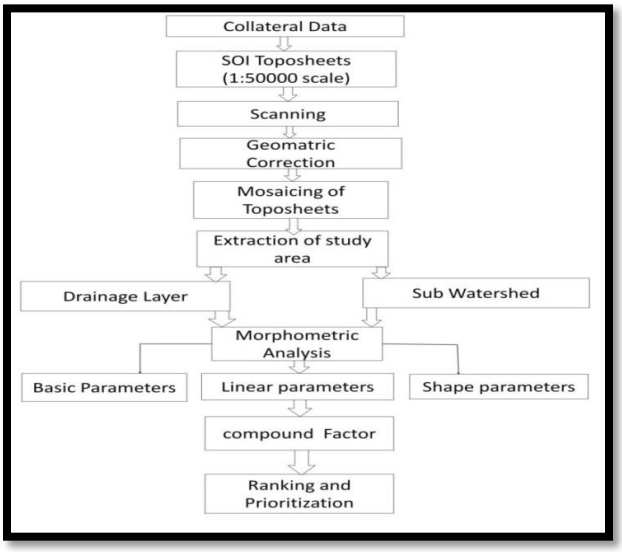


Figure 2: Flowchat of the methodology used in this study

using contour lines and elevation points extracted from SOI toposheets and additional attributes observed from GPS. The digitized vectors were gridded using programme available in ArcGIS 10 to convert vectored input into grids. Like contour map it represents the elevation values in meters.

The grids were interpolated using the Raster interpolation (topo to raster) method available in 3D analysist option in toolbox. The methodology used in this study is shown in fig. 2.

Table 1: Empirical relationships used in computation of morpho-metric parameters

Morphometric parameter	Formula	Reference
Stream order	Hierarchial rank	Strahler (1964)
Stream length (L_u)	Length of stream	Horton (1945)
Mean stream length (L_{sm})	$L_{sm} = L_u/N_u$ where, L_{sm} = mean stream length L_u = Total stream length of order 'u' N_u = Total no. of stream segments of order 'u'	Horton (1945)
Stream length ratio (R_L)	$RL = L_u / L_{u-1}$ where, R_L = stream length ratio L_u = Total stream length of order 'u' L_{u-1} = Total stream length of its next lower order	Horton (1945)
Bifurcation ratio (R_b)	$R_b = N_u / N_{u+1}$ R_b = Bifurcation ratio N_u = Total no. of stream segments of order 'u' N_{u+1} = no. of stream segments of the next higherorder	Schumm (1956)
Mean bifurcation ratio(R_{bm})	R_{bm} = Average of bifurcation ratios of all orders	Strahler (1957)
Basin length (L_b)	$L_b = 1.321A^{0.568}$ where, A= Area of the basin	Nookaratnam (2005)
Drainage density (D_d)	$D_d = L_u /A$ where, D_d = Drainage density L_u = Total stream length of all orders A = Area of basin (km^2)	Horton (1932)
Stream frequency (F_s)	$F_s = N_u / A$ where F_s = Stream frequency N_u = Total no. of streams of all orders A = Area of basin (km^2)	Horton (1932)
Texture ratio (R_t)	$R_t = N_u / p$ where, R_t = Texture ratio N_u = Total no. of streams of all orders P = Perimeter (km)	Horton (1945)
Form factor (R_f)	$R_f = A/L_b^2$ where, A = Area of basin (km^2) L_b^2 = Square of basin length	Horton (1932)

Shape factor (B_s)	$B_s = L_b^2/A^h$ where, L_b = Square of basin length A= Area of basin (km^2)	Nookaratnam (2005)
Circulatory ratio (R_c)	$Rc = 4 \times \pi \times A / P^2$ where, R_c = circulatory ratio A = Area of basin (km^2) P = Square of the perimeter (km)	Miller (1953)
Elongation ratio (R_e)	$R_e = (4 \times A / \pi)^{0.5} / L_b$ where, Re = Elongation Ratio A = Area of basin (km2) L_b = Basin length	Schumm (1956)
Length of overland flow (L_g)	$Lg = 1/2D_d$ where, L_g = Length of overland flow D_d = Drainage Density	Horton (1945)
Compactness constant (C_c)	$C_c = 0.2821P/A^{0.5}$ where, A = Area of basin (km2) P = Perimeter (km)	Horton (1945)

3. Results and discussion

Morphometric analysis

The information about basic morphometric parameters such as area (A), perimeter (P), length (L), and number of streams (N) was obtained from sub watershed delineated layer, and basin length (L_b) was calculated from stream length, while the bifurcation ratio (R_b) was calculated from the number of streams. Other morphometric parameters were calculated using the equations as described in Table 1. Linear parameters have a direct relationship with erodibility (Nooka Ratnam *et al*. 2005). Higher the value, higher is the erodibility. For prioritization of micro-watersheds, the highest value of linear parameters was rated as rank 1, second highest value was rated as rank 2 and so on, and the least value was rated last in rank. On the contrary, the shape parameters have an inverse relation with linear parameters, so that the lower their value, the more the erodibility (Patel and Dholakia, 2010; Patel *et al*. 2012). Thus the lowest value of shape parameters was rated as rank 1, next lower value was rated as rank 2 and so on and the highest value was rated last in rank. Compound factor was then worked out by summing all the ranks of linear parameters as well as shape parameters and then dividing by number of parameters. From the group of mini-watersheds, highest prioritized rank was assigned to micro-watershed having lowest compound factor and vice versa (Patel *et al*. 2012).

Basic parameters Basic parameters include watershed area, perimeter, stream length, stream order, and basin length.

Area

The rate of runoff of any drainage basin depends on its area and physiography. The drainage basin area is a dimensional parameter and it is denoted by A. The drainage basin is instrumental in governing the rate at which water is supplied to the main stream as it precedes to

the outlet. Area of basin of a particular order is defined as the total area projected upon a horizontal plane, contributing overland flow to the channel segment of a given order including all the tributaries of the lower order. The factors which are dependent on the basin length are length of stream, degree of slope, drainage frequency, drainage density, shape parameters (i.e. form factor, circulatory ratio and elongation ratio), rainfall, rate of runoff etc. Larger the area, smaller is the runoff and vice versa. The basin Area of different micro-watersheds is given in Table 3

Perimeter

Total Length boundary of a basin is known as the perimeter of the basin and it is denoted by P. The factors that are dependent on the basin parameter are elongation ratio and circulatory ratio. Earlier, the perimeter was measured with chartometer (a map measurer). All segments within the specified drainage network were used to measure successively without pause or recorded the cumulative length appeared on the dial of the chartometer. Perimeters of different micro-watersheds were derived from GIS software that gives the perimeter of each polygon. The basin Perimeters of different micro-watersheds are given in Table 3.

Basin Length

It is the length of longest dimension of a basin as projected on a horizontal plane and it is denoted by L_b. As the basin length increases, the peak discharge decreases. The basin lengths of different micro-watersheds are given in Table 3.

Stream Order

The designation of stream orders is the first step in drainage basin analysis. It is based on hierarchic ranking of streams proposed by (Strahler, 1964). The first order streams have no tributaries. The second order streams have only first order streams as tributaries. Similarly, third order streams have first and second order streams as tributaries and so on. After analysis of the drainage map, it is found that Sardha watershed is 3rd order stream and drainage pattern is dendrite. The basins Stream Order of different micro-watersheds are given in Table 2.

Stream Length

It is the total length of streams in a particular order and it is denoted as Lu. The numbers of streams of various orders in a micro-watershed were counted and their lengths measured in GIS. Generally, the total length of stream segments decrease with stream order. Length of different drain segments have been extracted in GIS and presented in Table 2. Higher length of streams in micro -watersheds revealed good morphologic characteristics. Table 3 shows that in Total length of stream of micro- watersheds value ranges from 10.16 km to 29.02 km for the micro-watersheds.

Basin length (L_b)

It is usually defined as the distance measured along the main channel from the watershed outlet to the basin-divide. Since the channel does not extend to the basin-divide, it is necessary to extend a line from the end of the channel to the basin-divide following a path where the greatest volume of water would travel. Thus, the length is measured along the principal flow path. Basin length is the basic input parameter to count the major shape parameters. Table 3 shows that in Basin length (L_b) of micro-watersheds value ranges from 3.90 km to 7.28 km for micro-watersheds 4G3F4n3 and 4G3F4n1 respectively.

Table 2: micro-watershed wise areal parameters

S.No.	Micro Watershed	Area (km^2)	Perimetes (km)	Number of Streams			Stream Length in km		
				1^{st}	2^{nd}	3^{rd}	1^{st}	2^{nd}	3^{rd}
1	4G3F4n1	20.45	32.81	4	2	2	2.94	0.33	16.18
2	4G3F4n2	11.57	17.71	10	3	1	6.67	19.58	2.77
3	4G3F4n3	6.79	14.77	6	1	0	2.44	7.72	0
4	4G3F4n4	13.54	23.66	4	2	2	5.38	2.64	16.93
5	4G3F4n5	13.72	26.34	6	6	0	2.66	8.66	0
6	4G3F4n6	14.51	23.40	8	3	0	5.34	6.53	0

Table 3: Morphometric parameters of micro-watershed

Micro Watershed	Area (km^2)	Perimeters (Km)	Elevation(m)		Basin Length (km)	Total Relief (m)	Number of Streams	Total Stream Length (km)
			Max	Min				
4G3F4n1	20.45	32.81	321.05	264.30	7.28	56.74	8	19.45
4G3F4n2	11.57	17.71	320.06	309.24	5.27	10.82	14	29.02
4G3F4n3	6.79	14.77	320.22	310.47	3.90	9.75	7	10.16
4G3F4n4	13.54	23.66	310.35	286.27	5.76	24.08	8	24.95
4G3F4n5	13.72	26.34	322.53	290.30	5.81	32.22	12	11.32
4G3F4n6	14.51	23.40	335.97	309.79	6.00	26.18	11	11.87

Linear parameters include bifurcation ratio, drainage density, stream frequency, texture ratio, and length of overland flow.

Bifurcation Ratio

It is the ratio of the numbers of streams of a given order to the number of streams of the next higher order. Horton (1945) considered bifurcation ratio (Rb) as an index of relief and dissections. Strahler (1957) demonstrated that Rb shows only a small variation for different region on different environment except where powerful geological control dominates. Lower Rb values

are the characteristic of structurally less distributed watersheds without any distortion in drainage pattern (Nag, 1998). Higher value of Rb for micro-watershed indicates high runoff, low recharge and mature topography. A high Rb is expected in the region of steeply digging rock strata, where narrow valley is confined between the ridges. Irregular Rb values in these micro-watersheds do not subscribe to Horton"s Law of stream numbers. These irregularities are dependent on geological and lithological development of drainage basin (Strahler, 1964). Table 4 shows that in mean bifurcation ratios (R_b) of the micro-watersheds values ranges from 2.83 to 3.67 for the micro-watersheds with lowest value for micro-watershed no 4G3F4n6 and highest value for the micro-watershed no 4G3F4n2 respectively.

Drainage Density

Drainage density (Dd) expresses the closeness of spacing of channels. It is the measure of the total length of the stream segment of all orders per unit area. It is affected by factors which control the characteristic length of the stream like resistance to weathering, permeability of rock formation, climate, vegetation etc. In general, low value of Dd is observed in regions underlain by highly resistant permeable material with vegetative cover and low relief. High drainage density is observed in region of weak and impermeable subsurface material and sparse vegetation and mountainous relief. Table 4 shows that in Drainage Density (Dd) of micro- watersheds value ranges from 0.82 to 2.5 for micro-watersheds with lowest value for micro-watershed no 4G3F4n6 and highest value for the micro-watershed no 4G3F4n2 respectively.

Length of Overland Flow

It is the length of water over the ground before it gets concentrated into definite stream channels (Horton, 1945). This factor relates inversely to the average slope of the channel and is quite synonymous with the length of sheet flow to a large degree. It approximately equals to half of reciprocal of drainage density. Table 4 shows that the Length of Overland Flow (Lg) of Micro-watersheds value ranges from 0.41 to 1.25 for micro-watersheds with lowest value for micro-watershed no 4G3F4n6 and highest value for the micro-watershed no 4G3F4n2 respectively.

Stream/Drainage Frequency

Drainage frequency is the measure of the topographic feature. Stream frequency/drainage frequency (fs) is the total number of stream segments of all orders per unit area (Horton, 1932). Table 4 shows that in Stream/Drainage Frequency (fs) of Micro-watersheds value ranges from 0.39 to 1.21 for micro-watersheds with lowest value for micro-watershed no 4G3F4n1 and highest value for the micro-watershed no 4G3F4n2 respectively.

Texture ratio

It is the total number of stream segment of all orders per perimeter of that area (Horton, 1945). Horton recognized infiltration capacity as the single important factor which influences Texture ratio (R_t) and considered the drainage texture to include drainage density and drainage frequency. Table 4 shows that in Texture ratio (R_t) of micro- watersheds value ranges from 0.24 to 0.24 for micro-watersheds with lowest value for micro-watershed no 4G3F4n1 and highest value for the micro-watershed no 4G3F4n2 respectively.

Shape parameters Shape parameters include form factor, shape factor, elongation ratio, compactness ratio, and circulatory ratio.

Form Factor

It is defined as the ratio of basin area to square of the basin length (Horton, 1932). The value of form factor would always be less than 0.7854 (for a perfectly circular basin). Smaller the value of form factor, more elongated will be the basin. The basins with high form factor have high peak flows of shorter durations, whereas, elongated micro-watershed with low form factor have lower peak flow of longer duration. Flood flows of such elongated basins are easier to manage than of the circular basin. Table 4 shows that in form factor (Rf) of micro-watersheds value ranges from 0.39 to 0.45 for micro-watersheds with lowest value for micro-watershed no 4G3F4n1 and highest value for the micro-watershed no 4G3F4n3 respectively.

Shape factor

It is defined as the ratio of the square of the basin length to area of the basin (Horton 1945) and is in inverse proportion with form factor (R_f). Table 4 shows that in shape factor (B_S) of Micro-watersheds value ranges from 2.23 to 2.59 for micro-watersheds with lowest value for micro-watershed no 4G3F4n3 and highest value for the micro-watershed no 4G3F4n1 respectively.

Elongation Ratio

It is the ratio between the drainage of the circle of the same area as the drainage basin and the maximum length of the basin. A circular basin is more efficient in runoff discharge than a elongated basin (Singh and Singh, 1997). The value of elongation ratio (Re) generally varies from 0.6 to 1.0 associated with a wide variety of climate and geology. Values close to 1.0 are typical of regions of very low relief whereas that of 0.1 to 0.8 are associated with high relief and steep ground slope (Strahler, 1964). Table 4 shows that in elongation ratio (Re) of micro-watersheds value ranges from 0.70 to 0.76 for micro-watersheds with lowest value for micro-watershed no 4G3F4n1 and highest value for the micro-watershed no 4G3F4n3 respectively.

Compactness coefficient (C_c)

Compactness coefficient (C_c) can be represented as basin perimeter divided by the circumference of a circle to the same area of the basin and also known as the Gravelius index (GI). Lower values of this parameter indicate more elongation of the basin and less erosion, while higher values indicate less elongation and high erosion. In this study, Table 4 shows that in Compactness coefficient (C_c) of micro-watersheds value ranges from 1.47 to 2.05 for micro-watersheds with lowest value for micro-watershed no 4G3F4n2 and highest value for the micro-watershed no 4G3F4n1 respectively.

Circulatory Ratio

It is ratio of the area of the basin to the area of circle having the same circumference as the perimeter of the basin (Miller, 1953). It is influenced by the length and frequency of streams, geological structures, land use/land cover, climate, relief and slope of the basin Table 4 shows that in circulatory ratio (Rc) of micro-watersheds value ranges from 0.24 to 0.46 for micro-watersheds with lowest value for micro-watershed no 4G3F4n1 and highest value for the micro-watershed no 4G3F4n2 respectively. micro-watersheds having circular to oval shape allows quick runoff and results in a high peaked and narrow hydrograph, while elongated shape of micro-watersheds allows slow disposal of water, and results in a broad and low peaked hydrograph. High value of Rc indicates mature and old topography.

Table 4 Analyzed morphometric parameters

Morphometric Parameters										
	Linear Parameters					Shape Parameters				
Micro Watershed	R_b	D_d	F_s	L_g	T	R_c	R_f	B_s	R_e	C_c
4G3F4n1	3.00	0.95	0.39	0.48	0.24	0.24	0.39	2.59	0.70	2.05
4G3F4n2	3.67	2.51	1.21	1.25	0.24	0.46	0.42	2.40	0.73	1.47
4G3F4n3	3.50	1.50	1.03	0.75	0.47	0.39	0.45	2.23	0.76	1.60
4G3F4n4	3.00	1.84	0.59	0.92	0.34	0.30	0.41	2.45	0.72	1.81
4G3F4n5	3.50	0.83	0.87	0.41	0.46	0.25	0.41	2.46	0.72	2.01
4G3F4n6	2.83	0.82	0.76	0.41	0.47	0.33	0.40	2.48	0.72	1.73

Prioritization of Sub Watersheds Based on morphometric analysis

The response of a watershed to different hydrological processes and its behavior depends upon various physiographic, hydrogeological and geomorphological parameters. Though these are watershed specific and there by unique, the prioritization of a watershed provides an idea about its behavior. Considering the massive investment in the watershed development programs, it is important to plan the activities on priority basis for achieving fruitful results, which also facilitate addressing the problematic areas to arrive at suitable solutions. For prioritization, the compound factor is computed by summing all the ranks of linear parameters as well as shape parameters and then dividing by the number of parameters. From the group of these micro-watersheds, highest rank was assigned to the micro-watershed having the lowest compound factor and so on. Depending upon the value of compound factor, ranking to each micro-watershed is assigned as shown in Fig. 3. For micro-watersheds, watershed no. 4G3F4n2 is given rank 1 with least compound factor value 2.1, followed by watersheds no. 4G3F4n3 and 4G3F4n4 as second and third, respectively. The values of compound factor and respective rank of all micro-watersheds are shown in Table 5.

Table 5 Calculation of compound factor and prioritized ranks

Morphometric Parameters												
	Linear Parameters					Shape Parameters						
Micro Watershed	R_b	D_d	F_s	L_g	T	R_c	R_f	B_s	R_e	C_c	Compound Factor	Prioritized Ranks
4G3F4n1	3	4	6	4	5	1	1	6	1	6	3.7	5
4G3F4n2	1	1	1	1	1	6	4	2	3	1	2.1	1
4G3F4n3	2	3	2	3	2	5	5	1	4	2	2.9	2
4G3F4n4	3	2	5	2	4	3	3	3	2	4	3.1	3
4G3F4n5	2	5	3	5	3	2	3	4	2	5	3.4	4
4G3F4n6	4	6	4	5	2	4	2	5	2	3	3.7	5

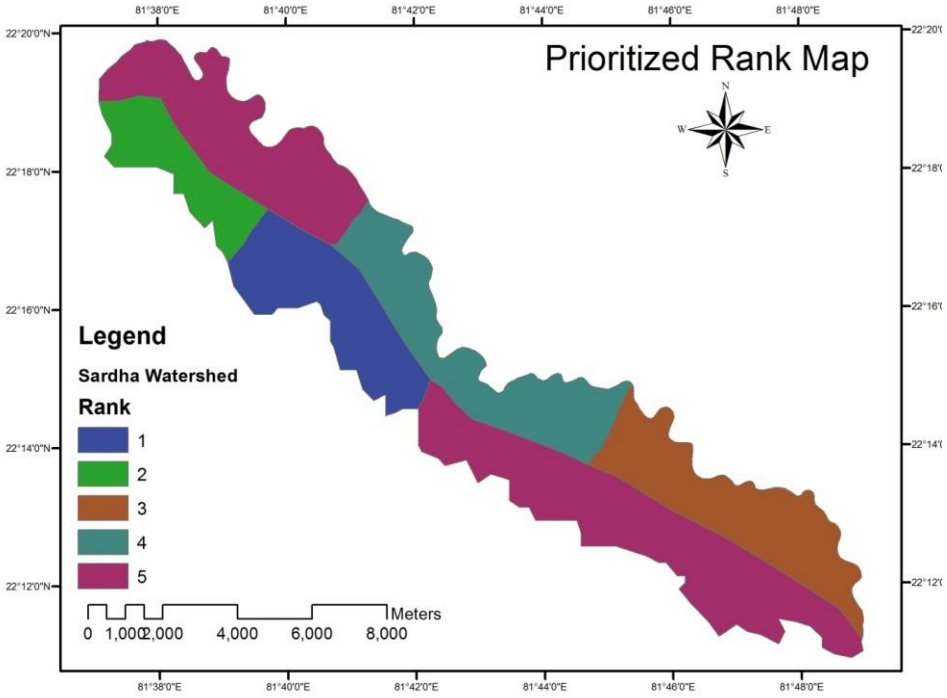


Fig. 3 Prioritized rank map of the study area

4. Conclusions

The present study reveals the effectiveness of Remote Sensing and GIS techniques for morphometric analysis of micro-watersheds of Maniari river catchment of Mungeli district, Chhattisgarh. The morphometric characteristics of different micro-watersheds show their relative influence on hydrologic response of the micro-watershed. The various morphometric parameters of each micro-watershed were ranked based on their susceptibility to run-off and erosion. 4G3F4n2 is found to be most vulnerable to high peak flows and erosion. This calls for setting up of immediate and viable remedial strategies for soil conservation and flood management. The present study further demonstrates the utility of Remote Sensing and GIS techniques in prioritization of watersheds, which may be helpful for taking the high priority implementation of soil and water conservation measures,

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RELATIONSHIP BETWEEN RAINFALL, RUNOFF, SOIL LOSS AND PRODUCTIVITY IN NORTH EASTERN GHAT ZONE OF ODISHA

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Abstract

A trial was conducted at All India Coordinated Research Project ,OUAT, Phulbani during the year 2007-09 with the objectives to quantify the runoff and soil loss under different cropping systems and develop relationship among them. The treatments tried were T_1-Sole crop of rice, T_2- Sole crop of pigeon pea. T_3- Sole crop of groundnut,T_4-Pigeonpea and rice in alternate strips,T_5- Pigeon pea and groundnut in alternate strips, T_6-Intercrop of rice and pigeon pea (5:2),T_7- Intercrop of groundnut and pigeon pea (4:2),T_8-Uncultivated fallow,T_9-Cultivated fallow, All crops were planted across the contour. Intercrop of groundnut and pigeon pea (4:2) gave significantly higher rice equivalent yield compared to other sole crops. Mean rice equivalent yield was 38.62 q/ha. Groundnut + pigeon pea (4:2) introduction increased the yield by 158 % as 97% and 21% when compared with sole crop of rice, pigeon pea and groundnut respectively. Groundnut + pigeon pea (4:2) gave the lowest runoff of 309mm which is 23 % less than the cultivated fallow (401mm).Groundnut + pigeon pea (4:2) gave the lowest soil loss (8.03t/ha) which is 47 % lower than the cultivated fallow (with highest soil loss 15.19 t/ha).The Groundnut + pigeon pea (4:2) gave the lowest (24.2 %) mean runoff of the rainfall compared to other treatments. The relationship among rainfall, runoff and soil loss was found out which can be used to predict the runoff and soil loss from rainfall for same type of soil condition and slope. The Thus it can be concluded that intercropping of groundnut with pigeon pea planted along contour may be practiced to increase crop yield and lowering the soil loss and runoff in the hilly tribal areas of Kandhamal district of Odisha.

Key words: Relationship, rainfall, runoff, soil loss, productivity

Introduction

Strip and intercropping of cereal crops with pulses/oilseeds are approved practices of breaking long slopes, which prevent soil loss, reduce runoff and enhance productivity. Therefore, this experiment has been designed to know the effect of strip as well as intercrop of pigeonpea, rice and groundnut on runoff, soil loss and productivity on sloppy agricultural land. These intangible benefits have not been assessed properly. Hence the present experiment has been designed. Samra, J.S.(2002) reported that renovation of terrace and plantation of fruit plants, timber plants improved biomass production, net returns, growth of crop, productivity, reduction of runoff in the range of 1.5-10.8 times, peak flow rate by 20 times& soil loss in the range of 1.2 to 5.2 times ,as well as water table rise. Subudhi et. al.(1999)have reported that effect of vegetative barrier like Vetiver has increased the rice yield ,decrease the soil loss and decrease the runoff

compared to farmers practice. Arora et.al.(2002) reported that there is a growing need for rain water management since 96 m ha out of 142 m ha of net cultivated land of the country is rainfed. Scientific use of these resources will definitely increase the productivity &conservation of resources like soil & water. Kumar (2002) reported that impact of different soil& water conservation techniques viz. contour bunding ,terracing, land leveling , smoothening& gully plugging, sowing across the slope, vegetative barrier, increase the Kharif crops by 25-30 percent. .Establishment of vegetative barrier with mechanical measures were more effective in controlling soil erosion(3.8 t ha^{-1}) over conventional method(9.64 t ha^{-1})and runoff thereby making more moisture available for crop growth. Anonymous (2005) reported that intercropping of groundnut with pigeonpea planted along contour gave the highest rice equivalent yield, lowest soil loss and runoff.

Objectives

To quantify the runoff and soil loss under different cropping systems and develop relationship among them

Materials and Methods

A trial was conducted at All India Coordinated Research Project, OUAT, Phulbani during the year 2007-09. The experiment was laid out on 2% land slope. Multi slot division box and drums were put to measure the runoff and soil loss daily after each rainfall. The treatments tried were T1-Sole crop of rice, T_2- Sole crop of pigeon pea. T_3- Sole crop of groundnut,T_4-Pigeonpea and rice in alternate strips,T_5- Pigeon pea and groundnut in alternate strips, T_6-Intercrop of rice and pigeon pea (5:2),T_7- Intercrop of groundnut and pigeon pea (4:2),T_8-Uncultivated fallow,T_9-Cultivated fallow, All crops were planted across the contour. Different crops and their varieties are, Rice- ZHU-11-26;Pigeon pea - UPAS-120; Groundnut- Smruti (OG-52-1).The experiment design was Randomized Block Design and number of replications were three. Plot size was 25mX2m. Seed rate were, Rice- 75kg/ha; Pigeon pea-25kg/ha; Groundnut- 150kg/ha (pod).Fertilizer applied was;

Basal:

Rice - 30:30:30kg N-P_2O_5-K_2O/ha; Pigeon pea - 20:40:20kg N-P_2O_5-K_2O/ha Groundnut-20: 40:40 kg N-P_2O_5-K_2O /ha

Top dressing:

Rice- 30kg N in two splits

The runoff collected daily at 8 AM was measured from the drum and 1 lit of runoff from each drum were collected for silt analysis, so soil loss can be measured from the silt sample collected after evaporating the sample in the heater. The rainfall was also measured. Thus the relation between rainfall (mm)-runoff(mm),rainfall(mm)-soil loss(t/ha) and runoff(mm)-soil loss(t/ha) were calculated and coefficient of determination was also calculated.

Result and Discussion

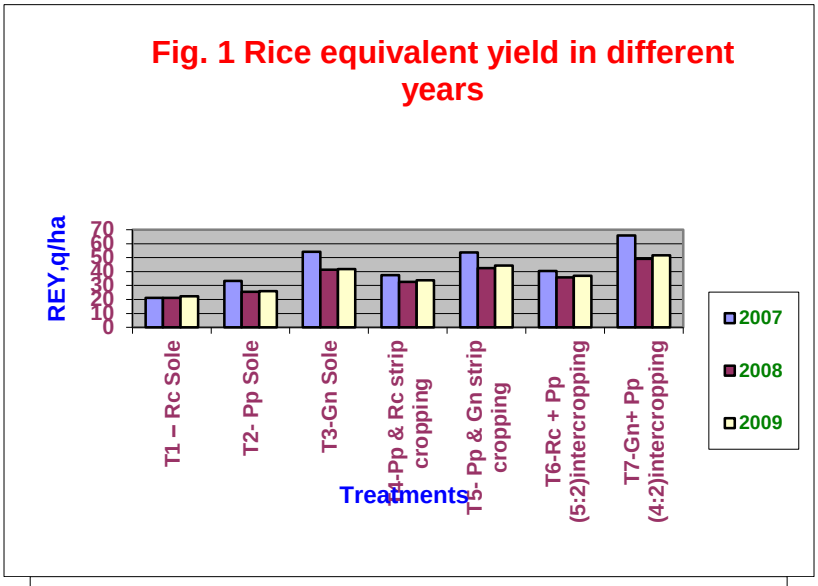
Rainfall, runoff and soil loss

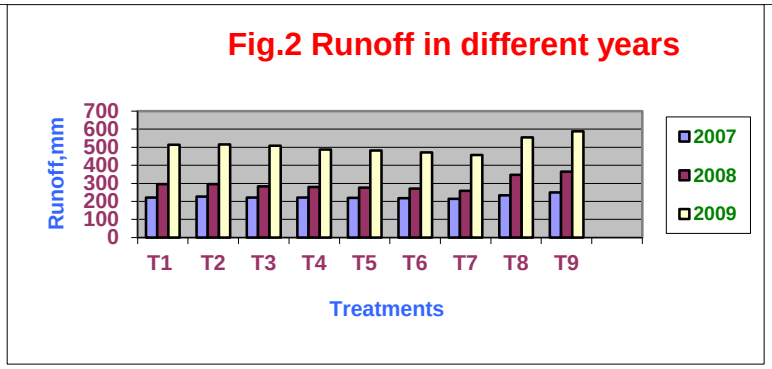
During 2009 Pigeon pea received the highest amount of rainfall (1544.8mm) this cropping treatment received the highest amount of runoff (516mm) In addition, Groundnut + pigeon pea (4:2) gave the lowest runoff of 309mm which is 23 % less than the cultivated fallow

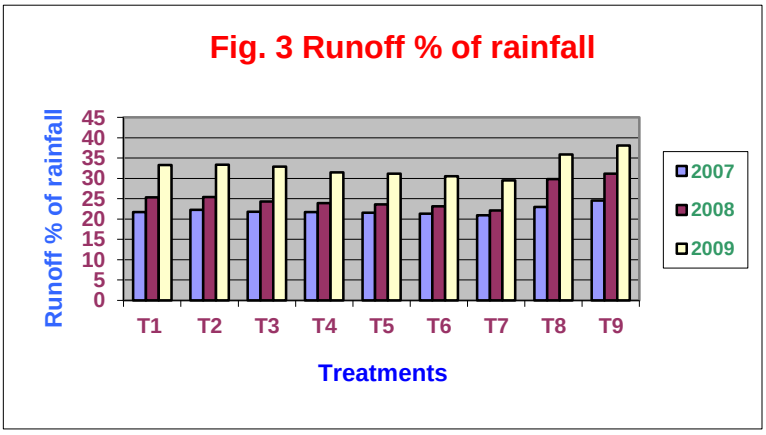
(401mm).Groundnut + pigeon pea (4:2) gave the lowest soil loss (8.03t/ha) (Table 1) which is 47 % lower than the cultivated fallow (with highest soil loss 15.19 t/ha).The Groundnut + pigeon pea (4:2) gave the lowest (24.2 %) mean runoff of the rainfall compared to other treatments. The poor and marginal farmers having lands in upland ecosystem may go for this technology.

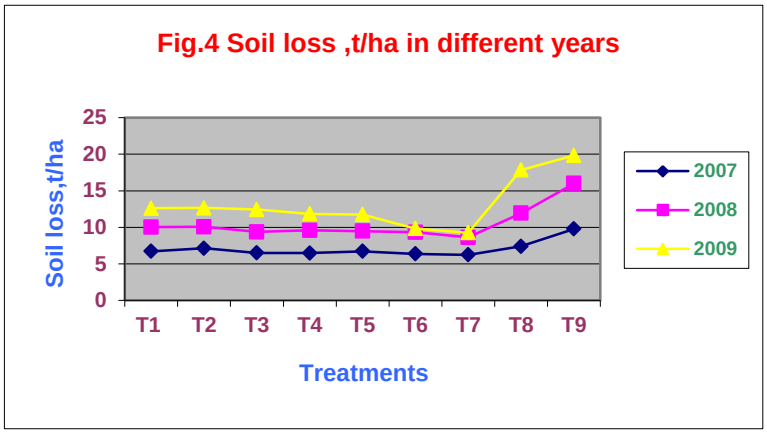
Table 1 Runoff and soil loss under different cropping systems during 2007 to 2009 (3 years)

Treatments	Runoff (mm)				Soil loss(t/ha)				Runoff (% of rainfall)			
	2007	08	09	Mean	2007	08	09	Mean	2007	2008	2009	Mean
T_1 – Rc Sole	221.268	295.339	514	344	6.72	10.01	12.60	9.78	21.7	25.3	33.3	26.8
T_2- Pp Sole	226.92	296.43	516	347	7.116	10.06	12.65	9.94	22.26	25.4	33.4	27
T_3-Gn Sole	221.943	284.03	508	338	6.49	9.35	12.43	9.42	21.77	24.3	32.9	26.3
T_4-Pp & Rc strip cropping	221.1	279.475	487	329	6.47	9.59	11.84	9.3	21.68	23.9	31.5	25.7
T_5- Pp & Gn strip cropping	220.003	275.847	482	326	6.708	9.47	11.75	9.31	21.58	23.6	31.2	25.5
T_6-Rc + Pp (5:2)intercropping	217.725	270.027	471	320	6.358	9.32	9.81	8.5	21.35	23.1	30.5	25
T_7-Gn+ Pp (4:2)intercropping	213.376	258.386	456	309	6.231	8.61	9.25	8.03	20.96	22.1	29.5	24.2
T_8-Uncultivated fallow	234.175	347.72	555	379	7.395	11.92	17.84	12.39	22.97	29.8	35.9	29.6
T_9- Cultivated fallow	250.119	364.675	588	401	9.772	15.99	19.82	15.19	24.53	31.2	38.1	31.3
Mean	225.214	296.881	509	344	7.029	10.48	13.11	10.21	22.09	25.4	32.9	26.8


Fig. 1 Rice equivalent yield in different years
REY,q/ha
70
60
50
40
30
20
10
0
T1 – Rc Sole
T2- Pp Sole
T3-Gn Sole
T4-Pp & Rc strip cropping
T5- Pp & Gn strip cropping
T6-Rc + Pp (5:2)intercropping
T7-Gn+ Pp (4:2)intercropping
Treatments
2007
2008
2009


Fig.2 Runoff in different years
Runoff,mm
700
600
500
400
300
200
100
0
T1
T2
T3
T4
T5
T6
T7
T8
T9
Treatments
2007
2008
2009


Fig. 3 Runoff % of rainfall
Runoff % of rainfall
45
40
35
30
25
20
15
10
5
0
T1
T2
T3
T4
T5
T6
T7
T8
T9
Treatments
2007
2008
2009



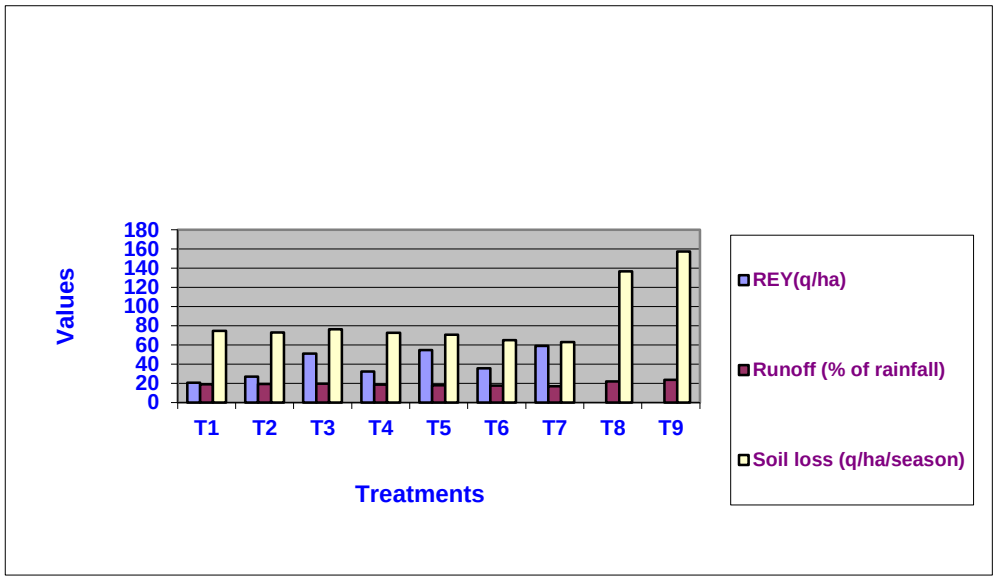


Fig 5 Rice Equivalent Yield (REY), Runoff and soil loss in different treatments (mean of three years 2007-09)



Fig 6 Multi slot division box with runoff collection tank

Moisture content

From Table 4.2.2 it is observed that the Gn+Pp (4:2) intercropping gave highest moisture content, plant height and other yield attributing characters compared to other treatments so moisture content might be the reason to increase the yield.

Table 2 Mean moisture content and yield attributing characteristics during 2007-09

Treatments	Mean Moisture Content
T_1 – Rc Sole	15.5
T_2- Pp Sole	16.1
T_3-Gn Sole	16.0
T_4-Pp & Rc strip cropping	16.2
T_5- Pp & Gn strip cropping	17.6
T_6-Rc + Pp (5:2)intercropping	17.1
T_7-Gn+ Pp (4:2)intercropping	17.8
T_8- Uncultivated fallow	15.6
T_9- Cultivated fallow	15.2
SE (m)±	0.251
CD(0.05)	0.903
Mean	16.3

Nutrient loss

Nutrient loss in different treatments were shown in Table 3, it is observed that total nutrient loss was highest in treatment 9 i.e. Cultivated fallow may be due to the reason that soil surface was exposed without any crop and cultivated and also soil loss was more in this treatment compared to other treatments. Lowest nutrient loss was in T_7(42.21kg/ha) i.e. -Gn+ Pp (4:2) intercropping.

Table 3 Nutrient lost from soil sample collected from runoff from different treatments

Treatments	Nutrient loss from different treatments,Kg/ha			Total nutrient loss, kg/ha
	N	P_2O_5	K_2O	
T_1 – Rc Sole	11.5	10.14	29.7	51.34
T_2- Pp Sole	11.5	13.24	35.62	60.36
T_3-Gn Sole	13.13	12.0	28.76	53.89
T_4-Pp & Rc strip cropping	11.13	9.69	23.52	44.34
T_5- Pp & Gn strip cropping	11.5	7.16	27.42	46.08
T_6-Rc + Pp (5:2) intercropping	10.38	6.14	25.94	42.46
T_7-Gn+ Pp (4:2)intercropping	12.25	4.62	25.34	42.21
T_8- Uncultivated fallow	11.5	4.17	36.02	51.69
T_9- Cultivated fallow	16.25	2.82	45.43	64.5

Yield attributing characteristics

The biometric characteristics of different crops under different treatments is given in Table 4.2.4.From table 4 it is observed that the Gn+Pp (4:2) intercropping gave highest plant height and other yield attributing characters compared to other treatments.

Table 4 Mean yield attributing characteristics during 2007-09

Treatments	Rice			Pigeonpea			Groundnut		
	Plant height,cm	Penicle length,cm	No of tillers /m run	Plant height,cm	Spread, cm	No of branches	Plant height, cm	No of branches	No of pods per plant
T_1 – Rc Sole	71.4	17.0	51.5						
T_2- Pp Sole				186.6	93.2	22.1			
T_3-Gn Sole							65.4	8.0	35.2
T_4-Pp & Rc strip cropping	74.6	17.4	53.8	191.6	99.4	22.2			
T_5- Pp & Gn strip cropping				198.0	106.0	23.1	74.5	8.6	37.9
T_6-Rc + Pp (5:2)inter cropping	78.1	18.2	61.2	201.7	97.9	21.9			
T_7-Gn+ Pp (4:2)inter cropping				209.6	106.8	23.1	76.0	9.0	42.1
Mean	74.7	17.5	55.5	197.5	100.7	22.5	72.0	8.5	38.4

Yield

Intercrop of groundnut and pigeonpea (4:2) gave significantly higher rice equivalent yield (REY) compared to other sole crops. Mean rice equivalent yield was 38.62 q/ha. Groundnut + pigeonpea (4:2) introduction increased the yield by 158 % as 97% and 21% when compared with sole crop of rice, pigeonpea and groundnut respectively.(Table 5)

Table 5. Rice equivalent yield, under different cropping systems during 2007 to 2009 (3 years)

Treatments	REY(q/ha)			
	2007	**08**	**09**	**Mean**
T_1 – Rc Sole	21.047	21.17	22.38	21.53
T_2- Pp Sole	33.393	25.436	25.85	28.23
T_3-Gn Sole	54.179	41.307	41.87	45.79
T_4-Pp & Rc strip cropping	37.528	32.584	33.70	34.6
T_5- Pp & Gn strip cropping	53.784	42.448	44.25	46.83
T_6-Rc + Pp (5:2)intercropping	40.429	35.843	37.08	37.78
T_7-Gn+ Pp (4:2)intercropping	65.996	49.043	51.68	55.57
T8- Uncultivated fallow				
T9- Cultivated fallow				
SE (m)+	0.961	0.612	0.601	0.586
CD(0.05)	2.914	1.885	1.823	1.778
Mean	43.78	35.404	36.69	38.62

Economics-

From Table 6 it is observed that the Gn+Pp (4:2) intercropping gave highest mean B:C ratio i.e. 2.06 compared to all other treatments among all the cropping system treatments.

Table 6 Economics and Rain water use efficiency during 2007-09 as affected by different in-situ conservation practices.

Treatments	Cost of cultivation (Rs/ha)	Gross income (Rs/ha)	Net income (Rs/ha)	Benefit Cost (B:C) Ratio	Rain water Use Efficiency (Kg/ha/mm)
T_1 – Rc Sole	14,000	17,933	3,933	1.28	1.62
T_2- Pp Sole	14,200	23,391	9,191	1.65	1.67
T_3-Gn Sole	21,721	39,582	17,861	1.82	2.91
T_4-Pp & Rc strip cropping	17,861	28,866	11,005	1.62	2.18
T_5- Pp & Gn strip cropping	19,294	38,839	19,545	2.01	2.86
T_6-Rc + Pp (5:2)intercropping	19,166	32,222	13,056	1.68	2.4
T_7-Gn+ Pp (4:2)intercropping	22,577	46,411	23,834	2.06	3.35

The relationship between rainfall (mm), runoff (mm) and soil loss t/ha was presented in Table 7, 8 and 9. The correlation coefficient was also found out. The relationship among rainfall, runoff and soil loss was found out which can be used to predict the runoff and soil loss from rainfall for same type of soil condition and slope.

Table 7. Relation between Rainfall (X)mm, Runoff(Y)mm and Soil loss (Z) t/ha in different treatments along with co-efficient of determination (2007-08)

Treatments	Relations		
	Rainfall(X) mm & Runoff(Y)mm (Co.det.)	**Rainfall(X)mm & Soil loss(Z) t/ha (Co.det)**	**Runoff(Y)mm & Soil loss(Z)t/ha (Co.det)**
T_1 – Rc Sole	$Y=0.36-0.011X+0.004X^2$ (0.969)	$Z= 0.03-0.006X+0.0002X^2$ (0.96)	$Z= -0.101+0.043Y$(0.976)
T_2- Pp Sole	$Y=0.49-0.015X+0.004X^2$ (0.966)	$Z=0.033-0.007X+0.0002X^2$ (0.957)	$Z= -0.102+0.044Y$(0.983)
T_3-Gn Sole	$Y=0.426-0.004X+0.004X^2$ (0.968)	$Z=0.023-0.004X+0.0002X^2$ (0.965)	$Z= -0.079+0.039Y$(0.988)
T_4-Pp & Rc strip cropping	$Y= 0.427-0.005X+0.004X^2$ (0.968)	$Z= 0.023-0.004X+0.0002X^2$ (0.965)	$Z= -0.079+0.039Y$(0.988)
T_5- Pp & Gn strip cropping	$Y= 0.401-0.0003X+0.004X^2$ (0.969)	$Z= 0.032-0.006X+0.0002X^2$ (0.958)	$Z= -0.1+0.043Y$(0.976)
T_6-Rc+Pp (5:2) intercropping	$Y= 0.383-0.002X+0.004X^2$ (0.969)	$Z= 0.021-0.004X+0.0002X^2$ (0.967)	$Z= -0.078+0.039Y$(0.988)
T_7-Gn+Pp (4:2)intercropping	$Y= 0.346-0.008X+0.004X^2$ (0.970)	$Z= 0.02-0.004X+0.0002X^2$ (0.969)	$Z= -0.076+0.039Y$(0.987)
T_8-Uncultivated fallow	$Y= 0.65-0.045X+0.005X^2$ (0.963)	$Z=0.04-0.008X+0.0003X^2$ (0.952)	$Z= -0.104+0.044Y$(0.984)
T_9-Cultivated fallow	$Y= 0.97-0.104X+0.006X^2$ (0.955)	$Z=0.052 – 0.01X+0.0003X^2$ (0.951)	$Z= -0.098+0.05Y$(0.996)

Table 8 Relation between Rainfall (X)mm, Runoff(Y)mm and Soil loss (Z) t/ha in different treatments along with co-efficient of determination (2008-09)

Treatments	Relations		
	Rainfall(X) mm & Runoff(Y)mm (Co.det.)	**Rainfall(X)mm & Soil loss(Z) t/ha (Co.det)**	**Runoff(Y)mm & Soil loss(Z)t/ha (Co.det)**
T_1 – Rc Sole	$Y=-0.5+0.156X+0.002X^2$ (0.975)	$Z= -0.019+0.003X+0.0001X^2$ (0.973)	$Z= -0.075+0.041Y$ (0.993)
T_2- Pp Sole	$Y=-0.432+0.152X+0.002X^2$ (0.975)	$Z= -0.019+0.003X+0.0001X^2$ (0.974)	$Z= -0.077+0.042Y$ (0.994)
T_3-Gn Sole	$Y=-0.414+0.14X+0.002X^2$ (0.975)	$Z= -0.017+0.003X+0.0001X^2$ (0.967)	$Z= -0.078+0.041Y$ (0.991)
T_4-Pp & Rc strip cropping	$Y= -0.532+0.15X+0.002X^2$ (0.977)	$Z= -0.01+0.002X+0.0001X^2$ (0.976)	$Z= -0.075+0.042Y$ (0.993)
T_5- Pp & Gn strip cropping	$Y= -0.531+0.15X+0.002X^2$ (0.977)	$Z= -0.018+0.003X+0.0001X^2$ (0.976)	$Z= -0.075+0.042Y$ (0.993)
T_6-Rc+Pp (5:2) intercropping	$Y= -0.571+0.15X+0.002X^2$ (0.974)	$Z= -0.018+0.003X+0.0001X^2$ (0.973)	$Z= -0.074+0.042Y$ (0.993)
T_7-Gn+Pp (4:2)intercropping	$Y= -0.513+0.136X+0.002X^2$ (0.972)	$Z= -0.018+0.003X+0.0001X^2$ (0.961)	$Z= -0.081+0.041Y$ (0.99)
T_8-Uncultivated fallow	$Y= -0.1+0.14X+0.004X^2$ (0.976)	$Z= -0.018+0.003X+0.0001X^2$ (0.974)	$Z= -0.083+0.042Y$ (0.996)
T_9-Cultivated fallow	$Y= -0.2+0.14X+0.003X^2$ (0.967)	$Z= -0.018+0.003X+0.0001X^2$ (0.693)	$Z= -0.097+0.052Y$ (0.997)

Table 9 Relation between Rainfall (X)mm, Runoff(Y)mm and Soil loss (Z) t/ha in different treatments along with co-efficient of determination (2009-10)

Treatments	Relations		
	Rainfall(X) mm & Runoff(Y)mm (Co.det.)	Rainfall(X)mm & Soil loss(Z) t/ha (Co.det)	Runoff(Y)mm & Soil loss(Z)t/ha (Co.det)
T_1 – Rc Sole	$Y=-1.33+0.384X+0.00004X^2$ (0.982)	$Z= -0.036+0.007X+0.00004X^2$ (0.985)	Z= -0.082+0.031Y(0.979)
T_2- Pp Sole	$Y=-1.35+0.387X+0.00003X^2$ (0.984)	$Z= -0.036+0.007X+0.00004X^2$ (0.987)	Z= -0.082+0.031Y(0.98)
T_3-Gn Sole	$Y=-1.39+0.391X-0.00008X^2$ (0.981)	$Z= -0.037+0.007X+0.00003X^2$ (0.984)	Z= -0.085+0.031Y(0.979)
T_4-Pp & Rc strip cropping	$Y= -1.47+0.392X-0.0002X^2$ (0.973)	$Z= -0.41+0.007X+0.00003X^2$ (0.975)	Z= -0.092+0.031Y(0.979)
T_5- Pp & Gn strip cropping	$Y= -1.53+0.391X-0.0002X^2$ (0.975)	$Z= -0.041+0.007X+0.00003X^2$ (0.978)	Z= -0.075+0.03Y(0.976)
T_6-Rc+Pp (5:2) intercropping	$Y= -1.57+0.394X-0.0004X^2$ (0.974)	$Z= -0.045+0.008X+0.0000001X^2$ (0.907)	Z= -0.041+0.024Y(0.921)
T_7-Gn+Pp (4:2)intercropping	$Y= -1.59+0.388X-0.0004X^2$ (0.968)	$Z= -0.039+0.007X+0.000002X^2$ (0.900)	Z= -0.046+0.024Y(0.922)
T_8-Uncultivated fallow	$Y= -1.23+0.387X+0.0003X^2$ (0.983)	$Z= -0.042+0.009X+0.00007X^2$ (0.985)	Z= -0.127+0.041Y(0.975)
T_9-Cultivated fallow	$Y= -1.23+0.414X+0.0003X^2$ (0.972)	$Z= -0.054+0.011X+0.00006X^2$ (0.972)	Z= -0.116+0.041Y(0.986)

Conclusion

Thus it can be concluded that intercropping of groundnut with pigeon pea planted along contour may be practiced to increase crop yield and lowering the soil loss and runoff in the hilly tribal areas of Kandhamal district. The relationship among rainfall, runoff and soil loss was found out which can be used to predict the runoff and soil loss from rainfall for same type of soil condition and slope.

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EFFICACY OF BIO-ENGINEERING MEASURES FOR MANAGEMENT OF RED LATERITIC SOIL IN SLOPING LAND OF EASTERN *GHAT* REGION OF ODISHA

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Abstract

Eastern Ghats region of Odisha endowed with natural resources is highly fragile and vulnerable to varying degree of land degradation due to undulating topography, steep slopes, heavy runoff and high soil erosion. As a result, the soil health and productivity is deteriorating continuously leading to unsustainable agriculture in the region. To combat the problem of soil erosion and land degradation, an on farm experiment conducted during 2009-2015 in the research farm of ICAR-Indian Institute of Soil and Water Conservation, Koraput for evaluating the efficacy of bio-engineering measures for managing the red lateritic soil in sloping land of eastern ghat region of Odisha. Under the study, five different bio-engineering measures viz., stone bund + broom grass, stone bund, earthen bund + broom grass, earthen bund and broom grass along with control (farmers' practice) have been taken on 4% and 8% slope with cultivation of predominant crop Ragi of the region. From the study, results revealed that, earthen bunding combined with broom grass produced minimum runoff of 11.6 % followed by earthen bunding alone (12.3%) under 4 % slope with similar trend as well from the plots under 8 % slopes. Remaining treatments also effectively reduced the runoff in comparison to control. Unlike runoff, minimum soil loss of 8.8 t ha^{-1} resulted from stone bunding combined with broom grass followed by stone bunding alone (8.9 t ha^{-1}). Earthen bunding + broom grass and earthen bund alone produced slightly more soil loss than the stone bunding during initial years resulting from the soil disturbance because of bund making and planting of broom garss. Ragi yield was influenced by bio-engineering conservation measures with maximum yield of 14.5 q ha^{-1} followed by 14.0 q ha^{-1} and 13.5 q ha^{-1} from stone bunding with broom grass, stone bunding and earthen bund + broom grass, respectively at 4% slope and minimum yield of 9.6 q ha^{-1} from the control plot with similar trend under 8% slope. However, maximum average water-use efficiency (WUE) of 2.1 kg/ha-mm was obtained from earthen bund + broom grass followed by stone bund (1.9 kg/ha-mm) and stone bund + broom grass (1.8 kg/ha-mm) from both the slopes. Therefore, considering all the aspects of conservation as well as yield and water use efficiency, either type of bunding supported with broom grass may be adopted for the management of red lateritic soil in sloping land of Eastern Ghat region of Odisha for sustainable agriculture.

Introduction

Production with conservation is the vital of all the resource conservation and management. The stress on resource conservation had been necessitated due to the uncontrolled and unlimited exploitation of natural resources like soil, water and vegetation with

the sole aim of continuing the production. As far as crop production is concerned conservation of soil and water assumes paramount importance since without these resources, the production process itself is not possible. Conservation means not only the physical protection but the quality or health of these resources also, the latter being the crucial concern today. There is a tremendous pressure on hilly sloping upland in Eastern Ghat of Odisha for food production due to high population growth and limited scope in expansion of agriculture in low lands. Rainfed uplands consisting of red soils with medium to high erodibility (Chaudhary *et al.,* 1999) and the slope varies in the range of 2 to 15%. Topographically, the uplands are located just downside the denuded and shifting cultivation ravaged hillocks. Due to high and intense rainfall (about 1,500 mm $year^{-1}$) and no or very sparse vegetation, a large amount of runoff generated, which severely erode the downside cultivated lands (silt production rate 2.07– 8.96 ha-m per 100 sq km), and thus, jeopardizing the sustainability of crop productivity and ecological balance (Sudhishri *et al.,* 2003). It results lowering in crop production/yield periodically due to high runoff and continuous loss of top fertile soil leading to worst consequences. The productivity of these crops is less than 1 Mg ha^{-1} (Dass *et al.,* 2009) due to land degradation and low soil fertility resulting from the heavy water erosion and meager input use.

Hence there is an immediate need of implementing of soil and water conservation measures, which can bring sustainability in agriculture on sloping uplands. The practice of stone bunding is considered to be immediate answer to the increasing erosion induced degradation problems in hill tops slopes of Eastern Ghats region of Odisha (Sudhishri et al., 2006). The effects of various vegetative barriers on in-situ soil moisture conservation and in increasing crop yield were reported by several authors (Mishra *et al.,* 1999; Chunale and Patil, 2002; Prasad *et al.,* 2005; Tiwari and Kurothe, 2006). Implementation contour staggered trenches achieved in higher soil moisture in newly tea plantation area under hill slopes over farmers' practice of plantation without any conservation measures (Sahoo *et al.,* 2016). Contour bund with live bund of *Leucaena lucocephala* achieved the highest grain yield of pearl millet crop (Bhanavase and Bangar, 2002). Sahoo *et al.* (2016) reported higher green tea yield from all bio-engineering conservation measures taken under new tea plantation were recorded over control. Patil *et al.* (2002) stated that the contour ridge with vetiver (khus) recorded higher yield of 17.2 q ha^{-1}. However, the information on the effect of resource conservation measures in managing red lateritic soil in the Eastern *Ghat* region of Odishis very much limited. With this reference, an attempt was made to study the efficacy of different resource conservation measures for sensitizing the farmers and other stake holders about the cultivation with resource conservation on sloping lands in a sustainable manner red lateritic soil in the Eastern *Ghat* region of Odisha.

Materials and Methods

Study Area

On farm experiment conducted during 2009-2015 in the research farm of ICAR-Indian Institute of Soil and Water Conservation, Koraput for evaluating the performance of different bio-engineering measures on resource conservation. The site represents the most common 4-8 % sloppy area in the Eastern Ghat region of Odisha used for growing rainfed crops like Ragi, Niger and Upland paddy by the tribals without any protection measures for runoff and erosion control. The soil represents to red lateritic *Udic Paleustalfs* with sandy loam texture (sand 64.5 %, silt

19.3% and clay 16.2 %). The surface soil had organic carbon content of 0.38 % with available N, P, K of 186.5 kg ha^{-1}, 6.0 kg ha^{-1} and 294.6 kg ha^{-1} respectively.

Experimental details

The experiment was laid out on plot size of 800 m^2 with two stone/earthen bunds and/or vegetative barrier of broom grass in each plot dividing the total plot into three compartments and with time replications on two slopes (4 and 8%) to accommodate five soil and water conservation measures and one farmers' practice of cultivation (Table 1). The broom grass was planted in double row, staggered at row to row and plant to plant spacing of 50 cm and 20 cm respectively. A prevalent *Ragi* variety of '*Bhairbhi*' was sown at spacing of 15 cm x 10 cm with recommended seed rate of 10 kg ha^{-1}. Pre-emergence herbicide was applied in all the treatments two days after sowing to control weeds. The basal dose of nitrogen, phosphorus and potassium were applied in the form of DAP and MOP @ 220 and 110 kg ha^{-1}, respectively. Manual hand weeding was done and split dose of nitrogen was applied at one month after sowing.

Table 1. Treatment details

Treatments	Specification
T1: Stone bund + broom Grass	Graded bund (cross section- 0.56 m^2 and slope -0.6%)
T2: Stone bund	Graded bund (cross section-0.56 m^2 and slope - 0.6%)
T3: Earthen bund + broom grass	Graded bund (cross section-0.4 m^2 and slope - 0.6%)
T4: Earthen bund	Graded bund (cross section-0.4 m^2 and slope - 0.6%)
T5: Broom grass	Double row, staggered (row to row- 50 cm and plant to plant 20 cm)
Control	No conservation measure

Runoff and soil loss monitoring

The gauging device (Stage level recorders) are installed at the down end of the plots for runoff monitoring from the runoff chart. The plots were separated to isolate the runoff from the adjacent plots with earthen bunds along the slope and as per the treatments across the slope. The soil loss was estimated from runoff sample of 500 ml collected from runoff tank after stirring to determine the silt content. Runoff and soil loss analysis on daily basis was made and expressed in mm and t ha^{-1} yr^{-1}, respectively.

Results And Discussion

Runoff and soil loss

The annual runoff for the cropping period (July to November) during 2010-14 was monitored from all the treatments under both the slopes and presented in Table 2. Average minimum runoff of 11.6 % was observed from earthen bunding combined with broom grass followed by earthen bunding alone (12.3%). Remaining treatments were also effectively reduced the runoff as compared to control plot (16.3%). Exactly similar trend in runoff was observed from all the plots under 8% slope with minimum in earthen bunding combined with broom grass (13.7%) and maximum in control (24.5%). Maximum runoff was observed from all the conservation measures under both the slopes during 2010 due to first year of imposition of treatments and a lesser amount of time available for establishment. From the average runoff of entire period, higher runoff percent was observed in treatments under 8 % slope in comparison to the corresponding treatments at 4 % slope due to direct impact of difference in slope. The decreasing trend in runoff over the years in most of the treatments under both the slopes are due to settlement of bunds and establishment of the broom grass where it is combined with bunding. The lowest runoff in earthen bund + broom grass is due to strengthening of bund through better establishment of broom grass resulting from soil deposition against the bund.

Table 2: Annual runoff (%) under different bio-engineering measures

Bio-engineering measures		Year					
		2010	**2011**	**2012**	**2013**	**2014**	**Mean**
Under 4% slope							
T_1	Stone bund + broom grass	21.0	9.2	8.2	10.8	13.2	12.5
T_2	Stone bund	17.0	11.4	9.4	16.8	11.2	13.2
T_3	Earthen bund + broom grass	16.0	10.7	9.7	12.7	8.8	11.6
T_4	Earthen bund	11.9	12.8	10.8	15.8	10.1	12.3
T_5	Broom grass	20.0	13.5	12.5	14.2	15.5	15.1
Control		23.0	23.0	15.9	14.9	17.0	16.3
Under 8% slope							
T_1	Stone bund + broom grass	27.0	11.4	11.4	13.4	13.5	15.3
T_2	Stone bund	21.0	14.5	14.5	20.6	13.7	16.9
T_3	Earthen bund + broom grass	18.0	13.0	12.7	15.3	9.5	13.7
T_4	Earthen bund	14.5	12.0	16.8	18.4	11.6	14.7
T_5	Broom grass	30.0	20.5	20.5	17.3	14.6	20.6
Control		35.0	23.9	21.9	23.5	18.2	24.5

Unlike runoff, average minimum soil loss of 8.8 t ha^{-1} was observed from stone bunding combined with broom grass followed by stone bunding alone (8.9 t ha^{-1}) (Table 3). Remaining treatments were also effectively reduced the runoff as compared to control plot (16.3%). Earthen bunding + broom grass and earthen bund alone produced slightly more than the stone bunding due to excess soil loss during initial years of the experiment resulting from the soil disturbance in imposition of the treatment. Vegetative barrier of broom grass alone is not so much effective either in controlling either runoff or soil loss in both the slopes. Exactly similar trend in soil loss was observed from all the plots under 8 % slope. Maximum soil loss was observed from all the conservation measures under both the slopes during 2010 due during first year for the similar reason explained for runoff. Higher soil loss was observed in treatments under 8 % slope in comparison to the corresponding treatments in 4 % slope, due to higher slope as well as runoff.

Table 3: Annual soil loss (t ha^{-1}) under different bio-engineering measures

bio-engineering		Year					
		2010	**2011**	**2012**	**2013**	**2014**	**Mean**
Under 4% slope							
T_1	Stone bund + broom grass	13.0	9.2	6.9	6.4	8.6	8.8
T_2	Stone bund	8.5	5.9	8.1	12.3	9.5	8.9
T_3	Earthen bund + broom grass	14.0	9.8	7.8	9.9	8.8	10.1
T_4	Earthen bund	13.9	9.6	10.6	12.4	9.2	11.1
T_5	Broom grass	28.0	19.0	17.0	15.7	12.4	18.4
Control		36.0	24.5	18.5	19.0	14.1	22.4
Under 8% slope							
T_1	Stone bund + broom grass	15.0	10.7	7.3	14.0	9.6	11.3
T_2	Stone bund	12.0	8.3	9.7	13.9	11.2	11.0
T_3	Earthen bund + broom grass	18.0	12.6	12.5	11.0	10.8	13.0
T_4	Earthen bund	16.9	11.6	11.4	13.7	11.5	13.0
T_5	Broom grass	35.0	23.9	23.0	18.7	13.2	22.8
Control		46.0	31.4	25.4	23.9	16.3	28.6

Soil and water conservation efficiencies

Highest average water conservation efficiency (38.82 %) from both the slopes of was obtained in earthen bund + broom grass followed by stone bund + broom grass (34.32%) and earthen bund only (33.0%) with minimum in broom grass (13.1%) (Fig.1). However, in case of soil conservation efficiency, highest efficiencies was found in stone bunding with broom grass (58.2 %) followed by stone bunding alone (55.9%) with very close values in earthen bunding + broom grass and earthen bunding.

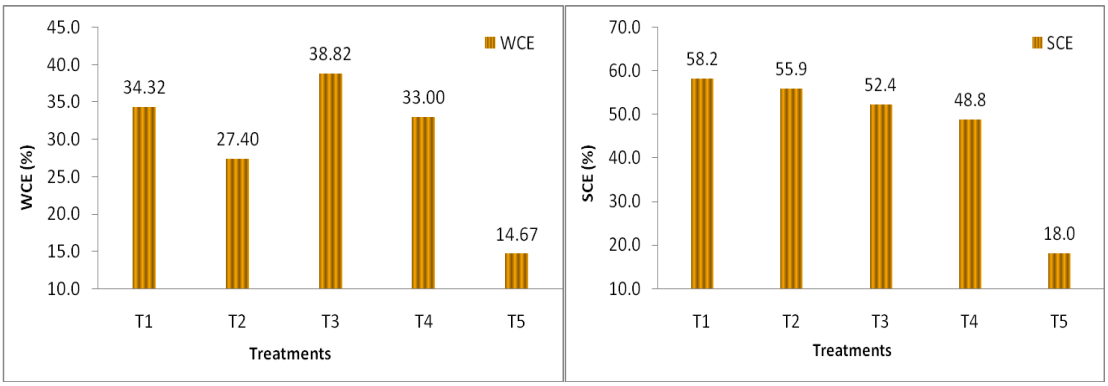


Fig. 1. Water and soil conservation efficiency under different bio-engineering

Crop yield and water use efficiency

Annual *ragi* yield as influenced by different bio-engineering measures during the project period (2010-14). Maximum yield of 14.5 q ha^{-1} followed by 14.0 q ha^{-1} and 13.5 q ha^{-1} were recorded from stone bunding with broom grass, stone bunding and earthen bund + broom grass, respectively at 4 % slope with minimum in control (9.6 q ha^{-1}). Exactly similar trend in yield was also obtained from the treatments under 8 % slope with insignificant variation in either type of bunding alone or in combination of broom grass. But the yield in control plots is minimum in both the slopes and the difference is quite significant from the remaining treatments. However, higher yield was obtained from all the treatments in 4 % slope in comparison to the corresponding treatment in 8% slope during this year as well as in entire period of experiment. The *ragi* yield was found in decreasing trend over the years despite decreasing runoff (%) as well as soil loss in both the slopes. This may be due to the fact that, in the later part of the experiment, irregular rain received just after sowing with heavy rain in the initial period resulted in heavy weed infestation followed by poor growth and yield.

The water use efficiency (Fig.2) was estimated using *ragi* yield from different conservation measures with the net rainwater consumed. The average maximum water-use efficiency (WUE) of 2.1 kg/ha-mm was obtained from earthen bund + broom grass followed by stone bund (1.9 kg/ha-mm) and stone bund + broom grass (1.8 kg/ha-mm). Lowest WUE of 1.2 kg/ha-mm was obtained from the control plot showing the effect of conservation measure either alone or combination in increasing WUE. The decreasing trend in WUE efficiency is resulted directly from the decreasing trend of yield.

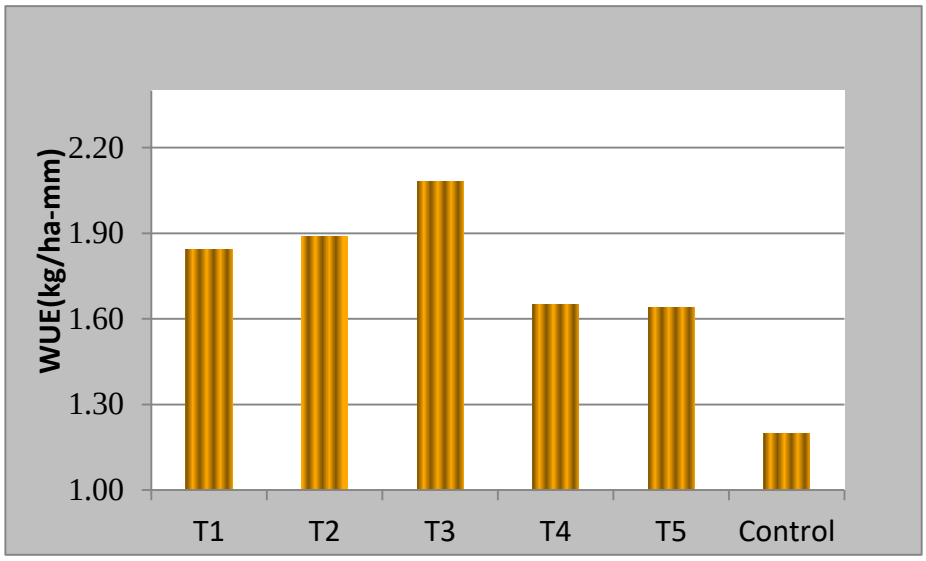


Fig.2. Water use efficiency under different bio-engineering measures

Conclusions

Bio-engineering conservation measures for managing the red lateritic soil in sloping land of Eastern *ghat* region of Odisha are highly effective in controlling runoff and soil erosion. Among different bio-engineering measures, considering water use efficiency, water conservation efficiency and other effectiveness of earthen bunding supported with broom grass is recommended as better soil and water conservation measures. However, the stone bunding with either broom grass or alone is also equally effective considering it's overall performance w.r.t resource conservation and water use efficiency when sufficient stones available in the field or nearby.

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EVALUATION OF DIFFERENT DRAINAGE CONFIGURATIONS ON SOYBEAN CROPS IN VERTISOLS

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Abstract

A field experiment was carried out at BRSM College of Agricultural Engineering and Technology & Research Station, Mungeli, in kharifseasonto study the effect of drainage configurations on performance of soybean crops. The specific objectives was to find out which drainage configurations works the best in reclamation of waterlogged areas in terms of quickly disposing the excess water from the field and lowering the water table. Field drainage channel of three size 20 cm, 30 cm and 40 cm depth with drain spacing of 10 m were laid out for the study. 40 cm drainage depth was found to be more effective in regulation of excess water from the field and lowering the groundwater table than the other two. At 40 cm drainage depth, the grain yield of soybean was maximum (18.66q/ha) with highest water productivity.

Key Words: *Water logging, Vertisols, Drainage depth, Drain spacing, Drainage configurations.*

Introduction

Globally soybean is cultivated over an area of 118.3 million hectares with aproduction of 318.25 million metric tons and having a productivity of 2.69 metric tons ha^{-1} (Anonymous, 2015). In India, during 2000, soybean occupies an area of 6.22 million hectares which is now increased to 10.8 million hectares in 2014 while the production was 7.08 million tons in 2000 and now it has been recorded to 10.43 million tons and the mean National productivity of the crop has decreased from 1138 kg ha^{-1} in 2000 to 959 kg ha^{-1}in 2014 (Anonymous, 2014). The major soybean producing states in India are Madhya Pradesh, Maharashtra, Rajasthan, Andhra Pradesh and Karnataka. In Chhattisgarh, *Kharif* season soybean occupies 147 thousand ha with a yield of 915 kg ha^{-1}(Anonymous, 2014). In Chhattisgarh, major soybean growing districts are Rajnandgaon, Durg, Bemetara, Kabirdham, Mungeli and Bilaspur. In central and eastern part of India there areextensive areas of black clay soils which are notefficiently used for growing *kharif* pulses andoilseeds because these crops are very sensitive towaterlogging at early stages of growth (Tomar*etal.,* 1996). Inequitable distribution of rains andpoor drainage are main causes of low yield of soybean in these areas. The rainfall is highlyvariable both in time and space. There is excessof water during *kharif* season and acute deficiencyduring *rabi* and *summer* season. The excess ofrain water causes water stagnation andwaterlogging in some areas creating unfavorableconditions for *kharif* pulses particularly soybean,pigeon pea and black gram.Waterlogging prevent with combination of surface drainage and raised bed.Surface drains

only remove excess surface water and thereby reduce the time over which the surface soil is inundated. Different drainage spacing and depth are used for removing the excess water. It is reported that10m drain spacing effective inregulation ofexcess water from the field and lowering the groundwater table than the 15 and 20 m (*Panigrah et al, 2007*). Looking to enhance the productivity of soybean in waterlogged situation, the current study planned with objective to study the effect of drainage configurations on performance of soybean crops.The specific objectives was to find out whichdrainage configurations works the best in reclamation ofwaterlogged areas in terms of quickly disposing theexcess water from the field and lowering the water table,

Materials and Methods

Study Area

A field experiment was carried out at BRSM College of Agricultural Engineering and Technology & Research Station, Mungeli, in *kharif*season. The study area is located at 22° 04" N latitude,81° 38" E longitude and at an altitude of 301 m abovethe mean sea level. The soil texture (34.20% clay, 40.60% silt and 25.20% sand) had Field Capacity 42.5 % , organic carbon 0.61%, Available Nitrogen278 Kg/ha, Phosphorus 12.9 Kg/ha and Potassium 421 Kg/ha. The profile was uniform in clay content, although the bulk density increased with depth and ranged from 1.16 to 1.70 Mgm^{-3} from surface to 1.8 m depth. The rainfall is mainly concentrated in four rainy season months from mid-June to mid-October and varies from 692 to 1671 mm per annum with frequent droughts after 2^{nd} or 3^{rd}years.

Layout Of Drainage System

Field drainage channel of three size 20 cm, 30 cm and 40 cm depth with drain spacing of 10m weretaken. The dimensions of each plot were15 m x 10m. Indrain spacing, theexcess water as well as seepage water from each plotwas drained out by the lateral drains, which collectedit and then conveyed to the collector drain. The collector drainswere connected to a main drain that collected the waterand finally disposed from the field. A typical layout plan of the drainagesystem under 10 m spacing showing field, collector,lateral and main drain are shown in Fig. 1a and Fig. 1b. The bottomwidth, top width, depth and side slope of the collector,lateral and main drains in case ofall the three drainage channel depthwere same. The bottom width, top width, andside slope of the lateral drains with 20 cm drainage depth were 20 cm, 60 cm,and 1: I, respectively. The bottom width, top width, and side slope of the lateral drains with 30 cm drainage depth were 20 cm, 80 cm,and 1: 1, respectively.The bottom width, top width, and side slope of the lateral drains with 40 cm drainage depth were 20 cm, 100 cm,and 1: 1, respectively.These values for collectorand main drains with 40 cm drainage depth in sequences were 20 cm, 100 cm, and1: 1, respectively. The total experimental area was 2700 m^2. The area lost due to drainagesystem for 20, 30 and 40 cm drainagedepth with 10 m drain spacing were 1227,1389 and 1561 m^2 per hectare, respectively. The slopeof all the plots and all the drains were 0.5%.

Cropping System

During *kharif*season soybean *(Glycin max*), "JS 335" wassown on raised beds. Recommended dose of fertilizers were given to eachplot. Plant protection measures were taken as and whenrequired.

Water Productivity (Wp)

Water productivity computed as crop yield to the total amount of water used in the fields.

$\boldsymbol{WP} = \frac{\textbf{Grain yield}}{\textbf{Irrigation+Rainfall}}$(g grain kg^{-1} water)

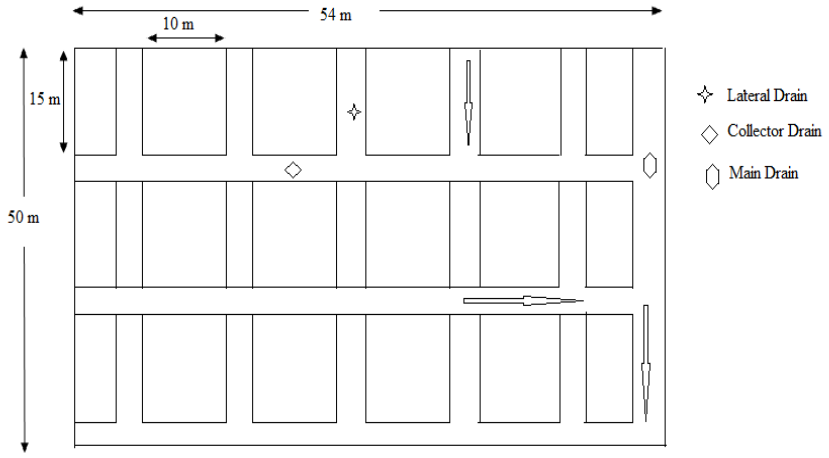


Fig. 1a:Layout of drainage system with 10 m drain spacing

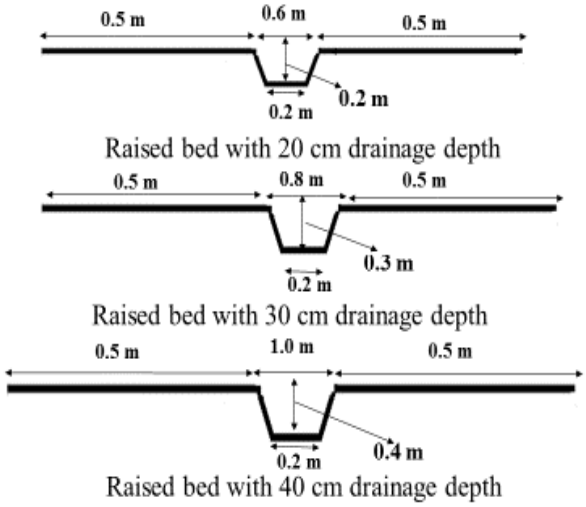


Fig. 1 b: Line diagram of Raised bed

Results and Discussion

Table 1. Yield and water productivity of crop as influenced by different drainage depth

S. No	Drainage depth, cm	Yield q^{-1}ha	Rainfall mm	Water Productivity g grain kg^{-1} water
1	20	13.36	498.7	268
2	30	17.77		329
3	40	18.66		374

The yield ofsoybean in case of 40 cm drainage depth with 10 m drain spacing is observedto be maximum with a value of 18.66 q^{-1}ha, which is higher than the 20 cm and 30 cm drainage depth. Theyield of soybeanmaximum for 40 cmdrainage depth whereas that for 20 cm drainage depth, it isthe lowest (Table 1). The reason for obtaining maximumyield of the soybean crop for 40 cm drainage depth may be dueto quick disposal of excess water from the plots andlowering of groundwater table to the maximum amountthat resultedin easy movement of air in the root zone of the cropsfavoring good growth of the crops. Water productivityobserved maximum for 40 cm drainage depth with 10mdrain spacing. HighestWater productivityis found 374 g grain kg^{-1} water for 40 cm drainage depth that is more than that of other two drainage depth.

Conclusions

The study indicates that irrespective of any drainage depth, soybean cropping system performs better by the surface drainagesystem.Increasing drainage depth of channel, field surface drain is observed to lower thegroundwater table to the maximum amount, quickly dispose of the excess surface water from the fieldand thereby increase the yield and water productivity of soybean crop.

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DESIGN OF SUB SURFACE DRAINAGE SYSTEM IN *VERTISOLS*

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Abstract

Agricultural drainage as a practice to improve the prevailing natural drainage conditions of the land is now about two centuries old. India, maximum area of vertisols is found in Maharashtra (29.9 Mha) followed by Madhya Pradesh (16.7 Mha). In India about 4.528 million hectare (Mha) and 7.006 Mha is having waterlogging and salinity problems respectively. The Bhopal region receives 1070 mm average annual rainfall and huge amount of rainfall (about 343 to 556 mm) may be received from 1 to 5 consecutive days respectively at 10year recurrence interval. High intensity of rainfall combined with poor physical properties of vertisols lead to flooding, surface ponding and / or water logging making them unproductive for crop cultivation during Kharif season. The present study was taken up at Central Institute of Agricultural Engineering (CIAE) farm, to investigate important soil properties and drainage parameters for designing the sub-surface drainage system for vertisols of Bhopal. For designing sub surface drainage system for Vertisols of Bhopal, important soil properties were measured / determined. The sub surface drainage system for soybean crop in vertisols was designed. The bulk density and porosity of top soil (0-30 cm) vary from 1.36 to 1.65 g/cc and 41.0 to 48.7% respectively. The average basic infiltration rate was found to be 10-13 mm/hr. the hydraulic conductivity of soil for the depth ranges of 0-40 cm and 0-150 cm was found to be 22 to 27 cm/day and 1.45 to 2.80 cm/day. The drainage coefficient was obtained to be about 5.30 mm/day. For the designed sub-surface drainage system for soybean crop in vertisols, the sub surface drain spacing was found to be 17.69 m say 20 m at 1.0 m drainage depth. The size of corrugated perforated PVC pipe of 41.88 mm diameter was estimated for effective disposal of drainage discharge.

Key Words: *Drainage, Water logging, Vertisols, Sub surface drainage, Drainage coefficient.*

Introduction

Agricultural drainage as a practice to improve the prevailing natural conditions of the land is now about two centuries old. Some ancient farmers were probably already aware of the benefits of improved drainage. Improved drainage started to attract wider interest and application from the mid of the 18th century as part of the birth of modern agriculture. Agricultural land drainage is both, a preventive and a curative measure for the prevention of physical and chemical of the degradation of soil and for the reclamation of the already degraded lands. Drainage, as a tool to combat waterlogging and salinity,has not been given importance as much as irrigation by the individual farmers as well as the governmental agencies. In only about 2.5 million ha of the affected lands some sort of drainage system has been installed (ICID, 2003). Subsurface

drainage was introduced only recently. Most systems are less than 15 years old andwidespread adoption did not take place (Gupta, 2002). So far subsurface drainage systems have been installed in about 18 000 ha (Nijland et al., 2005). For the prevailing conditions in India, subsurface drainage systems with rather deep drains, i.e. drain depth >1.75 m, are recommended (Gupta, 2002). Pipe drainage in modern times started in the United Kingdom in the 17th century in the form of trenches filled with bushes or stones and was further developed on a large scale in The Netherlands (van de Ven, 2004).Many studies have concluded that drainage design and management practices hold great potential for minimizing unwanted environmental effects associated with subsurface drainage systems (Dinneset al. 2002; Skaggs et al. 2005, 2006; Skaggs 2007; Sands et al. 2008; Thorp et al. 2008). In India about 4.528 million hectare (Mha) and 7.006 Mha is having waterlogging and salinity problems respectively. In order to restore these degraded lands drainage become an essential measure. In India, maximum area of vertisols is found in Maharashtra (29.9 Mha) followed by Madhya Pradesh (16.7 Mha). One of the most important challenges in agricultural water management is the drainage of clay soils. Most land has period during excess water occurs. However, these need not be too harmful provided the quantities are small, the periods of occurrence are of short duration, or the excess occurs during a non-critical part of the growing season. Most land also has some natural drainage, which assists in the removal of a certain amount of the excess water. It is only when large quantities occur for prolonged durations at critical periods that its removal by artificial means may be feasible and desirable. Drainage solutions for heavy clay soils depend essentially upon the rate of precipitation or irrigation, the rate of downward flow through the soil profile and the existence or absence of highly pervious subsoil. The study on sub surface drainage system for enhancing productivity in waterlogged vertisols was taken with objectives to investigate soil physical properties of vertisols and to design sub surface drainage system for vertisols of Bhopal region.

Materials and Methods

Study Area

The study area falls under Agro-Ecological Region VII of India “Semiarid Lava Plateau and Central Highlands” and is bounded by latitude 23^0 18’ to 23^0 20’ N and longitude $77^0$24’ to $77^0$25’ E at an altitude of 490 m (msl). The study was carried out at the Central Institute of Agricultural Engineering, Bhopal.

Measurement of Soil Properties

Bulk Density

To estimate the bulk density of the soil sample, the oven dry weight of a known volume of soil sample is determined and the mass per unit volume is calculated.

Porosity

Soil porosity was estimated by using the following relation:

$$Porosity = \left(1 - \frac{BulkDensity}{ParticledDensity}\right) \times 100$$

Infiltration Characteristics of Soil

To measure infiltration rate of soil, equipment required are two seamless mild steel concentric rings, 20 cm in length with one edge sharp, 30 and 50 cm in diameter for medium and fine textured soil. Stop watch, hammer, 20 litre plastic bottle, 1 m piece of muslin cloth to prevent puddling, triangular piezometer stand with 8 mm glass/capillary tube mounted on a graduated scale. Select a plan level, drive a set of concentric rings in the ground by hammering on the steel plate placed on the rings until 10 cm of each ring goes in the soil. Spread the muslin cloth on the soil surface of the inner ring. Fill the outer ring with water and then add water in the inner ring. Record the level of water in the piezometer tube and continue recording after 1, 3, 5,10,20, 45, 60, 90 and 120 minutes and then after each 30 minutes until the amount of water going into the soil per unit time becomes essentially constant. Refill the rings as soon as water level drops by 2 cm.

$$\text{Infiltration rate} = \left(\frac{R_2 - R_1}{t_2 - t_1} \right) \times F \times 100$$

Where R1 & R2 are piezometer readings at time t1 & t2 respectively, F is piezometer stand factor (F= Hypotenuses/height)

Hydraulic Conductivity

The saturated hydraulic conductivity (K) of soil was measured using Auger Hole method. The value of K can be calculated using following equation (Van Beers, 1976)
For X≥H/2 where H = D-WT

$$K = \frac{4000R^2 \Delta Y}{(H + 20R)\left(2 - \frac{Y}{H}\right)(Y\Delta t)}$$

Where, R is Radius of hole, X is the depth of impermeable layer below the bottom of hole, D is depth of hole below reference level, W is depth of water table in the hole from ground surface, H is depth of hole below water table (static water table), WT is depth of the water table below the measurement unit, Y is depth of water level from static level at any time t after the first reading, ΔY is the rise of water level in the hole over a period of measurement.

Design of Sub Surface Drainage System

The design of drainage structure consists of hydrologic design, and hydraulic design.

Hydrologic Design

The hydrologic design of drainage system include rainfall analysis, peak runoff rate and runoff volume (drainage coefficient) for surface drainage and recharge rate and drainage coefficient for sub surface drainage system. The rainfall distribution pattern, occurrence and its magnitude of the area are of vital importance.

Rainfall Analysis

A design rainfall may be considered as the rainfall of a given duration with a given recurrence interval. A safe excess water removal period may be considered as 2 days. This is based on the assumption that if the excess water is removed from the fields within 2 days, there may not be any irreversible adverse effect on the plant and hence, on the crop yield. Normally sub surface drainage system are designed for life span of 20 years with a designed rainfall of consecutive 2-days.

Drainage Coefficient

There are various approaches used for computing the drainage coefficient for sub surface drainage depending upon the objective and the cost effective scenarios of draining agriculture lands. The prevalent of these approaches are: SCS/USDA approach for irrigated land in arid region, leaching requiring, and average water balance during monsoon period.

$$Dc = \left(P + LR + C\right) \times Di / 100F$$

Where, Dc is drainage coefficient (mm/day), P is deep percolationand the leaching require of the soil expressed as % of the depth of irrigation, C is seepage losses from water courses as % of the depth of irrigation, LR is leaching requirement in % of irrigation water, Di is depth of irrigation water in an application, mm, F is irrigation frequency, days.

Hydraulic Design Of Sub Surface Drainage

Drain Spacing

The steady state concept of drainage design is based on the criteria that a time constant rate of rainfall is removed equally well at all distances from the drain. The steady state drain spacing formulae are thus based on a state of equilibrium between recharge and discharge and the hydraulic head remains constant. Hooghoudt equation considers steady state flow to vertically walled open drains reaching at impervious layer.

$$R = q = \frac{8K_b Dh + 4K_a h^2}{L^2}$$

Where, R is recharge rate per unit surface area (m/day), q is drain discharge rate per unit surface area(m/day), D is height of the water level in the drains above the impervious floor (m), K_a is hydraulic conductivity of the soil above the drain pipe (m/day), K_b is hydraulic conductivity of the soil below the drain pipe(m/day), h is water table height above at mid points between drain (m) and L is the drain spacing between drains.

Hydraulic Design of Drain Size

The amount of water to be conveyed by a pipe drain follows from the designed drainage coefficient and the area drained by the pipe. The size of subsurface drain pipe is estimated through solution of manning's equation for hydraulic flow for the using following equation

$$d = 51.7\left(DC * A * n\right)^{0.375} * S^{-0.1875}$$

Where, d inside diameter of the drain(mm), DC is drainage coefficient(mm/day), A is cross sectional area (m2), n is theMannings roughness coefficient (= 0.016 for corrugated PVC pipes) and S is hydraulic gradient

Results and Discussion

Soils Physical and Chemical Properties

Important soil physical properties such as soil structure, soil texture, bulk density, porosity, infiltration rate, saturated hydraulic conductivity, water holding capacity, field capacity, permanent wilting point and chemical properties such as pH and electrical conductivity were already measured by the Institute Scientists of Irrigation & Drainage Engineering Division. The average soil moisture retention at field capacity (0.33 bar and 0.50 bar) and permanent wilting point (15 bar) pressures were found to be 34.44%, 31.47% and 18.17% respectively. The soils of farm are heavy clay soil (vertisols) having low infiltration rate of approximately 12 mm/h. soil of study area is having sub angular blocky structure with predominant montmorillonite clay minerals. The particle size distribution of the soils mainly consist of 2.87-4.21% gravel, 16.70-21.60% sand, 23.2-29.5% silt and 51.4-54.8% clay content. The bulk density of top soil (0-30 cm) varies from 1.36-1.65 g/cc. the field capacity of top soil varies from 31.3% to 33.2%. The top soil porosity varies from 41.0 to 48.7%. The average infiltration rate of the soil varies from 10.0 to 13.0 mm/h. The hydraulic conductivity of soil for the depth ranges of 0-40 cm and 0-150 cm was found to be 22 to 27 cm/day and 1.45 to 2.80 cm/day. The soil pH varies from 7.4 to 8.1 and saturated electrical conductivity (EC) varies from 0.17 to 0.28 dS/m.

Rainfall Analysis

Huge amount of rainfall (about 343 to 556 mm) may be received from 1 to 5 consecutive days respectively at 10-year recurrence interval. This indicates the need of large size surface drains for safe and timely removal of excess water from the field. There is a fair chance to get rainfall during 25^{th} standard week (mid-June) to 37 standard week (mid-September) at 75% probability. Rainfall intensity for peak discharge can be taken as 7.6 and 8.5 cm/h for one hour duration at one and ten year recurrence interval respectively.

Drainage Coefficient

The drainage coefficient was obtained to be about 5.30 mm/day.

Determination Of Sub Surface Drain Spacing

The spacing of subsurface drains were calculated using Hooghoudt's equation and Ellipse's equation. Data on recharge rate and soil physical properties used in equations are recharge rate or drain discharge rate per unit surface area was 0.0053 m/day, hydraulic conductivity of soil above the drain pipe was 0.193 m/day, hydraulic conductivity of the soil below the drain pipe was 0.022 m/day, weighted hydraulic conductivity of root zone depth was 0.108 m/day, water table height above drains at mid-point between drains was 1.0 m, height of the water level in the drains above the impervious floor is 1.5 m, and subsurface drain spacings of 13.5 m and 17.69 m were obtained by using Hooghoudt's equation and Ellipse's equation respectively.

Determination Of Drain Pipe Size

The size of subsurface drain pipe was estimated 41.88 mm of the drain area of 0.3 ha and keeping slope of the drain 0.002 m/m and manning's roughness coefficient 0.0016 for corrugated PVC pipes. In, India, the commercially available corrugated PVC of minimum size (72

mm/ 80mm diameter) is considered for effective disposal of drainage discharge through subsurface drainage system.

Conclusions

The present study revealed that the bulk density and porosity of top soil (0-30 cm) vary from 1.36 to 1.65 g/cc and 41.0 to 48.7% respectively. The average basic infiltration rate was found to be 10-13 mm/hr. The hydraulic conductivity of soil for the depth ranges of 0-40 cm and 0-150 cm was found to be 22 to 27 cm/day and 1.45 to 2.80 cm/day respectively. The average soil moisture retention at field capacity (0.33 bar & 0.50 bar) and permanent wilting point (15 bar) pressures were found to be 34.44%, 31.47% and 18.17% respectively for a soil depth range of 0.0-1.2 m. The drainage coefficient was obtained to be about 5.30 mm/day. For the designed sub-surface drainage system for soybean crop in vertisols, the sub surface drain spacing was found to be 17.69 m say 20 m at 1.0 m drainage depth. The size of corrugated perforated PVC pipe of 41.88 mm diameter was estimated for effective disposal of drainage discharge. In order to save the drains from the chocking by the sediment carried in drainage water, the use of geo-textile envelope/filter material is suggested.

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HYDRO-PHYSICAL CHARACTERISTICS OF THE PADDY CULTIVATED SOILS OF JORHAT DISTRICT, ASSAM

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Abstract

*The study on "Hydro-Physical Characteristics of the Paddy cultivated soils of Jorhat district, Assam" was carried out with the objective to generate information on soil water relationships in soils of Jorhat district under paddy cultivation. Soil samples were collected from Titabor, representing Humid Alluvial Flood Free Zone (HAFFZ), Baghchung, representing Humid Alluvial Flood Prone zone (HAFPZ) and Nimatighat, representing Char areas (CA) of Jorhat district. From each agro-ecological zones representative samples (both disturbed and core) were collected from two (2) locations and in each location from two land situations viz. lowland and medium land and at each land situation from three depths viz. 0-15, 15-30 and 30-45cm. Soil samples are analyzed for determination of Soil Moisture Retention following standard procedures as outlined by Baruah and Barthakur (A Textbook of Soil Analysis). The soil moisture retention was increased as the clay content increased. Sand content of the soils had significant negative correlation with moisture retentions at different suctions viz. 0.3 bar (-0.77**), 0.5 bar (-0.707**), 1 bar (-0.716**), 5 bar (-0.554**) and 15 bar (-0.586**) suctions. The silt content had significant negative correlation (-0.529**) with moisture retention at 15 bar suction while the clay content had significant positive correlation with moisture retention at 0.3 bar (0.722**), 0.5 bar (0.707 **), 1 bar (0.622**), 5 bar (0.582**) and 15 bar (0.771**) suctions, respectively. Available water content of Titabor, Baghchung and Nimatighat are 21.11 and 22.32 per cent, 21.51 and 23.42 per cent and 23.72 and 20.56 per cent for both lowland and medium-land situations, respectively. The Profile Water Storage capacity of HAFFZ for both lowland and medium land situation are 20.11 and 20.66 cm $m^{-0.45}$ respectively. For both the land situations water storage capacity remained almost similar. For CA and HAFPZ the storage capacity ranged from 19.97 to 23.55 cm $m^{-0.45}$. In Pedotransfer Functions the exponent for Ψ-θ relationship decreased and exponent for K-θ increased as the depth increased. The findings of this study leads to the conclusion that the water storage capacity of the paddy soils of Jorhat district was high irrespective of land situations a second crop can be cultivated in these soils without irrigation immediately after harvesting of paddy. The functional relationships of soil water suction (Ψ) and hydraulic conductivity (k) with soil water content (θ) developed for the paddy soils of Jorhat district can be utilized for large can planning of efficient use of available water resources of the area. In this regard, value for exponent of water (θ) for Ψ-θ and K-θ relationship determined in this study for the paddy growing soils of HAFFZ, HAFPZ and CA of Jorhat district may be utilized for undertaking future research for crop efficient use of available water resources.*

Introduction

Knowledge on hydro-physical characteristics of a soil is essential for scheduling agricultural operations and preparation of any management strategy in water conservation, irrigation scheduling, drainage and solute migration, and development of various hydrological

models. Formulation of sound management strategy to improve water use efficiency will require a clear understanding of soil water functional relationships. Study of dynamics of water in unsaturated soil systems requires knowledge of ψ-θ and K-θ relationships in the soils (θ = volumetric water content, ψ = soil water potential, K = water flow rate). Information on this aspect is lacking for the soils of Jorhat district which are under transplanted paddy cultivation. The investigation was undertaken to determine the hydraulic properties of paddy cultivated soils of three agro-ecological zones (AEZ) of Jorhat District, Assam *viz*., Humid alluvial flood free, Humid alluvial flood prone and Char areas to generate information on soil water relationships in soils of Jorhat district under paddy cultivation.

Materials and method

Soil samples were collected from three AEZ *viz*., Humid Alluvial Flood Free Zone (HAFFZ), Titabor, Humid Alluvial Flood Prone zone (HAFPZ), Baghchung and Char areas (CA), Nimatighat of Jorhat district. From each AEZ, samples were collected from two locations and in each location from two land situations *viz*. lowland and medium land and at each land situation from three depths *viz*., 0-15, 15-30 and 30-45cm.

In order to establish relationship between ψ and θ, and between K and θ, a graph between log ψ and log θ/θ_s (where, θ = volumetric moisture content, K = Saturated hydraulic conductivity and θ_s = soil water content at saturation) was plotted for each soil group. For the graph data were best fit statistically to equation given: $\psi/\psi_e = (\theta/\theta_s)^{-b}$, where, ψ_e is air-entry suction, which refers to negative pressure of the soil water when the air at the atmospheric pressure enters the soil with a continuous water phase (Bouwer 1966) and b is a soil parameter. The parameter ψ_e and b were evaluated by measuring slope and intercept of the best fit equation, respectively.In order to establish the relationship of saturated hydraulic conductivity and soil water content following equation was used as given : $K_\theta=K_s(\theta/\theta s)^{2b+3}$. Statistical analyses were carried out for determining simple correlation coefficient and step forwarded multiple regressions between soil physical properties and hydrological properties using SPSS package program version 16.00 and 20.00.

Results and discussion

Soil water characteristics under paddy cultivation

There was a gradual decrease in moisture retention from 0.3 to 15 bar suctions in lowland and medium land paddy soils of all the agro-ecological zones of Jorhat district. In lowland paddy soils of HAFFZ the highest retention of water was observed at 15 – 30 cm depth but in medium land soils the highest water retention was observed at 0 – 15 cm depth. In HAFPZ lowland paddy soils though the highest water retention was found at 0 – 15 cm depth of the soils, the same in medium land situations was observed at 30 – 45 cm depth. The correlation co-efficient calculated between moisture retention at different suctions and sand, silt, clay and OC content of the paddy soils of Jorhat district, revealed that sand content of the soils had significant negative correlation with moisture retentions at different suctions while the silt content of the paddy soils showed significant negative correlation at 15 bar suction. The clay content of the paddy soils had significant positive correlation with moisture retention at all levels of suctions. Gajbhiye (1990) also reported that with increasing silt and clay content either individually or also in combination, there was an increase in water content both at 33 kPa and 1500 kPa tensions.

Step Forward Regression analysis done between moisture retention at different suctions and sand, silt, clay and OC content (%) of the paddy soils revealed that at lower suctions *viz*., 0.3 and 1.0 bars sand content of the paddy soils contributed significantly and negatively 59.3 and 56.3 per cent, respectively to the water retention by the soils. Addition of the parameter clay content increased the contribution significantly to 64.1 and 58.0 per cent under suction 0.3 and 1.0 bar, respectively. However, further addition of OC and silt did not have any further contribution to moisture retention.

Empirical relationships of soil water relation and pedotransfer functions

Field Capacity (FC), Permanent Wilting Point(PWP) and Available Water Content (AWC)

In HAFFZ, the AWC was found to be 21.11 per cent in lowland paddy soils and 22.32 per cent in medium land soils. The surface soils within depth 0 -15 cm had the highest AWC both in lowland and medium land situations. The AWC in lowland and medium land paddy soils of HAFFZ decreased with increase in soil depth. The AWC of HAFPZ was found to be 21.51 and 23.42 per cent, in both lowland and medium land situation, respectively. The AWC of the

Table 1 Step-wise multiple regression equation between moisture retention at different suctions and soil parameters of paddy soils of Jorhat district, Assam

Equation	R^2	Contribution R^2*100
0.3 bar		
Y1 = 47.147 - 0.384 x Sand	0.593*	59.3
Y2 = 37.634 - 0.261 x Sand + 0.118 x Clay	0.641*	64.1
Y3 = 36.969 - 0.254 x Sand + 0.122 x Clay + 0.168 x OC	0.641*	64.1
Y4 = 49.237- 0.376 x Sand - 0.122 x Silt + 0.01 x Clay + 0.168 x OC	0.641*	64.1
0.5 bar		
Y5 = 19.582 + 0.247 x Clay	0.500*	50.0
Y6 = 12.301+ 0.196 x Silt + 0.337 x Clay	0.572*	57.2
Y7 = 12.327 + 0.191 x Silt + 0.336 x Clay + 0.120 x OC	0.572*	57.2
Y8 = 45.954 - 0.336 x Sand -0.144 x Silt + 0.001 x Clay + 0.120 x OC	0.572*	57.2
1.0 bar		
Y9 = 39.003 - 0.344 x Sand	0.563*	56.3
Y10 = 33.590 - 0.274 x Sand + 0.067 x Clay	0.580*	58.0
Y11 = 39.783 - 0.335 x Sand - 0.0798926159 x Silt + 0.456 x OC	0.585*	58.5
Y12 = 39.783 - 0.335 x Sand - 0.079 x Silt + 0 x Clay + 0.456 x OC	0.585*	58.5
5.0 bar		
Y13 = 9.788 + 0.112 x Clay	0.388*	38.8
Y14 = 14.349 - 0.072 x Sand + 0.073 x Clay	0.390*	39.0
Y15 = 13.330 - 0.061 x Sand + 0.080 x Clay + 0.258 x OC	0.395*	39.5
Y16 = 21.423 - 0.142 x Sand - 0.080 x Silt + 0 x Clay + 0.258 x OC	0.395*	39.5
15 bar		
Y17 = 3.347 + 0.136 x Clay	0.594*	59.4
Y18 = 3.185 + 0.004 x Silt + 0.138 x Clay	0.594*	59.4
Y19 = 3.772 - 0.005 x Sand + 0.132 x Clay - 0.038 x OC	0.595*	59.5
Y20 = 17.035 - 0.138 x Sand - 0.132 x Silt + 0.001 x Clay - 0.038 x OC	0.595*	59.5

paddy soils of CA was 23.72 and 20.56 per cent in low and medium land, respectively. In both the land situation the AWC decreases with the increase in depth.

The profile water storage capacity (PWSC) of paddy soils of HAFFZ, HAFPZ and CA ranged from 20.11 to 20.66 cm $m^{-0.45}$, 21.78 to 23.55 cm $m^{-0.45}$and 20.19 to 19.97 cm $m^{-0.45}$ in lowland and medium land soils, respectively. As per classification of status of profile water storage capacity (PWSC) suggested by Rao and Prasadini (1998), the paddy soils of Jorhat district, irrespective of agro-ecological zones could be considered as very high.

Pedotransfer functions

The exponents for θ for soil water suction (ψ) and water content (θ) relationship (ψ – θ) in the lowland paddy soils of HAFFZ ranged from -2.55 to -2.95 while in the medium land soils it ranged from -2.63 to -3.11. The exponent for hydraulic conductivity and water content (k-θ) relationship for lowland paddy soils ranged from 8.10 to 8.90 and in medium land paddy soils it ranged from 8.26 to 9.22. In lowland and medium land paddy soils of HAFPZ of the exponent for ψ-θ functions ranged from -2.40 to -3.86 and -2.07 to -2.99, respectively and the same for k-θ relationships ranged from 9.08 to 9.46 and 8.82 to 9.34 in medium land situation, respectively. In paddy soils of CA the exponent for θ for ψ-θ relationship ranged from -2.67 to -3.08 and -2.60 to -3.15 lowland and medium land paddy soils, respectively. In these soils the exponent for hydraulic conductivity and water content (k-θ) varied from 7.62 to 8.82 in the lowland paddy soils and 8.44 to 9.40 in medium land situations. As the soil depth increased the general trend for exponent for ψ-θ relationship was decreased and the exponent for k-θ was increased in the paddy soils of Jorhat district. In general, exponent of θ for hydraulic conductivity increased with increase in clay content (Singh and Kundu, 2010). The capacity, intensity as well as rate of water availability were thus higher in fine textured paddy soils of HAFPZ and HAFFZ than in coarse textured paddy soils of CA of Jorhat district. In coarse textured soils the water filled pore volume decreased with increase in suction, because the volume of fine pores is not applicable in these soils but in finer textured soil a considerable portion of the pores remain filled with water even at higher suction. But in case of ψ-θ relationship, the exponent for θ decreased as the soil becomes finer in texture. At any given suction, maximum water was retained in fine textured than in coarse soil, which could be attributed to the difference in their clay content (Singh and Kundu, 2010).

Conclusion

The functional relationships of soil water suction (Ψ) and hydraulic conductivity (k) with soil water content (θ) developed for the paddy soils of Jorhat district can be utilized for large can planning of efficient use of available water resources of the area. In view of high profile water storage capacity of the paddy soils of Jorhat district, irrespective of land situations, cultivation of a second crop is possible in these soils by utilizing the residual moisture immediately after harvesting of paddy.

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Table 2 Physico-chemical properties of the rice soils of the of Jorhat district

Location	Depth (cm)	Clay (%)	Texture	AWC (%)	Ψ_e (cm)	b	PWSC (cm $m^{-0.45}$)
Titabor lowland 1	0-15	35	Sandy clay	20.57	12.07	2.56	19.58
	15-30	40	Clay loam	17.74	11.77	2.95	
	30-45	28	Sandy clay loam	21.4	10.56	2.62	
Titabor lowland 2	0-15	35	Clay loam	25.96	13.33	2.55	20.65
	15-30	37	Clay loam	20.11	13.91	2.8	
	30-45	27	Sandy clay loam	21.11	10.29	2.63	
Titabor medium land 1	0-15	34	Clay loam	26.81	13.79	2.63	21.19
	15-30	28	Sandy clay loam	19.06	10.48	2.79	
	30-45	38	Clay loam	24.71	12.15	3.01	
Titabor medium land 2	0-15	38	Clay loam	23.08	12.17	2.89	20.13
	15-30	40	Clay loam	21.38	11.18	3.04	
	30-45	45	Clay loam	18.99	11.27	3.11	
Baghchung lowland 1	0-15	39	Sandy clay	20.32	10.75	3.04	21.47
	15-30	36	Sandy clay	19.47	10.24	3.11	
	30-45	36	Sandy clay	19.91	10.03	3.07	
Baghchung lowland 2	0-15	45	Clay	22.95	11.98	3.23	22.10
	15-30	39	Clay loam	21.52	11.45	3.00	
	30-45	39	Clay loam	20.88	10.77	3.14	
Baghchung medium land 1	0-15	42	Sandy clay	21.60	11.61	2.91	23.23
	15-30	42	Clay	22.59	12.25	3.17	
	30-45	45	Clay	24.77	13.56	2.91	
Baghchung medium land 2	0-15	39	Clay loam	23.93	12.10	2.81	23.97
	15-30	42	Sandy clay	24.44	12.65	3.02	
	30-45	40	Sandy clay	22.67	11.71	3.09	
Nimatighat lowland 1	0-15	30	Clay loam	24.83	13.41	2.33	20.59
	15-30	27	Loam	23.00	12.05	2.46	
	30-45	24	Loam	21.11	11.55	2.31	
Nimatighat lowland 2	0-15	30	Clay loam	23.95	12.12	2.8	19.79
	15-30	28	Sandy clay laom	22.72	12.16	2.84	
	30-45	20	Loam	19.93	10.32	2.91	
Nimatighat medium land 1	0-15	28	Sandy clay loam	21.59	11.38	3.07	19.81
	15-30	24	Loam	19.83	10.22	2.74	
	30-45	15	Sandy loam	18.61	9.19	2.72	
Nimatighat medium land 2	0-15	28	Sandy clay loam	20.24	10.46	2.91	20.13
	15-30	30	Sandy clay loam	19.64	10.29	3.2	
	30-45	30	Sandy clay loam	20.36	10.15	3.13	

EVALUATION OF RAINFALL DISTRIBUTION PATTERN FOR AGRICULTURAL PLANNING IN MUNGELI DISTRICT OF CHHATTISGARH PLAIN

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Abstract

The knowledge of total rainfall and its distribution pattern round the year of a place is very important for better crop planning, determining irrigation and drainage requirement of crops, design and construction of soil and water conservation structures. The amount and distribution of rainfall holds the key of the success for agriculture production. Weekly, monthly and seasonal rainfall data are very useful for planning agricultural operations. In view of this, an attempt has been made to evaluate rainfall distribution patterns i.e. weekly, seasonal and annual rainfall, based on 16 years (2000-2015) data of Mungeli, Chhattisgarh in the year of 2016 at BRSM College of Agricultural Engineering and Technology, Indira Gandhi Krishi Vishva Vidylay, Mungeli, Chhattisgarh. The analysis showed that amongst various weeks of monsoon season, the 29th week received highest rainfall amount equal to 237.00 mm. However, average rainfall as 93.55 mm was found to be highest for 29th week. From the monthly rainfall analysis, it was found that maximum value of average monthly rainfall (333.12mm) and minimum value (1.82 mm) were recorded in the months of July and December, respectively amounting to 29.89 % and 0.16 % of the average annual rainfall with CV of 32.28 % and 22.93 %, respectively. On the basis of crop (Kharif) seasons received the highest rainfall 856.64 mm and contributing 76.86% of the total average annual rainfall. The highest average rainfall equal to 935.57 mm was observed in monsoon season of the region while the lowest of 35.66 mm was in the winter season. A major part of it generally lost through runoff, which can be stored through in-situ or ex-situ water harvesting structures and can be used during kharif/ rabi/ summer season for growing crops. It can also be utilized as life saving irrigation particularly in dry period of one or two weeks in rainy season also adversely affect standing kharif crops. The annual rainfall varies from 692.60 to 1670.90 mm with an average value of 1114.46 mm. The percentage deviation over mean annual rainfall (1114.46 mm) ranged in between (-) 37.85 % and (+) 49.93% at rained region of Mungeli during period under investigation.Hence the valuable information obtained from the analysis of rainfall in present study can be used for crop planning, designing of soil and water conservation structure in the Mungeli region.

Key Words: Rainfall, distribution patterns, agricultural planning , Mungeli

Introduction

India's economic backbone is constituted by agriculture, which is mostly rain-fed in nature. These regions have limited access to irrigation, because of which the agricultural developmental planning in rainfed agro-ecosystem is often complicated by extremely diverse agro-climatic conditions. Continuous augmentation in demand has put severe strains on the limited natural resources there by threatening the ecological balance. This foresees adequate

rainfall analysis for resource management .Water and agriculture sectors are likely to be most sensitive to climate change-induced impacts in India. Due to this variation that is responsible for many hydrological problems, such as floods and droughts. Rainfall analysis has been identified as one of the priority areas for achieving sustainable food security by raising land productivity, reversing land degradation and increasing biodiversity and the quality of the environment. The state of Chhattisgarh is dominated by tribal and backwards. Rice is the main crop of the state. The productivity is very low (1.34 t/ha) as compared to the national average (1.88 t/ha). The state receives fairly high amount of rainfall, 1200 to 1600 mm annually. But the shortage of water at critical growth stages is often experienced due to uneven distribution of rainfall resulting in frequent terminal droughts in wide spread areas leading to large scale migration of farm labours and farmers to other potential areas (Anonymous, 2006). More than 80 % of the average annual rainfall of Mungeli occurs during South West monsoon. Due to uneven distribution of rainfall and absence of suitable in-situ rainwater harvesting practices, the district is affected by water scarcity during rabi and summer seasons every year. However, analysis of rainfall data for computation of expected rainfall for the desired frequency and consequent excess rainfall is required for the safe design of any structure. The rainfall data need to be analyzed in different ways depending on the problem under consideration. While magnitude of rainfall values are of great importance for hydrological design of different soil and water conservation structures viz., contour trenches, contour bunds, spillways of different water harvesting structures and check dams etc., analysis of consecutive days rainfall is more relevant for drainage design of agricultural lands. Moreover, analysis of weekly rainfall data is more useful for planning cropping pattern as well as water management practices than that of monthly, seasonal and annual data. Sharma and Dubey (2013), Dahiya et al. (2013), Shriwastav and Shrivastav (2014) have suggested the use of daily, weekly, monthly, seasonal and annual rainfall distribution for crop planning. Keeping this in view, an effort was made in the present investigation to interpret daily, weekly, monthly, seasonal and annual rainfall of 16 years (2000-2015) data of Mungeli, Chhattisgarh in simple and meaningful form to make it more useful.

Materials and Methods

Mungeli was formed as tahsil in 1860. It is now newly formed district came into being on 1st January, 2012. The district consists of 3 administrative blocks/tehsils namely Mungeli, Patharia and Lormi and total numbers of villages in the district are 711(Fig 1). It is situated between latitudes 21^0 48'35" to 22^0 40'30" and longitudes 81^0 29'45" to 82^0 02' 10". It is bounded by Bilaspur on the north and east, Anuppur and Dhindori district ofMadhya Pradesh on the north, Kabirdham on the west, Bemetara district on the south andBaloda Bazar on the south-east. The area of the district is about 2750.36 km^2. Mungeli has a tropical wet and dry climate, temperatures remain moderate throughout the year, except from March to June, which can be extremely hot. The winter commences from November and last till the end of February. The summer season beings from March and continues till the second week of June. Monsoon season commences from middle of June and remains till the end of the September.

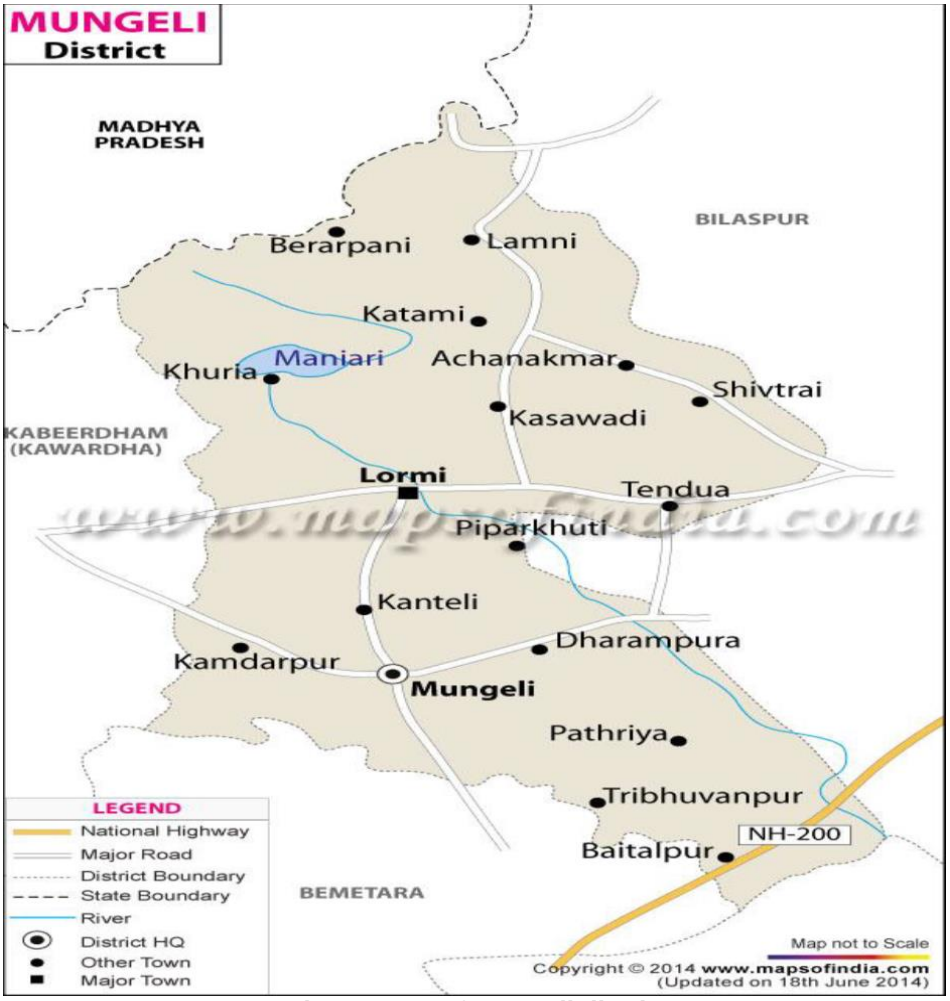


Fig.1: Map of Mungeli district

The daily rainfall data of the study area was collected from Tehsil office Mungeli. This was a 24 hours rainfall data measured with the help of non-recording and recording type rain gauge installed in nearby area. The daily rainfall data pertains to a period of past 16 years, *viz.* 2000 – 2015. Weekly rainfall data, monthly, seasonally and annually were obtained by summing up the daily rainfall values as per recommendation of IMD.

Analysis of Rainfall Data

An analysis of rainfall characteristics involved determination of statistical parameters such as maximum, minimum, mean, standard deviation, coefficient of variation, skewness and percentage deviation of weekly, monthly, seasonal and annual value of rainfall were also computed by using computer programme in MS excel. The maximum and minimum value of

rainfall was determined on accounting the highest and lowest rainfall in the respective week, month, season and year.

Results and Discussion

Analysis of Rainfall Characteristics

The characteristic of the rainfall of the region was evaluated on the basis of quantitative measures such as maximum, minimum, mean, standard deviation, and coefficient of variation, skewness and percentage deviation of weekly, monthly, seasonal and annual value of rainfall. The results of quantitative measures are discussed as under:

1. Weekly rainfall distribution pattern

The analysis of weekly rainfall data of 16 years (2000-2015) reveals that there was marked variation among the rainfall in Standard Meteorological Weeks (SMW) of the different years. SMW 24rd to 39th were found as monsoon weeks in which period greater concentration of higher rainfall was found. It can be clearly observed from the weekly rainfall distribution that 90 % of rainfall occurs during 24rd to 39th SMW. It is clear from the data that the highest average rainfall of 93.55 mm was observed in the 29thSMW which was 10.05 % of the average rainfall of monsoon weeks , while the lowest value 12.54 mm was recorded in 39th SMW shown in Table 1.

Table 1 :Variation of rainfall on weekly basis for year (2000-2015)

SMW	Avg (mm)	Max (mm)	Min (mm)	SD (mm)	CV (%)	Skewness
24	42.02	179.50	0.00	50.16	119.38	1.58
25	48.35	136.70	0.00	42.84	88.60	0.60
26	63.08	171.90	7.20	56.25	89.18	0.84
27	61.03	124.40	4.10	36.67	60.08	0.06
28	63.05	134.30	14.00	36.49	57.87	0.19
29	93.55	235.40	11.40	61.95	66.22	0.67
30	88.86	237.00	3.00	67.20	75.62	0.80
31	51.77	152.00	0.00	50.32	97.20	0.85
32	77.54	167.80	15.40	48.06	61.97	0.71
33	56.50	131.60	15.40	30.79	54.50	0.93
34	64.88	142.00	1.00	41.98	64.71	0.18
35	74.73	282.50	0.00	74.00	99.03	1.68
36	80.25	182.20	0.80	55.71	69.42	0.18
37	39.81	182.40	0.00	44.55	111.91	2.41
38	35.39	165.00	0.00	46.49	131.34	1.73
39	12.54	67.00	0.00	18.34	146.29	2.02

The variation in maximum weekly rainfall is observed in the range of 67 mm to 282.5 mm in 39th and 29th SMW respectively, whereas, minimum rainfall varied between 0.0 mm in 24th, 25th ,31st ,35th ,37th ,38th ,39th SMW and 15.4 mm in 32nd and 33rd SMW (Table 1). The variation in standard deviation (SD) was ranged from 18.34 to 74.00, whereas, coefficient of variation (CV) varied in between 54.50 % and 146.29 %, respectively. Higher value of standard deviation and lower value of coefficient of variation indicates dependability. This also shows the uniform and consistent rainfall pattern during the weeks. Skewness found to be varied in between 0.18 to

2.02. This analysis shows there is wide variations in quantitative measures which indicates that the rainfall received in region are highly erratic.

2. Monthly rainfall distribution pattern*:*

Monthly rainfall analysis (Table 2) clearly depicts this region receives more than 85 percent of annual rainfall during the month of June to October. July is the wettest month with an average of 333.12 mm rainfall and the 2nd highest month is August having an average of 285.11 mm rainfall. It is also very much clear that the chances of heavy rainfall during June to October are assured. It is also found from the analysis of 16 years data that the maximum and minimum value of average monthly rainfall of 333.12 and 1.82mm are found in July and December, respectively amounting to 29.84% and 0.15% of the average annual rainfall with coefficient of variation of 23.72 % and 282.39 %, respectively. High value of standard deviation of 107.53 in the month of July and minimum value of standard deviation of 5.14 in the month of December indicates its dependability. The variation in minimum monthly rainfall was observed in the range of 0.0 to 199.80 mm. Further from the analysis, it is also observed that the value of coefficient of variation, skewness were found to be lowest of 23.72% in the month of August which indicates less variation in rainfall distribution of the region and has a consistent and uniform rainfall pattern. December is the driest month with a average rainfall of 1.82 mm. It is due to receiving of lowest amount of rainfall throughout the year and contributes 0.15 percent to the annual rainfall which is also a negligible amount. It is also having the highest value of coefficient of variation of 282.39 %, which shows the erratic pattern of rainfall of the region presented in Table 2.

3. Seasonally Rainfall distribution pattern

Climatic season

The quantitative measures such as maximum minimum mean standard deviation and coefficient of variation, skewness and percentage deviation of climatic season are presented in Table 2 and Fig 4. It is evident from the analysis (Table 2) that the Mungeli region receives 977.30 mm, 54.96 mm, 35.66 mm and 45.92 mm of average rainfall during the monsoon (June-Sept.), post monsoon (Oct.-Nov.) winter (Dec.-Feb) and summer (Mar.-May) season respectively and contributes 87.6% ,4.7% ,3.49% ,4.14% of the average annual rainfall, respectively.

Table 2 : Monthly, Seasonally and Yearly Rainfall characteristics (2000-2015)

Month	Avg (mm)	Max (mm)	Min (mm)	SD (mm)	CV (%)	Skewness
January	19.63	98.00	0.00	33.45	170.46	1.62
February	14.22	63.30	0.00	21.42	150.66	1.49
March	12.14	47.10	0.00	17.10	140.86	1.16
April	21.49	94.20	0.00	29.33	136.45	1.56
May	12.29	79.70	0.00	21.17	172.33	2.44
June	165.87	300.50	45.00	82.24	49.58	0.07
July	333.12	511.60	140.80	107.53	32.28	0.15
August	285.11	442.80	199.80	67.63	23.72	0.85
September	193.01	387.70	47.00	100.78	52.22	0.30
October	45.39	234.20	0.00	61.85	136.26	2.13
November	10.38	62.60	0.00	18.47	178.04	1.89
December	1.82	18.10	0.00	5.14	282.39	2.81

Climatic season						
Summer	45.92	152.50	0.00	45.04	98.09	1.17
Monsoon	977.30	1440.50	691.40	195.25	19.98	0.48
Post Monsoon	54.96	234.20	0.00	60.90	110.81	1.81
Winter	35.66	120.50	0.00	36.63	102.72	0.93
Cropping season						
Zaid	211.79	426.40	64.40	103.65	48.94	0.28
Kharif	856.64	1267.50	572.20	180.62	21.09	0.46
Rabi	46.04	120.50	0.00	40.77	88.55	0.48
Annual						
Yearly	1114.46	1670.90	692.60	255.51	22.93	0.42

The maximum rainfall for season monsoon, post monsoon, winter and summer are 1440.5, 234.2, 120.5 and 152.5, respectively. The highest average rainfall equal to 935.57 mm was observed in monsoon season of the region while the lowest of 35.66 mm was in the winter season. A major part of it generally lost through runoff, which can be stored through in-situ or ex-situ water harvesting structures and can be used during *kharif/ rabi/ summer* season for growing crops. It can also be utilized as life saving irrigation particularly in dry period of one or two weeks in rainy season also adversely affect standing kharif crops .The coefficient of variation, standard deviation and skewness of the monsoon season were 19.98 %, 195.25, and 0.48 respectively, which indicates its dependability. The lower value of coefficient of variation depicted consistent occurrence of rainfall in monsoon season.

However higher value of coefficient of variation inferred the erratic distribution of rainfall in winter, summer and post monsoon in which agriculture can be practiced by depending on soil residual moisture or irrigation due to uncertainty of rainfall. Summer season or pre monsoon rainfall amounting 45.16 mm would be helpful for summer ploughing.

Cropping season

The rainfall data of cropping season was analyzed and presented in Table 2 which depicts the variations of the quantitative measures (maximum, minimum, mean, standard deviation, and coefficient of variation, skewness and percentage deviation) of the seasons. The average *kharif*(Jul-October), rainfall of 856.64 mm accounts for 76.61 % of annual rainfall with coefficient of variation of 21.09 % and standard deviation of 180.62 mm indicating its dependability. A major part of rainfall in this season generally lost through runoff, which can be stored through *in-situ* or *ex- situ* water harvesting structures and used during kharif/rabi/zaid season for growing crops. It can also be utilized as life saving irrigation particularly in dry period of one or two weeks in rainy season also adversely affect standing kharif crops in the region. The maximum and minimum amounts of rainfall in *kharif* season were 1267.5 mm and 572.20 mm, respectively.

The lower value of coefficient of variation depicted consistent occurrence of rainfall in kharif season. However, higher value of coefficient of variation inferred the erratic distribution of rainfall in *Rabi,* where agriculture can be practiced by depending on soil residual moisture or irrigation due to uncertainty of rainfall.

4. Yearly distribution*:* pattern*:*

The analysis of rainfall data of Mungeli region on annual basis showed a significant variation of average rainfall (Table 2) in the range of 692.60 mm to 1670.90 mm with an average rainfall of 1114.46 mm. It can be observed that the annual rainfall showed high standard

deviation and coefficient of variation The highest average annual rainfall of 1670.90 was observed in the year 2003 , whereas, it was found lowest average annual rainfall of 692.60 in the year 2000. About 56.25 % of the total years received highest rains than that of the average annual rainfall and 43.75% of the total years received lesser rains than that of the average annual rainfall. It is evident from the figure 2 that percentage deviation over mean annual rainfall (1114.46 mm) ranged in between (-) 37.85 % and (+) 49.93% at rained region of Mungeli during period under investigation as shown in Fig 2. Although the annual rainfall over sixteen years (2000-2015) was in no particular trend, however, annual average rainfall of years from 2003 to 2006 showed the decreasing trend while from 2008 to 2013 years of annual average showed the increasing trend.

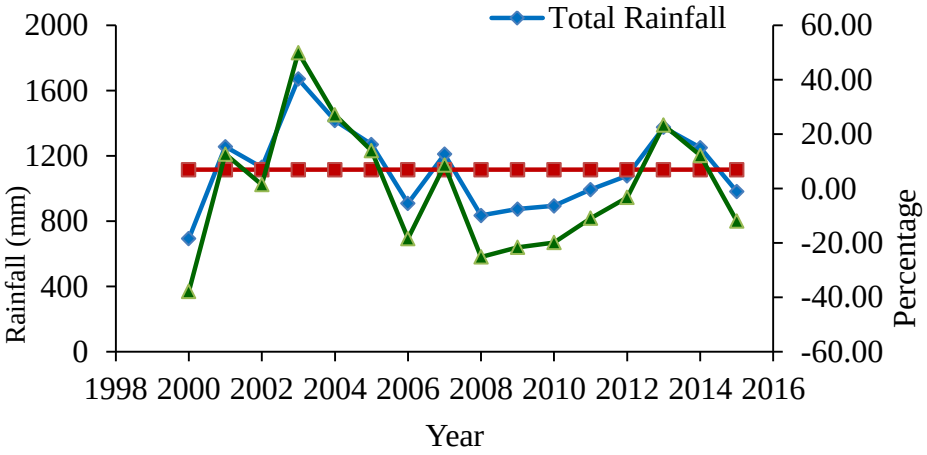


Fig. 2: Years-wise total annual rain distribution and percentage deviation

Conclusions

On the basis of rainfall analysis of rainfall data of Mungeli, it can be concluded that the highest value of average rainfall of 93.55 mm was observed in the 29th SMW which was 9.81 % of the average rainfall of monsoon weeks, while the lowest value (12. 54 mm) was recorded in 39th SMW of monsoon weeks. July is the wettest month with an average rainfall of 333.12 mm followed by August of 285.11mm while December is the driest month with an average rainfall of 1.82 mm. On the basis of crop (*Kharif*) seasons received the highest rainfall 856.64 mm and contributing 76.86% of the total average annual rainfall. The highest average rainfall equal to 935.57 mm was observed in monsoon season of the region while the lowest of 35.66 mm was in the winter season. A major part of it generally lost through runoff, which can be stored through in-situ or ex-situ water harvesting structures and can be used during *kharif/ rabi/ summer* season for growing crops. It can also be utilized as life saving irrigation particularly in dry period of one or two weeks in rainy season also adversely affect standing kharif crops. The annual rainfall varies from 692.60 to 1670.90 mm with an average value of 1114.46 mm. The percentage deviation over mean annual rainfall (1114.46 mm) ranged in between (-) 37.85 % and (+) 49.93% at rained region of Mungeli during period under investigation. Hence the valuable information obtained from the analysis of rainfall in present study can be used for crop planning, designing of soil and water conservation structure in the Mungeli region.

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INTEGRATED ICT- BASED KNOWLEDGE EXTENSION USING SOIL AND WATER INFORMATION FOR CLIMATICALLY VULNERABLE REGION

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Abstract

Agriculture is the major source of employment in India. Climatic Change is impacting the whole world, especially agriculture. Drastic change over a long term is being observed in monsoon (rain) pattern, shift in onset and departure of south west monsoon rains, change in Min. / Max. temperatures etc. These challenges are putting more burdens on the shoulders of farmers. Lack of information about crop rotation, crop planning, how to reduce excess drawing of ground water is adding to the wounds. So it is high time to think and act how to balance the requirement and the adverse effects of climate change. Understanding of the regional soil characteristics by soil testing of constituent components like N,P, K and other micro nutrients, their availability and deficiency in terms of regional rainfall patterns. There is need of scientific alternatives of water and land management techniques and their adaptions to improve crop variety and revised crop cultivation practices as recommended by agriculture institutes. Challenges of literacy of growers and limitation of reach and scalability of current physical extension system shall be overcome by collaboration of agriculture research, computer research and information and communication technology [ICT]. To adapt to the adverse effects of climate change, more focus has to be on scientific technologies of both agriculture like soil, irrigation (water management), nutrients, new crop varieties, and their management practices. This is very crucial to sustain the productivity and to ensure food and environment security to the country. Timely adaptive measures will both help farmers (backed by latest agriculture/climate research and application oriented outputs) as well as the decision makers to enable small and marginal farmers to cope with the ill effects of climate change. mKRISHI® - rural service delivery platform was found very successful in achieving above objectives of climate change adaptation and form a digital knowledge extension tool. This paper talks about the experience of ICT supported process of making farmer aware and educate about latest research in agriculture, establish two way interactive communication channel and access required information at right time. ICT components like audio and images have countered literacy issues and helped expert to view on ground situations for apt diagnosis.

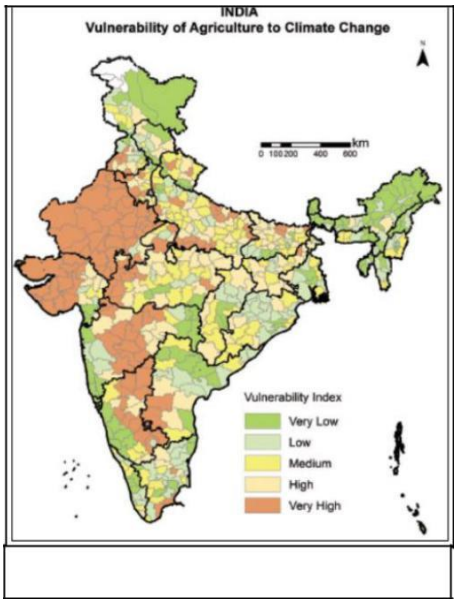
Keywords: *ICT, Knowledge Extension, Soil and Water, Climatically vulnerable regions*

Introduction & Background

India is an agricultural country and agriculture is one of the major contributors to the Indian economy. According to the ministry of agriculture and farmers' welfare more than 58 percent of India's population is dependent on agriculture. About 80 per cent of Indian farmers are small and marginal farmers. These small land holdings are mostly less than 1 hectare. Agriculture is contributing nearly 27% of the total Gross Domestic Product (GDP) and employing nearly two-thirds of the country's population.[9]

Climate change is having economic effects on agriculture, including changes profitability, prices, supply, and demand and agri trade. The magnitude and geographical distribution of such climate-induced changes may affect our ability to expand the food production as required to feed the rapidly increasing population. Climate change could thus have serious impacts on agriculture and food security.

Agriculture is dependent on changes in weather and seasonal changes and long term variations in climate. In this various parameters like soil, seed, pest and diseases, fertilizers and agronomic practices exert significant influence on crop yield. The burgeoning population, along with human-induced climate change and environmental problems is increasingly proving to be a limiting factor for enhancing farm productivity and ensuring food security. Climate change and change in weather pattern is now reached at the alarming stage and raising concern of food security. Climate change affects food security in numerous ways. It is showing impacts on crops, livestock, forestry, fisheries, aquaculture and all other allied sectors According to the Food and agriculture organization(2016) both biophysical and social vulnerabilities determine the impact of climate change on food security. In every Country, agriculture is largely dependent on regional climatic conditions. In India, monsoon winds cause 90% of the rainfall in the country. [10].



Source: CA Rama Rao et al (2013)

Small and marginal farmers have less financial and technological resources. This is the real situation what Indian farmer is facing. However, given that 62% of the cropped area is still heavily dependent on rainfall; [10] Indian agriculture continues to be fundamentally dependent on the weather and regional climatic conditions. For solving above problem ICT can help in providing right information at the right time to the right place. mKRISHI® services is one such ICT platform which enables two way communication between farmer and agri experts.

Methodology

Under the National Agricultural Innovation Program (NAIP) -

Last Mile connect channel in the form of mKRISHI® - A Rural Services Delivery platform was developed and hosted by Tata Consultancy Services (TCS) Innovation Lab – Mumbai. mKRISHI® CCA service were developed and offered in the four climatically sensitive districts in collaboration with Indian Agricultural Research Institute (IARI) New Delhi and Indore, Central Rice Research Institute (CRRI), Cuttack, Odisha University of Agricultural Technology (OUAT) and Central Marine Fisheries Research Institute (CMFRI), Mumbai. These regions were Dhar District of MP, Mewat of Harayana, Raigad of Maharashtra, Ganjam of Odisha.

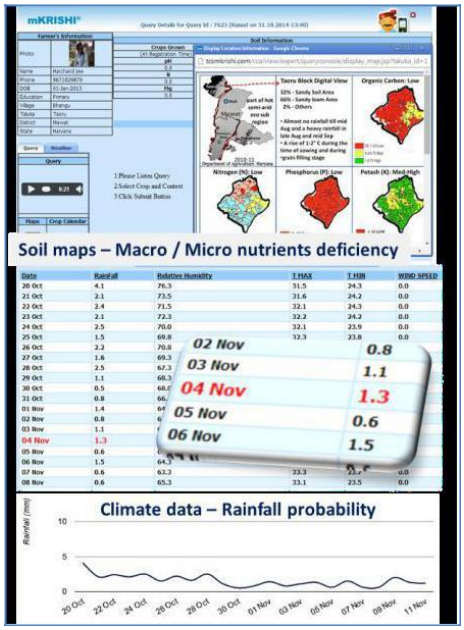
An ICT based two way interactive agro advisory system was tested in the above mentioned region. The platform empowers all the key stakeholders in the Agriculture value-chain starting from farmers, universities, agro input and processing industries, market players, research labs and so on, thereby eliminating the inefficiencies in the system. It provides a local language

mobile app for farmers and integrated web console for agri experts. Farmers can use the simple and easy to use mobile app to asking queries to the expert with the help of captured images and recorded voice files. Agri Experts can view the queries of the farmers in integrated web console with parameters like personal profile, land profile, crop profile etc of the farmer and can advice him in a personalized manner.

Detailed baseline survey was conducted in the pilot regions to understand the ground level difficulties, to collect the present data and current agriculture practices, water/irrigation sources etc. Past soil data for over a decade was incorporated in the web console as an integrated data base and helped agri experts to provide personalized advisory as per the soil characteristics of the region.

Service Features of mKRISHI® CCA

1) Local language based Interface: Application is developed in local language helping farmer to use the application without any hurdle.
2) Weather Report: Farmer use to get daily weather alerts and also alerts about the unseasonal rains which helped them plan their farming activity as per the weather condition and avoid heavy losses.
3) Mandi price alert: Farmer need not go to market to get updates about mandi price as they gets alerts about mandi price in their mobile itself.
4) Advisory system: farmer can ask their query any time using mKRISHI® services and agro experts advise them after analyzing farmer's farm data and weather/climate report of that particular area.
5) Best practices/Photo Gallery: this provides basic guidelines to be followed while farming in the forms of images. Photo Gallery contains photos of known diseases which help farmer to identify pest and diseases and how to manage them.
6) Farm management. This module helps farmer to maintain records of their farm, details like when they sowed their seed, what fertilizers were used, on what date they did irrigation, when they harvested their field, etc.



Mewat and Dhar Soil data analysis:

Samples had low Organic Carbon and phosphorus, lacked recommended levels of micro nutrients like Zinc, Fe (iron) and Mn (Maganese). Based on this study, scientist recommended the list of the suitable crop and the respective crop practices were prepared.

Climatic Study and Recommendations: Local region crops and risks they carried due to the changing climate were studied. New developed varieties and crop practices deployed. Late heat stress is a risk for the productivity of Wheat and Mustard crops in Mewat. Hence, farmers were communicated to use WR544 wheat variety which had terminal heat tolerance and suitable for late sown conditions. This increased yield

by 12 to 18% on the pilot farms. In Dhar, for Gram JG varieties showed 25-50% yield improvement over local variety. So, the integration of all the important parameters like soil maps, soil health report, weather forecasts, etc. helped in great way to incorporate soil and weather parameters to give the advices to the farmers in the context of the local climatic condition.

Challenges

Source	**Challenges**	**Knowledge of Climate change Action**
Peer Farmers/ Retailers	May not be dependable; biased; Motivated to sell particular brand or more margin	Very Less
KVKs / Universities	Far-Off; Accessibility to scientist is difficult	Significant
Extension workers, agents of agro input companies	Limited knowledge, may not be "in-time" and product promotion	Medium/Less.
Radio/TV, Newspapers Helpline	Generic, accuracy is less. Waiting time, Open in Working hours, generic advice	Medium/Less. Medium/Less

Observations & Results

ICT helps experts with integrated view of "other contextual data **(like soil, water, land, weather forecast).** These increases

- **Quality of the advice** – preventive or corrective, for e.g. medicine for a plant disease. Modern techniques of irrigation like drip irrigation etc.
- **Personalization of the advice** – as per symptoms in the query image, and local weather conditions.
- **Speed of the advice** – reuse of the existing knowledge-base and less turnaround time.
- Average query duration was 20 sec. This indicates that the farmers had very specific issues on their mind
- 33% of the queries were related to sowing. Farmers would want to know about the "varieties" suitable for "their farm"
- For the queries about pest/disease, farmers would describe the symptom and ask the remedies.
- Weather forecast was popular mainly to see if it will rain and if yes, then when. During winter, they tracked temperature and cloud coverage to decide on the probable pest attack or irrigation.
- Experts advised to harvest the excess water from the rain in small pits to increase the soil moisture and help other farm activities.

Voice alerts on unseasonal rain and Phailin Cyclone	Close to 3 Lakhs
Weather Forecast hits by farmers	1.5 Lakhs
Local language SMS Alerts	Close to 80 K
Land area covered (Acres)	Close to 35 K
No. of Queries	Close to 25 K
Farmer families covered	Above 12 K
Villages	Above 500
Crops	Above 30

Case Study of Dhar Farmer



Before : Dhannalal Mukati is a Young farmer of thirty five year old belonging to Borud village of Manawar district of Madhya Pradesh. After completing the education he chose agriculture as the full-fledged profession. He is doing the farming from past ten years. Before joining hands with mKRISHI® service, he was facing lots of problems like lack of information about advance agricultural technology, water and land management techniques, daily mandi prices of nearby Mandi, serial attack of insect, pest and diseases etc. He was also very limited with the resources available in his region like water availability etc.

After: After getting enrolled under mKRISHI® services, there was a huge change in the way he did agriculture. He was now getting personalized information at the right time of the agri season. He was provided with all the necessary information like what to sow, when to sow, when to irrigate etc. He also adopted inter- cropping methodology of doing farming, also started doing soil testing of his farms for land management, started using the drip irrigation system for adequate water management etc.

Crops						
	Before use of m KRISHI			**After use of m KRISHI**		
	Production	**Income**	**Market Price**	**Production**	**Income**	**Market Price**
Kharif						
Cotton	22 quintal/ha	Rs 84000	4000/quintal	30 quintal/ha	Rs 138000	Rs 4600/quintal
Rabi						
Wheat	30-35 quintal/ha	Rs 42000-49000	Rs 1400/quintal	35-40 quintal /ha	Rs 45000-60000	Rs 1500/quintal
Vegetable						
Chilli	55 quintal/ha	Rs 220000	4000/quintal	60 quintal/ha	Rs 480000	Rs 8000/ quintal

Conclusion

mKRISHI® has played a major role in availing different information and services as per the need of the farmer. This service proved very useful in providing the information to the farmers at the right time. Farmers were able to plan their activities proactively with the help of mKRISHI® services. Farmers adopted modern agri technologies like drip irrigation to effectively do the water management, soil testing for land management etc. Right information at right time helped farmer to increase their productivity and gains.

Climate change will have far-reaching effects on water management and land management in the domain of agriculture. Even if adaptive capacity is relatively strong the impacts will vary considerably from location to location such as more variable rainfall, lower water availability for irrigation and higher crop water demands. These stresses will be additional to the pressures to produce more food, with less water and less land degradation. So it is very necessary to equip farmers with service like mKRSIHI® which can help in these challenging situation and ensure food security.

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ADOPTION OF AGROMET-ADVISORY SERVICES (AAS) UNDER AICRPAM-NICRA AT MAHASAMUND DISTRICT OF CHHATTISGARH FOR IMPROVING LIVELIHOOD OF RURAL FARMERS

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Abstract

Study was conducted during 2015 at Mahasamund district of Chhattisgarh to quantify economic benefits through adopting the agromet-advisory in their day to day agricultural operations. For this purpose, two groups of farmers were selected namely, a group adopting the agro met advisories regularly in their operation (AAS farmers) and other group of farmers not aware of agromet advisories (Non-AAS farmers). 100 farmers (both AAS and Non AAS) from 2 villages namely Malidih and Jhalkhamaria have been identified and AAS information issued for only 50 farmers in two villages during Kharif season and care was taken to implement the advisories by this group. Crop situation of these farmers was compared with nearby fields having the same crops where forecast is not adopted categorized as non AAS farmers. Further Expenditure incurred by the farmers from land preparation till the harvest at every stage has been worked out and crop growth and yields were monitored regularly in the farmer's field belonging to both the groups. The crop growth and yield was observed to be good and high in case of farmers who have adopted the AAS information regularly compared to the farmers who have not adopted the AAS information. The farmers who have adopted the Agromet-advisories in their day to day operation have realized an additional benefit of Rs. 5809.47.The growers were classified as marginal (up to 1 ha), small (up to 2 ha), medium (2.01-4 ha) and large (above 4 ha) categories. It was observed that cost of cultivation comes down by 6.61 per cent by the farmers who follow AAS. Net cost: benefit ratio of AAS and non AAS farmers was found 1:2.29 and 1:2.04 respectively.

Key words: Economic impact, cost of cultivation, agro-advisory services and yield

Introduction

Agriculture in India is a gambling with monsoon. Under such circumstances, the farmers are unaware of the future behavior of monsoon for making decisions in their day to day agricultural operations. Farming community needs to be advised in time by producing custom-tailored weather forecasts to initiate suitable measures to increase the production and to minimize the impact of unfavourable weather on agriculture. The major objective of AAS is to help the farmers in capitalizing prevailing weather conditions in order to optimize the resource use and to minimize the loss due to harsh / aberrant weather conditions (Venkataraman, 2004). Agromet-advisory services is a vital tool which provides the valuable information about all agricultural operations from land preparation sowing to harvest based on weather forecasting. In this, weather is a key element which controls the success or failure of agricultural crop productivity. The main aim of Agromet-advisory services is to conserve the natural resources effectively and call for minimizing the weather hazards. It is a fact that AAS can be modified or may be the

agricultural operations can be reoriented to the forth coming weeks (3-10 days forecast). Accurate and timely forecast of rainfall patterns and other weather variables continued to be a major challenge for scientific community. The emerging ability to provide timely, skillful weather forecasts offers the potential to reduce human vulnerability to weather vagaries (Hansen, 2002). Therefore, any forecast on weather would have tremendous benefits in terms of management of the negative impacts of vagaries of weather.

Material and Methods

The present study was purposely conducted in Mahasamund block of the same district under AICRPAM-NICRA project. It can be observed from Table 1 that out of 100 farmers were selected for study purpose. Among the selected farmers 50 farmers follow agro advisory services (AAS) and 50 farmers do not follow AAS provided by AICRPAM-NICRA project from two intentionally selected villages namely Malidih and Jhalkhamariya under this project NICRA-AICRP on agrometeorology. Primary data was collected from selected agro-advisory service (AAS) farmers of neighboring villages and non AAS farmers of neighboring villages. Data was collected through personal interview method with the help of pre-tested questionnaires. The growers were classified as marginal (up to 1 ha), small (up to 2 ha), medium (2.01-4 ha) and large (above 4 ha) categories as per criterion followed by Marothia, 1986. The detailed enquiry was done in the *kharif* season of 2015. To estimate the cost of cultivation of selected paddy crop of different categories of farmers, whole data is divided into two major parts, *i.e*., variable cost and fixed cost. Variable cost includes land preparation, cost of seed and sowing, fertilizer and manuring, cost of intercultural operations, irrigation, plant protection materials, harvesting etc. Fixed cost carries rental value of land and interest on working capital. Different cost concept (cost A, cost B and cost C) analysis is made using these data to calculate the cost and returns of AAS and non AAS farmers of paddy crops as per standard procedure laid down by George *et al.*, 1972

2.1 Economic analytical tool

This includes the detailed analysis of costs and returns.

(a)Total input

It includes all the cash and kind expenses as detailed below:

a-1 Wages of hired labour paid in cash or kind.

a-2 Imputed wages for the farmer and his family used in crop and livestock production.

a-3 Value of seed, manure and fertilizers and other cash expenses.

a-4 Repairs to dead stock.

a-5 Depreciation on deadstock and livestocks.

a-6 Interest on fixed and working capital.

a-7 Rent of land whether rented or owned

a-8 Irrigation charges.

(b) Total output

The quantity of product produced for different crops and livestock enterprises was treated as the total output. When the output is multiplied by its price then it is the output value (Banafar and Singh 1998).

(c) Net income

It is the difference between total receipts and total expenses. It includes the pay of the farm manager and interest on capital invested in the business. It will be calculated as:

Net income = Gross income – Total expenses

(d) Input –output ratio

It can be expressed as the ratio of output to input. The ratio is calculated as:

Input-output ratio = O/I

Where, I = Net cost of cultivation and

O = Net return

(e) Cost of production per quintal (Rs.qt.$^{-1}$)

It refers to total input cost (in Rupees) divided by output (in Quintals) (Shrivastava, 1990)**.**

(f) Cost concept

The cost of production of different crop has been presented in terms of cost A, cost A_1, Cost B and cost C. The cost concepts are given below (Niharika, 2012).

Cost A:

- Value of hired human labour (permanent and casual)
- Value of owned bullock labour
- Value of hired bullock labour
- Value of owned machinery
- Hired machinery charges
- Value of fertilizers
- Value of manure (owned and purchased)
- Value of seed (farm produce and purchased)
- Value of insecticide and pesticide
- Irrigation charges (both owned and hired)
- Canal water charges
- Land revenue and other taxes
- Miscellaneous expenses (artisans, ropes and repair to small farm implements).

Cost A_1: Cost A_1 + Rent paid for leased in land.

Cost B: Cost A_1 + Imputed rental value of owned land + interest on fixed capital

Cost C: Cost B + imputed value of family labour.

Results and Discussion

The economic benefit obtained by farmers following the Agro met has been evaluated for *Kharif* seasons for the period 2015. Total cost of cultivation, crop yield and net returns for rice crop grown by the AAS and non AAS farmers during *Kharif* season are presented in Table 1 and 2. The total cost of cultivation was found to be lower in the case of AAS farmers who have effectively adopted the ago-advisory compared to non AAS farmers. From the Table 1 it is observed that the AAS farmers are realized good benefit than non-AAS farmers. Similarly, even here also the yield and other returns were lower in case of non-AAS farmers compared to the AAS farmers. Similar observations were also reported by Singh *et al.* (2004) and Venkataraman

(2004). According to them the need for Agromet advisories and input requirements for Agromet advice on field operations, crop prospects and avoidance of pest and disease under adverse environment condition is essential. The economic benefit of the advisories for different Agromet field units that ranged between Rs. 330/ and 3750/ and 1410 to 1885/ hectare for maize, wheat and rice crop, respectively (Rana *et al.,* 2005). Fifty farmers who are aware of the agro advisory bulletins are utilizing AAB in operational farm management and all farm activities is 76% farmers rated the usefulness of forecast between good to excellent. Similarly, Ravindrababu *et al.*, 2007, reported that the forecasts were found to be encouraging and of benefit to the AAS farmers compared to non AAS farmers sampled It was observed that farmers who follow NICRA- AAS have average saving of 16.82% in manures and fertilizers, about 16.15% in weeding, about 17.43% in plant protection, 23.77% in irrigation and the overall saving during crop growing season is 6.61%. Manures and fertilizers saving could be done by AAS farmers as by following advice, saving in top dressing of urea was there. In plant protection also, a saving of Rs. 630/hectare was made mainly focusing on the cost saving in spraying of herbicides/insecticides. However harvesting, thrashing, winnowing and transportation costs are coming out to be almost same under both the systems. Linear equation has been drawn and it can be observed from the Fig. 1 that cost towards various operations goes on decreasing during later part of the growing season. Major cost of production in rice crop is during initial stages.

Gross returns have been shown; therefore impact of agro-advisory services is clear with gross returns and net returns significantly higher Table 3. One term Cost of production (Rs. /quintal) has been calculated for the main product grain and the production cost comes down with AAS services farmers by Rs. 79.54 per quintal mainly because of better management and efficient practices followed by AAS farmers. Net cost: benefit ratio of AAS and non AAS farmers was found 1:2.29 and 1:2.04 respectively.

Conclusion

The study has revealed that the information gathered through agro-advisory service has been very useful and helpful to the farmers. The farmers have started taking interest in accessing information on the management of crops. The rainfall and crops management have been the major aspects on which farmers interested to get information. Since the initial stage of the programme, sufficient numbers of farmers have been found to be benefitted through the agro-advisory service. Hence, to provide the agro-advisory in a sustainable manner, convergence of such types of programmes with state department are technical help from Indira Gandhi Agricultural University along with KVKs personnel is recommended as it will help uplift livelihoods of the rural people in a rapid way.

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Table No 1: Number of households under different categories of selected villages in Mahasamund district

S.No		AAS Farmers			non-AAS farmers			
	Size Group	Numbers of Farmers		Total	Numbers of Farmers		Total	Grand Total
		M	**J**		**M**	**J**		
1	Marginal	4	5	**9**	10	6	**16**	25
2	Small	6	11	**17**	7	9	**16**	33
3	Medium	7	5	**12**	5	7	**12**	24
4	Large	8	4	**12**	3	3	**6**	18
	Total	25	25	**50**	25	25	**50**	**100**

M= Malidih **J**=Jhalkhamaria

TABLE 2: Average cost of cultivation of paddy in different category of farms (Rs. / ha)

S.No	Particulars	Average cost with-AAS	Average cost with Non –AAS	Average saving with AAS	Percentage saving with AAS*
(A) Variable cost					
1	Field preparation	3019	3019	0	0
2	Manure & fertilizer	4100	4790	690	16.82
3	Sowing	2039.75	2039.75	0	0
4	Transplanting	2798.5	2798.5	0	0
5	Weeding	2413.75	2803.75	390	16.15
6	Plant protection	3613	4243	630	17.43
7	Irrigation	1859	2301	442	23.77
8	Harvesting	1700	1700	0	0
9	Threshing, winnowing & transportation	2571	2571	0	0
	Sub Total	24114	26266	2152	8.92
(B) Fixed cost					
1	Land rent	8500	8500	0	0
2	Interest on working capital	241.14	262.66	21.52	
	Total fixed cost				
(C) A+B					
1	Total cost (A+B)	32855.14	35028.66	2173.52	6.61

*** Percentage was calculated from with AAS data**

TABLE 3: Cost of cultivation, product values and bi-product values

S.No.	Particulars	AAS farmers	Non- AAS farmers	Gross benefits with AAS
1	Input cost (Rs)	32,855.14	35,028.66	2173.52
2	Production (Qt./ha)			
	a.Main product	51.62	48.95	6.25
	b.By-product	64.25	65.62	-1.37
3	Price (Rs)			
	a. Main product	1390	1390	0
	b. By-product	55	55	0
4	Cost of production (Rs/qt)			
	a. Main product	636.48	716.02	79.54
	Return (Rs./ha)			
5	a. .Main product	71751.80	68040.50	3711.30
	b. By-product	3533.75	3609.10	-121
6	Gross return (Rs./ha)	75285.55	71649.60	3635.95
7	Net Return	42430.41	36620.94	5809.47
8	Net cost benefit ratio	1:2.29	1:2.04	

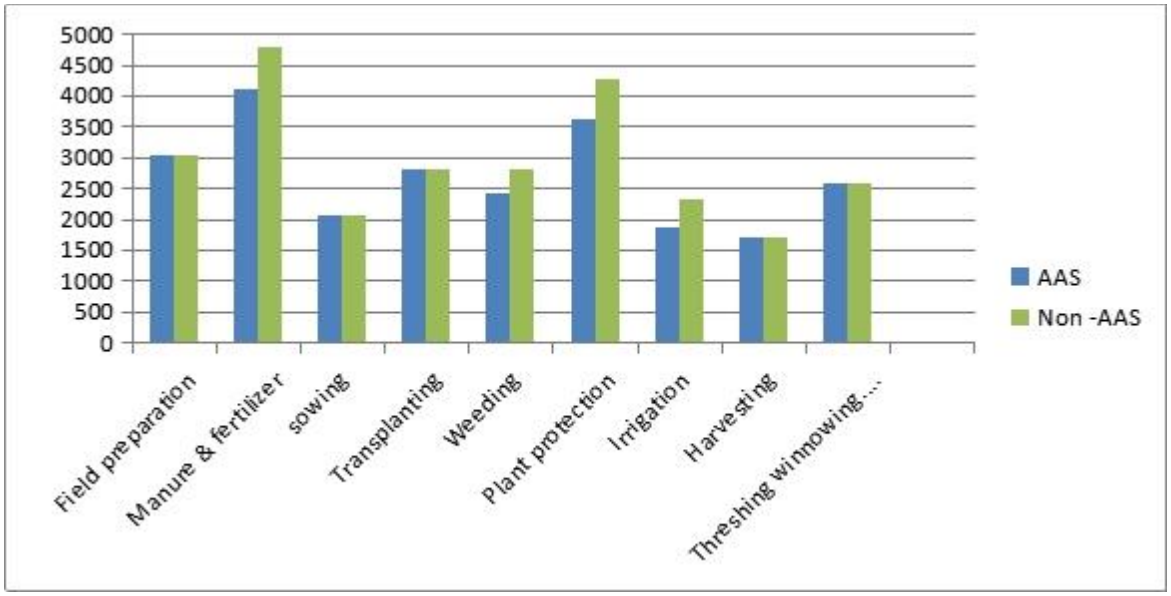


Fig.1: Cost of cultivation with AAS and non-AAS farmers for various cropping operations

METEOROLOGICAL DROUGHT ASSESSMENT IN JAGDALPUR STATION OF CHHATTISGARH STATE

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Abstract

In rainfed rice ecosystem rainfall is one of the most important natural resources which is. available free of cost and plays very vital role for crop planning and can also help to boost rice productivity. The rice cultivation of the eastern India including Chhattisgarh state is mainly dependent on monsoon rain. Even the growing of rabi crops is also subjected either by good rains and their proper distribution. Thirty five year (1980-2014) daily rainfall data recorded at SGCARS, Jagdalpur Chhattisgarh India were taken for study and analysis. This long term data was subjected to various statistical analysis to quantify the amounts of monsoon rainfall received on weekly, monthly, seasonal and yearly basis. The average annual rainfall of Bastar was 1407.5 mm. On the basis of long term drought frequency analysis studies, it has been found that the observed frequency of drought was highest in 39th week to the tune of 18 times while December month is facing the dry spell to the tune of about 32 times. Based on rainfall analysis, it was found that during 35 years there were no severe and extreme drought year was experienced. However, there was 3 moderate drought (1992, 1997 and 2002) and 14 mild drought (1981, 1984, 1989, 1993, 1994, 1995, 1996, 1998, 1999, 2000, 2007, 2009, 20011 and 2013) years were come in notice on that basis we can conclude that there is ample scope to increasing cropping intensity and productivity of rice as well as other kharif and rabi crop by interventions of appropriate agro-technique as per physiography, prevailing agro-climatic condition and socio- economic structure of the zone.

Key words : Meteorological drought, drought year, dry spell, rainfall analysis.

Introduction

Rainfall is the most important natural hydrologic event and is a unique phenomenon varying both in space and time. The monsoon rains are erratic in nature and its distribution is also uneven during season. Its total quantity also fluctuates from year to year and varies from place to place within zone.. India receives adequate amount of rainfall annually through the four seasons *viz*, south–west monsoon (74%), north-east monsoon (3%), pre-monsoon (13%) and post-monsoon (10%) (Dabral *et al.*, 2009). In rainfed farming, the crop planning and its success depend upon the amount and distribution of rainfall. For planning agricultural operations weekly data are more useful than monthly, seasonal and annual rainfall.

Deficiency of rainfall is the basic cause of drought. As such no general method is available which can be applied for the drought prediction (Salas, 1986). Meteorological drought is the condition when a region receives less than half the amount of normal precipitation (IMD, 1971). The meteorological drought analysis is mostly done based on point rainfall data as reported by several researchers earlier. Sharma *et al.* (1979, 1987a and 1987b) analysed the rainfall forcrop planning to overcome drought like scenario. Shrivastava *et al*. (2008) assessed meteorological

droughts in North Lakhimpur district of Assam.

Bastar plateau ACZ lying in Chhattisgarh state is lying between 17°46' N and 20°34'N latitudes and 80°15' E to 82°15' E longitudes. This plateau having geographical area of 39114 sq. meter. Jagdalpur is district HQ of Bastar Plateau zone which is having meager socio-economic structure and life style. The annual avaerage rainfall of Bastar is 1407 mm mostly received during SW monsoon sason. The irrigated area in this zone is 4-5 per cent. The cropping intensity is very low i.e. about 105%. Moreover the production and productivity of crop is very low as compared to national and satte average. The average rainfall qunatity is not a constraint for improving the production level of this region. There is ample scope to increase productivity per unit area and time which needs sound planning and perfect execution. The present study is an effort in this direction. Keeping above facts in mind, an attempt has been made to work out the status of meteorological drought in Bastar plateau.

Materials and Methods

The study place, Jagdalpur is located at $19^0 08^0 16'$ North Latitude and $82^0 02'$ East Longitude with an altitude of 506 m above mean sea level. The average annual rainfall of Jgadalpur is 1407.5 mm. The weekly rainfall from 23^{th} to 39^{th} standard meteorological weeks (that coincides with the monsoon period of this region), monthly rainfall; seasonal rainfall (*i.e.* June to September- monsoon; October to December-post monsoon; winter (January-February) and pre-monsoon (Mar-May) and annual rainfall have been analyzed. The average weekly, monthly, seasonal and yearly rainfall values were worked out. The variation of rainfall for each week, month, season and year from the mean was determined and the mean deviation for the seasons was calculated. Total number of drought weeks, months, seasons and years were determined using the standard procedure (IMD, 1971). Weekly drought: the amount of rainfall is equal to the half of the normal rainfall or less (Ramdas and Mallik, 1948). Monthly drought: the actual rainfall is less than 50% of the average monthly rainfall (Sharma *et al.*, 1979). Seasonal drought: the seasonal rainfall is deficient by more than twice the mean deviation of the season. The yearly intensity of drought was also determined using the criteria suggested by IMD (1971) which is based on the percentage deviation of rainfall from its long term mean and it is given by Equation

$$D_i = \frac{P_i - \mu}{\mu} \times 100$$

Where,

D_i is the percentage deviation from the long-term mean,

P_i is the annual rainfall, mm and

μ is the long term mean of the annual rainfall, mm

Drought codes based on percentage departure of rainfall from normal is presented in table 1.

Results and Discussion

The results of drought analysis on week basis are presented in Table-1. It is the outcome of results that are presented in Table 2. The outcome of results indicates the average rainfall of

different weeks has a variation from 81.01mm in the 31st week to 26.9 mm in the 39th week. The minimum frequency of drought were recorded 6 times in 28th week while the maximum frequency of drought was observed 18 times in 39th week. The weekly variation of rainfall from standard week 23th to 39th week, and the frequency of drought occurred during these weeks is shown in fig. 1. The monthly drought analysis is presented in table 3. The highest rainfall of 383.7 mm was recorded in the month of July and the lowest average rainfall of 8.7mm occurs in the month of April. The highest frequency of drought was observed at a magnitude of 18 times in 35 years in November and lowest 1 times found in month of July and August. Outcome of seasonal rainfall analysis indicates that 10.31% of rainfall was received during winter, 1.47% during summer, 80.02% during southwest monsoon and 8.19% during northeast monsoon. No drought was observed during south-west monsoon period and the frequency of drought was 28, 33 and 24 during winter, summer and post-monsoon season, respectively. The yearly intensity of drought is presented in table 4. The years are codified according to IMD specification as described in the table 1. Further results indicate (Table-4) that there were 3 moderate and 14 mild drought years observed whereas the probability of severe/ extreme drought were negligible.

The annual average annual rainfall of Jagdalpur station was 1407.5 mm with a maximum of 2285.9 mm corresponding to the year 1990 and a minimum of 795.3 mm corresponding to the year 1992. The mean monthly rainfall of the place was 16.5, 197.1, 383.7, 367.0, 233.8 and 53.9.0 mm for the months of May, June, July, August, September and October, respectively. The highest rainfall was received during the month of July (383.7 mm) and the lowest average rainfall was received during the month of April (8.7 mm).

Conclusion

Drought analysis based on 35 years rainfall record showed that 39th week, had maximum frequency of drought, while lowest in 28th week. Month-wise, maximum frequency of drought was observed in the month of December followed by November and January month. When the rainfall records are analysed on seasonal basis, there was no drought during south west monsoon period and the frequency of drought occurrence was 28, 33 and 24 during winter, summer and northeast monsoon season, respectively. On the basis of analysis of 35 years data, we can conclude that there were 3 moderate drought (1992, 1997 and 2002) and 14 mild drought (1981, 1984, 1989, 1993, 1994, 1995, 1996, 1998, 1999, 2000, 2007, 2009, 20011 and 2013) years in the Bastar Plateau zone while there was no severe/extreme drought was realized during this period.

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Table 1 : Drought codification based on percentage departure of rainfall from normal value (IMD,1971).

Percentage departure of rainfall from normal	Intensity of drought	Code
0.0 or above	No drought	M_0
0.0 to - 25.0	Mild drought	M_1
-25.0 to - 50.0	Moderate drought	M_2
-50.0 to - 75.0	Severe drought	M_3
-75.0 or less	Extreme drought	M_4

Table: 2 Weekly drought occurrences.

SWM	Average rainfall(mm)	Half of the average rainfall(MM)	No. of drought week
23 (4^{th} to 10 June)	38.0	18.1	15
24 (11^{th} to 17^{th} June)	60.8	30.4	15
25 (18th to 24th June)	60.8	30.4	11
26 (25th to 1st July)	73.2	36.6	15
27 (2nd to 8th July)	69.8	34.9	10
28(9th to 15th July)	70.5	35.2	6
29(16th to 22nd July)	90.9	45.4	9
30(23rd to 29th July)	84.1	42.0	7
31(30th to 5th August)	84.1	41.1	8
32(6th to12th August)	90.1	45.0	10
33(13th to 19th August)	69.6	34.8	6
34(20th to 26th August)	70.0	35.0	9
35(27th to 2nd September)	75.5	37.8	10
36(3rd to 9th September)	66.2	33.1	7
37(10th to 16th September)	46.1	23.0	8
38(17th to 23rd September)	46.0	23.0	12
39(24th to 30th September)	26.9	13.5	18

Table 3 : Monthly and seasonal drought occurrence.

Month/ season	Name of the month/season	Average rainfall	Half of the average rainfall(mm)	No of drought (month/ season)
	JAN	22.0	11.0	11
	FEB	19.8	9.9	12
	MARCH	17.9	8.9	13
	APRIL	8.7	4.4	13
	MAY	16.5	8.3	11
	JUNE	197.1	98.5	4
Month	JULY	383.7	191.8	1
	AUGUST	367.0	183.5	1
	SEPT.	233.8	116.9	5
	OCT.	53.9	26.9	9
	NOV.	17.0	8.5	18
	DEC.	12.8	6.4	14
Season	Winter:Jan-Feb	145.1	72.6	28
	Summer:Mar-May	20.7	10.4	33
	South west monsoon : June-Sept.	1126.3	563.1	0
	North east monsoon: Oct-Dec	115.4	57.7	24

Table 4 : Drought Categorization on yearly basis.

Year	Mean rainfall(mm)	Normal rainfall(mm)	% Deviation	Category	Intensity of drought
1980	1575.9	1407.51	11.96	Mo	No drought
1981	1306.1	1407.51	-7.20	M1	mild drought
1982	1421.1	1407.51	0.97	Mo	No drought
1983	1506.3	1407.51	7.02	Mo	No drought
1984	1402.4	1407.51	-0.36	M1	mild drought
1985	1610.1	1407.51	14.39	Mo	No drought
1986	1470.2	1407.51	4.45	Mo	No drought
1987	1092.1	1407.51	-22.41	Mo	No drought
1988	1419.1	1407.51	0.82	Mo	No drought
1989	1365.2	1407.51	-3.01	M1	mild drought
1990	2285.9	1407.51	62.41	Mo	No drought
1991	1476.2	1407.51	4.88	Mo	No drought
1992	795.3	1407.51	-43.50	M2	Moderate drought
1993	1290.2	1407.51	-8.33	M1	Mild drought
1994	1274.6	1407.51	-9.44	M1	Mild drought
1995	1371	1407.51	-2.59	M1	Mild drought

1996	1224.3	1407.51	-13.02	M1	Mild drought
1997	994	1407.51	-29.38	M2	Moderate drought
1998	1168.2	1407.51	-17.00	M1	Mild drought
1999	1393.9	1407.51	-0.97	M1	Mild drought
2000	1251.5	1407.51	-11.08	M1	Mild drought
2001	1488.7	1407.51	5.77	Mo	No drought
2002	1032.2	1407.51	-26.66	M2	Moderate drought
2003	1653.3	1407.51	17.46	Mo	No drought
2004	1621.3	1407.51	15.19	Mo	No drought
2005	1472.7	1407.51	4.63	Mo	No drought
2006	1483.1	1407.51	5.37	Mo	No drought
2007	1186.4	1407.51	-15.71	M1	Mild drought
2008	1541	1407.51	9.48	Mo	No drought
2009	1213.6	1407.51	-13.78	M1	Mild drought
2010	2146.4	1407.51	52.50	Mo	No drought
2011	1270.6	1407.51	-9.73	M1	Mild drought
2012	1698.5	1407.51	20.67	Mo	No drought
2013	1324.6	1407.51	-5.89	M1	Mild drought
2014	1436.9	1407.51	2.09	Mo	No drought

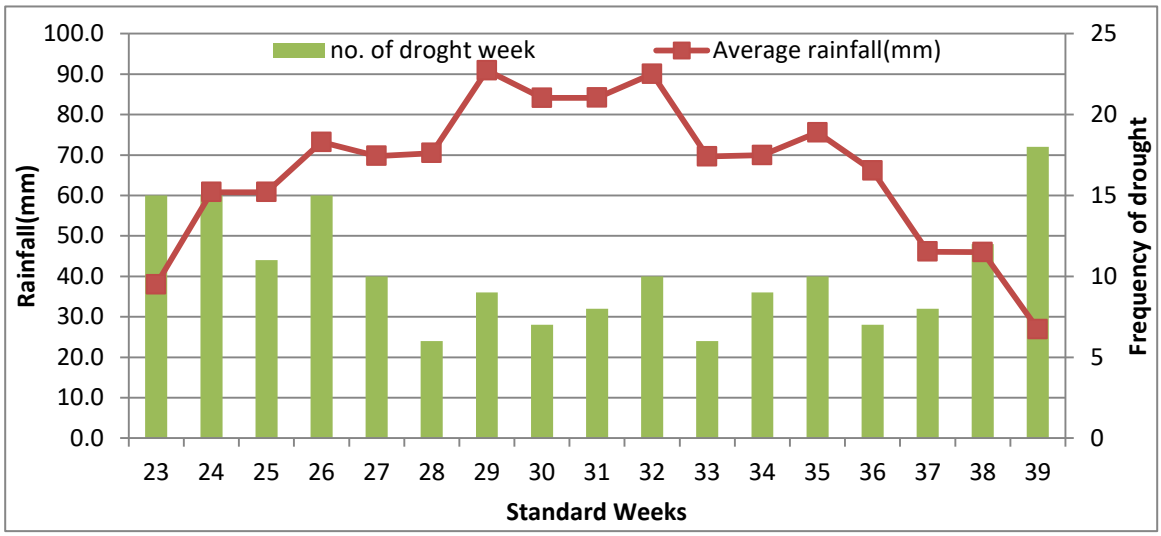


Fig. 1 : Variation in weekly rainfall and frequency of droughtat Jgadalpur station.

CLIMATE RESILIENCE BASED NATURAL RESOURCE CONSERVATION TECHNOLOGY FOR WHEAT IN THE RICE-WHEAT CROPPING PATTERN

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Abstract

The study was conducted in the district Balodabazar-Bhatapara of Chhattisgarh state under Project National initiative on climate resilience agriculture (NICRA) by Krishi Vigyan Kendra, Bhatapara through coordinating institution ICAR-CRIDA Hyderabad. Climate Resilience Based Natural Resource Conservation Technology typically results in increased crop water availability and agro-ecosystem productivity and reduced soil erosion. To evaluate the potential of conservation agriculture to improve soil water balance and agricultural productivity, the In-situ moisture conservation technique of Natural Resource Conservation module under NICRA project was demonstrated and calibrated using the data of a field experiment in NICRA Adopted village Bakulahi, Climatic vulnerability of the village is Draught. The average annual precipitation at the site is 863 mm, 73% of which falls during the growing season. The trial of four year was carried out during Rabi 2012-13, 2013-14, 2014-15, and 2015-16 on forty farmer's field of NICRA Project adopted village Bakulahi of Bhatapara block of the district with size of trial is one acre. The data collected from the field were analyzed and the result of the study in respect of percentage increase in yield in recommended practice increased 13.09% over farmers practice. The average yield in ZTSD method was recorded 27.18 q ha^{-1} over conventional sowing it is 24.06 q ha^{-1}. The B:C ratio was observed higher side in ZTSD is 2.61 as compared to conventional method sowing of wheat is 2.01. The additional wheat production from Zero tillage technology gives about Rs. 6300 Rs. ha^{-1}additional income. The finding have clearly established that wheat sowing can be advanced at least 1-17 days over conventional tillage system, enabling to harvest an advantage that cannot be obtained by using recommended varieties for late sown condition.

Key words: Zero tillage, Resource Conservation Technology, NICRA, Climate Resilience Technology

Introduction

The district Balodabazar-Bhatapara is located at central part of Chhattisgarh under Chhattisgarh plain agro-climatic zone. The annual rainfall of the district is 1100 mm but the study area Bhatapara block of the district in NICRA project Adopted village Bakulahi, Climatic vulnerability of the village is Draught. The average annual precipitation at the site is 863 mm, 73% of which falls during the growing season. The cropping intensity of the district is 130.91% with paddy grown in kharif season and wheat, gram, lathyrus in the Rabi season. However Mono cropping of paddy is the dominating system. Among the double cropping systems-lathyrus is important in the plains under rainfed conditions. The cultivable area of the district under upland is near about 24.22%, 50.83% is on midland and 24.94% under lowland. Swarna and Mahamaya are two very popular varieties of paddy in the district. Both varieties have 135-145 days duration.

In the rainfed system, double cropping is limited because of a lack of residual moisture for the establishment of a second crop after medium to late variety of paddy (Urkurkar and Sharma, 2007).

On-station and on-farm trials with ZT wheat in the rice-wheat systems of the IGP have shown primarily positive impacts on wheat crop management, particularly through reduced input needs combined with potential yield increases (Hobbs and Gupta, 2003b; Laxmi *et al*., 2007; Malik *et al*., 2002a; Malik *et al*., 2005a). Effects on land preparation and crop establishment that CT practices for wheat are very intensive in India's rice—wheat systems. Due to the adoption of ZT technology, the number of field operations for wheat crop establishment (including tillage) decrease from an average of seven to only one (Malik *et al*., 2002a, b). Effects on soils, weeds, pests and diseases in ZT typically improves soil quality in various dimensions, including soil structure, soil fertility and soil biological properties. Rice-wheat systems typically have low soil organic carbon (Duxbury *et al.*, 2000). ZT soils reportedly have higher organic carbon contents than CT soils, but also a lower pH (due to nitrification; Malik *et al.*, 2002a, b). ZT typically reduces the incidence of weeds in the wheat crop (Malik *et al.*, 1998, 2002a, b, 2004)). In fact, ZT reduced the nematodes population and enhanced both the earthworm population and predator diversity and density in wheat (Malik *et al.*, 2002a, b).

Yield, Cost savings and profitability effects

The generally positive yield effects of ZT on wheat are mostly due to: (i) timely sowing; and (ii) increased input-use efficiency and weed control (Mehla *et al.*, 2000). Terminal heat implies that wheat yield potential reduces by 1-1.5% per day if planting occurs after 20 November (Randhaw *et al.*, 1981; Ortiz-Monasterio *et al.*, 1994; Hobbs and Gupta, 2003). Approximately 30% of wheat cultivation is under late sowing in the Indian IGP, and ZT allows for timelier establishment. In direct sowing no planking is done and therefore most of the because of seeds remains exposed in the furrows and because of this energy required for metabolic activities of monocot seeds is less. This leads to early formation of seminal roots in 12-15 DAS. The formation of seminal roots in 12-15 conventional conditions is usually 15 DAS and become dysfunctional 30 DAS and crown root initiation stage is at 21-25 DAS. Therefore seminal roots which enhance crop growth formed 10-12 days before and are functional along with crown roots for another 5-10 days (Singh, *et al.*, 2009). Early growth promotes higher yield in late sown condition also. Two factors contribute to the overall profitability of ZT that the value of the yield increase and the production cost savings, particularly savings in land preparation and crop establishment. Savings in irrigation pumping and inputs may add to this.

Socio-economic and system impactswith Environmental impacts

Socio-economic and system impacts both large and small landholders adopt ZT (Laxmi *et al.*, 2003; Malik *et al.*, 2004). For now though, the technology has spread far more significantly and thereby primarily benefited the better endowed areas. In much the same way, the early adopters of ZT tend to be better endowed (e.g. larger landholdings, better educated; Pandey *et al.*, 2003). Using a conversion factor of 2.6 kg CO_2 emission per liter of diesel (Grace *et al.*, 2003) and a relatively conservative estimate of 35 liters of diesel saved per hectare, we estimate ZT annually saving 91 kg of CO_2 emission per hectare. (Grace *et al.*, 2003) have highlighted that ZT with residue retention and 50% of the recommended application of nitrogen/phosphorus/potassium fertilizer could effectively half the total carbon-equivalent emissions to 14 t $CO_2 ha^{-1}$ per year compared with a high-input CT cropping system with residue burning and organic amendments, due to improved nutrient use and environmental efficiency.

Materials and Methods

The trial was carried out during Rabi 2012-13, 2013-14, 2014-15, and 2015-16 on forty farmer's field of NICRA Project adopted village Bakulahi of Bhatapara block of the district with size of trial is one acre. The machine Zero till seed cum fertilizer drill was provided by Faculty of Agricultural Engineering, IGKV, Raipur (In rabi 2012-13) and CIAE Bhopal (In rabi 2013-14 to 2015-16), under central sector scheme of farm mechanization. The farmers were selected on the basis of their past experience. Before trial training were conducted to farmers about use of Zero till seed cum fertilizer drill machine by the KVK scientists. Yield effects, cost savings and profitability, socio-economic and system impacts, climate resilience environmental impacts and energy use pattern i.e. Energy use efficiency (energy ratio), energy productivity, specific energy (Khan and Singh, 1996), and net energy were calculated, as they are shown in Eqs 1–4 (Singh *et al.* 1997) were study on above trial.

$$\text{Energy efficiency} = \frac{\text{Total energy output (MJ/ha)}}{\text{Total energy intput (MJ/ha)}} \text{------ (1)}$$

$$\text{Energy productivity} = \frac{\text{Grain yield (kg/ha)}}{\text{Total energy intput (MJ/ha)}} \text{------ (2)}$$

$$\text{Specific energy} = \frac{\text{Total energy intput (MJ/ha)}}{\text{Grain yield (kg/ha)}} \text{------ (3)}$$

$$\text{Net energy} = \text{Energy output (MJ/ha)} - \text{Energy input(MJ/ha)} \quad \text{------ (4)}$$

Keeping in the view need, under rainfed farming to increase area under double cropping in the district therefore Krishi Vigyan Kendra Bhatapara has taken following technologies i.e. Promotion of short duration varieties of Paddy, Direct seeded line sowing of paddy and Use of Zero Till Seed cum Fertilizer Drill (ZTSD) for Sowing of Wheat, intervention by front line demonstration.

Results and Discussion

The data collected from the field were analyzed and the results of the study in respect of (i) Percentage increase in yield and (ii) Benefit Cost ratio are summarized below:

(i) Percentage increase in yield: the yield in recommended practice increased 10.62% over farmers practice. The average yield in Zero till seed cum fertilizer drill method was recorded 24.42 q ha^{-1}over conventional sowing it is 22.08 q ha^{-1}. The difference of yield in ZTSD and conventional sowing is justified in table 1.

(ii) Benefit Cost ratio: B:C ratio were also worked out for both farmers practice and demonstration plots from sowing to harvesting as given in table.The B:C ratio as observed from table has been more in ZTSD field as compare to conventional method of sowing of wheat. It is because of reduction in primary tillage operation in ZTSD method as well as due to higher production.

Table 1: Analysis of Zero tillage and conventional method

Treatment	Avg. Yield (q ha^{-1})	Avg. % change in Yield	Parameter* (Avg. No. of Panicle/m^2)	Avg. % change in Parameter	Avg. Cost of cultivation (Rs. ha^{-})	Avg. Gross Cost (Rs. ha^{-})	Avg. Net return (Rs. ha^{-})	Avg. B:C Ratio
T_1	22.08	10.62	243	8.65	15222	30685	15463	2.03
T_2	24.42		264		13298	33918	22195	2.56

T_1: Farmers practice (Conventional system - After harvesting of paddy tillage operation and sowing)

T_2: Recommended practice (Zero tillage system - After harvesting of paddy direct sowing of wheat by ZTSD)

Table 2: Analysis of sowing parameters, time and energy use pattern in wheat production for Zero tillage and conventional method

Parameters	Zero tillage system	Conventional tillage system
Sowing parameters		
a. Bulk density (g cm^{-3})	1.63	1.52
b. Moisture content (%)	16.80	15.20
Time required		
a. Preparatory tillage (h ha^{-1})	Nil	7.25
b. Sowing (h ha^{-1})	2.15	2.05
Diesel consumption(l ha^{-1}), Tillage+Sowing	6.50	28.20
Energy use pattern		
a. Total direct energy used (MJ ha^{-1})	366.02	1587.94
b. Total energy input (MJ ha^{-1})	10131.21	11734.31
c. Total energy output (MJ ha^{-1})	133869.15	137077.45
d. Net energy (MJ ha^{-1})	123737.94	125343.14
e. Energy ratio	13.21	11.68
f. Specific energy (MJ kg^{-1})	4.19	5.31
g. Energy productivity (kg MJ^{-1})	0.24	0.19

Data regarding time requirement under different tillage and seeding systems as well as direct seeding of wheat by zero-till fertilizer seed-drill are given in Table 2. The time requirement (h ha^{-1}) for seed bed preparation and seeding of wheat crop 9.30 and 2.15 under conventional and zero tillage systems, respectively. This clearly indicates that time saving under zero tillage was 76.88 percent over conventional system (Table 2). The fuel consumption for seedbed preparation and seeding of wheat crop under conventional system was 28.20 whereas it was 6.50 l ha^{-1} for zero till fertilizer seed drill system the percentage saving of fuel under zero till fertilizer

seed drill system was 76.95 percent compared to conventional system. This showed that zero tillage system of wheat sowing may be considered as fuel efficient compared to conventional system.



FLD at village Tikuliha, Bhatapara year 2013-14



FLD visit by AICRP Wheat, Scientist,year 2012-13



FLD at village Tikuliha, Bhatapara year 2013-14



FLD Training at village Maldi, Balodabazar, year 2012-13



Zonal Monitoring committee visit of NICRA project, year 2012-13



FLD visit by FAE, IGKV, Scientist, year 2012-13

The total direct energy used for tillage + seeding in both the zero tillage and conventional system were 366.02 and 1587.94 MJ h^{-1}, respectively. The conventional system of seeding (tillage + seeding) required 4.34 times more energy compared to zero till fertilizer seed drill system for sowing of wheat. However on the basis of total energy input for wheat cultivation under conventional method was 1.16 times more compared to improved method of seeding (zero till fertilizer seed drill). Economic analysis shows that zero tillage system resulted higher net benefit compared to conventional system and it is very well reflected through higher benefit cost ratio (2.56) as compared to conventional system. Comparing the energy parameters it was in zero tillage received higher energy ratio (13.21) and lower specific energy (4.19) compared to conventional system. Combining the factors like higher energy ratio, lower specific energy and higher benefit cost ratio, it may be said that the cultivation of wheat under zero till fertilizer seed drill was found better compared to conventional sowing and results proven that, zero tillage is the Climate Resilience Based Natural Resource Conservation Technology for Wheat in the Rice-Wheat Cropping Pattern.

Conclusion

The zero till fertilizer seed drill was found energy efficient and cost efficient compared to conventional sowing of wheat on the basis of energy ratio, specific energy and benefit cost ratio. The use of ZTSD besides being economical, time saving, energy efficient, manages weeds, soil along with its moisture and advances sowing time. Adoption of ZTSD enabled farmers to plant wheat about 10-15 days earlier conventional practice. Early planting resulted in 11% additional grain yield over conventional practice. The additional wheat production from Zero tillage technology gives about Rs. 6732/- per hectare additional income. Short duration varieties of paddy with line sowing and use of Zero Seed cum Fertilizer Seed Drill in seeding of Rabi crops; increase the prospect of double cropping under rainfed condition. The farmers were convinced of the above interventions. In the initial stage ZTSD should be given on custom hire and necessary modification may be carried out to make it a multipurpose ZTSD.

The present study has valued impact based on private gains alone, with environmental and social gains as added non-valued benefit. The challenge for NRM research thereby is to generate technologies that are privately attractive in their own right with environmental gains as added benefit. The present case also highlights the potential of a phased approach, building on the easy wins to subsequently use the momentum to address second-generation problems. ZT primarily has a positive environmental impact (fossil fuel savings, reduced greenhouse gas emissions, water savings) and this would enhance the social returns to the R&D investment. The water savings in the wheat crop are particularly interesting in view of excessive groundwater exploitation in intensive rice-wheat growing areas. Further research to substantiate and value the environmental impacts is needed. There is also significant scope for enhancing the environmental impact of ZT in rice-wheat systems. Two areas that merit particular attention in this respect are crop residue management and shifting towards direct-seeded aerobic rice. Leaving more crop residues as mulch, however, has implications for both ZT drill functioning and potential tradeoffs between residue use for livestock feed and conservation agriculture.

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WATER HARVESTING AND ITS MANAGEMENT THROUGH FARM POND AND UTILIZATION OF CONSERVED WATER FOR VEGETABLE CROPS

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Abstract

A trial was conducted during 20007 to 2009 at All India Coordinated Research Project for Dryland Agriculture Phulbani, Orissa ,India., with an objective to obtain the water loss and economics of the lined ponds .There were three treatments T1-Lined pond with soil cement plaster (6:1) 8cm thickness ,T2-Unlined pond,T-3-No pond.10% of the cropped area was dug for construction of the pond in Lined and Unlined pond treatments. The size of the pond is 7m top widths, 1m-bottom width, 3m heights, and 1:1side slope. The water harvested in pond was reutilized for the pumpkin crop, which was sown only in Lined pond treatment, as there was no water available in unlined pond so the crop was not sown there. The water loss was 17 lit/day/m^2 in lined pond and 831 lit/day m^2 in unlined pond. Provision of dugout pond in 10 % area of the plot at the downstream side with 8 cm thickness soil cement plaster (6:1) gave 41% higher cauliflower equivalent yield compared to no pond. The B:C ratio was found to be 2.25 in lined pond. The payback period for lined pond (soil cement plaster 6:1 of 8 cm thickness) is 5 years and unlined pond was estimated at 2 years.The light textured well-drained upland soils in North Eastern Ghat Zone provide scope for cultivation of vegetables during rainy season. Harvesting of this run-off water in farm pond with proper lining will conserve the run-off water and recycling of this water for life-saving irrigation will protect the crop from drought/dry spell grown in 90% of land area. The ponds will be helpful for sustainability in productivity of dry land crops. Soil structure and organic matter status decide the water holding capacity of the soil. Keeping those points in view, the present experiment involving two water management systems (no pond and pond) has been designed.

Introduction

The light textured well-drained upland soils in North Eastern Ghat Zone provide scope for cultivation of vegetables during rainy season. The intermittent dry spells and terminal drought affect the performance of those high value crops in most of the years. About 25% of the rainfall is lost as run-off. Harvesting of this run-off water in farm pond with proper lining will conserve the run-off water and recycling of this water for life-saving irrigation will protect the crop from drought/dryspell grown in 90% of land area. The ponds will be helpful for sustainability in productivity of dryland crops. Soil structure and organic matter status decide the water holding capacity of the soil. Keeping those points in view, the present experiment involving two water management systems (no pond and pond) has been designed. Ex situ water management is one type of management of land and conservation of rainfall excess which not only helped the havoc at the lower side but also provides lifesaving irrigation for a second crop. Many authors have focused on On Farm Reservoir (OFR) with lined and unlined system for increasing the yield and economic condition of the farmers. Different authors recently studied the effect of lined and

unlined pond in India .Some them are discussed below. Panigrahi and Panda (2003) found the average increase in yield of rice and mustard yield due to supplemental irrigation from the OFR is found to be 29.2% and 22,3% more over the average yield of corresponding crops under rainfed condition The side slope of the harvesting pond was maintained as 1:1..(Panigrahi and Panda,2003). The optimum size of OFR was found to be 12 % of the land area gave benefit cost ratio internal rate of return and payback period of 1.22, 16.1% and 13 years respectively with the cropping system of rice mustard (Panigrahi et. al. 2005)The benefit-cost value of lined and unlined OFRs occupying 10% of the farm area becomes 1.65 and 2.70, respectively (Sethy et.al.,2005). Suraj Bhan (2009), Jindal et. al. (2009), Sharma et.al. (2004) and Kumar et.al.(2006) found that the effect of rain water harvesting and ponds in different parts of the countries were suitable for soil and water conservation and increasing crop yield and economics of the farming communities.

Objectives

1. To quantify the increase in land productivity and land use efficiency through on-farm water harvesting
2. To quantify the water/seepage loss in different ponds

Methodology

10% of the cropped area was dug for construction of the pond in Lined (Fig.2) and Unlined pond treatments. Size of the pond is 7m top widths, 1m-bottom widt, 3m heights, and 1:1side slope. The water harvested in pond was reutilized for the pumpkin crop, which was sown only in Lined pond treatment, as there was no water available in unlined pond so the crop was not sown there.

Treatment details	:	T_1-Lined pond with soil cement plaster in 6:1 ratio (8 cm thickness) T_2- Unlined pond T_3- No pond (control)
Experimental design	:	No design
Plot size (sq.m)	:	
a) Gross plot		30m x 15m
b) Net plot		28.2m x 12.3m
Spacing (cm)	:	Cauliflower-45 cm X 45 cm Radish-45 cm X 5 cm
Seed rate (kg/ha)	:	Cauliflower-350gm/ha Radish-6 kg/ha
Basal manuring (NPK) Top dressing	:	Cauliflower-25: 40:60 kg N-P_2O_5-K_2O /ha 1st top dressing-50kg N /ha 2nd top dressing-50kg N /ha Radish-25: 50:75 kg N-P_2O_5-K_2O /ha 1st top dressing-25kg N /ha

Previous crop and fertilizer applied : As trial was conducted at same place so same fertilizer as mentioned above.

Layout Plan :

N ↑

	T_3
Lined Pond	Unlined Pond
T_1	T_2

Result and Discussion

The mean yield was highest (7.51 t/ha) (Table 1) in lined pond and water loss was lowest (235.8 lit/day)(17.06 lit/day/m^2)(Table 2) in lined pond. The mean *rabi* radish (Fig.1) yield in lined pond was 23.775 t/ha .The mean yield in last three years shows that the yield of vegetables in lined pond is highest (7.51 t/ha) which is 19% higher than the unlined pond due to more number of irrigation was given to unlined pond (6.33t/ha) and 42 % higher than the no pond (5.29 t/ha) as no irrigation was given in no pond. The seepage loss in unlined pond was highest (28.6 m^3/day) (831 lit/day/m^2). The cost of lined pond was Rs 9.967/- and that of unlined pond was Rs 2,993/-.). The water use efficiency was highest in lined pond (8.6 kg/ha/mm).The cost of lining per square meter was Rs 88.5/-. Water loss in lined pond is in increasing trend where as the water loss in unlined pond is decreasing trend may be due to siltation. It is observed that tomato yield was better than the cauliflower yield. The rich farmers or farmers can dug pond can go for this technology as higher cost benefit ratio (2.25) is obtained in lined pond compared to 2.12 in unlined pond and 1.97 in no pond treatment plots. Water balance study for lined pond showed that 21.6% of the total flow into the pond is lost due to over flow, 74.5% due to seepage and evaporation. Only 3.9% of the total inflow was utilized for irrigation to crops. Biometric observation during kharif and rabi are shown in Table 3 & 4 the biometric data shows the lined pond got highest plant height and spread compared to others due to more number of irrigation was applied to them (Table 5).From Table 6 it is observed that the runoff percentage is 15.4 % of rainfall. Only 3.9 % of is used for irrigation purpose.

Table 1 Kharif crop yield during 2007-08 to 2009-10

Treatment	Yield of Kharif produce (t/ha)				Yield of Rabi produce t/ha			
	2007-08 Cauliflower	2008-09 Cauliflower	2009-10 Tomato (C.E.Y.)	Mean C.E.Y	2007-08 Radish	2008-09 Radish	2009-10 Radish	Mean
T_1-Lined pond with soil cement (6:1) plaster 8cm	4.4	4.8	13.32 (5.328)	4.843	22.5	25.5	23.325	23.775

thickness								
T_2-Unlined pond	3.82	3.82	11.35 (4.54)	4.06				
T_3-No pond	3.53	3.02	9.33 (3.732)	3.427				
Mean	3.92	3.88	11.33 (4.533)	4.111				

Table 2 Water loss in different treatments

Treatments	**Total cost of the pond, Rs**	**Cost of lining, Rs**	**Water loss from the pond Lit/day**	**Time taken to dry up the pond, Days**	**Cost of storage, Rs/m^3**	**Economics loss due to seepage loss (Rs/day)**	**Water loss, lit/day/m^2**
1	**2**	**3**	**4**	**5**	**6=(7/4)X1000**	**7=2/5**	**8**
T_1-Lined pond with soil cement (6:1) plaster 8cm thickness	**9,967**	**88.5**	**235.8**	**318**	**133**	**31.34**	**17.06**
T_2-Unlined pond	**2,993**	**0**	**28,600**	**2.62**	**40**	**1142.37**	**831**
T_3-No pond							

Table 3 Biometric observations of Kharif

Treatment No	Plant Height(cm)			Spread(cm)			No of leaves		No of branches
Year	2007	2008	2009	2007	2008	2009	2007	2008	2009
Crop	C.flower	C.flower	Tomato	C.flower	C.flower	Tomato	C.flower	C.flower	Tomato
T1	39	45	110.2	51.6	61.6	71.6	17.6	17.6	6.2
T2	37.5	38.5	95.6	43.8	53.8	68.2	16.4	16.4	5.8
T3	31.2	32.2	94.6	36.8	46.8	66.2	13.2	14.2	5.2

Table 4 Biometric observations of Rabi (radish)

Treatment No	Plant Height(cm)			Spread(cm)			No of leaves		No of branches
Year	2007	2008	2009	2007	2008	2009	2007	2008	2009
T1	20.8	25.8	25.5	44.4	45.4	44.4	20.8	26.8	24.8

Table 5 Number of irrigation applied in different years

Treatment	**Irrigation numbers**			**Quantity of water applied, lit(mm)**		
	2007-08	2008-09	2009-10	2007-08	2008-09	2009-10
T_1-Lined pond with soil cement (6:1) plaster 8cm thickness	18	5	13	600X18=10,800 (24)	600x5=3,000(6.7)	600X13=7,800(17.33)
T_2-Unlined pond	1	1	6	300x1=300(0.7)	300(0.7)	300X6=1,800(4)

Table 6 Water balance in the lined pond during 2009

Item	Quantity, lit	%
Water in the tank on 1.04.2009	Nil	
Water from runoff and rainfall	2,01,753	100
Water loss during 2009-10	1,50,338	74.5
Irrigation	7,800	3.9
Over flow	43,615	21.6
Water on 31.03.2010	Nil	
Rainfdall volume	7,60,140	100
Runoff volume	1,17,293	15.4

Techno economic analysis

Net present worth (NPW)

The net present worth of investment made on lined pond where lined pond was made is Rs 40,487/- , whereas it was Rs 15,279/-for unlined pond and Rs 8,935/- for no pond system against an investment (Total PW Cash inflow) of Rs 72,877;Rs 28,873 and Rs 18,136 respectively. Based on the NPW and BC ratio it was concluded that the lined pond is economical and there is substantial increase in income of farmer by making lined pond and using the water of lined pond for raising a second crop.

Benefit cost ratio (BCR)

The benefit cost ratio for lined pond was 2.25 where as it is 2.12 in case of unlined pond. It indicates that the BCR is high in lined pond in comparison with unlined pond and no pond has lowest BCR ratio (1.97).Hence it is worth constructing the lined pond.

Internal rate of return (IRR)

The interim rate of return is 66% in lined pond. Internal rate of return is more than the present interest rate i.e. 12%.

Payback period

5The table was prepared to calculate the NPP, IRR and payback period. Payback period for both lined and unlined pond were found to be two years.



Fig.1 Rabi crop radish after giving irrigation from pond



Fig 2 Lined pond

Conclusion

1. Provision of dugout pond in 10 % area of the plot at the downstream side with 8 cm thickness soil cement plaster (6:1) gave 41% higher cauliflower equivalent yield compared to no pond. The B:C ratio was found to be 2.25 in lined pond.
2. The payback period for lined pond (soil cement plaster 6:1 of 8 cm thickness) is 5 years and unlined pond was estimated as 2 years.

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Enhancing crop productivity through water harvesting structures - An experience in tribal area of Uttar Bastar Kanker district

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Abstract

Uttar Bastar Kanker is the tribal dominating district, where agriculture is the main occupation of people. Most of the cultivated area of the district i.e. 65% comes under rainfed farming. Irrigation facility is limited, which is 35% &18% in the kharif and rabi season respectively. The total kharif crop area is 2.37 lakh ha. Whereas rabi crop area is 0.53 lakh ha. This is because of lack of irrigation facilities in the district. However average rainfall of the district is 1355 mm, which is optimum but the distribution of rainfall is erratic and some time long dry spell causes drastic yield reduction in rice crop. To overcome this problem harvesting of rainwater is one of the solution for providing life saving irrigation to kharif crops and successding rabi crops. With a view of the above situation KVK Kanker has done water conservation activities under Integrated Watershed Management Programme (IWMP2) and convergence with MGNAREGA in nine villages of kanker block. There were 24 water harvesting structures constructed for harvesting of rainwater i.e. pond, stop dams as a result of which, 195 ha area converted in to double cropping and farmers income increased from Rs. 20000 per ha to Rs. 32000 per ha in the operational area. In spite of this 12 ha wasteland comes under mango plantation.

Keywords: *Farm ponds, productivity, enhance, and double cropping*

Introduction

Climate change poses complex challenges like multiple abiotic stresses on crops and livestock, shortage of water, land degradation and loss of bio-diversity. There has been a significant rise in the frequency of extreme weather events in recent years affecting the productivity and income at the farm level and also impacting the availability of staple food grains at the national level.In India rainfall is uneven, erratic and varies from place to place and from year to year. The country's average annual rainfall is about 119.4 cm with average 130 rainy days in a year. In many parts of the country, ground water development has already reached a critical stage, resulting in acute scarcity of the resource. Over- development of the ground water resources results in declining ground water levels, shortage in water supply, intrusion of saline water in coastal areas and increased pumping lifts necessitating deepening of ground water abstraction structures. These have serious implications on the environment and the socio-economic conditions of the populace. Worsening ground water quality has also adversely affected the availability of fresh ground water in several areas.In rainfed area, agriculture is dependent on rainfall. For sustainable agricultural production in rainfed area, it is necessary to harvest rainwater, which will enhance soil moisture that is vital for the growth of crops. In order to achieve economic up gradation of tribal's in rainfed agricultural system through the adoption of watershed management. The runoff water is harvested in to the farm pond, which may later use as supplemental irrigation to the kharif crops. In rabi season, farmers grow wheat, and gram as

major crops. These crops, however, sustain on the soil moisture conserved into the soil during monsoon, the supplemental irrigation to such crops using pond water has raised the level of productivity. One supplementary irrigation of 6 cm depth could increases production from 30 to 50 % was observed in the crops of cotton, wheat, gram and cumin. (Bhoi et al 2004)

Material and methods

Integrated Watershed Management Programme (IWMP-2) under KVK is started in the year 2010-11. In the district KVK is the implementing agency for watershed project namely IWMP-2-Markatola. Markatola watershed has 9 micro watershed villages i.e. Markatola, Babudabena, Kodagaon, Potgaon, Andi, Kokanpur, Kewtintola, Talakurra and Siltara. Where KVK working on conservation of soil and water as well as livelihood improvement of farmers through formation of SGHs, FIG on Agri based enterprises. The main objective of the programme was to enhance livelihood status, crop productivity, soil status and ground water level of the micro-watershed area. In the first year KVK has identified the location specific problem of the micro-watershed through PRA, survey, group discussion, interview and visits to problematic locations. KVK also surveyed the ground water table, available water sources and site specific possible solution. Rice the main crop in the watershed area, after harvesting paddy most of the fields remain fallow due to unavailability of water for protective irrigation. Also ground water level was low ranges from 33.9 to 54.5 metre. The soil is medium in texture and very less organic carbon deficit in boron and potassium. Convergence with MGNAREGA in micro-watershed area, KVK has dug out farm ponds constructed check dam, gabbian structures. The use of farm pond is for collection of rainwater, stored it and used for protective irrigation.

Results and Discussion

In nine micro-watersheds 12 rainwater harvesting ponds, 6 check dams and 17 gabion structures were constructed for water & soil conservation. As a result of which total 72.2 ha area was converted in to double cropping directly through water harvesting structures and 128 farmers were benefited. Also the ground water level increases from average 44 metre to 26.9 meter, which results increased use of ground water for doubled cropping in the area.

Table 1. Details of ponds constructed and area converted in to double cropping

Sl. No.	Name of Micro Watershed and structure	Numbers	Storages area	Double crop area
	Ponds			
1	Kokanpur	2	6200 Cu m	6.4 ha
2	Babudabena	3	12500 Cu m	12.6ha
3	Potgaon	1	2500 Cu m	4.0ha
4	Kodagaon	2	7200 Cu m	7.9 ha
5	Talakurra	1	4100 Cu m	5.0 ha
6	Kewtintola	2	5600 Cu m	6.2 ha
7	Markatola	1	2200 Cu m	2.0 ha
	TOTAL	**12**		**44 ha**



Fig. 1 Constructed farm ponds and subsiding rabi crops in watershed area

Table 2. Details of Check dam constructed and area converted in to double cropping

Sl. No.	Name of Micro Watershed and structure	Numbers	Double crop area
1	Podgaon	2	10.0 ha
2	Andi	1	6.0 ha
3	Siltara	1	4.0 ha
4	Talakurra	1	4.2 ha
5	Kewtintola	1	3.9 ha
	TOTAL	**6**	**28.1 ha**



Fig. 2. Check dam and gabbian structures for soil and water conservation measures

The availability of stored rain-water in the month of December and January, encourage the farmers to take rabi crops i. e. Chick pea, field pea, linseed, etc. The area under pulses in rabi season increased from 38 ha to 92 ha in year 2014-15 in watershed area.

Table. 3 Effect of protective irrigation on crop productivity

Crop	Without any protective irrigation	With one protective irrigation
Chick pea	512	754
Field pea	589	762
Linseed	496	716

From table 3, one protective irrigation for chick pea crop increases production by 47%, whereas in field pea, it showed 29.4%, also for linseed it found that 44.4% enhancement in yield respectively. The main reason for increase in yield may be availability of moisture during flowering, which ensure the good pod bearing and result in better yield. This clearly shows that the crops yield can be increased with protective irrigation by utilizing stored water in the farm

pond. In addition to water conservation 17 ha waste land converted in to fruit plantations mango, custard apple at micro-watershed Markatola and Babudabena.



Fig. 3. Fruit plantation in watershed area

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WATER HARVESTING STRUCTURES FOR TRANSLATING FARMER'S ECONOMY IN RAINFED ECOLOGY OF CHHATTISGARH

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Abstract

Unreliable water supply constitutes the major bottleneck that has hindered growth in agricultural productivity and farm income in eastern India, where 80% of the cropped area depends on rainfall for supply of moisture. The region is endowed with high rainfall, but bulk of precipitation occurs as elsewhere in the country, in high intensity storms of very short duration. The water so received is prone to runoff, seepage and percolation much faster than its uptake for crop growth. This causes potential water shortage for rainfed rice at various stages and discourages adoption of modern rice technology. Thus development of irrigation is only the solution to meet-out the food demand of ever growing population and alleviating poverty from rural area. Expansion of irrigation through major and medium irrigation systems is nearly blocked due to many seasons. Adopting minor irrigation systems has its own limitation of ultimate irrigation potential of the area. Rainwater collection in dugout small farm-pond and recycle the collected water for irrigation purposes during in-season water stresses and for establishment of post rainy season crops are found profitable approach for rainfed areas of eastern India. Large number water harvesting ponds have been created but potential benefits are not realized owing to inefficient use of harvested water. The water harvesting pond can be making effective by adoption of farming system approach along with ferti-gation technique.

Introduction

India receives the highest rainfall among countries comparable to its size. Its landmass has gorgeous and perennial rivers criss-crossing it – particularly through the northern part. But the other side of the story is this: one part or another of India has continued to experience drought conditions with an alarming regularity. The rivers have been drying up and getting polluted. The underground water tables are shrinking rapidly. If water management is not accorded the importance it deserves, the country can very much expect to find itself in troubled waters as the years roll by. Estimates of the Central Ground Water Board are that the reservoir of underground water will dry up entirely by 2025 in as many as fifteen States in India – if the present level of exploitation and misuse of underground water continues. By 2050, when more than 50 per cent of the Indian population is expected to shift to the cities, fresh drinking water is expected to get very scarce. A new category of refugees is expected to emerge around that time: the water migrants. Future wars, between or within nations will be fought on the issue of water. The annual inter-State feuds over water are becoming more and more common in India. Per capita water availability in the country which was 5,000 cubic metres earlier, has dropped to 2,200 cubic metres. This is against the world figure of 8,500 cubic metres. As a result, India is fast approaching a phase of stressed water availability conditions.

The term rainwater harvesting is being frequently used these days; however, the concept of water harvesting is not new for India. Water harvesting techniques had been evolved and developed centuries ago. Since ancient times, farmers have been using ponds for livestock water

and for irrigation. Particularly in rainfed areas, ponds and tanks are made for harvesting rainwater for recycling to irrigate crops during water stress periods. Even in farms that already have irrigation water from canals or wells and tube-wells, provision of farm ponds may serve as an additional source of water. The demand for water has increased tremendously in recent years, and ponds are one of the most reliable and economical sources of water. Ponds are now serving a variety of purposes, including water for livestock and for irrigation, fish production, field and orchard spraying, fire protection, energy conservation, wildlife habitat, recreation, erosion control, and landscape improvement (Rathore et al., 1996 and 2006).

1. Water harvesting Farm pond

Water harvesting pond is a small tank or reservoir constructed on the farm for the purpose of storing rainwater essentially from surface runoff. The design and construction of water harvesting ponds require a thorough knowledge of the site conditions and requirements. Ideal components of the farm pond technology includes (1) creation of farm pond using about 10-15% area of farm, such that enough catchment available to generate runoff from major runoff events to fill the pond and place excavated soil to build embankments, (2) growing high value legumes, pulse or vegetable crops in the upper catchment area and rice in lower portion of the field during rainy season, (3) growing suitable post-rainy season crops using water saved in the pond and (4) fish and duck rearing in the pond as optional activity(Pal et al., 1994 and Rathore et al., 2001).Farm ponds are economically attractive in terms of economic returns but also in terms of unaccounted benefits such as increased employment, reduced risk of crop production, increased value of land, prospects of enhanced profitability by growing high value vegetables and fish culture. Furthermore, farm ponds can improve local hydrology (groundwater recharge, regulated stream flow and surface storage); reduce soil erosion, siltation and pollution of water bodies.

1.1 Farm pond water balance

Six farm ponds were constructed in each farming system models with view, to collect runoff and it's recycling for crop production during water stress periods in rainy season and for establishment of crops during post rainy season. Area of models was 0.40, 0.80 and 1.0 ha with and without shallow dug well. Inflow and outflow are the regular features of pond during rainy season. Therefore, collected rainwater was 1.6–3.6 times to the capacity of ponds. The inflow and outflow characteristics are described below.

Table 1: Characteristics of catchment and farm ponds (FP) constructed under farming system models (mean over 2005-06 to 2007-08)

Characteristics	FP-1	FP-2	FP-3	FP-4	FP-5	FP-6
Catchment area (ha)	0.27	0.27	0.56	0.57	0.62	0.77
Rainfall (mm)	1272	1272	1272	1272	1272	1272
Runoff (%)	45.5	46.6	34.9	43.8	37.5	36.4
Capacity (m^3)	655.7	779.0	1114.0	1407.7	1729.7	1723.3
Capacity inflow ratio	2.5	2.3	2.4	2.4	2.3	2.3
Depth (cm)	222.0	232.7	211.7	222.7	219.3	230.7
Seepage & percolation (cm/ day)	2.9	2.2	2.5	2.1	1.4	2.0
Water availability period (days)	116	118	117	129	158	148

Inflow: Direct rainfall and runoff from catchment are the components of inflow. No significant interflow was observed during the growing period. In different ponds 35-47% runoff was collected and 3-6% diverted as overflow from ponds to rice grown below. Of the total collected rainwater in pond, 77-82% received from runoff and remaining as direct rainfall into pond.

Outflow: Data of open pan evaporation was collected from meteorological laboratory located within 1 km distance from experimental site for calculation of evaporation from the ponds. As reported by several workers, 70% value of pan evaporation was taken for estimation of evaporation from the ponds. Of the total outflows, 4–10% collected water was lost as evaporation from different farm ponds depending on water storage duration and values of pan evaporation. Although measures are available to minimize the evaporation losses from water bodies but they are not cost effective vis-à-vis the losses are quite lower than other losses.

Table 2: Inflow and outflow characteristics of farm ponds under farming system models

Inflow/ outflow	Water balance of farm ponds											
	FP-1		FP-2		FP-3		FP-4		FP-5		FP-6	
	(m^{-3})	(%)	(m^{-3})	(%)	(m^{-3})	(%)	(m^{-3})	(%)	(m^{-3})	(%)	(m^{-3})	(%)
Inflow												
Runoff	1195	83.1	1327	82.6	1841	79.5	1983	79.1	2684	78.6	2637	77.2
Direct rainfall	251	16.9	287	17.4	482	20.5	526	20.9	737	21.4	772	22.8
Total	1447	100	1614	100	2323	100	2509	100	3420	100	3409	100
Outflow												
Irrigation	648	44.9	696	42.8	1021	44.3	1036	42.1	1499	44.0	1642	49.1
Seepage & percolation	728	50.2	832	51.9	1164	49.7	1316	51.4	1735	49.1	1492	42.3
Evaporation	70	4.9	85	5.4	139	6.0	158	6.4	237	7.0	275	8.5
Total	1447	100	1614	100	2323	100	2509	100	3471	100	3409	100
Overflow	176	5.6	163	2.5	386	5.7	361	5.5	516	5.8	502	5.9

Seepage and percolation*:* It was accounted to 42-52% of total outflow from the different ponds. On an average the S&P losses were 14 to 39 mm/day in different ponds (Tables 1). These losses were quite high therefore polythene lining is needed in the farm ponds. Minimizing these losses certainly enhanced water availability for crop production and other enterprises.
Irrigation: In different ponds 42-49% water was used for irrigation to different crops in various models.

1.2. Farm water balance
In field water balance; rainfall, supplemental irrigation, overflow from catchment, runoff/drainage and plant available soil moisture (PASM) are the measured factors. Based on these factors

evapo-transpiration and percolation (Et+ P) of the crops was computed. Rainfall (64-66%) and runoff (15-17%) were the major source of farm water whereas supplemental irrigation accounted to 8-9% of total water gained in the farm. Evapo-transpiration + percolation were recorded as major use of farm water (52-55%) whereas loss of 17-20% recorded drainage of water from upland and rice field area. Nearly 10% of farm water remained un-utilized as plant available soil moisture (PASM) after rabi crop (Table 3).

Table 3: Farm water balance of farming systems with farm pond and shallow dug well

Components	0.40 ha IFS		0.80 ha IFS		1.0 ha IFS	
Water gained	(m^3)	(%)	(m^3)	(%)	(m^3)	(%)
Rainfall in cropped area	5356	63.9	9669	65.7	12956	64.2
Overflow from pond diverted to rice	193	2.3	374	2.5	509	2.5
PASM after kharif crops	482	5.8	1022	6.9	1600	7.9
Direct rainfall in pond	285	3.4	504	3.4	730	3.6
Runoff from uplands collected in pond	1243	14.8	1912	13.0	2542	12.6
Irrigation to crops from pond & well	784	9.3	1185	8.1	1790	8.9
Water for livestock, farm and family use	40	0.5	47	0.3	49	0.2
Total	8382	100	14712	100	20175	100
Water use/ loss						
Evapo-transpiration + percolation	4355	52.0	8120	55.2	11074	54.9
Drainage from upland crops and rice	1704	20.3	2581	17.5	3467	17.2
PASM after rabi crops	756	9.0	1548	10.5	2313	11.5
Seepage and percolation from pond	725	8.6	1240	8.4	1539	7.6
Evaporation from pond	80	0.9	149	1.0	243	1.2
Irrigation from pond to crops	723	8.6	1029	7.0	1490	7.4
Water for livestock, farm and family use	40	0.5	47	0.3	49	0.2
Total	8382	100	14712	100	20174	100

Traditional use of farm ponds

Large number of farm ponds is constructed in MNREGA but farmers rarely using the collected water efficiently in crop production. Farmer use to irrigate water in rice at a once or twice in a season wherever shortage of water occurred during the season. If water remained in the pond after rice, that naturally percolate down in the pond without growing rabi crop. Thus farm ponds are not much attractive to farmers as source of assured water.

How to make Farm ponds an Economic and Attractive water resource?

Surface water harvesting structures are the alternative where ground water availability is meager. But WHS are costlier than GWS and require more investment compare to GWS. Normally WHS is constructed in sloping area whereas GWS are constructed in lowlands. Thus it is required to

make WHS economical and attractive to the farmers so that WHS become attractive in farm families.

Table 4: Investment cost and area brought under irrigation by surface water harvesting and ground water structures (Rathore *et al*.2015)

Type of structures	No. of structure	Cost of structure (Rs. In lakh)	Area irrigated (ha)	Average cost of structure (Rs. In lakh)	Cost of per ha irrigation (Rs. In lakh)
Surface water harvesting structure(WHS)	68	146.20	170.20	2.50	1.16
Ground water structure (GWS)	583	874.50	682.30	1.17	0.78

(a).Farm ponds with farming system approach

Farm pond with dug well helped in bringing the area under double cropping. Crop diversification encouraged efficient use of water for crop production (Table 5). With availability of water crop yields were almost double in all the crops adopted in the integrated farming systems. Net income and employment opportunities were almost double in all the farming systems with pond and well. A farmer may get nearly one-lakh by adopting suggested farming system with farm pond and dug well. Animal component in the suggested farming system contributed 60-70% farm income whereas cropping share was 30-40%. Therefore for livelihood security of small farmer, livestock rearing is important in addition to cropping.

Table 5: Production, net return and employment from various enterprises in farming system model with farm ponds (Rathore et al. 2008)

Enterprise	Area allotted to each enterprise			Production (kg/ Lit)			Net return (Rs.)			Employment (man day)		
	0.40 ha IFS	0.80 ha IFS	1.0 ha IFS	0.40 ha IFS	0.80 ha IFS	1.0 ha IFS	0.40 ha IFS	0.80 ha IFS	1.0 ha IFS	0.40 ha IFS	0.80 ha IFS	1.0 ha IFS
Crops												
Rice	0.13	0.26	0.35	537	1105	1514	2277	4707	6490	22	43	56
Soybean	0.05	0.10	0.16	76	172	270	606	1230	2059	7	7	23
Maize	0.01	0.03	0.04	42	95	150	512	1210	1877	10	19	31
Mustard	0.13	0.27	0.35	97	197	232	1033	1975	2059	16	31	38
Arhar	0.02	0.02	0.04	24	31	61	331	394	798	3	5	4
Gram	0.12	0.28	0.43	115	304	469	1642	4181	6371	16	33	50
Ladyfinger	0.04	0.09	0.15	318	829	1330	972	1859	4316	12	30	71
Tomato	0.02	0.02	0.02	186	268	289	625	1011	1188	6	9	8
Brinjal	0.01	0.03	0.03	193	368	527	860	1736	2669	8	14	14
Multi-cut sorghum	0.04	0.09	0.13	3770	7870	10142	1590	3227	6567	6	11	20
Marigold	0.01	0.01	0.01	70	89	104	463	527	537	3	4	4
Drumstick	0.05	0.13	0.16	10	20	27	42	193	334	9	20	14
Total crops	0.63	1.33	1.87	5437	11347	15114	10952	22248	35262	117	224	331
Milk produced												

Cow	0.06	0.10	0.12	1619	3029	4468	11136	39346	30531	50	94	92
Goat				50	61	120	1250	1820	2405	4	0	14
Meat produced												
Goat				302	408	689	5658	13199	21961	29	74	74
Poultry birds				10	13	22	550	930	1325	8	14	9
Fish				9	14	50	259	626	1477	5	11	11
Grand total	0.69	1.43	1.99	7428	14873	20463	29804	78169	92961	213	417	530
Traditional rainfed rice	0.40	0.80	1.00	760	1520	1900	2757	3995	4860	65	119	144

0.40 ha IFS: Rice + oilseed + pulse + vegetables + flower + fruit plants + green fodder + Farm pond+ dug well+ Cow (1) + Goat(6) + Poultry birds(15) + Fish

0.80 ha IFS: Rice + oilseed + pulse + vegetables + flower +fruit plants + green fodder + Farm pond + dug well + Cow(2)+ Goat(9) +Poultry birds(20)+ Fish

1.0 ha IFS: Rice + oilseed + pulse + vegetables + flower+ fruit plants + green fodder + Farm pond + dug well + Cow(2)+ Goat(12) + Poultry birds(25)+ Fish

(b). Surface water harvesting and trapping percolated ground water

Rain runoff flows on surface can be harvested in farm ponds but part of it percolated down in soil profile and thereafter recharges ground water. Soil profile water can be tapped in dug well and tube well (NATP progress report 2005). The open dug wells should be located in the recharge zone of the tanks. For optimum efficiency, the well diameter should be 6 m and depth should be 8m. In lower reaches of the drainage line, shallow ditches can also serve the purpose, especially if sufficient command area is not available or farmers are poor to invest in open dug well. Multiple use of water should form an integral part of the utilization of the system. The water body can be used for pisci-culture and duck rearing, and embankment can be used for cultivation of fruit crops as well as vegetables. This will improve nutritional uptake of the farmers and provide round the year income and employment. In-situ conservation of excess rainfall in a systematic manner, involving on-farm reservoirs in series is most appropriate and economically viable technology as first line of defense against drought.

(c.).Water harvesting ponds with farming system and micro irrigation

Farm pond has great potential for supplemental irrigation but to make economical viable approach, it should be promoted with farming system approach and irrigation adopting drip system or sprinkler. Inclusion of well or tube well assure promising income to the farmer by growing round-the year fish and duck in pond in addition to growing vegetable and fruit plants to fetch income on sustainable basis.

Policy suggestions

Farm ponds are being constructed on farmer's field and revenue or forest land for ground water recharge or alleviation of drought. But its potential benefits are not realized owing to non-integration of essential technologies. This leads to least attraction and adoption of the farm ponds even after free digging of the ponds on farmer's field under MNREGA and other schemes. To make more remunerative and farmer adoptable technology following point should be integrated along with digging of pond as part of the scheme:

1. Farm pond after digging must be polyethylene lined
2. Schemes should be linked for adoption of farming system approach and micro irrigation (drip or sprinkler irrigation) with construction of each pond

3. Farm pond for surface water, dug well for soil profile water and tube well for ground water shall be constructed in integration for conjunctive use of water
4. There should be a small pond for recharge and pisci-culture near each tube well

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WATER MANAGEMENT IN AGRICULTURE USING A WATERSHED APPROACH

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Introduction

We consider land as the most important natural resource for agricultural and allied uses. Land in such a definition comprises of soil, water, flora and fauna involving the total ecosystem. Over the last century, rapid increase in human population has put an enormous pressure on land resources leading to multiple problems including land degradation. Soil and water need a holistic management approach in order to satisfy the growing demands for the present and future generations. This would not only entail using the available water resources judiciously, but also preserving and further developing the precious water resources that are distributed highly unevenly across space and time. This is more pertinent keeping in mind the alternative uses of water that are always constraining its availability for agricultural and allied uses. It would be worthwhile to say that water in agriculture need to be managed to derive maximum advantage from whatever amounts are available. A silver lining however is that everywhere on earth, the supply of water is suitable to meet the needs of the native flora and fauna; largely due to the adaptations that have occurred over time. With anthropogeninc interventions in all ecosystems, there is a considerable increase in the demand of water. A watershed approach in such a situation is a holistic one as it takes care of the requirement of all concerned in that area and for all sectors. To quote Daniel Hillel, a well known Soil Physicist and winner of World Food Prize for 2012, **"Both soil and water belong to the biosphere, to the order of nature, and- as one species among many, as many generation among many yet to come- we have no right to destroy them."** There is a plenty of room for improvement in managing water resources, and many of the improvements are likely to come as a result of better management of soils. The soil serves as a massive reservoir and buffers the potentially harmful effects of excess and deficiencies of water.

What is a Watershed?

A watershed may be defined as an area with a well delineated topographic boundary that drains through a common outlet. The hydrological conditions characterising a watershed are such that the draining water concentrates in a particular area from where its drainage through a common outlet is facilitated. Not only the drainage, but also the water from any point outside a watershed cannot enter into it. All hydrological processes such as runoff, infiltration, seepage, percolation etc in a watershed are interlinked and confined within the watershed boundary. The most common practice since ancient times that uses the principle of a watershed is pond water harvesting practices on community scales. This probably evolved when early human civilizations settled in the areas where water was plentiful, gradually understood the temporal cycles of water availability and learnt to harvest water for agriculture.

A watershed, ecologically speaking, consists of a hierarchy of nested niches constantly influencing and interacting with each other. Similarly, those living within the watershed do not institute a homogeneous human community but an agglomeration of distinct groups or alliances in continual interchange with each other. Thus, both the watershed and watershed community

living therein are the distinct networks of dynamic relationships constantly in flux and in ever changing configurations and permutations both in relations to themselves and each other. Watershed, catchment area and drainage basin are synonymous terms. When we refer to a watershed as an area that contributes its runoff to a single outlet, a stream or river, it is called the catchment of that outlet, stream or river. The boundaries of a watershed are known as a drainage divide. Rains falling on opposite sides of drainage divide falls into a different watersheds. Naturally there are hierarchies of streams that flow into each other as tributaries. Likewise, there are hierarchies of watersheds – a watershed may be mini or micro (a few hectares) for a small stream upto macro (thousands of hectares or thousands of square kilometres0 for a large river system. The All India Soil and Land Use Survey (AISLUS) has attempted an orderly national level delineation and codification of the watersheds, featuring a five stage hierarchical system consisting of (i) regions, (ii) basins, (iii) catchments, (iv) sub-catchments and (v) watersheds. There is both a micro-level and macro-level delineation as in the table below:

Table: Classification of Hydrological units

Category of Hydrologic unit	**Size (lac hectares)**
Region	Above 300
Basin	30-300
Catchment	10-30
Sib-catchment	2-10
Watershed	0.5-2
Sub-watershed	0.1-0.5
Milli-watershed	0.01-0.1
Micro-watershed	0.001-0.01
Mini-watershed	0.0001-0.001

To make the definition of a watershed rhyme with the hydrologic cycle, it would not be an exaggeration to say that a watershed is a contiguous physical part of the hydrologic cycle that has minimum or nil interactions with the neighbouring areas except one which is a common drainage outlet. The hydrologic cycle describes the continuous movement of water on, above and below the surface of the earth. By virtue of the definition rhyming with the hydrologic cycle, a watershed is every infinitesimal part of the physical hydrologic cycle with a potential for stepwise integration to yield larger watersheds. Speaking of it in a more physical sense, a watershed is an area of land drained by a single system of streams and bounded by ridges that separate it from adjacent watersheds. All the precipitation falling on a watershed is either stored in the soil, returned to the atmosphere or discharges from the watershed as surface or subsurface flow (runoff).

Watershed concept in water management

Taking lead from our definition of a watershed in the context of hydrologic cycle, the concept of watershed development and water management in the context of a watershed consists of harvesting rainwater where it falls, regenerating the environment, increasing green cover and adopting sustainable land husbandry practices in the watershed. It implies making bunds, digging trenches, building gullies etc in a big way that will arrest the rapid flow of water from higher altitudes to the lower ground. This is necessary because water flowing in a downward direction at great speeds takes down the precious soil with it. When this flow is reduced or made to go in steps, water percolates into the ground at various spots and recharges the ground water

aquifers. The disposition of water in a watershed is often expressed by the water balance equation as below:

P = ET + SS + D, where,

P= precipitation (to include additional terms in case of anthropogenic interventions such as irrigation)

ET= evapotranspiration

SS=soil storage including surface detention

D= drainage

If we just rearrange this equation as D = P- ET-SS, we can very well comprehend that discharge can only be altered by altering the evapotranspiration or soil storage including surface detention. ET and SS are inversely related to the discharge. So our interventions to influence the discharge from a watershed can be observed or studied at the levels of practices aimed at modifying either the ET or SS. For instance deforestation would decrease ET and increase discharge. Hence water management in the gamut of a watershed concept encompasses land, water, people and livestock and all related enterprises that have constraining uses of water.

Water characteristics like inflows (precipitation, surface water inflow, ground water inflow), water use (evaporation, evapotranspiration, irrigation, drinking water), outflows (surface water outflow, ground water outflow) and storage (surface storage, ground water storage and root zone storage) are the principal factors to be taken care of in sustainable water management. For judicious water management, there is a need for rainwater harvesting, groundwater recharge, maintenance of water balance and preventing water pollution. The rainwater harvesting is of utmost importance so that the harvested rainwater can be utilized in the off-season. The rainwater collected can infiltrate into the soil tro form a part of groundwater. Some interventions can be done to harvest rainwater according to the local situation as topography, gradient, land available for making tanks, recharge trenches and other structures.

Why watershed as a unit

Although there has been a phenomenal growth in agricultural production and productivity over the last fifty years or so, the growth in agriculture has not been inclusive. Moreover, the areas where the growth has been recorded have now plateaued and there are already severe problems of degradation at multiple scales. This is mainly because of an imbalance between the various alternative uses and disproportionate allotment of resources leading to a virtual conflict and ultimately overexploitation of resources. Food security and environment quality are serious global issues that have to be addressed for enduring food and health security. Poor ecosystem management of a watershed will result in the impaired functioning of the watershed, which in fragile environment can lead to ecosystem collapse. Outside a watershed concept, the research and development efforts were primarily concerned with bio0mass production, with little attention to resource conservation and sustainability of the ecosystem. The watershed approach calls for identification of the thrust areas, additional capacity building, strengthening peoples participation, technological interventions based n research and management, resource mobilization, financial stability, priority delineation and codification of watersheds, monitoring and impact assessment. Such an approach ona watershed basis for obtaining synergic benefits of multiple interventions is now well validated. With industries added to agriculture, the watersheds have to be carefully selected. A working watershed size would differ with situations but in general the appropriate size of the watershed for development at the field level should be approximately 500-100 hectares. Only a part of the water that falls on a watershed ultimately gets into the stream – this is known

as runoff and varies widely among watersheds. Each watershed has its own unique and distinct characteristics that define its potentialities and problems. The size shape, relief, drainage, geology, soil, climate, surface conditions, land use, groundwater and socio-economic status of the watershed determine its runoff 9and the potential for development as a water resource), sedimentation, moisture conservation measures to be adopted, proper land use planning and other development programmes. The people and animals, all part of the watershed community, depend on the watershed and in turn influence – positively or negatively – what happens there. What happens in a small watershed also affects the larger watershed.

Rainwater harvesting in perspective

Rainwater storage in open surface depressions is a natural phenomenon across the globe. Almost all inland water bodies are a manifestation of stored rainwater either channelized through natural drainage outlets like seasonal streams or indirectly through surface ponding after oozing out of ground water that had entered the aquifers at higher altitudes. This is the natural manifestation of rainwater harvesting since time immemorial and occurs at the scale of natural drainage basins. The stored water in natural farm ponds has been historically instrumental in recharging the underground aquifers. Existence of farm ponds in all terrains has been documented in a wide variety of texts and this has historically supported the drawl of water from the underground aquifers by man. Initially, as man began to draw groundwater, the delicate balance was not affected since the drawls of water were almost compensated by natural recharge of the aquifers. However, increasing withdrawals (due to introduction of diesel and electric pump sets) with increasing demand of water due to increased population pressure, the natural recharge cycles of the underground aquifers has been adversely affected. Hence a need has been felt to install water harvesting systems to recharge the ground water aquifers. However, the objective of rainwater harvesting, apart from recharging the groundwater aquifers, is also to collect, store and make available the required quantity of water for direct use in agriculture and allied activities. Several agencies have put in substantial efforts to encourage construction of ponds for harvesting rainwater for use in agriculture, horticulture and allied activities. This is the more often desired purpose of any rainwater harvesting system in hilly terrains where ground water is difficult to tap due to greater water table depths and prevalence of hard rocks in the profile.

Some experiences of water harvesting systems prevalent in Rajouri area of Jammu and Kashmir

The plain areas in the state of Jammu and Kashmir historically had numerous ponds. However, there were hardly any ponds in the higher hills comprising the districts of Rajouri, Poonch, Udhampur, Kishtawar, Ramban, Reasi and Doda; probably due to the typical terrain and undulating topography. Unlike in the plain areas of Jammu where rainwater harvesting through ponds was being done since the nineteenth century and even before; the water harvesting systems prevalent in the hilly tracts was mainly through *kuhls*. These *kuhls* are simply minor irrigation channels that flow along the rivulets and streams to the adjoining fields sourcing their water from the same streams (at the upstream end of the *kuhl*). The *kuhls* inside the paddy fields have been made by laying down the stones and rocks from the fields along the bunds followed by covering them with heavy soils of the fields to block the leakages of water from the channels. The most wide spread use of the *kuhl* irrigation water can be seen in case of rice cultivation on terraced lands up the banks of natural streams in these areas.



Figure : *Kuhl* irrigated paddy fields being irrigated for puddling as seen from a higher position in the watershed.



Figure : Illustration of paddy fields adjoining a stream showing the water being harvested and diverted to the traditional *kuhls* which convey water to intricately laid out paddy fields.

Traditionally these *kuhls* were managed by the users at the local level but now their maintenance has been taken over by the irrigation department of the state government. *Kuhls*, however, have a limitation that these do not hold or store water. So the water availability is limited to the duration of water flow in the *kuhls* and in turn on the duration and amount of water flow in the parent streams. Further, the reach of the *kuhls* is also limited as water tapped in the upstream areas of the streams can only flow to a lower altitude along the path of the *kuhl*. Moreover, with

increasing efforts to intensify agriculture along with introduction of more water intensive land use systems such as horticulture on hilly terrains, a need has been felt to provide irrigation water in hitherto un-irrigated areas. With ground water at great depths under the rocks and the hills, rainwater harvesting and storage in dug out ponds treated somehow to reduce the infiltration losses has come up as a profitable proposition. Under various incentives from several government departments, a number of farmers have created facilities for storage of harvested water; be it rainwater converted into runoff being tapped at some point of the watershed, or water flowing out of the ground through natural springs diverted into a collection pond, or simply *kuhl* waters being diverted to a storage structure. Even with the slow discharge from the *kuhl*s in the lean season, substantial quantity of water gets accumulated over time to be used for irrigating field crops on need basis. It is pertinent to mention that simple presence of mind shown by the entrepreneurial farmers in applying the irrigation water to the fields using all sorts of available resources (such as barks of trees, PVC pipes and GI pipes) is no less than an improvisation. These techniques need to be studied on a scientific basis, researched upon for optimization and applied over a broader arena.



Figure : *Kuhl* water harvested in a pond and used for irrigating a mixed crop of clover and mustard in village Godar Kesar Gallan, Rajouri (Name of farmer – Mr Haji Mian).



Figure : *Kuhl* water harvested in a pond being taken to far off fields across the undulating terrain using indigenous adaptations and improvisations for irrigating vegetable crops in village Godar Kesar Gallan, Rajouri (Name of farmer – Mr Haji Mian).

Springs are a common sight on all hilly terrains that reflect the dynamic aquifers. The flow of waters in these springs depends on the seasonal recharge of the aquifers in the higher reaches through rainfall or snow melt, as the case may be. Appreciating this seasonality of flow in the springs, several traditional spring water recharge ponds that resemble step wells can also be seen in the hydrological conditions encountered in this area. These traditional harvesting structures were safe guarded and protected with a religious outlook, as can be seen with the presence of temples of local deities or a holy tree revered by the locals in the vicinity of the spring water harvesting structure. These structures were kept well maintained and protected from direct exposure to winds and runoff water. Traditionally these springs provided drinking and bathing

water for the humans but animals were not allowed to enter; however, with augmenting of domestic water supply through piped water, these have found alternative uses. People have started using them as a source of irrigation water to irrigate small areas in the neighbourhood, such as nurseries or kitchen gardens. For instance, at one location in Kalakote sub-division, farmers have set up a community vegetable nursery block near a revered spring water harvesting structure and put up a small 1 HP centrifugal pump that runs on electric power to irrigate the nursery area.

Another indigenous water harvesting structure encountered in this area is an open well with a wide mouth that is lined with stones on the sides. The well is found on the lowest contour of a hilly topography with fields located on higher contours. This arrangement allows the water percolating in the fields on higher contours to get collected in the well on the lowest contour. The farmer, Mr Abdul Quayum in village Dhangri of Rajouri has just put up a pump using electric power near the well and uses garden hose of PVC to convey water to the fields on higher contours and is successfully growing cruciferous vegetables with this water.



Figure: Spring water harvesting structures seen along with the temples of revered local deities or holy trees in Rajouri.



Figure : A community nursery block set up by farmers in Kalakote subdivision of Rajouri near a spring water harvesting structure for facilitating irrigation.



Figure : An open well with a wide mouth lined with stones on the sides. The farmer, Mr Abdul Quayoom in village Dhangri of Rajouri is successfully growing cruciferous vegetables by pumping water from the well using a pump that runs on electricity and conveys water to the fields using PVC hose.

Irrespective of the source of irrigation water available with a farmer, the farmers just find some ways and means to convey water through a tube or any impermeable carrier available with them. The basic fact that they take care of is still that the water should be transported from source to the point of application with minimum expenditure of energy and minimal wastage.



Figure : An indigenous improvisation using a length of GI pipe to covey water from a *kuhl* to a vegetable plot near Tatta Pani in Rajouri (Name of farmer: Mr Bagh Hussain)

Another couple of examples of indigenous need based improvisations were observed near village Bal Jarala in Rajouri. In first case, the waste water flowing from a site of a hand pump was tapped and carried to a location further downhill for irrigating vegetable crops. The guiding force behind this improvisation here is just the desire of the farmer to get some water for irrigation, somehow. The idea is just to make the water accumulate at a point down the drain and make it to flow through a pipe which can carry it to the destination using temporary arrangements which cost minimal to the farmer. Moreover, as the agriculture in this area is at subsistence level, the inputs used are not so refined. If there is an incentive to commercialize, this arrangement may just be seen as a precursor of a piped water conveyance system in a farm. Another instance of an indigenous improvisation was seen at a nearby site where a villager needed water for masonry work to construct a house. He improvised by constructing a small dug out pond with an arrangement to divert the excess runoff / drainage water from the nearby fields to that pond. As can be seen in the illustration below, the runoff collection system was designed using grassed area to tap the drainage waters so as to filter the sediment load in the drainage water to some extent. At the time of the photograph, the construction of his house had been completed and the water still being harvested was being used for irrigating vegetable crops in the vicinity.



Figure: Waste water from a community hand pump being harvested and carried downhill using indigenous improvisations to irrigate vegetable crops at a site near village Bal Jarala in Rajouri.



Figure: A dug out pond near Bal Jarala in Rajouri with an arrangement to collect the runoff / drainage water from the adjacent fields. The runoff collection system uses a grassed area to tap the drainage waters from a channel to filter the sediment load in the drainage water.

Indigenous drainage system of traditional maize fields in Rajouri: Tremendous potential to harvest rainwater in a series of small water harvesting ponds

Maize is the traditional staple crop of Rajouri and the adjoining hilly areas covering the districts of Poonch, Doda, Udhampur, Ramban, and Reasi. Cultivated along the hill slopes and also on terraced lands, maize is grown predominantly under rainfed conditions during the rainy season. The fields are prepared just after receiving the pre-monsoon showers using either traditional bullock drawn ploughs or tractors followed by broadcasting of the fertilizers and maize seeds. Thereafter, the seeds are covered under the soil by another cycle of ploughing. The desired drainage system of the maize fields is laid out at this stage only within a couple of days of sowing. This drainage system consists of extensively laid out channels across the contours so as to trap the water from all parts of the field through collecting channels (locally called *chidi*) and direct it to the main drainage channels (locally called *ballan* or *bal*). These drainage channels are laid in such a way that water is made to flow along the natural drainage path of the fields, although only through the designated channels. The direction, spacing and exact location of the drains is guided by the experience of the farmers. This layout ensures that water is guided out safely from the maize fields without concentrating in the main field and simultaneously avoiding erosion of the soil. A striking feature of these drainage channels is that these are almost never straight; rather they have a slight curvature, thus ensuring that the velocity of the draining water in the channels is checked and the possibility of soil erosion is reduced.

The essentiality of drainage system for the maize crop is very well recognized by the farmers of the area; the recognition stemming from two major reasons, first the inherent susceptibility of the maize crop to water logging and secondly the requirement of the maize crop for hoeing, weeding and earthing up (halloding) operations. As a traditional practice, a hoeing / weeding operation is done manually at about 15 days after planting followed by earthing up of the maize plants. An enquiry into the reasons for laying out such an extensive drainage system for the maize crop has revealed that the manual hoeing, weeding and earthing up operations would become too cumbersome for the farmers if water stagnates even for a short time resulting in compaction of the top soil.

The volume of water flowing out of these drainage channels is enormous during the period of strong rainstorms and can potentially be stored in some harvesting structures in the watershed. It appears promising to store this drainage water by constructing a series of dug out poly-lined farm ponds at contiguous locations in the watershed so as to avoid heavy concentration of water in the channels; so also to make available water for supplemental irrigation for the maize crop during the subsequent dry spells, which frequently occur during the rainy season, or for the next season crops. As against constructing a big farm pond at the lowest contour, construction of several small ponds at various locations in the watershed will facilitate irrigation of much greater areas in the watershed using gravity head. Sufficient scope exists to use various indigenous improvisations illustrated earlier in this text with potential upscaling to efficiently convey the harvested water in these ponds to the point of use.



Figure : Main drainage channels (*Ballan* or *Bal*) of the maize fields in Rajouri that convey drainage water safely outside the farm boundary to the natural drainage system. The curvature and the zig-zag layout of the channels ensure that the velocity of the runoff remains under check minimizing the risk of soil erosion.



Figure : Extensively laid out drainage channels across the contours in maize fields that trap the water from all parts of the field (locally called *chidi*) and direct it to the main drainage channels (locally called *ballan* or *bal*)

FOOD AND LIVELIHOOD SECURITY THROUGH WATERSHED MANAGEMENT APPROACH

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Abstract

India is the second largest country in the world and agriculture is an important occupation of the country. A large section of the rural populationin the Indian is dependent on agriculture and allied activities for its sustenance and country is passing through a crucial stage of development. Agriculture provides the bulk of employment, income and food for the rapidly growing population of the country. In India agricultural land is 142 million ha with 135% cropping intensity (NAAS, 2009) and about two third agricultural land is rainfed, which is characterized by water scarcity, land degradation, low use of inputs and low productivity. India is more vulnerable to the adverse impacts of droughts due to its dependence on rainfall in over two-third area characterized by arid to semi-arid climate and growing population. The large spatio-temporal variation in rainfall of different regions of the country even during normal rainfall years result in very low agricultural productivity and poor socio-economic conditions. Even slightly below normal rainfall creates drought like conditions leading to large scale failure of agriculture resulting in vide spread deprivation. Recurring droughts have a very damaging and irreversible impact on the country's economy. Droughts have very serious consequences on sustainability of water resources in irrigated agriculture also as already depleted water resources come under severe stress affecting agricultural productivity. Integrated water management in rainfed as well as irrigated areas holds the key for long term sustainability of water resources and agricultural productivity. In order to enhance agricultural productivity in rainfed regions with available limited water resources, the rainfed farming needs to be developed as a sustainable production system by adopting watershed management approachwhich is a single window approach addresses all the problems of an area with holistic development of agriculture and allied activities.

Introduction

Nearly 60% of the total 142 million hectares cultivated area in the country is rainfed and accounts for only 45% of the output, whereas, 40% of the cultivated area contributes about 55% to total food grain production. Rainfed agriculture is characterized by low levels of productivity and low input usage with low productivity resulted in poverty, malnutrition, food insecurity. Variability in rainfall results in wide variation and instability in yields. In spite of harnessing all replenishable surface and sub-surface water resources, nearly half of the cultivated area still remains rainfed. Rainfed agriculture is faced with low levels of productivity due to scarcity of water and consequently low input use. The large number of the rural poor live in the rainfed regions and their livelihood depends on agriculture. In order to increase agricultural productivity with available limited resources, the rainfed farming needs to be developed as a sustainable production system by adopting watershed management approach. The natural resources system is under great stress because of continuous increase in human and livestock population in the country resulted in depletion of the vegetative cover, increase in soil erosion and the alarming fall in groundwater level which are serious concerns. Loss of vegetative cover followed by soil

degradation through various forms of erosion have resulted into lands which are deficit in soil nutrients. Growing population pressure, higher demands for food and fodder coupled with impact of rapidly changing socio-economic conditions have added fuel to the fire. To tackle these problems, watershed management has accepted as the most favoured instrument. Therefore, Government of India accords highest priority to the holistic and sustainable development of rainfed areas through watershed development approach. Watershed, a single window approach addresses all the problems following the watershed approach which enables a holistic development of agriculture and allied activities. Thus for maximizing the advantages, all developmental activities should be undertaken in a comprehensive way on watershed basis.

Definition of Watershed

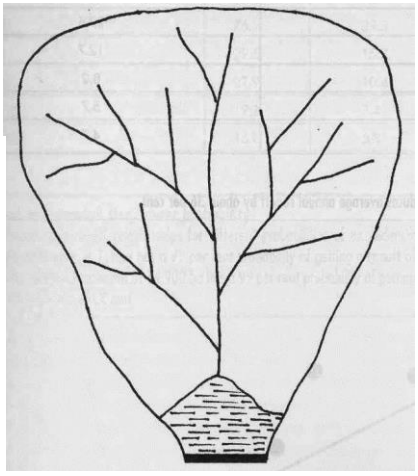
Watershed is derived from two words water and shed i.e. water is collected from an area to a single outlet. Watershed is entire geographic unit of particular land from where rainwater as runoff is drained out from ridges along the slopes of land to single particular point outlet or common drain point (Fig. 1). It is an ideal planning unit for conservation of important natural resources like soil, water and bio-diversity(Dhruva Narayana, 1997, Kumar et al., 2011).

A watershed is the area that drains to a common outlet. It is the basic building block for land and water planning. A watershed is an area that supplies water by surface or subsurface flow to a given drainage system or body of water, be it a stream, river, wetland, lake, or ocean World Bank (2001).

Watershed is a geo-hydrological unit of an area draining to a common outlet point. It is recognized as an ideal unit for planning and development of land water and vegetation resources. A watershed can simply be defined as any surface area from which rainfall is collected and drained to a common point (Li *et al.*, 2005).

Watershed is synonymous with a drainage basin or catchment area. A drainage basin, however, can involve several towns or regions and even countries (Ibid, 2005).

Watershed is not simply the hydrological unit but also socio-political-ecological entity which plays crucial role in determining food, social, and economical security and provides life support services to rural people (Wani *et al.*, 2008).



1: Conceptual diagram of a watershed

Watershed may also be defined as a natural unit of land which collects water and drains through a common point called as outlet by a system of drains. Therefore, watershed is the area encompassing the catchments, command and delta area of a stream. The top most portion of the watershed is known as “ridge” and a line joining the ridge portion along the boundary of the watershed is called as “ridgeline”. A watershed is thus a logical unit for planning optimal development of its soil, water and biomass resources.

Concept

In India about two-third population lives in rural areas and more or less their livelihood mainly depend on agriculture. However, approximately 65% of the countries agriculture is rainfed with low agriculture productivity therefore, top priority needs to be accorded for managing natural resources specially land and water in the most optimal way to increase agricultural productivity.

The concept of watershed management is based on sustainability and meeting the needs of present population without compromising the interests of future generation. The concept of watershed management is important for the efficient utilization of natural resources specially land and water. The basic concept of watershed management is as follows:

- Harvesting every drop of rainwater for purposes of irrigation, plantation including horticulture and floriculture, pasture development, fisheries etc. to create sustainable sources of income for the village community as well as for drinking water supplies.
- Ensuring overall development of rural areas through the gram panchayats and creating regular sources of income for the panchayats from rainwater harvesting and management.
- Employment generation, poverty alleviation, community empowerment and development of human and other economic resources of the rural areas.
- Mitigating the adverse effects of extreme climatic conditions such as drought and desertification on crops, human and livestock population for the overall improvement of rural areas.
- Restoring ecological balance by harnessing, conserving and developing natural resources i.e. land, water, vegetative cover especially plantation.
- Encouraging village community towards sustained community action for the operation and maintenance of assets created and further development of the potential of the natural resources in the watershed.
- Promoting use of simple, easy and affordable technological solutions and institutional arrangements that make use of, and build upon, local technical knowledge and available materials.

The watershed management aims at improving standard of living of the people residing in the watershed area by increasing their earning capacity, by creating facility such as good water for irrigation, drinking water supply and other purposes; electricity; freedom from fears of floods and droughts etc. The objectives of watershed management consists of efficient utilization of the entire resources mainly soil, water, crop including plantation, livestock, fishery and human population etc. for sustained prosperity of the watershed area.

Basically watershed management programmes include engineering and biological measures such as treatment of land and water resources water harvesting and storage structures and alternate land use like afforestation. Improved practices like *in situ* water conservation practices, cropping systems and other practices including horticulture, aquaculture and animal husbandry are also constitute important ingredients of the programme (Singh 2000). Watershed management is essentially adoption of soil and water conservation practices such as proper land

use, protecting land against all forms of deterioration, maintaining soil fertility, conserving water for farm use and increasing productivity, proper water management for drainage and flood protection. All the natural resources in particular watershed should be used as efficiently as possible with minimum watershed degradation. In watersheds, besides development of new water resources, emphasis is laid on efficient utilization of existing water resources based on indigenous technologies. The watershed management is rational utilization and conservation of land, water and biodiversity of natural resources without further deterioration of environment. It is an integrated participatory approach for sustainable development of natural resources. People's participation right from planning up to its implementation is important element in its proper execution. The problems of watershed are addressed and solutions sought using a single window approach. Watershed management is an ongoing process and therefore, essential that original watershed plans should be revised in case of new challenges. Different watershed activities is shown in Fig. 2.

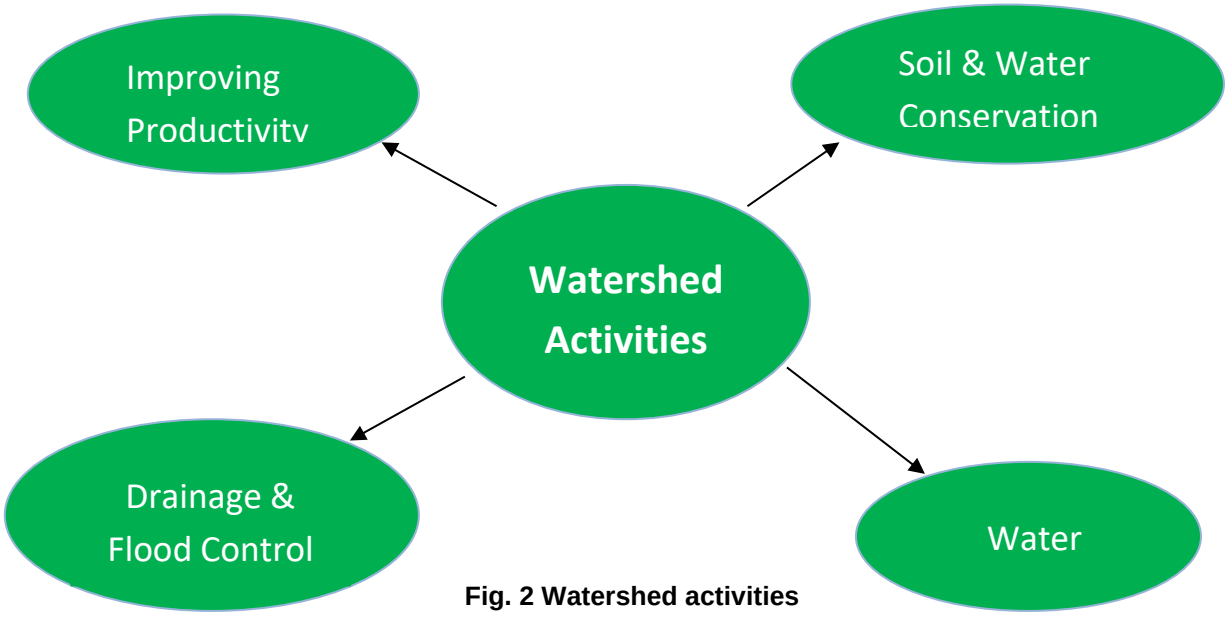


Fig. 2 Watershed activities

Approach

Watershed, an ideal manageable hydrologic unit of the area draining to a common outlet point is used for planning and development of natural resources (water, land and vegetation). The concept of watershed management has developed to ensure effective use of both natural and social resources. The watershed development programmes include land, water and human resources as indispensable components. The watershed approach is not confined to the development of agriculture lands alone but covers all the area starting from the highest point

(ridge line to the outlet of the nala or natural stream. By adopting watershed as a unit different development measures are adopted and implemented carefully according to its capability. The watershed development programme is basically a land based programme with a focus to enhance agricultural productivity through in-situ water conservation that leads to socio-economic development of rural people. The aims of watershed management programme is to improve livelihood of rural people with conserving and regenerating the natural resources.

Impact of Entry Point Programmes

Entry Point Programmes	Impact
1. Drinking water facilities for human beings and cattle	Involvement of women in programme
	Help in SHG formation for women
	Overall people's participation in planning and implementation increased
2. Class-rooms for schools and kindergartens	Helped in rapport building
	People started contributing for community works
3. Common bath & washing facilities	Reduced hardships of women and men

Watershed development Programmes

The watershed programmesbegains with early 1970s in India as a way to address to food security and rural poverty in India's rainfed areas. Population living in the rainfed areas are poor with insufficient access to education and agriculture market. The mainfocus of watershed development programme is to increase productivity of agriculture lands in rainfed areas may hold the key to meeting the challenge of food security in the years to come. The Government of India has given high priority to the watershed programmes. Initially, soil conservation programmes were undertaken to check soil erosion, restore soil productivity to increase food production. Adequate importance was assigned to development of technology for problem identification, formulation and implementation of problem oriented projects, enactment of appropriate legislation and constitution of policy coordination bodies. Watershed development programmes*viz.* Soil Conservation in Catchment of River Valley Project, Integrated Agricultural Development In Drought Prone Areas, Desert Development Programme (DDP), Himalayan Watershed Management Project in Uttar Pradesh, Operational Research Projects on Integrated Watershed Management, National Watershed Development Programme of Rainfed Agriculture (NWDPRA), Integrated Wasteland Development Programme (IWDP), Integrated Watershed Management in the Catchments of Flood Prone Rivers, Integrated Watershed Development Project (Hills), Integrated Watershed Development Project (Plains), and projects funded by International organizationsare being undertaken by the Ministry of Agriculture, Ministry of Rural Development, Planning Commission, Govt. of India and NABARD and various NGOs. These programmes are based on Participatory Rural Appraisal (PRA) with active involvement of the watershed community in planning, monitoring, execution evaluation post project maintenance of the created assets of watershed. The planning is made following bottom-up instead of top-down approach. Planners and policy makers have to provide technical and administrative support based on Common Guidelines (Anonymous 2008). The people's participation holds the key for successful implementation of watershed development programmes. At every step, views of the local

community are taken into consideration for planning, designing and implementing various watershed development activities.

People's Participation

Intermediate Panchayats have an important role in planning the watershed development projects at the intermediate level. They can also provide valuable support to PIAs and Gram Panchayats/Watershed Committees, Voluntary Organizations in technical guidance with the help of technical experts. Voluntary Organizations have an important role in to generation awareness, capacity building and other aspects of the projects. User Groups and Self Help Groups constituted by Watershed Committees with the help of Watershed development team to ensure the active participation of land owners, poor agricultural labourers, women, shepherds and SC/ST persons. The institutional arrangements at various levels and technical support of watershed development teams can deliver the desired results provided the active support and involvement of watershed beneficiaries is ensured at various stages of the projects. In this endeavour, different farming systems namely horticulture, agro-forestry, silvi-pasture, forests livestock and land-use based on crops, are thoroughly integrated with watershed programmes for all round socio-economic development through employment generation, poverty alleviation, community empowerment and development of human and other economic resources of the rural areas as well as harmonizing the use of natural resources.

Capacity building

As emphasized earlier, well trained watershed functionaries in technical as well as social and economical aspects have an important role to play in successful implementation of the projects and maintenance of assets for creating livelihood opportunities by increasing incomes and inclusive growth and consequently socio-economic upliftment of entire watershed community. Keeping this in view, one year diploma programme in watershed management has been developed by the School of Agriculture; Indira Gandhi National Open University for capacity building in this thrust area. The programmeconsist of seven courses dealing with different aspects of watershed development namely concept, scope and importance of watershed management, elements of hydrology, soil and water conservation including water harvesting, rainfed farming, livestock and pasture management, horticulture, agro-forestry and allied systems, and funding, monitoring, evaluation and capacity building.These courses has equal weightage to theory and practical. The courses adequately deal with practical aspects of different watershed activities to enable a person to evolve and apply cost-effective technologies using local material with the expertise and cooperation of the beneficiaries. The course is related to project formulation in which the learner is attached to the model watershed for a period of 10 days during which the learner will collect and compile the information on various aspects of watershed activities.

Rain water harvesting techniques

Following are traditional techniques are used for augmentation of water resources

1. Small Ponds
2. Dammed Ponds
3. Cemented/ Stone
4. Construction of "Bauwris"

New Technique

1. Run –off harvesting-short-term storage
2. Semi- Circular Hoops
3. Trapezoidal bunds
4. NalaBandhan" (Mini earthen check dams)
5. Off- contour bunds or graded bunds
6. Rock catchment
7. Ground Catchment

Flood water harvesting –Short term storage

9. Diversion of run-off
10. Check dams for aquifer recharge
11. Sub –surface dams
12. Roof Rain water harvesting

Reservoirs / Tanks/Ponds

- Earthen check dam reservoirs
- Excavated tanks

Rain water harvesting structures through earthen dam is shown in Plate 1 and 2.



Plate 1: Rain water harvesting structures through earthen dam



Plate 2: Low cost rain water harvesting structures

Rainwater Harvesting in Farm Ponds

It is used for water harvesting/storage structure in arable land. Farm ponds are different types:-

a) Embankment type b) Dug out type

Embankment type pond is built across the stream in areas of gentle to moderately slope.Dug out type pond are constructed by excavating the soil, relatively in level areas.For harvesting of rainwater, farm ponds played a crucial role in the Himalayan region, and were the mainsource of water for irrigation as well as drinkingin horticulture, agro-forestry).Solution to waterscarcity problem in the Himalayan region lies to a greatextent in the rejuvenation of farm ponds.Farm pond need for scientific assessment of storage capacityand related hydro-geomorphic characteristics. The percolating type15 thousand litres capacity may be constructed forground water recharge. In addition earthen farmponds as well as poly lined farm pond of differentcapacity are most suitable and viable for hilly areas.Due to lost cost of these farm pondmarginal farmers can afford .The construction costof poly lined farm pond nearly @0.50 paise/litre storage for the drinkingwater as well as may be used in lean season for lifesaving irrigation in vegetable and fruit crops. LDPE farm pond is shown in Plate 3-4



Plate 3: Lined farm pond with brick pitching

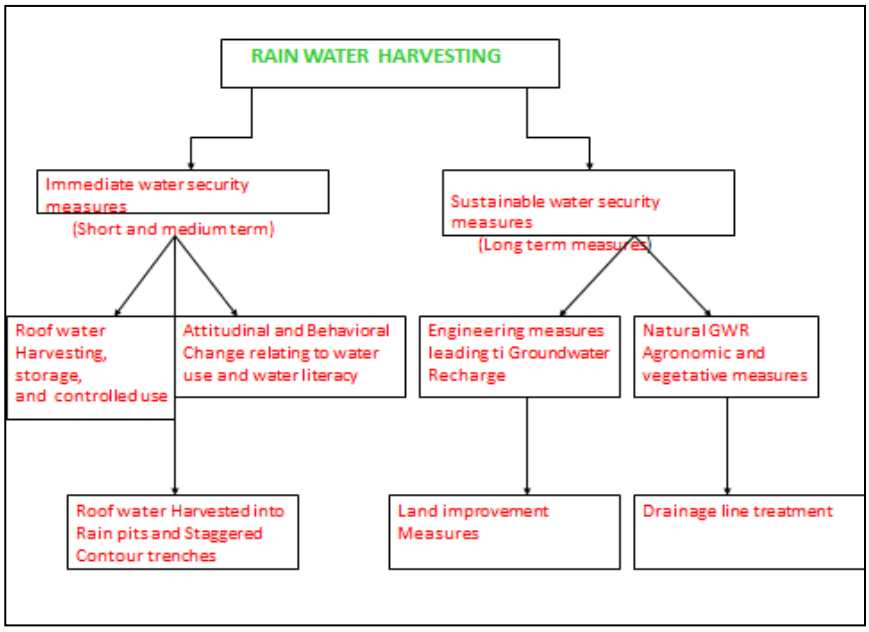


Plate 4: lined farm pond without pitching



Plate 5: Lined farm pond without pitching at Mansbal Srinagar

Rain water harvesting can be done for immediate security measure as well as forsustainable watersecurity measures which is shown in below diagram.



Climate change and Water Resources

Following are the sources of water resources

1. Natural precipitation
2. Groundwater resources
3. Freshwater rivers, streams, rivulets and lakes, dams and reservoirs and
4. Natural precipitation is the key source of water that feeds all the other water resources. Therefore a decrease in rainfall due to climate change will deleteriously affect all the other water resources.

Observed and projected decline in per capita average annual freshwater availability and growth of population from 1951 to 2050 is shown in Fig. 3. It is evident from Fig. 3 that the 'two-sided' effect on water resources as the rise in population will increase the demand for water leading to faster withdrawal of water and this in turn would reduce the recharging time of the water-tables. Increasing population is also concern as mean per capita annual freshwater availability decreases with increase in population.Change in climate will affect the soil moisture, groundwater recharge, and frequency of flood or drought, and finally groundwater level in different areas. Rise in sea level will increase the risk of permanent or seasonal saline intrusion into ground water and rivers.

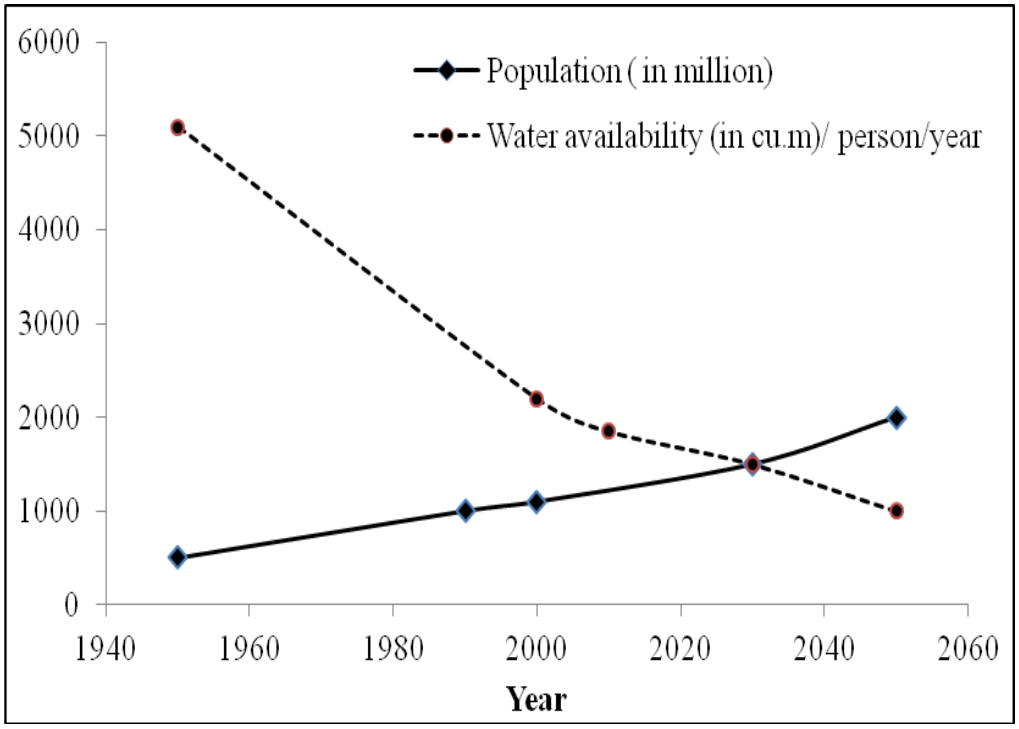


Fig. 3: Observed and projected decline in per capita average annual freshwater availability and growth of population from 1951 to 2050

The higher temperatures and changing precipitation patterns will severely affect the production patterns of different crops. Climate change has a direct impact on crop evapotranspiration (ET). In arid regions of Rajasthan state an increase of 14.8 per cent in total ET

demand has been projected with increase in temperature with one degree increase in temperature 5-10% wheat yield will fall & overall crop yield could decrease by 30%.Due to these effects India could experience 40% decline in agriculture productivity.The overall impact of climate change on worldwide food production is considered to be low to moderate with successful adaptation and adequate irrigation (IPCC, 1998).

In 2007, Union Ministry of Water Resources of the countryinitiated a Farmer Participatory Action Research Programmed in over2000 villages all over the country to assess the impact of water savingtechnologies on agriculture production. It has been found that yieldand income can be increased by 50 to 100 per cent in most of the cropsby using water saving technologies. Additional yield of 1 ton perhectare can be realized through supplemental irrigation. Ouragriculture is more prone to monsoon rains as we are growing highwater requiring crops like rice and sugarcane. We should increase areaunder low water requiring but high value crops like pulses and oilseedsto counter the erratic monsoons (Kumar andGautam, 2014).

Conclusion

World population has crossed the 7 billion figures and the most important challenge before the planners is the availability of adequate food for everyone. There is need to achieve sustainable increase in agricultural production but climate change has affects the sustainable agricultural production.Agricultural production can only be increased by reducing prevailing knowledge deficit of latest agricultural technologies with the farmers and watershed management approach. Climate change is posing the greatest threat to agriculture and food security in the 21st century, particularly in many of the poor agriculture based countries. Climate change is a real concern for the sustainable development of agriculture production globally.

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Prioritization of sub-watersheds of a Western Himalayan catchment using morphological parameters

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Abstract

Identification of vulnerable areas within the watershed has to be the first and primary step for any watershed management and planning project, since success of the project largely depends upon the accuracy in prioritization. In developing countries like India where availability of data is a major constraint, preparation of a fruitful watershed management project plan is a challenging task. Owing to scarcity of primary hydrological data, researchers have been constrained to link different morphological characteristics of watershed with the lithology of existing rocks and the permeability of the underneath strata, which are responsible for generation of surface runoff from the rainfall. In the present study, various morphological parameters representing one dimensional view via linear, two dimensional view via areal and three dimensional view via relief aspect of the catchment have been extracted in GIS environment by partitioning a western Himalayan catchment from Indian subcontinent into nine sub-watersheds (SW1 to SW9).The study catchment was found to be an eighth order drainage basin as per Strahler stream ordering scheme. The catchment is dominated by the trellis, parallel and dendritic drainage patterns in different sub-watersheds. Higher bifurcation ratios between the first and second order streams imply the presence of active gullies in the catchment. Medium to high drainage densities, ranging from 2.84 to 3.92 km/km^2 were found in the study area indicating weak or impermeable subsurface material, high mountainous relief and fine drainage texture. Most of the sub-watersheds are characterized with high relief ratio, relative relief and average slope, which are favorable to generate significant runoff even for a small volume of rainfall. In order to prioritize the catchment, a compound index was calculated by considering the individual rank assigned to all nine sub-watersheds based on 13 morphological parameters. Study reveals that SW6 sub-watershed has top priority and SW1 watershed has least. Compound ranking evaluated using morphological parameters in the present study may be helpful in identifying the critical areas in an un-gauged catchment and accordingly deciding the treatment measures in volume and space.

Keywords: GIS, Morphological parameters, Prioritization of watersheds, Himalayan catchment

Introduction

The response to soil and water conservation measures for alleviating erosion would be different for different parts of a catchment due to their physiographical variability throughout the catchment or in other words exhibit different physiographical settings in the sub-watersheds of the same catchment. Thus, it is not only necessary to know the state of erosion of the watershed but it is equally important to quantify the rate of erosion within the watershed to proportionately allocate the funds for their treatment for achieving the best output. In developing countries like India, observations of discharge and suspended sediment yield are usually gauged only at the

outlet of large watersheds normally when these rivers enter the plain areas. However, the major sources of sediment are the upstream hilly areas and eroded soils from these areas are transported through small mountainous tributaries, which are unfortunately un-gauged. Process of soil loss from a watershed is exclusively influenced by erosion, deposition and transportation sub-processes that continuously occur along the sediment flow path within the watershed (Aksoy and Kavvas 2005; Rawat et al. 2016). Therefore, using sediment data from the outlet of a large watershed to identify the actual source areas of sediment within the watershed cannot be justified. To overcome this problem, various morphometric parameters (drainage density, drainage frequency, form factor, length of overland flow, elongation ratio, circulatory ratio, compactness coefficient, drainage texture, bifurcation ratio, etc.) have been correlated with surface and sub-surface features like slope, soil, rock resistance, structure and geological history of the watershed which are responsible for runoff and consequent erosion from the watershed. Furthermore, most of the morphometric parameters are in the form of ratio, scale does not limit their application while comparing for different watersheds. These morphometric parameters have been linked with hydrological behavior of an un-gauged watershed through popular GIUH theory (Rodriguez-Iturbe et al. 1979), prioritization of sub-watersheds for their vulnerability of soil erosion (Nookaratnam et al. 2005 and Singh and Singh 2014), estimation of sediment production rate (Jose and Das 1982 and Rymbai and Jha 2012), identification of artificial recharge locations (Ghayoumian et al. 2005), permeability of underlying geological formation (Anbazhagan et al. 2005) and many more. Manual estimation of geomorphologic parameters is a tedious and cumbersome process and often discourages the field engineers from developing regional methodologies for solving various hydrological problems of un-gauged catchments or in limited data situations (Singh et al. 2003). With the advancement in the field of geo-spatial technologies like GIS and Remote Sensing (RS), geomorphological parameters can easily be extracted from the digitalized toposheets (Tarboton et al. 1991).

Therefore, considering the strong interaction between the morphology and hydrologic response of the watershed, in the present study morphological characterization of nine sub-watersheds of Tawi catchment has been carried-out using geospatial technique. The prioritization of sub-watersheds has been done through the compound index based on extracted morphometric parameters.

Study Area

In the present study, Tawi River catchment located in Jammu division of Jammu and Kashmir State of India (Fig. 1) is selected for detailed morphometric analysis. River Tawi, a major river in Jammu region is the left bank tributary of river Chenab, originating from the lap of Kali Kundi glacier in Bhaderwah flows through some parts of Doda and Udhampur districts, reaches Jammu from where it enters Pakistan and finally merges into Chenab. The Tawi River has a very high social impact as it is the only major source of water for drinking as well as agricultural and industrial needs of almost 20% population of Jammu and Kashmir. The average annual rainfall of the study area is about 1000 mm. Huge amount of sediment carried from the upstream hilly area by the flood water ultimately gets deposited along the banks and in the river channel when Tawi enters in the plains. Consequently, the channel capacity reduces significantly and stage of the river getting elevated causing overflow.

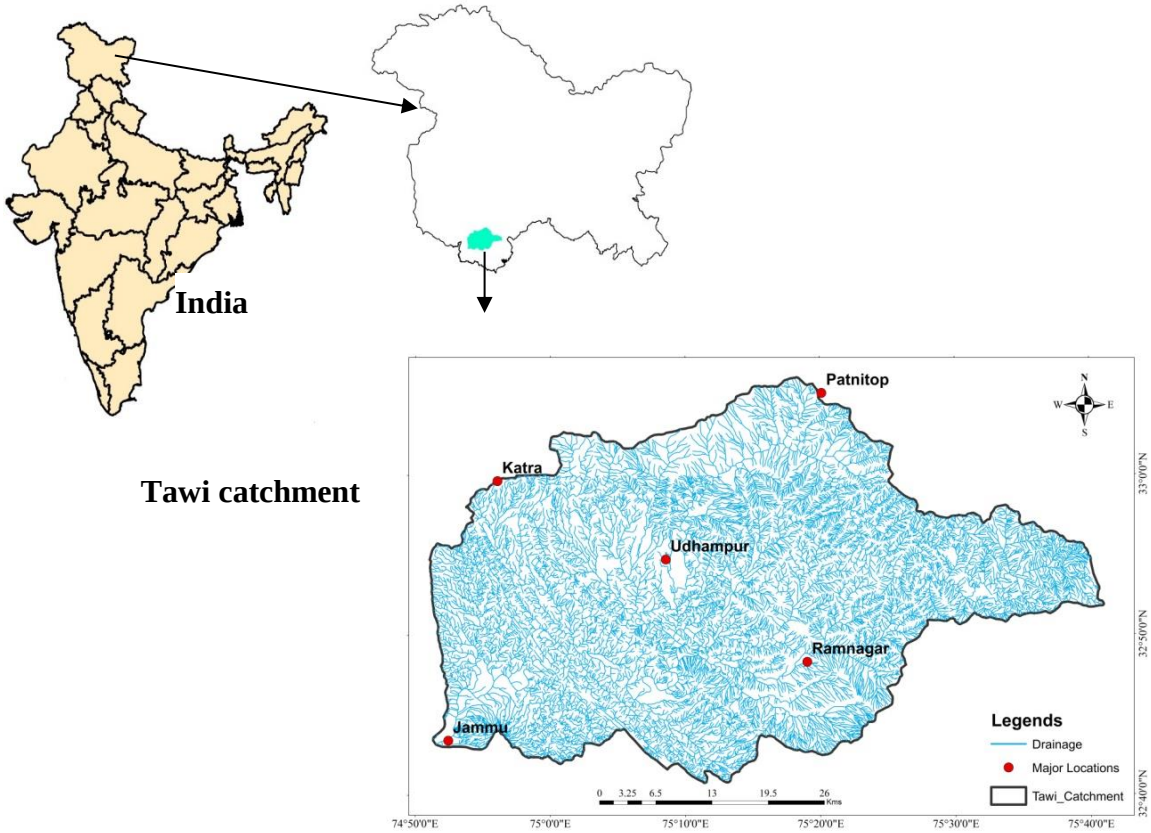


Fig. 1 Location of Tawi catchment

Materials and Methods

Data sources and analysis

In the present study, Tawi River catchment and its drainage network has been delineated from toposheets obtained from the Survey of India (SOI). Total eight toposheets of 1:50,000 scale viz., 43O4, 43O8, 43L13, 43P5, 43P9, 43L14, 43P2 and 43P6 have been geo-referenced in ArcGIS10.2 followed by digitalization of drainage network. By following the Strahler (1964) method, stream ordering has been carried-out for the entire Tawi catchment and it has found to be an eighth order catchment. According to the extracted drainage network, the entire drainage area of 2163 sq. km was subdivided into nine sub-watersheds having areas ranging from 97 sq. km to 487 sq. km for greater understanding of morphometric parameters and their correlation with hydrological response and consequent soil erosion in the catchment. In the subsequent discussions, these sub-watersheds will be termed as SW1 to SW9.The location of each sub-watershed is depicted in Fig. 2. The drainage networks of the nine sub-watersheds have been analyzed as per Horton's (1945) laws in ArcHydro module of ArcGIS. All sub-watersheds have been examined from all dimensional aspects i.e., linear aspect indicates one dimensional view of the watershed, aerial aspect shows two dimensional, while relief aspect explored three

dimensional characteristics of the watersheds. The formulae for computation of the different morphometric parameters are shown in Table 1.

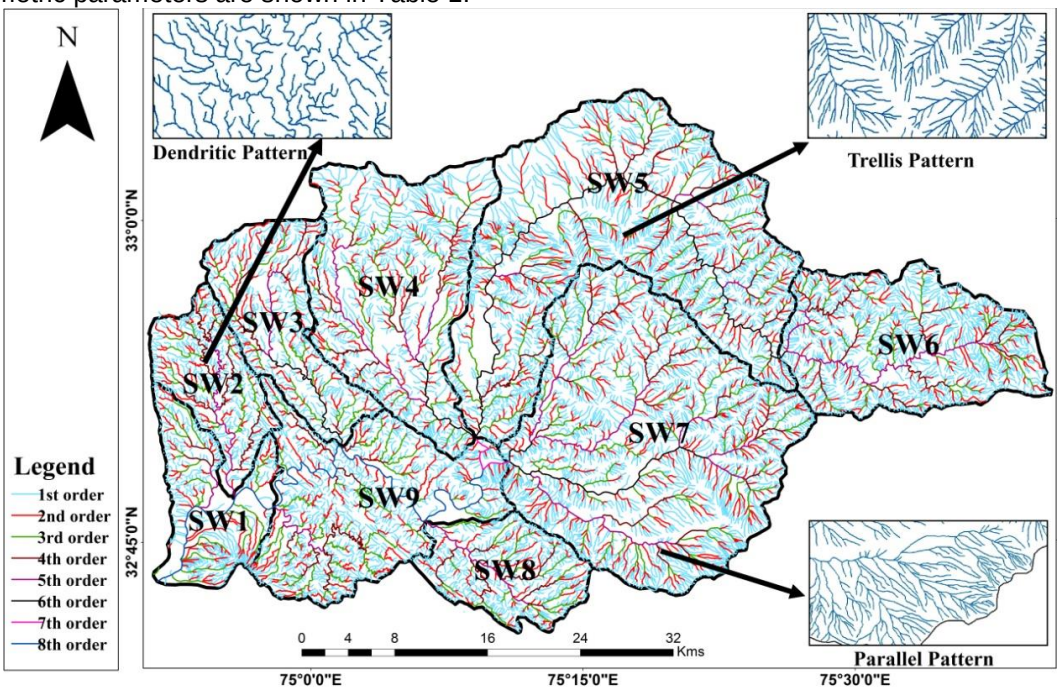


Fig. 2. Delineated sub-watersheds of Tawi catchment and their drainage network according to stream order.

Table 1 Different morphometric parameters used in the study and their standard formulae.

	Morphometric Parameter	Formula	Reference
Linear	Stream order(u)	Hierarchical rank	Strahler(1964)
	Basin Length(L)	$L=1.31*2A^{0.568}$ Where L=Basin length (km) A=Area of the basin (km^2)	Nookaratnam et al.(2005)
	Stream length(L_u)	Length of the stream	Horton(1945)
	Bifurcation ratio (R_b)	$R_b=N_u/N_{u+1}$ Where, Rb=Bifurcation ratio Nu=Total no. of stream segments of order 'u', Nu+1=Number of segments of the next higher order	Schumm (1956)
	Mean bifurcation ration (R_{bm})	R_{bm}=Average of bifurcation rations of all orders	Strahler (1957)

Areal	Drainage density (D_d)	$D_d=L_u/A$ where, D_d= drainage density, L_u= total stream length of all, A= Area of the basin	Horton (1945)
	Form factor(R_f)	$F_f=A/L^2$ Where F_f=Form factor A=Area of the basin (km^2) L=Basin length(km)	Horton (1932, 1945)
	Stream frequency (F_s)	$F_s=N_u/A$ where, F_s=stream frequency, N_u=total no. of streams of all orders, A=area of the basin	Horton(1945)
	Drainage texture (T)	$T=N_u/L_p$, where N_u=total no. of streams of all orders, L_p=perimeter of th basin	Horton(1945)
	Elongation ratio(R_e)	$R_e=1.128xA^{0.5}/L$ A=area of the basin (km^2) L=basin length(km)	Schumm(1 956)
	Circularity ratio(R_c)	$R_c=4\pi A/P^2$ Where R_C=circularity ratio A=Area of the basin (km^2)P=Perimeter(km)	Miller(1953), Strahler(1964)
	Compactness Coefficient (C_c)	$C_c=0.282L_p/A^{0.5}$, where L_p=perimeter of the basin, A=area of the basin	Horton(1945)
	Length of overland flow (L_o)	$L_o=1/(2XD_d)$, where D_d= drainage density	Horton(1945)
Relief	Total Relief (H)	H= Difference between maximum and minimum elevation of the watershed	Schumm(1956)
	Relative Relief (R_r)	$R_r=H/L_p$ where, H=total relief, L_p=basin perimeter	Schumm(1956)
	Relief Ratio (R_o)	$R_o=H/L$ where, H=total relief, L=basin length	Schumm(1956)

All thirteen morphological parameters pertaining to the one, two and three dimensional views of the watershed have been calculated for each sub-watershed of Tawi catchment. Keeping in view the nature of relationships (direct/inverse) of different morphological parameters with erodability, each sub-watershed has been ranked 1 to 9 based upon thirteen morphological parameters. Rank 1 indicates most severe, whereas 9 denotes least severe with respect to soil erosion. Final prioritization was worked out by considering all ranks of a particular sub-watershed, which were assigned on the basis of thirteen geomorphological parameters considered in the study. The sub-watershed having lowest compound index value has given highest severity towards soil erosion and vice-versa.

Results and Discussion

The various morphometric parameters of the Tawi catchment estimated in the present study are summarized in Tables 2&3.

Linear aspects

Stream ordering is the first step to extract the geomorphological parameters of a catchment. Tawi catchment was adjudged as eighth order basin according to the Strahler (1964) hierarchical rank. The drainage map with stream order of the Tawi catchment is shown in Figure 2. As the stream order increases the total number of streams decreases as suggested by Strahler (1957) and shown in Table 2. The drainage pattern of an area reflects the nature of slope, geological structure and lithologic controls of the underlying rocks (Zernitz 1932; Easterbrook 1969, Nag and Chakraborty 2003).Study area comprises three kind of drainage pattern viz., trellis, parallel and dentritic (Fig. 2). In trellis type drainage pattern primary or secondary tributaries meet the main stream at about right angle. Such patterns are developed in the areas of folded sedimentary rocks of various resistances to erosion. In sub-watersheds SW5 and SW6, trellis is the dominant drainage pattern (Fig. 2). However, in SW7, SW3 and SW1, parallel drainage pattern is the dominant drainage pattern (Fig. 2). In parallel drainage system primary and secondary stream flow parallel to each other and meet main channel at about same angle. Such drainage pattern is controlled by the regional slopes and normally starts from the water divide of the watershed. However, dentritic drainage pattern is found frequently in SW4, SW2 SW8 and SW9 sub-watersheds and some parts of other sub-watersheds. Dendritic type of drainage pattern reflects the homogeneity in texture, rock and lack of structural control.

Streams of various orders in all sub-watersheds were counted and their lengths from mouth to drainage divide were measured with the help of GIS software and depicted in Table 2. Generally, the total lengths of stream segments are highest in first order streams and decreases as the stream order increases (Table 2). It can be observed from Table 2 that number and length of first order streams in SW5, SW6 and SW7 sub-watersheds are proportionately higher as compared to other sub-watersheds. This can be attributed to the lithology of the underlying surface and local converging terrain, which facilitates quick conversion of rainfall into runoff and eventually early formation of drainage network (Singh and Singh, 1997).

In the study area, the values of R_b are in the middle range and vary from 3.0 to 5.0 (Table 2). The minimum and maximum value was found to be 3.23 and 4.93 for watershed SW9 and SW8, respectively. In general, it can be witnessed from Table 2, that the bifurcation ratios between the first and second order streams are higher than the higher order streams in all sub-watersheds, indicating that the catchment falls under areas of active gullies and ravines, hence prone to higher erosion rates.

Table 2 Extracted streams of different orders and their bifurcation ratios

Sub-watershed	Parameter	Stream Order								Mean Bifurcation ratio (R_{bm})
		I	II	III	IV	V	VI	VII	VIII	
SW1	No. of Stream	370	75	18	3	2	0	0	1	4.15
	Stream Length(km)	197.9	71.2	50.1	8.0	5.2	0.0	0.0	17.8	
	Bifurcation ratio	4.93	4.2	6.0	1.50	-	-	-	-	
SW2	No. of Stream	369	81	18	6	1	0	0	0	4.51
	Stream Length(km)	189.4	64.6	34.1	37.8	20.7	0	0	0	
	Bifurcation ratio	4.6	4.5	3.0	6.0	-	-	-	-	
SW3	No. of Stream	418	96	19	7	2	1	0	0	3.52
	Stream Length(km)	236.8	86.4	46.5	24.0	9.6	13.6	0.0	0.0	
	Bifurcation ratio	4.4	5.05	2.71	3.5	2.0	-	-	-	
SW 4	No. of Stream	709	158	37	9	3	1	0	0	3.77
	Stream Length(km)	484.1	144.9	83.5	34.4	28.9	10.5	0.0	0.0	
	Bifurcation ratio	4.49	4.27	4.11	3.00	3.00	-	-	-	
SW 5	No. of Stream	1809	363	74	19	3	1	0	0	4.62
	Stream Length(km)	1051.3	276.4	126.2	61.7	8.2	61.9	0.0	0.0	
	Bifurcation ratio	4.98	4.90	3.89	6.33	3.0	-	-	-	
SW 6	No. of Stream	1110	207	45	11	2	1	0	0	4.31
	Stream Length(km)	617.4	139.2	71.0	43.9	29.6	0.9	0.0	0.0	
	Bifurcation ratio	5.36	4.6	4.09	5.5	2.0	-	-	-	
SW 7	No. of Stream	1849	370	84	20	6	2	1	0	3.66
	Stream Length(km)	1072.3	290.5	143.8	56.7	58.0	24.1	0.2		
	Bifurcation ratio	4.99	4.40	4.2	3.33	3.0	2.0	-	-	
SW 8	No. of Stream	446	89	24	8	1	0	0	0	4.92
	Stream Length(km)	239.9	60.0	42.7	27.1	13.1	0.0	0.0	0.0	
	Bifurcation ratio	5.01	3.7	3.0	8.0	-	-	-	-	
SW 9	No. of Stream	881	183	44	11	2	3	2	1	3.23
	Stream Length(km)	462.6	139.9	96.9	41.1	9.8	0.4	5.9	41.8	
	Bifurcation ratio	4.81	4.15	4.0	5.5	0.66	1.5	2.0	-	

Areal aspects

Areal aspects include different morphometric parameters, like drainage density (D_d), stream frequency (F_s), drainage texture (T), form factor (R_f), infiltration number (I), circulatory ratio (R_c), elongation ratio (R_e) and length of the overland flow (L_o) and compactness coefficient (C_c). The values of these parameters were calculated and results are given in Table 3.

Drainage density in the study area varies between 2.84 (SW4) and 3.92 (SW6) indicating medium to high drainage density (Table 3). High drainage density in SW6 sub-watershed may be resultant of weak or impermeable subsurface material, high mountainous relief and fine drainage texture. However, low drainage density in SW4, SW1 and SW3 sub-watersheds indicate areas of highly resistant or permeable subsoil material, low relief and coarse drainage texture.

Table 3. Aerial aspect of the Tawi River Catchment

Sub-Watershed	D_d (km/km^2)	F_s (no./km^2)	I	R_c	R_f	R_e	T	L_o (m)	C_c
SW1	3.232	4.328	13.99	0.350	0.307	0.626	7.516	155	1.69
SW2	3.576	4.901	17.53	0.496	0.312	0.630	9.586	140	1.42
SW 3	3.054	3.977	12.15	0.434	0.298	0.616	8.643	164	1.52
SW4	2.846	3.318	9.44	0.496	0.270	0.587	10.964	176	1.42
SW5	3.257	4.660	15.18	0.370	0.250	0.565	17.653	154	1.64
SW6	3.923	5.984	23.48	0.579	0.277	0.594	19.489	127	1.31
SW7	3.407	4.828	16.45	0.674	0.251	0.565	24.575	147	1.22
SW8	3.675	5.454	20.05	0.586	0.309	0.627	12.020	136	1.31
SW9	3.356	4.737	15.89	0.382	0.276	0.593	12.735	149	1.62

Stream frequency of the sub-watersheds varies from 3.32 to 5.98. Sub-watersheds SW6 and SW8 are associated with high stream frequency, while sub-watersheds SW4 and SW3 have low stream frequency. Drainage density and stream frequency are similar measures of stream network of a drainage basin. The drainage texture of all the 9 sub-watersheds varied from coarse to very fine. The sub-watersheds located in the downstream part of the Tawi catchment (SW1, SW2, SW3, SW4 and SW9) comprises of coarse drainage texture; however, sub-watersheds of upstream part or hilly region (SW5, SW6 and SW8) have moderate to very fine texture. The finer the texture, more will be the dissection of the watershed, which will lead to higher erosion rates.

The values of form factor of the studied sub-watersheds are between 0.2 and 0.3. According to the values of form factor SW5, SW7 and SW4 sub-watersheds are relatively more elongated with lower values of form factor. However, SW2, SW8 and SW1 are having relatively less elongated shape and so have higher values of form factor. Sub-watershed SW4 has the lowest infiltration number 9.44 and the SW6 has the highest infiltration number of 23.48. Higher the infiltration number lower will be the infiltration and consequently higher will be the runoff. It gives an idea about the infiltration characteristics which play vital role in transformation of rainfall into the runoff. High value of infiltration number in SW6 and SW8 reveal that these sub-watersheds may have impermeable lithology and higher relief. The elongation ratio ranges from 0.0 to 1.0 over a wide variety of climatic and geological environments. High value (nearing 1) of elongation ratio is typical of regions of low relief, whereas low values are generally associated with strong relief and steep ground slopes. In Tawi catchment area SW4, SW5, SW6, SW7 are having high relief (consisting high average slope) and hence associated with low values of elongation ratio. Elongated basin with high bifurcation ratio like SW5 yields a low but extended peak flow (Verstappen 1983). The circularity ratio is a similar measure as elongation ratio, originally defined by Miller (1953). The circularity ratio for all sub-watersheds is in the range of 0.35 to 0.67. It is clear from the Fig. 2 that SW5 is elongated and hence attributed to low value of circularity ratio (0.37), however, SW7 is circular in nature and associated with higher value of circularity ratio (0.674). The term length of overland flow is used to describe the length of flow of water over the ground before it becomes concentrated in definite stream channels. Overland flow lengths range from 127 meters to 176 meters in Tawi sub-watersheds. SW6 has highest relief among all sub-watersheds and hence has lowest length of overland flow i.e. 127 meters. However, smaller the value of overland flow the surface runoff will quickly enter the streams having well developed drainage network and higher slope. In such watersheds a significant amount of surface runoff will be contributed to the stream discharge for even a low amount of

rainfall. is used to express the relationship of a hydrologic basin with that of a circular basin having the same area as the hydrologic basin. The values of Compactness coefficient (C_c) in the nine sub-watersheds of Tawi catchment varies from 1.22 to 1.69 showing variations across the watersheds. It can be seen from Fig 2 that SW7 is almost circular in shape, which tends to have a low value of compactness coefficient (close to unity). However, SW1, SW5, SW9 have higher values of Cc due to their elongated shape. A circular basin is the most hazardous from a drainage stand point because it will yield the shortest time of concentration before peak flow occurs in the basin.

Relief aspect

Relief aspects of drainage basin relate to the three dimensional features of the basin involving area, volume and altitude of vertical dimension of landforms wherein different morphometric methods are used to analyze terrain characteristics. In this study, thus, relief aspect includes the analysis of total relief or watershed relief, relief ratio, relative relief and average slope of all nine sub-watersheds of the Tawi catchment and presented in Table 4.

Total relief or watershed relief controls the gradient of drainage lines within the watershed and hence significantly influences the soil erosion of the watershed (Ozdemir and Bird 2009). SW5, SW6, and SW7 are characterized by high relief i.e. 2737 m, 2704 m, 2157 m, respectively and SW3, SW4, SW8 and SW9 display medium relief i.e. 1469 m, 1967 m, 1215 m and 1012 m, respectively. However, SW1 and SW2 are characterized by low relief i.e. 457 m and 561 m, respectively. Most of the watersheds display high relief and hence are severely prone to generation of significant runoff and consequent soil erosion. Relief ratio is defined as the ratio between the total relief of a basin and the longest dimension of the basin parallel to the main drainage line (Schumm 1956). The advantage of relief ratio over the total watershed relief is that it removes the size effect by dividing the total relief by the basin length. In Tawi catchment, relief ratio varies from 19.19 m/km (SW2) to 82.74 m/km (SW6) (Table 4). Significantly high relief ratio especially in SW6 indicates the steepness of the principal flow path, which eventually eroded the bank of the stream. The relative relief represents actual variation of altitude in a unit area with respect to its local base level. It means that the steeper the slope the higher is the surface above its base. The values of the relative reliefs for 9 Sub-Watersheds of Tawi catchment varies from 7.32 m/km to 38.3 m/km, indicating the terrain of Tawi catchment is highly undulating. Very high values of R_r for SW6 sub-watershed indicates that it is highly susceptible to soil erosion. Average slope of the watershed S_a has direct influence on the erodibility of the watershed. It has been proved by researchers that more the slope, more will be the erosion, if other factors remain unchanged. The average slope for different sub-watersheds varies between 10.35% (SW1) to 44.44 % (SW6) (Table 5). It was observed that high relief ratio and relative relief sub-watersheds were characterized by high slopes and vice versa.

Table 4. Relief aspect of the Tawi River catchment

Sub-Watershed	H (m)	R_o (m/km)	R_r (m/km)	S_a (%)
SW1	457	19.55	7.32	10.35
SW2	561	19.19	11.32	15.38
SW 3	1469	51.17	23.38	19.37
SW4	1967	61.87	23.52	24.05
SW5	2737	42.21	21.30	35.16
SW6	2704	82.74	38.30	44.44
SW7	2157	68.19	22.73	30.77
SW8	1215	61.21	25.71	20.23
SW9	1012	0.022	0.011	20.33

Prioritization of sub-watersheds using morphological parameters

Morphological parameters (linear, aerial and relief) for all sub-watersheds were calculated separately and shown in Table 2-4. For prioritization, all nine sub-watersheds are ranked based on their corresponding values of morphological parameters. Morphological parameters like drainage density, stream frequency, bifurcation ratio, infiltration number and texture ratio have direct relationship with erosivity. Therefore, the sub-watershed having highest numerical value of these individual parameters was ranked first and next higher sub-watershed was ranked second and so on. Similarly, aerial parameters like elongation ratio, circularity ratio, form factor and compactness coefficient have inverse relationship with erosivity. Therefore, the sub-watershed having lowest value for these individual parameters was assigned first rank and next lower was second and so on. Similarly, sub-watersheds are ranked according to relief aspect as it has direct relationship with the erosivity. Finally, based on all individual ranking, a compound rank value was calculated for each sub-watershed and is depicted in Table 5. It is evident from the Table 5 that SW6 has the first priority (lowest value of compound rank value i.e. 2.3) and SW1 has the least priority (highest value of compound rank value i.e. 7.2). The highest priority indicates the greater degree of erosion in the particular sub-watershed and it becomes a potential candidate for applying soil conservation measures. Thus, in order to check soil erosion, treatment has to be started from SW1 and then to others depending on their priority. The priority map of Tawi catchment is shown in Figure 3.

Table 5. Prioritization of Sub-watersheds of Tawi catchment according to morphological parameters.

Sub-Watershed	Ranking based on individual morphological parameter													Compound rank value	Final Ranking
	R_b	D_d	F_s	I	R_c	R_f	R_e	T	C_c	H	R_h	R_r	S_a		
SW1	5	7	7	7	1	7	7	9	9	8	8	9	9	7.2	9
SW2	3	3	3	3	5	9	9	7	6	9	9	8	8	6.3	8
SW 3	8	8	8	8	4	6	6	8	4	5	5	4	7	6.2	7
SW4	6	9	9	9	6	3	3	6	5	4	3	3	4	5.4	5
SW5	2	6	6	6	2	1	5	3	8	1	6	6	2	4.2	3
SW6	4	1	1	1	7	5	1	2	3	2	1	1	1	2.3	1
SW7	7	4	4	4	9	2	2	1	1	3	2	5	3	3.6	2
SW8	1	2	2	2	8	8	8	5	2	6	4	2	6	4.3	4
SW9	9	5	5	5	3	4	4	4	7	7	7	7	5	5.5	6

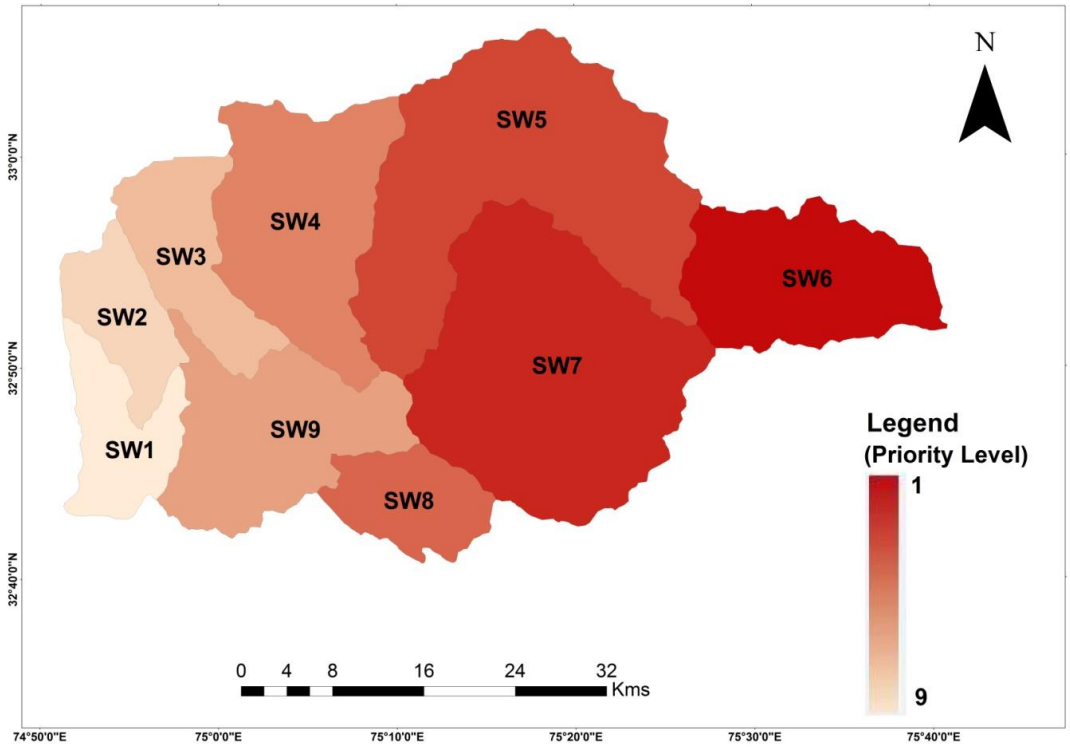


Figure 3: Sub-watershed wise priority map of Tawi catchment.

Conclusions

Hydrological response and consequent soil erosion characteristics of a western Himalayan catchment have been discussed using the morphological parameters as extracted in GIS environment. Besides, dendritic drainage pattern, a common drainage pattern in Himalayan areas, existence of trellis drainage pattern in some part of Tawi catchment indicates the presence of folded sedimentary rocks that has strong control on the drainage network. However, presence

of parallel drainage pattern in some areas of the catchment indicates the dominance of regional slopes. A moderate to high drainage density and stream frequency indicate moderate to steep slopes and presence of impervious subsurface layers in the sub-watersheds of the Tawi catchment. High total relief, relative relief and relief ratio especially in upstream catchments give less time to infiltrate the storm water into the ground and it immediately turns into runoff. High infiltration number and low overland flow length values calculated from morphological parameters for these particular sub-watersheds in the present study also implies the erosive nature of these sub-watersheds. Hydrologic responses and sediment production rates as evaluated in the present study for different sub-watersheds using morphological parameters suggest that the Tawi catchment produces moderate to high amount of sediments annually and the catchment is characterized by high runoff zone. The proposed methodology for prioritization of a catchment using morphological parameters in GIS environment is easy to use and very useful for an un-gauged catchment. Identifying the criticality of these watersheds using morphological based approach would help in facilitating investment decisions and making best use of the available resources.

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ESTIMATION OF CROP WATER REQUIREMENT FOR MULTIPLE CROPS IN THE LOWER BHAVANI PROJECT COMMAND OF TAMILNADU USING AQUACROP 4.0 WATER PRODUCTIVE MODEL

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Abstract

The planning and design of irrigation system is essential to supply the required amount of irrigation water.For effective scheduling of irrigation process proper knowledge on the water requirement of crops,water deficits and growth stages are needed.A study was conducted at the Singiripalyam distributory of Lower Bhavani Project(LBP) command in Tamilnadu for assesing the crop water requirement for multiple crops grown in area by using Aqua Crop 4.0 water productive model developed and modifed by FAO(2012).The reference crop evapotranspirationETo was computed from the ETo calculator program developed by FAO.The average crop water requirement for the crops like Sugarcane, Banana,Paddy, Maize, Groundnut, Turmeric, Coconut and vegetables were estimated for the period 2004-2013.In this study Crop water requirement for normal,excess and deficit rainfall years were alsocomputed by using the AquaCrop4.0 model.The highest crop water requirement was found to be for sugarcane (831mm) and the lowest for the Maize (319mm).

Key words: Water requirement,ReferenceCrop evapotranspiration(ETo),Effective rain fall

The planning and design of irrigation system is essential to supply the required amount of irrigation water. The water requirement of the plant per day depends on the water that is taken by the plant from the soil and amount of water evaporating from the soil in the immediate vicinity of the root zone in a day. The plant intake is affected by the leaf area,stage of growth,climate,soil conditions etc. The water requirement and irrigation schedule can be determined from the soil or plant indicators based methods or soil water budget method, but the simplest and most commonly method is to use pan evaporimeter data. To make maximum use of available water supplies, the irrigator must have the knowledge of total seasonal water requirements of crops and how water use varies during the growing season. The seasonal requirement is necessory to select crops and areas that match the availablility water supply. Knowledge of the variation during the season aids in scheduliing irrigations. The expected effective rain fall is to be considered in determinning the field irrigation requirement.

Materials and Methods

Estimation of Crop Water Requirement for LBP command

Study area

Singiripalyam distributory is located at 11°15N latitude and 77°17 E longitude and at an altitude of 266 meter above mean sea level in the Lower Bhavani Project(LBP) command of Tamilnadu. The climate of this region is semiarid and subtropical,with average rain fall of 670 mm received mostly during monsoon season..The weather data recorded at observatory of Agricultural Research Station,Bhavanisagar (Table-3) were utlized for estimation of ETo and irrigation water requirement of crops in the distributory command. The crop water requirement of the crops like Maize,groundnut,banana,sugarcane,paddy turmeric,coconut and vegetable crops grown both in kharif and rabi seasons during normal,excess and deficit rainfall years were assessed by using the FAO dveloped programs like ETo calculator and AquaCrop 4.0 model.

Cropping pattern

The soil in the command area is sandy loam and the crops grown generally are paddy, maize, groundnut, sugarcane, banana, turmeric, coconut and Vegetables like tomato, brinjal etc. The average annual rain fall of of the study area is 670 mm. The net irrigation requirement for the above crops grown in the study area for the years 2006,2007 and 2013 were obtained by running the Aqua Crop 4.0 model as they refers to be normal, excess and deficit rain fall years respectively during the period 2004-13. The average irrigation requirement for these crops were also assessed during the above period The annual rainfall values for the years 2006,2007,2013 were 650mm,921mm and 498mm respectively.

Description of AquaCrop 4.0 – FAO crop-water productivity model

AquaCrop 4.0 is a crop water productivity model developed and modified by the Land and Water Division of FAO (2012) to simulate yield response to water. AquaCrop is a general model, as it is widely used for a wide range of herbaceous crops, including forage, vegetable, grain, fruit, oil, and root and tuber crops. It simulates yield response to water of herbaceous crops, and is particularly suited to address conditions where water is a key limiting factor in crop production.

Input requirement

The Input consists of five components such as weather data, crop and soil characteristics, and field and irrigation management practices that define the environment in which the crop will develop .

1 Climate component

The atmospheric environment of the crop is described in the climate component of AquaCrop and deals with key input meteorological variables. Five weather input variables are required to run AquaCrop: daily maximum and minimum air temperatures (T), daily rainfall, daily evaporative demand of the atmosphere expressed as reference evapotranspiration (ETo), and the mean annual carbon dioxide concentration in the bulk atmosphere (Predetermined).While the first four components are derived from typical agro-meteorological stations, the CO_2 concentration uses the Mauna Loa Observatory records in Hawaii..

2 Crop component

AquaCrop model can be used for fruit or grain producing crops, root and tuber producing crops, leafy vegetable producing crops and forage crops. Each crop type has its own

corresponding developmental stages. The root system in AquaCrop is simulated through its effective rooting depth and its water extraction pattern. The effective rooting depth (Z) is defined as the soil depth where most of the root water uptake is taking place.

3 Soil component

The soil component of AquaCrop is configured as a dispersed system of variable depth allowing up to 5 horizons of different textural composition along the profile. The model performs a water balance that includes the processes of runoff (through the curve number), infiltration, redistribution or internal drainage, deep percolation, capillary rise, evaporation, and transpiration. A daily step soil water balance track of the incoming and outgoing water fluxes at the boundaries of the root zone and soil water retained in the root zone can be kept. A distinctive feature of the water balance in AquaCrop is the separation of soil evaporation (E) from crop transpiration (Tr) based on a modification of the Ritchie's approach (Ritchie, 1972). In the simulation of E, the effects of mulches, withered canopy cover, partial wetting by localized irrigation, and the shading of the ground by the canopy can also be included.

4 Field management component

The field management related to the fertility level or regime to be adopted during the crop simulation, and to field-surface practices such as mulching to reduce soil evaporation, or the use of soil bunds to control surface run-off and infiltration can be considered.

5 Irrigation water management

The water management options related to (i) rain fed-agriculture (no irrigation) and (ii) irrigation where, after selecting the method (sprinkler, drip, or surface, either by furrow or flood irrigation) can be considered. The user can define their own schedule on the basis of depth or timing criteria, or allow the model to automatically generate the scheduling on the basis of fixed interval, fixed depth, or fixed percentage of soil water content criteria. The irrigation option is particularly suited for simulating the crop response under supplemental or deficit irrigation.

Reference evapotranspiration

The ETo Calculator, an evapotranspiration model developed by FAO was used to compute the reference evapotranspiration values. The model uses Penman-Monteith method to calculate the ETo values. The ETo values thus obtained are uploaded to AquaCrop model.

Effective rainfall

The effective precipitation is one of the water inputs to the soil root zone. For irrigation purpose the effective rainfall is defined as the part of total precipitation during the crop growing period that is available to meet the evapotranspiration needs of that crop. USDA Soil Conservation Service Method (USDA-SCS Method) is used by the crop model for calculating the effective rainfall.

In this method the monthly effective rainfall can be calculated according to

ER=R(125-0.2*R)/125 for R_{tot} <250 mm and

ER= 125-0.1 *R for R_{tot} >250 mm

The net irrigation requirement for crops grown in the distributory is computed by the AquaCrop4.0model.

Net Irrigation requirement of crops

The net irrigation requirement (NIR) of a crop is the amount of water, in addition to rainfall, that must be applied to meet crop evapotranspiration (Etc) without significant reduction in yield. To avoid crop water stress, rainfall and irrigation must be sufficient to meet the crop ET requirement. Various methods are available to estimate the reference crop evapotranspiration (ETo).The crop evapotranspiration is calculated uses the following equation,

$$ET_c = K_c * ET_O$$

Where,

ET_C= crop evapotranspiration (mm/day)

K_c= crop coefficient and

ET_O= reference evapotranspiration (mm/day)

The net irrigation requirement of crop can be estimated from the following equation,

$NIR = ET_C - ER$

Where,

NIR = Net irrigation requirement in a given month, mm/month and

ER = Effective rainfall in a given month, mm/month

The NIR for the multiple crops grown in the study area for the years 2006,2007 and 2013 were obtained by running the AquaCrop 4.0 model as they refers to be normal, excess and deficit rain fall years respectively during the period 2004-13.

Results and Discussion

Assessment of Irrigation water Requirement

Assessment of crop water requirement for various crops is an important factor and basic requisite for crop planning in a command. During 2012-13 the total cultivable area in the Singiripalyam distributory is 513 ha. The major area (126 ha) in the distributory was under Banana which is nearly 25 percent of the total cropped area. The other major crops grown are paddy, sugarcane, maize, groundnut, turmeric, coconut and vegetables like tomota and brinjal. The crop water requirement for all these crops were calculated using Aqua Crop 4.0 model developed and modified by Raes et al. (2012) for the normal, excess and deficit rainfall years of 2006,2007,2013 respectively. The cropping pattern in the Singiripalyam distributory is given in Table1.

Table1. The cropping pattern in the Singiripalyam distributory during 2012

S.No	Name of crop	Cropped Area (ha)
1	Banana	126
2	Sugarcane	110
3	Paddy	105
4	Maize	37
5	Groundnut	24
6	Turmeric	38
7	Coconut	16
8	Vegetables	57

Groundnut 1 and Groundnut 2 represent the groundnut crop grown in monsoon (June-Sept) and non-monsoon periods (Oct-Mar). Similarly, Maize1 and Maize2 represent the crop grown monsoon periods (Jun-Sept) and in non-monsoon period (Feb-May) and Veg1 and Veg2 represent the vegetable crops grown in monsoon season (June-Oct). and non-monsoon season (Feb-May) respectively. Cropping calendar in the study area is given in Table2

Table 2. The cropping calender in the Singiripalyam distributory

S.No	Name of crop	Duration of crop (days)	Starting date of season
1.	**Maize-1**	110	June 30
2.	**Maize-2**	110	Feb 20
3.	**Groundnut-1**	105	June 20
4.	**Groundnut-2**	105	Oct 25
5.	**Paddy**	120	June 15
6.	**Sugarcane**	360	July 5
7.	**Banana**	335	June 15
8.	**Turmeric**	300	May 25
9.	**Coconut**	360	July 10
10.	**Vegetables-1**	115	June 5
11.	**Vegetables-2**	115	Feb 15

4.6.1. Reference Evapotranspiration

From the daily weather data i.e., maximum and minimum temperatures, maximum and minimum relative humidity, wind speed, and sunshine hours, the monthly ETo values were calculated (2004 – 2013) using ETo Calculator developed by FAO. The average weather parameters of the study area are as given in Table 3. It can be seen that the monthly average reference evapotranspiration is highest during the month of May (7.10 mm/day) which is due to higher temperature, low relative humidity, high wind velocity and more sunshine hours during the day, while, ETo value was minimum in the month of December (2.1 mm/day) as represented in Fig. 1

Table 3. Average climatological data of the study area (2004-2013)

Month	Max. Temp, ^{0}C	Min. Temp, ^{0}C	Max. RH, percent	Min. RH, percent	Wind Velocity, kmph	Sunshine, hrs	ETo, mm/day
January	24.6	5.7	84.4	36.8	2.9	9.2	2.32
February	26.5	7.7	73.8	28.3	3.6	9.6	3.14
March	31.5	12.9	57.4	21.2	4.5	9.8	4.52
April	36.2	19.1	42.6	18.8	5.7	10.2	6.09

May	38.4	24.4	47.5	22.5	7.5	10.6	7.10
June	36.3	25.7	66.3	40.6	8.7	8.4	6.62
July	30.8	24.2	82.5	65.6	7.4	4.6	4.36
August	29.2	22.9	87	71.3	5.4	4.3	3.67
September	31.3	20.9	84.2	56.2	4.2	7.4	4.15
October	32.5	15.5	76.9	31.9	3.1	9.3	3.91
November	28.9	10.4	74.4	31.5	2.8	9.1	2.98
December	24.4	6.2	82.5	33.2	2.4	8.8	2.10

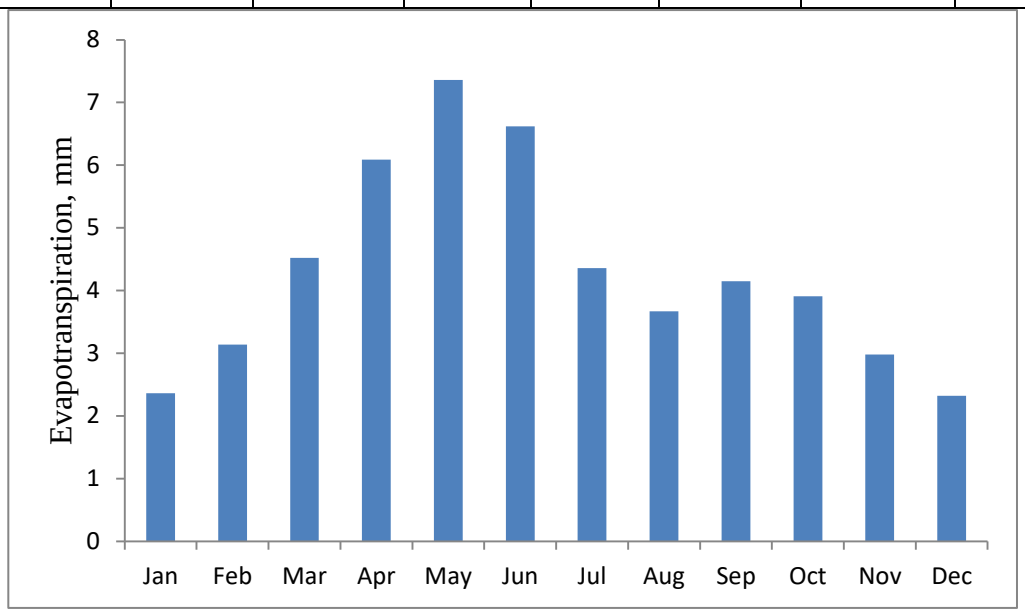


Fig 1. Average monthly reference evapotranspiration (ET_0) in the command area

The model uses the input data such as maximum and minimum temperatures, relative humidity, evapotranspiration, soil type, depth to root zone, number of days of crop growth, crop coefficient at different stages, crop canopy cover, plant population and finally irrigation methods such as flooding, furrow, drip and sprinkler method. The model computes the Net irrigation requirement, Soil water balance, runoff, drainage, yield and biomass index and water use efficiency parameters. The model was run for multiple crops and multiple crop periods (2004-2013) successively.

The monthly irrigation water requirements for crops grown in Singiripalyam distributory command area for normal rainfall year (2006) followed by excess rainfall year (2007) and deficit rainfall year (2013) are presented in Table 4, Table 5 and Table 6 respectively.

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The irrigation water requirement for sugarcane crop is 825mm during the normal rainfall year(2006) and highest value in the month of March which is139.5mm. due to higher ETo values

during summer month. The monthly irrigation water requirement for Gnut1 during (June-Dec) was less when compared to Gnut2 grown in non-monsoon period. The rainfall received during NE monsoon period was was sufficient to meet the water requirement with little supplemental irrigations. The higher relative humidity in early stages, followed by strong sunlight upto 12 hrs during flowering stage are conducive for Gnut1 crop. The water requirement for Gnut2 was 174 mm due to less rainfall during Jan-Mar . Higher water requirements during vegetative and reproductive stages are beneficial for the crop. During the normal rainfall the highest water requirements for needed for sugarcane(825mm) and banana(822 mm) since these crops are grown throughout the year. The next highest water requirement is for the coconut crop(754mm)

The irrigation water requirement for the crops were highest during the months of Feb and May due to summer months . The irrigation water requirement was nil during Nov and it was just 9.3 mm during the month of Dec. The monthly water requirements in excess rainfall year (2007) were less when compared to normal rainfall year, 2006.The reasons for variation in water requirement depends not only on rainfall but also climatic conditions such as temperature, relative humidity etc. Relative humidity will be less in monsoon period than in non-monsoon period resulting in less irrigation water requirement. The irrigation water requirement during the year 2013, (a deficit rainfall year) were higher compared to the years 2006 and 2007 are presented in Table.7The water requirement of Sugar cane is highest (1007mm) and the lowest being the groundnut-2 during the deficit rainfall year The variations in irrigation water requirements for deficit, normal and excess years is shown in Table7

Table 7. The variations in irrigation water requirements for deficit, normal and excess years

S.No	Name of crop	Normal Rainfall year(2006)	Excess Rainfall year(2007)	Deficit Rainfall year(2013)
1.	**Maize-1**	349	324	372
2.	**Maize-2**	404	357	429
3.	**Groundnut-1**	354	315	360
4.	**Groundnut-2**	174	179	325
5.	**Paddy**	334	294	340
6.	**Sugarcane**	825	734	1007
7.	**Banana**	822	619	915
8.	**Turmeric**	754	458	745
9.	**Coconut**	713	570	872
10.	**Vegetables-1**	383	332	450
11.	**Vegetables-2**	387	349	456

The average irrigation water requirements of the different crops during the years 2004-2013, under existing cropping pattern are given in Fig 2. The average irrigation water requirement for crops grown in monsoon period were less when compared to the crops grown during the non monsoon period.The average irrigation water requirement of sugarcane crop was nearly 831 mm with highest water requirement during 2013 and 2012 (1007 and 967 mm respectively) due to deficit rainfall during those years**.** The net irrigation requiremnt of banana varied from 619 to 923 mm with lowest water requirement during 2007 due to dry soil moiture regime during crop growth period. The varaition in crop water requirement for Gnut1 and Gnut2 (125 mm and 391 mm) between the seasons is significant. The net irrigation requirement is almost doubled during non monsoon period due to retrival of rainfall during Jan-Mar. In Maize crop, being drought resistant did not show much significant variation in water requirement over the years in both seasons. Similarly, variation in water requirement was observed within seasons and also over years in Vegetable crops.The vegetable crops grown under irrigated conditions during Feb-Jun consumed more water than monsoon period crop (Jun-Sept).

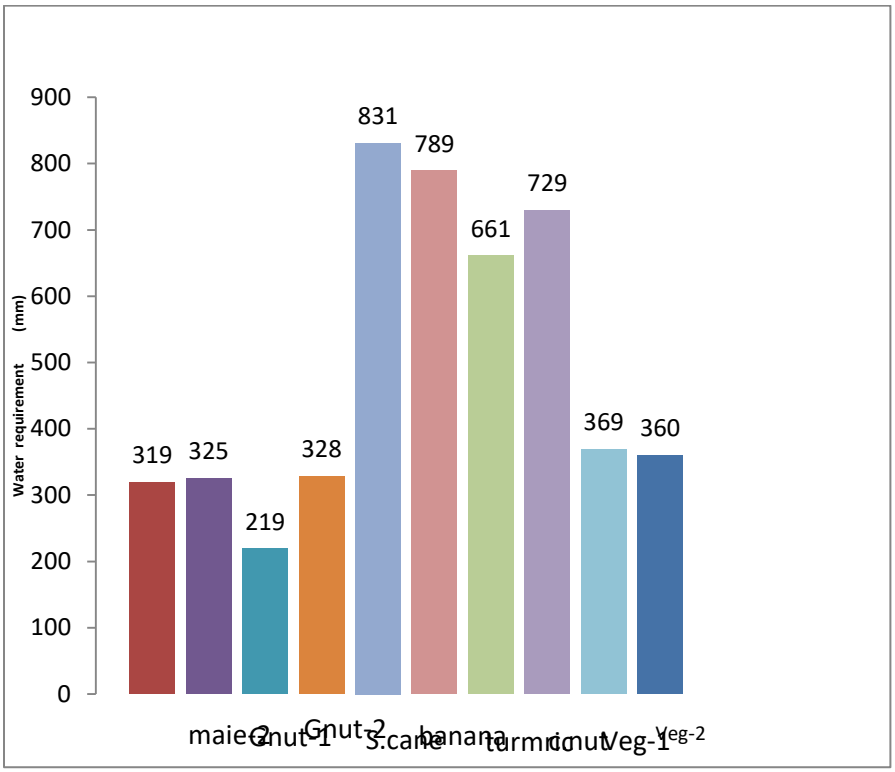


Fig 2. Average irrigation water requirement for existing crops in the command area

Conclusions

The model AquaCrop can be successfully used as a planning tool or to assist in management decisions for both irrigated and rainfed agriculture. The model provides required quantity of water during the critical stages of the crop growth there by reducing the fall in the final yield of the crop. This will particularly help to develop irrigation strategies under water deficit

conditions .The crop water requirements and yield of any crop under different situations can be easily found from this model. This model also useful to predict climate change impacts on crop production and for planning purposes for use by economists, water administrators and managers.

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Impact of Landuse Changes on the Flows of Tawi River in Western Himalaya

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Abstract

The river Tawi, the left bank tributary of Chenab river is endowed with vast water resources with irrigation, domestic water and hydropower potential which are yet to be assessed in details. The increasing demand of the development of Tawi river for beneficial uses of the population of Jammu, Udhampur and Doda districts calls for the systematic hydrological studies for the river. Since last four decades, few minor schemes for irrigation, hydropower and domestic water supply have also come up. Tawi river is the major source of water supply to the Jammu city. The J&K state government officials have emphasized that Tawi river has seen a lot of changes in land use in the upper catchment, which may pose a threat to the river flows and the river ecosystem. In this limelight, this study was taken up to understand how land use/cover changes affect the flow regime of Tawi river. The land use / land cover (LULC) maps have been prepared for the years 1985, 1995 and 2005 by using the LANDSAT imageries through the unsupervised classification in ERDAS software. The thematic maps have been prepared considering the six LULC classes i.e. Built-up (urban & rural), Crop land, Evergreen Broad Leaf Forest, Grass Land, Shrubs Land and Water Bodies. There has been decrease in the area under Evergreen Broad Leaf Forest and Crop Land. This decrease has been due to increase in the area under Built-up, Grass Land and Shrubs Land. As land use component is strongly built in the SWAT model, ArcSWAT software has been selected for runoff simulations in this study. The data required for the model set up has been procured, processed and digitized. The model has been calibrated for the period from 1983 to 1992 and validated for the years from 1993 to 1997. The LULC map pertaining to the year 1995 has been used for the calibration and validation. The model simulated the discharge of Tawi catchment upto Jammu satisfactorily with the Coefficient of Correlation (CC) and Nash–Sutcliffe efficiency (NSE) as 0.715 and 0.453 during calibration and 0.855 and 0.835 respectively during validation. Further, the discharge simulations have been made by using the LULC maps for the years 1985 and 2005 for the calibration and validation periods. While observing the simulated discharges for the LULC pertaining to years 1985 and 2005, it is found out that the discharges of the Tawi river in general are decreasing due to the changing landuse except for the months of July and August. It is concluded that due to conversion of forest area into grassland or agricultural land into built-up area, the monsoon discharges are increasing while non-monsoon discharges are decreasing. At present, there is no major abstraction of water from the Tawi river, but, in future, as the various water demands may increase and there may be more abstraction from Tawi river, the efforts are required to rejuvenate the degraded forest cover to the natural conditions as existed prior to 1985.

Key Words: Land use, flow regime, ArcSWAT, Tawi river

Introduction

Background

Flow regime of a river is an important component of project hydrology, on the basis of which development of water resources of a river for various beneficial uses is thought of. During recent decades, concerns about the impacts of changing patterns of landuse associated with deforestation and agricultural transformation on water resources have created social and political tensions from local to national levels. Major concerns focus on consequences of landuse change for water supply and demand, for local and downstream hydrological hazards, and for biodiversity conservation. These land use changes may alter the amount of infiltration into the groundwater system and can affect the quality of water discharged from a watershed. The groundwater flow regime is significantly impacted due to a reduction in recharge. Since recharge can be the driving force of groundwater flow, not only can this reduction change flow magnitude and direction, it can reduce the hydraulic heads of the system, affect the surface-water groundwater interaction and reduce the volume of water available for withdrawal. Reduced recharge can affect the ability of the system to serve as a reliable water supply. Pollutants that accumulate on impervious surfaces during dry periods are flushed into streams, rivers, lakes, and reservoirs during rainfall events and can degrade water quality. This can increase the maximum pollutant loads that the receiving natural systems eventually have to assimilate. Vegetation is sometimes completely stripped from the land during site development and the bare soil is exposed to the erosive forces of rainfall which could, in turn, increase the sediment loads in runoff during storm events. If the groundwater and surface water systems are hydrologically adjacent and interact dynamically, the pollution of one can cause reduction in quality of the other.

It can be concluded that climatic variability and land use change are the most important factors affecting the changes in the hydrologic regime of a river. Therefore, an active management strategy aimed at the conservation and regeneration of the natural vegetation is needed, in order to improve the availability of water during both dry and wet periods. Also, the increased competition for water and alterations in land use in the upstream of many rivers, are argued to have contributed to change in hydrological regimes and consequently, the river ecology of many rivers. While that has been acknowledged, few studies have been conducted in developing countries. Therefore, it is important to study and understand how land use/cover changes affect the flow regime and the sustenance of environmental flows of a river.

The Problem Definition

The river Tawi, the left bank tributary of Chenab river is endowed with vast water resources with irrigation, domestic water and hydropower potential which are yet to be assessed in details. The increasing demand of the development of Tawi river for beneficial uses of the population of Jammu, Udhampur and Doda districts calls for the systematic hydrological studies for the river. Since last four decades, few minor schemes for irrigation, hydropower and domestic water supply have also come up. Tawi river is the major source of water supply to the Jammu city. Recently, one project for recreational activity is also coming up on Tawi river at Jammu.

Based on the discussions with J&K state forest deptt. officials, it is concluded that Tawi river has seen a lot of changes in land use in the upper catchment, which may pose a threat to the river flows and the river ecosystem. Based on the recent research, it is concluded that the presence of some pollution indicator species directly points to the shifting status of the Tawi river from non-polluted to polluted. Municipal sewage and domestic waste showed alarming shift or total elimination of sensitive biotic community from the river. As the human population continues

to grow, it will contribute significantly towards the process of river biodegradation. Therefore, there is a need to discuss hydrological impacts due to land use changes in the Tawi basin. Towards this objective, the present study is aimed at developing a runoff model which has land use/cover as one of the main components alongwith the meteorological variables and soil characteristics to assess the impact of land use changes on sustenance of environmental flows of Tawi river.

STUDY AREA

The River Tawi, which passes through the heart of the Jammu city, is one of the major left bank tributaries of the river Chenab. It rises from the lapse of Himalayan glaciers at a place named Kalikundi and adjoining areas. The basin shape in the upper part is elongated while broad in the lower part. The catchment of Tawi river upto Jammu is about 2165 sq. km. falls mostly within the districts of Jammu and Udhampur of J&K state. Just below the bridge at Jammu Ranbir canal also crosses the river. Immediately below the canal crossing, the river divides into two channels. These two channels are termed as Nikki Tawi which flows towards left and Waddi Tawi flows towards right. Location of the Tawi catchment is shown in Fig. 1.

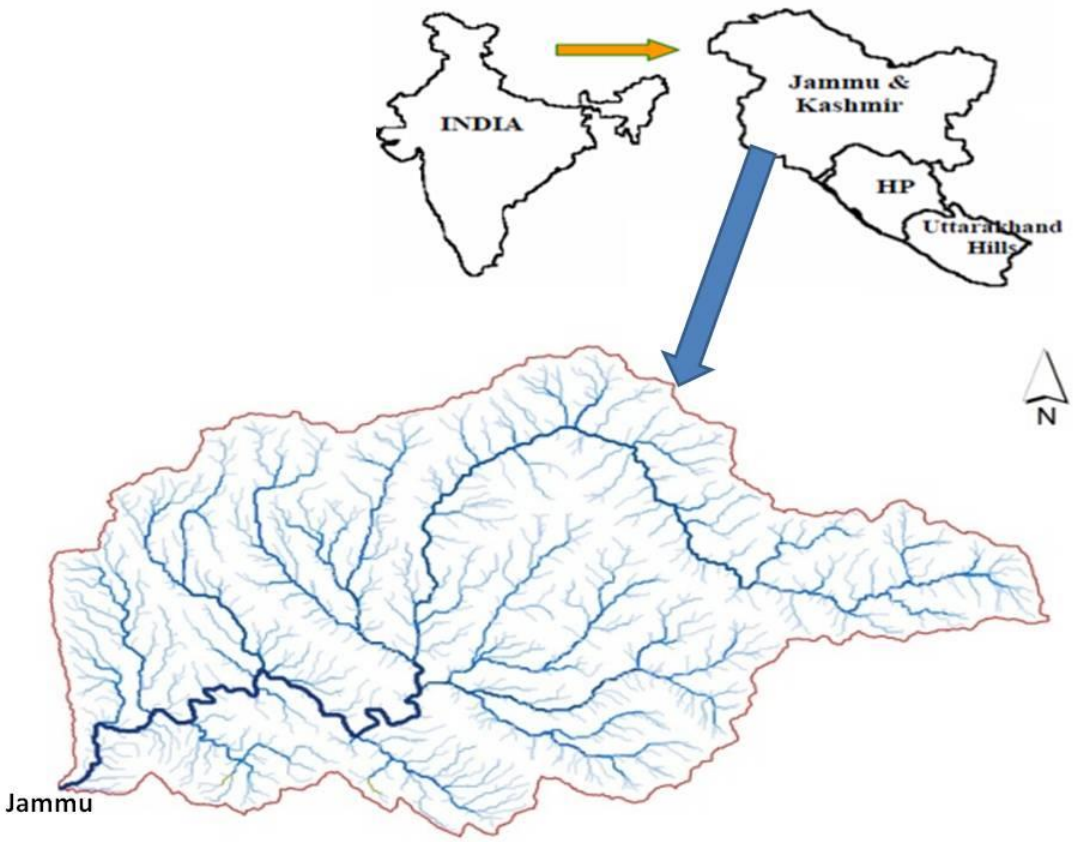


Fig. 1: Location Map of Tawi Catchment

The upper part of the catchment is characterized by rugged mountainous topography; whereas lower catchment consists of low hills and aggradatioal plain. The average height of the catchment is about 2200 m above mean sea level (msl). The catchment elevation varied from 4000 m in the upstream to about 300 m above msl in the plains. The variation in elevation can be understood by the Digital Elevation model (DEM) of the Tawi catchment. The slope of the basin is from east to west in the upper part and north east to south west in the lower part. From origin to outfall the longitudinal section of the river exhibits wide variation. The gradient changes from very steep at upper part to concave and flat in the lower part of the river.

The region experiences hot summers and severe winters. Temperature is lowest between November & February when the minimum night temperature dips below zero degree in the hill area and 3° – 4° C in the outer plain area. Temperature rises from March onward. It becomes unbearable during May-June. Maximum day temperature in June touches sometime 47° C in the outer plain and about 30°- 35°C in the hills.

Most of the rainfall is received through the southwest monsoon which lasts from the last week of June to end of September. During the remaining period, rainfall is sporadic and scanty. July and August are the principal rainy months contributing about 55 % of the total annual rainfall. The average annual rainfall over Jammu district Varies from 900 to 1000 mm, over Udhampur district from 1400 to 1900 mm and over Doda district from 900 to 1400 mm. Rainfall in lower parts and snow fall in upper parts of ,the catchments occur in winter in association with passage of western disturbances and troughs in the westerlies. Snowfall is very heavy in the months December to February in upper reaches. At Higher elevations snowfall 1s experienced even during the month of May. Winter precipitation contributes nearly 45 % of the annual precipitation.

Data and Methodology

Soil and Water Assessment Tool (SWAT) has been successfully used for simulating runoff, sediment yield and water quality of small watersheds for Indian catchments (Pandey et al., 2008; Pandey et al., 2005). However, studies related to applicability of SWAT to the catchments located in Himalayan region of India are rarely available in literature. Jain et al (2010) calibrated and validated SWAT on an intermediate watershed of Satluj river, located in Western Himalayan region and obtained the coefficient of determination (R^2) for the daily and monthly runoff as 0.53 and 0.90 respectively for the calibration period and 0.33 and 0.62 respectively for the validation period. The R^2 values in estimating the daily and monthly sediment yield were computed as 0.33 and 0.38 respectively during calibration and 0.26 and 0.47 respectively during validation. Lack of reliable measured data in Himalayan watersheds is probably the main hindrance in application of sophisticated models. Since the topographical and land use conditions in Himalayan catchments are different from those in other parts of the country, it is desirable to assess the applicability of SWAT for Himalayan catchments. Moreover, the land use and land cover component is strongly built-in Arc SWAT model, it has been selected for assessing the impact of land use changes on the flow regime of the Tawi River.

Soil and Water Assessment Tool (SWAT) is a river basin or watershed scale model developed by the USDA Agricultural Research Service (Arnold et al., 1998). SWAT is a spatially distributed, continuous time model that operates on a daily time step. It was developed to predict the impact of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land use and management conditions over long periods of time. It can incorporate the effects of tanks and the reservoirs/check dams off-stream

as well as on-stream. SWAT requires specific input about weather, soil properties, topography, vegetation, and land management practices to model hydrology and water quality in a watershed (Neitsch et. al., 2005). The model allows a basin to be subdivided into sub-basins which are then further subdivided into hydrological response units (HRUs) with homogeneous land use, soil type and slope. The SWAT system embedded within ARCGIS can integrate spatial environmental data, including soil, land cover, climate and topographical features. Model outputs include all water balance components (surface runoff, evaporation, lateral flow, recharge, percolation, sediment yield, etc.) at the level of each watershed and are available at daily, monthly or annual time steps. For setting up the SWAT model a variety of data are required, mainly the climatic parameters, hydrologic data, soil data and the land use land cover information. The source, period resolution of the various data used in the study area depicted in the Table 1.

Table 1: Summary of various data used in the study

Data	Source	Scale	Period	Description
Topographic Data	SRTM	30m	2014	Elevation, aspect, slope, flow direction and accumulation
Soil Data	NBSSLUP	1:2,50,000	1999	Soil component parameter
Satellite Images	USGS (LANDSAT)	-	1985, 1995, 2005	To build the land use maps for different time periods
Hydrological Data	CWC	Daily	1977-2007	Water level, streamflow
Meteorological Data (Observed)	IMD and WHRC	Daily	1983-1998	Precipitation, Humidity, Temperature, Solar Radiation, Wind Speed

NBSSLUP: National Bureau of Soil Survey and Land Use Planning
USGS: United States Geological Survey
CWC: Central Water Commission, Jammu
IMD: Indian Meteorological Department, Pune
WHRC: Western Himalayan Regional Centre, NIH, Jammu

Although the catchment area of Tawi is more than 2000 sq. km but it has only one discharge measuring point at Jammu which has been considered as the outlet of the catchment and the entire study is focused on the catchment up to Jammu bridge. The details for preparation of the data are described below:

Digital Elevation Model

The digital elevation model (DEM) of Tawi catchment was generated using Shuttle Radar Topography Mission (SRTM) data. The elevation models derived from the SRTM data are used in geographic information systems. They can be downloaded freely over the Internet, and their file format (.hgt) is widely supported. The GDEM's pre-production accuracy estimates were 20 meters at 95% confidence for vertical data, and 30 meters at 95% confidence for horizontal data. For this study, grids covering the study areas were downloaded from internet and DEMs of the study areas were prepared (Fig. 2).

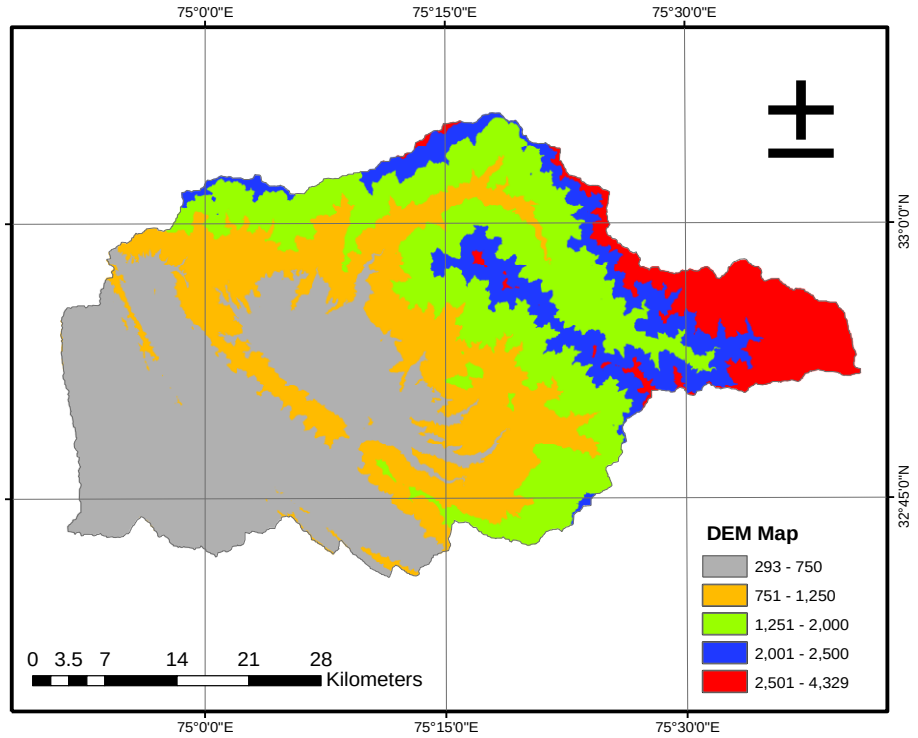


Fig. 2: DEM of the Tawi river catchment

Land Use/Cover

The land use map of the study area was prepared using LANDSAT imageries. The classification of satellite data mainly follows two approaches i.e. supervised and unsupervised classification. As the data pertains to the historical time, field verification could not be carried out and hence, in the present study, unsupervised classification has been carried out to prepare the land use maps. The intent of the classification process is to categorize all pixels in a digital image into one of several land cover classes, or themes. This categorized data then used to produce thematic map of the land covers present in an image (Fig. 3). The land use categories and their coverage in the study catchment is presented in Table 2.

Table 2: Major land use classes in study areas of Tawi catchment

Land use	Tawi River Catchment	
	Area (km^2)	% Total
Built-up (Urban & Rural)	62.23	2.87
Crop Land	317.04	14.63
Evergreen Broad Leaf Forest	1147.16	52.94
Grassland	25.02	1.15
Shrubs Land	552.45	25.49
Water Bodies	63.10	2.91
Total	2167.00	100

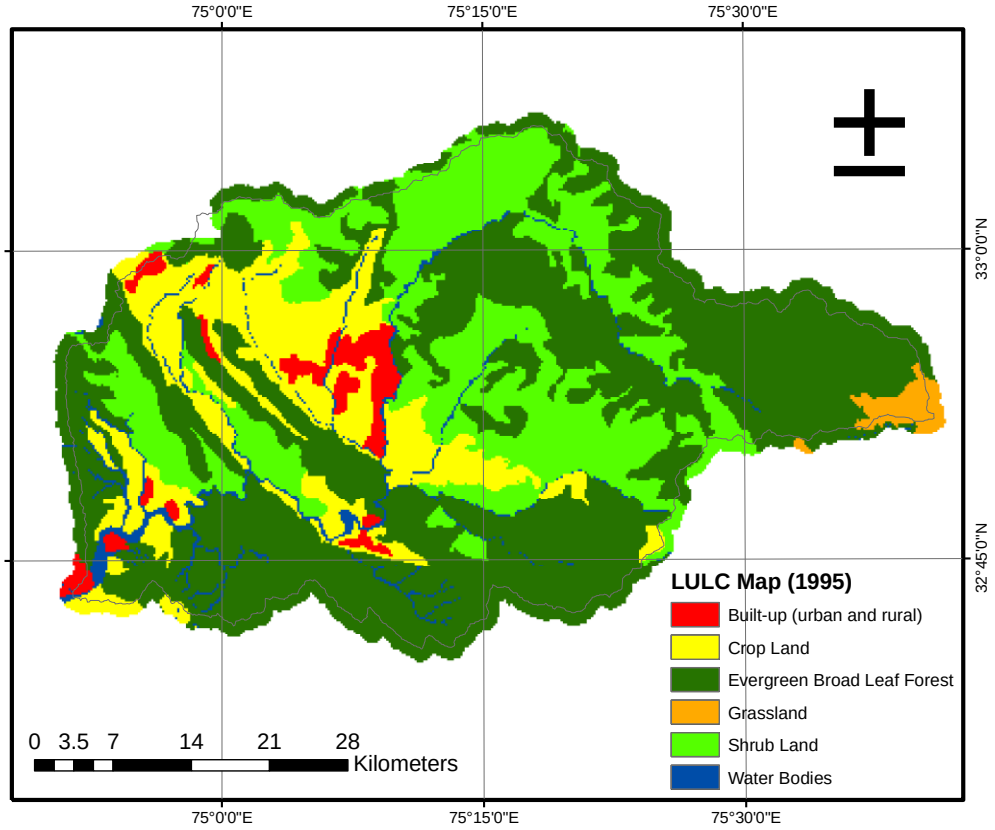


Fig. 3: Land use map of Tawi river catchment

Soil

Soil map of the study area was digitized using the hard copies of soil map of the National Bureau of Soil Survey and Land Use Planning (NBSS & LUP) at a scale of 1:50,000. The soil properties like soil texture, hydraulic conductivity, organic carbon content, bulk density, available water content which are required by SWAT as input to the model for simulating various hydrological processes are given in Table 3. The soil map of Tawi river catchment is shown in Fig. 4.

Table 3: Physical and chemical properties of soil series in Tawi River catchment

Soil Type	SANDY_LOAM		LOAM		CLAY		FINE LOAM	
	Layer 1	Layer 2	Layer 1	Layer 2	Layer 1	Layer 2	Layer 1	Layer 2
SOL_Z (mm)	300	1000	300	500	300	500	60	190.00
SOL_BD (g/cm3)	1.3	1.7	1.1	1.3	1.2	1.2	1.62	1.65
SOL_K (mm/hr)	55.66	5.47	21.28	7.52	13.43	13.7	9.83	22.41
SOL_CBN (%)	0.4	0.3	1.5	1	0.7	0.3	0.34	0.25
CLAY (%)	13	21	26	31	41	42	15.30	7.90
SILT (%)	9	9	30	29	34	32	49.20	50.20
SAND(%)	78	70	44	40	25	25	35.50	41.90
USLE_K factor	0.283	0.283	0.252	0.252	0.2902	0.2902	0.17	0.17

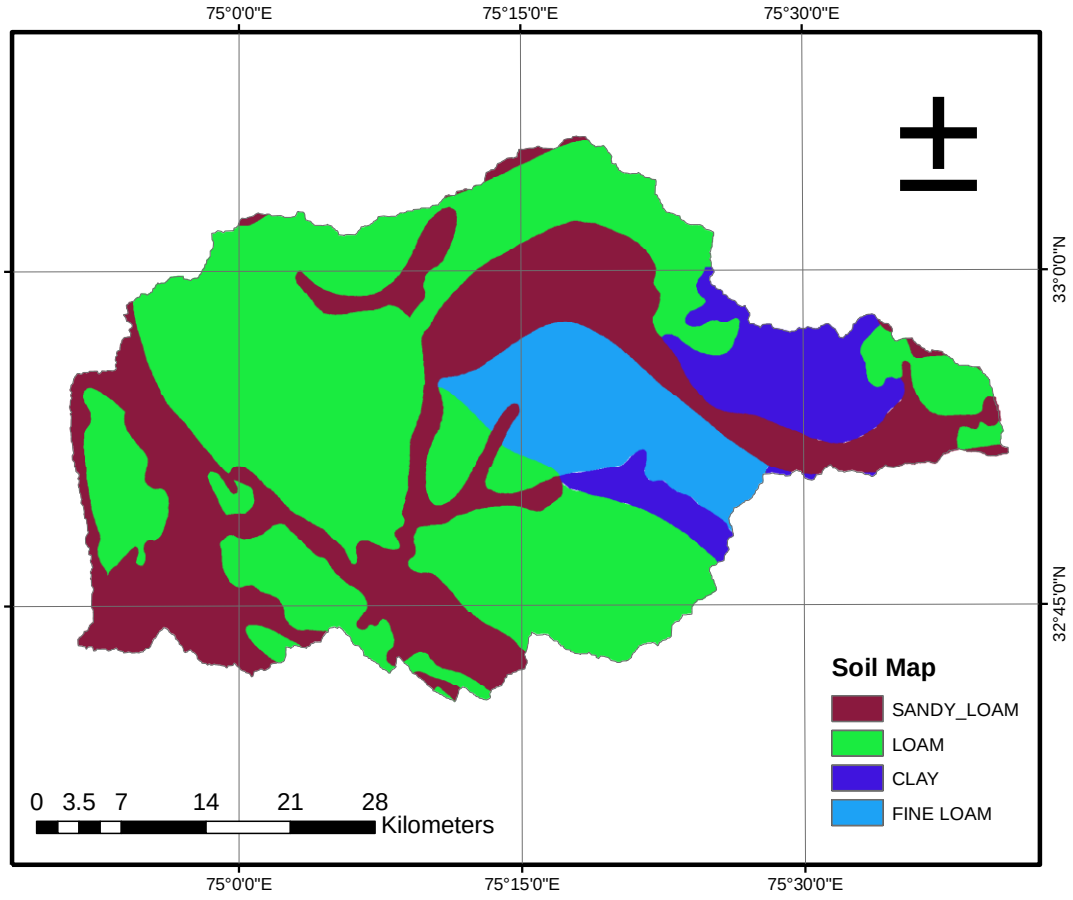


Fig. 4: Soil map of Tawi river catchment

Meteorological Data

A hydro-meteorological observation network maintained by IMD and CWC in the Tawi river catchments has been used. Three stations namely, Jammu, Bhaderwah and Batote lie in the study area of Tawi catchment. The daily data of rainfall, and maximum and minimum temperatures of these stations for the period 1983 to 2007 were used in the study. The daily data of wind speed, relative humidity and solar radiation other missing meteorological data for the Tawi catchment and was downloaded for the available stations from the website at URL: http://globalweather.tamu.edu/home/view/3668.

Hydrological Data

The daily discharge data monitored by CWC at Jammu gauging sites on Tawi river was utilized in the study. These gauging sites were monitored for 24 hours during the monsoon period to observe the high floods. The data for the years from 1976-77 to 2006-07 for Jammu gauging site was procured and processed.

RESULTS AND DISCUSSION

Arc SWAT Model Setup and Calibration

SWAT model was set up on Tawi river catchment up to Jammu Bridge. The ArcSWAT interface compatible with SWAT 2009 was used for the setup and parameterization of the model. A digital elevation model (DEM) was imported into the SWAT model. A masking polygon (in grid format) was loaded into the model in order to extract the area of interest, delineate the boundary of the watershed and digitize the stream network in the study area. The minimum threshold area for generation of streams was taken as 3000 ha and no sub-catchments were created as we were having only one discharge site at catchment outlet at Jammu. The land use/cover and soil maps of the study watersheds (in grid format) were also imported into the model and overlaid to obtain a unique combination of land use, soil and slope. Multiple HRUs with 15% land use, 15% soil and 30% slope thresholds were set to eliminate minor land uses and slope classes in catchment as recommended in the SWAT user manual (Neitsch *et al*., 2002). The daily data of rainfall, minimum and maximum temperature, relative humidity, wind speed and solar radiation were prepared in the appropriate file format and imported into the model.

The daily flow data for the period 1983 to 1992 of Jammu gauging sites were used for calibration. The data of initial one year in both catchments were utilized for warming up and initialization of the model variables. The warm up period was not used for evaluation of the model predictions. The SWAT model includes a large number of parameters that describe different hydrological conditions and characteristics across the watershed. These parameters need to be calibrated to adequately simulate streamflow and sediment processes in the study catchments. Parameters can either be calibrated manually or automatically. In this study, the calibration was done manually based on physical catchment understanding and sensitive parameters from published literature (Bärlund et al., 2007; Xu et al., 2009) and calibration techniques from the SWAT user manual. The hydrological components of the model were calibrated sequentially until the average simulated and measured values were in close agreement. Results of many studies have indicated that SCS curve number (CN_2), a function of soil permeability, landuse and antecedent soil water conditions, is an important parameter for surface runoff (Oeurng *et al.,* 2011; Das *et al*., 2007; Parajuli *et al*., 2007; Arabi *et al*., 2008; Wang *et al*., 2008). The runoff curve numbers were adjusted within ±10% of the tabulated curve numbers. The other important parameters that were calibrated for simulation of flow included 'baseflow recession coefficient'

(ALPHA_BF), 'soil evaporation compensation factor' (ESCO), 'plant water uptake compensation factor' (EPCO), 'surface runoff lag time' (SURLAG), 'groundwater delay' (GW_DELAY), 'deep aquifer percolation factor' (RCHRG_DP), 'Manning's ''n'' value for tributary channels' (CH_N1), 'Manning's ''n'' value for main channel' (CH_N2), and 'Maining's ''N'' for overland flow' (OV_N). SWAT uses MUSLE (Williams, 1975) for prediction of sediment concentration. Therefore, the MUSLE "crop cover and management factor' (C), 'support practice factor' (USLE_P),and the channel sediment routing variables, viz., a linear parameter for calculating the maximum amount of sediment that can be entrained during channel sediment routing (SPCON), an exponential parameter for calculating the channel sediment routing (SPEXP) were adjusted during the calibration.

Arc SWAT Model Validation

In the validation process, the model was run with calibrated input parameters and the model predictions were compared with an independent set of observed data of the period 1993 to 1997 for Tawi River. As the main objective of the study was to assess the impact of landuse changes on the flow regime of Tawi river. The calibrated and validated Arc SWAT model (which used the LULC map of the year 1995) was applied to simulate the discharges of the Tawi river by using the LULC map for the years 1985 and 2005 while retaining other parameters.

Performance of ArcSWAT in Calibration and Validation

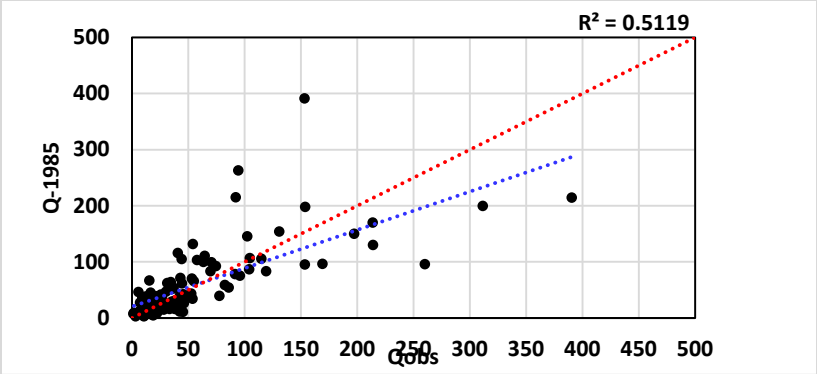
The performance results in the form of statistical indices of the ArcSWAT model in calibration, validation and simulation (for the calibration and validation periods) are given in Table 4. The scattered plots between observed and simulated discharges by using the LULC maps of the years 1985, 1995 and 2005 for the calibration and validation periods have been presented in Figs. 5(a) to 5(c) and Figs. 6(a) to 6(c) respectively.

Table 4: Results of performance indicators during calibration and validation period for discharge simulation

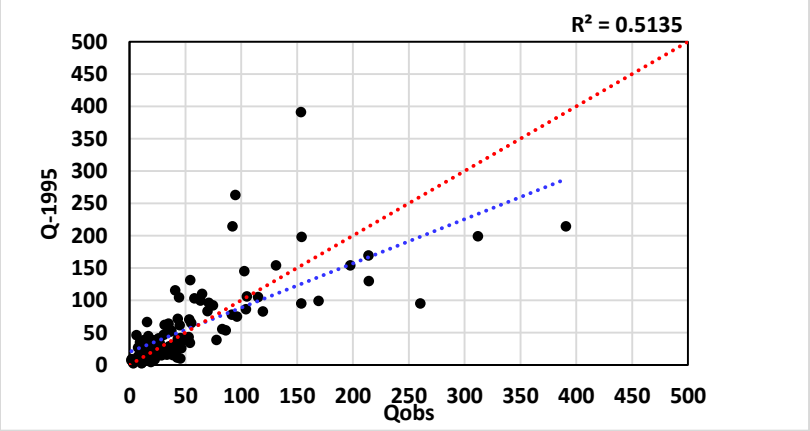
LULC year	Calibration/Validation	Root Mean Squared Error (RMSE)	Mean Absolute Error (MAE)	Coeff. of Correlation (CC)	Coeff. of Determination (R^2)	Nash and Sutcliffe Efficiency* (NSE)
1985	Calibration	47.477	0.348	0.715	0.512	0.453
	Validation	33.769	0.593	0.925	0.855	0.835
1995	Calibration	47.403	0.349	0.717	0.513	0.455
	Validation	33.807	0.592	0.925	0.855	0.835
2005	Calibration	47.424	0.350	0.716	0.513	0.455
	Validation	33.718	0.594	0.925	0.855	0.835

* Nash, J. E. and J. V. Sutcliffe (1970)

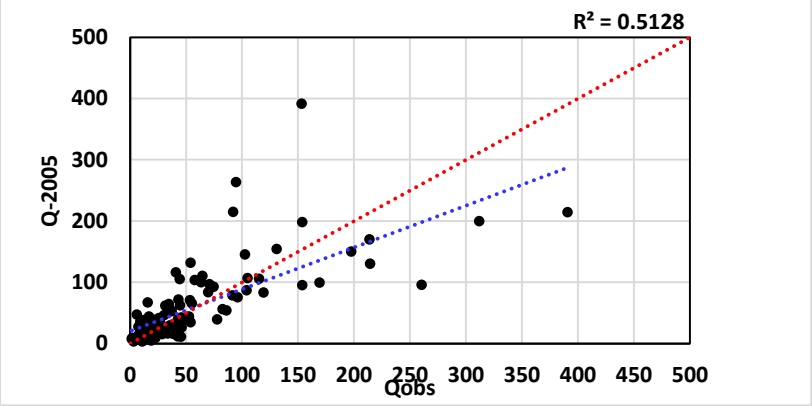
It is evident from the table that the results of the performance indicators are well within the range and the scattered plots also show the close agreement between the observed and simulated discharges. Hence, it may be concluded that the model satisfactorily simulates the hydrological regime of the Tawi river for the calibration and validation periods (1983-1997).



(a) using the LULC Map of 1985

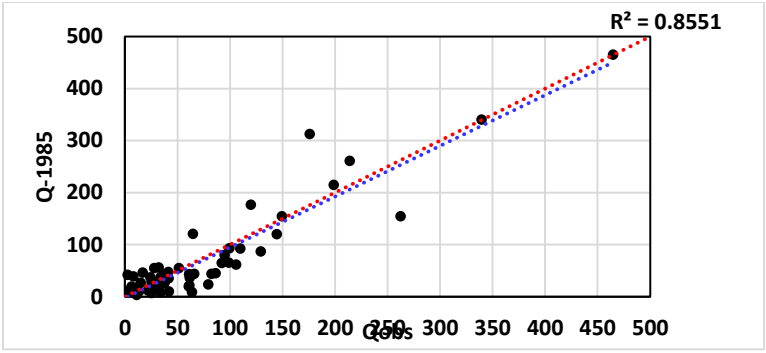


(b) using the LULC Map of 1995

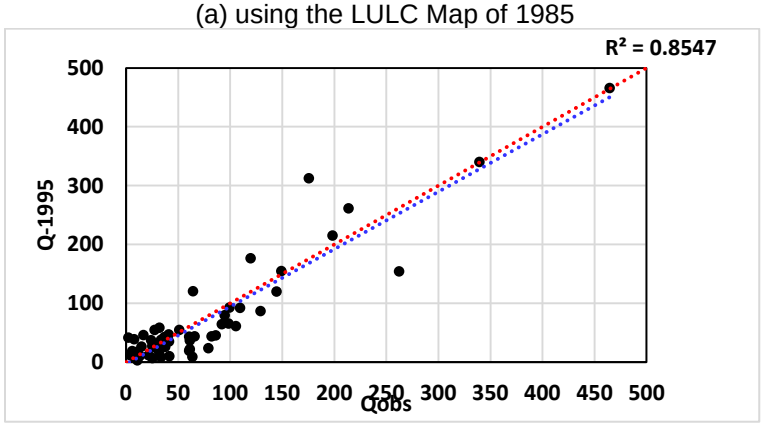


(c) using the LULC Map of 2005

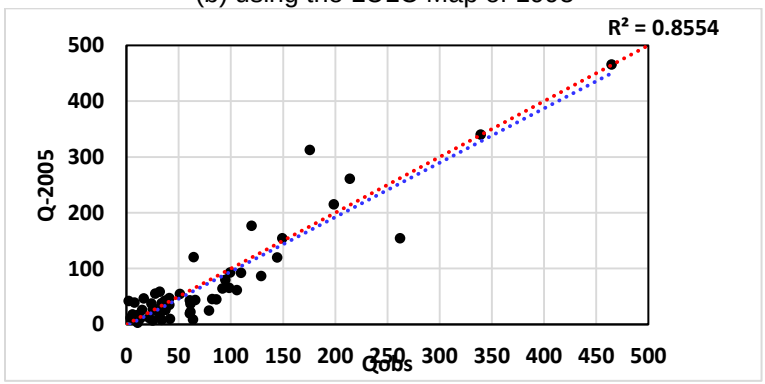
Fig. 5: Scattered plot between observed and simulated discharge during calibration period for 1985, 1995 and 2005 year based LULC maps



(a) using the LULC Map of 1985



(b) using the LULC Map of 1995



(c) using the LULC Map of 2005

Fig. 6: Scattered plot between observed and simulated discharge during validation period for 1985, 1995 and 2005 year based LULC maps

Assessment of Change in Flow Regime due to Change in LULC

The simulated discharges of Tawi River by using the calibrated ArcSWAT model are presented in the Table 5 as well as in Fig. 7. As the discharge simulations have been carried out only by varying the land uses at different years, while fixing the other parameters of the model, the table suggests that the discharges of the Tawi river in general are decreasing due to the changing landuse. The change in average flow per annum for the simulated discharges comes out to be 1.006 cumec per year which is in close agreement with the value of 0.731 cumec per year assessed through the Mann-Kendall Test and Sen's Slope estimator method. The changes in land use has been shown in Table 6 which suggests that due to conversion of forest area into grass land or shrubs land and crop land into built-up area, the monsoon discharges are increasing while non-monsoon discharges are decreasing.

Table 5: Average monthly discharge variation due to different years LULC maps

Month	Average discharge (cumec)			
	Observed	Simulated		
	Q-Obs	Q-1985	Q-2005	% Change
Jan	25.14	34.24	11.9	65.245
Feb	42.31	46.95	21.75	53.674
Mar	59.38	40.08	15.98	60.130
Apr	39.12	26.93	8.02	70.219
May	36.55	17.84	4.45	75.056
Jun	29.05	35.59	11.3	68.250
Jul	141.39	152.35	142.76	6.295
Aug	164.18	191.21	175.51	8.211
Sep	117.3	105.96	75.62	28.633
Oct	37.99	34.74	11.49	66.926
Nov	22.82	21.13	5.39	74.491
Dec	23.4	31.63	13.13	58.489
Average	61.5525	61.55417	41.44167	32.674
Change per Annum (cumec)				1.006

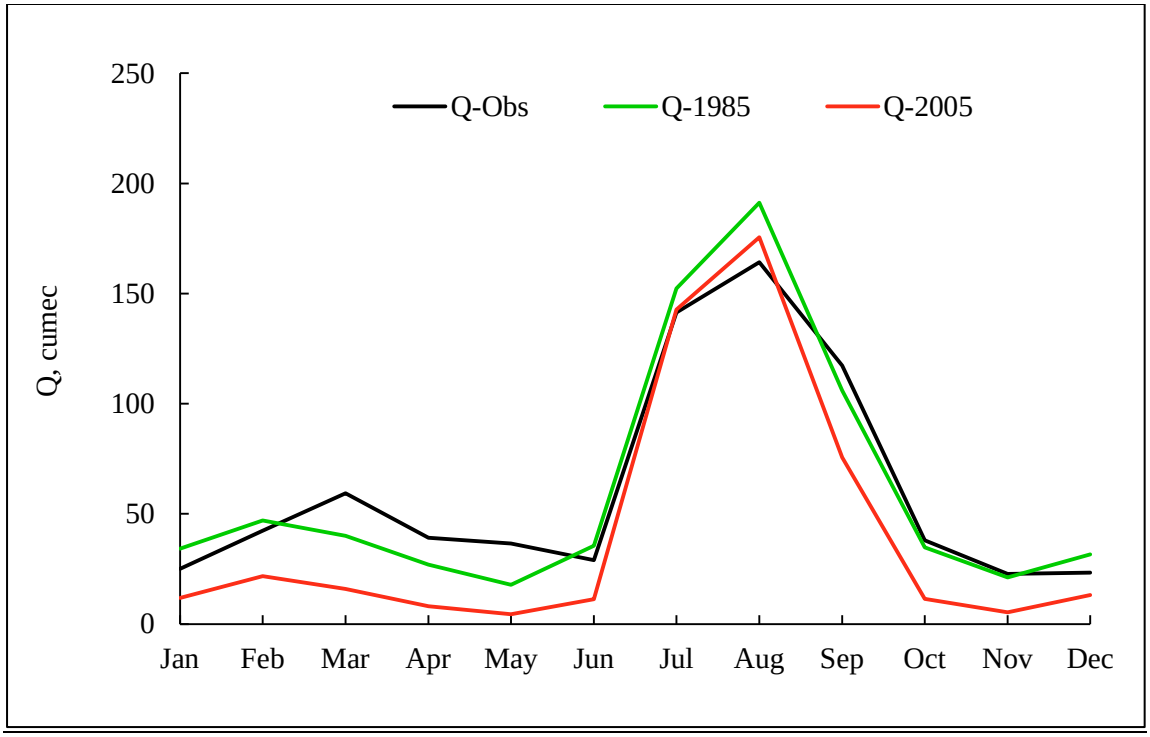


Fig. 7: Average monthly flow at Jammu for observed data and simulated flow for different land use and land cover for 1985, 1995 and 2005

Table 6: LULC change in the Tawi catchment during 1985 to 2005

Land use	1985		2005		Change (km^2)
	Area (km^2)	%	Area (km^2)	%	
Built-up (Urban & Rural)	31.41	1.45	44.72	2.06	13.3
Crop Land	248.93	11.5	201.02	9.28	-47.9
Evergreen Broad Leaf Forest	1482.2	68.4	1425.1	65.8	-57.2
Grassland	23.41	1.08	65.16	3.01	41.8
Shrubs Land	278.03	12.8	316.45	14.6	38.4
Water Bodies	102.99	4.75	114.57	5.29	11.6
Total	2167	100	2167	100	

CONCLUSIONS

The present study was envisaged to assess the impact of land use/cover changes on flow regime of Tawi river. The LULC maps have been prepared for the years 1985, 1995 and 2005 by using the LANDSAT imageries through the unsupervised classification in ERDAS software. The thematic maps have been prepared considering the six LULC classes i.e. Built-up (urban & rural), Crop land, Evergreen Broad Leaf Forest, Grass Land, Shrubs Land and Water Bodies as shown in the table below. There has been decrease in the area under Evergreen Broad Leaf Forest and Crop

Land. This decrease has been due to increase in the area under Built-up, Grass Land and Shrubs Land.

As the major objective of the study was to assess the impact of LULC change on the flow regime of Tawi river and Land Use component is strongly built in the SWAT model, ArcSWAT software has been calibrated and validated for the runoff simulation in this study. The data required for the model set up has been procured, processed and digitized. The model has been calibrated for the period from 1983 to 1992 and validated for the years from 1993 to 1997. The LULC map pertaining to the year 1995 has been used for the calibration and validation. The model simulated the discharge of Tawi catchment upto Jammu satisfactorily with Coefficient of Correlation (CC) and Nash–Sutcliffe efficiency (NSE) as 0.715 and 0.453 during calibration and 0.855 and 0.835 respectively during validation. Further, the discharge simulations have been made by using the LULC maps for the years 1985 and 2005 for the calibration and validation periods.

While observing the simulated discharges for the LULC pertaining to years 1985 and 2005, it is found out that the discharges of the Tawi river in general are decreasing due to the changing landuse except for the months of July and August. It may be concluded that due to conversion of forest area into grassland or agricultural land into built-up area, the monsoon discharges are increasing while non-monsoon discharges are decreasing.

ACKNOWLEDGEMENTS

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MONITORING AND EVALUATION OF VARIOUS INDICES OF WATERSHED MANAGEMENT PROGRAMMES- A CASE STUDY FROM COASTAL DISTRICTS OF ODISHA.

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Abstract

Watershed management is an approach of an area planning of natural resources, specially, land, water and plants for the socio-economic need of human society and community concerned. It provides a systematic way for integrated development in any given area. Watershed management has to be sustainable on ecosystem principles, when the treated watershed would permit maximum possible stability through the process of production, consumption and regeneration. To achieve all these objectives there is need to have proper monitoring and evaluation after implementation of the watershed programmes. Keeping in view the importance and actual output of watershed development programme and considering the major role of soil & water conservation measures a study has been undertaken in Barpita Nalla micro-watershed of Khurda district of Odisha to measure the impact of soil and water conservation measures on, cropping pattern of farmers, production and productivity of crops in study area. A random sampling method for collecting the primary data was used. Schedules and questionnaires were prepared according the objectives. Study was focused on impact from tanks and earthen embankment strengthening. For impact study different watershed development indicators were used such as (1) Bio-physical Indicators - Land Leveling Index ,Crop Diversification Index Crop Productivity Index, Cultivated Land Utilization Index and Irrigability Index,(2) Participatory and Socio-economic Indicators- People's Participation Index, Benefit Cost Ratio, Net Present Value (NPV) and Internal Rate of Return (IRR) etc. In the present study inequality of income was measured in terms of Gini concentration ratio.

Key words: *LLI, CDI, CPI, CLUI, II, PPI, B.C. Ratio, NPV, IRR, Gini Concentration Ratio*

Introduction

The impact of various watershed interventions has not been objectively evaluated for comparison across the watershed, state and region due to lack of availability of appropriate indicators. A huge knowledge gap exists with respect to the impact of soil and water conservation technologies in particulars, such as the effectiveness of unfarmed technologies in controlling soil erosion, their impact on human and natural resources, cost-benefit ratio or the level of integration into prevailing farming system. It is very much required to know impact on the people, land, water, natural resources and the cropping system. How had peoples' life change better or how has the environment actually been improved. There is need to monitor and to evaluate the impact of soil and water conservation projects that are multi-sectoral in essence for various points of view to achieve the objective of sustainable development. Interventions to conserve soils and develop watersheds are commonly undertaken but it is needed to access the impact of these

interventions. The National Watershed Development Programme is a single window, integrated, participatory and sustainable development programme.

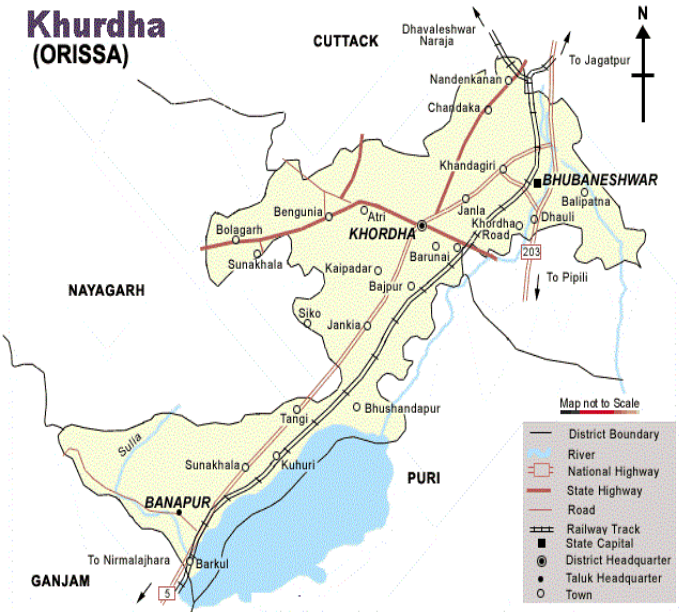
The literature related to various studies and researches on impact of soil and water conservation measures in micro-watersheds are readily available. Prasad et al. (1997) studied the impact of watershed management on runoff, water resource activity and productivity of arable land in Chhaljawa watershed of Baran dist. in Eastern Rajasthan and results indicated that integrated watershed development treatment such as graded bunds, gulley control structures etc. halted the process of land degradation and improved the ground water recharge which could be successfully exploited for increasing the productivity of arable land. The investment made recovered in four years indicating that the programme was economically viable. Panda (2000) in his case study of Economics of watershed treatments in Odisha, two stage stratified random sampling techniques was used and for the study. He concluded that the beneficiary village recorded 36% to 114% higher productivity of crops in comparison to non beneficiary village. The production of paddy, sesamum and groundnut in watershed area was 198%, 152% and 173% resp. higher than that of the non beneficiary village. The productivity of paddy and groundnut was 114% and 105% higher in watershed area resp. Black gram also registered 75% higher productivity. Cattle per household of the beneficiary village were 3.5 against 1.36 of non beneficiary village. Kanaujaa et al.(2000)studied the watershed management for enhancing crop production and economic advantages in tribal areas of Madhya Pradesh. Various soil and water conservation, water harvesting and vegetal cover improvement viz. bunding, staggered trenching, loose boulder checks and vegetative barriers, earthen embankment and ponds, pasture and plantation resp. were taken up. After 4 yrs. they surveyed and concluded that the area under paddy, sorghum, wheat, gram, mustard and linseed increased by 60.200, 102.24, 179 and 83 % resp. Before implementation of watershed works, the irrigated area was 34.7 ha through one earthen embankment, one pond and natural nala. After execution of soil conservation works and construction of earthen embankment across natural nallas and ponds the irrigated area was increased by 2.53 times i.e. 87.8 ha in 4 yrs. Yield of paddy, sorghum, wheat, barley, pigeon pea, gram and mustard had increased by 51, 22, 65, 43, 25, 57 and 70 % respectively. Sharda et al.(2005)studied the participatory watershed management programmes for sustainable development and the research area located in diverse ecological region of the country, namely Eastern Ghats, Western Ghats (Nilgiris), Shiwaliks (Himalayan foot hills), Bundelkhand region, western coast Gujarat plains and Chambal ravines. They concluded that the various agronomical interventions improved the yield of traditional crops. The overall crop productivity of watersheds measured in terms of crop productivity index (CPI) increased by 12 to 45% and considering 5 watersheds together, CPI improved from 0.50 in pre-project 0.64 in after project implementation. The crop diversification index considering all watersheds together improved from 0.67 in pre project period and to 0.82 after implementation of the project. Also they concluded that the overall utilization of cultivable land showed that CLUI had increased from 0.26 before the project to 0.33 in post project period. Mondal et al.(2006)studied the impact evaluation of watershed development on socio-economic indicators in Andhra Pradesh. The results showed that the total cultivable area was 4677 ha which constituted 93.5% of the total geographic area of watershed before implementation of the project. During the project period an additional area of 14 ha (out of 17 ha. of cultivable waste) and 9 ha of endowment land which was also not under cultivation were converted to cultivated land and 3 ha degraded land was brought under social forestry which resulted into increase of 47% in cultivated area. Introduction of soil and water conservation programme improved cropping intensity from 97% during pre project period to 113.8% during

post project period. Increased ground water availability and improved packages of practices for crops brought 67.9 ha area under double cropping. They also concluded that the adoption of package of practices and land treatment increased the level of production and productivity. Goel et al.(2007)studied the performance evaluation of some soil and water conservation measures in hot arid zone of India. During 1993-2004 the soil and water conservation measures adopted in Jhanwar watershed located in Rajasthan. They revealed that the natural resource base in arid region can be substantially improved and the agricultural productivity could be sustained even in extreme arid condition through watershed approach. Introduction of improved crop varieties and other dry land framing techniques has resulted in substantial improvement in productivity of various dry land crops viz. pearl-millet (51.87 %), mung bean (177.4 %), moth bean(393.7 %) and cluster bean(546.5 %). Similarly adoption of alternate land use system like agriculture like ber, agro-forestry with *Prosopis Cineraria* and farm forestry with Acacia tortilis resulted in production of various products and byproducts like fruit, fuel, fodder, pods, top feed grains etc. resulting in better sustainability of farmers of the project area. Naik(2009)studied the impact of the National Watershed development programme for rainfed agriculture and the programme was implemented in Sukli watershed selected which is situated at Nagpur-Hyderabad highway, Maharashtra. He concluded that the after project cropped area was increased by 32 ha but gross cropped area was increased by 175 ha. with a significant increase in the area under horticulture (675 ha.) and flower cultivation (3.4 ha.) With adoption of integrated watershed management the productivity of major Kharif crops increased by 25% to 37% and figure for Rabi crops was 33% to 44%. Training of primary stakeholders, field demonstration on crop, agro- forestry and improved composting had created mass awareness on soil and water conservation in the area and expected to yield good results in long run. Panda (2000) observed the water table level in wells during study period of both watershed and non watershed villages and concluded that the average annual water table depth in non watershed area was 5.2 m. The watershed area was found with average ground water table of 9.1 m, which was 3.9 m higher than that of the non watershed area in the state of Odisha.

Gitte et al. (2002) reported that the water table in all the wells started rising since mid of June and attended its peak in September. There was steady decline in water table since September to December and then that water table was maintained a constant level up to March in almost all wells. The water conservation measures were found to be effective for rising and water table in observation wells located in middle and lower reaches of watershed. Generally it should be seen that there was overall build up in water levels in entire watershed area due to impoundment of water in water harvesting structures. Naik (2009) studied that rise in the water table was found to be in order of 0.30 to 0.45 m. adjoining the structures. In Rabi season pumping increased as 2-3 hrs and in summer in order of 1-1.5 hrs. Hence farmers were encouraged to construct more no. of wells from 124 before project to 141 after the project. Number of bore wells increased from 3 to 8 during this period.

Materials and Methods

The present study area Barpita-Nalla Micro-Watershed comes under agro-climatic zone of east and south-eastern coastal plain (Code No.-078) of the state of Odisha. The project is coming under the range of Chandaka P.S of Bhubaneswar Block of Khurda District, at a distance of 15 to 18 km from Bhubaneswar. The project area is located in between 20°17′ to 20°20′ N latitude and 85°40′ to 85°44′ E longitude. It comprises of three villages such as (1) Giringaput, (2) Bhagabatipur and (3) Barapita with a total geographical area of 1442.71 ha.



Location of study area

The watershed is generally flat with undulating topography. Physiographically the zone is located in the coastal belt and has an altitude ranging from 40 to 70 m from mean sea level with flat topography. The area is a sedentary landscape with two distinct phases, such as erosion phase which includes the ridge and up land and depositional phase which includes medium and low land. There is a small fringe of level on both side of the nala. Detailed soil survey of the area reveals that the soil is mostly sandy loam to sandy clay loam and depth of soil is about 90 cm (D_5 class). The details of soil mapping units are given in appendix. Basically it is a fan shaped watershed. Water from entire project area is drained by a number of small channels into the Gangua watershed of Chilika catchment. Morphological characteristics of the watershed are given in Table No. 3.1

Table: 3.1 The morphologic characteristics of Barpita Nalla micro-watershed

Sl. No.	Watershed characteristics	Value	Sl. No.	Watershed characteristics	Value
1	Stream order	III	6	Basin perimeter (km)	13.50
2	Number of streams		7	Basin area (km^2)	14.42
	I	5			
	II	2	8	Drainage density (km/km^2)	0.70
	III	2	9	Length of overland flow (km)	0.71
3	Stream length (km)		10	Circulatory ratio	0.99
	I	4.15			
	II	4.35	11	Elongation ratio	0.87
	III	1.58	12	Stream frequency (per km^2)	0.62
4	Length ratio	1.35	13	Form factor	0.59
5	Basin length (km)	4.95	14	Bifurcation ratio	2.69

Different indicators

Monitoring and evaluation of various developmental interventions was carried out during the implementation phase to quantify their impact on ecology, productivity and socio-economic conditions by evolving and employing appropriate indicators /indices. The following indicators were used in pre project and post project scenarios to evaluate the overall impact of the watershed development programme.

Land Leveling Index

For comparing the efficiency of land levelling activity during the pre project and post project periods, an index called as Land Levelling Index is employed, which is ratio recommended land slope to the existing land slope as defined below

$$\text{Land Leveling Index(LLI)} = \frac{\text{Recommended slope}}{\text{Existing or treated slope}} \qquad 1$$

Where, existing slope refers to the individual land slope before the commencement of the project and treated slope is the moderated slope resulting from land leveling activities. Higher the value of LLI is a measure of better moderation in land slope. LLI can attain a maximum value of 1.0, which refers to a perfectly leveled field.

Crop Diversification Index

Crop Diversification Index (CDI) was used to assess the changes in the cropping patterns/systems due to crop improvement programmes. It is defined as:

$$\text{Crop Diversification Index(CDI)} = \sum_{i=1}^{n} P_i \log\left(\frac{1}{P_i}\right) \quad (2)$$

Where, P_i is the proportion of the i^{th} crop in comparison with total cropped area and n is the total number of crops in the watershed. The CDI can attain any value > 0 and higher value of CDI is an indicator of better crop diversification.

Cultivated Land Utilization Index

Cultivated Land Utilization Index (CLUI) is an indicator of the use of land for intercropping and multiple cropping systems. It indicates that the impact of watershed interventions on changes in cultivable land area and duration of crop cultivation in pre-project and post-project periods. It is calculated by summing the products of land area planted under each crop, multiplied by actual duration of days of that crop, and dividing the sum by the cultivated land area times 365 days as given below:

$$\text{Cultivated Land Utilization Index(CLUI)} = \frac{\sum_{i=1}^{n} a_i d_i}{A \times 365} \quad (3)$$

where, n are the total number of crops; a_i is the area occupied by i^{th} crop; d_i are the days that the i^{th} crop occupied in d_i area; and A is cultivated land area. The CLUI can attain a maximum value 1.0 and higher value of CLUI indicates more uses of available cultivable land area of the watershed and / or duration of crop cultivation period.

Crop Productivity Index

For assessing the overall improvement in crop productivity at the watershed level, Crop Productivity Index (CPI), which indicates the extent of crop productivity level in comparison to the normal yield of crops before and after the project, is calculated by dividing the crop yield obtained in the watershed by the yield obtained under recommended package of practices.

$$\text{Crop Productivity Index(CPI)} = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{y_i}{Y_i}\right) \quad (4)$$

Where, n is the total number of crops in watershed, y_i is the avg. yield of i^{th} crop cultivated in watershed, and Y_i is the yield of i^{th} crop with standard package of practices. The CPI can attain any value > 0 in a given location. Higher value of CPI is indicative of crops' yield closer to the maximum attainable yield under standard package of practices

Irritability Index

Major utilization of harvested water is for irrigation of crops to ensure sustainable agricultural production in the watershed. Irrigability Index (II) is a ratio of additional gross irrigated area and net incremental irrigated area. Gross irrigated may be estimated by adding the net incremental irrigated area as many times as it was irrigated.

$$\text{Irrigability Index} = \frac{\text{Additional gross irrigated area}}{\text{Net incremental irrigated area}} \quad (5)$$

The index can attain any value more than 0, and a higher value will indicate successful utilization of harvested water in watershed management project.

Results And Discussions

Productivity of paddy crop increased by 19.04% in kharif and 26.47% in rabi. Productivity of vegetable crops increased by 25% in kharif and in rabi it gave production as 42 qtls/ha. 6.4 Ha. of land was under cashew cultivation from which 12 qtls/ha production was obtained. 17,000 numbers of rose flowers per ha was produced by one of the beneficiary. With the reference of all these output it was found that the Crop Productivity Index was increased from 0.49 to 0.52.

Mono-cropping system changed and farmers were taking interest in cultivating vegetable crops in rabi season and floriculture on experimental basis also. Community cashew plantation was adopted and was fruitful. This resulted in increase in Crop Diversification Index from 0.301 to 0.775.

Near about 2,527,720 liters of water was stored throughout the year in 6 ponds located in the village. As a result of this harvested water, the irrigation intensity was increased from 142.79% to 187.37% and cropping intensity was increased from 113.62% to 186.37%. It was observed that Cultivable Land Utilization Index was increased from 0.103 to 0.67.

During the period of study, considerable development in water resources such as no. of tube wells were increased from 5 to 13, wells from 10 to 12 and 7 hand pumps were installed in the village.

Conclusions

From the study it was concluded that total income of households contributed mainly agriculture, off farm activities and minor forest activities. The contribution of all these three activities were changed from 41.27% to 84.82% in case of agriculture, in case of forest activities contribution was changed from 35.03% to 8.42%, and in case of off farm income it was 23.36% to 6.72%. It was also observed that the contribution through off farm income was decreased; it was the indicator of reduction in migration of people in near-by town area as most of the people were engaged in farm activities.

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PERFORMANCE INDICATORS FOR KARWADI-NANDAPUR WATERSHED DEVELOPMENT PROGRAMME IN KALAMNURI TALUKA OF HINGOLI DISTRICT IN MAHARASHTRA STATE

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Abstract

Watershed is a hydrologic unit with a certain extent of homogeneity and uniformity and is a limited, convenient, clearly defined unit. It can be adopted as a basic erosion landscape unit where land and water resources interact in a perceptible manner. Natural resources are developed by adopting the watershed as the basic developmental planning unit. Monitoring and impact evaluation should also be the part of programme in natural resources management and has the potential to be used in these activities. The current study was carried out in Karwadi-Nandapur watershed in Kalamnuri taluka of Hingoli district of Maharashtra state during 2009-10 to 2014-15. To evaluate the impact of watershed development activities there is no common scale to assess the natural resources and climatic parameters that influence the end result. An effort has been made to combine all the relevant parameters and develop an index to assess the watershed development. The average value of crop productivity index was increased from 0.59 in the pre-implementation phase to 1.02 in the post implementation phase. Soybean recorded highest value of CLUI as 0.177 in pre-implementation as well as 0.237 in post implementation phase while, the fodder crops and green gram/ black gram recorded the minimum values of 0.00 and 0.002 in the pre and post implementation phases respectively. The crop diversification index value was increased from 0.73 in the pre-implementation phase to 0.89 in the post implementation phase. A new green area of 220 ha has been created after the implementation of watershed development programme. The induced watershed eco-index (IWEI) of the watershed was found to be 0.285; thereby indicating additional 28.5% watershed area was rehabilitated through green biomass cover.

Introduction

India is a home to about 18% of the world's human population and 15% of the live stock population but it has only two per cent of the world's geographical area and 0.5 per cent of the pasture lands. About 70% of the population is dependent on agriculture, and two thirds of the cropped area is dependent on rainfall without any protective irrigation. The per capita availability of forests in India is about one per cent of the world average. Clearly, the land, water and natural vegetation resources of the country are under tremendous pressure. Droughts, floods and other climatologically extremes are common phenomenon in one or the other parts of the country. These extremes cause widespread damage and setback to economic development of the country. Drought occurs over an extended period of time and space, making it unpredictable and losses are not quantifiable easily. During several droughts a large population of the region migrates with their livestock to far off places with better resource availability. Under such a

scenario, the challenge is to manage land and water resources in a sustainable manner to achieve higher productivity levels, conserve resources for future generations and derive livelihoods in the most equitable manner possible. As a unit of land and water management, the watershed offers immense scope to improve crop productivity-whether of rainfed crops or under small-scale irrigation and biomass for livestock. The concept of integrated and participatory watershed development and management has emerged as the important tool of rural development in the dry and semi-arid regions and other rainfed regions of the world and is a shift from earlier based approaches to soil and water conservation.

Review of Literature

There are no single definitive indicators or measures and indices for overall impact measurement/assessment in view of complexities and diverse/ multiple objectives of watershed development projects. In view of this, a set of quantitative and qualitative simple surrogate measures, indicators and indices may be evolved and/ or used to assess changes as a result of watershed impact. Biophysical/ technical, socio-cultural, economic, community participation, institutional and sustainability indicators are developed based on consultations with the project staff, farmers representative and other stake holders.

1. Samra *et.al.*(2002) calculated People's participation Index (PPI) for a typical Shiwalik Watershed and observed to range from 28 to 84 per cent. The stakeholders participated in all the project activities right from the inception. With the increase in agricultural and animal husbandry components the women participation also increased considerably.
2. Sadeghi (2005) suggested two methods namely, quantitative and qualitative, in order to assess the impact measures of the watershed management. The quantitative method is extremely suitable and more accurate than the latter, on condition that, the statistics registered prior and after the implementation of the project are present. If this is not the case, it is essential that efficient and applicable methods are applied to qualitative methods in regions lacking registered statistics.
3. Sharda *et.al.* (2005) elaborated participatory watershed management for the six watersheds as per the Integrated Wasteland Development programme (IWDP) guidelines. The watersheds belong to different agro-ecological regions of the country having diverse physiographic, climatic and socio-economic conditions. Various indicators were employed to assess the impact of different activities showed significant improvement in biophysical, participatory and socio-economic attributes. The analysis of the data revealed that watershed interventions on arable and non-arable lands in a participatory mode significantly reduced runoff and soil loss which in turn improved crop productivity on an average by 28%.
4. Sharda *et.al.* (2005), assessed a cumulative effect of the interventions on agriculture improvement in the watersheds through the Cultivated Land Utilization Index (CLUI), which was based on the period of the year for which the cultivated area is under the different crops. The index value estimated for each of the six watersheds under study showed that land utilization improved by 2 to 81 %. The CLUI of all the watersheds had increased from 0.26 in the pre- implementation to 0.33 in the post-implementation period as a result of increase in overall utilization of land.
5. Sharda *et.al.* (2005) revealed that the various agronomical interventions improved the yield of traditional crops by 9 % (ladyfinger, Salaiyur) to 256 % (tomato, Kokriguda). The overall crop productivity of the watersheds measured in terms of the Crop productivity index (CPI)

increased from 12 to 45% depending upon the location and type of crops. The value of CPI improved from 0.50 to 0.64 after the post-implementation phase considering the five watersheds together from the different agro-clamatic regions.

6. Sharda *et.al.* (2005) reported the increase in crop diversification index from 6 to 79 % in all the watersheds except the Badakhera watershed. The increase in crop diversification index is attributed to the fact that earlier the farmers were practicing subsistence type of farming system with many crops but with better availability of resources, they switched over to lesser number of high yielding food and remunerative cash crops. The overall diversification of crops considering all watersheds together increased from 0.67 in the pre-project period to 0.82 after the project implementation.
7. Osman *et.al.* (2009) developed CRIDA index, which accounts both area and income and used in their study to assess the impact of Watershed Development Programme (WDP) on land use diversification. However, most of the studies are confined to *ex-ante* analysis immediately after the completion of the project where impacts are clearly visible, but the question remains, to be answered is whether they are sustainable in the medium to long run after the project period. The study focuses on ex-post analysis after a gap of one decade to understand the various aspects of sustainability and their drivers for drawing conclusions from the success of Kadwanchi watershed in Jalna district of Maharashtra state.

Material and Methods

The survey was conducted by using the questionnaire to collect the primary data from respondents. While preparing the questionnaire the questions was set according to the objectives of the research work. These questionnaires were distributed to the selected farmers/beneficiaries and taken back once filled. Questionnaire has the open ended and close ended questions. It was structured and informative. The questionnaire was prepared by understanding awareness about different aspects of watershed development works.

Profile of the study area

The study area is Karwadi-Nandapur watershed is a micro watershed which falls in the Kayadhu river watershed in Marathwada region of Maharashtra. Agriculture is the main occupation in the area. The Kayadhu river basin falls under the sub catchment of Upper Penganga upstream from conflict with Kayadhu in the catchment of Wardha River. Catchment of Wardha River falls under the Godavari river basin. Finally the study area falls under the region of Bay of Bengal. The GSDA has given nomenclature to the Karwadi-Nandapur watershed under study as PPG8/01/13. The catchment area of the watershed is 772.56 ha. The watershed comprises 480 ha of cultivable area, it consists of 48 ha of current fallow land, 233 ha area is non cultivable area out of which 155 ha is mostly the wasteland, 6.12 ha land is under habitation and 4.44 ha is under tanks and river. The watershed is characterized by hilly area having steep slopes ranging from 15 to 35% slope in the upper reach. The general slope of cultivated land in watershed ranges from l to 3 percent. However, at some location maximum slope of 15 percent is observed. Most of the area is covered by medium to deep soils and the soils are having the clay loam to clayey texture. The soils in the watershed are well drained. Nearly 70 ha area of the upper reaches of the watershed is vulnerable to very severe soil degradation due to occurrence of heavy storms in the watershed. Ground water from open wells as well as from bore wells is the chief source

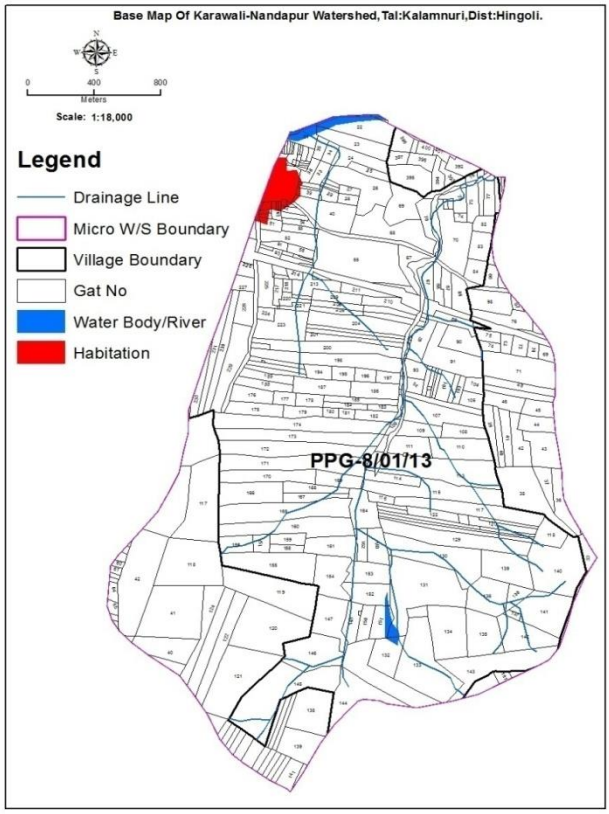


Fig.3.1: Base map showing the drainage pattern of Karwadi-Nandapur watershed

Various Performance Indicators of the Watershed

Various watershed indicators like crop diversification index, cultivated land utilization index, crop productivity index etc. are calculated in pre project and post project scenarios to evaluate the overall impact of the watershed development programme on crop diversification, crop productivity, land utilization. The various performance indicators are used to assess the changes in the cropping pattern, to assess the use of land for intercropping and multiple cropping systems. Crop productivity index is the indicator of crop productivity level in comparison to the normal yield of crops. Induced watershed eco-index is an indicator of additional area brought under vegetative cover due to crops, pastures, grassland development, horticultural development and forestry plantations in a watershed.

Crop productivity index

For assessing the overall improvement in crop productivity at the watershed level, Crop productivity index (CPI), which indicates the extent of crop productivity level in comparison to the normal yield of crops before and after the project, is calculated by dividing the crop yield obtained in the watershed by the yield obtained under recommended package of practices.

$$\text{Crop productivity index (CPI)} = \frac{1}{n} \sum_{i=1}^{n} (y_i / Y_i) \quad \text{---------- (3)}$$

Where, n is the total number of crops in the watershed, y_i is the average yield of i^{th} crop cultivated in the watershed and Y_i is the yield of i^{th} crop with standard package of practices. The CPI can attain any value greater than zero in a given location Higher value of CPI is indicative of crop's yields closer to the maximum attainable yield under standard package of practices.

Cultivated land utilization index

Cultivated land utilization index (CLUI) is an indicator of the use of land for intercropping and multiple cropping systems. It indicates the impact of watershed interventions on changes in cultivable land area and duration of crop cultivation in pre-project and post-project periods. It is calculated by summing the products of land area planted under each crop, multiplied by actual duration of days of that crop, and dividing the sum by the cultivated land area times 365 days as given below

$$\text{Cultivated land utilization index (CLUI)} = \frac{\sum_{i=1}^{n} a_i d_i}{A \times 365} \quad \text{---------- (2)}$$

Where, n are the total number of crops; a_i, is the area occupied by i^{th} crop; d_i are the days that the i^{th} crop occupied in the a_i area; and A is cultivated land area. The CLUI can attain a maximum value of 1.0 and higher value of CLUI indicates more usages of available land area of the watershed and or duration of crop cultivation period.

Crop diversification index

Crop diversification index (CDI) was used to assess the changes in the cropping patterns/systems due to crop improvement programmes. It is defined as:

$$\text{Crop diversification index (CDI)} = \sum_{i=1}^{n} P_i \log (1/P_i) \quad \text{---------- (1)}$$

Where,

P_i is proportion of i^{th} crop in comparison with total cropped area and n is the total number of crops in the watershed. The CDI can attain any value > 0 and higher value of CDI is an indicator of better crop diversification.

Induced watershed eco-index

Induced watershed eco-index (IWEI) is an indicator of additional area brought under vegetative cover due to crops, pasture and grassland development, and horticultural and forestry plantations in a watershed during the project period. It is calculated as:

$$\text{IWEI} = \frac{\text{Additional area vegetated during the project}}{\text{Total area of the watershed}} \quad \text{---------- (4)}$$

The IWEI can attain a maximum value of 1.0 which indicates that whole of the watershed area has been brought under some form of vegetation.

Results and discussions

The ever increasing population of the country, depleting water resources due erratic rainfall and over-extraction of groundwater resources and depleting land resources due to industrialization and the consequent urbanization is increasing the pressure on the available cultivated land for increasing crop productivity day by day. Increasing crop productivity, efficient and proper utilization of the precious land resources, cultivation of crops in a diversified way considering the climate and availability of other natural resources and simultaneously maintaining the ecological balance in a watershed are some of the objectives of a watershed development programme and are expressed in terms of crop productivity index, cultivated land utilization index, crop diversification index and induced watershed eco-index.

Crop Productivity Index

Crop productivity index indicates the extent of crop productivity level in comparison to the normal yield of crops before and after the project. The crop productivity index is calculated by taking the ratio of productivity of crop in a watershed to the productivity of the same crop under the standard package of practice.

Table 1: Comparison of crop productivity with standard crop productivity during the pre-development and post-development phase

Crops	Prod. Pre-implementation (Q/ha)	Std. Prod. (Q/ha)	Ratio	Prod. Post-implementation (Q/ha)	Std. Prod. (Q/ha)	Ratio
Soybean	17.5	22.5	0.78	24	22.5	1.07
Greengram	6	12	0.50	12	12	1.00
Blackgram	6	11	0.55	10	11	0.91
Cotton	17.5	20	0.88	27.5	20	1.38
Pigeon Pea	15	15	1.00	17.5	15	1.17
Sorghum	15	34	0.44	21	34	0.62
Turmeric	8	20	0.40	32	20	1.60
Wheat	30	33	0.91	35	33	1.06
Chick Pea	18	20	0.90	22.5	20	1.13
Safflower	7.5	13.5	0.56	10.5	13.5	0.78
Rabi Sorghum	15	19	0.79	24	19	1.26
Sweet Orange	120	300	0.40	250	300	0.83
Sugarcane	0	180	0.00	82	180	0.46
Groundnut	0	24	0.00	20	24	0.83
Fodder Crops	38	52	0.73	59	52	1.13

(Prod.: Productivity, Std.: Standard, Q/ha: Quintals per hectare)

From the Table 1, it was revealed that during the pre-implementation phase, the crop productivity index values range from 0 (groundnut, sugarcane) to 1 (pigeon pea) respectively. After the implementation of the watershed development programme, the crop productivity index values ranged from 0.46 to 1.60 for sugarcane and turmeric respectively. For the individual crop, turmeric has recorded a substantial increase of 300 % in the crop productivity index value in the post implementation phase as compared to pre-implementation phase followed by sweet orange (108.33 %) and green gram (100 %) while the minimum increase of 16.67 % in the crop productivity index value was observed for wheat and pigeon pea in the post implementation phase. During the post implementation phase, each crop in the watershed has observed the positive impact on their productivity as compared to that of during the pre-implementation phase. The average value of crop productivity index for the Karwadi-Nandapur watershed was increased from 0.59 in the pre-implementation phase to 1.02 in the post implementation phase recording an increase of 72.46 %.

Cultivated land utilization index

The land utilization under different crops is one of the important aspects of the watershed development activity and it is expressed with the help of cultivated land utilization index. A cumulative effect of the interventions on agriculture improvement in the watersheds is judged through the cultivated land utilization index (CLUI). An area of 480 ha was cultivated under different crops in the pre-implementation phase and recorded an increase of 109 ha resulted into 589 ha area under cultivation in the post implementation phase. Table 4.31 revealed that soybean recorded highest value of CLUI as 0.177 in pre-implementation as well as post implementation phase while, the fodder crops and green gram/ black gram recorded the minimum values of 0.00 and 0.002 in the pre and post implementation phases respectively. The increase in the value of cultivated land utilization index was observed to be highest for fodder crops (3349 %) followed by turmeric (511.20%), wheat (462.28%) and green gram (256.5%). The decrease in the crop diversification index values have been recorded maximum for pigeon pea (-37.87%) followed by sorghum (-32.94%) and sweet orange (-18.51%). The average value of cultivated land utilization index for the Karwadi-Nandapur watershed was increased from 0.41 in the pre-implementation phase to 0.65 in the post implementation phase recording an increase of 56.77 %.

Crop diversification index

The crop diversification is an important aspect of the watershed development activity and it is expressed with the help of crop diversification index. From Table 4.32, it was revealed that various agronomical interventions improved the yield of traditional crops by 16.7% (pigeon pea and wheat) to 100% (green gram). In addition to the introduction of high yielding varieties (HYVs) of traditional crops, some cash crops were also introduced in the watershed for better economic returns through crop diversification. There were thirteen crops cultivated in the Karwadi-Nandapur watershed area before the implementation of the programme and increased to fifteen crops after implementation of the programme adding sugarcane and groundnut. During the pre-implementation phase, the crop diversification index values ranged from 0 to 0.15 for groundnut and pigeon pea respectively and the average crop diversification index for the Karwadi- Nandapur watershed area was 0.73. After the implementation of the watershed development programme, the crop diversification index values ranged from 0 to 0.16 for sweet orange and wheat respectively and the average crop diversification index of the watershed area was 0.95 recording

an increase of 29.92 % in the crop diversification index. For the individual crop, turmeric has recorded a substantial increase of 280% in the crop diversification index value in the post implementation phase as compared to pre-implementation phase followed by green gram (177%), wheat (99%) and black gram (47.3%). The decrease in the crop diversification index values have been recorded maximum for pigeon pea (-26.61%) followed by Soybean (-26.30%) and sorghum (-24.75%).

Induced watershed eco-index

Watershed management has become an accepted tool for development and utilization of natural resources of land, water and plants especially perennial ones, on continuing basis. Sustainability of natural resources base is thus essential both from ecological and socio-economical point of view. Vegetative measures implemented in the arable and non-arable lands in conjunction with the mechanical measures helped in soil moisture conservation, which resulted in establishment and regeneration of vegetation and provided additional green biomass cover to the soil in all the watersheds. After the implementation of soil and water conservation interventions, the cultivated area has been increased from 480 ha to 589 ha, forest area has been increased from 12 ha to 106 ha and the grazing land has been increased from 19 ha to 36 ha as compared to the pre-implementation phase. Thus, a new green area of 220 ha has been created after the implementation of watershed development programme. The induced watershed eco-index (IWEI) of the Karwadi-Nandapur watershed was found to be 0.285; thereby indicating additional 28.5% watershed area was rehabilitated through green biomass cover. If the induced watershed eco-index (IWEI) is equal to or more than one, the watershed could be considered environmentally stable.

Table 2: Induced watershed eco-index for all the crops in watershed during the pre-development and post-development phase

Crops	IWEI Pre-development 2009-10	IWEI Post-development 2014-15	Difference	Total WS Area
Soybean	282	464	182	772.56
Greengram	1.6	7	5.4	772.56
Blackgram	3	6	3	772.56
Cotton	54.65	75	20.35	772.56
Pigeon Pea	34.76	26.5	-8.26	772.56
Sorghum	18.23	15	-3.23	772.56
Turmeric	4	30	26	772.56
Wheat	32.9	227	194.1	772.56
Chick Pea	125.5	300	174.5	772.56
Safflower	9.88	20	10.12	772.56
R.Sorghum	10	18	8	772.56
Sweet Orange	1.68	1.68	0	772.56
Sugarcane	0	1.5	1.5	772.56
Groundnut	0	24	24	772.56
Fodder Crops	0.5	2.1	1.6	772.56
Induced Watershed Eco-index = 0.285				

This would depend on extent of area under plants and quality of their stands. This will also take care of the concerns expressed on decreasing soil carbon pool.

From Fig. 1, it was revealed that the crop productivity index increased from 0.59 in the pre-development phase to 1.02 in the post-development phase with an increase of 72.88%. The cultivated land utilization index increased from 0.41 in the pre-development phase to 0.65 in the post-development phase with an increase of 58.53 %. The crop diversification index increased from 0.73 in the pre-development phase to 0.95 in the post-development phase with an increase of 30 %. The induced watershed eco-index was found to be 0.28 indicating the increase in green area by 28% during the post-development phase as compared to that of in pre-development phase. Six watersheds were selected from the different agro-eco regions and various watershed indices were assessed (Sharda *et.al.*2005). The study revealed that the overall crop productivity index, crop diversification index, cultivated land utilization index and induced watershed eco-index were increased from 0.50 to 0.64, 0.67 to 0.82, 0.26 to 0.33 and 0 to 0.12 from pre-implementation phase to post-implementation phase indicating the overall improvement in the land use, crop productivity, crop diversification and ecological restoration through increased green bio-mass cover.

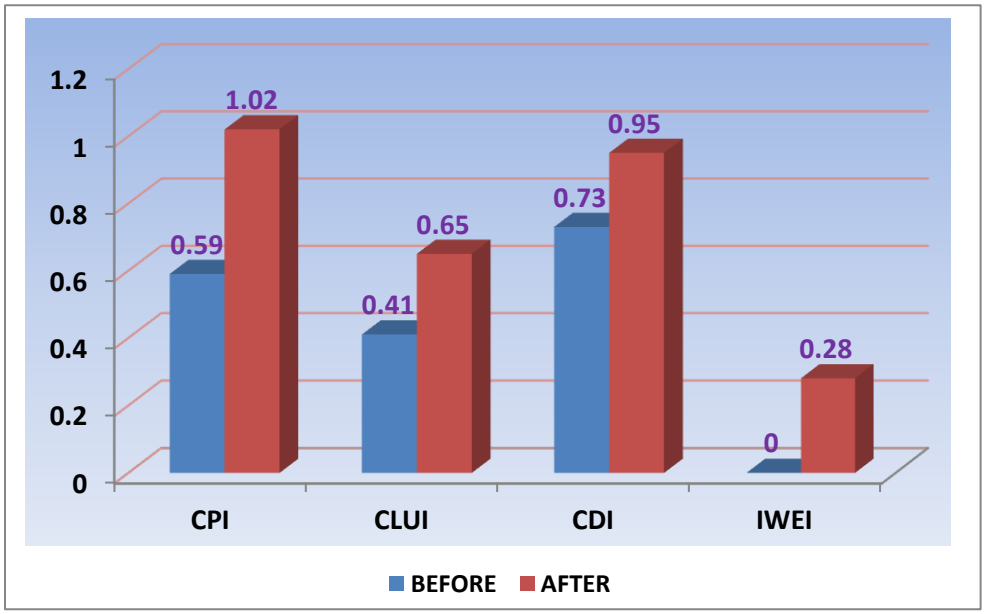


Fig.1: Comparison of various watershed indices for Karwadi-Nandapur watershed in Pre and Post-development phase

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Samra *et.al.*(2002) calculated People's participation Index (PPI) for a typical Shiwalik Watershed and observed to range from 28 to 84 per cent. The stakeholders participated in all the project activities right from the inception. With the increase in agricultural and animal husbandry components the women participation also increased considerably.

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ANALYZING THE EFFECT OF URBANIZATION ON SURFACE RUNOFF CHARACTERISTICS AT CATCHMENT SCALE

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Abstract

Urbanization and pressure of increasing population are two main challenges to urban water management, especially for cities in developing countries like India. The assessment of changes in catchment surface runoff due to urbanization is critical for water resource planning and management.This study has made use of the well-established tool, Service Curve Number (SCS-CN) method to observe surface runoff over the study area in conjunction with Geographic information system and remote sensing. This paper assesses changes in runoff characteristics due to urbanization in catchment of Raipur city. The catchment for Raipur city has been delineated from a sub basin of KharunRiver which is tributary of SeonathRiver. Pixel based Runoff depth of each sub- catchment was estimated by incorporating Digital elevation model, rainfall analysis data for the years 1971–2015, and Landsat ETM+, TM, MSS, Land Use/Land Cover (LULC) information within the rainfall-runoff model. SCS-CN was modified for Indian condition and the Hydrologic Engineering Center's Geospatial Hydrologic Modeling System (HEC-Geo-HMS) extension was utilized for evaluating the Basin characteristics. Spatio-temporal variation in each sub-catchment has been computed and significant change in runoff has been observed.The idea behind this study is to understand and to identify the nature of changes as well as the emerging urban growth pattern, to quantify surface imperviousness and change in surface runoff. To support the planning processes and policies making to guide or redirect spatial growth in Raipur city.

Keywords*:* landuse-land cover, HEC-HMS, SCS-CN, surface runoff, urbanization.

Introduction

To adequately manage impacts of ongoing or future land use changes, knowledge about existing landuse and trends of change is essential to tackle the problems associated with haphazard and uncontrolled growth. It is evident that land and water, an important life supporting systems are under intense pressure due to human induced accelerating factors (UNICEF, 2013).Around the globe, people are moving towards cities from countryside causing enormous growth of cities. Cities are nourishing ground for economic growth and good employment opportunities to the fast-growing population and thereby, attract more and more population towards it(Strohschön *et al.*, 2009; Strohschön *et al.*, 2013). Urbanization refers on one hand to a process in which an increasing proportion of an entire population lives in cities and the suburbs of cities. On the other hand it implies change of land use from agriculture, barren land or vegetation

to human settlements, commercial sectors and industries. Such process of urbanization is persistent for many decades due to continuous population growth, reclassification of rural localities into urban centers and migration of people from rural areas towards cities (UN, 2004; UN, 2009; UN, 2012). In 2008, for the first time in history, more than half of the world's population was living in towns and cities. It is expected that half of the population of Asia will live in urban areas by 2020 (UN, 2012). According to census data of 2011, India's total population has risen from 1.02 billion in 2001 to 1.21 billion in 2011. The urban population of the country is now more than 377 million constituting 31.16% of the total population. The other obviously mentioned facts by this census data are that, India has experienced a very high growth of urban population over the past years and urban population is assumed to raise more in near future.

The study about spatiotemporal characteristics of urban sprawl and urban pattern is useful for the sustainable land management and urban land planning (Strohschön *et al.*, 2013; Wakode *et al.*, 2013). After some significant literature review, Landsat satellite images are found to be best suitable and available for this study so those are used for the landcover classification. In this paper, a spatiotemporal analysis using a time series data of Landsat, aims at detection of the urban growth pattern and changes during three consecutive time periods: 1972-1991, 1991-1993, 1993-1999, 1999-2002, 2002-2008 and 2008-2015 in the Raipur urban agglomeration.

This paper covers landuse land cover analysis of an urbanized catchment using ERDAS Imagine software and rainfall-runoff simulation using HECHMS modelling platform. It has been seen that due to high urban growth and building of informal/unrolled structures the surface imperviousness is increasing which is directly affect the runoff condition in the catchment(Chen *et al.*, 2009). Hence a huge changing pattern would be seen in groundwater recharge and flooding in urban area. The land use classification is based on multispectral supervised classification approach using maximum likelihood classifier. Later the landuse land cover maps were used to generate curve number (CN) values and percentage imperviousness values for the catchment. This is again used as an input in HEC-HMS model to create continuous rainfall runoff simulation for different years.

Materials And Methods

Present study is focused on a Raipur city in India. As far as the study concern with catchment scale, a small catchment has been delineated from available DEM (Digital Elevation Model) based upon the one inlet and one outlet point. The above catchment can be seen in Figure 1. The delineated Raipur catchment area is 1118 sq km. which is located between 21°00'N to 21°30'N latitude and 81°20'Elongitude. The whole of Raipur catchment is part of Kharun sub basin, which is thickly populated and closely cultivated(Sinha *et al.*, 2016). The climate of the study area is sub-tropical with three distinct seasons. Temperatures remain moderate for most of the year. May is the hottest month and December is the coldest. The city experiences the average annual rainfall of 1200 mm. The Kharun River flows to the west of the city of Raipur, and passes through the center from the Raipur catchment, which is also a source of domestic water supply to the city (RMC, 2010). All the analysis is performed in the catchment scale using HEC-HMS but the present paper covers the anomalies only inside the Raipur municipal corporation area (shown in Red colour) which has approximately 300 sq km area. The city has a population of 1.125 million and experienced a growth rate of 51.06% during decade 2001-2011(Census-of-India, 2011).

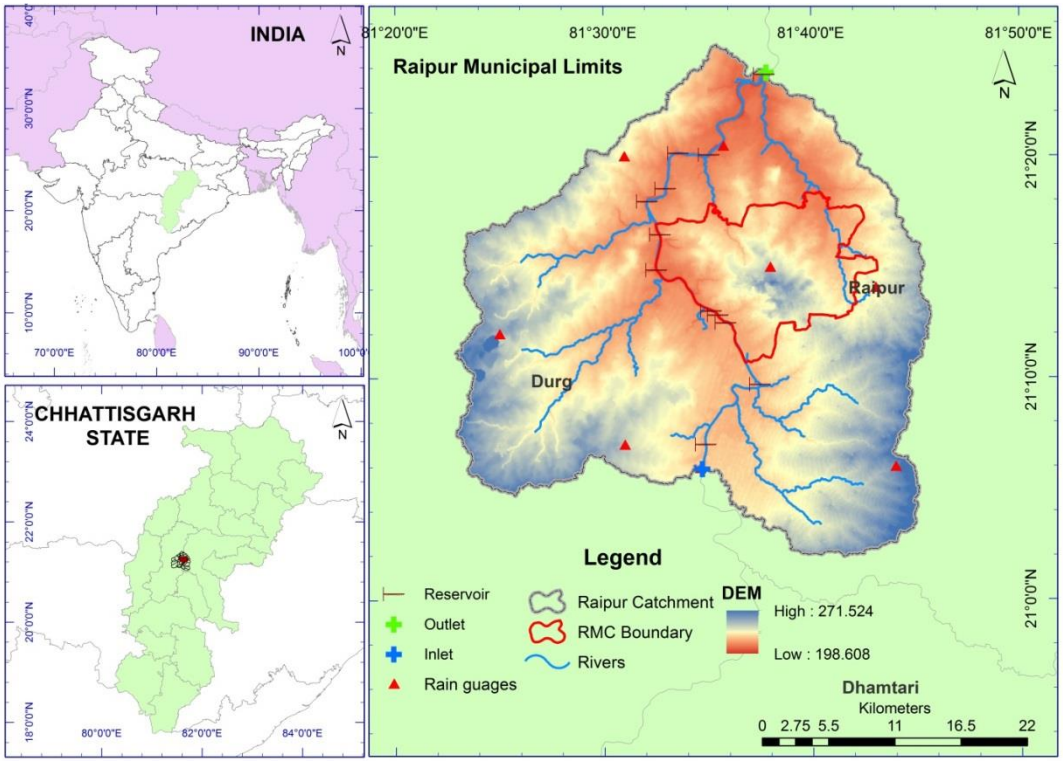


Figure 1.Location map of the study area

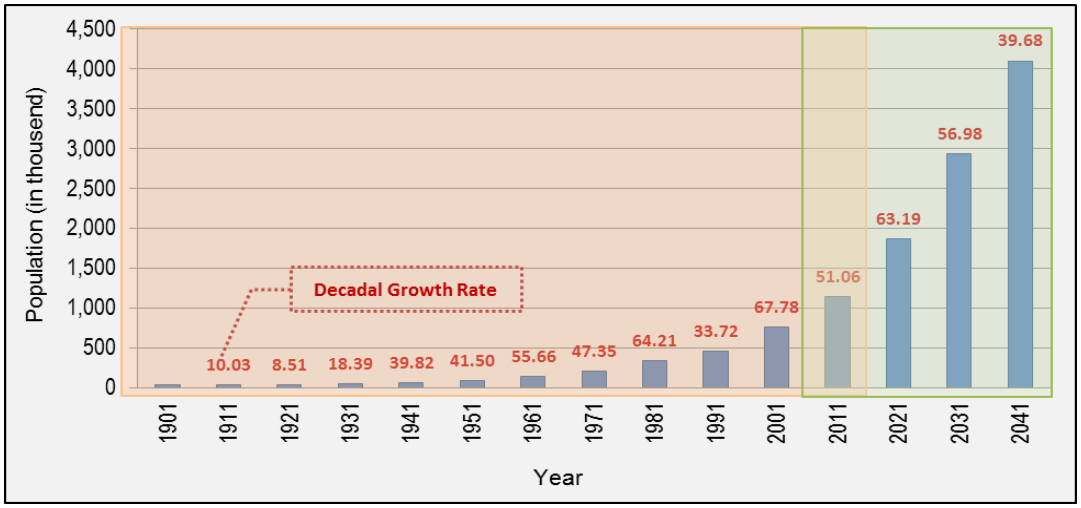


Figure 2. Population growth of Raipur city, modified after(Census-of-India, 2011; GIZ *et al.*, 2011; RMC, 2011)

Rainfall-runoff relationship is very complex, influenced by various storm and drainage characteristics. There are several approaches to estimate the runoff. The Soil Conservation Service-Curve Number (SCSCN) method developed by National Resources Conservation Service (NRSC), United States Department of Agriculture (USDA) in 1969, is simple, predictable and stable conceptual method for estimation of direct runoff based on storm rainfall depth(Ahmad *et al.*, 2015). In the present study SCS-CN method is used for estimating the runoff volume in the Raipur city part of Kharun sub-basin of Chhattisgarh State. Soil map, and land use / land cover map of the study area have been prepared using Indian Remote Sensing for year 1972, 1989, 1993, 1999, 2002, 2008, and 2015. These data's were used to generate CN map for each year. Figure 3 below shows detail procedure of rainfall-runoff modeling for each year.

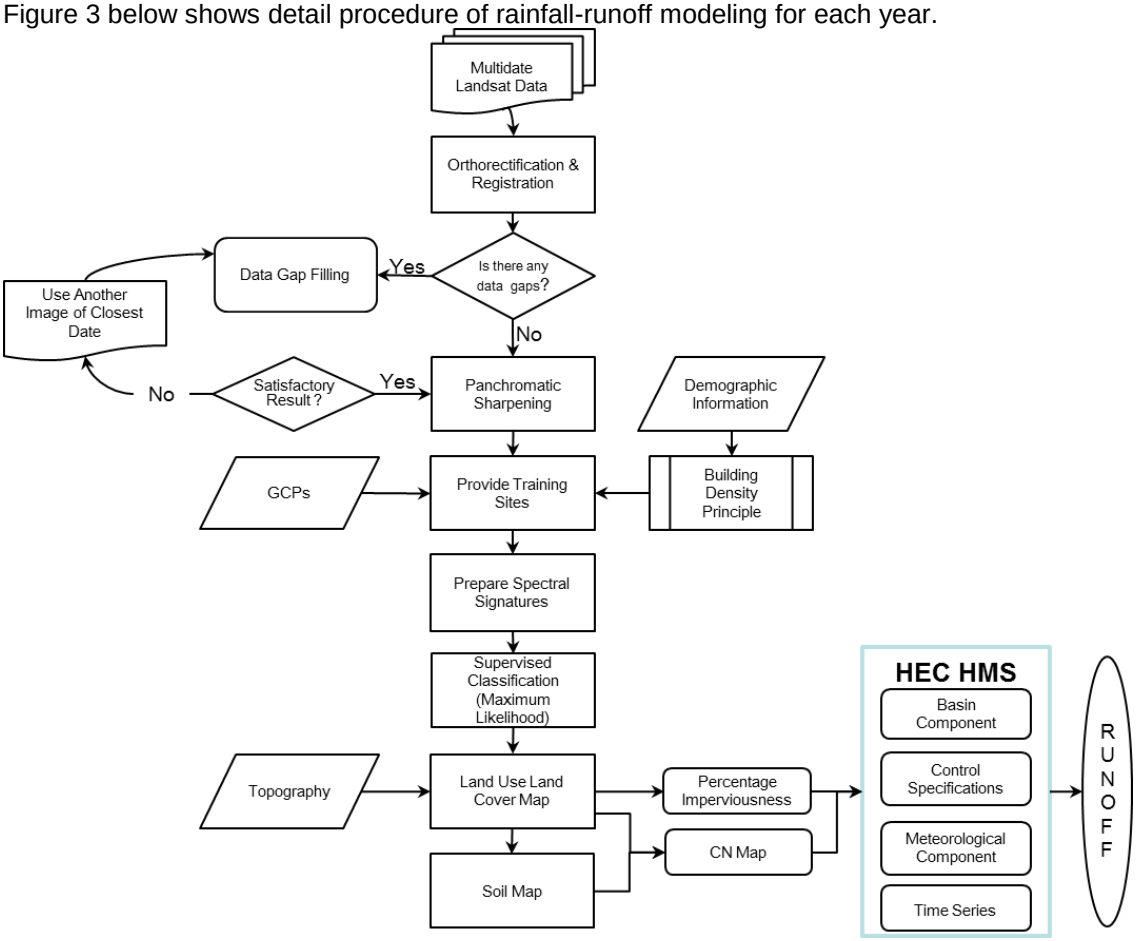


Figure 3. Flow chart of the methodology used, modified after (Wakode *et al.*, 2013)

HEC-HMS

HEC-HMS is hydrologic modeling software. It is open source product of U.S. Army Corps of Engineering´s Hydrologic Engineering Center (HEC). HMS stands for Hydrologic modeling system. One of the important model components of HMS is Rainfall Runoff Model. This model converts the precipitation data in the particular watershed to runoff. For mathematical modeling purpose, complex sub basin characters are divided into five components which are modeled separately. They are loss method, canopy method, surface method, transform method and baseflow method. Different methods are available in each component. The methods to be adopted for those components depend on site condition and data availability(Feldman, 2000). In this assessment HEC-HMS 4.5 version is used. Basic Model components and their data requirement is shown in figure 3. HEC-HMS has been evolving over past 30 years; recent researches prove that it is accepted for official purposes also. Since the software has many options in each method, it is flexible for different site conditions. The Methods / process used in present study is:

Table 1. Process, input data used to generate HEC-HMS model for Raipur catchment

S.No.	Process	HMS Model	Method used	Input data	Equation used
1	Computing Runoff Volume	Loss method	Grided SCS CN method	Initial Abstraction, Curve Number, Percent Impervious.	$Q = \frac{(P - \lambda)^2}{P + (1 - \lambda)S}$
2	Modelling direct runoff	Transform method	SCS Unit Hydrograph model	Basin Lag.	$\text{Lag time} = \frac{I^{0.8} \times (S + 1)^{0.7}}{1900 \times Y^{0.5}}$
3	Modelling Base flow	Baseflow method	Recession	Observed Gauge & Disharge.	$Q_t = Q_0 k^t$
4	Modelling Channel flow	Routing method	Muskingum Kung	Mannings n, Shape(8 point).	Bsed on water balance eq.

Where,

P = daily rainfall in mm,

λ = In the SCS method in Indian condition the NIH, 1998 gave the value of λ coefficient equal to 0.2.although for black soil region the value are taken as follows:

1. For black soil region AMC-I(Antecedent Moisture condition I) and for other regions:Ia =0.3S
2. For black soil region AMC-II & AMC-III:Ia =0.1S

Eq. is used with the assumption that the cracks which are typically of black soil when in dry conditions get vanished due to the expansive characteristics of the black soils.

The potential maximum retention by the soil is given by dimensionless parameter known as curve number CN that depends upon the hydrologic soil groups, AMC and land use land cover factors of the catchment area.

S = 25400/CN – 254

I (in m.)=Hydraulic length of watershed ,

Y= Average land slope,

Q_0= initial baseflow (at time zero) in m^3/s,

k = an exponential decay

Figure 4 shows a typical model setup in HEC HMS of Raipur catchment. All the model processes are assigned in HEC-Geo-HMS and input parameters are assigned using HEC-DSS tool(a database management tool from US Army crops).

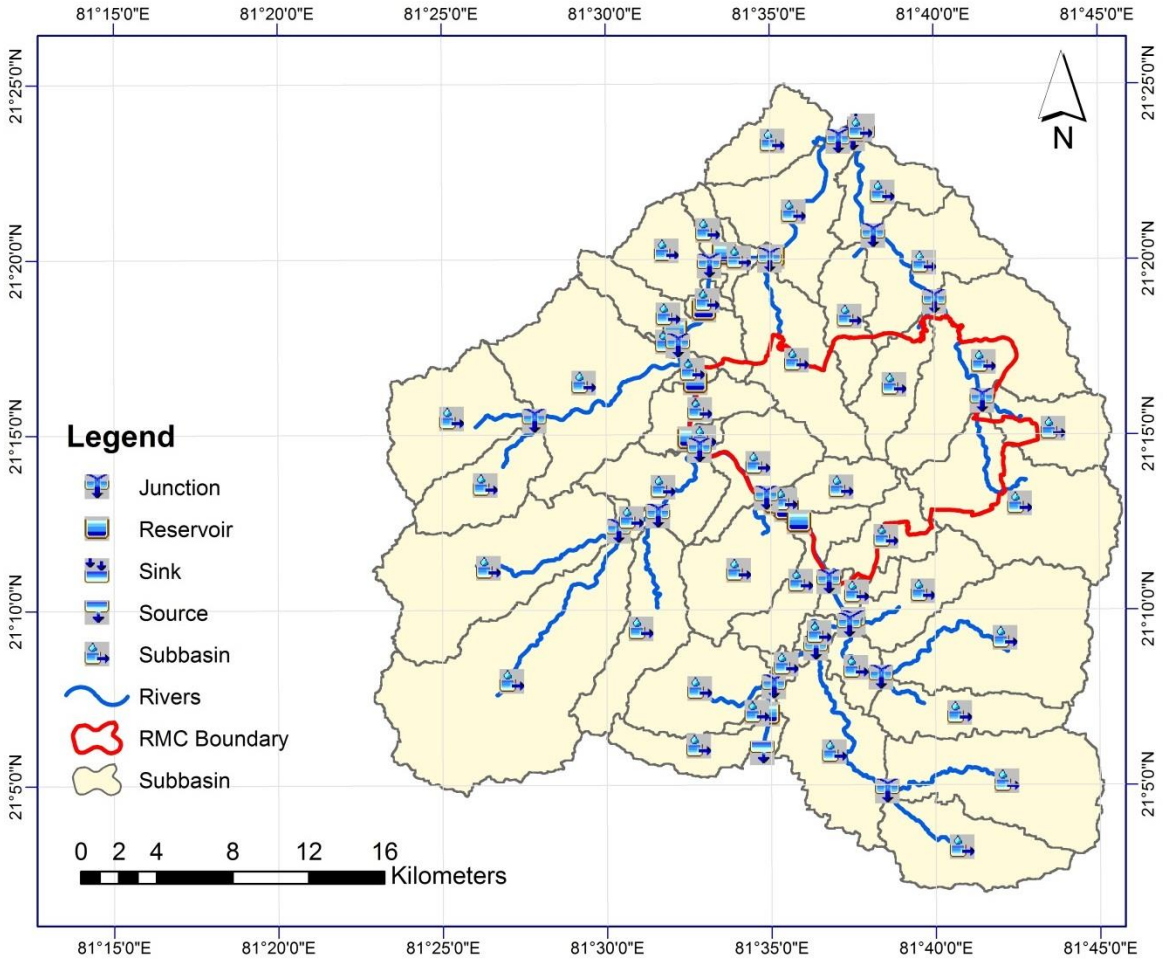


Figure 4. HEC-HMS model setup with HEC symbology of Raipur catchment

Results & Discussion

The supervised land use classification provided the following results in the form of numbers, as shown in Table 2. It shows the total area covered by each land use class in each year according to pixel size. The results clearly show that urban areas have expandingand water bodies are decreasing since 1989 with continuous population growth. Due to rapid socio-economic development and the concentration of business activities inside and surrounding the central part of the city, such rise in urban area isexpected. In other hand agriculture land and vegetation land has random anomaly in different years. Due to coarser resolution imagery it can be consider that the agriculture land and vegetation land has not been recognized at the time of visual interpretation. Also the Raipur city is the most polluted city in India in terms of air pollution(Verma *et al.*, 2016). This is also a reason for lack of visual interpretation and histogram error in north side of the city where industrial area is populated.

Table 2. Landuse landcover classification using supervised classification

Sat. Sensor	MSS	TM			ETM+			Area change in 1972-2015	Dynamic degree in % 1972-2015
Year/ LULC	1972	1989	1993	1999	2002	2008	2015		
Agricultural	199.4	92.96	164.3	214.1	184.2	137.1	173.5	-25.82	0.30
Open Land	44.38	125.7	67.25	42.25	34.88	28.34	16.76	-27.62	1.45
Urban	3.9	6.3	7.52	9.12	12.98	37.5	53.39	49.49	-29.51
Vegetation	48.9	71.86	58.09	32.01	65.24	94.92	54.34	5.44	-0.26
Water Bodies	3.88	3.88	3.53	3.2	3.4	2.88	2.52	-1.36	0.82
Total	**300.4**	**300.7**	**300.7**	**300.7**	**300.7**	**300.7**	**300.5**		

Note: All values are in sqkm.

With the start of socio-economic development, areasof agriculture and open land area were converted into urban areas. Also, the category which has lost theresourceslargest area is the open land and agriculture land use category which has lost an area of 27.62 km^2 and 25.82 km^2 respectively to other categories. Water bodies, Open land and Agriculture area have experienced continuous urban encroachmentduring this process of urbanization since 1972 to 2015 (figure 5). The dynamic degree of landuse types mentioned in Table 2, calculates the quantitative variation of a landuse category within certain time. It can be calculated by using following equation(Lu *et al.*, 2011):

$$K(\%) = \frac{(Z_a - Z_b)}{Z_a} . \left(\frac{1}{T}\right) . 100$$

Where;
K = the dynamic degree of land-use category
Za = the area of a category of land-use before the change
Zb = the area of a category of land-use after the change
T = the time interval

Instead presenting change in percentage area, dynamic degree has been computed which has a time factor. Negative values in dynamic degree shows higher growth in land use change and vice versa.Using the resulted landuse classification and soil classification curve number map has been generated. This is further used for input for HMS model as Basin CN and percentage imperviousness. The above shown HEC-HMS model in figure 4has been run and simulate for seven different control specifications to compute runoff at each pixel length as it is mentioned the gridded SCS CN method has been implemented for present study. The purpose of selection of grid based method for calculation is because of RMC boundary which is different than sub-basin boundaries in Raipur catchment model.This approach reduces the limitation of composite CN, instead using grid based method in this study. Daily rainfall data has been used to delineate the runoff quantity in the catchment which is summarized in Table 3 as monthly.

Table 3. Monthly variation in rainfall runoff result

	1972		1989		1993		1999		2002		2008		2015	
Month	RF (mm)	Dishcharge m3	RF (mm)	Dishcharge m3	RF (mm)	Dishcharge m3	RF (mm)	Dishcharge m3	RF (mm)	Dishcharge m3	RF (mm)	Dishcharge m3	RF (mm)	Dishcharge m3
Jan	0	0	0	0	0	0	0	0	13.8	41.2	7.6	19.2	9.4	27.5
Feb	5	10.4	0	0	10.2	18.7	11	30.8	5.2	25.1	11.6	50.9	2.2	9.3
Mar	0	0	12.6	34.4	18.5	99.2	0	0	5.7	30.9	24.8	150.1	19.3	106.9
Apr	8.6	28.6	0	0.2	14.2	88.4	0	0	3	17.4	5.2	34.5	51.4	350.5
May	21.2	119.5	12	59.8	32.8	214.5	70	447.4	14.1	86.5	0.6	4	13.4	95.8
Jun	213.2	1503	457.1	3287.8	135.4	985.9	98.6	696.8	195.6	1404.3	203.6	1448.3	271.6	1989
Jul	199.6	1545.6	391.1	2909.2	499.8	3688.2	135.9	1015.8	71.8	492.2	125.1	940.1	173.2	1281.9
Aug	374.3	2790.4	227.7	1649.1	405.2	2991.1	421	3030.6	344.6	2570.7	229.3	1627.5	267.4	1971
Sep	192.4	1483.8	196.2	1488.2	166.5	1238	263.7	2030.1	90.2	676.5	219.8	1693.2	219.6	1630.5
Oct	22	147.1	0	0	45.3	335.1	21	155.8	23.2	171.5	12.6	93.2	0	0
Nov	51	403.4	0	0	0	0	0	0	0	0	0	0	0	0
Dec	2	16.9	13.6	99.5	0	0	0	0	0	0	0	0	13.8	101.1
Total	**1089.3**	**8048.7**	**1310.3**	**9528.2**	**1327.9**	**9659.1**	**1021.2**	**7407.3**	**767.2**	**5516.3**	**840.2**	**6061**	**1041.3**	**7563.5**

From this continuous rainfall runoff simulation in table 3 the annual rainfall is decreasing so that runoff is also decreasing. In table 3 two variables that are rainfall and CN / year of landuse. Both are changing means it is difficult to interpretate the changes in runoff due to urbanization because landuse is also changing as in the same time rainfall patterns changes which is natural in nature. To draw or conclude result from the present analysis a change in dynamic degree between rainfall runoff and urban landuse has been computed (Table 4). The annual rainfall and runoff has been successfully correlated by commuting correlation coefficient which is varies from 0.76 to 0.86. Three new parameter is calculated which includes time duration of landuse change are Rainfall, runoff and urban landuse change as % dynamic change. To correlate the change in landuse with runoff the values were plotted in line graph type against duration (Figure 6). The results shows that the runoff is follow the exact urban landuse distribution which means dynamic degree change in runoff is same as urban landuse change. It may happed due to runoff calculation in this method is dominated by CN values which is directly related with landuse. So it can be concluded that as urban land is increasing the runoff trend is also increasing.

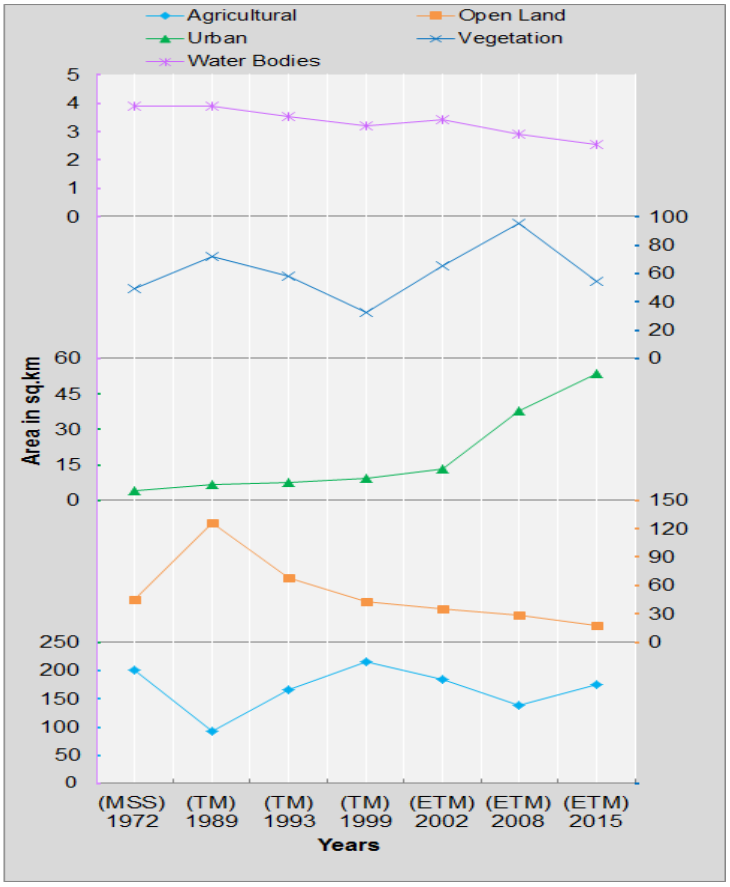


Figure 5.Temporal variation inlanduse landcover classification of Raipur city

Table 4. Rainfall runoff correlation and dynamic degree change with urban landuse

Year	Annual Rainfall in mm	Annual Runoff in m3/s	Urban landuse in sqkm	Dynamic degree in %			Correlation between Rainfall-Runoff	
				Rainfall	Runoff	Urban landuse		
1972	1089.3	8048.7	3.9	-	-	-	y = 7.5069x - 10.717	R^2 = 0.82
1989	1310.3	9528.2	6.3	-3.62	-1.19	-1.08	y = 7.3315x - 6.5197	R^2 = 0.86
1993	1327.9	9659.1	7.52	-4.84	-0.34	-0.34	y = 7.4213x - 16.299	R^2 = 0.79
1999	1021.2	7407.3	9.12	-3.55	3.85	3.89	y = 7.3506x - 8.2597	R^2 = 0.81
2002	767.2	5516.3	12.98	-14.11	8.29	8.51	y = 7.4469x - 16.413	R^2 = 0.76
2008	840.2	6061	37.5	-31.48	-1.59	-1.65	y = 7.381x - 11.711	R^2 = 0.79
2015	1041.3	7563.5	53.39	-6.05	-3.42	-3.54	y = 7.423x - 13.836	R^2 = 0.86

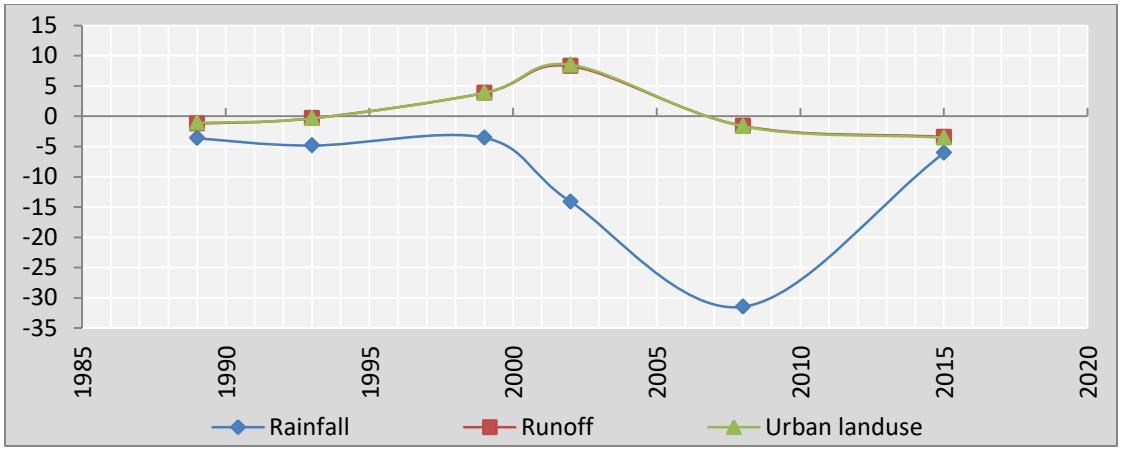


Figure 6. % Dynamic degree change between Rainfall, runoff and urban landuse

Conclusion

This study shows that using remote sensing and geographic information techniques, the process of urbanization can be analyzed efficiently. The freely available temporal Landsat MSS, TM and ETM+ data along with demographic information from census record has helped in detection of the change in land use and land cover over the period of time in Raipur city. It shows that total urban area has grown since 1972 to 2015 by 49.49 km^2.Open land and agriculture landuse are the categories which are mostly affected by the urban growth. Many surface water bodies are lost since 1972 and most of the remaining water bodies showed reduction in surface area. The total no of registered lakes in Raipur city was 185 in numbers now only 85 has been left. Such loss of surface water resources is also one of the reasons in changes of surface runoff pattern in Raipur city. Result of HEC-HMS model reveals that the landuse change is a most important factor for changing pattern in runoff in Raipur city. The simulation result of HEC-HMS model can also be used for forecasting the future changes in runoff pattern in the city if proper calibration has been applied. This study produces very valuable results for planner/policy makers as it reveals a very comprehensive indication of surface runoff distribution in Raipur city. The results can be conveniently utilized by the water resource engineering decision-makers for scientific management planning to mitigate the quantity of water resources. Moreover, it provides a sound base for planning of land use practices.

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DRY MATTER YIELD, CONTENT, UPTAKE AND PARTITIONING OF N, P AND K BY DIFFERENT PARTS OF PAPAYA AS AFFECTED IN ORGANIC AND INTEGRATED NUTRIENT MANAGEMENT SYSTEM UNDER SOUTH GUJARAT CONDITION

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Abstract

Pooled data of field experiment conducted at Organic Farm, F-block, NAU, Navsari FRBD with three replications at during 2009-10 and 2010-11 along with one control outside the organic farm revealed that among the different organics treatments, O_4 treatment recorded significantly higher fruit dry matter yield (103.24 q/ha) of papaya as compared to O_1, O_2 and O_3. Like organics, sap effect was also significant and treatment S_1 recorded significantly higher fruit dry matter yield (96.20 q/ha) in comparison to no application of sap (S0). In all the case, INM control recorded significantly higher values of petiole, leaves and fruit dry matter yield as compared to means of organics treatments. The N, P and K content in petiole, leaves and fruit of papaya were affected significantly due to individual effect of O except P and K content of petiole and leaves. Similarly, application of banana pseudostem sap (S_1) found significant in N, P and K content of petiole, leaves and fruit of papaya over no application of sap (S_0) except P content in petiole. In case of control v/s rest analysis, mean of organics showed significant effect on N, P and K content of petiole, leaves and fruit of papaya. The magnitude of significance in uptake of N (14.39 kg/ha) and P (5.51 kg/ha) through petiole as well as N (17.78 kg/ha), P (2.50 kg/ha) and K (29.00 kg/ha) through fruit of papaya was found with treatment O_4, however, it was at par with O_3 with respect to N and P uptake by petiole. Application of banana pseudostem sap showed significantly higher uptake of N (14.49 and 17.17 kg/ha), P (5.16 and 2.31 kg/ha) and K (10.36 and 25.92 kg/ha) through leaves and fruit of papaya, respectively.

Keywords: Papaya, Yield attributes, Quality, Organic, Pseudostem sap. INM

Introduction

Papaya is native to tropical America and is believed to have originated in Southern Mexico. It belongs to the family Caricaceae, and according to Purseglove (1968), it is probably originated in Southern Mexico and Costa Rica. Papaya (Carica papaya Linn.) is an important fruit crop of tropical world and has long been known as wonderful fruit of the tropics. Papaya is the fifth important fruit crop of India. It gives higher production of fruits per hectare and an income next to banana (Singh, 1990). Papaya crop being heavy feeder and the fruit are harvested fresh, the nutrient requirement of this crop is also very high. Growing papaya crop under organic farming can be possible only if integration of different sources of organics is done in such way that the nutrient release pattern matches with the nutrients demands of the crop. Information regarding these aspect is very scanty under South Gujarat and more so under organic farming situation. Hence, present study was planned to assess the effect of different proportion of organics with and without sap on yield and quality of papaya grown on organic farm.

Material and Method

A field experiment consisting of eight treatment combinations involving different proportion of three organics on N equivalent basis [O_1: 50 % RDN through bio compost (BC) + 50 % RDN through castor cake (CC), O_2: 50 % RDN through bio compost + 50 % RDN through vermi compost (VC), O_3: 50 % RDN through bio compost + 25 % RDN through vermi compost + 25 % through castor cake and O_4: 33.3 % RDN through bio compost + 33.3 % RDN through vermi compost + 33.4 % RDN through castor cake] and two levels of banana pseudostem sap application (S_0: without sap and S_1: with sap @ 8 l/plant) along with one INM controls outside the organic farm were tested in FRBD with three replications at Organic Farm, F-block, NAU, Navsari during 2009-10 and 2010-11.Plants sample collected at the time of harvest were first air-dried and then oven dried at 65 ^{0}C till reaches the constant weight and powdered with the help of stainless steel mixture grinder. The powdered samples were stored in plastic bags and were used for analyzing method describe for N by **Warnke and Barber (1974)** as well as P and K by **Jackson (1979)**.

Result and Discussion

Dry matter yield

The pooled results pertaining to dry matter yield of petiole, leaves and fruit of papaya under different treatments are reported in table 1. The perusal of results indicated that neither individual nor interactive effect of O and S could influence the dry matter yield of petiole and leaves significantly except fruit dry matter yield of papaya. Among the different organics treatments, application of organics as per O_4 treatment recorded significantly higher fruit dry matter yield (103.24 q/ha) of papaya as compared to O_1, O_2 and O_3. Similar variation in papaya fruit yield due to different sources of organics viz., FYM, urban compost, rural compost, sun hemp green manure and Vermicompost have also been reported by **Reddy *et al.* (2010)**. Like organics, sap effect was also significant and treatment S_1 recorded significantly higher fruit dry matter yield (96.20 q/ha) in comparison to no application of sap (S_0). Similar beneficial effect of sap application on yields of banana (3 l/plant), sugarcane (5000 l/ha) and onion (1500 l/ha) have also been observed with INM system under South Gujarat conditions **(Anon., 2012)**. In all the cases, the interaction effect between O and S was absent. But, between the two i.e., INM control and means of organics treatments, INM control recorded significantly higher dry matter yield of petiole (17.68 q/ha), leaves (5.05 q/ha) and fruit (120.10 q/ha) of papaya as compared to means of organics treatments.

Table 1: Effect of different treatments on dry matter (q/ha) yield of petiole, leaf lamina and fruit (Pooled)

Treatments	Petiole		Leaf lamina		Fruit	
O_1	14.02		4.00		78.39	
O_2	14.59		4.17		86.26	
O_3	14.32		4.09		97.45	
O_4	15.01		4.29		103.24	
S_0	14.44		4.12		86.47	
S_1	14.53		4.15		96.20	
Mean of Organic	14.49		4.14		91.34	
Mean of Control	17.68		5.05		120.10	
Source	**SEm±**	**CD at 5%**	**SEm±**	**CD at 5%**	**SEm±**	**CD at 5%**

O	0.42	NS	0.12	NS	1.05	3.03
S	0.30	NS	0.08	NS	1.48	4.29
O x S	0.59	NS	0.17	NS	2.09	NS
Cont. v/s rest	0.41	1.18	0.12	0.34	1.47	4.23
CV %	10		10		6	

Content, Uptake and Partitioning of N, P and K

The N, P and K content in petiole, leaves and fruit of papaya were affected significantly due to individual effect of O except P and K content of petiole and leaves (Table 2). Treatment O_4 recorded significantly higher level of N content in petiole, leaves and fruit of papaya with a value of 0.961 %, 3.50% and 0.171 %, respectively, however, significantly higher content of P (0.024%) and K (0.280%) over rest of the organic treatment except O3. These results clearly indicated that when the bulky (BC, VC) and concentrated (CC) organic sources are used in equal proportion, it enhances translocation of nutrients from vegetative parts to reproductive parts. This might be one of the reasons for recording significantly higher content under O4 treatment as compared to O2 and O1. Similar results were also reported by Reddy *et al*. (2010) who used combination of FYM and Sun hemp. Similarly, application of banana pseudostem sap (S_1) found significant in N, P and K content of petiole, leaves and fruit of papaya over no application of sap (S_0) except P content in petiole. The magnitude of significant increased was found with S_1 for N, P and K content (3.486%, 0.557% and 2.496, respectively) in leaves, N, P and K content (0.178%, 0.025% and 0.267%, respectively) in fruit of papaya as well as N and K content (0.947% and 3.256%, respectively) in petiole over S_0. It seems that the presence of cytokinin and GA3 apart from supplementation of nutrients in sap might have facilitated translocation of nutrient form vegetative to reproductive part. As far as interaction effect of O x S is concerned, O_4S_1 (3.702 %) was significantly higher than rest of the combinations with respect to N content in leaves. In case of control v/s rest analysis, mean of organics showed significant effect on N, P and K content of petiole, leaves and fruit of papaya.

The uptake of N and P through petiole as well as N, P and K through fruit of papaya was affected significantly due application of different proportion of organics. The magnitude of significance in uptake of N (14.39 kg/ha) and P (5.51 kg/ha) through petiole as well as N (17.78 kg/ha), P (2.50 kg/ha) and K (29.00 kg/ha) through fruit of papaya was found with treatment O_4, however, it was at par with O_3 with respect to N and P uptake by petiole. Application of banana pseudostem sap showed significantly higher uptake of N (14.49 and 17.17 kg/ha), P (5.16 and 2.31 kg/ha) and K (10.36 and 25.92 kg/ha) through leaves and fruit of papaya, respectively. The N and K uptake by fruit of papaya showed significant variation due to O x S, however, significantly higher value of N (20.75 kg/ha) and P (33.28 kg/ha) uptake was found with O_4S_1 over rest of the organic treatment combinations. In control v/s rest analysis, treatment analysis was turned out to be not significant for uptake of N, P and K through different parts of papaya. The per cent distribution values (Table 3) clearly revealed that under O_4 treatment, the accumulation of N, P and K in fruit with O_4 treatment was 37.69, 24.08 and 33.09 per cent as against the respective values recorded with O_1 were 33.21, 19.31 and 25.53 per cent. These results clearly indicated that when the bulky (BC, VC) and concentrated (CC) organic sources are used in equal proportion, it enhances translocation of nutrients from vegetative parts to reproductive parts. This might be one of the reasons for recording significantly higher yield under O_4 treatment as compared to O_2 and O_1. Similar results were also reported by Reddy *et al*. (2010) who used combination of FYM and Sun hemp. In case of sap, the magnitude of increase in accumulation of

N, P and K with S_1 treatment was 37.81, 24.32 and 30.93. The corresponding values for S_0 treatments wee 32.66, 19.47 and 27.80 per cent. It seems that the presence of cytokinin and GA3 apart from supplementation of nutrients in sap might have facilitated translocation of nutrient form vegetative to reproductive part.

Table 2: Effect of different treatments on N, P and K content (%) by petiole, leaves and fruit of papaya (Pooled)

Treatments	N			P			K		
	Petiole	Leaf lamina	Fruit	Petiole	Leaf lamina	Fruit	Petiole	Leaf lamina	Fruit
O_1	0.884	3.255	0.161	0.321	0.515	0.020	3.045	2.347	0.228
O_2	0.910	3.346	0.159	0.342	0.531	0.022	3.119	2.299	0.242
O_3	0.945	3.426	0.162	0.351	0.544	0.022	3.158	2.393	0.252
O_4	0.961	3.500	0.171	0.367	0.554	0.024	3.214	2.441	0.280
S_0	0.904	3.278	0.149	0.337	0.516	0.019	3.009	2.244	0.234
S_1	0.947	3.486	0.178	0.354	0.557	0.025	3.259	2.496	0.267
Mean of O	0.925	3.382	0.164	0.345	0.536	0.022	3.134	2.370	0.250
Mean of C	0.828	2.953	0.135	0.292	0.450	0.016	2.240	2.105	0.195

Source	N						P						K					
	SEm±	CD	SEm±	CD	SEm±	CD	SEm±	CD	SEm±	CD	SEm±	CD	SEm±	CD	SEm±	CD	SEm±	CD
O	0.011	0.031	0.031	0.089	0.003	0.008	0.012	NS	0.016	NS	0.001	0.002	0.085	NS	0.053	NS	0.006	0.018
S	0.015	0.044	0.043	0.126	0.002	0.006	0.008	NS	0.011	0.033	0.001	0.002	0.060	0.174	0.038	0.109	0.004	0.013
O x S	0.021	NS	0.061	0.178	0.004	NS	0.017	NS	0.023	NS	0.001	NS	0.120	NS	0.075	NS	0.009	NS
Cont. v/s rest	0.014	0.041	0.042	0.121	0.003	0.007	0.012	0.034	0.017	0.049	0.001	0.002	0.080	0.229	0.050	0.145	0.006	0.017
CV %	6		6		6		12		10		9		9		8		9	

Table 3: Effect of different treatments on N, P and K uptake (kg/ha) by petiole, leaves and fruit of papaya (Pooled)

Treatments	N			P			K		
	Petiole	Leaf lamina	Fruit	Petiole	Leaf lamina	Fruit	Petiole	Leaf lamina	Fruit
O_1	12.41	13.05	12.66	4.50	2.06	1.57	42.79	9.40	17.89
O_2	13.27	13.95	13.80	5.00	2.21	1.90	45.62	9.58	20.91
O_3	13.57	14.03	15.87	5.02	2.23	2.20	45.29	9.80	24.63
O_4	14.39	15.00	17.78	5.51	2.37	2.50	48.17	10.47	29.00
S_0	13.06	13.52	12.89	4.86	2.13	1.69	43.43	9.26	20.29
S_1	13.75	14.49	17.17	5.16	2.31	2.40	47.51	10.36	25.92
Mean of O	13.41	14.01	15.03	5.01	2.22	2.04	45.47	9.81	23.11
Mean of C	14.63	14.88	16.23	5.19	2.27	1.88	43.06	10.62	23.44

Source	SEm±	CD	SEm±	CD	SEm±	CD	SEm±	CD	SEm±	CD	SEm±	CD	SEm±	CD	SEm±	CD	SEm±	CD
O	0.43	1.25	0.47	NS	0.33	0.96	0.23	0.66	0.09	NS	0.07	0.20	2.01	NS	0.35	NS	0.67	1.94
S	0.31	NS	0.33	0.96	0.23	0.68	0.16	NS	0.06	0.18	0.05	0.14	1.42	NS	0.25	0.72	0.47	1.37
O x S	0.61	NS	0.66	NS	0.47	1.35	0.32	NS	0.12	NS	0.10	NS	2.84	NS	0.50	NS	0.95	2.75
Cont. v/s rest	0.42	NS	0.45	NS	0.33	NS	0.23	NS	0.09	NS	0.07	NS	1.90	NS	0.34	NS	0.66	NS
CV %	11		12		8		16		14		12		15		12		10	

Note: CD is at 5%

Table 3: Petiole, leaves and fruit N, P and K partitioning

Plant component	Organics				Sap		O-Mean	INM
	O_1	O_2	O_3	O_4	S_0	S_1		
N								
Petiole	32.56	32.35	31.22	30.51	33.09	30.28	31.59	31.99
Leaves	34.23	34.01	32.28	31.80	34.25	31.91	33.00	32.53
Fruits	33.21	33.64	36.51	37.69	32.66	37.81	35.41	35.48
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
P								
Petiole	55.35	54.88	53.12	53.08	55.99	52.28	54.05	55.57
Leaves	25.34	24.26	23.60	22.83	24.54	23.40	23.95	24.30
Fruits	19.31	20.86	23.28	24.08	19.47	24.32	22.01	20.13
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
K								
Petiole	61.06	59.94	56.81	54.96	59.51	56.70	58.00	55.84
Leaves	13.41	12.59	12.29	11.95	12.69	12.36	12.51	13.77
Fruits	25.53	27.47	30.90	33.09	27.80	30.93	29.48	30.39
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

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SOIL HEALTH IMPROVEMENT THROUGH PULSES: AN OVERVIEW

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Abstract

Good soil health is the foundation of food security and pulses help to increase soil microbial biomass and activity, thus improving soil biodiversity. World-wide more than 16,000 species of legumes are known, including herbs, shrubs and trees, but only about 200 are cultivated. An important attribute of pulses is their ability to biologically fix nitrogen. These plants, in symbiosis with certain types of bacteria, namely Rhizobium and Bradyrhizobium, are able to convert atmospheric nitrogen into nitrogen compounds that can be used by plants, while also improving soil fertility. Some varieties of pulses are also able to free soil-bound phosphorous, and phosphorous also play an important role in the nutrition of plants. The presence of pulses in agro-ecosystems helps to maintain and/or increase vital microbial biomass and activity in the soil, so nourishing the development of those organisms that are responsible for promoting soil structure and nutrient availability. All these features are particularly important for mainstreaming soil health, which is the foundation of food security and health.

Key words: Pulses, Resource Conservation**,** Soil health

Introduction

India is the largest producer of pulses in the world, with 25% share in the global production, 27% of consumption and 34% of food use. Chickpea, pigeonpea, mungbean, urdbean, lentil and field pea are important pulse crops. In India, production of pulses is around 19.3 million tonnes with a very low average productivity of 764 kg/ha. Currently, total area under pulses is 26.3 million ha. Pulses are an integral part of vegetarian diet of a large population in India. Besides being a rich source of proteins and essential amino acids; they also maintain soil fertility through biological nitrogen fixation in symbiotic association with *Rhizobium* bacteria present in their root nodules. Thus, pulses play a vital role as nitrogen fixing mini-factories which help in sustaining crop productivity and soil health (Poonia *et al*., 2015). The potential of pulses—beans, peas, chickpeas, lentils, and other pulses—to help address future global food security, nutrition and environmental sustainability needs has been acknowledged through the UN declaration of the 2016 “International Year of Pulses”.

Pulses are rich source of protein and energy, but in India, these are largely cultivated under poor soil conditions resulting in poor pulse productivity. This is mainly because of unavailability of quality seed at right time, cultivation on marginal and sub-marginal lands, imbalanced use of fertilizers and non adoption of crop improved management practices. Still, prime attention is required to meet the food security challenges, especially in case of pulse sector. In order to enhance and sustain the pulse productivity at high levels, the development and promotion of low–cost pulse production technology need greater attention so that technology is widely adopted by the practicing farmers. The most potential technologies in pulse production include improved crop establishment and management practices, integrated soil fertility and pest

management practices, etc. which enhances not only the productivity and profitability but also warrants environmental and social sustainability besides nutritional security.

An important attribute of pulses is their ability to biologically fix nitrogen. These plants, in symbiosis with certain types of bacteria, namely *Rhizobium* and *Bradyrhizobium*, are able to convert atmospheric nitrogen into nitrogen compounds that can be used by plants, while also improving soil fertility. Some varieties of pulses are also able to free soil-bound phosphorous, and phosphorous also play an important role in the nutrition of plants. The presence of pulses in agro-ecosystems helps to maintain and/or increase vital microbial biomass and activity in the soil, so nourishing the development of those organisms that are responsible for promoting soil structure and nutrient availability. A high soil biodiversity provides ecosystems with not only greater resistance and resilience against disturbance and stress, but also improves the ability of ecosystems to suppress diseases. All these features are particularly important for mainstreaming soil health, which is the foundation of food security and health.

Conservation of Natural Resources

Soil, air, water and biodiversity are the core natural resources which need to be conserved and utilized more optimally and efficiently for survival of mankind. However, the conventional agricultural practices which exploited natural resources for short-term gain without much concern for sustainable agriculture development has exposed soil to various kind of degradation. Pulse crops are endowed with unique ability to trap atmospheric nitrogen in their root nodules in association with *Rhizobium* bacteria, add huge amount of organic matter to soil through root biomass/ crop residue/ leaf fall, recycle nutrients and enhance soil biota and therefore, considered to be an important component of conservation agriculture.

Soil Quality Improvement

Soil quality benefits of pulses include increasing soil organic matter, improving soil structure & porosity, decreasing bulk density & pH, breaking hard sub-soil layer, recycling soil nutrients, diversifying the microscopic life in soil and breaking disease build up. Pulse-cereal crop rotation improves organic organic carbon, total N and available P content in soil as compared to cereal-cereal rotation (Table 1).

Table 1. Change in fertility status of soil under different cropping systems

Crop rotation	Organic carbon (%)	Total N (kg/ha)	Available P (kg/ha)
Paddy – Wheat	-0.004	-8.0	1.4
Paddy – Wheat – Green Manure	0.010	15.0	13.8
Paddy – Lentil	0.006	10.0	4.8
Pigeonpea – Wheat	0.006	9.0	8.8

Source: Singh *et al.* (1996)

In cereal- based systems, major concern for sustainability is deterioration in soil health, especially depleting soil organic carbon (SOC). Conservation agriculture-based management in general and inclusion of pulses in intensive cereal systems in particular have demonstrated tremendous potential in addressing the issue of soil health. Studies conducted at the ICAR-Indian Institute of pulses Research, Kanpur on inclusion of pulses in paddy systems (Table 2) showed significant improvement in available soil nutrients with inclusion of pulses compared to cereal – cereal rotation.

Table 2. Effect of pulse-based cropping system on soil chemical properties in a long term experiment

Cropping System	Available P (kg/ha)	Available K (kg/ha)	Available S (kg/ha)	B (kg/ha)	DTPA-Zn (kg/ha)
Maize-wheat	16.0	173.0	17.3	0.9	0.6
Maize-wheat-mungbean	17.2	186.0	19.4	0.9	1.1
Maize-wheat-maize-chickpea	18.0	185.9	18.5	1.0	0.8
Pigeonpea-wheat	16.8	183.2	19.1	1.0	0.8
Paddy- chickpea	21.6	243.4	17.2	0.9	1.8
Paddy- wheat-mungbean	18.7	271.6	16.7	0.9	1.6
Paddy-wheat-paddy-chickpea	21.2	247.9	17.5	0.9	1.7

Source: Jat *et al.* (2016)

A long duration pigeonpea crop adds 8-16 kg N, 2.5-5.0 kg P and 13.5-24.0 kg K/ha. The low C: N ratio of pulse residues (17) compared to wheat straw (31) facilitates bacterial growth and faster decomposition of crop residues for their conversion to soil-building organic matter. Pulses improve physical (soil aggregates, pore space, B.D.) chemical (O.C., pH, CEC, elemental balance, and recycling balance) and biological properties (biological nitrogen fixation, soil enzymes, biodiversity, earthworm, soil biota population efficiency and synergy) of soil. The improvement in soil structure is attributed to increase in more stable soil aggregates. The fungi present in the rhizosphere of pulse crop produces a glycoprotein called 'Glomalin'. The sticky part of glomalin entraps soil minerals, organic matter and debris to form stable soil aggregates. The aggregates stability increases pore space and reduces soil erodibility and crusting.

Water Economics

Globally, water resources is depleting fast. Among different sources, ground water is most important which provides 70 percent of the irrigation and 80 percent of the drinking water

supplies. Indiscriminate use of ground water resources is shrinking the total resource-base itself, as water table is dropping steadily and thus farmers are facing economic distress. Therefore proper choice of crops and cropping systems with high water productivity is essential for sustainable agricultural growth. Water requirements of pulses are low varies from 200-250 millimeter and high water-use efficiency, are considered for future agriculture. Global water consumption by pulses is reported to be about 4 percent compared to 60 percent in cereals. By consuming 1 ha-mm of water, chickpea could produce about 12.5 kg grain as against 7 kg wheat (*Triticum aestivum* L) and 2.5 kg paddy (*Oryza sativa* L.). Water use efficiency of pulses is much higher than other sources of protein e.g. pulses need 9,463 litre water for each tonne produce compared to 17,034 litre for chicken, 20,820 litre for mutton and 51,103 litre from beef (Solh, 2016). Pulses have ability to use water more efficiently than other crops because of their morphological and physiological features. Owing to their deep root-system, pulses are able to draw moisture even from deeper layer of soil profile.

Soil Erosion Reduced

Loss of soil from both non-agricultural and agricultural lands is a serious problem throughout the world. More than ½ of the water erosion and about 60 percent of wind erosion are on croplands that produce most of the country's food. Marked differences among crops in their ability to maintain soil cover emphasize the value of appropriate crops and crop rotation to reduce erosion. Several short growing pulses crops e.g. mugbean, Urdbean, rice bean, cowpea and horse gram develop dense canopy in a short period and cover soil surface, thus protect the surface of soil against beating action of raindrops and thus reduce splash and rill erosion. They also act as a vegetative barrier against flowing water, reduce run-off and improve water infiltration. Pulse crops like pigeonpea and moth bean act as a shelterbelt and thus reduce wind erosion.

Environmental Service and Nitrogen Fixation

Pulses provide enormous environmental services to maintain ecological harmony. Soil degradation (soil erosion) air and water pollution (CO_2 and nitrate) are restricted when pulses are including in cropping systems. Pulses have low carbon-and –water-footprint. The ability of symbiotic N_2 fixation makes legumes a superb species on Earth planet. Globally, legumes supply 47 million tonnes N/year as compared to 87 million tonnes by industrial fertilizers N (Table 3). The emission of CHGs is reduced by 1.25 kg Ce/kg of nitrogenous fertilizers (Lal, 2016). The nitrogen use efficiency of industrial nitrogen is low due to gaseous losses contributing to global warming, and leaching and erosion losses contributing to pollution of water courses and storage which is not the case with BNF. Among different sources of protein food, CO_2 produced per kg of lentil is only 0.9 kg as against 1.9 for milk, 2.7 for paddy, 2.9 for potato, 6.9 for chicken and 39.2 for lamb (Solh, 2016).

Table 3. Regional difference in reliance of agriculture on legume fixed N and fertilizer N for food production (million tonnes/ year)

Continents	Legume N	Fertilizer N
Asia and Middle East	19	47
Africa	3	5
Europe	3	14
Oceania	4	1
North America	8	14
South America	10	6
Total Global Value: > US$ 500 billion	47	87

Source: Peoples et al. (2009)

Pollution of ground water due to leaching of nitrates is a relatively new concern in India. Choice of appropriate cropping systems and management practices minimize nitrate leaching besides improving N-use efficiency. Legume intercropping in cereals grown with wider row reduces nitrate leaching.

The potential of legumes for improved and sustained soil fertility has been known for ages and mixed cropping as well as crop rotations of cereals with pulse crops were employed to capitalize on BNF. Non-legumes deplete the nitrogen content of soil, whereas leguminous can restore nitrogen, primarily in organic forms which are not readily leachable. The residual effect of pulse crop is equivalent to 0-244 kg/ha (Table 4) which is of greater ecological and agronomic importance. However, improved crops, microbes, and appropriate management practices must be developed if higher levels of production and sustainability are to be realized.

Table 4. Proportion (Ndfa) and range of nitrogen fixation in important pulse crops

Pulse Crops	*Ndfa (%)	Amount of nitrogen fixed (kg N/ha)
Pigeonpea	10-81	7-235
Chickpea	8-82	3-141
Common bean	0-73	0-125
Lentil	39-87	10-192
Pea	23-73	17-244
Mungbean	15-63	9-112
Urdbean	37-98	21-140

*Ndfa: nitrogen derived from atmosphere; *Source:* Peoples *et al*.(1995)

The present government of India is advocating for increase in the pulse are not only to maintain soil health but for proper human nutrition. The UN has declared 2016 year as International year of pulses showing its concern for food and nutritional security for every individual.

Conclusion

Pulses in cropping system improve soil quality, meet their own nitrogen requirements and also benefits succeeding crops. They fix 20-90 kg N/ha through symbiotic N fixation and thus curtail production of industrial N-fertilizers. Pulses are also ideal for crop diversification and intensification. Owning to low water-foot print, negative C-footprint and soil conserving values, pulses provide an important environmental services for sustainable agriculture.

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THE PERFORMANCE OF MAIZE-WHEAT CROPPING SYSTEM AS INFLUENCED BY SUBSOIL COMPACTION AND NITROGEN FERTILIZATION IN SEMI-ARID IRRIGATED CONDITIONS

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Abstract

The rice-wheat cropping sequence (RWCS) is the predominant cropping system followed in the Punjab state, utilizes major portion of ground water resources, leading to fast decline in ground water table. The falling water table problem got worsen when subsoil compacted layer formed due to use of heavy machinery and puddling in RWCS. Maize-wheat system is emerging as best substitute to high water demanding rice-wheat cropping. In an experiment at research farm of department of soil science, Punjab agricultural University, Ludhiana, India, the effect of subsoil compaction and nitrogen fertilization on the yield of maize-wheat cropping system was accessed. Three main plot treatment of subsoil compaction levels (C_0- Control/deep tilled (bulk density, Db = 1.55-1.65 Mg m^{-3}), C_1- Moderate compaction, (Db = 1.70-1.75 Mg m^{-3}) and C_2- High compaction (Db>1.80 Mg m^{-3}) at 15-30 cm depth) and three doses of Nitrogen fertilizer (nitrogen treatments were N_0-155 Kg N ha^{-1}, N_1-195 Kg N ha^{-1} and N_2-235 Kg N ha^{-1}) as subplot treatment were arranged in Split plot design with three replications. The maize grain yield reduction of 15.5 to 23.5 per cent was recorded in C_2 treatment as compared to C_0 subsoil compaction level; while 14.8 to 16.1 per cent higher yield was observed under N_2 treatment as compared to N_0 treatment. Yellowing of lower leaves of wheat was observed after first irrigation under C_1 and C_2 subsoil compaction treatments that persisted for few days indicating the deficiency of oxygen in root zone due to subsoil compaction. The results also revealed that the wheat yield reduction of 7.2-18.5 percent under different subsoil compaction treatments. The present investigation encourage the use of chiseling/subsoiling to break subsurface hard pan and improve the yield of maize-wheat cropping system.

Keywords: Subsoil compaction, Nitrogen, Yield, Maize-wheat cropping system.

Introduction

Soil compaction is emerging as a serious problem affecting the yield of field crops leading to soil degradation of about 68 million hectares of land globally (Flowers and Lal, 1998). Harris (1971) defined soil compaction as “the compression of soil by external forces that decrease the volume of pore space while increasing the soil density”. Tursic *et al* (2008) reported that a thick compacted layer builds up below the surface layer as a consequence of poor tillage practices, as the farmers fail to vary the depth of ploughing over several years. The development of compacted layer is the function of soil type and water content, vehicle weight, speed, ground contact pressure and intensity of vehicular use, and their interactions with cropping frequency and farming practices (Larson et al 1994, Chamen et al 2003). The compact layer also formed as a result of puddling that destroys soil aggregates, reduces water transmitting macro pores and

hydraulic conductivity of soil (Prihar et al., 1976), which also reduces ground water recharge (Sur et al., 1980) by affecting water transmission characteristics such as saturated hydraulic conductivity and infiltration, etc.The subsoil compaction also known to reduce root and shoot growth and crop yield (Gaultney *et al*., 1980; Siemens & Peterson, 1997) by reducing root growth, water and nutrient transformation and uptake. The rice-wheat system involves intensive tillage and puddling in Punjab that create favourable condition for the development of subsurface compact layer. The yield of maize wheat system may be affected on shifting from rice-wheat system to maize wheat system. Further the farmers apply excessive nitrogen to cover the risk of yield losses. The present study was conducted to access the impact of subsurface compaction and nitrogen fertilization on the yield of maize-wheat system.

Materials and Methods

Site and experimental design

The experimental was conducted at the research farm, Department of Soil Science, Punjab Agricultural University, Ludhiana, in the central plain region of Indian Punjab. The soil is classified as alluvial, sandy loam in texture, calcareous, typic Haplustept. The physico-chemical properties of soils are reported in Table-1. The treatments were imposed using split-plot design with three blocks, three subsoil compaction levels (main plot treatments) and three levels of nitrogen fertilizers (subplot treatment). The subsoil compaction treatments were executed by removing 15-cm surface soil and then sub-surface layer was compacted with passes of tractor mounted roller to achieve the desired bulk density. After achieving the desired bulk density, surface soil was put back on the place. The soil compaction treatments were C_0- Control (bulk density, D_b= 1.55-1.65 g/cm^3), C_1- Moderate compaction, (D_b= 1.70-1.75 g/cm^3) and C_2- High compaction (D_b>1.80 g/cm^3) at 15-30 cm depth. The nitrogen levels applied were -155 kg N ha^{-1}, N_1-195 kg N ha^{-1} and N_2-235 kg N ha^{-1}. Phosphorus, potassium and zinc sulphate were applied @ 60, 30 and 25 kg ha^{-1}, respectively during both the years. Entire quantity of P, K and Zinc Sulphate along with one third of N (as Urea 46 % N) was applied at the time of sowing and remaining N was applied in two equal splits i.e. at knee high and at pre-tasselling stages in Maize, while half N was applied at the time of sowing and remaining half at first irrigation in wheat. The "PAU package of practices for *kharif* crops" was followed to ensure proper weed, insect and pest control. All the maize ears from each net harvested plot were sun dried for three days and shelled. Moisture content of grains from each plot was determined. The grain yield (t ha^{-1}) was adjusted to 15 per cent moisture content on fresh weight basis in maize. Similarly wheat grain yield was adjusted to 14% moisture content on fresh weight basis. Statistical analysis of differences between various means was carried out using the general linear model procedure (PROC GLM) of the Statistical Analysis System (SAS 9.1, from SAS Institute Inc. CA) as per the standard procedure for split plot design given by Gomez and Gomez (1984). Differences between treatment means were determined using Duncan's Multiple Range Test (DMRT).

Results and discussion

Effect of subsoil compaction on the grain yield of maize system

The highest maize grain yield was recorded under C_0 treatment than that in C_1 and C_2 treatments. The C_2 treatment resulted in yield reduction of 15.5 and 24.3 per cent than that in C_0 treatment during the year 2012 and 2013, respectively(Table 2).Gaultney *et al*. (1980) also reported 45-50 per cent yield reduction in maize due to subsoil compaction, while compaction due to vehicular traffic resulted in average yield reduction of about 13 per cent (Siemens and

Peterson, 1997). The maize yield reductions under higher degree of subsoil compaction occurred due to root growth restrictions. Allmaras *et al*. (1988) also recorded lower yields due to root growth restrictions under higher subsoil compaction. The crop took less number of days to mature ((Singh and Hadda, 2014) data published elsewhere) under C_2 treatment might had resulted in reduced crop yields. Muchow, (1990) also observed grain yield reduction due to shorter grain filling period due to early maturity of crop. The N application had significantly improved the maize grain yield. The N_2 treatment resulted in 14.8 and 16.1 per cent increase in grain yield than that in N_0 during the year 2012 and 2013, respectively. An increase in grain yield may be attributed to higher plant growth in response to higher level of N fertilization over the recommended doses of N. The study supports the finding of Inamullah *et al.* (2011) who reported an increase in grain yield with higher dose of N application. However, no significant interaction was observed for yield due to subsoil compaction and nitrogen fertilization.

Effect of subsoil compaction on the grain yield of maize-wheat system

The perusal of data reveals significant effect of subsoil compaction and nitrogen fertilization on the yield of wheat during the year 2012 and 2013.The highest wheat grain yield was recorded under C_0 treatment than that in C_1 and C_2 treatments. The grain yield reduction due to subsoil compaction was 8.4 – 14.8 percent and 7.2 – 18.5 percent during the year 2012 and 2013, respectively than that in control treatment. The Yellowing of lower leaves of wheat was observed after first irrigation under C_1 and C_2 subsoil compaction treatments that persisted for few days indicating the deficiency of oxygen in root zone due to subsoil compaction. The root growth restrict due to subsoil compaction might be the reason for the yield reduction of the wheat.

Conclusions

The present investigation showed that grain yield of maize-wheat system is influenced by subsoil compaction and nitrogen fertilization. The results revealed that subsoil compaction reduces grain yield of maize-wheat system. Nitrogen fertilization improved the grain yield even under compacted subsurface soil, by providing proper fertilization leading to higher grain yield. The grain yield reduction of 7.2 -24 % has been recorded in maize-wheat system due to subsoil compaction. The study shows that deep tillage/chiseling/subsoiling can be done to improve yield and groundwater recharge to arrest falling water table.

Table: 1.Physico-chemical properties of experimental site

Parameter	Value
Sand (%)	64.8
Silt (%)	17.9
Clay (%)	16.3
Bulk density, (Mg m^{-3})	
0-15 cm depth	1.49
15-30 cm depth	1.63
pH	7.63
E C (dS m^{-1})	0.51
Plant available water (cm/180 cm profile)	21.8
Saturated Hydraulic conductivity (cm hr^{-1})	
0-15 cm depth	5.87
15-30 cm depth	1.95

Table: 2. Maize and wheat grain yield as affected by subsoil compaction and nitrogen fertilization.

	Maize Yield (t ha^{-1})		Wheat yield (t ha^{-1})	
	2012	2013	2012	2013
C_0	6.307a	5.494a	4.472a	4.781a
C_1	5.738b	4.391b	3.806b	4.437b
C_2	5.326b	4.158b	4.094b	3.894c
p-value C	<0.1	<0.1	<0.1	<0.1
N_0	5.40b	4.346b	3.839b	4.169b
N_1	5.76ab	4.646ab	4.100ab	4.341ab
N_2	6.20a	5.049a	4.433a	4.604a
p-value N	0.01	0.038	0.007	0.044
p-value C X N	0.65	0.99	0.95	0.54

Different letters in each column show significant differences between treatments at < 0.05 probability level.

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IMPACT OF DIFFERENT LEVELS OF PHOSPHORUS AND FYM ON YIELD AND SOIL NUTRIENT STATUS OF CHICKPEA

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Abstract

A field experiment was conducted during rabi 2013 in Vertisol at Instructional farm of Indira Gandhi Agricultural University; Raipur (C.G) to study the Impact of different levels of phosphorus and FYM on yield and soil nutrient status of Chickpea. The objectives of the study were to estimate the nutritional requirement, efficiency of fertilizer, soil test and organic source (FYM), to estimate the fertilizer requirement of Chickpea crop based on soil test levels using INM approach. Chickpea crop required 0.46 kg P to produce one quintal of grain. Fertilizer and Soil test efficiencies estimated were 10.01 and 30.03 percent, respectively for phosphorus. The FYM contribution for P nutrient was estimated as 4.42.

Keywords: Soil test, *Vertisol,* Chickpea, nutritional requirement, INM approach.

Introduction

India ranks Ist in Chickpea production. In India Chickpea is grown in area of 8.25 million ha with an annual production of 7.33 million tonnes and productivity 889 kg/ha (Anon., 2014). The fertilizer application practices based on targeted yield approach indicated the possibility of enhancing production potential of chickpea crop. During recent years, there has been rapid decline of phosphorus nutrient in soil which has to be replenished through external supply. At the present level of crop production and fertilizer use, there is an estimated gap of about 10 million tonnes between the quantity of nutrients removed by the crop and the quantity of nutrients added through fertilizer. The organic resources available (organic manure, crop residues and bio-fertilizers) presently could meet this gap but the present level of organic sources used in agricultural production is only one third of the potential availability. Hence, the fertility status of the soil is fast declining and in the long run, it may affect the productivity and its sustainability. Therefore, it is essential to protect the soil health by adopting balanced fertilization through soil testing and organic source as an INM approach. The present study was undertaken to develop balanced fertilizer schedule with FYM application for desired yield targets of chickpea in *Vertisols* of Chhattisgarh state. The effective fertilizer recommendation should consider crop needs and nutrient already available in the soil. Continuous use of inorganic nutrients may adversely affect the physico-chemical properties of soil and thereby affect the crop yields. In order to sustain the yield and reduce the dependency on inorganic fertilizer use, conjunctive use of organic manures and fertilizers is essential.

Materials and Methods

A field experiment was conducted at the farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh) on soil test crop response correlation with chickpea (JG-130) during rabi season, 2013 in Vertisol. The soil of the experimental field comes under the soil order of

Vertisol. This soil is locally known as *Kanhar* and identified as Arang II series. It is clayey in texture with 24.3 % Sand, 21.4% silt and 54.3% clay, dark brown to black in color, neutral to alkaline in reaction due to presence of lime concretion in lower horizon. The soil is deep to 1 -1.5 meter. The structure varied from coarse angular blocky to massive and cloddy and in few cases from prismatic or columnar. Soil is represented as typical *fine montmorillonitic, hyperthermic, udic chromustert.* Some physico-chemical properties of experimental soil were 8.03 pH (1:2.5), 0.18 EC (dSm^{-1}), 36.32 CEC (Cmol (p^{+}) kg^{-1}), 5.80 Organic C (g kg^{-1}), available N 238 kg ha^{-1}, available S 27.08 kg ha^{-1} 19.3 available P (kg ha^{-1}), 486 available K (kg ha^{-1}). A special field technique developed by Ramamurthy et al. (1967) was used for this study. The field was divided in to three equal long strips and denoted as L_0, L_1 and L_2. Prior to conducting the actual field experiment, a fertility gradient was created by applying the graded doses of N, S, P and K fertilizer for obtaining the appropriate variation in soil fertility in different strips. The source of P were used as Diammonium-phosphate. Each strip was divided in to three equal sizes for three levels of FYM (0, 5 and 10 t ha^{-1}) and was treated as block. A representative sample of FYM applied was analyzed for nutrient content and resulted as 0.40, 0.30 and 1.00 per cent N P and K, respectably. The 24 selected fertilizer treatments constituted 4 levels of each of P_2O_5 (0, 30, 60 and 90 kg ha^{-1}). These were distributed in each block of the strips having 8 treatments in each block. Soil samples were analysed for available P (0.5M $NaHCO_3$ at pH 8.5 as described by Olsen *et al* 1954).

Results and Discussion

Establishment of Fertility Gradient

Soil available nutrient: The range and mean values of available nutrient P (Table 1) indicate that soil test P varied with different fertility strips although soil test P variations with respect to fertility strip were marginal.

Table 1: Range and mean values of available P (kg ha^{-1})

Soil Nutrients	L_0	L_1	L_2	SD	CV %
Olsen's-P	11.00-17.67 (13.91)	13.40-24.56 (18.53)	18.76-39.93 (27.89)	6.81	33.86

Crop yield: Table 2 gives the range and averages of chickpea yield in relation to different fertility strips. It was observed from the results that there was increasing trends in chickpea yields from L_0 to L_2 fertility strips due to increasing P level. Highest yield of 23.51 q ha^{-1} was observed in L_2 strip with a good response to the application of highest dose of fertilizer and 7.33 q ha^{-1} was observed in the L0 strip without fertilizer (Control).

Table 2: Range and mean of grain yields of Chickpea (Var JG-130**) yield (q ha^{-1})**

Fertility Strips	Grain yield (q ha^{-1})			SD	CV %
	Minimum	Maximum	Average		
L_0	7.33	22.21	15.56	4.21	27.07
L_1	9.09	22.44	16.39	3.81	23.23
L_2	10.19	23.51	17.10	3.99	23.33
All strips	**7.33**	**23.51**	**16.35**	**4.00**	**24.47**

Relationship between yield and Nutrient Uptake

The chickpea yields showed the close association with total S uptake. This relation was used to estimate t he nutrient requirement for chickpea (Table 3). The nutrient requirement (NR) is defined as the amount of nutrient required to produce per unit amount of yield. The nutrient requirement can be given by the regression co-efficient (b_1) of yield (Y) and total nutrient uptake (U).

$Y = b_1 U$ or $U = 1/b_1 * Y$

Where, 1/ b_1 give the NR.

Table 3: Relation of chickpea yield (Y) with total nutrient uptake (U)

Nutrient	Chickpea	
	Y = b1 U	R^2
P	Y = 2.165 U	0.99

Nutrient requirement and Development of basic parameters

Results presented in Table 4 show the nutrient requirement (NR) for P (kg q^{-1}), efficiency of fertilizer (E_f), Soil test (Es) and FYM were estimated. The Chickpea required about 0.46 kg P to produce one quintal of grain. Fertilizer efficiencies for P was less than soil test efficiency. Contrary to this, efficiency of FYM was found to be less with P.

Table 4: Nutrient requirement, fertilizer, soil and FYM efficiencies

Nutrient	NR (kg q^{-1})	Fertilizer Efficiency (%)	Soil Test Efficiency (%)	FYM Efficiency (%)
P	0.46	10.01	30.03	4.42

In the present investigation, presence of adequate variability in Chickpea grain yield and P uptake was observed due to operational range of soil test values. Olsen's-P were found to be the highest in strip III(L_2) followed by strip II(L_1) and least in strip I(L_0). The marked fertility gradient built up was reflected in terms of grain yield and nutrient uptake. Similar kind of trend for mean nutrient uptake was observed in the experiment. Mean nutrient

requirement for producing one quintal of chickpea grain was 0.46 kg P.

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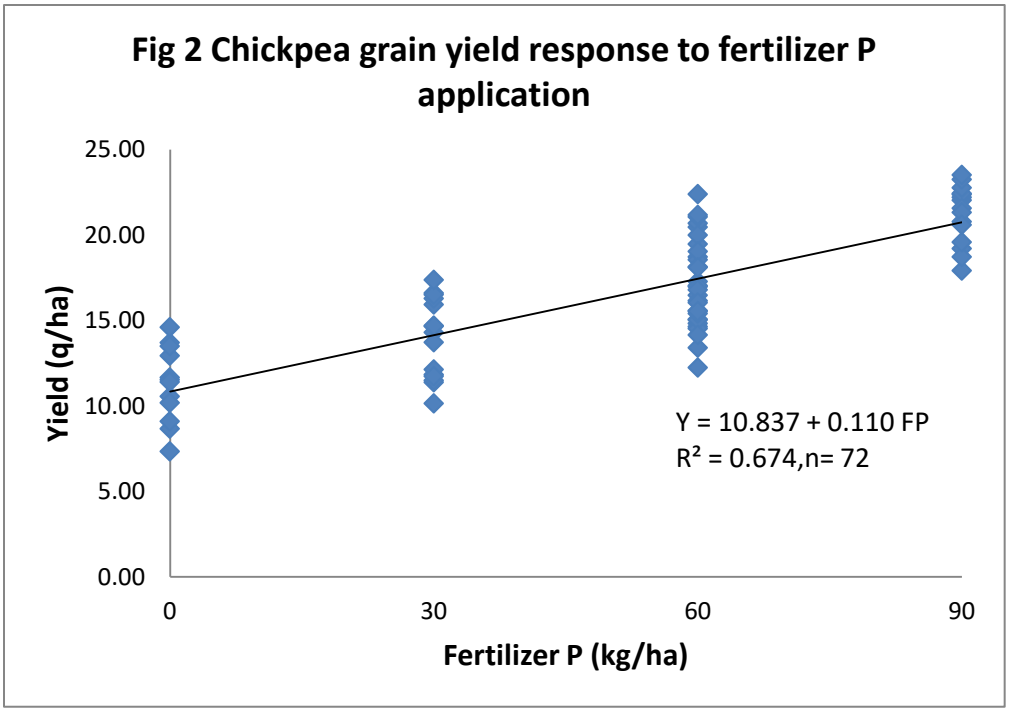
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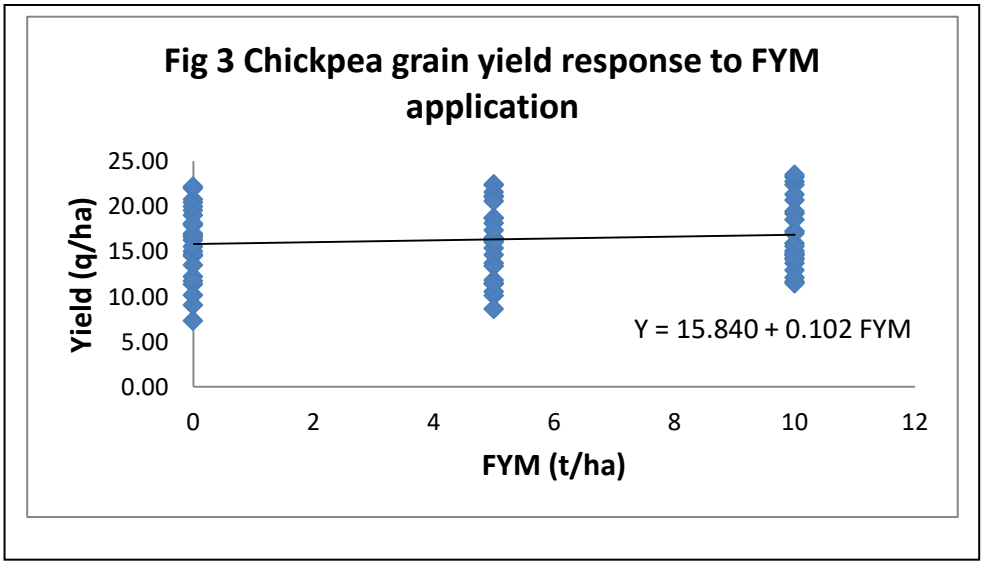
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Fig 2 Chickpea grain yield response to fertilizer P application
25.00
20.00
15.00
10.00
5.00
0.00
Yield (q/ha)
Y = 10.837 + 0.110 FP
R² = 0.674,n= 72
0
30
60
90
Fertilizer P (kg/ha)


Fig 3 Chickpea grain yield response to FYM application
25.00
20.00
15.00
10.00
5.00
0.00
Yield (q/ha)
Y = 15.840 + 0.102 FYM
0
2
4
6
8
10
12
FYM (t/ha)

OILSEEDS FOR FOOD AND LIVELIHOOD SECURITY: A MICRO LEVEL EVIDENCE FROM BASTAR PLATEAU OF CHHATTISGARH, INDIA

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Abstract

An attempt has been made in this study to examine the oilseeds for food and livelihood security : a micro level evidence from Bastar Plateau of Chhattisgarh, India. The study was conducted in Tokapal and Lohandiguda blocks in Bastar district of Chhattisgarh state. One hundred farmers were selected randomly from ten villages from these blocks to collect the required information on the cost and returns, marketing and other aspects for the present study. The primary data was collected from the major oilseeds producers through personal interview method with the help of well prepared schedule and questionnaire for the production and post harvest year for rabi crops 2013-14 and kharif crops 2014-15. The average cost of cultivation and input-output ratio of major oilseeds were worked out as Rs. 11030.14/ha. and 1: 1.23, Rs. 25823.47/ha. and 1:1.35, Rs. 3228.57/ha. and 1:2.00, Rs. 19951.84/ha. and 1:1.67 and 25027.91 and 1:1.65 of Niger, Rapeseed-Mustard, Sesamum, Linseed and Soybean are respectively. The maximum cost of cultivation per ha. was observed to be Rs. 25823.47 in Rapeseed-Mustard crop and minimum Rs. 3228.57/ha. in Sesamum crop. The highest input-output ratio observed was 1:2.00 in sesamum and lowest as 1:1.23 in niger crop. The average gross return was calculated as higher at soybean crop (Rs.41394.34/ha.) followed by sesamum crop (Rs. 3222.98 /ha.) farms. All the oilseed farmers were of the view that there was lack of improved and high yielding varieties of all the oilseeds crop studied in the region. Lack of recommended package and practices, particularly, doses of fertilizer, insecticides and pesticides were perceived by 84.00 per cent of oilseed farmers. In view of finding of this study, it may be suggested that there is need to increase the profitability from major oilseeds cultivation by the use of good quality and high yielding varieties, use of balanced fertilizers and agrochemical, improved package and practices, low cost farm machinery, marketing and remunerative prices, effective extension along with conducive policy measures.

Key words: *Major Oilseeds, Cost and returns and Major Constraints*, *Livelihood Security*.

Introduction

India is amongst the largest producer and consumer of vegetable oils in the World. Oilseeds have been the backbone of agricultural economy of India since long. Indian vegetable oil economy is the fourth largest in the world next to USA, China and Brazil. Oilseed crops play the second important role in the Indian agricultural economy next to food grains in terms of area and production. The Indian climate is suitable for the cultivation of oilseed crops; therefore, large varieties of oilseeds are cultivated here. The major oilseeds cultivated in our country are Groundnut, Rapeseed and Mustard, Castor seed, Sesamum, Niger seed, Linseed, Safflower, Sunflower and Soybean. However, Groundnut, Rapeseed/Mustard, Soybean and Sunflower account for a major chunk of the output. At present, more than 27 million hectares of land is

under oilseeds cultivation. The total oilseeds area, production and productivity was 22.7 million hectares, 18.4 million ton and 810 kg/ha respectively during 2000-01, which increased to 27.6 million hectares, 27.7 million ton and 1006 kg/ha during 2008-09. It is heartening to note that the significant growth in production is coming from the yield effect. It is welcoming sign as the area for cultivation is limited. The advance estimates reveals that the Kharif oilseed production will meet the set targets of the year 2010-11. India accounts for about 14.46 per cent of world's oilseeds area and 6.97 per cent of world's oilseeds output (FAO Year Book, 2013). It has second and third rank in the world in the production of groundnut (8.2%) and rapeseed-mustard (13.7%). The vegetable oil consumption in India is continuously rising and has sharply increased in the couple of years touching around 13.8 kg/head/year. States ranking of oilseeds in 2012-2013 are Madhya Pradesh (29.93%), Rajasthan (19.99%), and Maharashtra (16.19%) (Pocket Book on Agricultural Statistics, 2013). The total geographical area is around 137.87 lakh ha. in the state of which cultivable area is 47.99 lakh ha. which is 34.80 per cent of total geographical area of Chhattisgarh state. Total area under oilseeds cultivation is 301226 ha. while production is 167370 metric tonnes in Chhattisgarh. The area under oilseeds in Bastar Plateau is 26123 ha. (8.67%) and production is 6629 metric tonnes (3.96%) of total area and production in Chhattisgarh. In Bastar district, oilseed crops were grown in 10153 ha. (38.87%) and production was 2968 metric tonnes (44.77%) of total oilseeds area and production in Bastar Plateau, thus this district has 9^{th} position in area and 12^{th} position in production of oilseeds in the state. (Source : Commissioner of Land Revenue, 2012). The state is mono cropped where more than 90 per cent of area is allocated under paddy crop during kharif season of which about 80 per cent paddy is based on rains. The oilseeds cultivated in Bastar district include Niger, Rapeseed-Mustard, Sesamum, Linseed, Soybean, Coconut, Sunflower and Castor. Of these oilseed crops, Niger, Rapeseed-Mustard, Sesamum, Linseed and Soybean are among the major oilseeds on the basis of area and production. Looking to above facts, a study is essential to undertake through which a detailed insight can be obtained to analyse an economics analysis of production in major oilseed crops in Bastar plateau of Chhattisgarh state, India with the following specific objectives:

1. To estimate the cost and return of major oilseeds in the sampled households.
2. To identify the major constraints in production of major oilseeds and suggest suitable measures to overcome them.

Methodology

1. Cost of cultivation

The cost concepts approach to farm costing is widely used in India. To work out the cost of cultivation standard method of cost of cultivation employed by Commission on Agricultural Costs and Price (CACP), Directorate of Economics and Statistics, Government of India was adopted which include Cost A_1, Cost A_2, Cost B_1, Cost B_2, Cost C_1, Cost C_2 and Cost C_3.

Results and Discussion

1: Demographic characteristics of sample households

The demographic characteristics of the sampled farmers in the study area are described in Table 1. The schedule caste, schedule tribes, other backward caste and general caste consists 1.00 per cent, 72.00 per cent, 13.00 per cent, and 14.00 per cent, respectively of the total households. About 51.91 per cent population belonged to 15-60 years age group in this sample. The population below the 15 years of age consists about 28.72 per cent while 19.37 per cent of population may fall in the group of above 60 years. The overall male-female ratio is

observed as 1000:1098.19 in this population. The literacy of total family members is observed high in large (61.70 per cent) categories. The people having the education level up to primary school, middle school, higher secondary school and above higher secondary school are 22.76 per cent, 13.40 per cent, 14.68 per cent and 6.38 per cent respectively of the total households. The occupation of farmers is also presented in Table 1. As it is clear from this table, about 83.61 per cent of working group is involved in the agriculture at sample farms. The percentage of agriculture as the main occupation is estimated as about 82.99 per cent, 73.61 per cent, 93.15 per cent and 84.61 per cent in case of marginal, small, medium and large farmers, respectively. Service is the second important source of income where 7.38 per cent people depend on service. The other source of income of the farmers is business, and wages in the study area.

2: Land use pattern

Size of holding at sampled farms is presented in Table 2. The per farm total cultivated area is observed to be 0.67 hectares, 1.42 hectare, 2.12 hectare and 4.98 hectare at marginal, small, medium and large farms, respectively along with 2.08 hectare as an overall average. It is clear from the table that the leased-in land at sampled farms is decreasing as the size of holding increased. It varied from 1.41 per cent at small farm and 0.94 per cent at medium farms to total cultivated area. The overall percentage of irrigated area is only 3.36 per cent to the total cultivated land. The percentage of irrigation varied from 1.49 at marginal farms to 2.11 per cent at small farms, 3.30 per cent at medium farms and 4.02 per cent at large farms. The overall allocation of area under major oilseeds was found to be 32.21 per cent of the total cultivated area.

3: Irrigation

The category-wise irrigated area at sampled farms is shown in Table 3. Most of the area under irrigation is covered by tube well (33.93 per cent) followed by pond (24.32 per cent) and canal, well and other (17.42 per cent). These figures are clear indication that farmers of this region are very cautious about the irrigation in agriculture. They are investing to create the irrigation facilities at their farms if they easily get the electric connection. The total irrigated area, though is very less at 0.0666 per cent per farm.

4: Cropping pattern

The cropping pattern at sampled farms is presented in Table 4. It may be seen that the total cropped area is observed to be 0.86 ha., 1.81 ha., 2.86 ha. and 6.68 ha. and 2.75 at marginal, small, medium, large and average farms respectively. The highest cropped area is found to be in kharif season among all the categories. The area under different crops in kharif season is observed to be 77.91 per cent, 78.45 per cent 74.12 per cent 74.55 per cent and 75.64 at marginal, small, medium, large and average farms. The area under different crops in rabi season is observed to be 24.00 per cent at average farm. The average cropping intensity has 130.38 per cent at sampled household. The overall area under kharif oilseeds i.e. niger, sesamum and soybean was observed at 0.25 ha./farm, 0.11 ha./farm and 0.10 ha./farm (9.09 %, 4.00%, 3.64%) of total cropped area, respectively. The overall area under rabi oilseeds i.e. mustard and linseed was observed 0.17 ha./farm (6.18%) and 0.06 ha./farm (2.18%) of total cropped area. Among oilseeds, niger (0.25 ha./farm) occupied the highest area followed by rapeseed-mustard (0.17 ha./farm), sesamum (0.11 ha./farm), soybean (0.10 ha./farm) and linseed (0.06 ha./farm) on an average. Looking to the small area covered under oilseeds, there is need to increases the same in the study area.

5: Cost and returns of major oilseeds

The cost of cultivation of major oilseeds production is presented in Table 5. It reveals that average total cost of cultivation were found to be Rs. 11030.14/ha., Rs.25823.47/ha. Rs.3228.57/ha., 19951.84/ha. and 25027.91 in niger, rapeseed-mustard, sesamum, linseed and soybean crops respectively in which varies from Rs. 3228.57/ha. at sesamum crop to Rs. 25823.47/ha. at rapeseed-mustard crop. The higher cost incurred on cultivation was by rapeseed-mustard crop followed by soybean crop. The contribution of total labour cost for cultivation of crop were found to be Rs.4329.16/ha., Rs.12806.61/ha., Rs.1573.08/ha., Rs.10790.52/ha. and Rs.11147.95. different crop respectively. The average total human labour share to total cost for cultivation were observed as 25.38 per cent, 32.71 per cent, 28.93 per cent, 30.27 per cent and 26.93 per cent to the total cost of cultivation, which was higher at rapeseed-mustard crop 30.27 per cent followed by linseed crop 30.27 per cent. When we see through the operation wise labour use, then the average intercultural operation cost was higher, followed by harvesting operation. The contribution of total bullock labour estimated were Rs. 1369.69/ha.(12.42 per ent), Rs. 3493.61/ha. (13.52 per cent), 451.72/ha.(13.99 per cent), 3817.71/ha.(19.13 per cent) and 3620.31/ha.(14.46 per cent) which ranges from 12.42 per cent at niger crop to 14.46 per cent at soybean crop. The average input cost for cultivation of major crops were observed as Rs. 5534.78/ha.(50.18 per cent), Rs.16403.28/ha.(63.52 per cent), Rs.2293.04/ha.(71.02 per cent), Rs.13816.16/ha.(69.23 per cent) and Rs.18349.63/ha.(73.32 per cent) which varies from 50.18 per cent at niger crop to 73.32 at soybean crop. The average fixed cost were found to be Rs. 5495.36/ha.(49.82 per cent), Rs. 9420.19/ha.(36.48 per cent), Rs.935.53/ha.(28.98 per cent), Rs.6138.68/ ha.(30.77 per cent) and 6678.28/ha.(26.68 per cent) at niger, rapeseed-mustard, sesamum, linseed and soybean crops respectively which were percentages of the total cost.

6. Yield, cost and return of major oilseeds at the sampled farms

The yield, value of output per hectare and cost of production per quintal of major oilseeds on the sample farms have been worked out in Table 6. It indicates that the average yield per hectare of in niger, rapeseed-mustard, sesamum, linseed and soybean crops respectively came to 2.68 qtl./ha., 12.74 qtl./ha., 1.07 qtl./ha., 8.91 qtl./ha. and 11.89 qtl./ha. where higher yield was found at soybean crop (11.89 qtl./ha.) and the lowest was observed at sesamum crop (1.07 qtl./ha.). The average gross return estimated were Rs. 13597.17/ha., Rs. 34778.77/ha., Rs. 6451.55/ha., Rs. 33286.50/ha. and Rs. 41394.34/ha. which varies from Rs. 6451.55/ha. at sesamum crop and Rs. 41394.34 /ha. at soybean crop. The average net return were calculated as Rs. 2566.97/ha., Rs. 8954.73/ha., Rs. 3222.98/ha., Rs. 13334.66/ha. and Rs. 16366.43/ha. which was higher at soybean crop (Rs. 16366.43/ha.), followed by linseed crop (Rs. 13334.66/ha.

7. Cost concept – cost and return of major oilseeds on the sampled households.

The cost and returns on the basis of cost concept in the cultivation of major oilseeds has been presented in Table 7. These costs were observed highest at Rs. 9303.53, Rs.9466.41, Rs.15633.07, Rs.18861.24, Rs.25027.91 and Rs. 27530.70 respectively under soybean crop situation. The incomes over different costs were also worked out. The average per hectare income over Cost-A_1, Cost-B_1, Cost-B_2, Cost-C_1, Cost-C_2 and Cost-C_3 calculated was Rs.32090.81, Rs.31927.93, Rs.25761.27, Rs.22533.10, Rs.16366.43 and Rs.13863.64. respectively. The average input-output ratios were estimated1:1.12, 1:1.33, 1:1.82, 1:1.52

and1:1.51 in niger, rapeseed-mustard, sesamum, linseed and soybean crops respectively which was higher at sesamum crop followed by linseed crop.

8. Constraints in production of major oilseeds

The constraints in major oilseeds production are presented in Table 8. There is gap about the latest technical knowledge of major oilseeds among the growers in the study area. Majority of the major oilseeds growers (77.00 per cent) faced this particular constraint. In view of this, effective and strengthened extension efforts are very much needed in the study area, as it is a tribal and backward region for major oilseeds production technology. All the major oilseeds farmers were of the view that there was lack of improved and high yielding varieties in the region. Even if it were there, it were not available to them. Looking to this, there is a need to develop improved and high yielding varieties of major oilseeds. Lack of recommended package and practices, particularly, doses of fertilizer, insecticides and pesticides were perceived by 84.00 per cent of major oilseeds farmers. Timely advice in this direction may improve the production of major oilseeds in the study area in particular. Major constraints pertaining to cultivation of major oilseeds under study were lack of resources (71.00per cent), generally faced by small category farmers. Due to this reason, these farmers were not able to invest for better production technology. There is a need for creation of major oilseeds grower's co-operative societies which can cater to the needs of the farmers related to major oilseeds production. About 91 per cent rapeseed-mustard farmers reported that they were not aware about the name and quantity of applications needed for insecticides and pesticides. In such conditions, they were completely dependent on the shopkeepers who sold the insecticides/pesticides. They further perceived that soil-testing facilities should be created by the Department of Agriculture at least at the block level in order to test the soil fertility of land. About 97 per cent farmers faced this problem. Establishment of soil testing facilities may prove very useful in improving the productivity of rapeseed-mustard in the study area on one side and in reducing the per hectare cost of cultivation on the other. A large number of oilseed growers perceived that the lack of irrigation facilities (89.00 per cent) was one of the major constraints in major oilseeds cultivation in the study area. According, capital investment on enhancing irrigation should receive priority in the region. The scarcity of labour is another problem as 31 per cent of major oilseeds farmers perceived it. This problem becomes more acute at the time of sowing and harvesting stage of the crop. Consequently, the farmers had to pay higher wages in order to complete the work on time. Lack of financing at reasonable rate of interest is also a constraint in the study area as about 100.00 per cent major oilseeds producers were facing this problem. This problem can be overcome by financial institutions by providing the loan to the farmers at their doorsteps. They were of an opinion that it was inconvenient and time taking procedure to get the money from financial institutions. Consequently, they were forced to take required money from money lenders of village at higher rate of interest in order to fulfill their financial requirement.

Conclusion

In view of findings of this study, it may be suggested that in order to enhance food and livelihood security of oilseeds growers in India, there is a need to increase the profitability from oilseeds cultivation by the use of low cost farm machinery, irrigation, good quality and high yielding varieties, use of balanced fertilizers and agrochemical, improved package and practices, marketing and remunerative prices, effective extension along with conducive policy measures.

Table 1: Demographic features of sample oilseeds famers

S.No.	Particulars	Marginal	Small	Medium	Large	Aggregate
1.	Total number of households	19	32	33	16	100.00
2.	Social group					
	a. Scheduled tribe	12 (63.16)*	26 (81.25)*	25 (75.76)*	9 (56.25)*	72.00 (72.00)*
	b. Scheduled caste	0 (0.00)*	0 (0.00)*	1 (3.03)*	0 (0.00)*	1.00 (1.00)*
	c. Other backward caste	3 (15.79)*	4 (12.5)*	3 (9.09)*	3 (18.75)*	13.00 (13.00)*
	d. General	4 (21.05)*	2 (6.25)*	4 (12.12)*	4 (25.00)*	14.00 (14.00)*
3.	Total family member	87 (100.00)	143 (100.00)	146 (100.00)	94 (100.00)	470.00 (100.00)
	a. Male	42 (48.27)	70 (48.95)	71 (48.63)	41 (43.62)	224.00 (47.66)
	b. Female	45 (51.72)	73 (51.05)	75 (51.37)	53 (56.38)	246.00 (52.34)
4.	Age group					
	i. Below 15 year	24 (27.59)	42 (29.37)	43 (29.43)	26 (27.66)	135.00 (28.72)
	a. Male	11 (12.64)	18 (12.59)	20 (13.70)	12 (12.76)	61.00 (12.98)
	b. Female	13 (14.94)	24 (16.78)	23 (15.75)	14 (14.89)	74.00 (15.74)
	ii. 15-60 year	47 (54.02)	72 (50.35)	73 (50.00)	52 (55.32)	244.00 (51.91)
	a. Male	23	34	34	25	116
	b. Female	24 (27.59)	38 (26.57)	39 (26.71)	27 (28.72)	128 (27.23)
	iii. Above 60 year	16 (18.39)	29 (20.28)	30 (20.57)	16 (17.02)	91.00 (19.37)
	a. Male	7 (8.04)	13 (9.09)	14 (9.61)	9 (9.57)	43.00 (9.16)
	b. Female	9 (10.34)	16 (11.19)	16 (10.96)	7 (7.45)	48.00 (10.21)
5.	Occupation					
	Working member	47	72	73	52	244.00
	a. Agriculture	39 (82.99)	53 (73.61)	68 (93.15)	44 (84.61)	204 (83.61)
	b. Business	0.00 (0.00)	7 (9.72)	3 (4.11)	2 (3.85)	12.00 (4.92)
	c. Service	3	7	2	6	18.00
		(6.38)	(9.72)	(2.74)	(11.54)	(7.37)
	d. Wages	5 (10.63)	5 (6.95)	0.00 (0.00)	0.00 (0.00)	10.00 (4.10)
6.	Education					
	a. Illiterate	42 (48.27)	62 (43.36)	61 (41.78)	36 (38.30)	201.00 (42.76)
	b. Primary school	19 (21.84)	31 (21.68)	35 (23.97)	22 (23.40)	107.00 (22.76)
	c. Middle school	13 (14.94)	17 (11.89)	20 (13.70)	13 (13.83)	63.00 (13.40)
	d.Higher secondary school	9 (10.34)	23 (16.08)	21 (14.38)	16 (17.02)	69.00 (14.68)
	e. Above higher secondary school	4 (4.61)	10 (6.99)	9 (6.17)	7 (7.45)	30.00 (6.36)

Note: Figures in the parenthesis indicate the percentages to the total number of family members. Figures in the parenthesis with star indicate the percentages to the respective number of sample households.

Table 2: Size of holding and irrigation at sampled farms (ha/farm)

S.No.	Particulars	Marginal	Small	medium	Large	Average
1.	Total owned land	0.74 (110.45)	1.53 (107.75)	2.35 (110.85)	5.19 (104.22)	2.24 (107.69)
	Non- agriculture use land	0.07	0.11	0.23	0.21	0.16 (7.69)
3.	Leased-in land	0.00 (0.00)	0.02 (1.41)	0.02 (0.94)	0.00 (0.00)	0.01 (0.48)
4.	Leased-out land	0.00 (0.00)	0.00 (0.00)	0.10 (4.72)	0.25 (5.02)	0.07 (3.36)
5.	Area under total oilseeds	0.23 (34.33)	0.56 (39.44)	0.89 (41.98)	1.14 (22.89)	0.70 (33.65)
6.	Irrigated area	0.01 (1.49)	0.03 (2.11)	0.07 (3.30)	0.20 (4.02)	0.07 (3.36)
7.	Un-irrigated area	0.66 (98.51)	1.39 (97.89)	2.05 (96.70)	4.78 (95.98)	2.01 (96.63)
8.	Area under major oilseeds	0.23 (34.33)	0.53 (37.32)	0.85 (40.09)	1.08 (21.69)	0.67 (32.21)
9.	Total cultivated area	0.67 (100.00)	1.42 (100.00)	2.12 (100.00)	4.98 (100.00)	2.08 (100.00)

Note: Figures in the parentheses indicate the percentages to the total cultivated area.

Table 3: Source- wise irrigated area at sampled farms (ha/farm)

S. No.	Particulars	Marginal	Small	medium	Large	Average
1.	Tube well	0.00 (0.00)	0.01 (33.33)	0.02 (28.58)	0.08 (40.00)	0.0226 (33.93)
2.	Canal	0.00 (0.00)	0.00 (0.00)	0.01 (14.28)	0.01 (5.00)	0.0049 (7.36)
3.	Tank	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
4.	Ponds	0.00 (0.00)	0.01 (33.33)	0.02 (28.58)	0.04 (20.00)	0.0162 (24.32)
5.	Well	0.01 (100.00)	0.01 (33.33)	0.01 (14.28)	0.02 (10.00)	0.0116 (17.42)
6.	Other	0.00 (0.00)	0.00 (0.00)	0.01 (14.28)	0.05 (25.00)	0.0113 (16.97)
	Total irrigated area	0.01 (100.00)	0.03 (100.00)	0.07 (100.00)	0.20 (100.00)	0.0666 (100.00)

Note: Figures in the parentheses indicate the percentages to the total irrigated area.

Table 4: Cropping pattern followed by sampled farmers(ha/ farm)

S.No.	Particulars	Marginal	Small	medium	Large	Average
1.	Kharif					
	a. Rice	0.40 (46.51)	0.50 (27.62)	0.78 (27.27)	1.76 (26.35)	0.77 (28.00)
	b. Maize	0.13 (15.12)	0.32 (17.68)	0.50 (17.48)	1.40 (20.96)	0.52 (18.91)
	c. Soybean	0.00 (0.00)	0.10 (5.52)	0.18 (6.29)	0.07 (1.05)	0.10 (3.64)
	d.Niger	0.07 (8.14)	0.22 (12.15)	0.32 (11.19)	0.40 (5.99)	0.25 (9.09)
	e. Urd	0.02 (2.32)	0.05 (2.76)	0.06 (2.10)	0.52 (7.78)	0.12 (4.36)
	f. Other	0.05	0.23	0.28	0.83	0.31
		(5.82)	(12.72)	(9.79)	(12.42)	(11.27)
	Sub-total	0.67 (77.91)	1.42 (78.45)	2.12 (74.12)	4.98 (74.55)	2.08 (75.64)
2.	Rabi					
	a. Mustard	0.15 (77.90)	0.11 (6.08)	0.15 (5.24)	0.39 (5.84)	0.17 (6.18)
	b. Chickpea	0.00 (0.00)	0.12 (6.63)	0.14 (4.89)	0.20 (2.99)	0.12 (4.36)
	c. Maize	0.04 (4.65)	0.16 (8.84)	0.21 (7.34)	0.56 (8.38)	0.22 (8.00)
	d. Linseed	0.00 (0.00)	0.00 (0.00)	0.08 (2.80)	0.19 (2.84)	0.06 (2.18)
	e. Other	0.00 (0.00)	0.00 (0.00)	0.11 (3.85)	0.36 (5.38)	0.09 (3.27)
	Sub-total	0.19 (22.09)	0.39 (21.55)	0.69 (24.12)	1.70 (25.45)	0.66 (24.00)
3.	Summer					
	a. Maize	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	b. Other	0.00 (0.00)	0.00 (0.00)	0.05 (1.76)	0.12 (1.80)	0.03 (1.09)
	Sub-total	0.00 (0.00)	0.00 (0.00)	0.05 (1.75)	0.12 (1.80)	0.00 (0.36)
	Total cropped area	0.86 (100.00)	1.81 (100.00)	2.86 (100.00)	6.68 (100.00)	2.75 (100.00)
	Cropping intensity (%)	128.35	127.46	132.55	134.14	130.38

Note: Figures in the parentheses indicate the percentages to the total cropped area.

Table 5: Input wise cost of cultivation of major oilseeds on the sampled farm

S. No.	Particulars	Owned/ hired	Niger	Rapeseed-Mustard	Sesamum	Linseed	Soybean
A. Variable cost							
1.Human labour cost	i).Field preparation	Owned	264.87 (2.40)	476.72 (1.85)	54.07 (1.67)	162.71 (0.81)	372.43 (1.49)
	ii).Application of manure and fertilizer	Owned	278.18 (2.52)	198.73 (0.77)	68.17 (2.11)	318.07 (1.59)	460.94 (1.84)
	iii).Sowing	Owned	289.54 (2.62)	725.93 (2.81)	70.10 (2.17)	368.17 (1.85)	428.05 (1.71)
	iv).Intercultural	Owned	755.76 (6.85)	1620.93 (6.27)	274.24 (8.49)	1252.95 (6.28)	1962.71 (7.84)
		Hired	47.22 (0.43)	188.14 (0.27)	37.11 (1.15)	410.93 (2.06)	471.47 (1.88)
	v).Irrigation	Owned	0.00 (0.00)	129.15 (0.50)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	vi).Plant protection	Owned	0.00 (0.00)	671.29 (2.60)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
		Hired	0.00 (0.00)	14.84 (0.06)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	vii).Harvesting	Owned	454.4 (4.12)	1341.26 (5.19)	162.45 (5.03)	1200.62 (6.02)	1116.16 (4.46)
		Hired	4.02 (0.04)	252.8 (0.98)	24.32 (0.75)	336.98 (1.69)	328.95 (1.31)
	viii).Transportation from field to threshing place	Owned	297.4 (2.70)	932.53 (3.61)	80.55 (2.49)	564.48 (2.83)	505.58 (2.02)
		Hired	5.04 (0.04)	125.88 (0.49)	8.64 (0.27)	101.82 (0.51)	72.48 (0.29)
	ix).Threshing and winnowing	Owned	268.25 (2.43)	1173.73 (4.54)	98.86 (3.06)	783.07 (3.92)	664.53 (2.65)
		Hired	31.45 (0.28)	163.18 (0.63)	12.16 (0.38)	270.31 (1.35)	93.59 (0.37)
	x).Transportation from field to home	Owned	103.34 (0.94)	431.52 (1.67)	43.25 (1.34)	269.37 (1.35)	264.12 (1.05)
	Total human labour cost		2799.47 (25.38)	8446.63 (32.71)	933.91 (28.93)	6039.48 (30.27)	6741.01 (26.93)
2.Bullock labour cost	-	Owned	1317.49 (11.94)	3209.83 (12.42)	451.72 (13.99)	3817.71 (19.13)	3620.31 (14.46)
		Hired	52.2 (0.47)	283.78 (1.10)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	Total bullock labour cost		1369.69 (12.42)	3493.61 (13.52)	451.72 (13.99)	3817.71 (19.13)	3620.31 (14.46)
3.Machine cost	-	Owned	160 (1.45)	280.44 (1.08)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
		Hired	0.00 (0.00)	585.93 (2.27)	187.48 (5.81)	933.33 (4.68)	786.67 (3.14)
	Total hired machine cost		0.00 (0.00)	866.37 (3.35)	187.48 (5.81)	933.33 (4.68)	786.67 (3.14)
	Total labour cost		4329.16 (39.25)	12806.61 (49.59)	1573.08 (48.72)	10790.52 (54.08)	11147.99 (44.54)

4.Material cost	i).Seed		654.11 (5.93)	184.28 (0.71)	311.13 (9.37)	1141.56 (5.72)	4413.09 (17.63)
	ii).Fertilizer + Manure		308.33 (2.79)	2896.3 (11.21)	297.38 (9.21) +76.87 (2.38)	1764.84 (8.84)	2202.48 (8.80)+ 381.06 (1.52)
	iii).Plant protection		119.84 (1.09)	397.32 (1.54)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	Total material cost		1082.28 (9.81)	3477.9 (13.47)	685.38 (21.23)	2906.40 (14.57)	6997.44 (27.97)
	Interest on working capital		123.34 (1.12)	118.77 (0.46)	34.55 (1.07)	116.19 (0.58)	204.18 (0.81)
	Total variable cost		5534.78 (50.18)	16403.28 (63.52)	2293.04 (71.02)	13813.16 (69.23)	18349.63 (73.32)
B. Fixed cost	i).Rental value of owned land		4940 (44.77)	6592.25 (25.53)	865.48 (26.81)	5692.96 (28.53)	6166.66 (24.64)
	ii).Land revenue		2.15 (0.02)	2.08 (0.008)	0.33 (0.01)	1.83 (0.00)	2.19 (0.01)
	iii).Depreciation value		422.15 (3.83)	2323.25 (9.00)	46.89 (1.45)	294.17 (1.47)	346.55 (1.38)
	vi).Interest of fixed capital		131.06 (1.19)	502.61 (1.95)	22.82 (0.71)	149.72 (0.75)	162.88 (0.65)
	Total fixed cost	-	5495.36 (49.82)	9420.19 (36.48)	935.53 (28.98)	6138.68 (30.77)	6678.28 (26.68)
Total (A+B) cost		-	11030.14 (100.00)	25823.47 (100.00)	3228.57 (100.00)	19951.84 (100.00)	25027.91 (100.00)

Note: Figure in the parentheses indicates the percentages to the total cost of cultivation**.**

Table 6 : Yield, cost and return of major oilseeds on the sample farms (Rs./ha)

S.No.	Particulars	Oilseeds				
		Niger	Rapeseed-Mustard	Sesamum	Linseed	Soybean
	Sample farm (n)					
1.	Input cost (Rs.)	11030.14	25823.47	3228.57	19951.84	25027.91
2.	Yield (Qtl/ha)	2.68	12.74	1.07	8.91	11.89
3.	Gross return (Rs.)	13597.17	34778.24	6451.55	33286.50	41394.34
4.	Net return (Rs.)	2566.97	8954.73	3222.98	13334.66	16366.43
5.	Cost of production (Rs./qtl)	4115.72	2026.96	2971.80	2285.44	2109.45
6.	Input-Output ratio	1 : 1.23	1 : 1.35	1 : 2.00	1:1.67	1 : 1.65

Table 7: Break-up of cost, cost concept wise income over different cost in rapeseed-mustard on the sample farm (Rs./ha)

S.No.	Particulars	Niger	Rapeseed-Mustard	Sesamum	Linseed	Soybean
	Sample farm (n)					
A.	Break-up cost					
	1.Cost A_1	3247.35	8797.18	1488.63	9209.21	9303.53
	2. Cost B_1	3378.45	8978.17	1511.72	9358.93	9466.41
	3. Cost B_2	8318.45	15653.84	2376.92	15051.90	15633.07
	4. Cost C_1	6090.14	17120.78	2363.11	14184.34	18861.24
	5. Cost C_2	11030.14	23796.45	3228.59	19951.83	25027.91
	6. Cost C_3	12133.15	26176.09	3551.45	21947.01	27530.70
B.	Income over different cost					
	1.Income over cost A_1	10349.82	26016.31	4962.92	24077.29	32090.81
	2.Income over cost B_1	10218.72	25835.32	4939.83	23927.57	31927.93
	3.Income over cost B_2	5278.72	19159.65	4074.63	18234.60	25761.27
	4.Income over cost C_1	7506.03	17692.71	4088.44	19102.16	22533.10
	5.Income over cost C_2	2566.03	11017.04	3222.96	13334.67	16366.43
	6.Income over cost C_3	1463.02	8637.40	2900.10	11339.49	13863.64
C.	Gross income	13597.17	34813.49	6451.55	33286.50	41394.34
D.	Total cost	12133.21	26176.09	3551.45	21947.01	27530.70
E.	Input-output ratio	1 : 1.12	1 : 1.33	1 : 1.82	1 : 1.52	1 : 1.51

Table 8: Constraints in production of major oilseeds n= 100
(In Per cent)

Sl. No.	Constraints	Number of Respondents In percentages	
		Yes	No
1.	Are you aware about the latest technical knowledge of the crop?	23.00	77.00
2.	Lack of improved and high yielding varieties of oilseeds	89.00	11.00
3.	Lack of recommended package of practices of the oilseeds in the study area	84.00	16.00
4.	Lack of resources i.e. equipment etc.	71.00	29.00
5.	Do you know the recommended dose of different chemical fertilizers for oilseeds?	9.00	91.00
6.	Are there sufficient soil testing facilities in your area?	3.00	97.00
7.	Have you sufficient irrigation water facilities?	11.00	89.00
8.	Have you problem of availability of labour during the crop season?	31.00	69.00
9.	Have you sufficient fund to purchase different inputs for crop cultivation	9.00	91.00
10.	Have you received the funds for oilseed production from financial institution?	0.00	100.00
11.	Do you face any problem in financing from the financial institution	100.00	0.00
12.	Are you aware about the crop insurance scheme?	41.00	59.00
13.	So you have any problem to get machines on hire basis for oilseeds production?	86.00	14.00

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WATER PRODUCTIVITY EFFECT OF BROAD BED FURROW SYSTEM FORRAINFED SOYBEAN CULTIVATION

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Abstract

A field study was carried out during Kharif 2014-15, 2015-16, and 2016-17 on thirty seven farmers field of Mohbhatta village of Simga block of the district Balodabazar-Bhatapara of Chhattisgarh statewith size of trial is one acre each farmers to determine the impact of sowing techniques on yield of soybean under farmers' conditions. Soybean is more water stress crop and at the time of germination sudden rainfall affects the crop. For this purpose, broad bed planting technology was introduced in the study area to compare it with the conventional sowing of soybean by flat bed methods. Six-row broad bed furrow machine was used to plant soybean having top bed width of 2.35 cm. Result showed that growth character (plant height, number of branches per plant and number of root nodules per plant) and yield contributing character viz. number of pods per plant, seed yield weight per plant, seed index, seed yield, straw yield and harvest index (%) found higher in broad bed furrow compared to the normal flat bed sowing which subsequently resulted in yield enhancement to the extent of 28.38 % for soyabean crop. The average yield in broad bed furrow method recorded 15.20 q ha^{-1}.The B:C ratio was observed 2.05 due to drainage of excessive rain water from the fields and stronger plant anchorage on the beds. Similarly, 40 to 50% saving in irrigation water was recorded with broad bed furrow method of soybean in comparison with flood irrigation of controlled plots. Results indicated that broad bed furrow technology has a lot of potential to increase water productivity of soybean.

Introduction

The productivity of rainfed farming is low as compared to the irrigated crop production. The crop yield in the rainfed farming is often reduced due to the lack of soil moisture. It is necessary to adopt suitable technology to conserve the rain water in-situ to ensure adequate moisture during the various growing stages of the crop in rainfed farming. Animal drawn broad bed-furrow former are available but their efficiency is very less therefore it is necessary to develop suitable tractor operated BBF planter to overcome this problem (Srinivas, 2005). BBF farming has many advantages in regard to water saving, mechanical weeding, fertilizer placement, available moisture conservation, less lodging and better crop stand (Astatke et al., 2002). In-situ water conservation makes the moisture available for the sown crop. Use of BBF can have several benefits depending on its use. Raised beds are primarily a field drainage tool aimed at decreasing water logging and increasing crop yield. Soybean [*Glycine max* (L.) Merrill] is known as the "Golden bean" of the 21st century. Though, soybean is a legume crop, yet it is widely used as oilseed. Majority of the area under soybean –wheat based cropping system is in Central India and is covered under *Vertisols* and associated soils (Bhatnagar and Joshi 1999).The area normally receives assured annual rainfall ranging from 1000 -1200 mm per annum. Almost 90 % of which is received between June to September.

Tomar et al. (1996) reported that maximum average seed yield of soybean was recorded in 6 m wide raised bed followed by 9m raised bed and minimum in flat plots. Besides providing adequate surface drainage to soybean crop, the land configurations were also useful during prolonged dry spell thereby, minimizing any adverse effect of soil moisture stress at flowering and seed development stages of rainy season crops.Post rainy seasons crops were successfully grown with successfully high yields with higher gross and net returns. Jat and Singh (2003) reported higher biological yield and highest net and gross return from land configuration treatment as compared to conventional system has been reported. Singh et.al. (1999) and Nagavallemma (2005) reported that land treatments (raised sunken bed system, ridges and furrows, broad bed and furrows) increased in situ soil moisture conservation, minimized runoff, and soil erosion and increased the yield of principal crops grown in the region. Verma (2008) also reported that the plant population of soybean was influenced significantly due to different land configurations, he recorded significantly higher plant population under Ridge and Furrow Planting of soybean. Similar findings were obtained by Tomar et al. (1996) for plant population. Raut et al. (2000) and Autkar et al. (2006) reported that ridge-and-furrow sowing was significantly superior to conventional flat sowing in increasing plant height. The lowest number of root nodules per plant was recorded under flat bed sowing; however, highest number of root nodules per plant was produced under ridge and furrow system. Ralli and Dhingra(2003) reported higher nodule count and nodule dry weight under ridge sowing when compared with flat sowing. Lupwayi et al., (1997) reported that water logging adversely influenced the nodules dry matter it reduced the nodules dry matter by 33%, he recommended broad bed and furrow system to drain the water in the *Vertisols*.

Materials and Methods

The trial was carried out during Kharif2014-15, 2015-16 and 2016-17on thirty seven farmer's field of Sigma block of district Balodabazar-Bhatapara of Chhattisgarh state with size of trial is one acre to determine the impact of sowing techniques on yield of soybean under farmers' conditions. Soybean is more water stress crop and at the time of germination sudden rainfall affects the crop. Broad bed furrow machine was developed basically to cope up with the problem of moisture stress in the soybean fields. The soil moisture is managed by maximizing the use of rainfall through increasing infiltration and moisture retention and reducing runoff and soil erosion. Thus by this machine the performance of high yielding improved varieties is optimized as the deep furrows created under BBF provides, effective drainage during excess rains while serves as in-situ moisture conservation during dry spells, thus mitigating the detrimental effects of both extreme situations. For this purpose, broad bed furrow technology was introduced in the study area to compare it with the conventional sowing of soybean by broadcasting and seed planter methods. The broad bed furrow machine was provided by Faculty of Agricultural Engineering, IGKV, Raipur (In Kharif2014-15), under central sector scheme of farm mechanization and machine is purchased by KVK Bhatapara under the ICAR project National Initiative on Climate Resilient Agriculture(In Kharif 2015-16 and 2016-17). The farmers were selected on the basis of their past experience. Before trial training were conducted to farmers about use of broad bed furrowmachine by the KVK scientists. Keeping in the view need,under rainfed farming to increase area in the district therefore KrishiVigyan Kendra Bhatapara has taken following technologies.

The technical details of broad bed furrow machine is given in table1.These furrows are useful to drain out excessive rainwater during heavy storms and for storing rainwater in furrows for enriching soil moisture through percolation in case of deficit rainfall. The soil moisture thus stored sustains the crop during dry spells. The plant growth character and yield contributing data such as plant height, number of branches per plant, root length, number of root nodules per plant, number of pods per plant, pod length, number of seeds per pod, seed index (weight of 100 seeds), seed yield per plant, stover yield, harvest index (%), seed yield, net monetary returns, benefit: cost ratio (B: C ratio) were recorded for soybean crop.

Results and Discussion

The data collected from the field were analyzed and the results of the study in respect of (i) Growth characteristics of soybean(ii) Yield attributing characters of soybean: (iii) Percentage increase in yield and (iv)Benefit Cost ratio and are summarized below:

(i) Growth characteristics of soybean: The plant population, plant height, number of branches per plant, root length, and number of root nodules per plant of soybean crop were recorded for the Kharif2014, 2015 and 2016 and are presented in Table 2.Plant growth parameters were found better in broad bed furrow system plot as compared to normal flat bed sowing. The increase in plant growth due to proper drainage of excess rainfall through furrows. The plant population ranged 9 -11 % higher on planting soybean using broad bed furrow seed cum fertilizer drill machine as compared to sowing by normal seed drill.

(ii) Yield attributing characters of soybean: Post Harvest observation on various yield attributing characters of soybean crop were taken and presented in Table 3. The number of pods per plant, pod length and seed index were observed more in the broad bed furrow system compare to normal flat bed sowing.

(iii) Percentage increase in yield: The yield in recommended practice increased 28.38% over farmers practice. The average yield in broad bed furrow seed cum fertilizer drill method was recorded 15.20q ha^{-1}over conventional sowing it is 11.84q ha^{-1}. The difference of yield in BBF and conventional sowing is justified in table 4.

(iv)Benefit Cost ratio: B:C ratio were also worked out for both farmers practice and demonstration plots from sowing to harvesting as given in table4.The B:C ratio as observed from table has been more in BBF field as compare to conventional method of sowing of soybean. It is because of reduction in primary tillage operation BBF method as well as due to higher production.

Table 1: Technical specification of broad bed furrow machine

S.No.	Particulrs	Details
1.	No. of ridgers	2
2.	Width of bed	2.35 meter
3.	No. of plant rows in bed	6
4.	Row to row spacing of plants	14 inch (35 cm)
5.	Seed and fertilizer metering mechanism	Fluted roller type
6.	Type of furrow openers	Shoe type

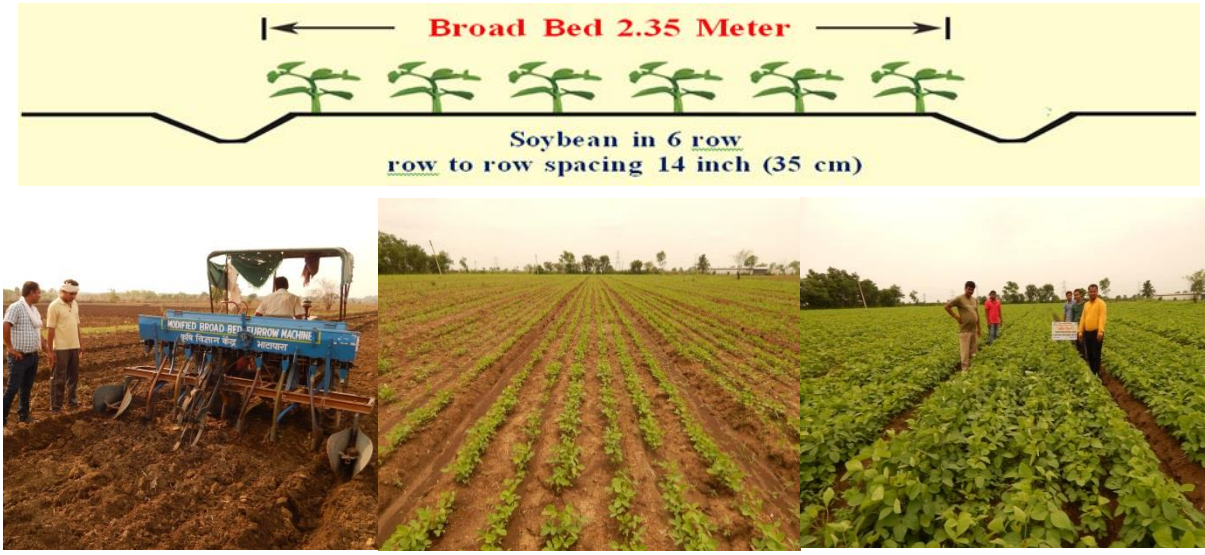


Figure 1: Operational view of broad bed furrow seed cum fertlizer drill machine

TABLE 2: average growth character of soybean for broad bed furrow system (Avg. of 3 years)

Parameters	Broad bed-furrow system s-Kharif	Normal flat bed sowing-Kharif
Plant population (No./m^2)	45.6	41.2
Plant height (cm) at harvest	58.7	55.4
No. of branches/plant at harvest	5.12	5.03
Root length (cm) at 60DAS	24.3	19.7
No. of root nodules/plant at 60DAS	31.4	27.3

TABLE 3: yield attributes and economics of soybean (Avg. of 3 years)

Parameters	Broad bed-furrow system - Kharif	Normal flat bed sowing-Kharif
Number of pods / plant	47.21	36.54
Pod length (cm)	4.68	4.32
No. of Seeds / pod	2.61	2.37
Seed yield wt. / plant (g)	11.14	10.78
Seed Index (g)	5.79	4.37
Seed yield (kg/ha)	1520	1184
Straw yield (kg/ha)	1821	1523
Harvest index (%)	45.32	43.48

TABLE 4: analysis of broad bed furrow and flat bed method

Treatment	Avg. Yield ($q\ ha^{-1}$)	Avg. % change in Yield	Parameter* (Avg. No. of pods per plant)	Avg. % change in Parameter	Avg. Cost of cultivation ($Rs.\ ha^{-1}$)	Avg. Gross return ($Rs.\ ha^{-1}$)	Avg. Net return ($Rs.\ ha^{-1}$)	Avg. B:C Ratio
T_1	11.84	28.38	36.54	29.20	26447	40848	14401	1.54
T_2	15.20		47.21		25610	52440	26830	2.05

T_1: Farmers practice (flat bed method)
T_2: Recommended practice (broad bed furrow method)

Conclusion

Soybean is more water stress crop and at the time of germination sudden rainfall affects the crop. These rainfed crops are often subjected to extreme stresses of soil saturation as well as poor moisture due to erratic rainfall pattern. The BBF machine was introduced basically to cope up with the problem of moisture stress in the soybean fields. The soil moisture is managed by maximizing the use of rainfall through increasing infiltration and moisture retention and reducing runoff and soil erosion. Thus, by this machine, the performance of high yielding improved varieties is optimized as the deep furrows created under BBF provides effective drainage during excess rains, while serves as in situ moisture conservation during dry spells, thus mitigating the detrimental effects of both extreme situations.

The maximum seed yield of soybean was recorded when grown on broad bed furrow system of planting as compared to conventional method of sowing i.e. flat bed sowing. Effect of on broad bed furrow planting system on the growth characters of soybean was found better in comparison with normal flatbed sowing. The results of experiment indicate that for achieving maximum productivity from soybean crop in Balodabazar district of Chhattisgarh, the soybean crop should be sown on broad bed furrow planting system.

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RESPONSE OF GRADED DOSE OF FLY ASH APPLIED WITH AND WITHOUT FYM ON PHYSICO-CHEMICAL PROPERTIES OF SOIL, YIELD ATTRIBUTES AND YIELD OF RICE

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Abstract

The present investigation was carried out during kharif season of 2015-16 at Gaitara village, Tilda block, Raipur District (C.G.) to evaluate the effect of different doses of fly ash applied with or without fly ash on physico-chemical properties of soil, yield attributes and yield of rice. Results revealed that there is no any significant impact on soil pH, EC, bulk density and Partical density while organic carbon content was significantly increased by the application of graded dose of fly ash with and without FYM. The application of graded dose of fly ash with and without FYM could not influence the available soil N significantly while available soil P and K increased significantly. The yield attributes and yield viz. effective tillers per hill^{-1}, number of grain per panicle and test weight, grain and straw yield of rice increased significantly by the application of graded dose of fly ash with and without FYM. The treatment of 75% GRD + 40 t fly ash ha^{-1} + 5 t FYM ha^{-1} (T_7) give highest effective tillers per hill^{-1}(6.15), number of grain per panicle (96.35), test weight (25.72), grain yield (48.00 q ha^{-1}) and straw yield (68.73 q ha^{-1}) of rice. From the study it was concluded that the treatment of 75% GRD + 40 t fly ash ha^{-1} + 5 t FYM ha^{-1} (T_7) found to be most effective on crop yield and treaded to improve soil physico chemical properties and nutrient status as compared GRD.

Key words: *Fly ash, FYM, organic carbon, yield, rice.*

Introduction

Rice (*Oryza sativa* L.) is the world's most important crop and the primary source of food for more than half of the world's population, especially in Asia. Rice contains a large amount of starch, some proteins, minerals, fibers and vitamins like B and E. The slogan 'Rice is life' is most appropriate for India as this crop plays a vital role in our national food security and is a means of livelihood for millions of rural household. In India, it accounts for > 40% of food grain production, providing direct employment to 70 % people in rural areas (Anonymous, 2012). India has the largest acreage under rice of 44 mha and with a production of about 141 mt and the national productivity of 3.21 t ha^{-1}. The burgeoning population of our country may stabilize around 1.4 and 1.6 billion by 2025 and 2050, requiring annually 380 and 450 mt of food grains respectively. In Chhattisgarh state more than 70 % area comes under the rainfed condition, where rice cultivation is depends on south-west monsoon in spite of that state is known as "Rice Bowl of India". About 130 coal-based thermal power stations in India are producing over 165 million tons fly ash per

year. Fly ash is a by-product of the thermal power station, where coal energy is converted into electrical energy. The demand for electrical energy is increasing day by day and in the absence of its utilization of the byproduct of thermal plant, it is been getting accumulated and for storing large area of arable land will be required which is therefore finding immediate use of fly ash for different purposes is very important. Fly ash being an inert heterogeneous SiO_2, Al_2O_3 and Fe_2O_3 as a main components and material containing mineral nutrients as minor components which attracts the agriculture scientists for its utilization in improving crop and soil productivity.

A part from nutrition fly ash generation is expected to increase to 300 million tons per annum by 2017 and 900 million tons per annum by 2031-32, it is a fine, grey, amorphous powder and rich in Si, Al, spherical in shape having excellent physical properties. The physic-chemical properties of fly ash may vary widely, depending upon the nature of the coal, the efficiency of the coal combustion process and the selection process. It is similar to soil in some of physical and chemical properties, as it contains major, secondary and trace elements, which are found in earth crust. Total major nutrients N and P were low i.e. 0.056 and 0.087 %, respectively, but it contains sufficient by higher amount of total K (0.172%), CaO (1.60%), MgO (0.96%) and total trace elements i.e. Mn 3.98 ppm, Cu 3.60 ppm , Zn 1.30 ppm and Fe 3.81 ppm, respectively (Bhoyer, 1998).Presence of organic matter (FYM) in soil has an additive effect as it reduces the concentration of toxic metals through sorption, lowers the C/N ratio and provides organic compounds, which promote microbial proliferation and diversity (Pitchel and Hayes, 1990). The emerging scenario necessitates the need for the adoption of package of practices which maintain soil health, makes the production system more sustainable and provides better food for meeting the nutritional requirements. The use of organic soil amendments has been associated with desirable soil properties including higher plant available water holding capacity and cation exchange capacity and lower bulk density, and can foster beneficial microorganisms (Drinkwater et al., 1995). In combination with various organic manure, fly ash can enhance soil physico-chemical properties, nutrient availability and plant productivity (Sikka and Kansal, 1995). The combined effect of fly ash and FYM on available nutrient status and recorded the highest available N, P, K, Fe and Zn contents at the harvest of rice crop (Reddy et al., 2010). Singha (2013) reported that fly ash in combination with farmyard manure or other organic amendments improves soil physico-chemical characteristics, yield and microbial processes in paddy fields and concluded that fly ash at lower doses improving paddy crop yields. Hence the studies with the objectives to assess the response of graded dose of fly ash applied with and without FYM on physico-chemical properties of soil and yield attributing characters of rice.

Materials and Methods

The present experiment was conducted at the research village - Gaitara, Tilda block, Raipur district (C.G.) during *kharif* season - 2015. Raipur lies at $21^0$4' North latitude and $81^0$35' East longitude with an altitude of 290.20 meter above the mean sea level. The soil of experimental site was sand in texture with pH 6.8, EC 0.12 dSm $^{-1}$ and CEC 19.15 Cmol (p +) kg $^{-1}$, organic carbon 0.42 %, available N 138.0 kg ha^{-1}, available P 2.31 kg ha^{-1}, available K 228.8 kg ha^{-1}, Rice plants variety MTU- 1010 was transplanted in open field on 2nd August 2015 with 15 cm x 10 cm spacing. The experiment was carried out using 8 treatment they are T1- Control,T2- GRD (100:60:40), T3- 75% GRD + 20 t fly ash ha^{-1}, T4- 75% GRD + 40 t fly ash ha^{-1}, T5- 75% GRD + 60 t fly ash ha^{-1}, T6- 75% GRD + 20 t fly ash ha-1 + 5 t FYM ha^{-1}, T7- 75% GRD + 40 t fly ash ha-1 + 5 t FYM ha^{-1}, T8-75% GRD + 60 t fly ash ha-1 + 5 t FYM ha^{-1} The treatment were

replicated three times in Randomized Block Design (RBD) and allocated randomly to different plots. All nutrients management practices (chemical fertilizers, organic manures and fly ash) were applied as per the treatments. Nutrients were applied through urea, DAP, murate of potash, FYM and fly ash respectively. Soil pH and EC was determined by method described by Jackson (1967), organic carbon by Walkley and Black rapid titration method (1934), bulk density by Black method (1965), particle density by using picnometer. Available N was determined by alkaline permanganate method (Subbiah and Asija, 1956). The available phosphorus by Olsen method (Olsen et al., 1954). Available K by Flame-photometer method (Chapman and Pratt, 1961). The total number of tillers, effective tillers plant^{-1} was observed at harvest. The data was recorded by averaging the observation from the randomly tagged five plants in each plot No. of grain per panicle was recorded from marked five hills of middle row of each plot and averaged. Test weight by randomly cleaned seed samples were taken from each plot and 1000 seeds were counted and same weight was recorded in gram accurately by using an electronic digital balance. The weight of seed and straw yield of rice was recorded from each net plot and reported in q ha^{-1}.

Results and Discussion

Physico-chemical properties of fly ash

Fly ash is a by-product of the Thermal Power Station, where coal energy is converted into electrical energy. The physico-chemical properties of fly ash ((Table 1) depends on the quality of coal which is used as source, process of combustion, extent of weathering, particle size, collection setup. Attempts are being made to find out its useful application dose in growing of rice. The fly ash used in the experiment was having particle size (2-0.02mm) 44%, (0.02-0.002mm) 50% and (<0.002mm) 6%. The bulk density of the fly ash was 0.71 Mg m^{-3} (Karmakar et al., 2010). Fly ash is a complex heterogeneous material consisting of both amorphous and crystalline phases (Mattigod et.al., 1990). The pH of the fly ash sample was 7.7. The total nitrogen, phosphorus and potassium content of fly ash were 0.14, 0.08 and 0.02 % respectively (Ravikumar et al., 2008).

Physico-chemical properties of soil

The application of different doses of fly ash either with or without FYM had no significant influenced on soil reaction (pH) after harvest of crop (Table 2) (Sikka and Kansal, 1995). Similarly there is no any significant difference was found among the treatments for EC of soil after harvest of crop (Table 2) (Robinson et al., 2001). The Soil organic carbon content was significantly affected by the different treatments as compare to 100 % GRD and control (Table 2). The treatment 75% GRD + 40 t fly ash ha^{-1} + 5 t FYM ha^{-1} (T_7) showed highest organic carbon content (0.55 %) as compared to as compare to 100 % GRD, but it was at par with 75% GRD + 20 t fly ash ha^{-1} (T_3), 75% GRD + 40 t fly ash ha^{-1} (T_4), 75% GRD + 60 t fly ash ha^{-1} (T_5), 75% GRD + 20 t fly ash ha^{-1} + 5 t FYM ha^{-1} (T6) and 75% GRD + 60 t fly ash ha^{-1} +5 t FYM ha^{-1} (T_8). The minimum 0.44 % was found in control (T_1). The different graded dose of fly ash with FYM was found to increase in organic carbon than without FYM. The increased in organic carbon due to the application graded doses of fly ash and FYM. The effect was more pronounced when organic source where applied along with fly ash (Sarangi et al., 2001). The data from Table 1 show that application of fly ash did not change the bulk density and particle density of soil significantly among the treatments after crop harvest (Sharma and kalra, 2006). Deshmukh et al., 2000 also reported decrease in the soil bulk density as the fly ash levels increased.

Available macronutrients status

The effect of the different treatments was no significant on available soil N status (Table 2). Further when fly ash was applied with FYM, showed higher soil available N compare to without FYM and 100 % GRD. It ranged between 127.9-139.1 kg ha^{-1}. The maximum available N in soil (139.1 kg ha^{-1}) was recorded in treatment of 75% GRD + 40 t fly ash ha^{-1} + 5 t FYM ha^{-1} (T_7) while, the minimum under control (T_1) 127.90 kg ha^{-1}. The higher status of soil available N by integration of fly ash and FYM with inorganic fertilizer ascribed to increase release and availability of soil N due to additive effect of mineralization of the nutrients and their uptake thereby the higher yields under the treatments. (Singh et al., 2010). All the treatments showed significantly higher soil available P as compared to control (T_1). The differences among the treatments was non significant with respect to soil P status at harvest (Table 2). The maximum P content (3.50 kg ha^{-1}) was found under 75% GRD + 40 t fly ash ha^{-1} + 5 t FYM ha^{-1} (T_7) while, the minimum (2.70 kg ha^{-1}) in control (T_2). The increasing in soil P content at harvest compared to initial was ascribed due to P content of fly ash and FYM and also due to its effect on increase in biotic activity (Lee et al., 2007). The available soil K was increased significantly by the application of treatments over control except 75% GRD + 60 t fly ash ha^{-1} (T_5) (Table 2). The treatment 75% GRD + 40 t fly ash ha^{-1} + 5 t FYM ha^{-1} (T_7) showed highest soil K status (239.2 kg ha^{-1}) as compare to 100 % GRD. but it was at par with 75% GRD + 20 t fly ash ha^{-1} (T_3), 75% GRD + 40 t fly ash ha^{-1} (T_4), 75% GRD + 20 t fly ash ha^{-1} + 5 t FYM ha^{-1} (T6) and 75% GRD + 60 t fly ash ha^{-1} +5 t FYM ha^{-1} (T_8). The minimum value (220.5 kg ha^{-1}) was observed in control (T_1). The increased availability of K with application of fly ash, FYM and fertilizer (Das et al., 2013)

Yield attributes and Yield

The effective tillers per $hill^{-1}$ are significantly affected by the treatments application (Table 3). The maximum effective tiller per $hill^{-1}$ (6.15) was recorded in 75% GRD + 40 t fly ash ha^{-1} + 5 t FYM ha^{-1} (T_7) while, the minimum effective tiller (3.74) was recorded in control (T_1). The application of fly ash with and without FYM showed higher effective tillers than control (T_1) and 100 % GRD (T_2). The treatment 75% GRD + 40 t fly ash ha^{-1} + 5 t FYM ha^{-1} (T_7) and 75% GRD + 60 t fly ash ha^{-1} + 5 t FYM ha^{-1} (T_8) showed significantly higher effective tillers as compared to 100 % GRD (T_2) and control (T_1). Increase in the number of tillers and productive tillers could be attributed to the enhancement of germination of crop, improvement in soil physical and chemical properties and abundance of different nutrients by the addition of fertilizer, FYM and fly ash (Kamakar et al., 2010; Murgan and Murugaianyan, 2013). Number of grains per panicle (Table 3) significantly enhanced under treatment of 75% GRD + 40 t fly ash ha^{-1} + 5 t FYM ha^{-1} (T_7). The minimum number of grains per panicle (68.65) recorded in control (T_1). The treatment 75% GRD + 40 t fly ash ha^{-1} + 5 t FYM ha^{-1} (T_7) was found significantly superior (96.35) over control (T_1) and 100 % GRD (T_2), but statistically at par with 75% GRD + 20 t fly ash ha^{-1} + 5 t FYM ha^{-1} (T_6) and 75% GRD + 60 t fly ash ha^{-1} + 5 t FYM ha^{-1} (T_8). Higher root activity and nutrient absorption and consequent complementary effect in fly ash and FYM on soil properties might have resulted in higher number of grains per panicle of rice. Synergistic effect of integration of fly ash with FYM and chemical fertilizer on nutrient supply system might be resulted in better nutrient uptake and more numbers of grains (Karmakar et al., 2010).

Application of different treatment combination significantly affects the test weight of rice over control (Table 3). The Highest test weight (25.72 g) was recorded in 75% GRD + 40 t fly ash ha^{-1} + 5 t FYM ha^{-1} (T_7), while lowest test weight (18.58 g) was observed control (T_1). The

treatment 75% GRD + 40 t fly ash ha^{-1} + 5 t FYM ha^{-1} (T_7) was found superior over control (T_1) and 100 % GRD (T_2) , but it was at par with 75% GRD + 20 t fly ash ha^{-1} + 5 t FYM ha^{-1} (T_6) and 75% GRD + 60 t fly ash ha^{-1} + 5 t FYM ha^{-1} (T_8). Increase in test weight of rice could be due to abundance of different nutrients by the addition of fertilizer, FYM and fly ash (Sahu et al., 2007). The highest status of all the yield attributes viz. effective tillers per $hill^{-1}$, number of grain per panicle and test weight was noticed with the treatment 75% GRD + 40 t fly ash ha^{-1} + 5 t FYM ha^{-1}(T_7) might be due to improved soil health by combined application of Fly ash with chemical fertilizer and FYM (Sahu et al., 2007; Karmarkar et al., 2009). The grain yield of rice (Table 3) as influenced by the different treatments was significant. The treatment 75% GRD + 40 t fly ash ha^{-1} + 5 t FYM ha^{-1} (T_7) produced the highest yield (48.00 q ha^{-1}) while the lowest (17.17 q ha^{-1}) was by control (T_1). The fly ash when applied without FYM increased the yield, but was at par with 100 % GRD (T_2). Further, the different doses of fly ash application with FYM showed significantly higher yields which compared to 100 % GRD (T_2). The treatment 75% GRD + 40 t fly ash ha^{-1} + 5 t FYM ha^{-1} (T_7) gave significantly yield as compared to 75% GRD + 20 t fly ash ha^{-1} + 5 t FYM ha^{-1} (T_6) but it was at par with 75% GRD + 60 t fly ash ha^{-1} + 5 t FYM ha^{-1} (T_8). Similar result was recorded for straw yield. The higher straw yield (68.73 q ha^{-1}) was recorded in 75% GRD + 40 t fly ash ha^{-1} + 5 t FYM ha^{-1} (T_7), while the minimum straw yield (48.83 q ha^{-1}) was recorded in control (T_1). The treatments 75% GRD + 40 t fly ash ha^{-1} + 5 t FYM ha^{-1} (T_7) was found significant over all other treatments. The results also clearly indicate that the effect of fly ash was more pronounced in the presence of organic source. The conducive physical environment leading to better aeration, root activity and thereby increase in soil moisture holding capacity and nutrient absorption by the consequent complementary effect of fly ash and FYM application would have produced higher crop growth and yield attributing characters and which resulted in increased grain and straw yield of rice (Das *et a*l., 2013).

Conclusion

The application of different doses of fly ash either with or without FYM have significantly increased the available soil P, K status and the yield attributes and yiled viz. effective tillers per $hill^{-1}$, number of grain per panicle and test weight, grain and straw yield of rice. The above treatments could be promoted in rice cultivation as an alternative source of nutrients to further improve the physico – chemical properties of soil as well as nutrient availability and yield of rice.

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Table 1: Physico-chemical properties of fly ash

Particulars	Analysis value
Particle size (a) 2-0.02 mm (b) 0.02-0.002 mm (c) <0.002 mm	 44 % 50 % 6 %
Clay (%)	
Ph	7.72
EC (dSm^{-1})	0.17
OC (%)	0.36
PD ($g\ cm^{-3}$)	2.22
BD ($g\ cm^{-3}$)	0.71
WHC (%)	70.22
Total N (%)	0.144
Total P (%)	0.075
Total K (%)	0.028

Note- EC: Electrical Conductivity; OC: Organic Carbon; BD: Bulk Density; PD: Partical Density; N: Nitrogen; P: Phosphorus; K: Potassiu

Table 3. Effect of different combinations of treatments on yield attributes and yield of rice

Treatments	Effective tillers/ Hill	Grain per panicle	Test weight/ 1000 seed (g)	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})
T1 – Control	3.74	68.65	18.58	17.17	48.83
T2 - GRD (100:60:40)	4.82	80.60	20.45	39.57	52.37
T3 - 75% GRD + 20 t fly ash ha^{-1}	4.99	79.14	21.88	38.97	55.77
T4 - 75% GRD + 40 t fly ash ha^{-1}	4.69	83.38	20.73	41.17	52.00
T5 - 75% GRD + 60 t fly ash ha^{-1}	4.97	81.50	21.61	42.73	51.00
T6 - 75% GRD + 20 t fly ash ha-1 + 5 t FYM ha^{-1}	5.40	85.20	24.38	43.67	57.97
T7 - 75% GRD + 40 t fly ash ha-1 + 5 t FYM ha^{-1}	6.15	96.35	25.72	48.00	68.73
T8 - 75% GRD + 60 t fly ash ha-1 + 5 t FYM ha^{-1}	5.65	94.97	23.23	44.33	56.13
SEm±	**0.24**	**4.54**	**1.18**	**1.10**	**2.10**
CD (P = 0.05)	**0.75**	**13.79**	**3.59**	**3.60**	**6.40**

PHYSICO-CHEMICAL PROPERTIES AND AMOUNT AND DISTRIBUTION OF FORMS OF NITROGEN IN HUMID ALLUVIAL FLOOD FREE ZONE OF JORHAT DISTRICT OF ASSAM UNDER DIFFERENT LAND USE

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Abstract

"Physico-chemical properties and amount and distribution of forms of nitrogen in Humid Alluvial Flood Free Zone of Jorhat District of Assam under different land use" was studied on soils of three land use viz., tea, bamboo and rice. Soil sample was collected from three depths viz., 0-15 cm, 15-30 cm and 30-45 cm and from three locations under each land use type. The texture, pH, organic carbon, CEC and Av. N, TN, Av. P, Av. K, bulk density (BD), particle density (PD), and porosity of the soils ranged from sandy loam to clay, 4.74 to 5.69, 0.26 to 0.99 per cent, 6.2 to 9.26 cmol (p^+) kg^{-1}, 175.61 to 234.15 kg ha^{-1}, 0.056 per cent, 13.03 to 31.2 kg ha^{-1}, 32.37 to 187.74 kg ha^{-1}, 1.30 to 1.43g cm^{-3}, 2.59 to 2.67 g cm^{-3}, 48.18 to 50.43 per cent, respectively. Forms of nitrogen viz. total hydrolysable nitrogen (THN), hydrolysable ammonium nitrogen (HAN), ammonium amino-sugar nitrogen (AASN) and amino acid nitrogen (AAN) was determined by diffusion method (Bremner, 1965). The total nitrogen (TN), THN, HAN, AASN and AAN found to be the highest in soils under bamboo plantation (0.056 %, 245.77 ppm, 183.55 ppm, 169.22 ppm and 148.33 ppm, respectively) and lowest in soils under rice cultivation (0.042%, 112.83 ppm, 147.55 ppm, 148.22 ppm and 145.88 respectively). In Tea soil OC content of the soils had significant positive correlation with CEC, Av. N and Av. K and The TN content of soil under rice cultivation was correlated significantly and positively with CEC, MBC and MBN of the soils. The TN of the soils was found to have significant positive correlation with AAN, the THN significantly correlated with HAN, AASN and AAN and the HAN was significantly correlated with AASN only.

Introduction

In the surface layer of most soils, over 90% of N occurs in organic forms. The forms of soil organic N can be divided into two broad categories: 1) organic residues and 2) soil organic matter or humus. All these materials play key roles in maintaining or improving soil fertility and plant nutrition through the direct and indirect effects on microbial activity and nutrient availability (Patel *et al.,* 2007). The process of separating soil N into different fractions viz. Total Hydrolysable N (THN), Ammonium-Amino sugar N (AASN), Hydrolysable Ammonium N (HAN) and Amino Acid N (AAN) for evaluating their individual responses to field management practices and land use types are useful ways to detect soil N changes (Bremner, 1965). These fractions of N contributed to the major part of available nitrogen sources for different plant type and had major contribution in soil total nitrogen (Bolstad *et al.,* 2005). These fractions of N had different stabilities and turnover rates and they were influenced by agricultural management practices and land use type. Therefore, the fractions can be used as early and sensitive indicators of changes in Total Nitrogen (Bremner, 1965).

Nitrification and NO_3-N content of soils under different land use was found to decreased in the order of grassland, cultivated, woodland and fallow land which was caused by increased leaching rates of N The increased total N in grassland and cultivated land than woody land was due to increased N mineralization (Mubyana and Musamba, 2014). Similar observation of decreasing N content in the order of paddy field followed by forestland and slopping cropland land was reported by Yang *et al.* 2005. There was decreased NO_3^-N and NH_4^+N in desert than in paddy field followed by forestland and slopping cropland land (Halvorson *et al*., 2005). Greater NO_3^-N content was found in grassland than row crop land use (Jha *et al.,* 2010). However, there was no significant difference in total nitrogen content of various land uses in soils Mexico (Geissen *et al.,* 2009) and southern Ethiopia (Moges and Holdens 2008, Moges *et al.,* 2013). Cropping systems and soil management practices could reduce N leaching loss. For perennial crops it was less than annual cropping systems due to the ability of perennial vegetation to maintain high soil organic nitrogen content, greater water concentration and provide greater evapotranspiration during vulnerable leaching periods (Brye *et al*., 2001; Jha *et al*., 2010).

Variation in N distribution with soil profile depth had been widely reported (Malhi *et al*., 2009; Onweremadu *et al*., 2011; Zhijing *et al.,* 2013). For instance, it had been observed that total N decreased with profile depth in most Southern Spain Mediterranean agricultural land and southern Ethiopian soils of various land uses which was ascribe to the leaching of soluble organic nitrogen and high clay content (Diecow *et al.,* 2005). High nitrate concentrations had been reported within the 0-400 cm soil depth of various land uses for dry land agriculture in Northern China. However, no distinct pattern with soil depth had been reported for NO_3 and NH4-N in different land uses of a watershed on loess plateau of China (Zhijing *et al.,* 2013).

The process of separating soil N into different fractions (i.e., Total Hydrolysable N (THN), Ammonium-Amino sugar N (AASN), Hydrolysable Ammonium N (HAN) and Amino Acid N (AAN) for evaluating their individual responses to field management practices and land use types are useful ways to detect soil N changes. These fractions of N contribute major part of available nitrogen sources for different plant type and play major contribution in soil total nitrogen. They also featured different stabilities and turnover rates and are influenced by agricultural management practices and land use type. Therefore, the different fractions of N can be used as early and sensitive indicators of changes in Total Nitrogen.

Materials and Methods

Three (3) composite soil samples were collected from each land use type (LUT) from three different locations of Jorhat. To make the composite sample, at each location samples were taken randomly from five points. At each point soil samples were taken at three depths viz. from 0-15, 15-30 and 30-45 cm depth. Sub samples from the five points were bulked into a composite sample. Hence for each LUT bulked samples were collected from three locations and each location had composite samples from three depths. The detail of the sample collected is given in Table 1. The composite samples were transported to laboratory in ice box, sieved through a 2 mm sieve and immediately stored in sealed plastic bags for further analyses.

Table 1. Details of the soil samples

Sl. No.	Notation	Land Use Type	Location	Taxonomic order	Latitude	Longitude
1	T_1	Tea	AAU, Jorhat	Inceptisol	26°43′02.09″	94°11′56.30″
2	T_2	Tea	Baghchung	Inceptisol	26°52′ 28.04″	94°13′31.60″
3	T_3	Tea	Moabondha	Inceptisol	26°69′ 48.35″	94°07′56.18″
4	B_1	Bamboo	Jamuguri	Inceptisol	$26^0$39′58.00″	$94^0$06′55.01″
5	B_2	Bamboo	Baghchung	Inceptisol	26°52′ 28.54″	94°13′31.40″
6	B_3	Bamboo	Mohbondha	Inceptisol	$26^0$69′48.72″	$94^0$13′31.65″
7	P_1	Paddy	Kuwari-pukhuri	Inceptisol	26°41′ 51.50″	94°12′25.4″
8	P_2	Paddy	Bagmia	Inceptisol	26°43′ 60.07″	94°05′50.04″
9	P_3	Paddy	Moabondha	Inceptisol	26°69′ 48.55″	94°07′56.08″

The physico-chemical properties of the soils were determined following standard procedures as outlined by Jackson (2003).

Different forms of Nitrogen

The Diffusion Method out lined by Bremner (1965) was adopted for determination of different forms of Nitrogen.

Soil Hydrolysates

To prepare soil hydrolysates, samples of soil were heated under reflux for 12 h after treatment with 20 mL of 6 M HCl and two drops of octyl alcohol. The hydrolysis mixture was filtered through Whatman no. 50 filter paper under vacuum, after which replicate hydrolysates were combined and transferred to refrigerator for storage. Prior to use, the hydrolysate was neutralized by addition of NaOH (Bremner, 1965) to obtain a pH of 6.5 to 6.8.

Total hydrolyzable nitrogen

Five milliliters of soil hydrolysate was pipetted into a 50-mL Pyrex digestion tube and treated with 0.5 g of K_2SO_4–catalyst mixture and 2 mL of 18 M H_2SO_4. A 25-mm filtering funnel was placed in the mouth of the tube to minimize loss of H_2SO_4 during digestion, and the tube was then transferred to an Al block digester and heated for 1.5 h at 150^0C, then for 1 h at 250^0C, and finally for 3 h at 350^0C. After cooling, the digest was diluted with 2 mL of deionized water from a wash bottle, homogenized by vortex mixing, and decanted into a Mason jar. The latter operation was repeated three times to ensure complete transfer of N in the digest to the Mason jar, after which the wall of the jar was rinsed with 5 mL of deionized water from a wash bottle. Using a graduated cylinder, the digest was neutralized with 10 mL of 10 M NaOH, and within 30 seconds the jar was sealed by attaching a lid equipped with a petridish containing 5 mL of H_3BO_3–indicator solution, swirled to mix the contents, and then transferred to a hot plate maintained at 48 to 50^0C. After 4 h, the jar was removed from the hot plate, 5 mL of deionized

water was added to the H_3BO_3 solution in the petridish, and NH_4–N was determined by titration with 0.01 M H_2SO_4.

Hydrolyzable ammonium-nitrogen

Ten milliliters of soil hydrolysate in a Mason jar was treated with 0.05 g of MgO using a calibrated spoon. The jar was swirled to mix the contents and then sealed by attaching a lid equipped with a petridish containing 5 mL of H_3BO_3–indicator solution. Diffusion was performed for 28 h in an incubator maintained at 20^0C (the preferred technique), for 26 h at room temperature (25^0C), or for 2 h on a hot plate (48–50^0C), followed by titrimetric determination of NH_4–N.

(Ammonium + amino sugar)–nitrogen

Two milliliters of 10 M NaOH was added to 10 mL of soil hydrolysate in a Mason jar. After swirling the jar to mix the contents, a lid equipped with a petri dish containing 5 mL of H_3BO_3 solution was attached within 30 s, and the jar was heated on a hot plate (48–50^0C) for 5 h. The amount of NH_4–N collected was determined as described previously.

Amino acid–nitrogen

After completing diffusion of ($NH4^+$ amino sugar–N), 2.5 mL of 5 *M* H_2SO_4 was added to the jar, followed by 1 mL of ninhydrin solution. The jar was swirled to mix the contents, and after being covered (but not sealed) with an unmodified lid to minimize the loss of water, was placed within the central two-thirds of the surface area of a hot plate, and heated for 90 min at 95 to 100^0C. A few minutes were allowed for the jar to cool, after which the contents were treated with 1 mL of 10 M NaOH and mixed by swirling. Within 30 s, the jar was sealed by attaching a lid with 5 mL of H_3BO_3 solution in a petri dish, and then heated at 48 to 50^0C for 2 h on a hot plate. The H_3BO_3 solution was titrated as described previously

Statistical analysis

Statistical analyses were carried out for determining simple correlation coefficient between soil physicochemical properties and land use type and between different forms of N using SPSS 20.00 package program.

Results and Discussion

Effect of land use on soil physico-chemical properties,

The data on physico-chemical properties of the soils of Humid Alluvial Flood Free Zone (HAFFZ) of Jorhat district under tea, bamboo and rice cultivation at various depths are presented in Table 2.

Table 2. Physico-chemical properties of soil of different land

Land use type	Depth (cm)	Sand	Silt	Clay	Texture	pH	OC (%)	Av. N (Kg/ha)	CEC (cmol(p+)/ kg soil)	BD (g/cm3)	PD (g/cm3)	Porosity (%)	Av. P (Kg/ha)	Av. K (Kg/ha)
TEA	0-15	39.33	38.03	16.5	l	5.49	0.67	200.70	7.93	1.3	2.62	50.38	31.21	166.49
	15-30	38.76	38.66	18.03	l	5.47	0.57	196.53	7.3	1.35	2.64	48.86	28.43	111.58
	30-45	38	36.67	20.6	l	5.44	0.48	192.33	6.5	1.38	2.66	48.12	27.26	76.51
	Mean	**38.69**	**37.78**	**18.37**	**-**	**5.46**	**0.57**	**196.52**	**7.24**	**1.34**	**2.64**	**49.12**	**28.96**	**118.19**
BAMBO	0-15	44	34.87	17.8	sl	4.74	0.99	234.15	9.26	1.3	2.58	49.61	16.46	98.19
	15-30	42.66	34.77	22.64	l	5	0.98	229.96	8.23	1.32	2.63	49.8	15.47	80.95
	30-45	39.26	33.52	25.83	cl	5.38	0.76	225.80	7	1.32	2.65	50.18	13.03	72.37
	Mean	**41.91**	**34.38**	**22.09**	**-**	**5.04**	**0.91**	**229.97**	**8.16**	**1.31**	**2.62**	**49.86**	**14.98**	**83.83**
RICE	0-15	41.11	28.88	26	cl	5.45	0.61	204.88	7.2	1.37	2.6	47.3	29.74	187.74
	15-30	34.48	25.61	35.24	cl	5.62	0.32	169.34	6.9	1.4	2.63	46.76	25.21	167.44
	30-45	31.66	26.31	41.68	c	5.44	0.26	175.61	6.2	1.43	2.67	46.44	24.51	151.74
	Mean	**35.76**	**26.93**	**34.3**	**-**	**5.5**	**0.39**	**183.27**	**6.76**	**1.4**	**2.63**	**46.83**	**26.48**	**168.97**
	CV(5%)	**-**	**-**	**-**	**-**	**1.73**	**23.02**	**11.73**	**7.92**	**2.79**	**5.04**	**5.76**	**2.54**	**17.37**

Effect of land use on soil physico-chemical properties, Physical properties Texture

There was distinct variation in texture of the soils of HAFFZ of Jorhat district under tea, bamboo and rice cultivation. The finest texture was observed in rice soils which varied from clay loam to clay with depth (Table 2). On the other hand there was no change in texture of the soils under tea plantation with depth which was loam from 0 to 45 cm depth. The soils under bamboo plantation had intermediate texture ranged from loam to clay loam from surface to lower depths.

The sand fraction of the bamboo soils at surface 0-15 cm depth was the highest (44 per cent) and lowest in tea (39.33 per cent) plantation and it was decreasing with depth irrespective of LUT. A decreasing trend in the amount of silt fraction was also observed with increasing soil depth in all LUT. In contrast, the clay content was increasing with increasing depth from 0 to 45 cm in all LUT. The increase was the highest in soils under rice cultivation (15.68%) and lowest in soils under tea plantation (4.1%). Clay content of soils had significant positive correlation with CEC in all LUT viz. tea (0.857**), bamboo (0.790*) and rice (0.477*). Moreover, clay content was significantly correlated with Av. K (0.794*) in tea soils and with organic carbon (0.954**) in bamboo soils (Table 4). But when soils of all LUT was considered clay content of the soils was found to correlate significantly with OC (0.639**) and CEC (0.532**) of the soils (Table 4).

Bulk density

Bulk density (BD) showed a uniform increasing trend with increasing depth in all LUT (Table 2). The soils under rice cultivation had the highest bulk density at all depths (1.37 to 1.43 g cm^{-1}) in comparison with tea (1.30 to 1.38 gcm^{-3}) and bamboo soils (1.3 to1.32 gcm^{-3}).

The higher BD in rice soils may be due to the paddling operation followed in rice cultivation over a long period of time. Similar observation was also reported by Agarwal *et al.,* (2008). Higher bulk density values in soils of lower depths might be due to low organic matter content of the soils at lower depth (Swarnam *et al*., 2004).

Particle density

There was no conspicuous variation in particle density (PD) of the soils of HAFFZ of Jorhat district under tea, bamboo and rice cultivation. It was ranged from 2.59 to 2.67 gcm^{-3}in these soils (Table 2). It was found to be increased slightly with increasing soil depths irrespective of the LUT.

Total porosity

The total porosity of the soils did not found to vary significantly with depth in all the LUT (Table 2). It ranged from varied from 48.18 to 50.43 per cent in these soils. The mean porosity (mean of three depths) of the rice soils was the highest (50.18 %) and the bamboo and the tea soils had almost equal total porosity i.e., 49.38 and 49.13 per cent , respectively.

Chemical properties

pH

The pH ranged from 5.44 to 5.49 in tea soil, 4.74 to 5.38 in bamboo soil and 5.44 to 5.62 in rice soils of HAFFZ of Jorhat district 0-15 cm to 30-45 cm depth (Table 3). Distribution of pH with soil depth was found to have completely different trends in tea, Bamboo and rice LUT. The pH was decreasing slightly with depth in soils in tea plantation (0.05 units) whereas; pH was increasing in bamboo plantation (0.64 units) and had no definite trend in distribution in rice cultivation. Similar trend in distribution of pH in rice cultivated soils was reported by Baruah and Borthakur (1997). The lowest pH in bamboo soil might be due its highest OC content (Tanle 2).

In tea soils the pH was significantly correlated with Av. N (0.712*) (Table 5) in bamboo soil it had significant correlation with CEC (0.705*), Av. P (0.710*), TN (0.700*), MBC (0.782*), and MBN (0.880**) and in rice soil pH had highly significant correlation with TN (0.890**), MBC (0.963**), and MBN (0.832**). The activities of soil microorganisms, microbial and biochemical properties and the nutrient availability was reported to be reduced significantly under acidic pH condition because of the combined effect of H^{+} and Al^{3+} (Blevins e*t al.,* 2012). As the soils of HAFFZ of Jorhat district are acidic nature, the existence of significant correlation of pH with nutrient availability parameters viz., Av. N and Av. P and microbial properties of the soils viz., MBC and MBN is supported by findings of (Blevins e*t. al.,* 2012).

Organic carbon (OC)

The organic carbon content of the soils under tea, bamboo and rice cultivation ranged from 0.67 to 0.48 per cent, 0.99 to 0.76 per cent and 0.61 to 0.26 per cent, respectively from surface to lower depths of the soils (Table 2). The highest amount of OC (0.91 per cent) was observed in bamboo soil and the lowest of it was found in rice soil (0.40 per cent). Depth

distribution of OC showed a decreasing trend irrespective of differences in land use of the soils. The highest OC content in bamboo soil and The lowest OC content in rice soil might be due to rapid decomposition caused by disruption of soil structure as it was subjected to conventional tillage operation every year for cultivation of transplanted rice (Davidson and Ackerman, 2013; Murty *et al.,* 2002). In bamboo plantation the soil is completely undisturbed as no tillage operation has been done. Moreover, leaf litter accumulation in bamboo soil was also high as it is a high residue crop. Therefore, the highest OC content as found in bamboo cultivation (Nelson and Sommers, 2012).

The OC content of the soils under tea plantation was found to have significant positive correlation with CEC (0.374**), Av. N (0.330*) and Av. K (0.812**) content of the soils (Table 10). In soils of bamboo plantation it had significant correlation with CEC (0.776*), Av. N (0.448*) and MBC (0.880**) of the soils and in rice soil OC was significantly correlated with only Av. K (0.812**) of the soils only. When the soils under three different land use were taken together, the OC was found to be significantly correlated with CEC (0.658**), Av. N (0.630**), TN (0.531**) and MBC (0.729**) of the soils.

5.2.2 Available N

The available N (Av. N) content of tea, bamboo and rice soils ranged from 192.33 to 200.7 kgha^{-1} , from 225.8 to 234.15 kgha^{-1}and from 175.61 to 204.88 kgha^{-1} , respectively from lower (30-45 cm) to upper layers (0-15 cm) of the soils (Table 2). The Av. N was found to be the highest (229.97 kg ha^{-1}) in bamboo soil and the lowest (183.28 kg ha^{-1}) in rice soil. In terms of soil fertility Av. N content of the soils under tea, bamboo and rice land use was rated as low (< 272 kg ha^{-1}). Invariably, Av. N was decreased with depth in all LUT.

In all the LUT viz. tea, bamboo and rice the correlation of the Av. N content of soil were significant with OC content of the soils (0.330*, 0.448* and 0.469*, respectively) only (Table. 11). The Av. N content of soil was significantly correlated with TN content of bamboo soil (0.671*) and rice soil (0.826*). But when all the soils were taken together the Av. N was found to be significantly correlated with OC (0.630**), TN (0.414*) and MBC (0.600**) of the soils.

Therefore, in the soils of HAFFZ of Jorhat district Av. N was found to have positive relation with OC content of the soils. The bamboo soil contained the highest amount of Av. N as it contained the highest OC content (Table 3). There was a decreasing trend of Av. N with increasing in depth of soil under all LUT as the depth distribution of OC was also followed the same trend in these soils (Table 2). Moreover, Av. N was reported to be loss significantly in agricultural soil in comparison to forest soils (Liang *et al*., 2009). Therefore, there might be higher Av. N content in soils under bamboo which is an agro-forestry than the rice cultivated soils.

Cation exchange capacity (CEC)

There was a decreasing trend of CEC with increase of soil depth irrespective of LUT in soils of HAFFZ of Jorhat district. These soils could be arranged in the decreasing order of CEC as: bamboo soil (8.16 cmol (p+) kg^{-1}) > tea soil (7.24 cmol (p+) kg^{-1}) > rice soil (6.77 cmol (p+) kg$^{-1)}$ (Table 2). The CEC was the highest in bamboo soil and lowest in rice soil might be due the highest OC content in bamboo soil and the lowest in rice soil. Amount of organic matter in soil depends on plant cover type and therefore, CEC is positively influenced by land uses type (Moges *et al.,* 2013). Hence, the CEC showed similar trend as that soil OC content in soils. Cation exchange capacity is significantly correlated with soil organic carbon content Masto *et al.*, (2007).

The CEC was found to correlate significantly with organic carbon (0.374*), Av. K (0.805**), total N (0.886**), MBC (0.710*), and MBN (0.890**) in soils of UBVZ of Jorhat district under tea plantation (Table 6). In bamboo soils the CEC had significant correlation with OC (0.776*) and MBC (0.880**), and in rice soils it had to significant correlation with OC (0.374*) and Av. K (0.812**) of the soils. In soils of all LUT together the CEC was found to have significant correlation with OC (0.658**), TN (0.777**), MBC (0.691**) and MBN (0.697**). Masto *et al.*, (2007) also reported the existence of significant correlation CEC is with soil organic carbon content.

Available N

The available N (Av. N) content of tea, bamboo and rice soils ranged from 192.33 to 200.7 kgha^{-1} , from 225.8 to 234.15 kgha^{-1}and from 175.61 to 204.88 kgha^{-1} , respectively from lower (30-45 cm) to upper layers (0-15 cm) of the soils (Table 2). The Av. N was found to be the highest (229.97 kg ha^{-1}) in bamboo soil and the lowest (183.28 kg ha^{-1}) in rice soil. In terms of soil fertility Av. N content of the soils under tea, bamboo and rice land use was rated as low (< 272 kg ha^{-1}). Invariably, Av. N was decreased with depth in all LUT.

In all the LUT viz. tea, bamboo and rice the correlation of the Av. N content of soil were significant with OC content of the soils (0.330*, 0.448* and 0.469*, respectively) only (Table. 11). The Av. N content of soil was significantly correlated with TN content of bamboo soil (0.671*) and rice soil (0.826*). But when all the soils were taken together the Av. N was found to be significantly correlated with OC (0.630**), TN (0.414*) and MBC (0.600**) of the soils.

Therefore, in the soils of HAFFZ of Jorhat district Av. N was found to have positive relation with OC content of the soils. The bamboo soil contained the highest amount of Av. N as it contained the highest OC content (Table 3). There was a decreasing trend of Av. N with increasing in depth of soil under all LUT as the depth distribution of OC was also followed the same trend in these soils (Table 3). Moreover, Av. N was reported to be loss significantly in agricultural soil in comparison to forest soils (Liang *et al*., 2009). Therefore, there might be higher Av. N content in soils under bamboo which is an agro-forestry than the rice cultivated soils.

Available P

The status of available P (Av. P) in soils of HAFFZ of Jorhat district under different land use ranged from low to medium (13.03 to 31.21 kg ha^{-1}) (Table 2). The Av. P content decreased with increase in depth of soils irrespective of LUT (Table 3). Available P varied from 27.26 to 31.21 kg ha^{-1}, 13.03 to 16.46 kg ha^{-1}, and 24.51 to 29.74 kg ha^{-1} in tea, bamboo and rice soils, respectively at different soil depths. The highest Av. P in tea soils might be due to intensive fertilization practice followed in tea plantation and lowest Av. P in bamboo plantation might be due to the farmer's practice of the area i.e. no fertilization practice adopted in bamboo plantation. The Av. P content of the soils was found to have significant positive correlated with MBC (0.737*) and MBN (0.687*) in tea soils, with MBN (0.697*) in bamboo soils and with MBC (0.881*) and MBN (0.806**) in rice soils of UMVZ of Jorhat district (Table 7). Therefore, from the significance of correlation of Av. P mostly with the MBC and MBN in the soils of HAFFZ of Jorhat district in tea, bamboo and rice LUT it can be inferred that availability of P in these soils is mostly controlled by biological processes. Though it is almost established that availability of P in acid soils mostly controlled by pH (Nath and Bhattacharyya, 2014) no significant correlation of Av. P with pH was

observed in this study. However, Av. P content was higher in soils irrespective of tea, bamboo and rice cultivation at higher pH of soil (Table 2).

Available K

The available K (Av. K) content of the HAFFZ of Jorhat district under tea, bamboo and rice cultivation ranged from low to medium (72.37 to 187.74 kg ha^{-1}) (Table 2). In all LUT Av. K was decreasing with increasing depth of soil. The highest and the lowest Av. K was observed in rice cultivated soils (168.97 kg ha^{-1}) and bamboo soils (83.83 kg ha^{-1}), respectively. Tea and bamboo soils had more amount of Av. K in surface (0-15cm) soil but rice soil contained more amount of Av. K in lower depths (30-45cm). Higher Av. K at surface soils of bamboo and tea plantation might be due to recycling of Av. K to upper layer of soils through leaf litter accumulation in bamboo plantation and in tea plantation addition of leaf litter accumulation was accompanied by addition of K fertilizer. In transplanted rice cultivation system puddling caused leaching of K from surface layers and it was accumulated above the hard pane existed in rice soils which resulted in more Av. K at lower depths of these rice cultivated soils (Sparks *et al*., 2000).
The Av. K was significantly correlated with clay (0.794*), organic carbon (0.812**), CEC (0.805**), and MBC (0.830**) in tea soils and in rice the same was observed with organic carbon (0.710*), CEC (0.890**), MBC (.947**), and MBN (0.877**) of soil (Table 8). However, there was no significant correlation of Av. K content of the soil under bamboo plantation with any of the soil characteristics. When all soils in all LUT was taken together, the Av. K was found to have significant positive correlation with active biological fraction of soil carbon and nitrogen only i.e. MBC (0.123*) and MBN (0.537**) of the soils.

Forms of N in different land uses

The data on forms of N viz. total N (TN), total hydrolysable N (THN), hydrolysable ammonium nitrogen (HAN), ammonium and amino sugar N (AASN) and amino acid N (AAN) in soils of Humid Alluvial Flood Free Zone (HAFFZ) of Jorhat district in different land uses and at various soil depths are presented in Table 3 and Fig. 1-5.

Total N

The soils total N (TN) content of the soils ranged from 0.032 to 0.056 per cent in the soils of HAFFZ of Jorhat district under tea, bamboo and rice cultivation (Table 3). The soils of tea and bamboo plantation did not vary in TN content (0.054 and 0.056 %, respectively). The average TN content was the lowest (0.032 %) in rice soils. All the soils under tea, bamboo and rice cultivation TN content had a decreasing trend with increasing depth of the soils.
The TN was found to be significantly correlated with CEC (0.880**), MBC (0.768*) and MBN (0.847**) in tea soils of HAFFZ of Jorhat district (Table 4). In the soils under bamboo plantation TN was found to be correlated significantly with CEC (0.700**), Av. N (0.671*) and MBN (0.871**) of the soils. In rice cultivated soils TN had significant correlation with CEC (0.963**), Av. N (0.797*) and MBN (0.842**) of the soils. In soils of all land use types together, TN content showed significant positive correlation with OC (0.729**), CEC (0.691**), MBC (0.593**) and MBN (0.871**) of the soils.

Table 3. Forms of nitrogen at various depths under different land use type

Land use type	Depth (cm)	TN (ppm)	THN (ppm)	HAN (ppm)	AASN (ppm)	AAN (ppm)
	0-15	820.00	214.66	192.00	181.66	141.33
TEA	15-30	450.00	158.66	149.33	170.00	120.66
	30-45	360.00	102.66	137.33	146.66	116.66
	Mean	**543.33**	**158.66**	**159.55**	**166.10**	**126.21**
	0-15	730.00	308.00	242.66	184.00	157.00
BAMBO	15-30	510.00	252.00	177.33	170.00	147.66
	30-45	400.0	177.33	130.66	153.66	140.33
	Mean	**546.66**	**245.77**	**183.55**	**169.22**	**148.33**
	0-15	400.00	142.66	184.00	160.66	153.66
RICE	15-30	320.00	121.33	137.33	149.00	146.66
	30-45	230.00	74.66	121.33	135.00	137.33
	Mean	**316.66**	**112.83**	**147.55**	**148.22**	**145.88**
	CV (%)	**21.56**	**11.06**	**18.29**	**4.06**	**4.94**

TN= Total nitrogen, THN= Total hydrolysable nitrogen, HAN= Hydrolysable ammonium nitrogen, AASN= Ammonium amino-sugar nitrogen, AAN= Amino acid nitrogen

The TN content also showed a similar trend distribution as that of Av. N in the soils of HAFFZ of Jorhat district under tea, bamboo and rice plantation. But no significant correlation of TN with OC was observed in any of the LUT studied. But, when soils under all LUT were taken together, TN found to have significant correlation with OC content of the soil. Nath and Bhattachacharyya (2012) had reported a significant correlation of TN with OC in tea soils of Dibrugarh district of Assam. Moreover, existence of significant correlation of TN with MBC and MBN of the soils in all the LUT studied leads to the conclusion that like Av. N the TN content of the soils was also controlled mostly by microbial process vis-à-vis soil microorganisms.

Total hydrolysable N

In tea, bamboo and rice LUT soils of HAFFZ of Jorhat district, THN was found to be decreased form 0-15 cm depth to 30-45 cm depth (Table 3). This result is in conformity with the finding of Singh *et al.,* (2004). The THN was the highest in bamboo plantation soils (245.77, ppm)

and it was followed by THN in tea soils (158.66 ppm) and rice soils (112.88 ppm). The THN significantly correlated with HAN (0.667**), AASN (0.708**) and AAN (0.412*) (Table 4.).

Hydrolysable ammonium N

The HAN of the soils followed the similar trend of THN in soils under tea, bamboo and rice cultivation (Table 3). In all the LUT it was decreased with increase in depth of the soils. A similar observation was also reported by Meysner *et al*., (2006). Also, the highest amount of HAN was observed in bamboo soils (183.55 ppm), intermediate amount in tea soils (159.66 ppm) and the lowest amount in rice cultivated soils (147.55 ppm). The HAN was significantly correlated with AASN (0.58**) only

5.3.3 Ammonium and Amino sugar N

The AASN content of the soils was found to have the similar trend as that of THN and HAN (Table 3). In all LUT it decreased with the depth of the soils. The content of AASN was the highest in bamboo soil (169.22 ppm) and the lowest in rice soils (148.22 ppm).

5.3.4 Amino acid N

Though the depth distribution of AAN was similar to THN, HAN and AASN in soils of HAFFZ of Jorhat district, the trend in magnitudes of its content in these soils under tea, bamboo and tea land use was different (Table 3). The AAN was found to be highest in rice soils (145.88) and the lowest amount of AAN was observed in tea soils (126.22).

Table 3. Correlation coefficient in between the forms of nitrogen

	TN	THN	HAN	AASAN	AAN
TN	**1**				
THN	**0.319**	**1**			
HAN	**0.021**	**0.657****	**1**		
AASN	**0.372**	**0.708****	**0.580****	**1**	
AAN	**0.702****	**0.412****	**0.063**	**0.302**	**1**

N=27, Correlation coefficient, * P < 0.05, ** P < 0.01.
TN= Total nitrogen, THN= Total hydrolysable nitrogen, HAN= Hydrolysable ammonium nitrogen, AASN= Ammonium amino-sugar nitrogen, AAN= Amino acid nitrogen

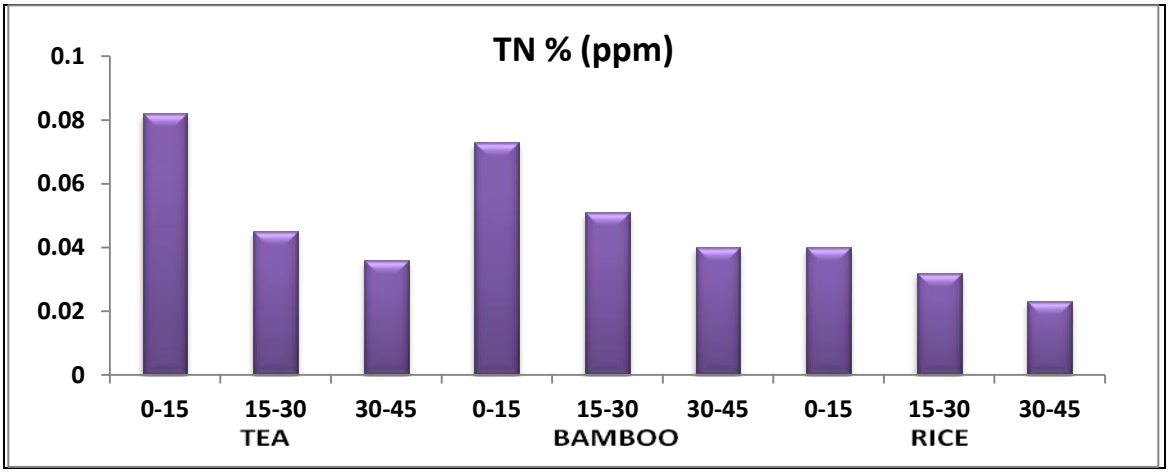


Fig. 10. Effect of land use type on total nitrogen at different depths

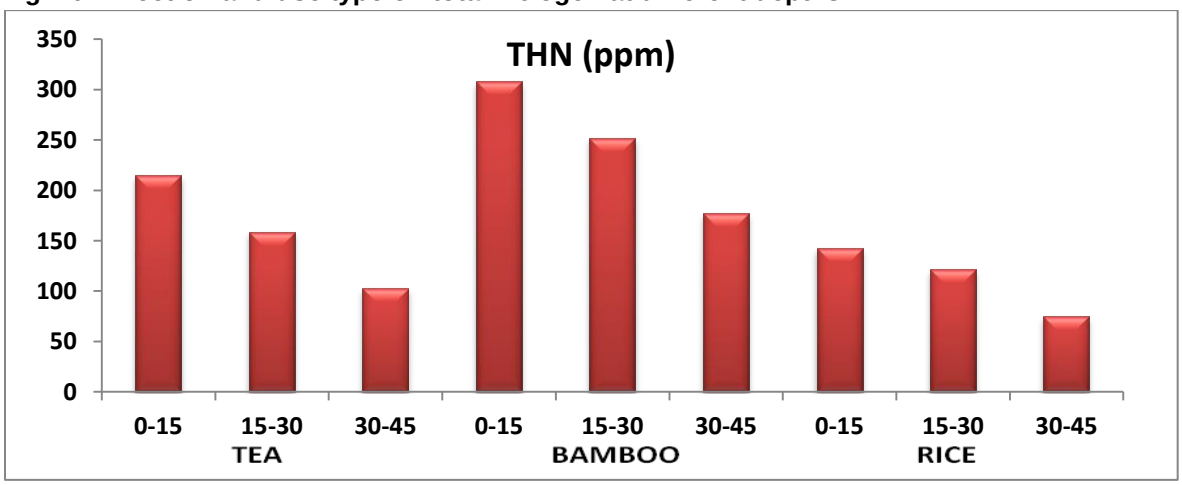


Fig. 13. Effect of land use type on total hydrolysable nitrogen at different depths

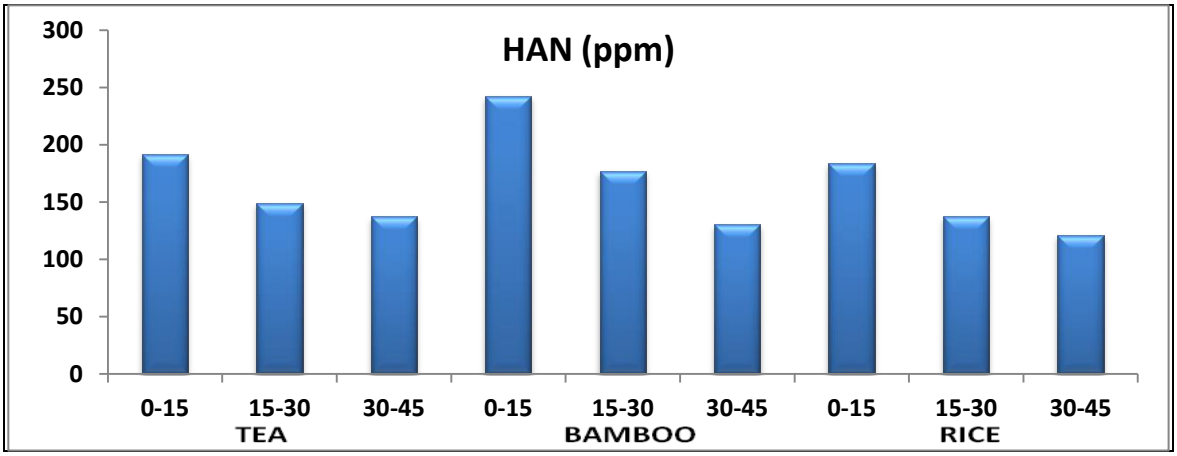


Fig. 14. Effect of land use type on hydrolysable ammonium nitrogen at different depths

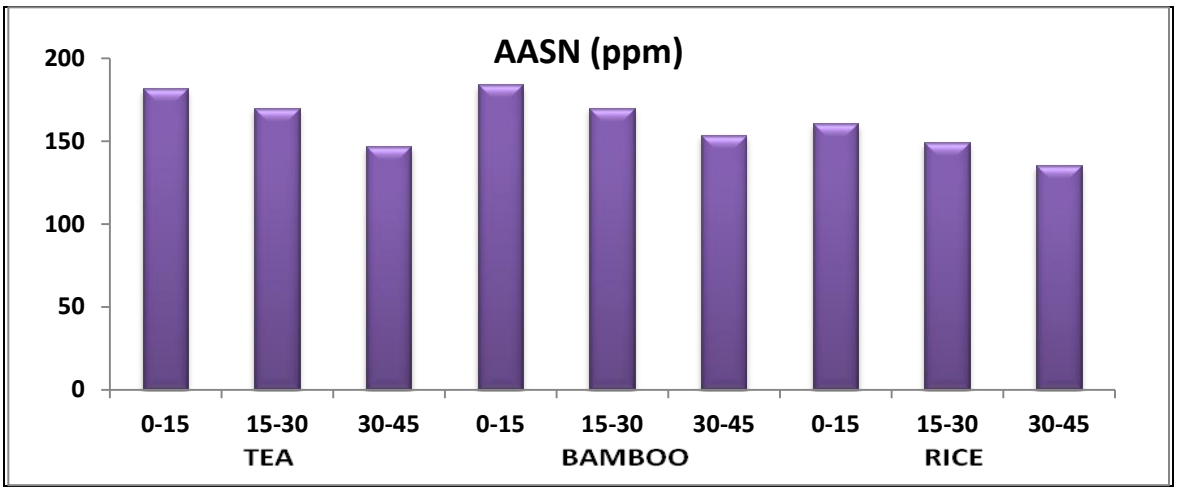


Fig. 15. Effect of land use type on ammonium amino-sugar nitrogen at different depths

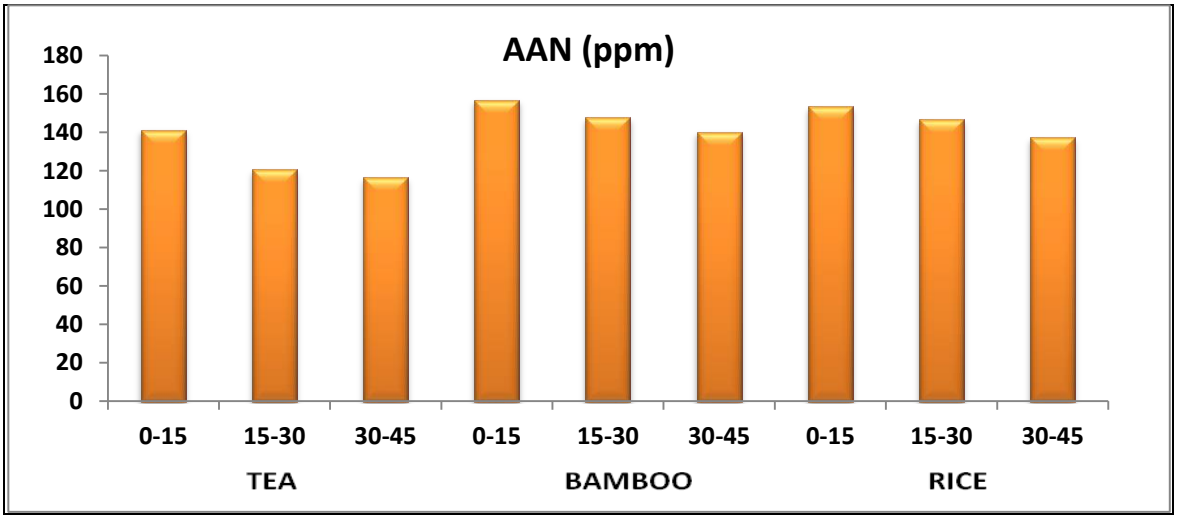


Fig. 16. Effect of land use type on amino acid nitrogen at different depth

Conclusion

The findings of the present investigation lead to the conclusion that in Humid Alluvial Flood Free zone of Jorhat district, the three land use type viz. tea, bamboo and paddy had significant effect on physic-chemical properties n forms of nitrogen. A significant relationship was also observed between forms of nitrogen and the OC content of the soils under these LUTs. The OC accumulation is the highest in bamboo plantation which leads to higher content of all forms of N in these soils and reverse is the trend in soils under rice cultivation.

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SOIL CARBON AND NITROGEN STATUS AND MICROBIAL BIOMASS CARBON (MBC) AND MICROBIAL BIOMASS NITROGEN (MBN) IN HUMID ALLUVIAL FLOOD FREE ZONE OF JORHAT DISTRICT UNDER DIFFERENT LAND USE

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Abstract

"Soil carbon and nitrogen status and microbial biomass carbon (MBC) and microbial biomass nitrogen (MBN) in Humid Alluvial Flood Free Zone of Jorhat District under different land use" was studied on soils of three land use viz., tea, bamboo and rice. Soil sample was collected from three depths viz., 0-15 cm, 15-30 cm and 30-45 cm and from three locations under each land use type. Organic carbon (0.99 per cent) and MBC (461.26 µgg^{-1}) were highest in soils under bamboo plantation. Nitrogen status viz., Av N (229.97 kg ha^{-1}) and total nitrogen (0.056 %) was the highest in bamboo soil. The MBN (74.43 µg g^{-1}) was the highest in soils under bamboo. In all land use types soil OC content of the soils had significant positive correlation with CEC, Av. N and Av. K and the Av. N was correlated positively with OC. The TN content of soil was correlated significantly and positively with CEC, MBC and MBN of the soils. The change in C and N status as well as MBC and MBN lead to change in soil physical and chemical characteristics.

Key words: *Organic carbon, nitrogen, microbial biomass carbon, microbial biomass nitrogen and land use type.*

Introduction

Important factors controlling organic matter levels in soils include climate, hydrology, parent material, soil fertility, biological activity, vegetation patterns and land use type. In the short term, the carbon balance of terrestrial ecosystems is sensitive to impact of human activities which are deforestation, biomass burning, land-use changes and environmental pollution. Many studies have shown that field management has a strong effect on soil C and N cycles (Liang *et al.,* 2012). However, changes in total C and N caused by management practices have been difficult to detect because these changes occur slowly and are relatively small compared to the abundant soil organic carbon (SOC) and total nitrogen (TN). Plant type play significant role in changing soil C and N status. Different plant type varies significantly in their productivity and biomass allocation patterns. Perennial plant allocates a higher proportion of their photosynthates belowground to roots and rhizomes in comparison to annual plant type. Litter quality has also been found to differ greatly among plant. Some plants have high contents of N and low C: N ratios, which favour microbial decomposition. For annual plant, significant human activities such as tillage are also needed, leading to soil perturbations as well as surface residue mixture into deep soils. These activities will likely to alter residue distribution in the soil C and N as well as microbial biomass.

The C and N pools largely represent degraded plant material together with microbial tissues and products that are not associated with mineral soil particles. Microbial activities or population depends upon the rate of decomposition of plant biomass or plant parts and also in rooting behaviour of plant type. These fractions represent an unprotected pool of soil organic matter (SOM) that responds more rapidly to agricultural management and land use type than the total SOM pool. Thus, these fractions of C and N can serve as early indicators of the effects of management practices and land use type.

Materials and Methods

Three (3) composite soil samples were collected from each land use type (LUT) from three different locations of Jorhat. To make the composite sample, at each location samples were taken randomly from five points. At each point soil samples were taken at three depths viz. from 0-15, 15-30 and 30-45 cm depth. Sub samples from the five points were bulked into a composite sample. Hence for each LUT bulked samples were collected from three locations and each location had composite samples from three depths. The detail of the sample collected is given in Table 1. The composite samples were transported to laboratory in ice box, sieved through a 2 mm sieve and immediately stored in sealed plastic bags at 4^0C for further analyses. All microbial determinations were completed within 1 week after sampling.

Table 1. Details of the soil samples

Sl. No.	Notation	Land Use Type	Location	Taxonomic order	Latitude	Longitude
1	T_1	Tea	AAU, Jorhat	Inceptisol	26°43′02.09″	94°11′56.30″
2	T_2	Tea	Baghchung	Inceptisol	26°52′ 28.04″	94°13′31.60″
3	T_3	Tea	Moabondha	Inceptisol	26°69′ 48.35″	94°07′56.18″
4	B_1	Bamboo	Jamuguri	Inceptisol	$26^0$39′58.00″	$94^0$06′55.01″
5	B_2	Bamboo	Baghchung	Inceptisol	26°52′ 28.54″	94°13′31.40″
6	B_3	Bamboo	Mohbondha	Inceptisol	$26^0$69′48.72″	$94^0$13′31.65″
7	P_1	Paddy	Kuwari-pukhuri	Inceptisol	26°41′ 51.50″	94°12′25.4″
8	P_2	Paddy	Bagmia	Inceptisol	26°43′ 60.07″	94°05′50.04″
9	P_3	Paddy	Moabondha	Inceptisol	26°69′ 48.55″	94°07′56.08″

The physico-chemical properties of the soils were determined following standard procedures as outlined by Jackson (2003). For the determination of MBC and MBN contents in samples collected for this purpose fumigation-extraction technique was used (Vance *et al.,* 1987)

The computation of MBC was as below:

$$MBC = Ec / kEC$$

Where Ec is the difference in the organic carbon extracted from fumigated soils and the un-fumigated soils and KEC = 0.38, the fraction of the killed biomass mineralized to CO_2 over the incubation period (Vance *et al.,* 1987).

The computation of biomass N was as below:

$$MBN = EN / kEN$$

Where EN is the difference between total N in fumigated soils and the un-fumigated soils, kEN = 0.46, the fraction of the killed biomass mineralized to nitrogen over the incubation period (Jorgensen, 2006).

Statistical analysis:

Statistical analyses were carried out for determining simple correlation coefficient between soil physicochemical properties and organic carbon, nitrogen, microbial biomass carbon and microbial biomass nitrogen using SPSS 20.00 package program.

Results And Discussion

Effect of land use on soil physico-chemical properties,

The data on physico-chemical properties of the soils of Humid Alluvial Flood Free Zone (HAFFZ) of Jorhat district under tea, bamboo and rice cultivation at various depths are presented in Table 2.

Table 2. Physico-chemical properties of soil of different land

Land use type	Depth (cm)	Sand	Silt	Clay	Texture	pH	CEC (cmol(p+)/kg soil)	BD (g/cm3)	PD (g/cm3)	Porosity (%)	Av. P (Kg/ha)	Av. K (Kg/ha)
TEA	0-15	39.33	38.03	16.5	l	5.49	7.93	1.3	2.62	50.38	31.21	166.49
	15-30	38.76	38.66	18.03	l	5.47	7.3	1.35	2.64	48.86	28.43	111.58
	30-45	38	36.67	20.6	l	5.44	6.5	1.38	2.66	48.12	27.26	76.51
	Mean	**38.69**	**37.78**	**18.37**	**-**	**5.46**	**7.24**	**1.34**	**2.64**	**49.12**	**28.96**	**118.19**
BAMBO	0-15	44	34.87	17.8	sl	4.74	9.26	1.3	2.58	49.61	16.46	98.19
	15-30	42.66	34.77	22.64	l	5	8.23	1.32	2.63	49.8	15.47	80.95
	30-45	39.26	33.52	25.83	cl	5.38	7	1.32	2.65	50.18	13.03	72.37
	Mean	**41.91**	**34.38**	**22.09**	**-**	**5.04**	**8.16**	**1.31**	**2.62**	**49.86**	**14.98**	**83.83**
RICE	0-15	41.11	28.88	26	cl	5.45	7.2	1.37	2.6	47.3	29.74	187.74
	15-30	34.48	25.61	35.24	cl	5.62	6.9	1.4	2.63	46.76	25.21	167.44
	30-45	31.66	26.31	41.68	c	5.44	6.2	1.43	2.67	46.44	24.51	151.74
	Mean	**35.76**	**26.93**	**34.3**	**-**	**5.5**	**6.76**	**1.4**	**2.63**	**46.83**	**26.48**	**168.97**
	CV(5%)	**-**	**-**	**-**	**-**	**1.73**	**7.92**	**2.79**	**5.04**	**5.76**	**2.54**	**17.37**

Carbon, nitrogen and microbial biomass carbon (MBC) and microbial biomass nitrogen (MBN) status

The data on Carbon, nitrogen and microbial biomass carbon (MBC) and microbial biomass nitrogen (MBN) status of the soils of UBVZ of Jorhat district under tea, bamboo and rice land use are given in Table 3 and Fig. 1-5.

Table 3. Carbon, Nitrogen and Microbial biomass carbon and microbial biomass nitrogen status in different land use at various depths

Land use type	Depth (cm)	OC (%)	Av. N (Kg/ha)	TN %	MBC (µg/g)	MBN (µg/g)
TEA	0-15	0.67	200.70	0.082	429.24	91.29
	15-30	0.57	196.53	0.045	318.85	50.71
	30-45	0.48	192.33	0.036	247.42	30.43
	Mean	**0.57**	**196.52**	**0.054**	**331.83**	**57.47**
BAMBO	0-15	0.99	234.15	0.073	526.21	101.58
	15-30	0.98	229.96	0.051	449.47	81.15
	30-45	0.76	225.80	0.040	408.10	40.57
	Mean	**0.91**	**229.97**	**0.054**	**461.26**	**74.43**
RICE	0-15	0.61	204.88	0.040	634.91	111.58
	15-30	0.32	169.34	0.032	208.77	50.71
	30-45	0.26	175.61	0.023	129.36	30.43
	Mean	**0.39**	**183.27**	**0.031**	**324.34**	**64.25**
	CV (%)	**23.02**	**11.73**	**21.56**	**25.07**	**24.32**

Table 4. Correlation coefficient of OC with CEC Av. N, Av. P, Av. K, TN, MBC and MBN under different land use types

	Tea (N=9)	Bamboo (N=9)	Rice (N=9)	Combined (N=27)
CEC	0.374*	0.776*	0.507*	0.658**
Av. N	0.330*	0.448*	0.330*	0.630**
Av. P	0.281	0.601	0.281	0.195
Av. K	0.812**	0.092	0.812**	0.265
TN	0.382	0.516	0.382	0.531**
MBC	0.531	0.880**	0.531**	0.729**
MBN	0.102	0.559	0.102	0.255

Correlation coefficient, * P < 0.05, ** P < 0.01.

Table 5. Correlation coefficient of Av. N with OC, MBC and MBN under different land use type

	Tea (N=9)	Bamboo (N=9)	Rice (N=9)	Combined (N=27)
OC	**0.330***	**0.448***	**0.469***	**0.630****
TN	**0.314**	**0.671***	**0.826***	**0.414***
MBC	**0.283**	**0.580**	**0.535**	**0.600****
MBN	**0.627**	**0.550**	**0.279**	**0.199**

Correlation coefficient, * P < 0.05, ** P < 0.01.

Table 6. Correlation coefficient of TN with pH, OC and CEC under different land use type

	Tea (N=9)	Bamboo (N=9)	Rice (N=9)	Combined (N=27)
pH	**0.124**	**0.463**	**0.254**	**0.328**
OC	**0.382**	**0.516**	**0.423**	**0.729****
CEC	**0 .880****	**0.700***	**0.963****	**0.691****
TN	**0.314**	**0.671***	**0.826***	**0.414***
MBC	**0.768***	**0.600**	**0.797***	**0.593****
MBN	**0.847****	**0.871****	**0.842****	**0.871****

Correlation coefficient, * P < 0.05, ** P < 0.01.

Table 7. Correlation coefficient of MBC with pH, OC, CEC, Av. N, Av. P, Av. K, TN and MBN under different land use type

	Tea (N=9)	Bamboo (N=9)	Rice (N=9)	Combined (N=27)
pH	**0.090**	**0.158**	**0.165**	**0.328**
OC	**0.531**	**0.880****	**0.815****	**0.729****
CEC	**0.710***	**0.782***	**0.832****	**0.691****
Av. N	**0.283**	**0.580**	**0.535**	**0.600****
Av. P	**0.737***	**0.423**	**0.881****	**0.205**
Av. K	**0.830****	**0.027**	**0.947****	**0.123**
TN	**0.768***	**0.600**	**0.797***	**0.593****
MBN	**0.722***	**0.667****	**0.933****	**0.639****

Correlation coefficient, * P < 0.05, ** P < 0.01.

Table 8. Correlation coefficient of MBN with pH, OC, CEC, Av. N, Av. p, AV. K, TN and MBC under different land use type

	Tea (N=9)	Bamboo (N=9)	Rice (N=9)	Combined (N=27)
pH	**0.244**	**0.663**	**0.189**	**0.663**
OC	**0.102**	**0.559**	**0.807****	**0.559**
CEC	**0.890****	**0.880****	**0.895****	**0.880****
Av. N	**0.627**	**0.550**	**0.279**	**0.550**
Av. P	**0.687***	**0.697***	**0.806****	**0.697***
Av. K	**0.582**	**0.632**	**0.877****	**0.632**
TN	**0.847****	**0.871****	**0.842****	**0.871****
MBC	**0.722***	**0.667***	**0.933****	**0.667***

Correlation coefficient, * P < 0.05, ** P < 0.01.

Organic carbon (OC)

The organic carbon content of the soils under tea, bamboo and rice cultivation ranged from 0.67 to 0.48 per cent, 0.99 to 0.76 per cent and 0.61 to 0.26 per cent, respectively from surface to lower depths of the soils (Table 3). The highest amount of OC (0.91 per cent) was observed in bamboo soil and the lowest of it was found in rice soil (0.40 per cent). Depth distribution of OC showed a decreasing trend irrespective of differences in land use of the soils. The highest OC content in bamboo soil and The lowest OC content in rice soil might be due to rapid decomposition caused by disruption of soil structure as it was subjected to conventional tillage operation every year for cultivation of transplanted rice (Davidson and Ackerman, 2013; Murty *et al.,* 2002). In bamboo plantation the soil is completely undisturbed as no tillage operation has been done. Moreover, leaf litter accumulation in bamboo soil was also high as it is a high residue crop. Therefore, the highest OC content as found in bamboo cultivation (Nelson and Sommers, 2012). The OC content of the soils under tea plantation was found to have significant positive correlation with CEC (0.374**), Av. N (0.330*) and Av. K (0.812**) content of the soils (Table 4). In soils of bamboo plantation it had significant correlation with CEC (0.776*), Av. N (0.448*) and MBC (0.880**) of the soils and in rice soil OC was significantly correlated with only Av. K (0.812**) of the soils only. When the soils under three different land use were taken together, the OC was found to be significantly correlated with CEC (0.658**), Av. N (0.630**), TN (0.531**) and MBC (0.729**) of the soils.

Available N

The available N (Av. N) content of tea, bamboo and rice soils ranged from 192.33 to 200.7 $kgha^{-1}$, from 225.8 to 234.15 $kgha^{-1}$and from 175.61 to 204.88 $kgha^{-1}$, respectively from lower (30-45 cm) to upper layers (0-15 cm) of the soils (Table 3). The Av. N was found to be the

highest (229.97 kg ha^{-1}) in bamboo soil and the lowest (183.28 kg ha^{-1}) in rice soil. In terms of soil fertility Av. N content of the soils under tea, bamboo and rice land use was rated as low (< 272 kg ha^{-1}). Invariably, Av. N was decreased with depth in all LUT. In all the LUT viz. tea, bamboo and rice the correlation of the Av. N content of soil were significant with OC content of the soils (0.330^{*}, 0.448^{*} and 0.469^{*}, respectively) only (Table. 5). The Av. N content of soil was significantly correlated with TN content of bamboo soil (0.671^{*}) and rice soil (0.826*). But when all the soils were taken together the Av. N was found to be significantly correlated with OC (0.630^{**}), TN (0.414^{*}) and MBC (0.600^{**}) of the soils. Therefore, in the soils of HAFFZ of Jorhat district Av. N was found to have positive relation with OC content of the soils. The bamboo soil contained the highest amount of Av. N as it contained the highest OC content (Table 3). There was a decreasing trend of Av. N with increasing in depth of soil under all LUT as the depth distribution of OC was also followed the same trend in these soils (Table 3). Moreover, Av. N was reported to be loss significantly in agricultural soil in comparison to forest soils (Liang *et al*., 2009). Therefore, there might be higher Av. N content in soils under bamboo which is an agro-forestry than the rice cultivated soils.

Total N

The soils total N (TN) content of the soils ranged from 0.032 to 0.056 per cent in the soils of HAFFZ of Jorhat district under tea, bamboo and rice cultivation (Table 3). The soils of tea and bamboo plantation did not vary in TN content (0.054 and 0.056 %, respectively). The average TN content was the lowest (0.032 %) in rice soils. All the soils under tea, bamboo and rice cultivation TN content had a decreasing trend with increasing depth of the soils. The TN was found to be significantly correlated with CEC (0.880^{**}), MBC (0.768^{*}) and MBN (0.847^{**}) in tea soils of HAFFZ of Jorhat district (Table 6). In the soils under bamboo plantation TN was found to be correlated significantly with CEC (0.700^{**}), Av. N (0.671^{*}) and MBN (0.871^{**}) of the soils. In rice cultivated soils TN had significant correlation with CEC (0.963^{**}), Av. N (0.797^{*}) and MBN (0.842^{**}) of the soils. In soils of all land use types together, TN content showed significant positive correlation with OC (0.729^{**}), CEC (0.691^{**}), MBC (0.593^{**}) and MBN (0.871^{**}) of the soils.

The TN content also showed a similar trend distribution as that of Av. N in the soils of HAFFZ of Jorhat district under tea, bamboo and rice plantation. But no significant correlation of TN with OC was observed in any of the LUT studied. But, when soils under all LUT were taken together, TN found to have significant correlation with OC content of the soil. Nath and Bhattachacharyya (2012) had reported a significant correlation of TN with OC in tea soils of Dibrugarh district of Assam. Moreover, existence of significant correlation of TN with MBC and MBN of the soils in all the LUT studied leads to the conclusion that like Av. N the TN content of the soils was also controlled mostly by microbial process vis-à-vis soil microorganisms.

Microbial biomass carbon

Microbial biomass carbon (MBC) ranged from 324.35 to 461.26 µg g^{-1} in soils of HAFFZ of Jorhat district under tea, bamboo and rice cultivation (Table 3). There was a distinct decreasing trend of MBC with increasing soil depth irrespective of LUT. At 0-15 cm depth the rice soils had the highest MBC (634.91 µgg-1) and the tea soils contained the lowest MBC (429.24 µg g^{-1}). In contrast, at 30-45 cm depth the rice soils contained the lowest MBC (129.36 µg g^{-1}) and the bamboo soil contained the highest MBC (408.10 µg g^{-1}). The MBC was found to be significantly correlated with CEC (0.710*), Av. P (0.737*), Av. K (0.830**), TN (0.768*) and MBN (0.722*) in tea soils (Table 7). In bamboo soil MBC had significant correlation with OC (.880**), CEC (.782*) and MBN (.667**) of soils and rice soil it was significantly correlated with OC (0.815**), CEC (0.832**), Av. P (0.881**), Av. K (0.947**), TN (0.797**) and MBN (0.933**) of the soils. In soils of all land use type together MBC was found to be significantly correlated with OC (0.729**), CEC (.691**), Av. N (0.600**), TN (0.593**) and MBN (0.639**) of the soils (Table 7).

Due to fibrous rooting characteristics the roots of rice presents within 20cm depth and hence microbial population were more in 0-15cm depth i.e. near rhyzoshere resulting higher MBC content. Similar results were also reported by Sharma *et al*., (2004). In bamboo soils microbial activity might be extended up to 30-45 cm depth because of the extension of bamboo roots up to that depth and MBC content was the highest. Considerably higher soil enzymatic activities and microbial population were in soils of bamboo forests were also reported by Zhihua Tu *et al.,* 2014). Moreover, soil microbes are typically carbon limited (Paul *et al.,* 2004) and hence lower microbial biomass in soils from conventional agro-ecosystems is often caused by reduced OC content in the soil (Cabrera and Kassel 2008). In this investigation also OC content of rice soil was the lowest and hence MBC was found to be the lowest. The highest OC content of the bamboo soils also lead to the highest MBC of the soil. The MBC also found to correlate significantly with AV. P, Av. K, TN and MBN in all the LUT. The existence of these correlations leads to the conclusion that soil microbes, the living part of soil organic matter, functioned as a transient nutrient sink and were responsible for releasing nutrients from organic matter for use by plants (Paul *et al.,* 2011).

Microbial biomass nitrogen

Similar to MBC the Microbial biomass nitrogen (MBN) showed a decreasing trend with soil depth in soils of HAFFZ of Jorhat district under tea, bamboo and rice cultivation (Table 3). In respect of MBN content the soils, they could be arranged in the order of the highest to lowest as: bamboo (74.43 µg $g^{-1)}$ > rice (64.24 µg $g^{-1)}$ > tea (57.54 µg $g^{-1)}$. The MBN was found to be significantly correlated with CEC (0.890**), Av. P (0.687*), TN (0.847**) and MBC (0.722*) in tea soils (Table 8). In bamboo soil MBN was found to have significant correlation with CEC (0.880**), Av. P (0.697*), TN (0.871**) and MBC (0.667*) of soil and in rice soil MBN was significantly correlated with OC (0.807**), CEC (0.895**), Av. P (0.806**), Av. K (0.877**), TN (0.842**) and MBC (0.933**) of the soils.

In all the LUT, MBN was found to have positive correlation with TN of the soils. This relationship of MBN with TN might lead to the conclusion that that microbial biomass N contributed to the primary N source of potentially mineralisable N in soil (Bohn *et al*., 2010).

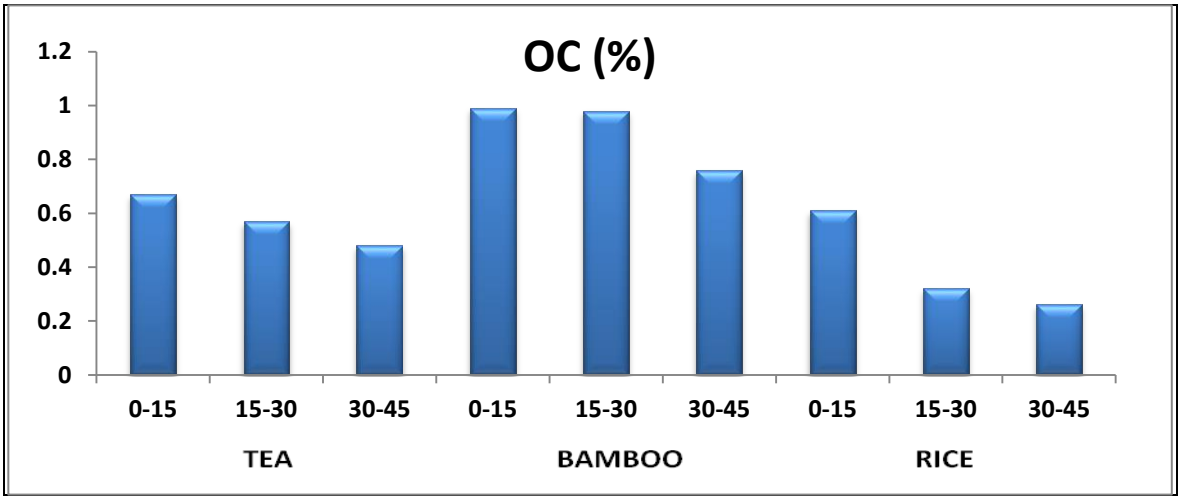


Fig. 1. Effect of land use type on organic carbon at different depths

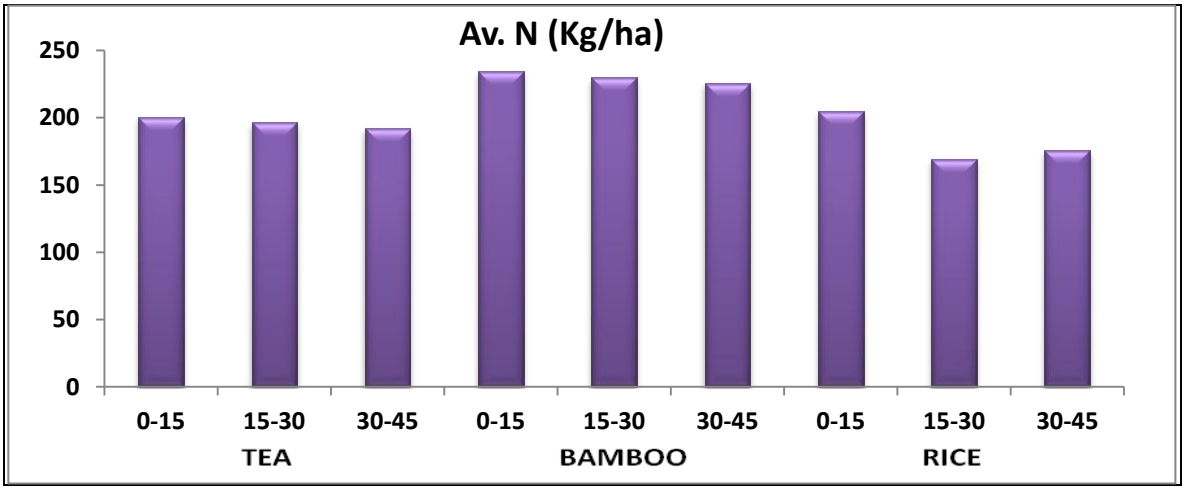


Fig. 2. Effect of land use type on available nitrogen at different depths

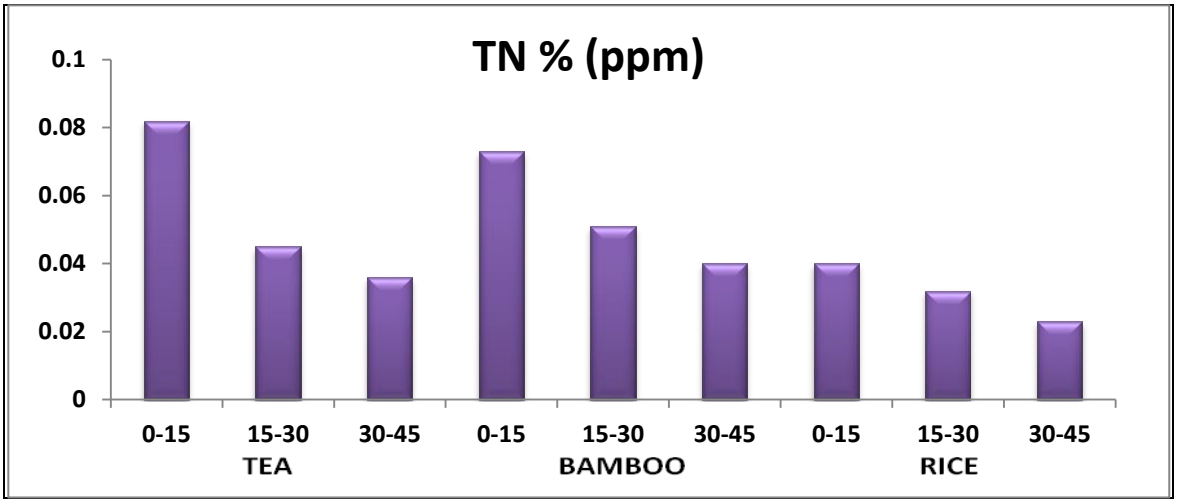


Fig. 3. Effect of land use type on total nitrogen at different depths

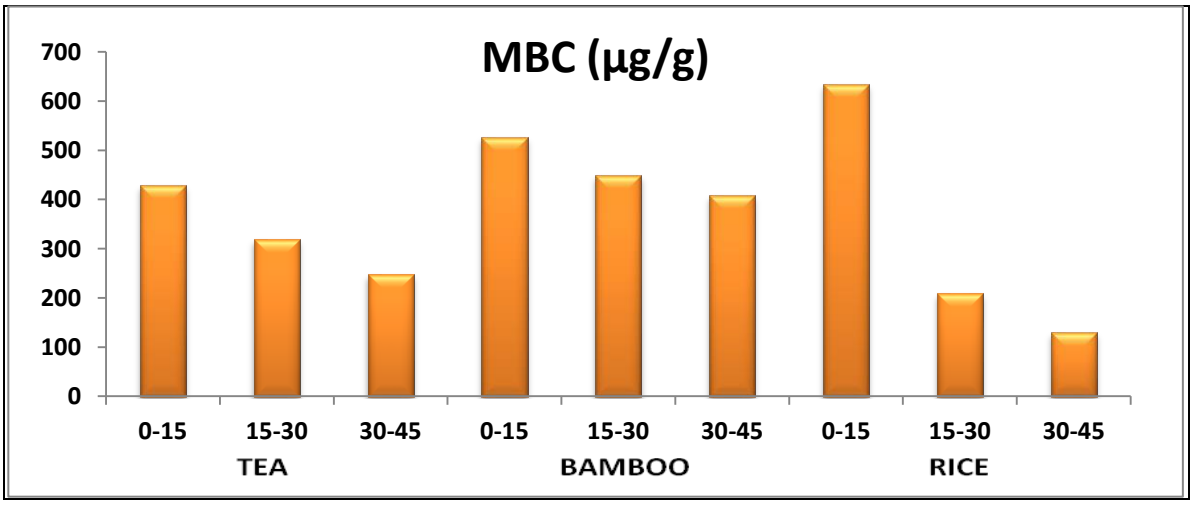


Fig. 4. Effect of land use type on microbial biomass carbon at different depths

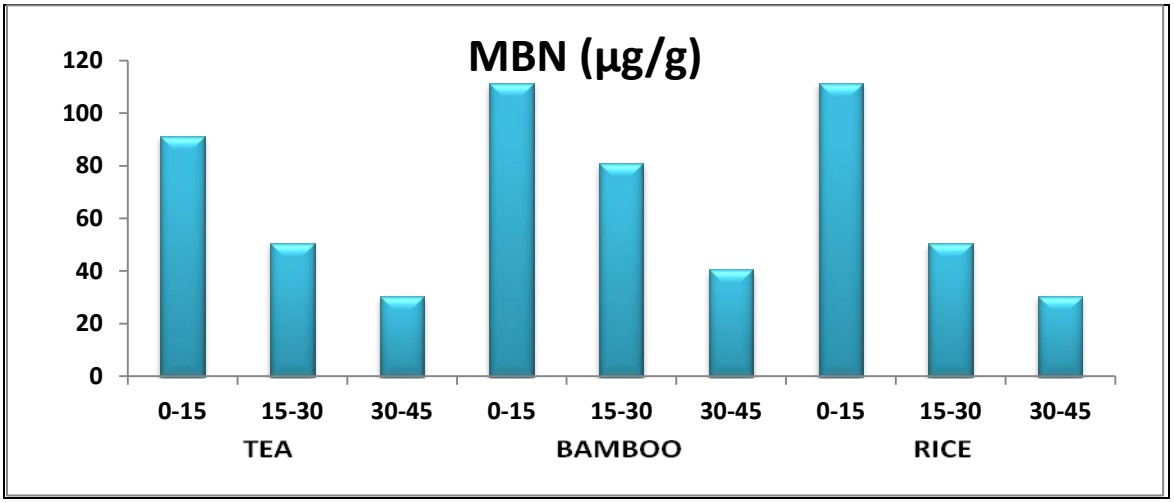


Fig. 5. Effect of land use type on microbial biomass nitrogen at different depths

Conclusion

The findings of the present investigation lead to the conclusion that in Humid Alluvial Flood Free zone of Jorhat district, the three land use type viz. tea, bamboo and paddy had significant effect on C, N and MBC and MBN status of the soils. The change in C and N status as well as MBC and MBN lead to change in soil physical and chemical properties which is supported by the existence of significant correlation of OC, N, MBC and MBN with important soil physico-chemical characteristic.

Among the LUT investigated the bamboo ecosystem could be considered as the most dynamic and sustainable in terms of soil OC, N, MBC, MBN status and the forms different hydrolysable N. All these indicators are found to be the highest in bamboo plantation, intermediate in tea plantation and the lowest in rice cultivation.

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WATERBORNE *E. COLI* O157:H7 INACTIVATION UNDER SEDIMENT AND NO-SEDIMENT ENVIRONMENT AT LOW AND HIGH MESOPHILIC TEMPERATURE CONDITIONS

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Abstract

Pathogen contamination in stream/river water is a serious concern, which can pose risks to public and animal health. To understand how the sediment potentially can affect pathogen inactivation and survival in stream water samples, we executed a series of inactivation experiments using E. coli O157:H7 strain. The experiments were conducted at 30 °C (lower mesophilic temperature) and 40 °C (upper mesophilic temperature). The stream water and sediment were collected from multiple locations of Yosemite River Watershed, California, USA. The inactivation experiments at lower mesophilic temperature and at high mesophilic temperature lasted for 7 days. The two types of microcosm studies were conducted: 1)water-only microcosm (WM); and 2) water-sediment microcosm (WSM). The WM was filled with stream water, and WSM was filled with water and sediment. Both microcosms were inoculated with with E. coli O157:H7 strain. The initial concentrations of the E. coli in stream water with and without sediment at 30 °C were 4.58 × 10^{10} CFU/mL and 2.50 × 10^{9} CFU/mL, respectively. At 40 °C, these values were 8.00× 10^{7} and 7.00× 10^{7}, respectively. The preliminary data of this study showed that in both low mesophilic and high mesophilic temperatures, pathogen concentrations were reduced by3.8 -7.7 orders of magnitude within 7 days of inactivation experiment. The data presented here will be useful for understanding the effects of thermal treatment methods for pathogen inactivation in stream water.

Keywords: *stream water, sediment, pathogens, public health, inactivation, E. coli*

Nomenclature

WM: water-only microcosm
WSM: water-sediment microcosm

Introduction

Of the total 748,072 km of assessed streams in the United States, 53% are classified as impaired. Elevated pathogen contamination is regarded as one of the leading cause of these impairments (USEPA, 2012a,b). These elevated pathogen levels influence recreation facilities negatively. One of the major reactional parks in California is Yosemite National Park. This national park is one of the largest habitat regions in the Sierra Nevada, is a natural wonder home to many outstandingly remarkable values, and invites more than 3.8 million people annually. Famous for its grand waterfalls, the park has approximately 3,200 lakes (more than 100 m^2), two reservoirs, and 1,700 miles (2,700 km) of streams. Although the park covers an area of 748 thousand acres (3,027 km^2), majority of visitors are concentrated in the 18 km^2 area of Yosemite Valley (Nature & Science, 2007). This national park consists of

Merced River Watershed. When assessing stream water quality, one of the major parameters to evaluate public health risks is measuring pathogen indicator such as *E. coli* levels in stream water samples. *Escherichia coli*is a commonly accepted faecal indicator organism because of its similar and representative manner compared with other faecal bacteria when released to the aquatic environment (Gonzalez et al., 1992). One of the major factors which influence pathogen survival and inactivation in water is temperature (Pandey et al., 2015). Other factors which influence pathogen survivals include salinity, nutrient deficiencies, and sunlight (Davies et al., 1995; Özkanca and Flint, 1997; Thomas et al., 1999). In addition to above, suspended particles in the water column may also affect bacteria survival (Brettarand Höfle, 1992). Previous studies have shown that under both natural and laboratory conditions, more bacteria are attached to suspended sedimentparticles than floating in waters (Crump and Baross, 1996; Fish and Pettibone, 1995). Because of tendency of bacteria to attach with particles, there is a potential to increase in pathogen levels due to the resuspension of contaminated sediments in streambed. The disturbance ofstream bed by external activities (such as recreational activities) is likely to enhance the suspended bacteria in the water column. A previous study showed that under room temperature (18-20 °C) and static conditions, both *E.coli* and *Salmonella* levels in sediment-containing microcosms were increased for the first 10 days (Fish and Pettibone, 1995). Subsequently, it remained stable for 56 days. Another study reported that *E. coli* persisted in coastal sediment for over 28 days at 10 °C. The survival time was reduced in higher temperature (20°C and 30°C) in both water and sediment. Results also suggested that the reduction of *E. coli*in sediment was slower than that in the water (Craig et al., 2003). Our literature review showed that no study was conducted yet to evaluate the survival of *E. coli O157:H7* in stream water microcosm with and without sediment at low mesophilic (30 °C) and high mesophilic conditions (40 °C).The goal of this study was to understand *E. coli O157:H7*inactivation in stream water. The specific objectives are: 1) assess the inactivation of *E. coli O157:H7*under with and without sediment environment at 30 °C; and 2) determine the inactivation of *E. coli O157:H7* under with and without sediment environment at 40 °C.

Method and Experiment Design

The streambed sediment and water column samples were collectedfrom 10 randomly selected sampling locations in four sub-watersheds of Merced River. These sub-watersheds include (from downstream to upstream): Ingalsbe Slough-Merced River, Maxwell Creek-Merced River, Bear Creek-Merced River, and Yosemite Creek-Merced River Watersheds. To inoculate the feedstock, 20 uL freezer stockof *E. coli* O157:H7 was grown in DifcoLB (Luria-Bertani) Broth Miller growth media for 24 hours at 37 °C under shaking conditions (200 rpm) (ThermoFisher Sci.,MaxQ 4000). The culture was pelletized using a centrifuge (ThermoFisher Sci., Sorvall Legend X1R)at 5000 rpm for 20 min, and the pellet was suspended in 40 mL PBS buffer. To makewater-only microcosm (WM), 40 mL in-stream water from each of the 10 water samples and 10 mL suspended cellswere mixed and added. The total volume of WM was 410 mL.The water-sediment microcosm (WSM) consisted of100 mL from each10 water samples, 20 g sediment from each 10 sediment samples, and 20 mL suspended cells. Thus, the total content of water/sediment microcosm was 1000 mL stream water, 200 g of sediment and 20 mL of*E.coli*growth.During the inactivation process, air was pumped (Whisper® 10 Air Pump) into the water column in both microcosms to maintain oxygen level.

During sample collection, 5 mL of liquid samples from both microcosms (i.e., WM and WSM) were collected for *E. coli* enumeration. MacConckey II agar with sorbitol (BBL, Becton, Dickinson and Company, Sparks, MD, USA), a selective and differential media for the detection of sorbitol-nonfermenting*E. coli*, was used for *E. coli* enumeration. Thepink colonies on the plateswere enumerated as *E. coli O157:H7* colonies. To enumerate *E. coli O157:H7*concentrations, the samples were serially diluted in PBS, and several levels of

diluted samples were platted in agar plates. Each sample was analyzed induplicate. After platting, MacConckey agar plates were incubated at 37 °C for 24 hours following Bacteriological Analytical Manual (BAM) procedure (USFDA, 2014). The growth of the respective pathogens was enumerated using a colony counter. Finally, pathogen level in per unit mass (mL) of original was calculated based on colony numbers.

Results and Discussion

Inactivation of *E. coli O157:H7* in WM and WSM at 30 ° C are shown in Figure 1. At initial state, *E. coli O157:H7* concentration in WM was 4.58 $\times 10^{10}$CFU/mL, while concentration in WSM was 2.50×10^{9}CFU/mL.In the first 4000 minutes (~2.8 days), concentrations of *E. coli O157:H7*in both microcosms were pretty stable. In WM, it had a slight decline to 4.50×10^{9}CFU/mL, while in WSM, there was even an increase to 8.15×10^{9} CFU/mL, which was four times of initial concentration (Table 1). Subsequently, the concentrations sharply dropped to ~10^{3} CFU/mL during the next 2760 minutes (~2 days). As shown in Table 1,at the end of 7th day (9960 minutes), there was still a high concentration of *E. coli O157:H7* at 1.45×10^{3}CFU/mL, while in WSM the concentration was relatively lower(5.00×10^{1}CFU/mL). The linear fit in inactivation data resulted in coefficient of determination(R^2) value of 0.87 and 0.79 for WM and WSM, respectively. This indicates that the fitted regression lines were good. The standard deviation within replicates was small as shown in Figure 1. The data points (circles) shown in the figure indicate the average *E. coli* levels estimated from two replicates of each sample.

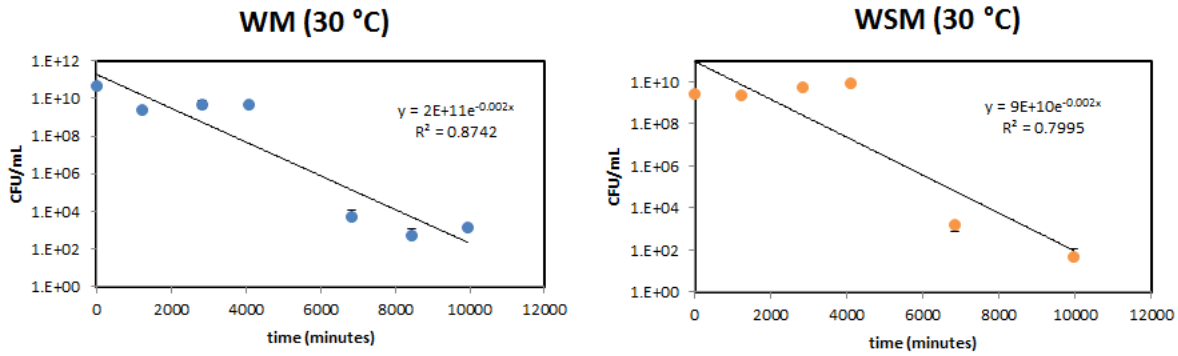


Figure 1: *E. coli O157:H7* inactivation in WM and WSM under 30 °C (circles indicate average *E. coli* levels; and error bars indicate standard deviation within replicates).

As shown in Figure 2 and Table 1, under 40 °C condition, original concentration of *E. coli O157:H7* was 8×10^{7}CFU/mL and 7×10^{7}CFU/mL in WM and WSM, respectively. In the first two days (4780 minutes), concentration of *E. coli O157:H7*levels were reduced consistently in both WM and WSM. At the end of two days, WM had a concentration of 2.95×10^{3}CFU/mL,

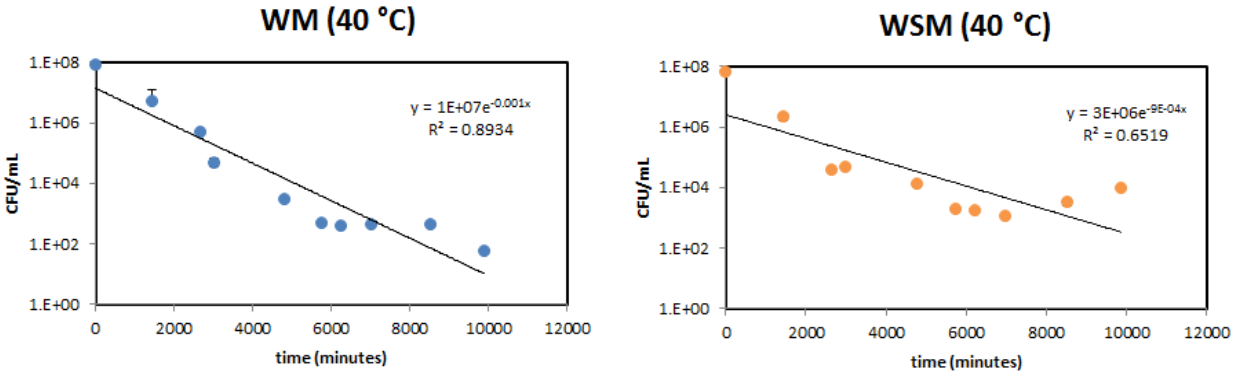


Figure 2: *E. coli O157:H7* inactivation in WM and WSM under 40 °C(circles indicate average *E. coli* levels; and error bars indicate standard deviation within replicates).

And WSM had a concentration of 1.32×10^{4}CFU/mL. Thereafter, concentration had a slight drop to 5.15×10^{2}CFU/mL and 2.05×10^{3}CFU/mL in the next 950 minutes (~0.66 days) in WM and WSM, respectively. In WM, the concentration remained roughly constant for the next two days and dropped to 6×10^{1}CFU/mL at the end of 7th day. While in WSM, after a slight decline to 1.13×10^{3} CFU/mL at the end of 6990 minutes, it raised slowly to 1.01×10^{4}CFU/mL at the end of 7th day.The R^2 equals 0.87 and 0.79 for WM and WSM.

Our study showed that at 30 °C, WM and WSM had comparable inactivation rates. In WM, there was 7.5 orders of magnitude reduction within 7 days of inactivation experiment, and in WSM, the reduction was 7.7orders of magnitude. At 40 °C condition, however, WM had higher inactivation rate than WSM. In WM, there was 6.12 orders of magnitude reduction within 7 days of inactivation experiment, while in WSM the reduction was only 3.84orders of magnitude. There was a regrowth of *E. coli O157:H7*during the last two days of the experiment. The potential reason for longer survival in WSM will be the effect of sediment.

Table 1: *E. coli O157:H7* concentrations in WM and WSM with respect to time under different temperatures (30 °C and 40 °C)

Time (minutes)	Concentrations (CFU/mL)			
	30 °C		40 °C	
	WM	WSM	WM	WSM
0	4.58E+10	2.50E+09	8.00E+07	7.00E+07
4080	4.50E+09	8.15E+09	--	--
4780	--	--	2.95E+03	1.32E+04
9870	--	--	6.00E+01	1.01E+04
9960	1.45E+03	5.00E+01	--	--

Conclusions

In our study, inactivation of *E. coli O157:H7* strain were conducted at 30 °C and 40 ° in water-only microcosm (WM) and water-sediment microcosm (WSM). The results showed that decay rate of *E. coli O157:H7*in 30 °Cand40 ° C was comparable. WSM had a significantly slower decay rate compared with WM under 40 °C. This indicates that the sediment particles prolong the survival of*E. coli*at higher temperature. We anticipate that this study will provide important insights with regards to the inactivation of *E. coli O157:H7*at mesophilic temperature with and without sediment particles.

Acknowledgements

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Improved Composting System for Converting Food Waste into Soil Amendment

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Abstract

Composting is an eco-friendly and sustainable method for converting organic waste into soil amendment. In composting, the thermophilic phase caused by microbial activity can help accelerated the organic material degradation and eradicate pathogens existed in the waste streams. The final product (compost) is pathogen-free and can be applied to cropland safely. The low operational cost also makes it an economically feasible method. In-vessel composting system is a well-controlled method to improve composting efficiency. In this study, a biodigester (200 L) with external heating and mixing was used to conduct experiments on organic waste streams including food waste, horse manure, green waste and palm tree waste. The pure culture of Escherichia coli O157:H7 was inoculated into the feedstock at the beginning of the experiment. The temperature was controlled at about 60^{o}C for rapid pathogen inactivation and accelerated decomposition. The pH was low (about 4) in the process. No E.coli positive samples were obtained after 1200running minutes, indicating high efficiency of pathogen inactivation in in-vessel composting system. Keywords: food waste, in-vessel composting, pathogen inactivation

INTRODUCTION

With the increasing world population, excess food waste generation, which accounts for important portion of municipal solid waste, is a serious concern. While mitigating excessive food waste production is important, the methods which can convert food waste into useful products are required. Currently, disposal in landfills is the common method for management of these waste as 54% of the municipal solid waste were buried in landfills [1]. However, finding a suitable place for landfill is a concern for most modern cities [2]. Besides, some organic and inorganic leachate will be produced from landfill, posing threat to groundwater contamination [3]. Consequently, composting is an alternative to landfill which was advantageous in producing natural fertilizer and soil conditioner for agricultural land [4]. In-vessel composting is a better controlled process compared with windrow and aerated static composting processes. In comparison, the in-vessel composting system requires less space and produces more uniform compost with high maturity. In addition, the shorten period required for in-vessel composting system to obtain mature compost is also the advantage over other processes[5]. However, the pathogen persistence during in-vessel composting is an issue that should be addressed. Failure to eliminate pathogen in food waste composting might lead to the penetration and transmission of pathogenic microorganisms into the crop land when compost was applied as soil amendment. Those pathogens may enter the food chain and cause serious public health issue. The United States Environmental Protection Agency (USEPA) set the regulation for compost prior to field application. The minimum inactivation temperature of 55^{o}C must be achieved for a minimum of 3 days during in-vessel

and aerated static pile composting. The recommended values for faecal coliforms and *Salmonella* spp. in compost is <1000 most probable number (MPN)/g dry solid and <3 MPN/4 g total solid. However, the temperature/ time relationship might not be sufficient enough to guarantee the pathogen free compost if temperature is below 55^{o}C.As an example, Droffner found that *E.coli* survived at least 9 days at 60-70^{o}C while *Salmonella* also survived for 9 days over 60^{o}C [6]. Therefore, the pathogen inactivation pattern should be explored further to have the better understanding in the in-vessel composting process, which prompted this study. The objective of this study is to determine *E.coli* inactivation pattern in in-vessel co-composting of food waste, palm tree waste, horse manure and green waste.

MATERIAL AND METHODS

The study was conducted in the South side of University of California, Davis.A pilot bio-digester (2.5 KW, and 5 RPM) with a capacity of 200 L (Daega Powder Systems LTD, Korea) was used to digest the feedstock. Temperature was controlled by heating jacket. The schematic of the digesteris shown in Figure 1.

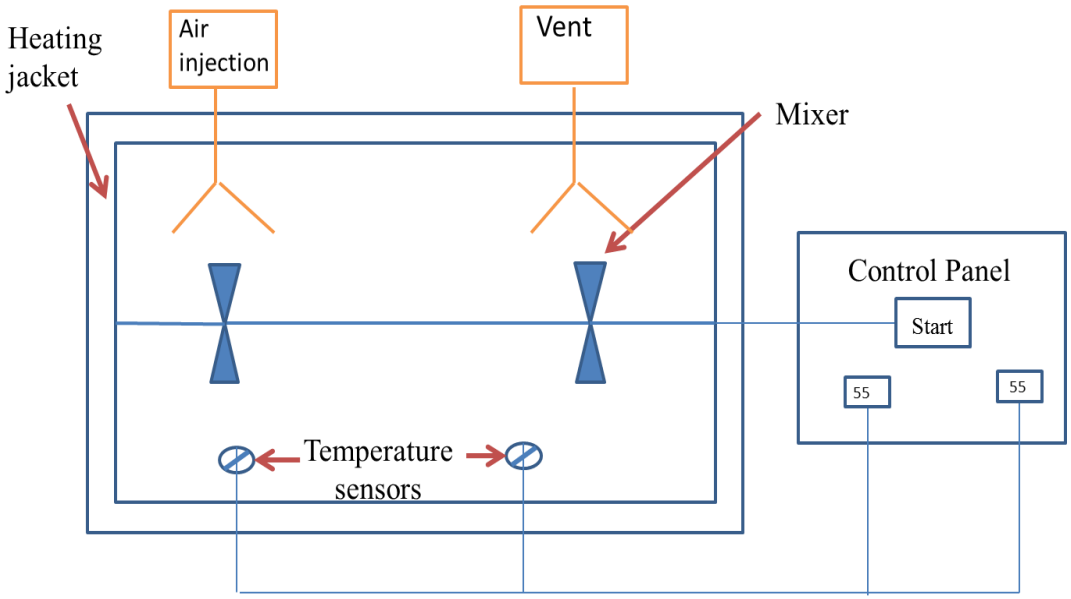


Figure.1 Schematics of composting experiment

A feedstock was prepared from the mixture of food waste (green vegetables and bakery), horse manure, grass, and shredded branches of palm. The ratio of each was 12:4:2:1, respectively. Horse manure was collected from center for equine health, UC Davis. Grass and palm tree wastes were collected from the campus of UC Davis. Food waste (vegetables and bakery) were collected from food bank in Woodland, CA and Scrubs in UC Davis. The digester was used to homogenize the mixture of four types of waste at room temperature for 1 hour to prepare the feedstock. The source of *Escherichia coli* in the feedstock was indigenous (mostly horse manure). To start the digestion/composting process, the temperature of the digester was set to 60 °C.The air pump was set as 5 minutes on and 15 minutes off.

Sampling and testing parameters

Digested samples were collected at 10 minutes interval in the first hour, 20 minutes interval in the second hour, 30 minutes interval in the next two hours, and 1 hour interval for the next three hours during the first day of experiment. Compost samples were collected at 1 hour interval during the second day of experiment while the digester ran for 12 hours and third day for 2.5 hours. The total duration of experiment after inoculating the feedstock was around 22 hours.

Compost samples were analyzed for testing various parameters including moisture content, carbon content, pH, and *E.coli*. The temperature profile of the compost or digested samples were recorded over the sampling time from the sensor installed within the digester. Moisture content and carbon (C) content were measured using American Public Health Association (APHA) standard protocol. To determine the pathogens (*E. coli*) of compost, 5 g of compost sample was dissolved in 45 mL of Phosphate Buffer Solution (PBS) and then blended (Magic bullet, MB1001B) for 3 min to homogenize the slurry. For identification and enumeration of *E. coli* in compost, blended samples were serial diluted and 0.1 mL was streaked on the petri dishes with appropriate agars. MacConckey II agar with sorbitol (BBL, Becton, Sparks, MD, USA) was used for *E. coli* enumeration.

Result and Discussion

The temperature of the digester was set 60^{o}C and the temperature increased from room temperature to the desired temperature in about 30 minutes. Afterwards the temperature within the digester varied between 56-60^{o}C (Fig 2) for the whole period. In comparison, the proposed system achieved high temperature over 55^{o}C in much shorter time while the conventional composting required several days to achieve the elevated temperature. In addition, the time required to achieve elevated temperature as well as the range of the temperature is often uncertain in conventional composting due to many factors such as feedstock, pile size and air concentration in the pile. It is challenging for conventional composting to obtain the pathogen free compost as the thermophilic temperature and lasting period in composting is essential for pathogen inactivation. In comparison, the proposed in-vessel composting system facilitates the consistence temperature.

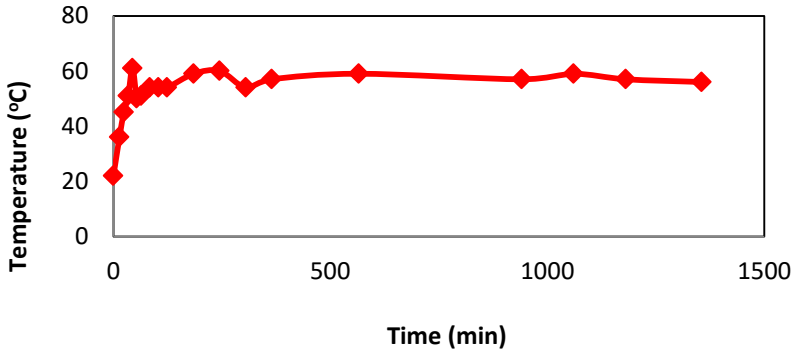


Figure 2. Temperature variation of the feedstock

The variation of moisture level is shown in Fig. 3. As shown in the figure, the moisture content varied between 80% to 50%. Moisture content is one of the most significant parameter in food waste composting which is related to the physical (bulk density, free air space, thermal conductivity) and biological reactions (microbial activity) in the composting process. The most favorable moisture content for organic degradation was reported to be 50%-70% [7]. Therefore, in this study, the moisture level was maintained in the optimal range for biodegradation and microbial activity.

The carbon content is shown in Fig. 4. The carbon content increased from 17% to about 23% while the average carbon content was 17.18%. Theoretically, the carbon in the composting will be consumed by microbes for metabolism and production of carbon dioxide under the aerobic environment. Previous study also reported the decrease of carbon in the composting process [7, 8]. However, the carbon content in this study showed the increasing trend, which requires further study to validate the reason.

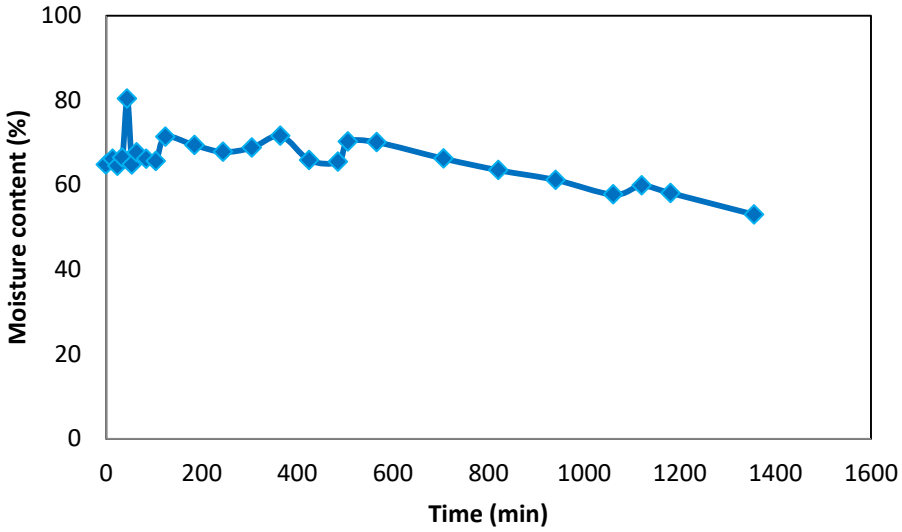


Figure 3. Moisture variation of the feedstock

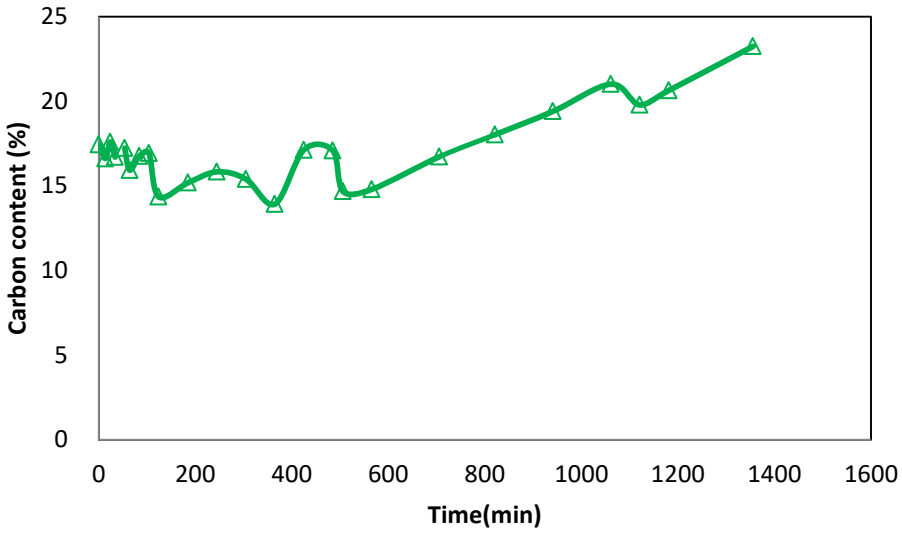


Figure 4. Carbon variation of the feedstock

Variations of *E.coli* counts are shown in Fig. 5. The initial concentration of *E.coli* was about 7 orders of magnitude. It reduced to non-detectable in about 1200 minutes (20 hours).The results obtained in this study indicated that the *E.coli* inactivation in proposed

system could occur in very short period with high efficiency. In previous study, Cekmeculiogle[9] conducted in vessel food waste composting system and monitored the change of facal coliform, *Salmonella* and *E.coli O157:H7* for 12 days. The end concentration was 228.3 MPN/g, 43.5 MPN/g and 43.1MPN/g, respectively. The author came to the conclusion that temperature profile and pathogen concentration should both be checked before application to the cropland [9]. In contrast, the proposed in-vessel composting system is considerably faster than the conventional composting process in *E.coli* inactivation. As a matter of fact,the *E.coli* inactivation in conventional composting process is often uncertain due to the uneven distribution of heat in the pile [2, 9].

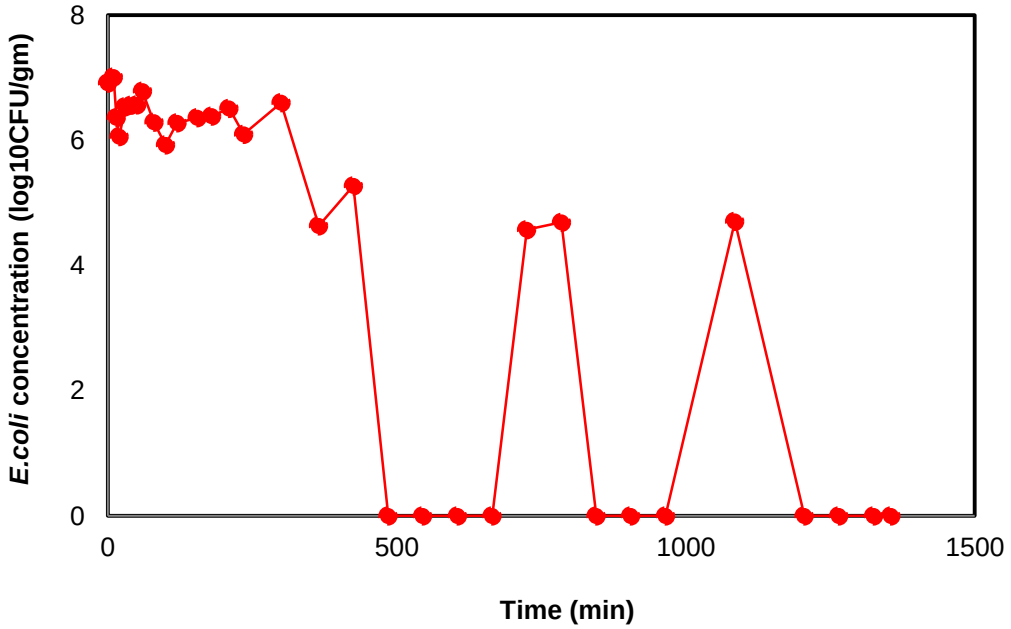


Figure 5.*E.coli*levels in feedstock

The change of pH is shown in Fig. 6. The pH change kept stable over 4 in the whole process. The average pH was 3.9. Low pH around 4 indicated the acidic environment probably due to the existence of fruits like oranges which contains kinds of organic acids [2]. Additionally, the short-chain organic acids were generated from the feedstock which will also contribute to low pH environment[7]. A low pH value might inhibit the microbial activity and hence have negative effect on composting reactions. Adjusting pH value was reported to be an effective method to improve the composting performance. The bulking agents (e.g. fly ash) with buffer capacity can be supplemented to maintain the pH at suitable level and enhance the composting efficiency[10].

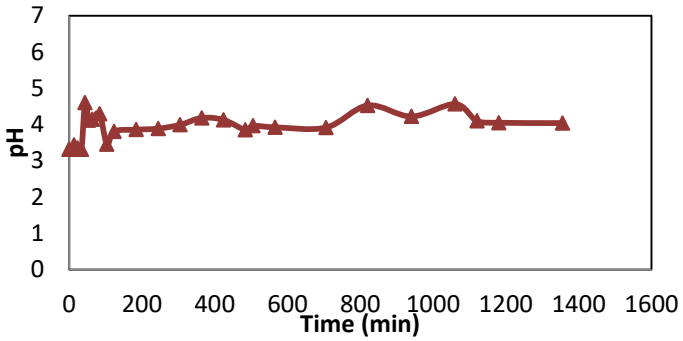


Figure 6.pH change in feedstock

The result obtained in this study showed that the proposed composting system has more efficiency in terms of pathogen inactivation than conventional windrow and in-vessel composting which requires multiple months to get the pathogen free compost. The proposed system can be applied in limited space and used for expediting foodwaste treatment.

Conclusions

To develop the effective food waste composting process for producing pathogen free compost, this study was conducted in bio-digester with external heating at 60^{o}C. The ingredients including food waste, horse manure, palm tree waste and green waste were prepared as the feedstock. The results showed *E.coli*concentrations in the final feedstock were non-detectable. In 1200 minutes,*E.coli*werereduced from 7 orders of magnitude to undetectable level. The proposed method produced the pathogen free compost in about 1200 minutes compared with conventional composting process which requires several months (around 90 days), and pathogen inactivation is often uncertain. Additional studies are needed to develop a full scale system, and verify the system applicability and effectiveness at largescale foodwaste treatment.

Acknowledgment

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EFFECTS OF CO-COMPOSTING OF SEWAGE SLUDGE ON AGRICULTURE

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Abstract

Sanitation is one of the biggest management challenges faced by urban and rural governing bodies. The rapid pace of urbanization and deteriorating fresh water resources has accelerated the search for safe water supply system as well as hygienic sanitation for the public health in developing countries. The use of digested sludge as soil amendments and bio-fertilizers has received wide attention in the current scenario because of its high organic matter and nutrient contents. It is generally believed that intensified agricultural practices had resulted in release of carbon to the environment through the reduction of soil organic carbon. However, this is highly dependent on the apparent changes in the land use, extent of soil tillage as well as predominant cropping pattern. Co-composting of faecal sludge along with organic matter has been suggested as a good combination to provide all necessary nutrient components, thereby closing the nutrient loop in the soil. There exists many methods to prepare unique blend of different co-composting options, but a scientific review of their implications in the environment is highly missing. In this study, we review the critical impacts of co-composting on the direct uptake of nutrients by crops and the subsequent change in soil characteristics. The study also focuses of the effect of pre-treatment for enhanced co-composting, determination of organic fraction required for effective composting, transport and transformation of organic carbon and nitrogen compounds and microbial dynamics and enzyme activities during composting. It is interesting to note that co-composting of sewage sludge with agricultural residues have resulted in maintaining the macro-nutrients in the soil to a great extent. Although co-composting with sludge will alter the soil nutrient distribution to a great extent, selection of suitable cropping system and agricultural practices is believed to be compensating for the anticipated alterations in nutrient dynamics. Based on the above results, we postulate a list of reliable and practical solutions for co-composting in Indian scenario.

Key words: Co-composting, sewage sludge, agriculture, nutrient cycle, soil organic matter

Introduction

The rapid pace of urbanization and deteriorating fresh water resources has accelerated the search for safe water supply system as well as hygienic sanitation for the public health in developing countries. It is reported that 53.1% of the households do not have a toilet, and for the 38% of the urban households in India who use toilet, there is no provision for safe disposal of faecal sludge (WaterAid, 2015). Under the campaign of “My Clean India”, the urban sanitation was allotted focused attention in the national level “Swachh Bharat Mission”, launched on 2nd October 2014, to ensure sanitation facilities and safe and adequate

drinking water to every person by 2019. Even though there are lot of initiatives for creating sanitation facilities in the state, there is little attention going to the proper management of the faecal sludge for the safety of people and environment. Therefore, it is essential to ensure that proper faecal sludge management is implemented by considering its impacts on the current and future ecosystem.It is generally believed that intensified agricultural practices had resulted in release of carbon to the environment through the reduction of soil organic carbon (Warner et al. 2013). However, this is highly dependent on the apparent changes in the land use, extent of soil tillage as well as predominant cropping pattern. The organic carbon and total nitrogen levels in a sugarcane mono-cultured soil has resulted in reduction in organic carbon by 58%, which was recovered in a chrono-sequence of 0.3% per year (Beza and Assen, 2016).Municipal solid waste is known to contain sufficient quantity of plant nutrients such as carbon (19kg/person/annum), nitrogen (0.8kg/person/annum), potassium (0.5kg/person/annum) and phosphorus (0.3kg/person/annum). However, the excessive pathogens and carbonaceous matter in the faecal sludge make is difficult to process along with the overall sewerage in a wastewater treatment plant. The use of digested sludge as soil amendments and bio-fertilizers has received wide attention in the current scenario because of the high organic matter and nutrient contents (Jonsson et al. 2004). Co-composting of faecal sludge along with organic matter has been suggested as a good combination to provide all necessary nutrient components, thereby closing the nutrient loop in the soil (Strauss et al. 2003; Cofie et al. 2009; Cofie et al. 2012). It is also reported that pathogenic inactivation level achieved by co-composting is satisfactory (Omanhene, 2003; Kone et al. 2007).However, in the Indian context, the neglected features of open dumping and land application activities are, in fact, becoming more problematic when the soil contamination is reaching the groundwater table. The rate and extent of leaching of these compounds depends on the sludge type and nature of amendment. Therefore, it is essential to understand the fate and transport of these nutrients and pathogens in the subsurface in order to implement suitable strategy for faecal sludge disposal through co-composting with solid waste.

Characteristic Features of Co-composting

Septage co-composting has been tried for many communities with various aeration conditions, but without much scientific reasoning (Lombardo, 1977; Dalmat et al. 1982; La Trobe and Ross, 1992). The specific advantages of designing a co-composting facility has been perceived as complementing the nutrients into the soil while achieving natural inactivation of pathogens (Strauss et al. 2003; Cofie et al. 2009). Although municipal solid waste is low in nutrients, it can provide huge organic carbon to the soil (Table 1). Based on the conventional proximity analysis, fertilising equivalent of human excreta is identified to provide the essential macro-nutrients to the plant (Drangert, 1998). Typical raw liquid faecal sludge consists of 8.2g/L nitrogen, 1.1 g/L phosphorous, 2.2 g/L potassium and 21.3 g/L of organic carbon (Asare et al. 2003). Therefore, suitable mixing ratio for solid waste and faecal sludge is estimated to be 2:1 in order to facilitate quick nutrient discharge to the soil environment (Cofie et al. 2009). Smith and Tibett (2004) showed that soil nitrogen transformation was directly proportional to the undigested components in the sludge, which was reduced significantly by dewatering. It was also observed that while organic carbon remains as the prime electron donor for the metabolism, there is a chance for pooling of immobilized nitrogen compounds such as nitrate-nitrogen in the soil which can result in leaching.

Table 1: Equivalent fertilization capacity of human excreta (adopted from Drangert, 1998)

Elements	Faecal sludge			Municipal solid waste
	In urine (500L/year)	In faeces (50L/year)	Total	(kg/capita/year)
Carbon (as C)	2.9	8.8	11.7	16-22
Nitrogen (as N)	4.0	0.5	4.5	0.55-1.1
Phosphorous (as P)	0.4	0.2	0.6	0.2-0.4
Potassium (as K)	0.9	0.3	1.2	0.55

3. Impacts and Challenges of Sewage Sludge Co-composting

Even today, the most common practice is to dump the sludge in the low-lying open lands of sub-urban periphery, which is highly vulnerable for transmitting the contaminants to the poor settlements as well as the surrounding water bodies. Birley and Lock (1998) and Allison et al. (1998) have highlighted health impacts and risks of solid and human waste use in urban agriculture. However, the impact of pre-treatment of faecal sludge has considerably inactivated the pathogens level (Matthews, 2000). When high temperature is attained in thermophilic composting (55^0C to 65^0C), thermal inactivation of pathogens becomes quicker (Strauss et al. 2003).

4. Significance on Soil Properties and Crop Yield

Generally, it is believed that addition of organic matter to soil improves its workability by enhancing soil aeration, tilth, porosity and water holding capacity (Bationo et al. 1998; Agassi et al. 2004; Faucette et al. 2004; Zougmoré et al. 2008). Co-composting facilitates direct uptake of carbon and nitrogen thereby enhancing nutrient mineralization during subsequent decomposition due to the increased organic matter and make the land more productive for high yield (Kumar and Goh, 1999; Singh et al. 2012; Clough et al. 2013).

5. Fate and Transport of Nutrients

Various numerical models are available for simulating nitrogen transport and transformation in the unsaturated porous media (Iskandar and Selim 1981; Antonopoulos 1993; Tindall et al., 1995; Lafolie et al., 1997) as well as in the saturated porous media (MacQuarrie and Sudicky 2001; Lee et al., 2006). Several models have been postulated over the last two decades for simulating organic matter dynamics in the soil. In most of the models, the transformation kinetics assumed to follow first order kinetics where the rate coefficient has to be determined empirically (Jenkinson, 1990; Smith et al. 1997; Andriulo and Jérôme, 1999).

The usefulness of any transport model is to understand the phenomena resulting from the interaction between the contaminant and the subsurface features like groundwater flow, type and size of soil grains, presence of natural organic matter etc. Interactions at the molecular level results in binding of the contaminant to the soil surface due to chemical, physical or exchange-based reactions. It may not be clear always whether (a) the processes

that constitute the physical environment have been properly recognized, and (b) the driving forces have been appropriately included in the model (McCarthy and Zachara, 1989; Chu et al. 2007). Therefore, it is important to study the prevailing mechanisms of mass transfer and transport in a typical subsurface system with the idea of developing a comprehensive numerical model for the fate and transport of dissolved nutrients and pathogens in the subsurface.

6. Indian scenario

Septage management has to be considered as a part of sanitation which has great influence on public health and environment. In India, faecal sludge is being directly applied to the farm lands without proper treatment and discharged into lakes and fish ponds or disposed to the low lands. As a result of the repulsive perception on the faecal sludge among the public, most of the low-cost technologies such as Imhoff tanks, batch-operated settling-thickening system, anaerobic digestion, extended aeration as well as co-composting often remain expensive and impractical (Ingallinella et al. 2002). Currently, the State Sanitation Strategy extends to eleven states (Himachal Pradesh, Chhattisgarh, Andhra Pradesh, Kerala, Maharashtra, Karnataka, Uttar Pradesh, Madhya Pradesh, Uttarakhand, Odisha and Bihar) (WaterAid, 2015). As per Census 2011, 17 million urban households (more than 20% of the total 79 million urban households) lack adequate sanitation whereas 18.6% of urban households having no latrine (WaterAid, 2015; Wankhade, 2015). Only 15% of the municipalities have an underground sewage system, while no town panchayath has a sewage treatment plant. It is postulated that carbon present in soil is about two times carbon present in the atmosphere and is about three time carbon stored in plant issues. The impact of agriculture on soil organic matter revealed that size of organic carbon decreased with the intensity of cultivation which is largely dependent on the prevailing crop management practices (Wang and Hsieh, 2002). This is especially true in Indian context where intensified cultivation and mono-culture is promoted largely (Bronson et al. 1998). There are a few studies about co-composting of solid waste with various admixtures and industrial sludge. In India, fresh faecal sludge collected from bucket latrines and frequently emptied latrine vaults were informally co-composted in olden days (Shuval et al. 1981). Most of these composting initiatives were successful and used for producing compost at a regular rate. In a study by Gaind and Gaur (2003), co-composting of wheat straw and 2% rock phosphate (w/w) with fly ash has resulted in reduction in carbon-nitrogen ratio, and high total phosphorous. Results of the pilot study conducted (Gautam et al. 2010) in the low, middle and high income areas of Jabalpur city with a population over 5 lakh showed that windrow composting of the source-separated organic matter of municipal solid waste has resulted in crumbly earthy smelling materials with pH about 8, organic matter as 45%, moisture content as 36% and have acceptable amount of plant nutrients carbon 35%, nitrogen (0.05%), phosphorous (0.002), sodium (4.8%), and potassium (0.35%). An integrated composting–vermin-composting process has been developed for utilization of primary sewage sludge (Hait and Tare, 2011). They found that low temperature with high humidity is favorable environmental condition for vermin-composting.

7. Integrated Sludge Management for Agriculture

Land application of co-compost has proved to have positive impacts on the physical, chemical and biological characteristics of soils and replenishes organic matter and crop nutrients. By properly managing the solid-cum-faecal sludge compost, most of the valuable crop nutrients and organic matter can be reused. It can also contribute towards improving the physical and chemical characteristics of the soil, thereby enhancing the soil ecology by neutralizing pathogens and toxins. The present depletion in soil fertility and nutrient mining in arable soils can be mitigated substantially; thus ensuring benefits in manifold. Although co-

composting of faecal sludge is practiced widely, nutrient recycling can be effective only when the rules of the art in process control are adhered to. There is an urgency to define proper mixing ratio under the varying conditions of bulk density of organic matter, consistency of faecal sludge, proficiency of dewatering system and the practice of composting method. Apart from this, the interaction of leaching nutrients and pathogens with the subsurface hydrogeology is of utmost importance considering the extent of the problem. In order to elucidate the environmental impacts and thereby planning remedial measures, we need to understand the fate and transport of these target compounds in the subsurface.

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RESPONSE OF URBAN LAKES DUE TO INFORMAL URBAN SETTLEMENTS: A CASE STUDY IN RAIPUR CITY

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Abstract

It is evident that land and water, an important life supporting systems are under intense pressure due to human induced accelerating factors. Rapidly increasing population, over exploitation of resources, environmentally unsound infrastructural development and inadequate management practices are disturbing, damaging and degrading the natural resources especially the water regime.The area under study is Raipur city which is a capital city in Chhattisgarh state, faces the problem of urban growth on surface water quality issues. Once, Raipur was blessed with 154 lakes, which had either been built by nature or by human intervention. Over the years of imagery analysis, reduction in surface water body dominated by urban development has been identified. Presently only 85 lakes survived. Out of which 34 prominent lakes were chosen for water quality assessments. Two water quality indices are computed CCMEWQI (Canadian Council of Ministers of the Environment) and NSFWQI (National Sanitation Foundation) for the standards of the parameters provided by the Central pollution control board, Ministry of Environment and Forests (Government of India). These investigations signify that there is no surface water body in the city whose water can directly use for drinking purpose. Results indicate that surface water bodies are free from nitrate contamination but there is an alarming condition for organic load. From the total 34 locations, 24 were failed to be on the safe limit. Due to increased urbanization that attracts population enhance pollution load. Large amount of organic content is the reason for obsoleting surface water body by the time.

Keywords*:* CCMEWQI, NSFWQI, land use change, urbanization, water quality index.

Introduction

The interaction of urbanization and surface water quality is considerably controlled by the city's land use structure as different types of land use labor various sources of contaminants and hazards which influence both water quality and quantity(Baier *et al.*, 2014; Baier *et al.*, 2015). Urbanization refers to a process in which an increasing proportion of an entire population lives in cities and the suburbs of cities and change of land use from agriculture to human settlements, commercial sectors and industries(Putra and Baier, 2008). The growing human population and development activities, increased human access to environmental resources and the exploitation of renewable or non-renewable resources of land and has led to changes in water quality (Ghorbani *et al.*, 2014). The issue of surface water contamination of wastewater disposal is an intense problem in cities of developing countries where, generally, dense populated and unsewered areas created by high rates of

migration into cities. These areas are unplanned and located in the outskirts of the cities forming shanty towns (typically between 30 and 60 percent of the overall urban population) where pit latrines or septic tanks are common. In some cities, septic tanks and pit latrines are the only way to dispose of sewage (Putra and Baier, 2008). The consumption of these different contaminants through biodegradation or toxicity resistance to these pollutants by the microbial communities can provide information about pollutant exposure, metabolic diversity and the potential source of contamination and the potential for the ecosystem natural attenuation, thus may be a practical indicator of the water quality (Karbassi *et al.*, 2011). Water quality index was first introduced in 1848 about 168 years ago in Germany where the presence or absence of certain organism in water was used as fitness indicator of a water source. The use of numerical scale to represent gradation in water quality levels is a recent phenomenon, beginning with Horton index in 1965 (Mustapha and Aris, 2011). The concept also aims at eliminating the subjective assessment of water quality and the individual biases of water resource managers (Sarkar and Abbasi, 2006).Water quality is the function of anything and everything the water might have picked up during its journey to the water body in dissolved, colloidal and suspended form. Water quality may be assessed in terms of: Quality for life (e.g., the quality of water needed for human consumption), Quality for food (e.g., the quality of water needed to sustain agricultural activities), Quality for nature (e.g., the quality of water needed to support a thriving and diverse fauna and flora in a region) and the selection of parameters used to assess the quality of water depends largely on the intended use of the body of water(Poonam *et al.*, 2013; Nikoo *et al.*, 2011).

Materials and Methods

Description of Study Area

The area under this study is focused on Raipur city in India. This city is located between 21°12'N to 21°18'N latitude and 81°33' to 81°41'E longitude. The whole of Raipur city is part of the open Chhattisgarh plain, which is thickly populated and closely cultivated. The climate of the study area is sub-tropical with three distinct seasons. Temperatures remain moderate for most of the year. May is the hottest month and December is the coldest. Area has hydrogeological formations comprising mainly of either limestone or sandstone/shale layer in different parts. The city experiences the average annual rainfall of 1200 mm. The Kharun River flows to the west of the city of Raipur, which is also a source of domestic water supply to the city(RMC, 2010; Sinha *et al.*, 2016). The city has a population of 11,46,383 and experienced a growth rate of 51.06% during decade 2001-2011.Present study is focused on the lakes existing in the municipal boundaries of Raipur City, Chhattisgarh, India.

The sanitation ratings conducted as per national urban sanitation policy, Raipur ranked 274 out of 423 cities with a score of 30.8/100 and falls in the red category. Raipur was blessed with 154 Talabs, which had either been built by nature or by human intervention, has presently only 85 Talabs survived. These 85 surface water bodies of varying sizes (2800 - 402000 sq.m) occupying a total surface area of 2.83 sq.km, which is about 2% of the city's area. 34 prominent Talabs were chosen for water quality assessments in this study(GIZ *et al.*, 2010; GIZ *et al.*, 2011; RMC, 2011).

Selection of Water Quality Parameters

Water quality parameters were selected to identify the most affected parameter due to pollution load on the water body. These parameters were selected on the basis of their:

- How strong is the influence of urban area on the parameter?
- Do the data values show anomalies as compared to expected values in ponds?

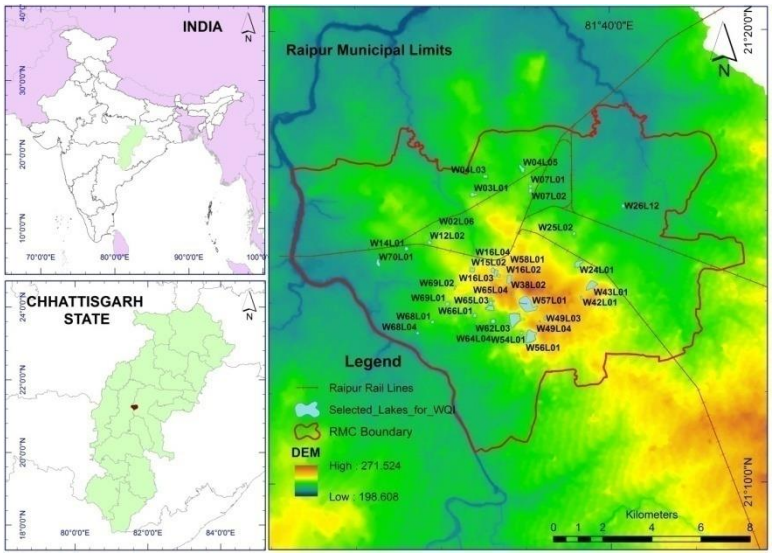


Figure 1.Location map of the study area

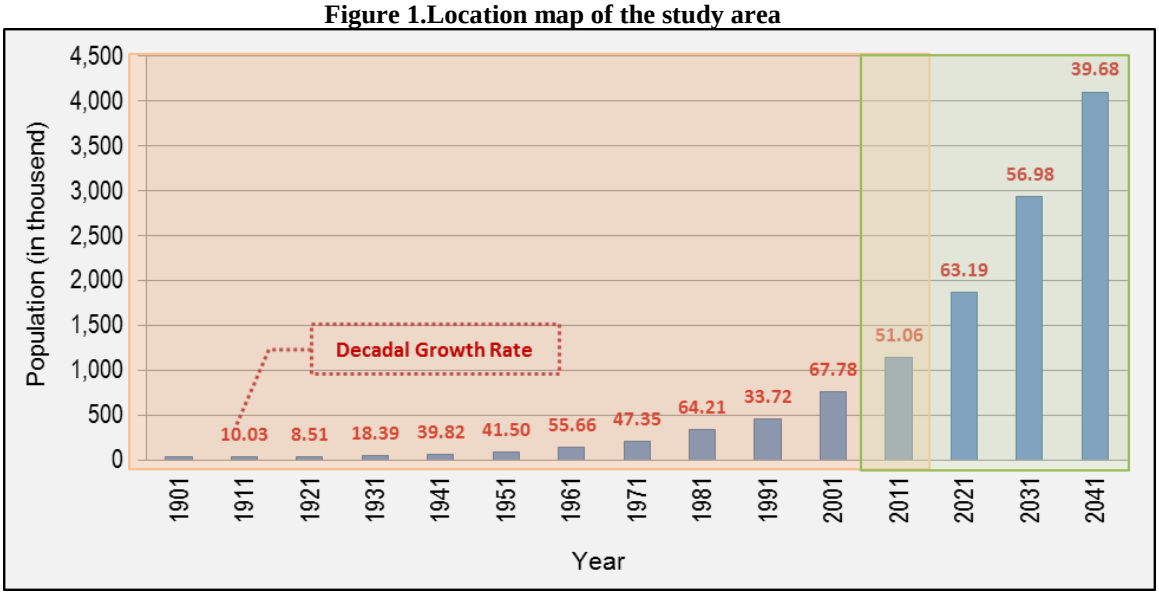


Figure 2. Population growth of Raipur city, modified after(Census-of-India, 2011; RMC, 2010)

-Pollution intimation property for the different types of uses of water body. General information, environmental effects and the different point and non-point sources for the selected water quality parameters are evaluated in present work.

DO: This constituent is measured to assess the health of the surface water body. Decreased DO level is indication of too many bacteria and an excess amount of BOD which use up DO. This reduction may be due to fertilizer runoff from farm fields and lawns.

BOD: BOD is defined as the amount of oxygen required by bacteria to decompose organic matter for 5 days under aerobic conditions. Domestic pet excreta, dumping untreated sewage sludge or discharging treated water, organic laden effluent from paper and pulp industry contribute.
EC: EC estimates the amount of total dissolved ions in the water. EC is controlled by the chemistry of the watershed soil and ultimately the lake, wastewater from septic systems, drain field on-site wastewater treatment, disposal systems and urbanrunoff from roads.
pH: The pH of water determines the solubility and biological availability of chemical constituents such as nutrients and heavy metals. Pollution can change water's pH, which in turn can harm animals and plants living in the water.
SAR: Salinity and SAR, must be considered together for evaluation of the ultimate effect on water infiltration rate. Other related problems such as soil crusting, poor seedling emergence, lack of aeration, plant and root diseases, weed and mosquito control problems caused by the low rate of infiltration may further complicate crop management.

Total Coliforms: All members of the total coliform group can occur in human feces, but some can also be present in animal manure, soil and submerged wood and in other places outside the human body. Their presence indicates contamination of a water supply by an outside source.
Temperature: If the overall water body temperature of a system is altered, an aquatic community shift can be expected. Water temperature is affected by air temperature, stormwater runoff, groundwater inflows, turbidity, and exposure to sunlight.
Phosphate: This may cause a change in the types of plants which live in an ecosystem. Sources of phosphate include animal wastes, sewage, detergent, fertilizer, disturbed land, and road salts used in the winter.
Turbidity: The series of turbidity-induced changes that can occur in a water body may change the composition of an aquatic community. Excess turbidity leads to fewer photosynthetic organisms available to serve as food sources for many invertebrates. As a result, overall invertebrate numbers may also decline, which may then lead to a fish population decline.

Sample collection and analysis method

Surface water samples were collected in the second week of every three months gap from July 2014 to April 2015 at three different sites fromeach lake like inlet, middle point and outlet. The water samples were analyzed to study the physic- chemical parameters by following the standard methods of APHA (2005). The physical parameters were examined at the spot, and chemical parameters like dissolved oxygen were also carried out near the spot. Other chemical parameters like Biochemical oxygen demand, Nitrate, Phosphate, Total hardness were analyzed at the laboratory. The pH and Dissolved Oxygen of water samples were measured immediately after sampling at the field itself. Samples were subjected to filtration before chemical analysis. The determination of TDS was done by gravimetric process while the total hardness was carried out by EDTA complex metric titration method APHA (2005). The Winkler's alkali iodide-azide method was followed for the estimation of DO and BOD. Nitrate was determined colorimetric procedure APHA (2005). Fecal coliform population was analyzed by MPN /100 ml method by growing on M-FC medium at temperature 44.5 °C and counted after 48 hr.

National Sanitation Foundation Water Quality Index

Brown *et al.* (1970) developed a water quality index paying great rigor in selecting parameters, developing a common scale, and assigning weights for which elaborate Delphic exercises were performed. This effort was supported by the National Sanitation Foundation (NSF) and that is why also referred as NSFWQI (Bharti and Katyal, 2011). The result of nine

parameters tests used to calculate the index value of a water body to define its health. The field data is transformed into Q-value which is nothing but the rating curve or sub-indices. Sub-indices transform to non-dimensional scale values from the variables of its different units. And weighting factor sets the relative importance of a particular parameter to overall water quality.

Table 1. Standard weight system of NSFWQI parameters

S.No.	Parameters	Weighting factors
1	DO	0.17
2	Fecal coliform	0.16
3	pH	0.11
4	BOD	0.11
5	Nitrate	0.1
6	Phosphate	0.1
7	Temperature	0.1
8	Turbidity	0.08
9	Total dissolved solids	0.07

The standard formula to calculate water quality index is:

$$WQI = W_{BOD}Q_{BOD} + W_{DO}Q_{DO} + W_{PH}Q_{PH} + W_{PHOSPHATE}Q_{PHOSPHATE} + W_{NITRATE}Q_{NITRATE} + W_{FC}Q_{FC} + W_{TDS}Q_{TDS} + W_{TEMP}.Q_{TEMP}. + W_{TURBIDITY}Q_{TURBIDITY}$$

where,
W_X = weight factors of the water quality parameters
Q_X = Q- value of the water quality parameters
X = water quality parameters
Based upon the weight factor and Q-values the water quality rankings for a specific pond by National Sanitation Foundation Water Quality Index are:

Table 2.Ranking system for NSFWQI

Index ranges	Water quality designation
0-25	Very bad
26-50	Bad
51-70	Medium
71-90	Good
91-100	Excellent

Canadian Council of Ministers of the Environment Water quality Index

A water quality index has developed by the Canadian Council of Ministers of the Environment (CCME). Water quality parameters (e.g., DO, BOD, pH, Total Coli, EC) are compared to water quality guidelines or site-specific objectives. The index is based on three attributes of water quality that relate to water quality objectives:
Scope- How many? The number of water quality variables that do not meet objectives in at least one sample during the time period under consideration, relative to the total number of variables measured.*Frequency*- How often? The number of individual measurements that do

not meet objectives, relative to the total number of measurements made in all samples for the time period of interest.

Amplitude- How much? The amount by which measurements which do not meet the objectives depart from those objectives.

$$CCMEWQI = 100 - [(F_1^2 + F_2^2 + F_3^2)/1.732]^{1/2}$$

where,

F_1 represents Scope: The percentage of variables above the guideline

F_1= [No. of variables whose objectives are not met /Total no of variables]*100;

F_2 represents Frequency: The frequency by which the objectives are not met

F_2= [No of tests whose objectives are not met /Total no of tests]*100;

F_3 represents Amplitude: The range to which the failed tests are above the guideline

(a) Range/Excursion = [Failed test value/Objective]-1

(b) nse = $\sum_{i=1}^{n} Excursion$/No of tests

(c) F3= [nse/0.01nse+0.01]

The constant, 1.732, is a scaling factor (square root of three) to ensure the index varies between 0 and 100. The result is further simplified by assigning it to a descriptive category.

Table 3.Categorical Description of CWQI

Category	CWQI value	Description
Excellent	95-100	Water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels. These index values can only be obtained if all measurements are within objectives virtually all of the time.
Good	80-94	Water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels.
Fair	65-79	Water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels.
Marginal	45-64	Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.
Poor	0-44	Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.

Results & Discussion

The pollution load on the surface water bodies has been analyzedby calculatingtwo above stated water quality indices. To protect the surface water body by degradation and maintain its respective uses water quality index calculated for the standards of the parameters provided by the Central pollution control board, Ministry of Environment and Forests (Govt. of India). There are manywater quality parameters that indicate the pollution by their aberrant concentration. According to the computation of NSFWQI the table 5 reveals the present condition of the water body in Raipur city. By observing the data it is found that according to BIS (ISO: 10500) desirable limits of drinking water for the parameters chosen in NSFWQI computation deviate from its standard. In any of the 34 locations turbidity and fecal coliform does not meet the drinking water quality standard. Also there are some locations at which pH, DO, BOD, Total phosphate and TDS violates the objective. It is revealed that only the Nitrate

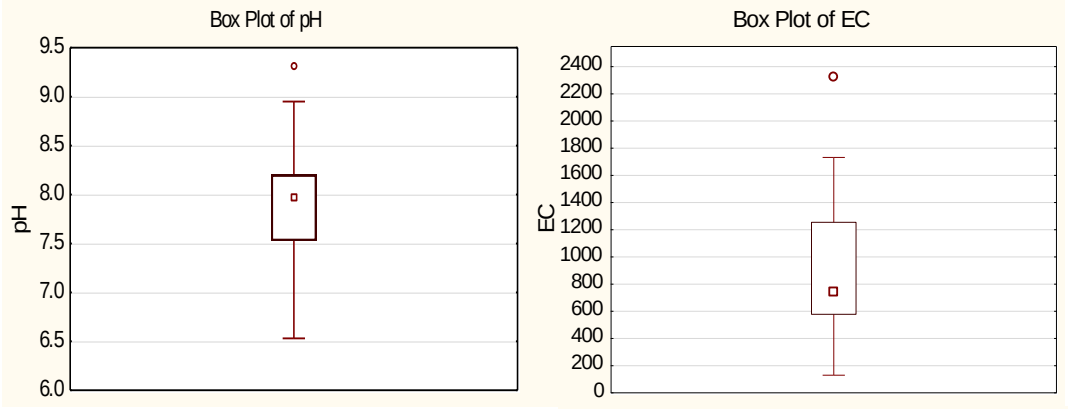
Nitrogen is in under desirable limit of 45 mg/l. The collective effect of these parameters by the NSFWQI computation represents that 5 water bodies (W12L02, W14L01, W62L03, W65L03, W65L04, W68L01) are in BAD condition and only 1 water body (W16L04) is in GOOD condition. The remaining 28 water bodies are in MEDIUM condition. Hence there is no surface water body in the Raipur city whose water can directly use for the drinking purpose.

Table 4. NSFWQI Categorization of Water body

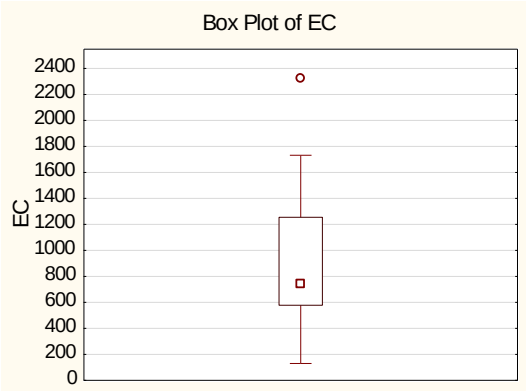
No.	LAKE_ID	LAKE_NAME	NSFWQI	Category
1	W02L06	GaonDabariTalab	69.40	MEDIUM
2	W03L01	GogaonTalab	62.34	MEDIUM
3	W04L03	GondwaraTalab	50.29	MEDIUM
4	W04L05	Bandhwa Talab-1	56.20	MEDIUM
5	W07L01	PankhatiaTalab (SHITALA TALAB)	68.19	MEDIUM
6	W07L02	KhamtaraiTalab	68.42	MEDIUM
7	W12L02	MahantTalab	47.99	BAD
8	W14L01	DumarTalab	42.88	BAD
9	W15L02	Karbala Pond	52.33	MEDIUM
10	W16L02	DhobinTalab	55.39	MEDIUM
11	W16L03	Amma Pond	61.39	MEDIUM
12	W16L04	GhorahiTalab	71.27	GOOD
13	W24L01	Raja Talab	65.90	MEDIUM
14	W25L02	PandariTahariTalab	51.12	MEDIUM
15	W26L12	MadhiyaTalab	64.01	MEDIUM
16	W38L02	HandiTalab (Old)	57.55	MEDIUM
17	W42L01	KatoraTalab	54.34	MEDIUM
18	W43L01	Telibandha	63.55	MEDIUM
19	W49L03	Naraiya Talab-2	53.10	MEDIUM
20	W49L04	ChhiuyaTalab	53.73	MEDIUM
21	W54L01	Sarjubandha	57.23	MEDIUM
22	W56L01	ChironjiTalab	53.45	MEDIUM
23	W57L01	BudhaTalab	53.06	MEDIUM
24	W58L01	KankaliTalab	55.90	MEDIUM
25	W62L03	Maharaja ban Talab	49.87	BAD
26	W64L04	MalshayTalab	50.64	MEDIUM
27	W65L03	KhokhoTalab	41.08	BAD
28	W65L04	BandhwaTalab	49.53	BAD
29	W66L01	PahariTalab	54.58	MEDIUM
30	W68L01	Sitala Mata MandirTalab	48.06	BAD
31	W68L04	Pankhatia	61.23	MEDIUM
32	W69L01	RohinpuramTalab	63.79	MEDIUM
33	W69L02	DanganiyaTalab	61.23	MEDIUM
34	W70L01	SaronaTalab	56.23	MEDIUM

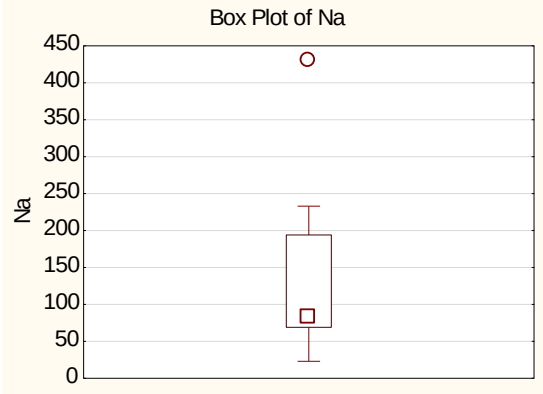
Table 5. Correlation matrix of all water quality parameters

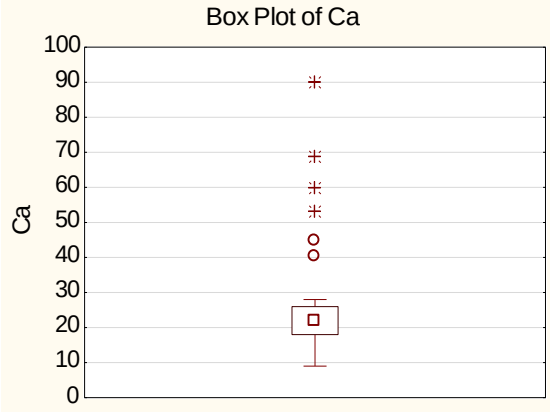
	pH	EC	TDS	Turb	Na	Ca	Mg	NO3	T.Ph.	DO	BOD	Tcoli	Fcoli	SAR	ΔT	NSFWQI
pH	1.00															
EC	-0.40	1.00														
TDS	-0.24	0.87	1.00													
Turb	0.06	0.15	0.15	1.00												
Na	-0.22	0.89	0.82	0.20	1.00											
Ca	-0.33	0.16	0.27	-0.03	-0.12	1.00										
Mg	-0.02	0.03	0.29	-0.35	0.02	0.47	1.00									
NO3	0.24	-0.28	-0.17	0.02	-0.30	0.18	0.15	1.00								
T.Ph.	-0.52	0.39	0.34	0.07	0.17	0.55	0.15	0.30	1.00							
DO	0.16	0.06	0.08	0.04	0.12	-0.24	-0.01	0.09	0.09	1.00						
BOD	0.41	-0.13	0.16	-0.04	-0.05	0.41	0.52	0.25	0.06	-0.15	1.00					
Tcoli	-0.01	0.14	0.12	0.31	0.22	-0.19	-0.05	0.04	0.12	0.13	-0.09	1.00				
Fcoli	0.02	0.15	0.12	0.31	0.21	-0.22	-0.11	-0.09	0.05	0.14	-0.10	0.94	1.00			
SAR	-0.09	0.81	0.74	0.22	0.97	-0.30	-0.09	-0.28	0.06	0.14	-0.06	0.24	0.24	1.00		
ΔT	0.27	-0.12	-0.16	0.10	-0.18	-0.04	0.14	0.05	-0.04	-0.04	0.11	0.25	0.17	-0.16	1.00	
NSFWQI	-0.08	-0.09	-0.18	-0.40	-0.10	-0.25	-0.11	-0.35	-0.28	0.56	-0.51	-0.30	-0.23	-0.09	-0.23	1.00

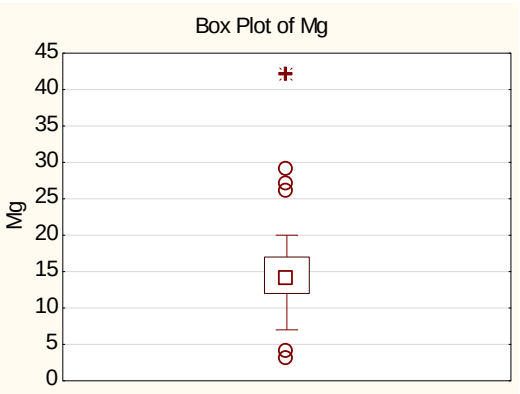

Box Plot of pH
pH
9.5
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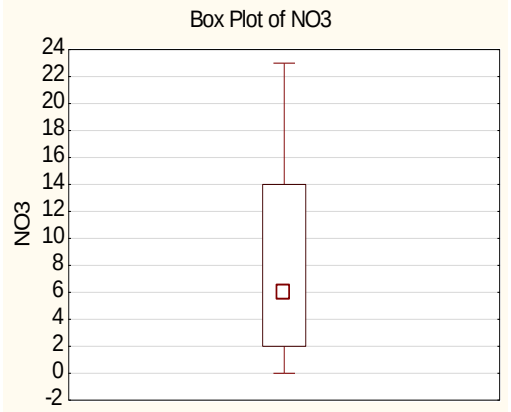
Box Plot of EC
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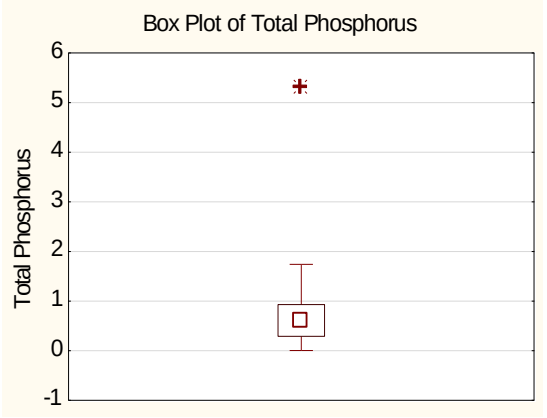

Box Plot of EC
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200
0

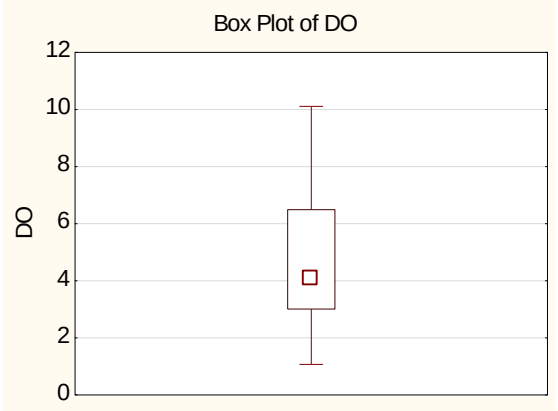

Box Plot of Na
Na
450
400
350
300
250
200
150
100
50
0

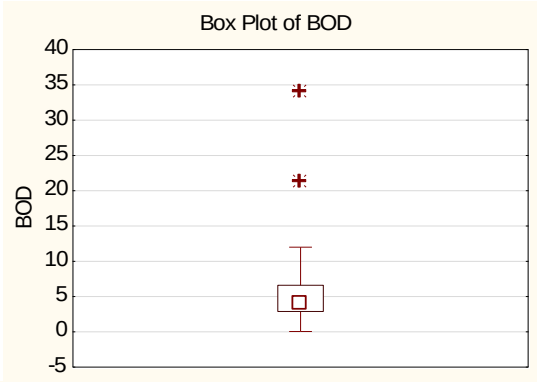

Box Plot of Ca
Ca
100
90
80
70
60
50
40
30
20
10
0

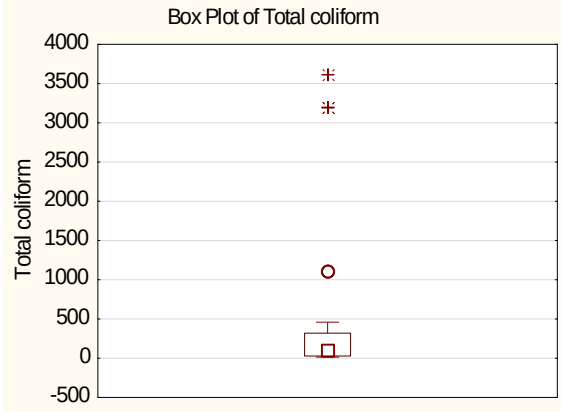

Box Plot of Mg
Mg
45
40
35
30
25
20
15
10
5
0

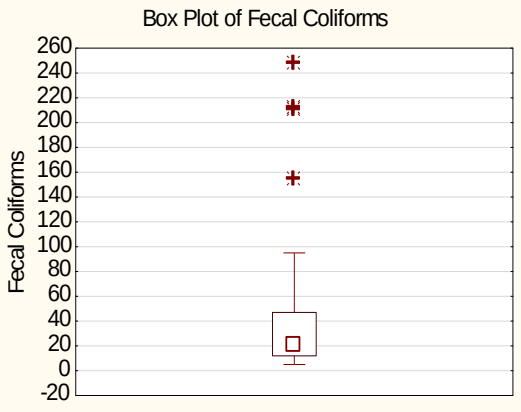

Box Plot of NO3
NO3
24
22
20
18
16
14
12
10
8
6
4
2
0
-2

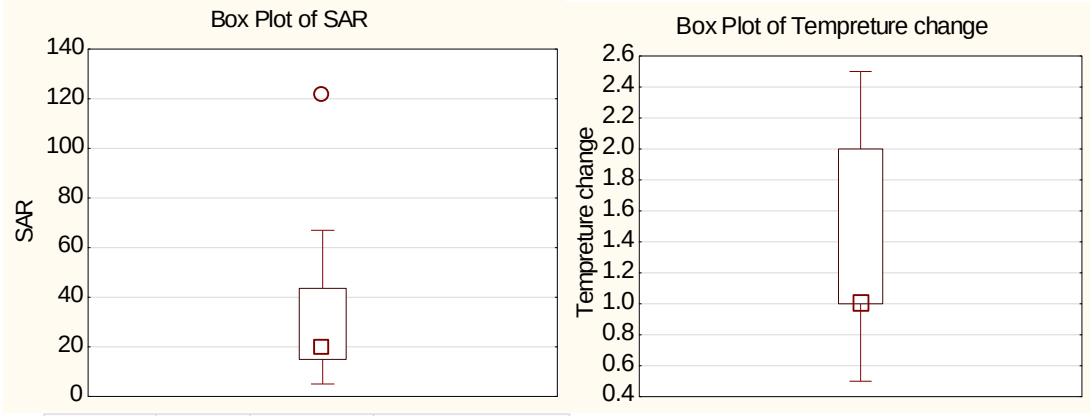

Box Plot of Total Phosphorus
Total Phosphorus
6
5
4
3
2
1
0
-1


Box Plot of DO
DO
12
10
8
6
4
2
0


Box Plot of BOD
BOD
40
35
30
25
20
15
10
5
0
-5


Box Plot of Total coliform
Total coliform
4000
3500
3000
2500
2000
1500
1000
500
0
-500


Box Plot of Fecal Coliforms
Fecal Coliforms
260
240
220
200
180
160
140
120
100
80
60
40
20
0
-20



		○ Outliers	* Extremes
Parameters	□ Median	▯ 25%-75%	Ξ Non-Outlier Range
pH	7.96	7.53 , 8.2	6.53 , 8.95
EC	747	578 , 1255	130 , 1732
TDS	487	326 , 870	164 , 149
Turb	16.27	9.9 , 36	4.23 , 65
Na	83.5	69 , 194	23 , 233
Ca	22	18 , 26	9 , 28
Mg	14	15 , 17	7 , 20
NO3	5.95	2 , 14	0 , 23
T.Ph.	0.61	0.29 , 0.93	0.005 , 1.74
DO	4.1	3.01 , 6.49	1.07 , 10.11
BOD	4.005	2.89 , 6.6	0.05 , 12
T.coli.	93	28 , 320	15 , 320
F. coli.	20.5	12 , 47	5 , 95
SAR	19.64	14.96 , 43.56	5.04 , 66.97
ΔT	1	1 , 2	0.5 , 2.5

Figure 3.Box Plots of all water quality parameters used to calculate WQI

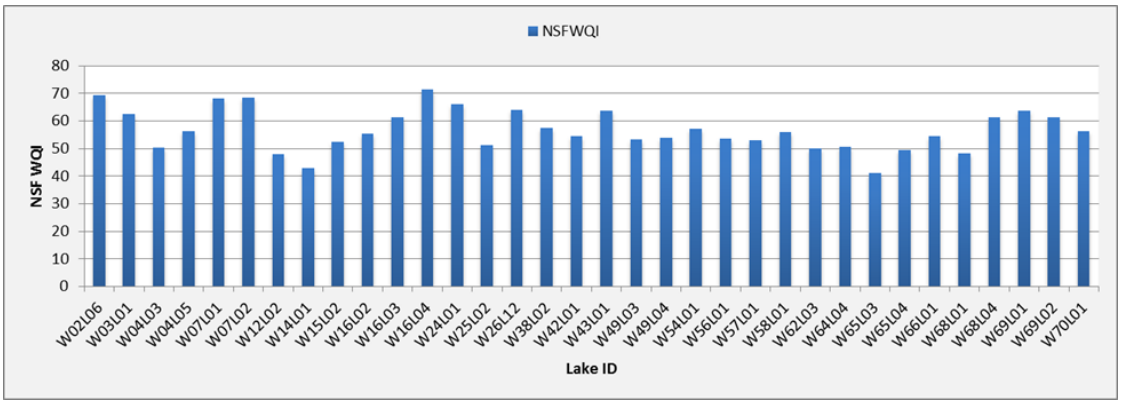


Figure 4. NSFWQI value variation for all lakes

To identify the prominent parameter that affected seriously by pollution, CCMEWQI applied location wise. Central pollution control board, Ministry of Environment and Forests (Govt. of India) guidelines are considered for maintaining the respective use without degrading its life span and quality. Table 6 depicts the CCMEWQI result.

Table 6. CCMEWQI analysisfor 34 surface water bodies in study area

Parameters	pH	EC	SAR	DO	BOD	Total Coli.	NO3
Total No. of locations	34	34	34	34	34	34	34
Number of failed locations	3	1	11	16	24	5	0
Total No. of tests	136	136	136	136	136	136	136
Number of failed tests	12	4	44	64	96	20	0
F1	8.82	2.94	32.35	47.06	70.59	14.71	0
F2	8.82	2.94	32.35	47.06	70.59	14.71	0
Excursion	0.18	0.04	11.51	10.37	35.25	19.40	0
Nse	0.01	0.00	0.34	0.31	1.04	0.57	0
F3	0.54	0.10	25.29	23.38	50.90	36.33	0
CWQI	**92.79**	**97.60**	**69.82**	**59.27**	**35.30**	**66.27**	**100**
Category	Good	Excellent	Fair	Marginal	Poor	Fair	Excellent

From the above table 6 BOD is that parameter which is particularly more affected by the urban pollution in most of the Raipur cities surface water body. It categorized under poor condition according to CCMEWQI criteria. DO is marginal and SAR & Total Coli is in fair condition. Table 7displays the water body ID's that violates the standard.

Table 6. Water body ID's violates standard

No.	pH	EC	SAR	DO	BOD	Total Coli
1	W02L06	W16L03	W03L01	W04L03	W02L06	W03L01
2	W14L01		W04L05	W04L05	W03L01	W07L01
3	W69L02		W16L02	W14L01	W04L03	W56L01
4			W16L03	W15L02	W12L02	W62L03
5			W38L02	W25L02	W14L01	W65L03
6			W54L01	W26L12	W15L02	
7			W56L01	W42L01	W16L02	
8			W64L04	W43L01	W16L03	
9			W65L03	W49L04	W25L02	
10			W68L01	W57L01	W38L02	
11			W68L04	W58L01	W42L01	
12				W65L04	W49L03	
13				W68L01	W49L04	
14				W68L04	W54L01	
15				W69L01	W57L01	

16				W70L01	W58L01	
17					W62L03	
18					W64L04	
19					W65L03	
20					W65L04	
21					W66L01	
22					W68L01	
23					W69L01	
24					W69L02	

It is observed from the above table 7 that there are 24 water bodies in which BOD violates the standard of pollution control board. After that DO and SAR violates the standard at 16 and 11 locations respectively. Total Coli, pH and EC are violates standard at 5, 3 and 1 location respectively.Above table depicts that the organic load is more on the surface water body of the Raipur city, which could be due to inadequate and deficiently designed, operated and managed individual and community toilets in the urban poor areas resulting in open defection. This leads to pollution and sever health impacts. The sewage management system is deficient in city of Raipur which is evident from the fact that roughly 54% of the properties are connected to unscientifically designed septic tanks, part of which overflows into the open drains/areas ultimately draining into the natural water bodies.

Conclusion

The contradictory research findings in relation to these measures clearly point to the significant role played by location specific factors influencing water quality rather than purely land use. The underlying processes and concepts relating to urban water quality are well known in a qualitative sense. However their quantification has proved to be extremely difficult. Chemical processes exert a strong influence on urban storm water quality characteristics. Rainfall and the resulting surface runoff transports a variety of materials of chemical and biological origin to the nearest receiving water body. This results in a water body which is fundamentally changed from its natural state. Urban expansion transforms local environments and can dramatically alter local conditions and in particular the rate of movement of pollutants into waterways, thereby adversely changing the quality of water. The concentration of contaminants in the atmosphere is influenced by meteorological, topographical and land use factors. The chemical composition and concentration patterns of atmospheric pollution can vary widely, either temporally or spatially due to meteorological factors which will result in processes such as dispersion and re-suspension. These processes do not lend themselves to simple mathematical modeling. Common substances include carbon monoxide, sulfur dioxide, nitrogen oxides, hydrocarbons and dust. They are brought into the urban atmosphere from long distances or could be emitted from various sources either on a regional or local scale. The primary sources include lawn fertilizer, sewer overflows, animal waste, vegetation debris, industrial activities, vehicle exhausts, power generation and atmospheric dry and wet deposition. Some of the atmospheric pollutants in the solute or gaseous phases will undergo further synthesis due to physical, chemical or photochemical processes.

Acknowledgements

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WATER CONTAMINATION RELATED TO INDUSTRY AND ITS EFFECTS ON HUMAN HEALTH A CASE STUDY

Tejinder Kaur

Introduction

Water is necessary for the very existence of man who appeared on the Earth in early Pleistocene two to three million years ago. It is in abundance in our globe and is a gift of nature because of its unique properties. It is also, essential for the survival of any form of life.The rest of the water of the universe is locked up in oceans as salt water, polar ice – caps and glaciers and in under grounds. In addition to the various domestic purposes, the major use of water is for drinking, apart from that it is required for irrigation, shipping, sanitation, power generation and industries (Rao, 1979). It has been experienced that for the past few decades, technology has been advancing at a faster rate and the domestic waste produced by man has also been increased at a larger scale. Many human activities require water. The property of water of dissolving many substances makes it very unique and useful in industries and in day to day use. The waste is nothing but nutrients, which find their way into the nearby water sources. Domestic, industrial and agricultural, waste water and solid waste (mainly domestic) contribute to the pollution of the sources of water. They reach the surface water sources by rain and ultimately reach the ground water sources which affect not only the public water supplies but also the domestic wells in rural areas (Dinges, 1976). Heavy metals and trace elements are present in the ecosystem and humans and other organisms are exposed to them through various pathways. Presence of these elements in subsurface water comes from both natural and anthropogenic sources.The weathering of minerals is one of the major natural sources. Anthropogenic sources of soil contamination include wastewater irrigation, solid waste disposal, sludge applications, vehicular exhaust, industrial effluents, fertilizers and insecticides. All these factors are related with urbanization and industrialization. The urbanization in any area is characterized by high density of residential and commercial buildings, extensive areas of impervious surfaces and extensive construction of subsurface drainage systems such as flushing water pipes, sewers and storm water drains. Indiscriminate action by man is polluting our water resources. Rivers are used as repositories for the disposal of sewage, industrial effluents and other waste materials. This has become a serious menace in the highly industrialized nations. Fertilizers and pesticides are also being used to increase greatly the salt content.However, due to rapid growth of population and increased needs for agriculture and industries is causing contamination of water due to agricultural as well as due to industrial activities (Rao, 1979). Water residues from factories contained waste and harmful substances called pollutants and these pollutants are residues of substances made by humans as waste products which pollute the environment in one way or other (Trivedi, 2004).

All biochemical reactions in the biological systems take place in water medium. When toxic chemicals are released into the environment, they enter into the human food chain. As soon as they enter our biological systems, they disturb the biochemical processes, thereby causing deaths in some cases (Rao, 2011). Groundwater is used domestically for drinking, cleaning and bathing purposes and also for irrigation purposes. The major source of surface and ground water pollution in industrial and urban areas is injudicious discharge of untreated effluents directly into the surface water bodies resulting in serious surface and ground water pollution. The quality of water resources is deteriorating due to the continuous pollution with

undesirable discharge of these pollutants and effluents into the water resources. Most industries generally produce water containing heavy metals along with hazardous organic and inorganic effluents. These chemicals contaminate ground water and severely pollute it. The industrial effluents include poisonous chemicals ranging from suspended solids, heavy metals, cyanides, several acids and alkalis to fluorocompounds. Pollutants from agricultural sources comprise pesticides and fertilizers and their breakdown products. Thermal pollution of water is caused by the discharge of hot water from cooling towers of power plants and other industries. Effluents from different sources contaminate valuable freshwater sources such as lakes, rivers, streams, ground water and ocean water. Pollutants impart colour, turbidity and unpleasant taste and odour and foaminess to water and contribute to eutrophication. A large number of infectious diseases are spread through contaminated water. Water pollution is detrimental to aquatic life and also affect thecomposition of flora and fauna. Consequently food chains and food webs are disturbed. Some chemical pollutants are so poisonous that they kill the aquatic organisms. Some others are persistent and pass through the food chain (Freedman,1989).

The initial effect of water pollution is to degrade the physical quality of the water. Later biological degradation becomes evident in terms of number, variety and organization of the living organisms in the water (Gray, 1989). Often the water bodies readily assimilate waste materials they receive without significant deterioration of some quality criteria; the extent of this is referred to as its assimilative capacity (Fair et al., 1971). The input of waste into water bodies therefore does not always impact negatively on aquatic environment because of the self-purification property of the water bodies. But there is always some limit to which water bodies can sustain pollutants. A high level of discharged effluents into water resources are a risk to human health. Industries produce a lot of pollutants and effluent. The disposal of untreated municipal, industrial and agricultural waste waters into water resources has degraded the quality of surface waters in different parts of the world. Extensive irrigation of agricultural lands as well as the drinking water supplies is mainly based on canal water / surface water.

Review of Literature

Govindarajalu (2003) studied the nature and impact of water pollution in the Noyyal river basin in Coimbatore, Erode and Karur districts, Tamil Nadu. The main thrust of the study was on the health status of villagers, agriculture and the livestock population. A total of 31 villages and 600 households were been selected for primary survey. To understand the magnitude of the impact of water pollution on the health status of the villagers, 3 major health camps were conducted. It was evident from the study that almost all the 31 sampled villages were affected by the industrial effluent. Health problems such as skin allergy, respiratory infections, general allergy, gastritis and ulcers were the common diagnosis by the medical team. The impact of water pollution was significant on the rural community in the areas of health, agriculture, livestock and drinking water. Dheri et al. (2007) studied heavy-metal concentration in underground and surface water, soil, and crop plants growing in farmers' fields near the industrial city of Ludhiana, (Punjab) that received irrigation with water contaminated with sewer and untreated industrial effluents. Results showed that the concentrations of lead (Pb), chromium (Cr), cadmium (Cd), and nickel (Ni) in sewage-contaminated water were 18, 80, 88, and 210 times higher than in shallow hand-pump water, and 21, 133, 700, and 2200 times higher than in deep tube-well water, respectively. The concentrations of Cd and Ni in shallow hand-pump underground water were significantly higher than in deep tube-well underground water. The concentrations of Pb, Cr, Cd, and Ni in deep tube-well water were 0.017mgL^{-1}, 0.003mgL^{-1}, 0.0002mgL^{-1}, and 0.0002 mg L−1, respectively. The mean concentrations of Pb, Cr, Cd, and Ni in crop plants growing on soils

irrigated with sewage-contaminated water were (4.88, 4.20, 0.29, and 3.99)mg kg−1, which were 1.2, 2.1, 8.7, and 1.9 times higher than in plants irrigated with deep tube-well water, respectively. The study concluded that, long-term accumulation of toxic metals in soils and their uptake by crop plants had a high potential for phyto-toxicity as well as for entering into the food chain. The findings also suggested the contamination of underground shallow drinking water through leaching of some highly mobile metals. Sharma et al. (2007) did an assessment of the impact of wastewater irrigation on heavy metal contamination of *Beta vulgaris* (palak) which is highly nutritious leafy vegetable that is widely cultivated and consumed in urban India. The field study was conducted at three major sites that were irrigated by either treated or untreated wastewater in the suburban areas of Varanasi, India according to normal practice. Samples of irrigation water, soil, and the edible portion of the palak (*Beta vulgaris* L.) were collected monthly during the summer and winter seasons and were analyzed for Cd, Cu, Zn, Pb, Cr, Mn, and Ni. Heavy metals in irrigation water were below the internationally recommended (WHO) maximum permissible limits set for agricultural use for all heavy metals except Cd at all the sites. Similarly, the mean heavy metal concentrations in soil were below the Indian standards for all heavy metals, but the maximum value of Cd recorded during January was higher than the standard. Also in the edible portion of *B. vulgaris*, the Cd concentration was higher than the permissible limits of the Indian standard during summer, whereas Pb and Ni concentrations were higher in both summer and winter seasons. The study concluded that the use of treated and untreated wastewater for irrigation had increased the contamination of Cd, Pb, and Ni in edible portion of vegetables causing potential health risk in the long term.

Adekunle et al. (2008) studied the impact of industrial effluent on water quality criteria of a river within Asa Dam industrial estate; Ilorin (In North Central Nigeria) was investigated. The effluents were found to cause gross pollution of the river. The major sources of pollution were identified to be the direct runoff from the industries and refuse dumps within the estate. Balakrishnan et al. (2008) evaluates the groundwater quality in and around the Kancheepuram town of Tamil Nadu with reference to drinking and irrigation purposes. Kancheepuram town is located at a distance of 76 km from Chennai on the northern bank of the river Vegavathy. Twenty groundwater samples were collected from various parts of the dyeing industrial region and the samples were analysed with standard analytic methods. Heavy metal pollutants such as cadmium, mercury, arsenic, iron and chromium were present in higher concentrations than the permissible standard values (WHO, 2003; BIS, 1991). The presence of iron in water may cause decolourisation of clothes washed in such waters (Kesavan and Parameswari, 2005). Akhilesh et al. (2009) in their study dealt with a short review and the determination of seven heavy metals namely Cu, Fe, Mn, Zn, Ni, Cr and Pb in the groundwater of different sites of two districts Sehore and Bhopal of Madhya Pradesh. The study was carried out in the month of February to April 2003. Seven water samples were collected from Bhopal district and eight water samples were collected from Sehore district from different sites in polyethylene container which were thoroughly cleaned with 1:1 HNO3, rinsed several times with distilled water and dried in electric oven. (The collected water samples were grouped under categories S1, S2, S3, S4, S5, S6, S7, (Bhopal District) and S8, S9, S10, S11, S12, S13, S14, S15(Sehore District)). According to the analysis, the concentration of nickel in only S5 in Bhopal and S15 sample in Sehore were out of limit, whereas in some water samples of Bhopal and Sehore district of Madhya Pradesh, Copper, Manganese, Lead, and Zinc were not found beyond limit. It was also found that Iron and Chromium were found towards little higher sides on some places and Nickel was found higher only in Balrampurghati (Bhopal District) and Larkui (Sehore District) sample, but these metals were essentials for human body metabolism. They play role of co-factor in activity of enzyme. The results obtained were compared with safe limits in parts per million (PPM) for heavy

metals laid down by Bureau of Indian Standards (B.I.S), World Health Organization (W.H.O), Indian Council of Medical Research (I.C.M.R), American Public Health Association (A.P.H.A).

Mulk et al. (2012) conducted the analysis of pollution load in industrial effluent and ground water of marble industries in District Buner, Khyber Pakhtunkhwa Pakistan,in 2011. The samples were collected from marble industries in district Buner for analysis of heavy metal content from the effluents out flow followed by the marble industries in District Buner along with groundwater samples from various tube wells and from main drain. Samples were collected in clean dry bottles of plastic (1500ml).The result showed that the unserious behaviour of local marble industries owners and wrong drainage of the wastes/ calcium of marble industries in Buner has not only endangered and threatened the aquatic biodiversity of local rivers but up to some extent the life of human as well as the natural beauty and filed crops too. The concentration of many pollutants in groundwater was often higher than that in the most contaminated surface water supplies. Many of the chemicals were tasteless and odourless at concentrations believed to pose a threat to human health. The major groundwater pollutants were chlorides, nitrates, heavy metals, and toxic organics.

Research Methodology

The present study was conducted in two villages one under Ludhiana District and the other under Patiala District of Punjab (India). This study explores heavy metal and trace element distributions in groundwater samples collected from villages situated along some water channels in Punjab. The results would help us to understand the potential threat to our ground water resources due to dumping of industrial waste into surface water channels/rivers.

The primary data was collected from village under Patiala District namely Arnetu and the village under Ludhiana District was Wallipur Kalan. The paper explores the amount of micro/trace elements and /or heavy metals in ground water samples from hand pumps and in river water samples at villages near two water channels namely River Ghaggar and *Buddha Nullah* of Punjab, India. Hand pump water samples (drinking water samples) were collected from 23 households. The pre-cleaned and dried polyethylene bottles (100 ml) rinsed with sample water were used for sample collection and preservation. All the water samples tested were used for drinking by farmers and families and farm workers. The concentration of essential elements (Zn, Cu, Fe, K, Mn, Mg, P, Se) and heavy metals (Cd, Cr, Ni, Pb, Ti, Sr, Co, Bi, Hg, U, As, Sn), total elements were 22 in number, were determined by Energy Dispersive X-Ray Fluorescence (EDXRF) Spectrometry in groundwater. The degree of water pollution for each metal was measured using the Metal pollution load index (MPLI) depending on soil metal concentrations compared with internationally accepted standards. The following modified equation was used to assess the MPLI level in water: MPLI = Mean value of the samples / Mean value of the permissible limits.

Results:

Table 1: Analytical analysis of drinking water samples

	Wallipur (Ludhiana)				Arnetu (Patiala)				
Elements	**Mean (ppm) N=23**	**S.D**	**Range**	**MPLI**	**Mean (ppm) N=23**	**S.D**	**Range**	**MPLI**	**Desirable limits**
Ca	0.209	0.329	0 to1.6	-	0.23	0.319	0.03 to 1.66	-	75mg/l (IS:1993)
Cr	2.645	0.561	1.35 to 3.55	52.8	2.80	0.452	3.76 to 2.06	56	0.05 mg/l (IS:1993)
Mn	0.765	0.260	0.1 to 1.15	7.6	0.97	0.460	0.53 to 1.26	9.7	0.1 mg/l (IS:1993)
Fe	0	0	0 to 0	-	0	0	0 to 0	0	0.3 mg/l (IS:1993)
Co	3.888	2.035	1.05 to 5.9	-	4.05	1.081	6.26 to 2.3	-	-
Ni	0.486	0.931	0 to 3.4	24.3	0.53	0.920	0 to 3.25	26.5	0.02 mg/l (WHO:1993)
Cu	13.102	7.747	0 to 27.9	262	15.18	4.912	23.4 to 4.76	10.12	0.05 mg/l (IS:1993)
Zn	2.761	1.239	0.05 to 5.85	0.55	3.035	0.777	4.25 to 1.95	0.202	5 mg/l (IS:1993)
As	0	0	0 to 0	-	0	0	0 to 0	0	0.05 mg/l (IS:1991)
Sb	46.790	63.381	0 to 204	9358	37.36	63.096	233 to 0	7472	0.005 mg/l (WHO:1993)
Ag	15.077	13.179	0 to 30.75	-	13.24	10.803	0 to 39.8	-	0.1mg/l (IS:1991)
Sn	3.286	0.740	1.65 to 4.4	-	3.71	0.601	4.66 to 3.06	-	No limits listed
Mo	0	0	0 to 0	0	0	0	0 to 0	0	0.07 mg/l (WHO:1993)
Bi	0.722	1.547	0 to 7.1	-	0.48	0.726	0 to 2.46	-	-
Pb	6.793	0.972	0 to 7.85	679	7.039	0.514	7.96 to 6.3	703.9	0.01 mg/l(WHO:1993)
Sr	0.906	0.911	0 to 3.2	-	1.202	1.435	0 to 6.56	-	No limits listed
Cd	0.572	0.735	0 to 2.15	190	0.34	0.374	0 to 1.53	113.3	0.003 mg/l (WHO:1993)
U	0.659	0.642	0 to 1.8	0.02	0.42	0.428	0 to 1.4	14	30 µg/l US EPA
Hg	0	0	0 to 0	0	0	0	0 to 0	0	0.001 mg/l (WHO:1993)
Se	0.025	0.117	0 to 0.55	0.5	0	0	0 to 0	0	0.01 mg/l (IS:1993)
Ti	2.202	2.531	0 to 0	-	0.83	0.898	0 to 2.85	-	No limits listed
I	0	0	0 to 0	-	0	0	0 to 0	-	-

Table 1 clearly revealed the contents of the heavy metals namely:- Calcium (Ca), Chromium (Cr), Nickel (Ni), Copper (Cu), Antimony (Sb), lead (Pb), Cadmium (Cd),and Uranium (U) were higher than the desirable standards advocated by different international/national bodies like (WHO/EPA/BIS/IS) engaged in environmental pollution control. While certain other heavy metals like Zinc, Selenium was present within the permissible limits.It also revealed that the metal pollution load index (MPLI) of five metals-: Cr, Ni, Pb, Cd, U was higher in Arnetu village of Patiala than that at Wallipur village of Ludhiana; while MPLI of Copper(Cu) ,Zinc(Zn), Antimony(Sb), lead(Pb), Cadmium(Cd) and Selenium(Se) were higher at Ludhiana than at Arnetu. While elements like Calcium (Ca) and Titanium (Ti) were found in higher concentration at Arnetu than village Walipur. Elements like Cobalt (Co), Tin (Sn) and Strontium (Sr) were found in higher concentration at Arnetu whereas Ag, Bi was in higher concentration at Walipur. These results were slightly intriguing. These metals may leach into water naturally through anthropogenic factors. Since Patiala district is not known to be rich in metals, so higher amount of these in shallow water aquifers may be attributed to extraneous factors rather than natural processes. Similarly the element Pb and Cu was also found in higher concentration in drinking water sample of the present study. Zinc concentration in present study was found in range of 0.05 to 5.85 mg/L with mean value 2.761 mg/L at Ludhiana, while it ranged from 1.95 to 4.25 mg/L with mean value 3.035 mg/L at Patiala. So observed Zn concentration value was within the permissible limit of 5-15 mg/L (according to IS: 10500) at Ludhiana and at Patiala. These results revealed that groundwater system in the vicinity of the *BuddhaNullah* seemed to be more polluted due to higher concentration of heavy metals (which are very harmful to health if ingested by humans) than that at Patiala district.

Table 2: Analytical analysis of the River Water/ Water Bodies

Elements	Buddha Nullah (Water stream)	Ghaggar (River water)	Desirable Limits (ppm)
	Mean (ppm) N=3	Mean (ppm) N=3	
Ca	0.55	0.23	75mg/l (IS:1991)
Cr	2.65	3	0.05 mg/l (IS:1991)
Mn	0.95	1.5	0.1 mg/l (IS:1991)
Fe	26.05	0	0.3 mg/l (IS:1991)
Co	3.65	5.4	--------
Ni	0.35	2.1	0.02 mg/l (WHO:1993)
Cu	15.6	19.5	0.05 mg/l (IS:1991)
Zn	7.05	3.83	5 mg/l (IS:1991)
As	0	0	0.01 mg/l (IS:1991)
Sb	67.5	52	0.005 mg/l((WHO:1993)
Ag	23.75	0	0.1 mg/l(IS:1991)
Sn	3.7	4.53	No limits listed
Mo	0	0	0.07 mg/l((WHO:1993)
Bi	0	0	-------
Pb	6.8	7.83	0.01 mg/l(WHO:1993)
Sr	0	0.23	No limits listed
Cd	1.2	0.83	0.003 mg/l((WHO:1993)
U	0.55	0.8	30 µg/l US EPA
Hg	0	0	0.001 mg/l(WHO:1993)
Se	0	0	0.05 (mg/l)US EPA
Tl	3.2	0	No limits listed
I	0	0	**------**

The analytical analysis of river water/ water bodies are presented in the table 2. In the present study the distribution of heavy were measured in surface river water and the bed of the river with the aim to monitor the impacts of heavy metals on the water quality. The table showed that the contents of the heavy metals: Chromium(Cr), Manganese (Mn), Nickel(Ni), Zinc(Zn), Antimony(Sb), Tin(Sn), Lead (Pb), Strontium(Sr), Cadmium (Cd), Uranium (U), Titanium(Ti) were higher than the safe limits prescribed by various organisations namely (US EPA/WHO/IS).

Among these several heavy metals, like cadmium, lead, Uranium, Strontium and Zinc are highly toxic at relatively low concentrations, and can accumulate in body tissues over long periods of time, and are nonessential for human health. The metal distribution pattern of the Ghaggar River and *Buddha Nullah* clearly indicates the source of pollution to be land-based and implicates the industries in the adjacent area as the most likely source.

Data revealed that very few respondents from Arnetu village considered join pain, diabetes and cough and cold as prevailing disease in the village.2.5% and 3.5% respondent's respectively opined fever and stomach upset whereas only 2% respondents considered child born with deformity as major diseases prevailing in the village. Whereas , in Wallipur village it was also found that a very few considered allergy, epilepsy and diabetes as the types of diseases prevailing followed by 3% and 4% respondents who considered heart attack and cancer as major health issues prevalent in the village. The table showed the prevalence of Cancer and Hepatitis C was only found in Wallipur while polio was noticed among residents of Arnetu village.

Discussion

The study clearly showed that hand pump water is not a safe source of drinking water. It taps into shallow aquifers and is heavy with chemicals. The untreated industrial effluents including dyes, from tanning, nickel and chrome plating units are discharged into Buddha Nullah. The Buddha Nullah pollutes the Sutlej River. There are reports that many factories instead of treating the effluents inject it into the earth through deep-bore wells. The high concentration of trace elements and heavy metals, as revealed in the present study, may be causing the detrimental effect on the inhabitants of the area. There were reports of hepatitis in the village.

Analytical analysis of drinking water samples

Essential elements Ca and Ti were found in higher concentration at Arnetu village than in Wallipur village. Subramani et al. (2010) opined that Ca in groundwater are known to originate mainly by the dissolution of carbonate minerals, but a fair amount of Ca can also contribute by silicate weathering so its higher concentration at any place may be partly due to natural processes alone. Co, Sn and Sr were found in higher concentration at Arnetu whereas Ag and Bi were in higher concentration at Wallipur. These results were slightly intriguing. These metals may have leached into water naturally or through anthropogenic factors. Bismuth occurs naturally as the metal itself and is found as crystals in the sulphides ores of nickel, cobalt, silver and tin. Greve et al.,(2007) mentioned that Strontium (Sr) minerals are widely distributed throughout the earth and are release to the groundwater by the natural re crystallization of rocks and weathering of rocks and soils. Since Patiala district is not known to be rich in metals, so higher amount of these in shallow water aquifers may be attributed to extraneous factors rather than natural processes. Many of the essential elements were also found to be in higher concentrations than permissible limits. For example, Cu is an essential element in human metabolism and was considered to be non-toxic up to 1.5 mg/L

concentration in drinking water (ISI 1991; WHO 1993). In the present study the concentrations of Cu was found ranged from 0 to 27.9 mg/L with mean value 13.10 mg/L at Ludhiana and ranged from 4.76 to 23.4 mg/L with mean value 15.18 mg/L at Patiala and thus majority of samples had values higher than maximum permissible limit of 0.5 mg/L. Zinc (Zn) is another essential trace element found in virtually all kind of food and potable water in the form of either salt or organic complexes. Zinc concentration was found in present study in range of 0.05 to 5.85 mg/L with mean value 2.76mg/L at Ludhiana, while it ranged from 1.95 to 4.25 mg/L with mean value 3.035 mg/L at Patiala. So it was observed that Zn concentration value was much higher than the permissible limit of 5-15 mg/L (IS: 1993) at Ludhiana, but was within the normal range at Patiala. The groundwater samples therefore were not Cu- and Zn-deficient.

In the present study, the Fe concentration was found 0.0 mg/L in all the samples at both the places. Hence the ground water was deficient for Fe. These results are contrary to many other studies where high level of Fe concentrations was found in some parts of western Uttar Pradesh (Kalicharan, 2007). Corrosion of hand pumps is known to lead to the presence of Fe in some studies (Langaneger, 1987). Similarly another essential element like Se was not found in the ground water in thepresent study.

The results of the systematic study of the chemical analysis of drinking water samples obtained clearly depicts the fatal effects of heavy metal toxicity in drinking water which includes damaged or reduced mental and central nervous function and lower energy level. These also caused irregularity in blood composition, badly effect vital organs such as kidneys and liver (Sher Ali Khan et al., 2011).

The presence of heavy metals like lead, iron, cadmium copper, zinc, chromium etc. in drinking water linked most often to human poisoning. They are required by the body in small amounts, but can also be toxic in large doses also they constitute one important group of environmentally hazardous substances if present (Singh et al.,2011). The long term exposure of these metals result in physical, muscular, neurological degenerative processes that cause Alzheimer's disease (Brain disorder), Parkinson's disease (degenerative disease of the brain),muscular dystrophy (progressive skeletal muscle weakness),multiple sclerosis (a nervous system disease that affects brain and spinal cord) (IOSHIC, 1999).

There are reports that many factories instead of treating the effluents, inject it into the earth through deep-bore wells. The high concentration of trace elements and heavy metals, as revealed in the present study, may be causing the detrimental effect on the inhabitants of the area. Singh et al. (2013) conducted a similar study to check the pollution level of *Buddha Nullah* water and its effect on groundwater and vicinity area. For this they evaluated the water quality of the rivers, groundwater and the impact of polluted groundwater on environment and health. Results showed that the heavy metal like Cr in the *Buddha Nullah* had value 0.031 mg/L, Fe had value 0.913 mg/L, Mn was 0.043 mg/L and Ni was 0.222 mg/L. The study revealed that the quality of ground water at many places was found to be unfit for drinking mainly due to high amount of total dissolved solids and most potable number being much higher than the prescribed limit as per drinking water specifications (IS:1993) standards.

Study by Bhalla et al. (2011) also had similar findings. The study was performed using multi-elemental analysis of the ground water samples from different locations of industrial waste water drain *Buddha Nullah* draining into Sutlej River near Ludhiana. The water samples were analysed using the EDXRF technique. The regions were known to be contaminated by Selenium and Uranium respectively.

Analytical analysis of River water/Water Bodies

As mentioned earlier the industries in Punjab are throwing its untreated toxic waste water into water streams. *Buddha Nullah* is notorious for this because of the Ludhiana based industry but now this picture is true about all the drains/ rivers of Punjab. The impact of water pollution in the areas along the sides of the moving water channel *Buddha Nullah* and river Ghaggar had been found out in the present study. Heavy metal contamination of soil and water was a cause of serious concern due to the potential health impacts of consuming contaminated produce. The *Buddha Nullah* received heavy discharge of waste effluent from the nearby city of Punjab i.e., Ludhiana which was the industrial belt and was one of the fastest developing industrial belt of Punjab. The river Ghaggar was known for a number of grain/molasses based distilleries.

The heavy metal concentrations in the river water were remarkably high and were not within the permissible limits in the present study. Similar trend has been seen in a study by (Bouraie et al., 2010).The distribution of heavy metals (Al, Ba, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn) in surface water and river sediments were remarkably high, but varied among sampling points, and the concentrations in water were mainly within the permissible limits. The heavy metal contents in bed sediment were highest during closure of winter period. The study concluded with a recommendation of constant monitoring of the Nile river water quality to record any alteration in the quality and mitigate outbreak of health disorders and the detrimental impacts on the aquatic ecosystem.

The results of the present study showed the highest values of the metals observed in downstream i.e., in the direction in which the *nullah* or river is flowing. The effluents deposited indicated that the industrial activities were responsible for heavy metal pollution of the River Ghaggar and the *Buddha Nullah*. The result of a similar study emphasizes the value of constant monitoring of rivers and water bodies receiving effluents in order to forestall cumulative effects of the metals in the river which may lead to sub- lethal consequences in the aquatic fauna and ensuing clinical poisoning to man (Ayenimo et al., 2005).

Metals in the river/water bodies came from natural as well as artificial sources. Metals that are naturally introduced into the river come primarily from such sources as rock weathering, soil erosion, or the dissolution of water-soluble salts. Naturally occurring metals move through aquatic environments independently of human activities, usually without any detrimental effects. However, as the habitation is settled and industrialization has taken place along the sides of the river, the metals added by human activities had affected the water quality of the river. Rivers serve as conveyors for transport of dissolved and particulate matter from continents to seas and oceans. In cases of anthropogenic pollution, substantial metal accumulation in sediments may take place.

Only a small fraction (about 2.5%) of earth's water is fresh and suitable for human consumption. Approximately 13% of this fraction is ground water, an important source of drinking water for many people worldwide (Bachmat, 1994). The present study revealed that the heavy metals through biomagnifications may enter the food chain thereby affecting the human beings and can create threat to the life of the residents of the villages.

Diseases prevailing in field areas

The International Fund for Agricultural Development (IFAD) Rural Poverty Report 2001, recognizes the importance of water assets for the poor. The report quoted that the accessible domestic water supplies, even if shared by a large number of households, can make more and better-quality water available for family needs, reduce female drudgery and

reduce the incidence of debilitating water-borne diseases. This was very close to the results of the present study.

In the present study 89% of the respondents from Arnetu village and 82% from Wallipur village refused to give information about the diseases the family members suffered. The data revealed the prevalence of Cancer and Hepatitis C was only found in Wallipur while polio was noticed among residents of Arnetu village. On the contrary Memon et al., (2011) found that polluted drinking water causes many diseases as diarrhoea, vomiting, gastroenteritis, dysentery and kidney problems etc. found in Thatta, Badin and Thar districts of southern Sindh, Pakistan.

Summary

The present study was conducted in two villages one under Ludhiana District and the other under Patiala District of Punjab. The village under Patiala District was Arnetu and the village under Ludhiana District was Wallipur Kalan. Two major objectives of the study were to assess the heavy metals toxicity in drinking and surface water sample and to ascertain potential health risk of heavy metal concentrations to local population The findings revealed that the Metal Pollution Load Index (MPLI) of 5 metals Chromium (Cr), Manganese (Mn), Nickel (Ni), Lead (Pb), Uranium (U) were higher in Arnetu village of Patiala District than in Wallipur village of Ludhiana District. The most common disease prevalent in Wallipur village was Hepatitis C and Cancer.

As quoted by the residents the health effects and diseases prevailing in the villages were due to the water of the drain which was flowing along the sides of the village. There were case histories incorporated to support the view. One of the case studies depicted a clear idea about the unavailability of the drinking water in the field areas and the prevalence of Hepatitis and other water borne diseases. The cases focussed on the health statistics of the studied areas; decreasing population due to the deaths of a number of residents because of the spread of Hepatitis C in (Wallipur village) which not only took away the lives of many but also left a threat to every resident.

The most common disease prevalent in Wallipur village was Hepatitis C and Cancer.

The results of the present study showed that the heavy metal level pollution was higher in Arnetu village for lead and Uranium than in Wallipur village, while in Wallipur village it was higher for Copper, Antimony, Selenium and Bismuth than that in Arnetu village. Also, Metal Pollution Load Index (MPLI) of 5 metals Chromium (Cr), Manganese (Mn), Nickel (Ni), Lead (Pb), Uranium (U) was higher in Arnetu village of Patiala than in Wallipur village. It is difficult to make any conclusion on the basis of the reported incidence because more than 80% of the respondents refused to share any information regarding diseases suffered by the family members of their households. The present study could not find any evidence of association of higher levels of certain heavy metals with diseases prevailing in the two areas. There was also no association found between ground water contamination and the diseases prevalent in the studied areas.

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CHALLENGES AND SCOPE OF VERMICOMPOSTING – A SUSTAINABLE APPROACH TO CONVERT FOOD WASTE INTO ORGANIC FERTILIZERS IN IMPROVISED RURAL COMMUNITY IN LEBANON

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Abstract

Although vermicomposting is a well-known technique that uses earthworms to transform organic materials into valuable soil amendment, still additional insights are needed to make it more adaptable in small-scale setting as well as in large-scale centralized setting. Despite its popularity in many developing countries including India and widely reported benefits, the Arab countries particularly Lebanon is not yet familiar with the vermicomposting. Taking into consideration the existing organic solid waste (OSW) crisis in the Lebanon, this study aims to assess the feasibility of vermicomposting as a strategy for OSW management and local food security. We particularly focused on understanding of ecological, environmental and economic benefits of vermicmposting. Further, we executed a cost benefit analysis that compares home vermicomposting to large scale municipality level vermicomposting. The study was carried in a rural village named "Warhanieh" in the Chouf region of Lebanon. An extensive demonstration and survey work was performed to investigate whether people would accept to carryout vermicomposting at a household level as a tool for managing OSW for improving soil quality. The results took into consideration the community preference, which was assessed through a willingness to pay survey. The findings revealed that the community was excited about the concept of vermicomposting and was ready to apply it in home gardens but almost 99% of the interviewed people preferred the technique to be managed at the municipality level. The setup of large scale vermicomposting systems however did not prove to be financially feasible indicating that money is not the main driver for adapting vermicomposting. However, vermicomposting would be preferred for its ecological and environmental benefits, as well as its importance for providing local food security by increasing the quality and quality of crops. Small scale household units established in home gardens provide these services and contribute best to local food security and to the existing OSW management crisis. This study is a unique attempt to help people consume nutritious food and promote healthy and environmentally friendly behaviors. The use of vermicomposting at homes can help closing the vicious cycle of foodwaste by converting foodwaste into organic fertilizers and putting back it into the soil.

Keywords: organic solid waste; vermicomposting; organic fertilizers; soil; environment

Introduction

Vermicomposting is a practice that contributes to sustainable agriculture and guarantees sustainable environmental and socio-economic growth (Lazcano et al., 2011; Sinha 2009). The process is defined as the transformation of organic material using earthworms to a valuable soil amendment (Blouin et al., 2013). The transformation is fast and odorless which makes it convenient for household application (Garg et al., 2006). For instance, vermicompost initiatives in India have contributed to environmental protection, local economic development, and enhanced social welfare of the participating communities. Vermicompost market is popular worldwide. India is considered the main producer and largest exporter of vermicompost in the world(Bogdanov, 2013). Other countries that produce

vermicompost at a large scale are France, Canada, Italy, Japan and many others (Sinha et al., 2010).

Earthworms used in vermicomposting are Eisineafetida, known to be the best since they have the highest efficiency among other worms and ability to survive extreme conditions such as soil toxicity and heavy metal pollution (Satchell, E., 1983). The life cycle of earthworms further contributes to satiability since they double in number every 60 days given optimal conditions of temperature, moisture, and feeding material. If earthworms don't get physically damaged they can live up to 220 days. They need 4 to 6 weeks to become sexually mature. On average worms produce 3 cocoons every week and produce 300 to 400 young worms during their lifecycle, Eisenia fetida species have a maximum net reproduction rate of 10.4 worms per week (Dynes, 2003). They are sensitive to light and prefer to live in the dark (Sinha et al., 2009).

Vermicompost production is profitable whether applied on small or large scale. However, to benefit from it financially markets should be established in order to facilitate the demand and supply chain. Figure 1.shows the marketing channels and marketing volumes of vermicomposting of 32 producers in Nepal. The study was done by Devkota et al (2014) and showed that vermicomposting is a feasible enterprise.

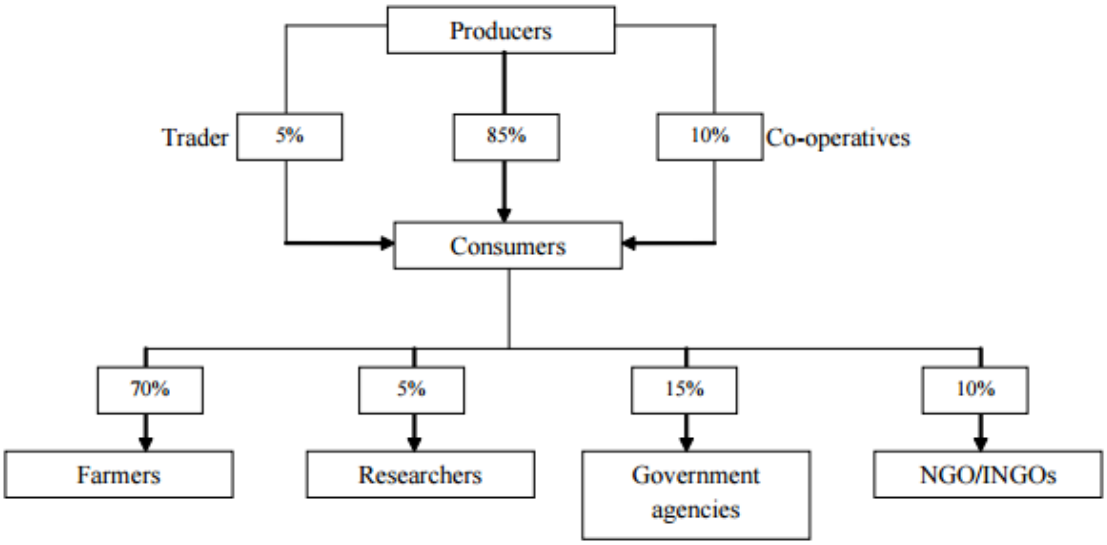


Figure 1: marketing channels and marketing volumes of vermicomposting of 32 producers in Nepal (Devkota et al, 2014)

Many previous studies showed that vermicomposting can be used as a tool for organic waste management (Prasad and S. K. Saini 2011) and socio-economic betterment in rural settings (Purkayastha, 2012). However, this is not the case in Lebanon since this technology is not yet practiced and there is no established market for vermicomposting hence, the interest in this technique as an organic waste management strategy and sustainable agriculture practice (Bhadauria et al, 2014). The aim of this study is to examine baseline information regarding the feasibility of vermicomposting in terms of ecological, environmental and economic benefits. This study also comparesthe value of small scale versus large scale vermicomposting through a cost benefit analysisin a rural community in Lebanon.In light of the current unfavorable crisis in the solid waste sector in Lebanon, vermicomposting is considered to be a potential strategy for managing organic waste (Garg et al., 2006) because

it combines several needed services such as improving the soil and enhancing food security (Vermicomposting, 2016).

1. Material and Methods

1.1 Study area and information retrieving

The data for this study was collected from "Warhanieh" a rural village in Lebanon that is known for its high production of apples, peach and apricot, olive and wide range of vegetables and other crops. The community is comprised mainly of farmers. The methodology fordata collection was face to face interviews to gather information about the soil quality and existing waste management strategy. In addition, people's preference of small scale versus large scale vermicomposting was investigated. Based on the results a cost benefit analysis was carried to decide which among the two choices is more feasible in Lebanon.To improve the understanding of study area and investigate the potential of vermicomposting, a series of information with regards to current practices and existing conditions such as Ecology and Livelihood, Home gardens, and fertilizer and pesticides application practices were obtained by personal interview as well as from existing literature, which is listed in sections 2.2, 2.3, and 2.4.

1.2 Ecology and livelihood practices in Warhanieh

Soils in Warhanieh are porous which are distinguished by high infiltration rates, low moisture retention, and poor fertility due to limited organic matter and nitrogen (Aulakh et al., 1997). To compound matters, when crops are harvested, nutrients are moved from the soil, leaving it depleted (Singh et al., 1995). Although fertilizers may help to increase crop yield, excessive usage may negatively impact the ecosystem, affecting other resources like water (Aulakh&Singh, 1997; Singh, et al., 1995). Synthetic fertilizers were first introduced in Warhanieh fifty years ago. Most farmers rely on fertilizers to increase crop yields. Because of cost, applications may be restricted to every other year. However, there is a general belief that fertilizers quality has declined, suggesting that nutrient composition has decreased. Studies have revealed that lack of trust in these chemicals have resulted in farmers using 20 to 30 percent more than label recommendations despite cost (Farajalla&Khoury, 2007).

1.3 Home gardens in Warhanieh

Family production systems whether called kitchen, home, or backyard gardens, are the oldest known production system (Marsh, 1998). Large or small in area, home gardens provide security to households by diversifying its sources of livelihood and by making them less vulnerable to external factors as food shortage. House gardening isn't necessary practiced by those of low income, but mainly by the households which have access to the needed resources such as water for irrigation, land, and labor (Marsh, 1998). Studies show that the successful household food security strategy would focus on the micro rather than macro level. In other words, the focus should be on the household not on the government, ministries, and municipalities. Home gardens are also important because they provide ecological niches for many insects, and function as conservation areas for beneficial organisms (Marsh, 1998).

1.4 Fertilizer and pesticides application practices

Although farmers use chemical fertilizers and pesticides in their farms, they still prefer to apply organic fertilizer in their home gardens. People believe that organic gardens are their only source for healthy and fresh food. The gardens have wide diversity of vegetables and fruits; especially the smallest gardens because they force people to group many different species in small numbers. While big gardens allow multipurpose use of the area and gives space to more diversity of plants, small gardens are managed in a way that allocate space for

the plants which constitute the highest portion of their diet. Besides, landless families tend to cultivate in pots. Daily practices in Warhanieh during the summer season involve harvesting vegetables directly from the garden to prepare fresh and healthy food for the family. Outsource purchase is very low, home gardens provide almost all the needed food products.

2. Results and Discussion

2.1 Vermicomposting preference

Looking into people's preferences, 200 people were interviewed. The percentage of people who showed willingness to do vermicomposting at the household level reached 71%, however this did not imply that they refused the other option since they also preferred large scale application because it is more binding and presents a solution for the organic waste. In total, 99% of interviewed people preferred large scale application of vermicomposting which means municipality level management of organic waste. The results can be justified when taking into consideration the existing solid waste crisis in Lebanon which urges people to go for a solution that has a wider benefit to the community. For example, it would require less effort for the community if the municipality took the initiative to construct operate and maintain the vermicomposting facility as they would be responsible only for sorting at the source and it would be mandatory for everyone to be part of the process.

2.2 Cost-benefit analysis of large scale versus small scale vermicomposting

Taking into consideration the community preference, it remains important to know which option is more feasible for rural areas small scale or large scale. To answer this question a cost benefit analysis was developed that compares the two options: 1) cost of large-scale application; 2) construction costs.

The project would involve some basic costs as the opportunity cost of the land for the installation of the facility, transportation and collection of the waste, employees and equipment to run the facility. Figure 2 summarizes the costs of operating a large scale vermicomposting facility. Costs are dependent on the size of the facility which is determined based on the volume of waste it should handle (Bogdanov, 2004). Besides, if vermicomposting is to contribute significantly to waste management, then the process must be sustained throughout the year. Based on this, the internal environment should be optimized through installing air conditioning system to control the temperature, and humidity.

In Lebanon the average organic waste production per household per week is estimated at 3Kg. According to a study done by Visvanthan in 2005, 20 tons of household waste is vermicomposted in France every day and this requires 1000 to 2000 million earthworms and produces 400 tons of vermicompost and 10 tons of earthworms (Visvanathan, et al., 2005). In the case study of Warhanieh, if we follow the same ratios, an estimated 300 households would produce an estimated 6 tons of organic waste per month. This amount of organic waste produced per month requires 12 tons of earthworms as they reportedly consume half their weight every day (Sinha, et al., 2009). So on a scale of 6 tons, 12 tons of earthworms will produce 0.8 tons of vermicompost and 0.02 tons of earthworms. The area required to carry the process is 1.22 Km^2 or 1,228,898 m^2 which is costly to buy and difficult to find especially in rural areas because land is considered an important asset.

Despite the high reproduction rate of earthworms, treating organic waste on a municipal level requires high amounts making the process expensive where 6 tons of earthworms will cost $1.1 Million. Although worm numbers will multiply with time, theirnumber should be available to initiate the process and guarantee that the 6 tons of waste will be treated and converted to vermicompost on time since there will be a continuous flow of waste to the treatment facility. In addition, water should be available on site all time to prepare the bedding and control the moisture in the compartments. The sources of water available in villages are either spring water or the water supplied by the government. These sources are not enough for keeping the process in progress; additional sources have to be delivered to the site in cisterns. In Lebanon, water



Figure 2: Operating cost of vermicompst at large scale in Warhanieh

availability is decreasing and the government has already initiated several campaigns to raise awareness on sustainable use. Vermicomposting as a soil amendment is an important technique because it improves the environment and protects its resources, however large scale would score low on this aspect.Other costs involve construction of the facility, building materials and equipment which includes cement blocks, wood, metal shelves and others. In addition to the cement and concrete building, the interior structures should be designed to hold the municipal waste and at the same time provide the adequate environment for the worms to live in. These costs will be invested once at the beginning before starting the

process. The size of the facility will determine the cost. In other words, the quantity of organic waste to be treated will vary based on the number of households in each village.

3.3 Operational, maintenance and accidental costs

Monitoring equipment to control the environment inside the facility (ex: log, pH meter, and others) will be needed along with tools to perform tasks and distribute the waste across the compartments such as shovels to mix and ensure aeration inside the beds.At least 6 workers should be present on site to aid in waste disposal and distribution across the worm beds. Moreover, there is the cost of collecting waste from households and transportation to the site. Additional costs include fuel and workers' salary.The cost of maintenance is minimal, mainly the worm population should be always in check, and any decrease should be compensated. Truck maintenance, tools and equipment is necessary.

In case the worms died or disappeared for reasons such as increase or decrease in temperature, dryness or increased moisture, invasion of ants, harmful insects, or chicken which are known to be direct threats to earthworms, higher costs will be incurred. The worms should be purchased and added immediately to control the process or else many additional problems might prevail some of which are: offensive odors, attraction of flies, waste leachate, increase of harmful bacteria and pathogens on site (Bogdanov, 1996). The waste will be piled and the facility will reach its full capacity in less than two weeks. For that reason, facilities usually are designed to account for emergency situations where they install an additional compartment to be used only in case of cleaning or defects in the process (Galante et al., 2010). However, if the back-up plan is to be applied, the area of the facility will to double, which is not feasible in the Lebanese model.

3.4 Benefits of large scaleversus small scale

Profit from large scale facilities is not guaranteed andtakes time to be realized because of the absence of vermicompost market to sell the product. In addition, it is not safe to depend solely on vermicomposting to manage the waste of an entire community due to the high risk of failure because earthworms are sensitive creatures and are subject to many threats. This is the major drawback of the large scale application. This model was found not feasible, because in absence of market there is no guaranteed profit. Moreover, in large scale the direct ecological benefitsfor the local community are limited since the produced vermicast will be sold in the market and not necessarily benefiting the local communities, for example the price per tonof vermicastmight exceed the community'sallocated budget thus it will not be applied on their lands and the soil quality will remain deteriorated which will be reflected also in the quality and quantity of crops. This implies that the whole community will be excludedfrom all the ecological andenvironmental benefits of vermicomposting. Using vermicomposting as a tool for organic waste management is important however, a better option would be one that includes all the benefits at the same time.Economic benefits in small scale vermicomposting are very low. The production rate is low and there is no market to sell whatever is produced. Thus Vermivcomposting will not be applied for its economic feasibility, but rather for its ecological, environmental, and health benefits. Therefore, people and farmers are recommended and encouraged to produce and use vermicompost for its benefits on ecology, health, and local food security. These are the added values that distinguish vermicompost from the rest of the existing fertilizers.

3.5 Household application cost

Carrying vermicomposting at the household is not costly (Lim et al. 2014); a small plastic crate can be used where the bedding material (soil) is put as well as earthworms, then cover the top with cotton sheets. A conceptual framework describing the household closed system

for recycling back energy outputs is shown in Figure 3. Managing organic waste at the site is effective because generation rates are relatively low per day, thus a small to medium size bins would be sufficient. Also the amount of earthworms needed would range between 400 to 500 grams as a starter which is also very low compared to large scale application. Keeping in mind that worms multiply fast, the vermicomposting process will be self-sustainable. In addition, the repair cost in case of unexpected faults and setbacks is low; at any time the user can design a new bin and reproduce the process with minimal time, effort and money. Therefore, household application is prefered over large scale because it involves less costs.

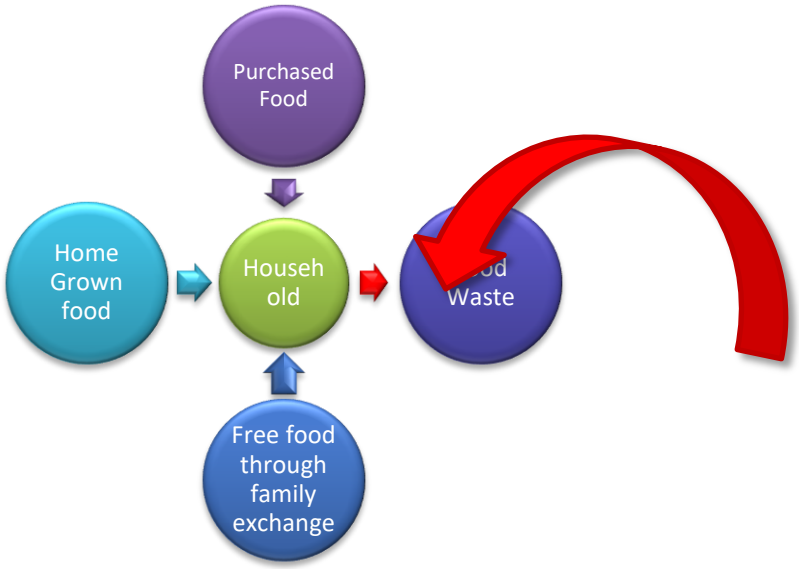


Figure 3: Household closed system – recycling back energy outputs

Conclusions

This study shows that in Lebanon, the profit from selling homemade vermicompost as well as upgrading to municipal scale vermicomposting facility is low, meaning that money is not the main driver for adopting vermicompost. However, vermicomposting should be demanded for the ecological benefits it possesses, as well as the nutritious food products it produces. In addition, its contribution to closing the system by recycling the energy back into the system through processing the organic kitchen waste back into the soil makes it a powerful tool for alleviating the level of environmental awareness and socioeconomic status of rural families. All this further contributes to local food security which is becoming a pressing need. Vermicomposting at the household level is the most cost effective approach that will guarantee the continuity of the practice, and spreads its benefits to wider populations. On the other hand, in case of large scale production, it is recommended to establish horticultural and agricultural markets (Chaudhary et al, 2004), well-trained sales staff, and a network of delivery and distribution facilities. Moreover, designing vermicomposting units for different sizes of home gardens would facilitate the application of the technology at different settings and increase its practicality which in turn increases the demand for its use.

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