Comparative Study on Canal Water Management through Water User Associations (WUA)

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By

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CERTIFICATE – I

This is certified that the thesis entitled ***"Comparative Study On Canal Water Management Through Water User Associations (WUA)"*** *submitted in partial fulfillment of the requirement for the degree of* ***MASTER OF TECHNOLOGY*** *in* ***AGRICULTURAL ENGINEERING*** *(Soil and Water Engineering) of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur is a record of the bonafide research work carried out by* ***Mr. Deepak Chouhan*** *under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instruction.*

No part of the thesis has been submitted for any other degree or diploma (Certificate awarded etc.) or has been published/published part has been fully acknowledged. All the assistance and helps received during the course of the investigation has been acknowledged by him.

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CERTIFICATE – II

This is to certified that the thesis entitled ***"Comparative Study On Canal Water Management Through Water User Associations (WUA)"*** *submitted by* ***Mr. Deepak Chouhan*** *to Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur in partial fulfillment of the requirement for the degree of* ***MASTER OF TECHNOLOGY*** *in* ***AGRICULTURAL ENGINEERING*** *in the Department of Soil and Water Engineering has been, after evaluation, approved by the External Examiner and by the Student's Advisory Committee after an oral examination on the same.*

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LIST OF ABBREVIATIONS

%	Percentage
M	Million
CCA	Culturable command area
ha	Hectare
M^3	Cubic meter
WUA	Water user association
°	Degree
‘	Minute
“	Second
et al.	And others
Deptt.	Department
N	North
E	East
LBC	Left Bank Canal
C	Celsius
&	And
Km	Kilometer
H	Horizontal
V	Vertical
Fig.	Figure
m/s	Meter per second
M^3/s	Cubic meter per second
hp	Horse Power
h	Hours

i.e.	That is
J.N.K.V.V.	Jawaharlal Nehru Krishi Vishwa Vidyalaya
CAE	College of Agricultural Engineering
No.	Number
Approx.	Approximately
Kg/m^3	Kilogram per cubic meter
W	Wheat
G	Gram
P	Pea
S.No.	Serial number
cm	Centimeter
Govt.	Government
Agril.	Agricultural
Engg.	Engineering
df	Degree of freedom
SS	Sum of square
ms	Mean sum of squar
F_c	F value calculated
$F_{5\%}$	5% table value of F
S	Significance
NS	Non-Significance
viz.	Namely

INTRODUCTION

1.1 General

Water is the most precious natural resource and a universal asset. Proper planning, development, management and optimal utilization of it, is of paramount importance for socio-economic development of the nation. Irrigated agriculture contributes much to food security and improved livelihoods of the rural population around the world. Occupying only 17% of the total cropland, irrigated agriculture produces more than 40% of the world's food. At the same time the development of new water resources and land for irrigated agriculture in order to increase food production is increasingly less economically, environmentally and socially viable. Irrigation development in India is mainly from three sources viz., canals, wells and tanks. Each of them was developed at different times as per demand for irrigation as well as technologies developed for storing, transporting and lifting of water. It is necessary to achieve maximum returns per unit of water used from cropping activities.

Real changes in irrigation water use can be achieved through improving the productivity of existing available water resources. Therefore, institutional interventions to improve irrigation water management are pre-requisite for increasing the productivity of limited water resources. A substantial investment has been made in the country for creating assured irrigation-facilities through major and medium irrigation projects to increase agricultural production. The irrigated area of the country has increased from 21 M ha in 1950-51 to 75 M ha during 2011-2012 (www.agricoop.nic.in).

1.2 Evaluation of irrigation system

The criteria for evaluating irrigation systems have undergone major modifications in the last 30 years from the classical irrigation efficiencies to measuring performance using a variety of indicators (Bastiaanssen and Bos, 1999), taking into account productivity of irrigation water with accent on yield (Perry and Narayanamurthy, 1998; Sarwar and Perry, 2002; Seckler *et al*., 2003), and revenue enhancement per unit of depleted water (Kijne *et al*., 2003); and equity in water distribution (Svendson and Small, 1990). As scarcity of irrigation water is becoming evident in many regions and demand for water increasing from other competing sectors of use, thus there is a need to assess the quality of irrigation services in relation to productivity of water rather than land (Sarwar and Perry, 2002). This means, the criteria for assessing system wide irrigation management strategies adopted by irrigation agencies also needs to be revisited. In other words, the factors that need to be taken into account for assessing the quality of irrigation also needs to change, the reason being the factors that influence yield are not exactly same as those, which influence water productivity. Crop water productivity can be defined either as the yield per unit of water depleted in crop production or applied for crop production; or the net return from crop production per unit of depleted water or water applied (Kijne *et al*., 2003). Hence, the key drivers of change in water productivity are: amount of water depleted in crop production as it changes denominator of productivity and all crop inputs including crop variety, fertilizer and pesticide dosage and labour as they determine the crop yields and net returns, which change the numerator of part.

1.3 Water User Associations

Canal irrigation in India is one of the principal methods used for improving the crop productivity. In order to have the equal distribution of canal water and to reduce the dependability in canal repair and maintenance with governing bodies, the water users (farmers) in the command area has created their own unions, popularly known as water user associations. A Water User Association (WUA) is a co-operative association of individual water users who wish to undertake water-related activities for their mutual benefit. A WUA is a group of farmer along a lateral canal who establish their own cooperative non-profit organization with a set of rules to manage water deliveries within their area (Lohmar *et al., 2003*). WUA is parallel or lower than panchayati raj which is considered as third tire of India. Madhya Pradesh was second state to complete elections to 1470 WUAs in April 2000 and to 90 Distributories Committees in February 2001. WUA's main aim is to increase water productivity in command area development (Hooja, 2005). Water productivity depends on several factors like crop genetic material, water management practices and agronomic practices. Water productivity can be expressed in physical or economic terms.

Physical productivity is quantity of product in kg per m³ of water used and economic productivity is income in Rupees derived by use of unit volume of water (m³) (Molden *et al.*, 2003).

Roles of WUA's in canal water management includes canal operation, canal maintenance, collection of funds and maintaining accounts, dispute resolution and other functions and services. Objective of WUA's are to promote and secure equitable distribution of water among its users, to provide efficient operation and maintenance of the irrigation system, to utilize water efficiently and economically, to increase agricultural production and to protect the environment. Functions of WUA are to prepare and implement a warabandi schedule for each irrigation season, promote economy in the use of water allocation, monitor flow of irrigation, prepare and maintain an inventory of the irrigation system within the area of operation, raise resources and to conduct regular water budgeting along with periodical social audit. WUA's constituted in the year 2008 in the state of Madhya Pradesh for different irrigation projects are working to achieve the productivity improvement of water applied.

1.4 Objective

The task of WUA's is a mixed one which include social, technical, economical and emotional aspects. The performance of WUA's if assessed through evaluation parameters of irrigation in command area may indicate the success of these bodies and may also suggest the necessary changes to achieve the goal of higher productivity per unit of water used in the system.

Keeping the above perspectives in view, present study is aimed to achieve following objectives:

1) To characterize and evaluate the working of selected Water User Association (WUA) in irrigation command.

2) To determine Water productivity in working areas under different Water User Associations.

REVIEW OF LITERATURE

In this chapter, a brief review is presented over the past work done related with the presented study. A concise and relevant presentation is made on impact of canal irrigation, role of Water User Association in command area, water distribution in command area, crop production in command area, water resource utilization in command area, use of ground water in command area and conjunctive use in command area.

2.1 Water user associations (WUA’s)

Participatory irrigation Management (PIM) or irrigation Management Transfer (IMT) is an approach of surface irrigation management where in the management of the canal system is gradually handed over to the farmers in the command area. This approach is based on the assumption that farmers have most to gain from improved irrigation services if they govern the irrigation systems than the earlier system when it is governed by irrigation institutions.

Water User Association are promoted and facilitated to take over the management of canal systems. Notable success has been achieved in many places (Joshi, 1997). However, many researchers feel that despite being tried out for so long, the results are not substantial. In India, Andhra Pradesh was the first state to pass a PIM act, i.e. an Act by which all irrigation systems were to shift to a PIM approach.

Under the Act of “Madhya Pradesh Sinchai Prabandhan Me Krishakon Ki Bhagidari Adhiniyam” (1999). The Farmers Organisation was formed under which the District Collector delineate every command area under each of the irrigation systems on a hydraulic basis which may be administratively viable and declare it to be a water users’ area for the purpose of this Act. Provided that in respect of the command area under the minor and lift irrigation system, the entire command area may as for as possible form a single water users’ area.

“Water Users” means any individual or body corporate or a society using water for agriculture, domestic, power, non-domestic, commercial or industrial or any other purpose from a Government source of irrigation.

The objects of the farmers' organisation shall be to promote and secure distribution of water among its users'; adequate maintenance of the irrigation system, efficient and economical utilisation of water to optimise agricultural production, to protect the environment and to ensure ecological balance by involving the farmers, inculcating a sense of ownership of the irrigation system in accordance with the water budget and the operational plan.

2.2 Functions of Water Users' Association

As per M.P. WUA's Act (1999) function of WUAs are enlisted below:

(a) to prepare and implement a warabandi scheduling for each irrigation season, consistent with operational plan based upon the entitlement, area, soil, and cropping pattern as approved by the distributory committee, or by Project Committee;

(B) to prepare a plan for the maintenance of irrigation system in the area of its operation at the each crop season and carry out the maintenance works of both distributory system and field drains in its area of operation with the funds of the association from time and to provide funds for the maintenance of staff including such persons who are placed by the State Government with the Water Users' Association for the purpose of regulation and maintenance of irrigation system;

(c) to regulate the use of water among the various pipe outlet under its area of operation according to the warabandi schedule of the system;

(d) to promote economy in the use of water allocated;

(e) to maintain a register of land holders as published by the revenue department;

(f) to prepare and maintain a register of co-opted members;

(g) to prepare and maintain an inventory of the irrigation system within the area of operation;

(h) to monitor flow of water for irrigation;

(i) to resolve the disputes, if any between the members and water users in its area of operation;

(j) to raise resources;

(k) to maintain accounts;

(l) to cause annual audit of its accounts;

(m) to assist in the conduct of elections to the managing committee;

(n) to maintain other records in manner as may be prescribed;

(o) to abide by the decisions of the distributory and project committees;

(p) to conduct general body meetings in such manner as may be prescribed;

(q) to conduct regular water budgeting ;

(r) to conduct periodical social audit in such manner as may be prescribed;

2.3 Working of WUA's

There are several studies carried out in past by several researchers on Water Users' Associations and their role all over the world.

Pant (1999) shows that the management transfer to the WUAs in Maharashtra is terms of area expansion under irrigation as well as water use efficiency. The WUAs have considerably improved the recovery of water charges thereby bringing revenue to the government. Moreover, by charging higher amount from the water users, the WUAs have accumulated funds for the maintenance of their microstructures and continue to survive and thrive even after management subsidy of the government has ceased to exist.

Sinha (2000) discussed farmer's participation in the Partapgarh sub project of the Uttar Pradesh Sodic Land Reclamation Project in India. The project aims to develop appropriate water-management strategies, including drainage infrastructure, with farmers' participation. The survey confirmed that because the farmers' association would not be able to sustain drainage activity alone, farmers in the pilot sub-project should be organized under canal water management, with drainage as an additional function.

Chandran *et al.* (2001) had quantified farmers' participation through Water Users' Associations (WUAs) under Command Area Development Programme (CADP) in Malampuzha Irrigation Project, Kerala State. The study has shown that only about 30 percent of participatory activities envisaged for

WUAs were being undertaken by farmers and hence participation is low. Most of the activities undertaken were related to irrigation water management. Activities such as consolidation of landholdings, group farming, adoption of suitable cropping pattern etc., were not carried out most of the WUAs. Farmers were found to contribute money/ labour for maintenance field channels constructed by CADA in order to ensure water availability. However, a system of farm channels for carrying out scientific on-farm water management through channel to field irrigation and Rotational Water Supply (RWS) does not exist for majority of the WUAs. Location (reach) of WUAs on the canal network was not found to influence farmer participation since water scarcity was not a problem in the different reaches. However, landholding size was found to influence participation.

Mollinga *et al.* (2001) studied the implementation of participatory irrigation management in Andhra Pradesh. He reported on the impact of the introduction of participatory irrigation management in two secondary canals (distributaries) in the Tungabhadra Right Bank Low Canal irrigation system. A significant amount of physical rehabilitation works had been undertaken resulting in a water distribution so far as it did not lead to increase in irrigation area. It was suggested that the lack of demand for policy reform was a feature not exclusive to Andhra Pradesh.

Wahaj (2001) studied the performance of irrigation system in Fordwah Irrigation system in Pakistan. Six water courses along the two distributaries at the tail of the system were selected for in-depth study. Collective and individual water management actions were studied to understand their dynamics and their impact on improving water delivery to the farm. The study suggested that there was neither a standard set of water management activities nor there was strict plan. Farmer's actions were mostly subjected to their desires to match water demand with supply. However, one could still see some of the water management activities that were inevitable to operate the system. Collective action was undertaken more at the watercourse or higher level in the irrigation system, whereas individual actions were mainly undertaken at the farm level. Main finding of the study were, farmers were knowledgeable and capable actors who took actions that improved water supply and compensated for dysfunctional delivery; farmer’s actions were not only technical and economically sound but also motivated other than just economic benefit; farmer’s management could be classified as contingent management and rather it was performance oriented; and performance indicators, which were not able to show realities of social relations shaping water availability could be improved by including criteria to performance of irrigation system from the perspectives of different actors. Patterns of conjunctive water use at the farm level suggested that in the future groundwater must continue to provide significant amount of water for crop production.

Chandrasekaran *et al.* (2004) studied participatory irrigation management for efficient water use and enhanced rice productivity in Tamil Nadu. They reported the result of community based on-farm irrigation management trials. Experiments were conducted during 1992 - 97 at two different sites of the Cauvery delta Zone, to determine the requirements and benefits of improved irrigation management. Treatments included continuous flooding (control) and improved irrigation management (intermittent). Improved irrigation management reduced water use at the head and middle reaches and spared more water for farmers at the tail-end compared with the control. Under the control treatment, an inadequate water supply at the tail-end area led to low rice yield, whereas the improved irrigation management permitted judicious use of water by the farmers and resulted in increased rice yield by 40 per cent at the head, middle and tail-end areas. Results indicated that farmers in an irrigation system could increase crop productivity through the judicious management if irrigation water and equal sharing of water from the head to tail-end area.

Hooja (2005) described water user association as a parallel or lower than panchayati raj which is considered as third tier of India’s federation, which has to operate, manage and maintain the canal system. In India WUA’s functions are preparing and implementing a warabandi scheduling, planning and implementing the maintenance of irrigation system, regulating the use of water and water budgeting. WUA’s main aim is to increase water productivity in command area development.

Reddy and Reddy (2005) studied the Water User's Associations (WUA's) in Andhra Pradesh. They observed that though substantial amount of money were spent on the reform process, money was mainly for improving the ailing irrigation systems rather than strengthening formal institutional structures. Despite the fact that WUA's were promoted as non-political institutions, elite captured the system and political involvement dominated their functioning. Devolution of powers to WUA's had not taken place, as most of the important functions like assessment, collection of water charges and sanctioning of works remained in the irrigation department.

Mini (2006) carried a study on water user association and irrigation management with special reference to environmental problems. There were two villages selected in Tungabhadra Left Bank Canal, Gundur (With WUA) and Hagedal (without WUA). WUA's parameters studied were irrigation management, water distribution, reason of violation of cropping pattern and unauthorized cultivation, production of grains in terms of higher yield and higher value crop, cases of water-logging, salinity and range of strategies currently used to manage them.

Karatas *et al.* (2007) determined the irrigation performance of Sarigol, Ba and Uzum WUAs in the vicinity of Ssrigol and Alaflehir using remote sensing techniques. The performance of the irrigation system for the 2004 irrigation season (May to September) was determined according to 5 indicators, namely overall consumed ratio (ep), relative water supply (RWS), depleted fraction (DF), crop water deficit (CWD), and relative evapotranspiration (RET). According to the seasonal average values of all the performance indicators, the irrigation performance of all WUAs was usually poor and only the depleted fraction indicator for Uzum WUA was within the range of acceptability. Thus performance indicators showed that less irrigation water was supplied to WUAs than needed.

Puranik (2008) described that WUA perform different functions namely increasing agro-economy and socio-economy of farmers, determine reason of poor utilization of irrigation potential, iniquitous and unreliable supply of water and system deficiency. Construction focused approach of water resources development causing neglect of operation and maintenance of irrigation system.

Cakmak *et al.* (2009) evaluated the irrigation system performances of the Water User Associations in Asartepe irrigation scheme in Turkey. Financial performance, productive performance and water delivery performance were determined. From the result, it was concluded that Asartepe irrigation association is successful in decision making on system development.

Kazbekov *et al.* (2009) evaluated the performance of Water User Associations (WUAs) located in Osh Province, Kyrgyzstan using indicators of adequacy, efficiency, dependability and equity for each irrigation season over the period 2003 to 2007. In general, all WUAs were found to be strong in terms of adequacy and efficiency standards. However, performance with respect to dependability and equity was poor. The results suggest that more effort is needed to improve temporal uniformity and equity in water distribution. The study concludes that the establishment of WUAs in Kyrgyzstan has helped to address the problem of water distribution and allocation among a large number of farmers. The finding of this research suggests that application of a predetermined set of indicators can be a useful and cost effective tool to measure the performance of WUAs. The study identified uncertainties in the estimation of WUA water demands based on previous methods and suggests more attention and required in calculating water requirements.

Basnett *et al.* (2011) performed a social assessment of the irrigation users of the Rani, Jamara and Kulariya system using two components. The study completes the development of a socioeconomic profile of the project, map out stakeholders in the project area, assess various social, economic and political factors that play in the design and implementation of the project and assess likelihood of the social impacts of the project. On the basis of the social assessment finding, it develops necessary interventions and mitigation strategies under the project in line with relevant government and World Bank requirements.

2.4 Performance of WUA through farmer's survey

Koc *et al.* (2006) assessed the impact of water users related to management-operation and maintenance services carried out by Water Users Associations in Great Menderes basin irrigation schemes. A survey was carried out using the random sampling methodology in order to investigate the opinion of water users. A questionnaire considering five different topics was used to analyse the management, operation and maintenance performance of the WUA's. The users' general opinion is that the turnover of the irrigation infrastructure to the WUAs has had a very positive impact.

Namboodiri *et al.* (2006) studied Surface Water Institutions in India. They analysed the performance of local level water user associations and irrigation co-operatives. The study covered 150 farmer respondents under the canal co-operatives, 100 from Gujarat and 50 from Maharashtra and 100 WUA's from Andhra Pradesh. Tobit Model was adopted to study the impact of the institutions on maintenance, equity within the structure of the institution and the rules followed for equitable water distribution. The study showed that the role of government dominated as regards to pricing of water and actual release of water for irrigation. On the other hand the institutions played a major role with respect to planning for capital investments, actual release of water for irrigation, collection of dues from farmer members and monitoring the use of water. The respondents partially agree or disagreed that those institutions had rigid rules or regular review of the rules. The respondents strongly agreed that they were aware of the rules and the management had enough power to bring compliance to the institutional objectives as well as the ability of the institutions to ensure fairness and justice to its members.

Gosh *et al.* (2011) assessed the performance of WUA from the farmers perspective through a questionnaire survey of 75 farmers (15 farmers selected as respondents from each of the five WUAs vis. WUA1, WUA2 and WUA4 under left distributary and WUA6, and WUA7 under right distributary) taking farmers responses on a total of 20 parameters related to issues like participation, operation and management, financial management and organizational linkage on a 5 point continuum scale. WUAs performance with respect to operation and management and organizational linkage is found better (score > 3.0) as compared to participation and financial management. Water management by the WUAs (WUA1 and WUA6) in head reach is found to be poor with score < 2.0 especially with respect to the efforts to save water. It is interesting to note that performance of WUAs in head reach is relatively less effective as compared to middle and tail reach as head reach always faces fewer problems related to irrigation service to the farmers.

Yakubov (2011) stated that irrigation performance important tools that irrigation service providers at various levels of the water management hierarchy can use for monitoring, benchmarking and self-improvement. Attempted was made to explore and sensitizing farmers views about irrigation service and related performance dimensions using qualitative research methods. Based on focus group discussions with a purposive sample of farmers from a range of water users associations in Central Asia and a grounded theory approach the study lays a conceptual foundation for future practical applications.

Phadnis and Kulshrestha (2012) evaluated the efficiency for WUAs of irrigation project Samrat Ashok Sagar (Halali) in India, using benchmarking by data envelopment analysis as the performance evaluation tool and to integrate the outcome of the benchmarking process for planning, design and effective management of available water resources. In the analysis the gap was compared with the scheme. The performance gap and the action required for closing the performance gap were explored. It is evident that considerable variations occur amongst the various WUAs in terms of the operational characteristics reflected by the independent variables.

2.5 Performance Indicators

Choice of performance indicators and some of the issue that emerge in using them, starting with the irrigation water delivery, sub-system bio-economic and social organizational sub-system then moving up to the irrigated agriculture system and the agriculture economic system.

Reddy (1986) stated that the performance of an irrigation project can be measured in terms of technical efficiencies with which the water was provided to the crop root zone, total agricultural production from the project and the equity. Performance of an irrigated agricultural production system is dependent upon technical, economic, institutional, and organizational support to the system under a given set of constraints.

Upadhyay *et al.* (2004) compared the performance of head, middle and tail reaches of the Patna canal command area. Canal using performance indicators such as output per unit command, per unit cropped area, per unit water consumed and actual water duty, water delivery capacity, relative water supply. The study also highlighted the attempt to adequacy, equity, timeliness, reliability, regularity and dependability of head to tail reach from 1954.44 ha/m^3 to 844.77 ha/m^3 and there is a large gap between actual water released indicate and irrigation requirement in canal command area.

Nelson (2002) studied performance indicators for irrigation canal system managers of water users associations. Indicators as tail-end ratio, area uniformity, delivery timeline's ratio, carrying capacity ratio, poor structure ratio, fee collection performance, maintenance budget ratio, personal cost ratio, manpower number ratio, financial self-sufficiency, sustainability of irrigated area, relative groundwater depth and area/infrastructure ratio were used.

Thakur (2005) evaluated irrigation performance of the minor irrigation project of Mehgawan Tola command area, on the basis of Physical, Bio-economical, and Social indicators. It was found that the overall irrigation efficiency was 67.3%and seepage rate was 5.12 cumec per square million sqm. of wetted perimeter of the canal.

Patidar *et al.* (2007) evaluated the performance of minor irrigation project of Mehgawan Tola command area. They reported that overall project irrigation efficiency decreased from head to tail reach of the command area. They found irrigation efficiency were 75.36%, 69.80% and 62.59% at head middle and tail reach respectively.

Chouhan (2009) studied the performance of Initial reach of Left Bank Canal Network of RABSP location in Madhya Pradesh, using physical indicators, bio-economical indicators and social organizational indicator. Analyses of physical performance showed that overall efficiency were decreasing from head reach to tail reach. Bio-economical performance indicators showed that production depends upon proper irrigation and water availability.

Jadia (2009) described the various techniques/tools used for performance assessment of the water resources projects. Nine minors of Itiadoh project have selected and applied the performance indicator. The indicators are divided in four categories which are System performance, agricultural productivity, financial aspect and environmental aspect.

2.6 Physical Indicators

Biswas (1984) described a list of parameters, which was monitored in relation to the operation and maintenance of irrigation projects. Table 2.1 shows the factors that influence performance of the irrigation delivery system.

Table 2.1 Factors influencing performance of delivery system

Factors influencing the performance of delivery system	
Planning	Cropping pattern (crop water requirements) equity, Layout of command area, Channel design, Rotation, continuous or on-demand
Design	Seepage losses, design discharge, depth of flow, Location, type and size of structures, section parameters (shape, size, roughness. slope)
Operation	Timing of operation, skills of the operator, communication related to supply and demand
Maintenance	Structure

. Bos and Nugteren (1990) presented the most widely concepts and definitions of irrigation efficiencies. They divided the overall project efficiency into various components so that the efficiencies associated with different components of the water delivery system-conveyance, distribution, and field application can be separately stated.

Goldsmith and Makin (1991) described the performance of warabandi system in India, Punjab and illustrated some of the practical aspect of carrying out a rapid performance assessment. They observed conveyance efficiency was of 53 per cent at time of study, however anticipated the same to fall to 42 per cent without improved maintenance.

Tyagi *et al*. (1992) concluded that the utilization efficiency of canal water in a monsoon climate is generally low, unless conjunctive use of other water resources (i.e. groundwater) is possible. A demand/supply decision model was formulated to aid in planning the optimal use of canal and groundwater with a view to improving this efficiency. The model was applied to a typical, watercourse command in the Bhakra Canal Project in Haryana, India. It indicated that the canal-water utilization efficiency could be improved from the existing level of 72 per cent to 95 per cent, if 70 per cent of the groundwater potential were developed. Nearly 98 per cent utilization efficiency could be achieved at 85 per cent development of groundwater potential.

Das *et al.* (1992) suggested the performance evaluation parameters of irrigation canal systems should involve factors such as command area, canal network, control structures, cropping patterns, weather conditions as well as human factors. Appropriate tools are needed to predict the possible outcomes of operational decisions. An integrated simulation and optimization approach is proposed to improve the irrigation delivery system operation and management strategy. This will help in providing optimal water levels in the main system, which in turn will guarantee proper flow diversion to laterals and farm turnouts.

Nihal (1992) suggested that best indicators and measures of irrigation water delivery performance are those that can be used both as evaluators of post-irrigation season performance and as management tools to keep track of the water delivery performance during an on-going season. Although, the 'Relative Water Supply (RWS)' variable has many advantages over the conventional 'Water Use Efficiency (WUE)' for evaluating water delivery performance, it encounters computational difficulties when used to assess performance of rice irrigation over short periods of time. This weakness can be overcome by using the Cumulative Relative Water Supply (CRWS). Both the RWS and CRWS can then be used jointly to assess the performance. Besides, CRWS can be used as a convenient management tool to keep track of water delivery of a channel or a subsystem. The CRWS also lends itself to identify where the irrigation supply is inadequate or inequitable or both in an irrigation system so that the necessary interventions and remedial measures can be applied.

Kaushal *et al.* (1992) considered equity (uniformity of water distribution), adequacy (ratio of seasonal supply and demand) and productivity (timing and quantity of water) as the criteria parameters of irrigation system performance, diagnostic analyses were performed for unit command areas of the Bhakra Canal System in Haryana. Low values of performance indices were due to improper unit command area and stream sizes, temporal mismatch between demand and supply and the rigid frequency schedules. Introduction of auxiliary storage, intra- and inter-seasonal changes in fixed frequency schedules to reduce the mismatch and improved design of unit command area size with consideration for soil characteristics would improve performance.

Van-der-Velde *et al.* (1992) conducted detailed studies of canal operations to investigate equity in the distribution of irrigation water on three distributaries in the Lower Chenab Canal system in Punjab Province, Pakistan. The studies were located in the Mananwala and Lager Distributaries off-takes in the head reach of the Gugera Branch Canal, and in the Pir Mahal Distributaries at the tail of the branch. Flow conditions for these distributaries and of selected outlets served by each were measured daily throughout 1988, and data were converted to discharges. These field observations show that discharge variation at the head of distributaries greatly exceeded the original design criteria. The data also indicate that two design assumptions for outlets - continuous full supply water level in the distributaries and outlet modular flow conditions-are no longer valid. Field measurements confirm that the distribution of surface water among the outlets of all three distributaries is substantially inequitable. Outlets in the head reaches of these channels commonly draw 3 to 6 times greater share of total supplies than tail outlets. Although all three selected distributaries are perennial canals, some outlets remained dry for up to 90 per cent of the annual total operational days. Finally, evaluation of field data also shows that better operational procedures at the distributary level can substantially improve water supply conditions in the tail reaches.

Sharma and Rao (1997) evaluated Paladugu major distributary in the Nagarjuna Sager Right Canal Command Area in Andhra Pradesh since 1980 in terms of water supply requirement ratio and other indices such as irrigation intensity, crop productivity and cropping pattern. A comparison with the performance of the system in the year before the scheme was introduced revealed that scheme effectively led to sustained increase in the irrigated area and irrigation (by > 25%) resulting in increased crop production. Yield of paddy and cotton went up by more than 100%.

Tyagi (1998) studied the performance of irrigation system (Fatehabad Branch of Bhakra Canal system in Haryana) at farm as well as watercourse level. Equity (in terms of uniformity coefficient and modified inter-quartile ratio), adequacy (in terms of relative water supply) and water productivity, which reflected both adequacy and timeliness, were evaluated. The equity of water distribution decreased with the size of the watercourse (flow rate). The average relative water supply (ratio of water supply and water demand over a period of time) was observed to be 0.72 in summer and 0.65 in winter at the head reach and 0.58 in summer and 0.50 in winter at the tail reach of watercourse. This clearly indicates the insufficiency of the available canal water supply to meet the demands. The significant reduction in relative water supply towards the tail end is due to seepage losses occurring in the watercourses.

Molden *et al.* (1998) defined set of comparative performance indicators which relates outputs from irrigated agriculture to the major inputs of water, land, and finance. Nine indicators were presented with the objective of providing a means of comparing performance across irrigation systems, namely, Output per cropped area, Output per unit command, Output per unit irrigation supply, Output per unit water consumed, Relative water supply, Relative irrigation supply, Water delivery capacity (per cent), Gross return on investment (per cent) and Financial self-sufficiency. These indicators require a limited amount of data that are generally available and readily analyzed.

Unal *et al.* *(*2003) reported on water delivery performance of the Menemen Left Bank Irrigation system in the west of Turkey. Performance evaluated at tertiary canal level, using the adequacy, efficiency, dependability and equity indicators. The water delivery performance to the territories in each irrigation season rated worse for adequacy, dependability and equity then for efficiency. The indicators showed that factors causing the problem derived in part from physical and from management.

2.7 Bio - economical Indicators

Tripathy (1984) suggested the principal objectives of (i) increasing the utilization of irrigation potential in selected major and medium projects (ii) raising productivity per unit of irrigated land through adoption of proper land, water and crop management; and (iii) making an equitable distribution of irrigation water between different size holding classes of farmers in various districts of the command areas. Analyses made both before and after and using with and without approaches indicate substantial changes in productivity, specifically in cereal crops.

Bhatti *et al.* (1991) Studied Irrigation performance in Pakistan has been cited for its low productivity in comparison to other countries with large proportions of irrigated area. These comparisons are usually on the basis of yield/unit area of wheat and rice, and conclusions based on them suggest major opportunities for improved performance through improved system operation. However, comparisons made solely on this basis reflect an inadequate understanding of the realities of irrigation in water scarce environments such as Pakistan and the conclusions can be misleading. Yield per unit water is a complementary and sometimes more appropriate measure. Yields in Pakistan are influenced both by the amount of water supplied to the farmers and by the economics of producing the major crops. This paper illustrates how Pakistan's irrigated wheat and rice production can be more appropriately evaluated using yield per unit water assessments.

Sisodiya (1992) evaluate the performance of “warabandi” (fixation of turns) system of management in Chambal command area of Madhya Pradesh. As a result of the introduction of Warabandi programme, irrigation ratio increased from 40.19 percent 1981- 82 (before Warabandi) to 87.39 percent in 1986 – 87. A steady increase in the irrigated area was observed during the implementation period of six years. The judicious use of water by the cultivator thus resulted in the larger coverage of the irrigated area. Farmer in the head and middle reaches showed stronger inclination to grow double crop then the tail-enders. The study further indicated that after the introduction of Warabandi the cropping pattern titled towards non-food grain which wear remunerative to the farmer.

Hasan and Degirmenic (2003) evaluated irrigation performance on the basis of six comparative indicators. They found output per unit cropped area in the order of $1223 - 9436 ha^{-1}, output per unit command $308 - 5771 $ha^{-1,}$ output per unit irrigation supply $0.12 - 2.16$m^{-3}$, output per unit water consumed $0.45 - 2.92 m^{-3}, relative water supplies 1.0 - 5.90, irrigation ratio 7 - 100 per cent.

Thiruchelvam (2004) evaluated the economic effects of recently completed Irrigation Management Transfer (IMT) to Distributory canal Farmers Organizations (DCFs) in Mahaweli system. Economics effects measured include value of water productivity and equity, agricultural productivity and profitability, financial viability and social implication. Result indicated that the water productivity is increased by 33 per cent.

Wilson *et al.* (2004) provided an integrative perspective of the most common whole farm physical and financial performance indicators and benchmarking practices used in Eastern Australia. The review is organized using a whole-farm family centered approach rather than an enterprise oriented approach. Available information from leading farm business consultants and related researchers has been brought together and the most commonly used physical and financial performance indicators are highlighted. Complementary comments are inserted aiming for an in-depth review of this issue; and the setting of new development proposals to strengthen farm business education, research, consultancy and extension.

Lecina *et al.* (2004) studied surface Irrigated District of the Bardenas Canal (Zaragoza, Spain) and evaluated. Alternatives were assessed to improve on-farm irrigation performance. Field work consisted of a soil survey and a campaign of irrigation evaluation. Shallow soils, a limited conveyance network, and poor irrigation management practices determine that the application efficiency in the district is low, with an average of 49%. The district wide irrigation efficiency only reaches reasonable values when the system operates under water scarcity (49% in 2000 versus 66% in 2001)

Yavuz *et al* (2006) was studied performance evaluation of water users associations in seyhan basin. Eight performance criteria namely standard gross value of production (SGVP) per unit of scheme command area, SGVP per hectare irrigated, SGVP per unit of water diverted, SGVP per unit of water needed, relative water supply, irrigation ratio, financial sufficiency ratio and fee collection rate were used to evaluate the 17 irrigation associations Evaluation was done on two aspects first production per unit area, per unit water other is water supply and expenditures involved.

2.8 Social-Organizational Indicators

Svendsen and Small (1990) presented comprehensive framework for conceptualizing irrigation performance by clarifying relationships among the many approaches to performance assessment, a basis for more systematic comparative assessments of irrigation is provided. The relationships of irrigation systems with broader agricultural and socioeconomic systems are specified in terms both of goals and of inputs and outputs. Goals are seen as crucial to performance assessments and the existence of many sometimes conflicting goals requires some clarification. Assessments can be categorized according to the goals, e.g. monitoring operational performance, improving performance or promoting accountability. Three distinct categories of performance measures are identified: process measures, which relate to a system's final output and impact measures, which pertain to the effects that the system's outputs induce in its larger environment. Performance measures are distinguished from performance standards.

Parker (1992) summarized some findings from several different IIMI studies in Bangladesh. Three of these have focused on command area utilization, yield, and equity under various irrigation systems or management changes. Another study has concentration on irrigation fees in all of the systems. In all studies the role of farmers and farm managers (or owners) in making decisions, in cooperating (or not), or in just reacting to the opportunities created by the action of others has been included. Farmers were Involved in the operation of the Ganges-Kobadak rotation scheme to contribute to the success of the programme. In the Rajshahi area, most well are dominated not by the irrigation agency but by one farmer or a group of farmers, who are de facto owners. It is these farmers' managers, in reaching to the opportunities before them, who determine the irrigation performance of their tube-wells. In the case of fee collection it again seems to have been farmers involvement in fee setting and collecting that has helped determine success or failure.

Gowing and Awad (1992) concluded that irrigation systems can be assessed as a combination of three indicators: predictability, convenience and tractability. Direct measurement of these indicators at field levels is generally not feasible and an alternative approach is proposed utilizing fuzzy set theory. The procedure can be seen as a rapid appraisal technique. The usefulness of the approach lies in its agility to gather data in imprecise terms from individual farmers to aggregate them rationally and objectively.

Samad *et al.* (1992) considered current state of irrigated agriculture and the contribution of irrigation to food production and the alleviation of poverty for the more water delivered per unit area than is required, which leading to low irrigation efficiencies. In many systems the actual irrigated area is less than the area commanded. Inequalities exist in water supplied to farmers in the head reaches and those downstream. Lack of maintenance has inhibited irrigation performance. Future trends in irrigated agriculture are discussed

Rao (1993) studied and suggested for using limited number of performance indicators for social viability and proposed two types of indicators "social capacity" and "social impact". Social Capacity in Response capacity, Farmers involvement in system management, Effectiveness of farmers organization, and Ratio of knowledge. Social Impact in Farmers satisfaction, Employment generation, and Quality of housing.

Rieser *et al.* (2000) studied socio-economic aspect of the irrigation system at phitsanulok Irrigation system in northern part of the central plain of Thailand, a system with an irrigated area about 100 ha, mainly paddy. The performance indicators suggested by using secondary data. In which they used to assess the socio-economic performance of the irrigation system such as farming system their household structure as well as the roll of irrigation for on farm performance.

Gulati *et al.* (2002) identified factors affecting organization and collective action among water users in major canal irrigation system in India. They concluded that water user's organizations increased the likelihood of collective maintenance work by farmers, but did not the likelihood of collective representation, or lobbying activities, which seemed to happen more spontaneously.

Ray and Williams (2002) studied and reported on illegal water diversion irrigation canal calibrated to a canal in Maharashtra on which farmers voted to cooperate to control water theft. The solution of the crop choice and profits of individually optimizing farmers who differ in their location. It reveals the spatial distribution of gain and losses from cooperation. It illuminates why voluntary bargaining will rarely achieve an efficient water allocation.

Satyal *et al.* (2006) conducted a study to examine the dynamics of water scheduling in a farmer managed irrigation system in a small mountain watershed (Tharigad) of the central Himalaya. Despite being ancient, these systems perform at high project irrigation efficiencies because of the proper water scheduling managed by the local community. These water distribution schedules functioned smoothly until recent times and helped the farmers to meet irrigation needs during the crucial period of crop germination when other areas of the region suffered water crises. The distribution of water was decided by an irrigation committee on the basis of the area to be irrigated and the distance of the village from the source. The studies revealed that with public participation the performance of irrigation system can be improved.

2.9 Improving water productivity

Molden *et al* (2003) carried out a study on water productivity framework for understanding and action. Water productivity depends on several factors like crop genetic material, water management practices and agronomic practices. There are two ways for increasing the productivity of water, deplete more available water supply for beneficial purpose by reducing and converting into beneficial purpose and produce more output per unit of water deplete (Kg per m^3). Three types of scenarios were reported to maximize the productivity of water, reducing in overall water supply, change in incentives associated with farm level water management and desire to increase farm level profitability.

Trivedi and singh (2004) worked on impact of quality and reliability of irrigation in field and farm level water production of crops. The irrigation quality index was higher for well irrigated fields as compared to canal irrigated fields and fields irrigated by both wells and canals in Skohpur and canal irrigated fields for most crops in Changarwan. The fields, which received irrigation water of higher quality and reliability got higher water productivity in rupee terms.

Reddy (2005) reported the impact of water management on production of rice in Balipatna command area of Orissa, India. The results indicated that irrigation through field channels had positive impact on the yield of kharif paddy. The variables like application of fertilizers, irrigation cost, seed and labour cost had significant positive impact on the paddy yields. The marginal productivity of inputs indicated fertilizers and seeds are not efficiently utilized as compared to other inputs.

Palanisami *et al.* (2006) reported in their studies on water productivity at different scales under canal, tank and well irrigation systems. It was clearly understood that there was a considerable reduction in water productivity under field level as compared to individual plant/crop level mainly due to losses through seepage, deep percolation and runoff in the canal irrigation systems.

Tiwari (2008) productivity of water is sum of the net multi-sectoral benefits per unit of water used in the river basin. Three basic thrust area addressed for improving the productivity of water are improving the institutional landscape, ensuring the efficient delivery system and following the management techniques. At system and river basin level, options for improving water productivity included better land use planning, use of medium term weather forecast, improved irrigation system and scheduling and use of various source of water.

Chandra *et al.* (2008) have worked on variations in groundwater use, water productivity and profitability across a canal command in the Indo-Ganagetic Basin, at the farmer field level in the command area of Pabnawa minor (tertiary canal) of Bhakra irrigation system. The groundwater contribution in the canal command was very high. Water productivity increased from head to tail due to wastage of canal water upstream and judicious use of groundwater at the tail end. Farmers practicing conjunctive use have higher profitability than tube-well irrigators and canal irrigators. The cost of water increases from head to tail, but because of the flat rate charge for electricity there is only a small difference in the costs of water for paddy and wheat.

2.10 Conclusion

After reviewing the literature for WUA's working and parameters used for evaluating the performance of irrigated commands as well as organizational efficiency it has been found that there is a lot of variation in selecting the parameters of performance evaluation. They depends on the data availability, aim of evaluation, requirement of the project and personal capability of dealing with the most learned community of farmers. It was the nature decided to undertake such parameters which will indicate the working and success of WUA's. Finally the water productivity may be considered an indicator of achievement of the WUA's, which shall vary spatially with respect to different location in canal head, middle and tail or in different command areas.

MATERIALS AND METHODS

3.1 General

Performance assessment of a command area has been focused on internal processes of irrigation systems. The type of performance measures chosen depends on the purpose of the performance assessment activity. It is useful to consider an irrigation system in the context of nested systems to describe different types and uses of performance indicators. Many internal process indicators related to assess performance of any irrigation system were analyzed. This chapter deals with the steps involved for performance assessment and procedure adopted for collection of data and their analysis for achieving the specific objectives.

3.2 Location of study area

The area selected for the present study is command area under three WUAs at their locations in Madhya Pradesh. They are Bijori WUA in Jabalpur district, Bauchhar WUA in Narsinghpur district and Govindgarh WUA in Rewa district (Fig. 3.1). Bijori and Bauchhar WUAs are a part of Left Bank Canal of Rani Awanti bai Sagar Irrigation Project and Govindgarh WUA is under Govindgarh tank.

The command area of L.B.C. lies between the 22^{o}52\`0\`\` to 23$^{o}$26\`30\`\`N latitude and 78^{o}45\`0\`\` to 79$^{o}$54\`0\`\` E longitude. The command area of Bijori WUA lies between the 23^{o}2\`27\`\` to 23$^{o}$4\`45\`\` N latitude and 79^{o}41\`35\`\` to 79$^{o}$42\`5\`\` E longitude (Fig. 3.2), command of Bauchhar WUA lies between the 22^{o}94\`73\`\` to 22$^{o}$98\`75\`\` N latitude and 79^{o}35\`54\`\` to 79$^{o}$28\`63\`\` E longitude (Fig. 3.3) and Govindgarh WUA command lies between the 24^{o}38\`15\`\` to 24$^{o}$41\`24\`\` N latitude and 81^{o}28\`0\`\` to 81$^{o}$28\`43\`\` E longitude (Fig. 3.4).

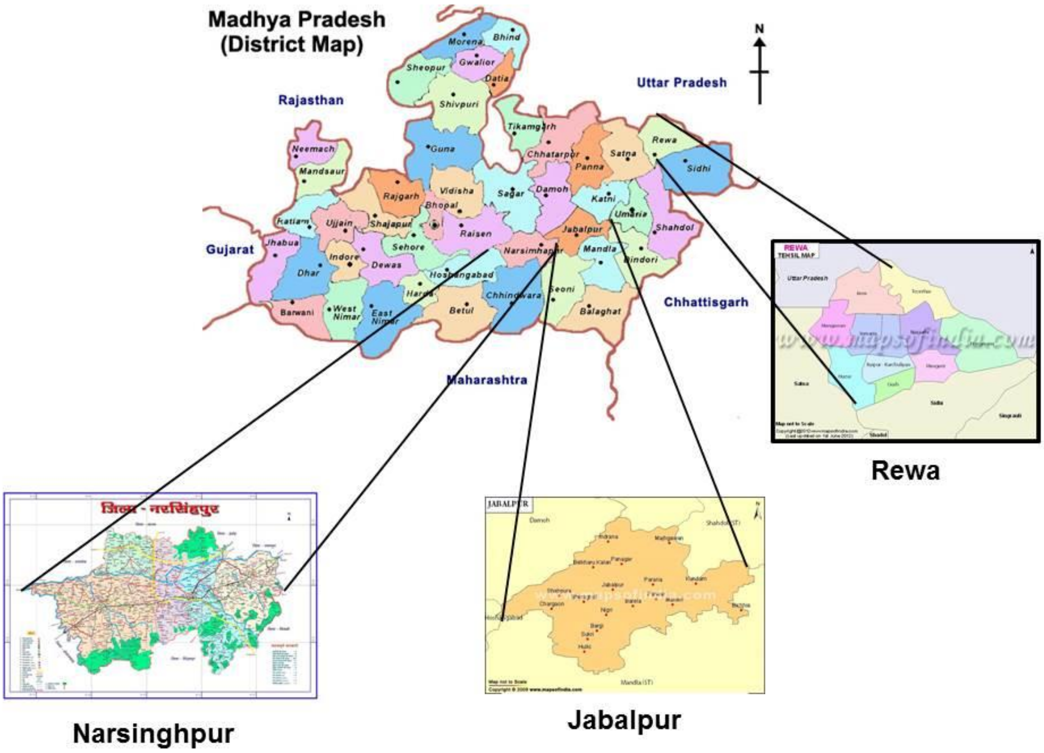


Fig. 3.1 Location map of study area in Madhya Pradesh.

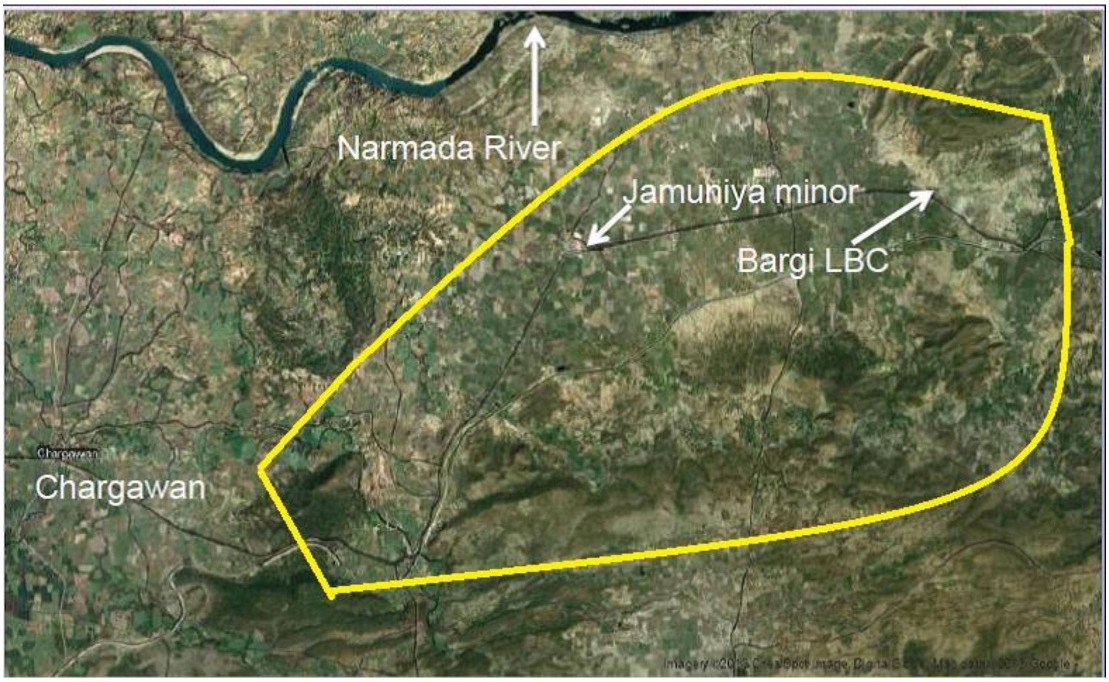


Fig 3.2 Command area of Bijori WUA under LBC of Bargi project in Jabalpur district.

Fig 3.3 Command area of Bauchhar WUA under LBC of Bargi project in Narsinghpur district.

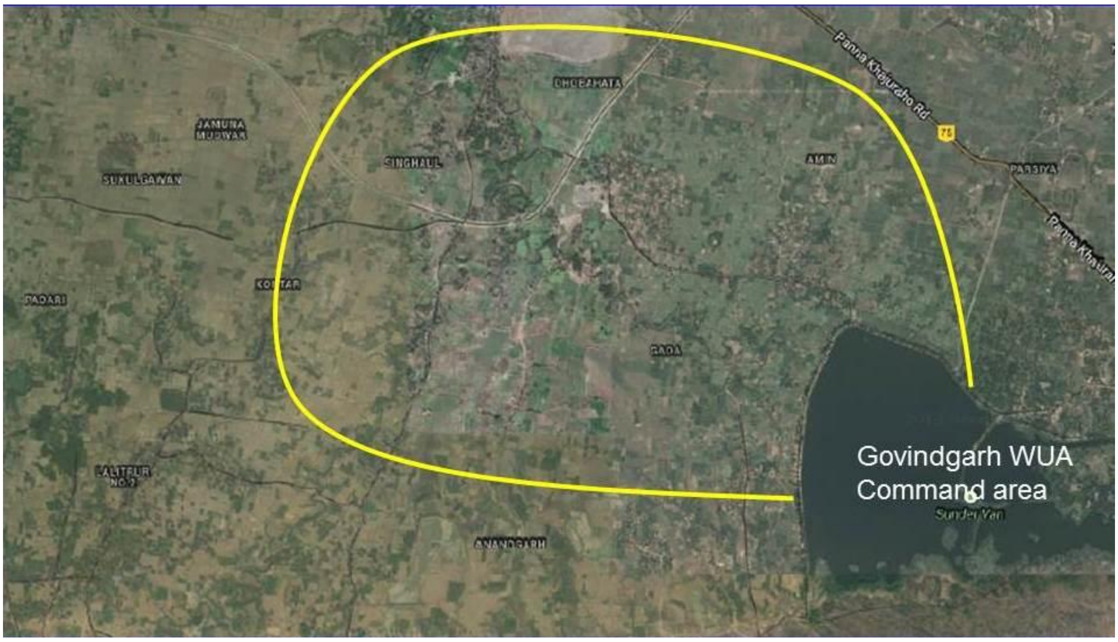


Fig 3.4 Govindgarh Tank and Command area in Rewa district.

3.3 Climate

The climate of the study area is subtropical monsonic characterized by an oppressive hot summer, high humidity and chilly winter. The temperature begins to rise rapidly from March till May, which is generally the hottest month.

The temperature data for these locations was collected from internet services. In Bijori WUA the average annual temperature is 25.7º C. The mean maximum temperature ranges between 25.8º C and 42.2º C and mean minimum temperature ranges between 9.2º C and 26.7º C. In Bauchhar WUA, the average annual temperature is 33.2º C. The mean maximum temperature ranges between 26.8º C and 42.5º C and mean minimum temperature ranges between 8.2º C and 26.1º C. and Govindgarh WUA, the average annual temperature is 25º C. The mean maximum temperature ranges between 21º C and 39º C and mean minimum temperature ranges between 8º C and 29º C. As the project area lies in hot zone, the variation in humidity is quite large.

3.4 Crops

The major crops grown in the area during rabi season are Wheat, Gram, Lentil, Pea, Arhar and some Vegetables crops and in kharif season the main crop is paddy. Information of sowing and harvesting of different crops, their duration and the cropping pattern of the study area were collected from the different sources including contacts with the local farmers and revenue records of the village

3.5 Water resource

Daily records of supply head in main canal were obtained from the Water Resources Department, Government of Madhya Pradesh. Based on cross sectional area, slope and outlet conditions, the discharge delivered to the command area was estimated. Operating hours of selected minor and the schedule of operation of the main canal during the irrigation season were observed to estimate the volume of water delivered to study area. Location of different fields, water courses, field channels, area irrigated and sources of irrigation water were also obtained from the records of the local irrigation authorities. Plate 3.1 & Plate 3.2 show main canal of three WUAs. Table 3.1 presents the area under irrigation in different WUA's. It also includes area irrigated by tube-wells.

Table 3.1 Irrigation in Command areas

S.No.	Description	Name of the WUA		
		Bijori	Bauchhar	Govindgarh
1	Gross command area(ha)	2082	1531	1840
2	Canal irrigated area(ha)	889	110	1120
3	Tube well irrigated area(ha)	960	190	362

Plate 3.1 Main Canal of Bijori and Bauchar WUAs

Plate 3.2 Main Canal of Govindgarh WUA

3.6 Data Collection

The data collection was carried out with the help of water resources department, district revenue department and meteorological department of JNKVV, Jabalpur. Few farmers and WUA presidents were consulted about the general condition of WUA's and irrigation project. Three WUA were selected for study and four farmers field were selected from the head, middle and tail water users of WUA command area, respectively to get the desired information. It included the following:

- Observations were made to record and investigate the method of application.
- Measurement of canal water discharge at head regulator and discharge from different outlets of head, middle and tail reach respectively as shown in Plate 3.3.
- Measurement of canal water flow at the different sections of main canal.
- Yield estimation of different crops in head, middle and tail reaches of WUA command area.
- The farmers under study area were divided into four groups i.e. marginal, small, medium and large. A questionnaire (Appendix A and B) was prepared and WUA and farmers from different reaches were interviewed.

Plate 3.3 Measurement of canal water flow velocity in head reach.

3.7 Survey of Water User Associations

A survey of water user association was conducted in three basins namely Narmada, Betwa and Tones basin. The districts covered were Jabalpur, Narsinghpur, Katni, Vidisha, Sager, Tikamgarh, Panna and Satna. 40 farmers distributed over 10 WUAs covered different irrigation project in above district where interview for knowing their working status, their operation and management of irrigation. The information was also collected regarding agitation of farmers, cooperation received by the farmers by different department, cooperation among the farmers, exposer of the farmers to modern crop technology's, awareness of the farmers for irrigation technics, working of WUAs in there commands and rights of the farmers about irrigation management.

Based on the information provided by farmers and the approach for the study area, cooperation expected from Water Resources Department, Cooperation expected Agriculture Department and responsive nature of the farmers. Bijori WUA near Gangai on Chargawan road under LBC command on Bargi Project in Jabalpur district, Bauchhar WUA near Karakbel in Narsinghpur district and Govindgarh WUA near Govindgarh Tank Project in Rewa district, where selected for conducting the project study for evaluation of Water User Associations.

Selected WUA's were surveyed and information was collected on Gross command area, cultivable command area, total number of structures, total number of damaged structures, water charges collection, expected water charges collection, total number of minors, total length of canal, total number of day water available in canal, total number of staff working in WUA, canal irrigated area, tube well irrigated area. This information was tabulated and analyzed characterises the WUA .All the information was collected with the help of questionnaire (Appendix A).

Table 3.2 shows number of minor and their length in different WUAs. Bijori WUA has nine minors in which Dulakheda minor is highest length of 3.21 km and Dabola minor has lowest length of 1.21 km. Bauchhar WUA has six minors with highest length in Karakbel minor (3.66 km) and lowest length in Basanpani mino (0.75 km). Govindgarh WUA with eight numbers of minors has Mohini minor with a length of 2.45 km and Nakta minor with lowest length of 0.90km.

Table 3.2 Length of minors in WUA.

Bijori WUA		Bauchhar WUA		Govindgarh WUA	
Name of minor	**canal length (km)**	**Name of minor**	**canal length (km)**	**Name of minor**	**canal length (km)**
Dabola	1.21	Basanpani	0.75	Govindgarh	0.87
Bicuva	2.41	Bauchhar-1	3.46	Parsiya	1.25
Nunpur	2.51	Bauchhar-2	1.34	Kapurhai	1.21
Chapra	1.22	Mekh	2.55	Nakta	0.90
Dulakheda	3.21	Karakbel	3.66	Mohani	2.45
Pipariya	2.21	Devri	2.64	Amin	1.46
Jhanshi	2.18			Dhobat	1.22
Jamuniya	3.19			Hardishankar	1.31
Badayakheda	2.32				

3.8 Farmer's survey

In order to assess the impact of introduction of canal irrigation on cropping pattern, intensity of cropping, land use and agricultural production, farmers were contacted personally to collect the desired information in proforma (Appendix B)(Plate 3.4).

Representative farmers from within the WUA command area as well as in the immediate vicinity were selected under different categories namely marginal, small, medium and large. Farmers were selected using stratified random sampling technique. Three farmers in each of four categories were selected in head, middle and tail reach of minors. Thus total 36 farmers were surveyed in each WUA area. The selected farmers were interviewed and the information on their agricultural practices, land use, crops grown, irrigation sources, irrigation practices were obtained. This information was tabulated and analyzed to determine the status of canal water use.

Plate 3.4 Collection of farmer information.

Fig. 3.5 shows distribution of farmers and area under different categories in Bijori WUA. Total number of farmers highest in marginal category is 40% of the total farmers but maximum area covered by small category farmers in Bijori WUA.

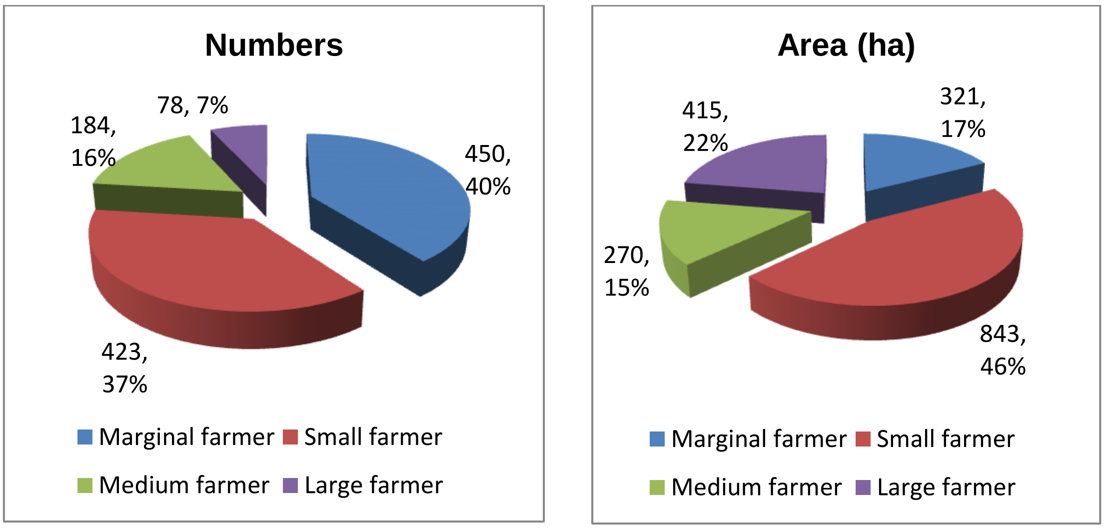
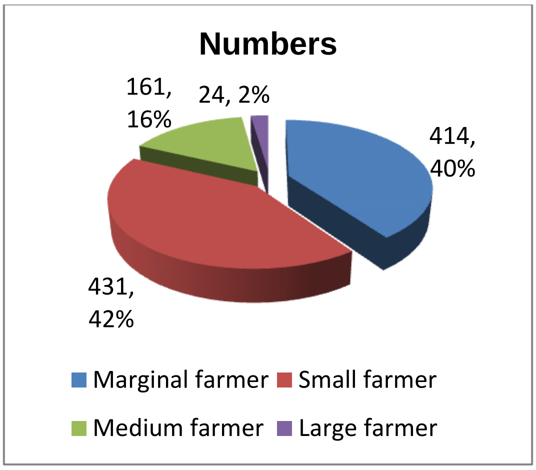


Fig. 3.5 Land holdings in Bijori WUA

Land holding distribution of Govindgarh WUA is presented in Fig. 3.6. Total numbers of farmers in marginal, small, medium and large category are respectively 431, 414, 161 and 24.



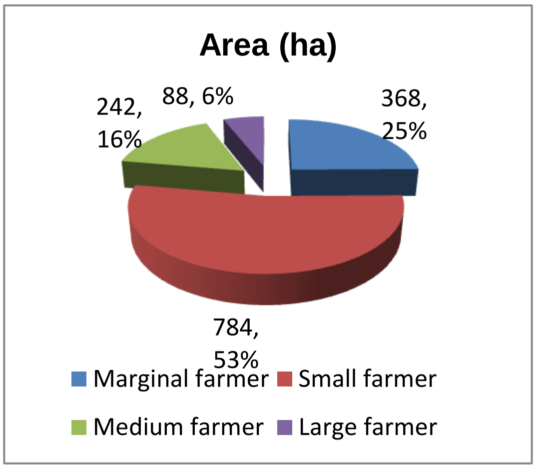
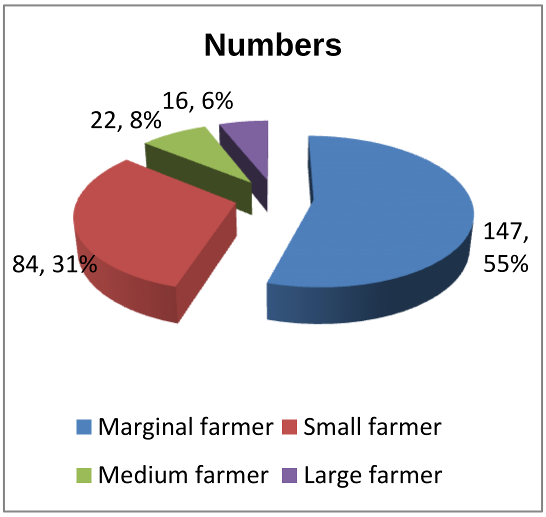


Fig. 3.6 Land holding in Govindgarh WUA

Fig. 3.7 present number of farmers and total area covered by marginal, small, medium and large farmer category in Bauchhar WUA. Marginal farmers are more in number as compare to other category and maximum area covered by small farmer category.



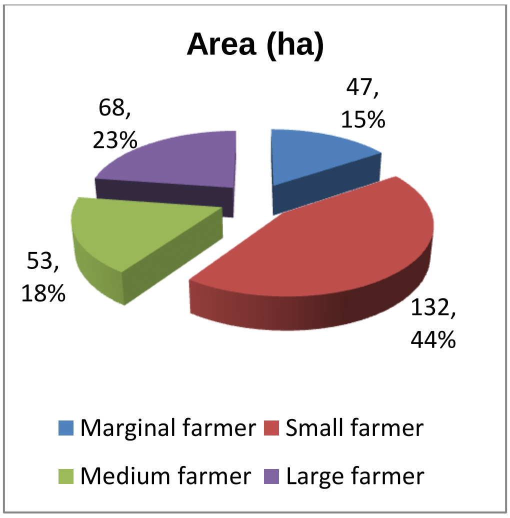


Fig. 3.7 Land holding in Bauchhar WUA

3.9 Field Observation

Field observations were recorded to determine the discharge of minor and field channel in different minors at different reach. Discharge of minors was estimates by velocity area method. Cross sectional area, velocity of flow and depth of flow were measured in the minors and canal. Cross sectional area was measured at three locations and averaged for head, middle and tail reach of each minor. Depth of flow was measured directly by depth gauge in the stream. Velocity of flow was measured with the help of current meter in main canal and minors, where as float area method was applied in field channels. The details regarding the area of cross section, depth of flow and velocity in minors and field channel obtained from the measurement along with the location are presented in Table 3.3 to Table 3.5. Bottom width of minors is 0.3 and side slope are 1:1.1 to 1:1.5, depth of flow change from 0.11 to 0.43 m. Accordingly velocity is recorded as 0.27 to 1.15 m/s in various minors.

Table 3.3 Average cross section details, flow depth and velocity in Bijori WUA.

Bijori WUA	Bottom width, m	side slope (H:V)	Top width, m	Depth of flow, m	Velocity of flow, m/s
Head	0.30	1:1.5	1.06	0.38	0.99
Middle	0.30	1:1.5	1.05	0.33	0.56
Tail	0.30	1:1.5	0.91	0.29	0.27

Table 3.4 Average cross section details, flow depth and velocity in Govindgarh WUA.

Govindhgarh WUA	Bottom width, m	side slope (H:V)	Top width, m	Depth of flow, m	Velocity of flow, m/s
Head	0.30	1:1.5	1.14	0.43	1.15
Middle	0.30	1:1.5	1.12	0.37	0.90
Tail	0.30	1:1.5	0.99	0.34	0.49

Table 3.5 Average cross section details, flow depth and velocity in Bauchhar WUA.

Bauchhar WUA	Bottom width, m	side slope (H:V)	Top width, m	Depth of flow,, m	Velocity of flow m/s
Head	0.30	1:1.1	1.11	0.36	1.14
Middle	0.30	1:1.1	1.01	0.26	0.89
Tail	0.30	1:1.1	0.73	0.11	0.45

3.10 Performance Indicators

Performance indicators as proposed by Nelson (2005) were used for evaluating the irrigation project commanded by WUA. These indicators are grouped into four categories namely, Water deliveries, Maintenance, Financial and Sustainability indicator.

3.10.1 Water Deliveries

Quality of water deliveries is evaluated in terms of tail-end supply ratio, area uniformity and delivery timeliness ratio.

3.10.1.1 Tail-end Supply Ratio (TSR)

The simplest indicator of water delivery performance is whether adequate water is reaching the farmers at the end of the canal system. The Tail-end Supply Ratio is the number of days that sufficient water reached the end of the canal system, divided by the total number of days. Ideally, this ratio would be close to one. TSR is simple and inexpensive, but is only a qualitative indicator. It is based on the common situation that irrigators at the end of the canal are usually the ones shorted.

$$\text{Tail} - \text{end Supply Ratio} = \frac{\text{Ns}}{\text{Nt}}$$

Where,

Ns = the number of days that sufficient water reached the end of the canal system

Nt = the total number of days the canal system was delivering water.

This information was collected through proforma.

3.10.1.2 Area Uniformity (AU)

Area uniformity is divide the worst supplied area on the canal system by the average supply, in terms of water depth supplied. This test requires good water measurement at the supply point for each area and the applied over various time periods or for the whole irrigation season. It is not necessary that a certain number of areas be used or that the areas size but each area must have accurate water measurement.

$$\text{Area Uniformity} = \frac{\text{Dw}}{\text{Davg}}$$

Where,

Dw = The water depth (volume/irrigated area) for the worst supplied area in the system. Which was tail end in all the cases.

Davg = The average water depth supplied to the whole system during the same time period.

3.10.1.3 Delivery Timeliness Ratio (DTR)

If water is delivered on request, an analysis of timeliness may be possible from the individual water order records. The Delivery Timeliness Ratio is the number of orders where water was delivered within the target time of the requested date, divided by the total number of orders. Ideally, this ratio would equal one. If there is a difference in DTR between the upper part of the canal system and the lower end or DTR is low, or lower than normal, this may be occur due to reasons like, if demand exceed the canal capacities, if demand exceed the available water supply, or the water supply itself miss-managed or it could also be caused by poor maintenance or management of the diversion dam, pump stations, or canals.

$$\text{Delivery Timeliness Ratio} = \frac{\text{Nt}}{\text{NT}}$$

Where,

Nt = is the number of orders where water was delivered within the target time. It was assumed that all the farmers have ordered for five irrigation in wheat , two in gram etc.

NT= is the total number of orders (from the individual water order records). All 36 farmers were considered as total number of orders.

3.10.2 Maintenance

Maintenance work in WUA is evaluation through Carrying capacity ratio and Poor structure ratio

3.10.2.1 Carrying Capacity Ratio (CCR)

Canal capacity can indicate problems related to sediment deposits, erosion, vegetation, or possibly inadequate capacity of some structures. The Carrying Capacity Ratio is the actual capacity for the selected canal, divided by its designed capacity. The ideal ratio would be one. In applying this indicator, flow should be measured at the designed water level or head. It is possible to operate a canal at a higher flow than its actual capacity, by operating the canal too full and reducing canal freeboard to an unsafe margin.

$$\text{Carrying Capacity Ratio} = \frac{\text{Ca}}{\text{Cd}}$$

Where,

Ca = is actual canal capacity for the selected canal (measured at designed head) during observations.

Cd = is the designed canal capacity for the selected canal as per WUA record.

3.10.2.2 Poor Structure Ratio (PSR)

The Poor Structure Ratio is the number of structures in poor condition, divided by the total number of structures. Poor can be defined as a structure not functioning adequately, or at risk of failing during the coming year. Ideally, this ratio should be zero.

$$\text{Poor Structure Ratio} = \frac{\text{NP}}{\text{NT}}$$

Where,

NP= is the number of structures in poor condition (not functioning adequately or at risk of failure) as per observation during survey.

NT = is the total number of structures on the system as per WUA record.

3.10.3 Financial

Financial indicators namely, Fee collection performance, Maintenance budget ratio, Personnel cost ratio and Manpower number ratio are used to evaluate financial status of WUA.

3.10.3.1 Fee Collection Performance

Fee Collection Performance is the annual irrigation fees collected, divided by the total annual fees assessed. This indicates the effectiveness of the collection program, but it can also be affected by the economic condition of the irrigators and the degree to which the irrigators feel the system is worth supporting. Values greater than 1 are possible if some delinquent assessments from previous years are collected.

$$\text{Fee Collection Performance} = \frac{\text{Fc}}{\text{Fa}}$$

Where,

Fc = the annual amount of water charges collected as per WUA records.

Fa = the annual amount of water charges assessed as per WUA records.

3.10.3.2 Maintenance Budget Ratio

The maintenance budget ratio is the annual maintenance expenditures divided by the total operation and maintenance expenditures. This ratio typically is too low.

$$\text{Maintenance Budget Ratio} = \frac{\text{Em}}{\text{Eo\& m}}$$

Where,

Em = Average annual expenditures for maintenance as per WUA records.

Eo&m = Average annual expenditures for both operations and maintenance as per WUA records.

3.10.3.3 Personnel Cost Ratio

Personnel cost ratio, which is the annual expenditures on personnel divided by the total expenditures. This ratio is often too high.

$$\text{Personnel Cost Ratio} = \frac{\text{Ep}}{\text{Et}}$$

Where,

Ep = annual expenditures on personnel (wages, fringe benefits, training, etc.) as per WUA records.

Et = total annual expenditures as per WUA records.

3.10.3.4 Manpower Numbers Ratio

The Manpower Numbers Ratio, which is the number of staff (full-time equivalent) divided by the total irrigated area. The optimum value for this indicator may vary widely among different regions of the world, because of differences in labor productivity and irrigation intensity.

$$\text{Manpower Number Ratio} = \frac{\text{Ns}}{\text{At}}$$

Where,

Ns = is number of staff (full-time equivalent) as per WUA records.

At = is total irrigated area as per WUA records.

3.10.4 Sustainability

Sustainability indicators are sustainability of irrigated area and Area/Infrastructure ratio.

3.10.4.1 Sustainability of Irrigated Area

Sustainability of Irrigated Area is the current irrigated area, divided by the initial irrigated area when the system was first fully developed. A trend toward reduced area generally indicates that the system is not sustainable (for water supply, environmental, or economic reasons). If area has increased significantly from the designed area, it may indicate that the water supply is now distributed over too much land, or delivery capacities are being exceeded.

$$\text{Sustanability of Irrigated Area} = \frac{\text{Ac}}{\text{Ai}}$$

Where,

Ac = is current total irrigated area as per WUA records.

Ai = is total irrigated area when system development was completed as per WUA records.

3.10.4.2 Area/Infrastructure Ratio

A key variable affecting the economic sustainability of a system is the Area/Infrastructure Ratio, which can be roughly defined as the irrigated area divided by the total length of canals and laterals. The critical value for this variable is determined by the economics of the region.

$$\text{Area Infrastructure Ratio} = \frac{\text{At}}{\text{Lc}}$$

Where,

At = is the total irrigated area as per records of WUA’s.

Lc = is the total length of canals and laterals on the system as per records of WUA’s.

3.11 Estimation of Bio-economical Indicator

Agricultural production performance indicators included crop yield, area harvested and land holding pattern. Indicators are easier to compute from generally available data than the indictors of water delivery performance.

This indicator relates to the performance of irrigated agriculture and performance of agricultural economics of water productivity. Water productivity of WUA's is determined by quantity of water used, yield. Water productivity is quantity of product in kg per m^3 of water used in field.(Molden *et al* , 2003).

$$\text{Water Productivity} = \frac{\text{Y}}{\text{Wq}}$$

Where,

Y = Yield per ha,kg as per surveyed

Wq = Quantity of water use per ha,m^3 as per farmers survey and field observation.

3.12 Social-Organizational Indicators

The information about all the social organizational input requirements have been fulfilled by using farmer's interview. The data were collected by personal contact with the farming community. (Appendix C)

The information was collected about the name of the farmers, area of land holdings, village, crop, and farmer's satisfaction with the canal, contribution for the irrigation system and about the effectiveness of water user association. Basic information of about the village was taken from the patwari. All the information was collected with the help of questionnaire.

3.13 Analysis of variance

Randomized complete Block Design with many observations was applied to conduct the experiment with four treatments (for category of farmers) and three replication namely head, middle and tail reach with three observations (three experimental units of farmers) in each category.

Number of treatment "t" = 4, which are as

C1 – Marginal farmer

C2 – Small farmer

C3 – Medium farmer

C4 – Large farmer

Number of Replication “r” = 3 which are as

R1 – Head reach

R2 – Meddle reach

R3 – Tail reach

Number of observation/Experimental plot “s” = 3

Total number of observation in each replication = r x t x s = 36

Grand total (GT) = $\sum_{ijk} Y_{ijk}$ where……...i = 1 to t, j = 1 to r, k = 1 to s

Where,

t = Number of treatment

r = Number of replication

s = Number of observation

$$\text{Coefficient factor (CF)} = \frac{\text{GT}^2}{\text{rts}}$$

$$\text{Total sum of square (Total SS)} = \sum_{i=1,j=1,k=1}^{4,3,3} \text{Y}_{\text{ijk}}^2 - \text{CF}$$

Table 3.6 gives the structure of ANOVA

Table 3.6 Statistics of the analysis of variance

Source of Variation due to	Degree of freedom (df)	Sum of squares (S.S)	Mean sum of squares (MS)
Replication, r (reaches)	(r – 1)	$\text{Replication SS (Rep. SS)} = \frac{\sum_{j=1} R_j^2}{\text{ts}} - \text{CF}$	$S_r^2 = \frac{\text{Rep.ss}}{\text{dfr}}$
Treatment, t, (categories)	(t – 1)	$\text{Treatment error SS (Tr. SS)} = \sum_{i=1}^{t} \frac{T_i^2}{rs} - CF$	$S_t^2 = \frac{\text{Tr. SS}}{\text{dft}}$
Experimental error	(r – 1) x (t – 1)	$\text{Experimental error SS} = \text{Total SS} - \text{Tr. SS} - \text{Rep. SS}$	$S_e^2 = \frac{\text{ErrorSS}}{\text{df(error)}}$
Sampling error	r x t (s – 1)	$\text{Sampling error SS} = \text{Total SS} - \text{Tr. SS} - \text{Rep. SS} - \text{Error SS}$	$S_s^2 = \frac{Sam.SS}{df\ (sa.er.)}$
Total	(r x t x s) – 1	$\text{Total SS} = \text{Rep. ss} + \text{Tr. ss} + \text{Error ss} + \text{sa. err. ss}$	

$$\text{Common error MS} = \frac{\text{Experimental error SS} + \text{Sampling error SS}}{(\text{ r} - 1\text{ })(\text{t} - 1\text{ }) + \text{rt}(\text{ s} - 1)}$$

$$\text{Coefficient of dispertion (CD)} = t\ (exp.error\ df + samp.error\ df)\sqrt{\frac{2\text{s}_\text{e}^2}{\text{rs}}}$$

Value of ‘t’ statistics at total degree of freedom for exp. Error and sum of error.

RESULTS AND DISCUSSION

After studying the different Water User Association (WUA) in Narmada Tones and Betwa basins, area under three associations namely Bijori, Govindgarh and Bauchhar were selected for further evaluation. The performance of Bijori WUA, Govindgarh WUA and Bauchhar WUA was evaluated under the concept of different efficiencies and the performance parameters. Results of the analysis are presented in this chapter. This chapter presents the characteristics of the selected WUA's; these characters are physical, Bio-economical and social indicator for comparison between water productivity in different reaches by different group of farmers. WUA's were evaluated based on these parameters.

4.1 Characteristics of WUA's

There are three WUA's namely Bijori, Govindgarh and Bauchhar were considered for the present study. Bijori WUA has Gross command area of 2082 ha out of which 889 ha has been irrigated by canal and 960 ha by tube-wells. It was largest area under tube-well irrigation among three WUAs. There are nine minor having length from 1.2 km to 3.21 km. Total number of farmers are 1135. Details of distribution of these farmers in marginal (0 – 1 ha), small (1 – 2 ha), medium (2 – 4 ha) and large (> 4 ha) category is already presented in table 3.3. Nine farmers in each category distributed in head, middle and tail end of command, were selected randomly for further study.

Table 4.1 shows land holding pattern of selected farmers under different WUAs. In Bijori WUA, numbers of farmers are highest in marginal category and lowest in large category as compare to other category. Area coverage under category of small farmers is highest and under medium farmers was lowest. The survey area is highest in large category farmers which covers 11.93% of total large area. Percentage of total number of farmers surveyed is also more in large category farmers as compare to other category because area per farmer is highest in this category.

Table 4.1 Details of the land holding pattern in the command area.

WUA name	Farmers Category	Total Farmer	Total area (ha)	No. of survey Farmers	Total survey Area (ha)	% of Total Farmers	% of Total Area
Bijori WUA	Marginal	450	321	9	4.56	2.00	1.42
	Small	423	843	9	12.76	2.31	1.51
	Medium	184	270	9	24.19	4.89	8.96
	Large	78	415	9	49.51	11.54	11.93
Govindgarh WUA	Marginal	414	368	9	8.02	2.17	2.18
	Small	231	784	9	15.52	2.09	1.98
	Medium	161	242	9	24.32	5.59	10.05
	Large	24	88	9	48.96	37.5	55.64
Bauchhar WUA	Marginal	147	47	9	5.34	6.12	11.36
	Small	84	132	9	14.16	10.71	10.73
	Medium	22	53	9	24.48	40.91	46.19
	Large	16	68	9	57.03	56.25	83.87

In Govindgarh WUA, total number of farmers is highest in marginal category and lowest in large category. Total area covered in command is highest in small category and lowest in marginal category. Area covered under survey was highest in large category farmer which was 55.64% because in this category total numbers of farmers are less as compare to other category.

In Bauchhar WUA, numbers of farmers are highest in marginal category and small farmers are dominating for area coverage. Survey area was highest in large category farmers which cover 83.87% of total area under large category and percentage of total numbers of farmers was also maximum in larger category farmers.

Govindgarh WUA has maximum (407) number of farmers among three WUAs, whereas, Bijori WUA has maximum small, medium and large category farmers. Small category farmers with land holding of 1 ha to 2 ha cover highest area under all the WUA’s.

Total survey area was highest in large category followed by medium, small and marginal in all the WUA’s. Percentage of total number of farmers covered three WUAs in different categories is highest in Bauchhar WUA because it has total number of farmers less as compare to other WUAs.

4.2 Discharge measurement

Discharge measured at different fields in all the minors is appended in Appendix – D. Table 4.2 shows the discharge measured in head, middle and tail reach of all nine minors under Bijori WUA. In head reach highest discharge was observed in Nunpur minor 0.443 m^3/s which decreases to 21.7% in tail reach (0.096 m^3/s). The lowest discharge was measured in Badayakheda minor was 0.025 m^3/s which decreases to 16% in tail reach (0.004 m^3/s.). In general tail end is receiving less water ranging from 6.02% to 41.5 %.

The discharge measurement of Govindgarh WUA is show in Table 4.3. In head reach highest discharge was obtained in Govindgarh minor (0.572 m^3/s) which decrease by 62.76% in tail reach (0.213 m^3/s). The lowest discharge was in Amin and Hardisankar minor which is 0.246 m^3/s. It decreases by 67.48% and 80.49% in tail reach (0.08 m^3/s and 0.048 m^3/s respectively).

Table 4.2 Discharge measurement in different minors under Bijori WUA

Name of Minor	Measured Discharge (m^3/s) at different reaches		
	Head	Middle	Tail
Dabola	0.328	0.140	0.055
Bichuva	0.299	0.142	0.059
Nunpur	0.443	0.178	0.096
Chapra	0.200	0.144	0.083
Dulakheda	0.285	0.107	0.042
Pipariya	0.347	0.209	0.068
Jhanshi	0.287	0.139	0.060
Jamuniya	0.266	0.094	0.016
Badayakheda	0.025	0.018	0.004

Table 4.3 Discharge measurement in different minors under Govindgarh WUA

Name of Minor	Measured Discharge (m^3/s) at different reaches		
	Head	Middle	Tail
Govindgarh	0.572	0.324	0.213
Parsiya	0.467	0.365	0.174
Kapurhai	0.434	0.312	0.151
Nakta	0.331	0.276	0.106
Mohani	0.325	0.244	0.078
Amin	0.246	0.163	0.080
Dhobet	0.255	0.124	0.062
Hardi Sankar	0.246	0.138	0.048

The Bauchhar WUA is presented in Table 4.4. In head reach, highest discharge was 0.408 m^3/s in bauchhar-1 minor which has a 87.01% decrease in tail reach and reaches to 0.053 m^3/s. The lowest discharge was measured in Basanpani minor at 0.189 m^3/s which decrease in tail reach is (0.075 m^3/s).

Table 4.4 Discharge measurement in different minors under Bauchhar WUA

Name of Minor	Measured Discharge (m^3/s) at different reaches		
	Head	**Middle**	**Tail**
Basanpani	0.189	0.104	0.075
Bauchhar - 1	0.408	0.301	0.053
Bauchhar - 2	0.310	0.125	0.002
Mekh	0.250	0.122	0.016
Karakbel	0.342	0.146	0.024
Devri	0.274	0.132	0.018

4.3 Performance evaluation in WUAs

Data collected through farmers survey as persecution 3.7 is compiled minor wise and appended in Appendix – E. Performance of water user associations was evaluated using performance indicators i.e. physical indicators, bio-economical indicators and social indicators in head, middle and tail reaches of different WUA.

4.3.1 Physical indicators

Various physical indicators were evaluated for performance assessment, which already discussed in chapter 3. Table 4.5 presents the computed values of performance indicators for Bijori WUA. There are nine minors under the jurisdiction of this WUA. Details are appended in Appendix D. Average value of indicators are presented in Table 4.5 and reference values as found in literature are also presented as reference range. Water delivery indicators namely Tail-end supply ratio (0.58), area uniformity ratio (0.96) and delivery timeliness ratio (1) are within the reference range, hence this can be said satisfactory in Bijori WUA, Sustainability indicators are also found satisfactory. However poor structure ratio was found very high as 0.63

and manpower number ratio was also observed as 0.011 which seems to be very high as compared to reference range.

Similar trend of values in indicators was found in case of Govindgarh WUA (Table 4.6) and Bauchhar WUA (Table 4.7). Poor structure ratio of 0.50 and 0.83 indicate the poor condition of structure and high man power number ratio 0.009 and 0.06 shows engagement of more staff then optimum.

4.3.1.1 Water Deliveries

Performance indicators under the water deliveries are tail-end supply ratio, area uniformity ratio and delivery timeliness ratio. The study revealed the tail-end supply ratio (TSR).

Fig. 4.1 shows that the tail-end supply ratio is highest in Govindgarh WUA because sufficient canal water is available for irrigation in tail reach .The area uniformity ratio in Govindgarh WUA is less because in this WUA tail reach water users have no wastage of water and the delivery timeliness ratio is low in Bauchhar WUA because of sufficient canal water is not available in the irrigation time.

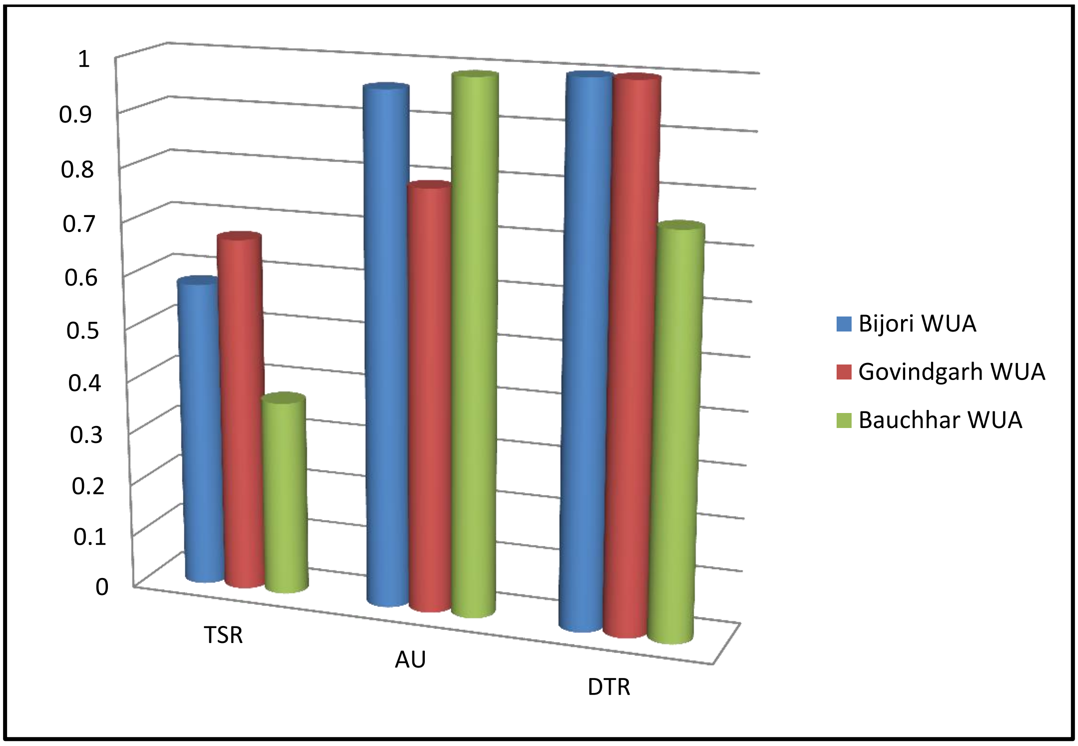


Fig. 4.1 Water deliveries performance indicator in different WUAs.

Table 4.5 Performance of Bijori Water User Association.

Parameters	Performance Indicator	Basic Input	Input Value	Value	Reference range
Water Deliveries	Tail-end Supply Ratio	N_s N_t	70 120	0.58	0.50-0.70
	Area uniformity Ratio	D_w D_{Avg}	8556.26 8942.77	0.96	0.50-0.90
	Delivery Timeliness Ratio	N_t N_T	4 4	1	0.72-0.90
Maintenance	Carrying Capacity Ratio	C_a C_d	292 318	0.92	0.60-1.26
	Poor Structure Ratio	N_p N_t	290 395	0.63	0.01-0.20
Financial	Fee Collection Performance	F_c F_a	288000 431614	0.67	0.62-1.0
	Maintenance Budget Ratio	E_m $E_{m\&om}$	55000 90000	0.66	0.40- 0.70
	Personnel Cost Ratio	E_p E_t	45000 90000	0.50	0.50-0.60
	Manpower Numbers Ratio	N_s A_t	20 1849.07	0.011	0.0004-0.001
Sustainability	Sustainability of Irrigated Area	A_c A_I	1849.07 2082.08	0.88	0.50-1.0
	Area/Infrastructure Ratio	A_t L_c	1849.07 20.46	90.37	

Table 4.6 Performance of Govindgarh Water User Association.

Parameters	Performance Indicator	Basic Input	Input Value	Value	Reference range
Water Deliveries	Tail-end Supply Ratio	N_s N_t	80 120	0.67	0.50-0.70
	Area uniformity Ratio	D_w D_{Avg}	4304.34 5460.95	0.79	0.50-0.90
	Delivery Timeliness Ratio	N_t N_T	4 4	1	0.72-0.90
Maintenance	Carrying Capacity Ratio	C_a C_d	350 364	0.96	0.60-1.26
	Poor Structure Ratio	N_p N_t	130 260	0.50	0.01-0.20
Financial	Fee Collection Performance	F_c F_a	280200 373100	0.75	0.62-1.0
	Maintenance Budget Ratio	E_m $E_{m\&om}$	45000 72000	0.63	0.40- 0.70
	Personnel Cost Ratio	E_p E_t	40000 72000	0.56	0.50-0.60
	Manpower Numbers Ratio	N_s A_t	14 1486	0.009	0.0004-0.001
Sustainability	Sustainability of Irrigated Area	A_c A_I	1486 1760	0.84	0.50-1.0
	Area/Infrastructure Ratio	A_t L_c	1486 10.67	139.27	

Table 4.7 Performance of Bauchhar Water User Association.

Parameters	Performance Indicator	Basic Input	Input Value	Value	Reference range
Water Deliveries	Tail-end Supply Ratio	N_s N_t	44 120	0.37	0.50-0.70
	Area uniformity Ratio	D_w D_{Avg}	7170.9 7237.5	0.99	0.50-0.90
	Delivery Timeliness Ratio	N_t N_T	3 4	0.75	0.72-0.90
Maintenance	Carrying Capacity Ratio	C_a C_d	284 318	0.89	0.60-1.26
	Poor Structure Ratio	N_p N_t	150 180	0.83	0.01-0.20
Financial	Fee Collection Performance	F_c F_a	40600 70500	0.57	0.62-1.0
	Maintenance Budget Ratio	E_m $E_{m\&om}$	25000 60000	0.42	0.40- 0.70
	Personnel Cost Ratio	E_p E_t	28000 60000	0.47	0.50-0.60
	Manpower Numbers Ratio	N_s A_t	18 300	0.06	0.0004-0.001
Sustainability	Sustainability of Irrigated Area	A_c A_I	300 850	0.35	0.50-1.0
	Area/Infrastructure Ratio	A_t L_c	300 14.4	20.83	

4.3.1.2 Maintenance

Performance indicators carrying capacity ratio (CCR) and poor structure ratio (PSR) comes under the maintenance parameter. The relationship between Carrying capacity ratio and poor structure ratio is shown in Fig. 4.2. Carrying capacity ratio is highest in Govindgarh WUA because actual water discharge in canal is near to design discharge. In Bauchhar WUA poor structure ratio is highest because in this WUA numbers of structures are in poor condition as compare to other WUAs.

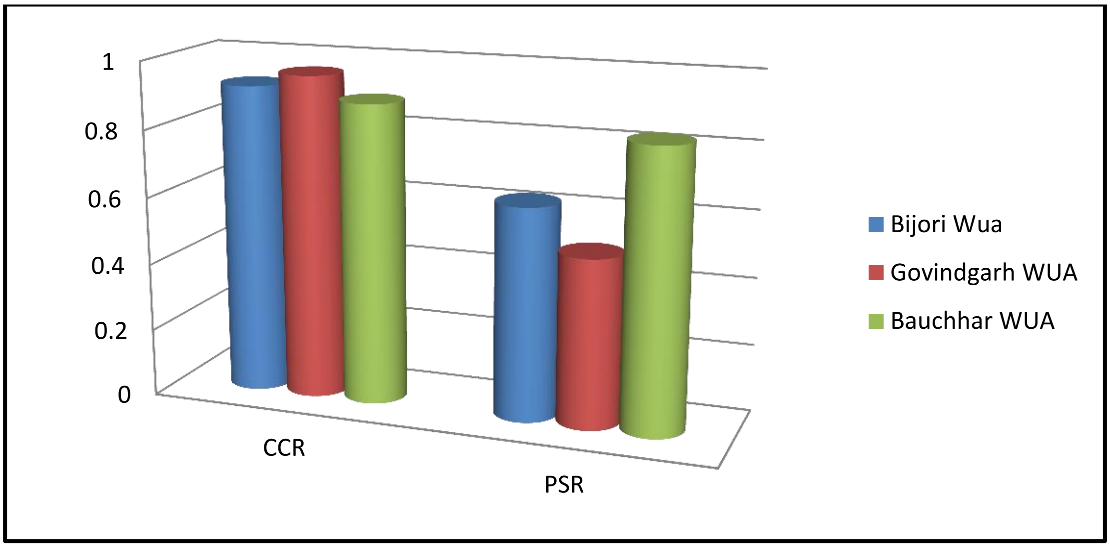


Fig. 4.2 Maintenance performance indicator in different WUAs.

4.3.1.3 Financial

In this parameter four performance indicators namely fee collection performance (FCP), maintenance budget ratio (MBR), personnel cost ratio (PCR) and manpower number ratio (MNR) are evaluated. Fee collection performance, maintenance budget ratio, personnel cost ratio and manpower number ratio are shown in the Fig.4.3. Fee collection performance of Govindgarh WUA is more than other WUAs, expenditure in maintenance is more in Bijori WUA so maintenance budget ratio is more in this WUA as compare to other WUAs. For Govindgarh WUA personnel cost ratio is more, due to expenditure in personnel activities like training, wages etc. The manpower number ratio (Fig. 4.4) is lowest in Govindgarh WUA because in this WUA number of staff is less as compare to other WUAs.

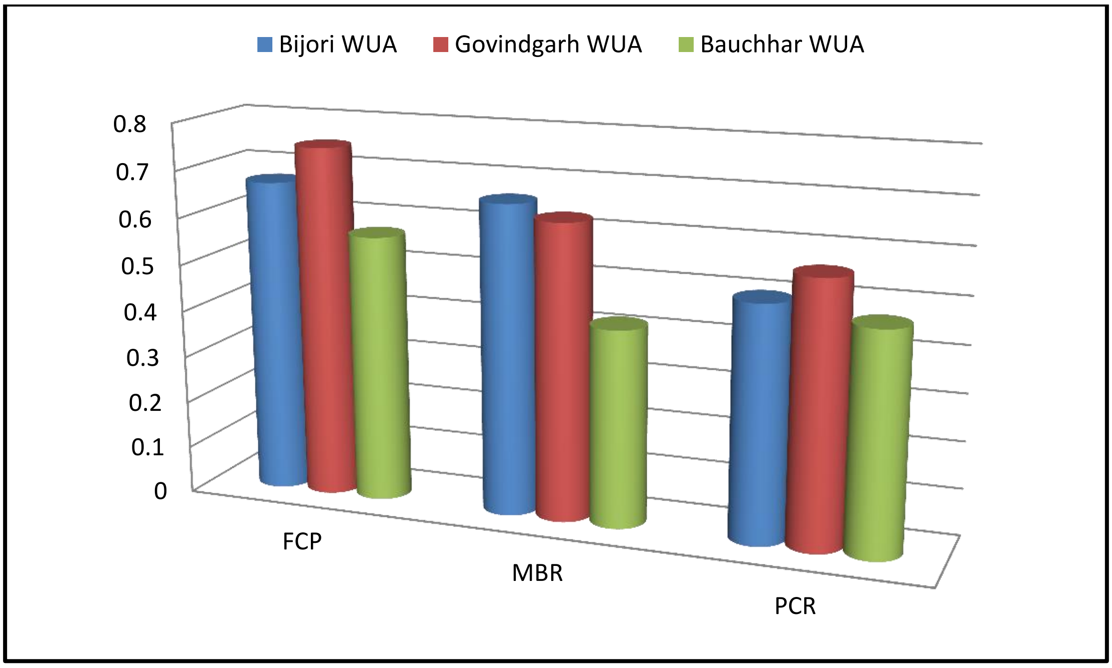


Fig. 4.3 Financial performance indicator in different WUAs.

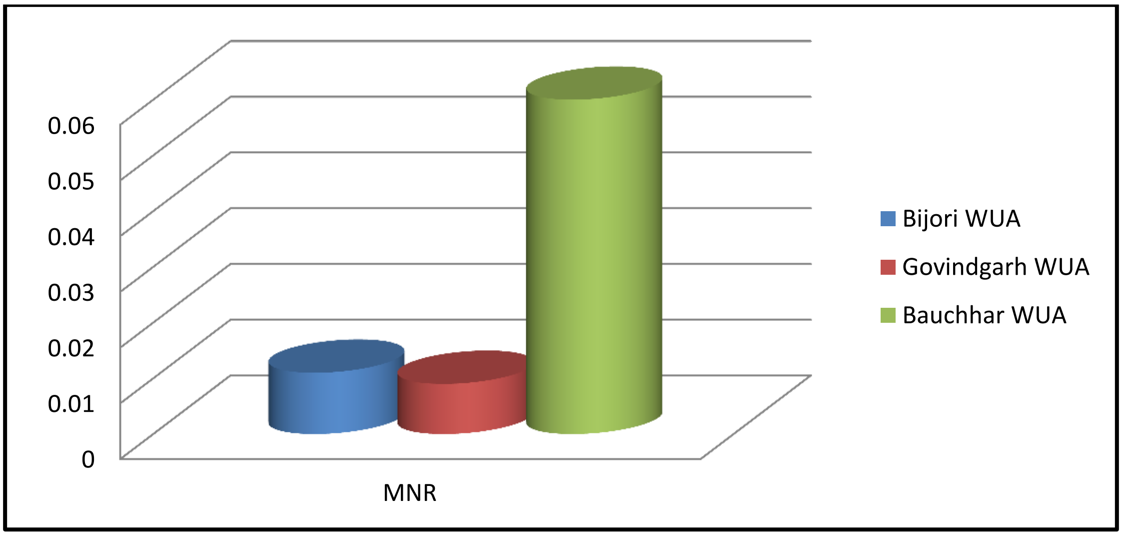


Fig 4.4 Manpower number ratio in different WUAs.

4.3.1.4 Sustainability

Sustainability parameter includes two performance indicators namely sustainability of irrigated area (SIA) and area/infrastructure ratio (AIR). Fig. 4.5 shows sustainability of irrigated area is more in Bijori WUA because actual irrigated area is more in this WUA as compare to other WUAs and Fig. 4.6 shows area/infrastructure ratio in Govindgarh WUA is more than other WUAs because the number of structure is less and irrigation area is more.

Overall comparison of WUA establishes the fact that Govindgarh WUA is performing better than other WUA.

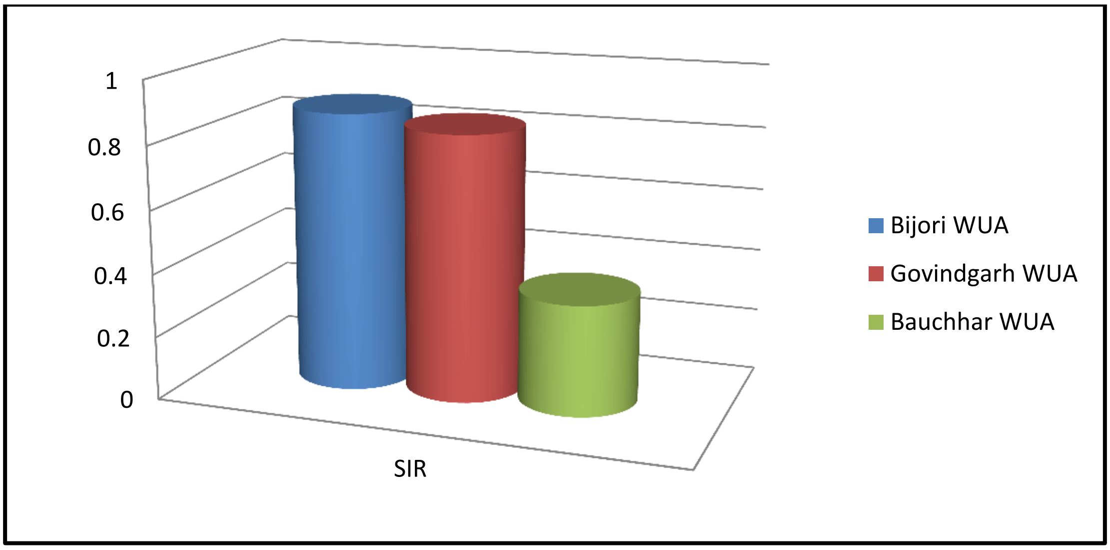


Fig 4.5 Sustainability of irrigated area in different WUAs.

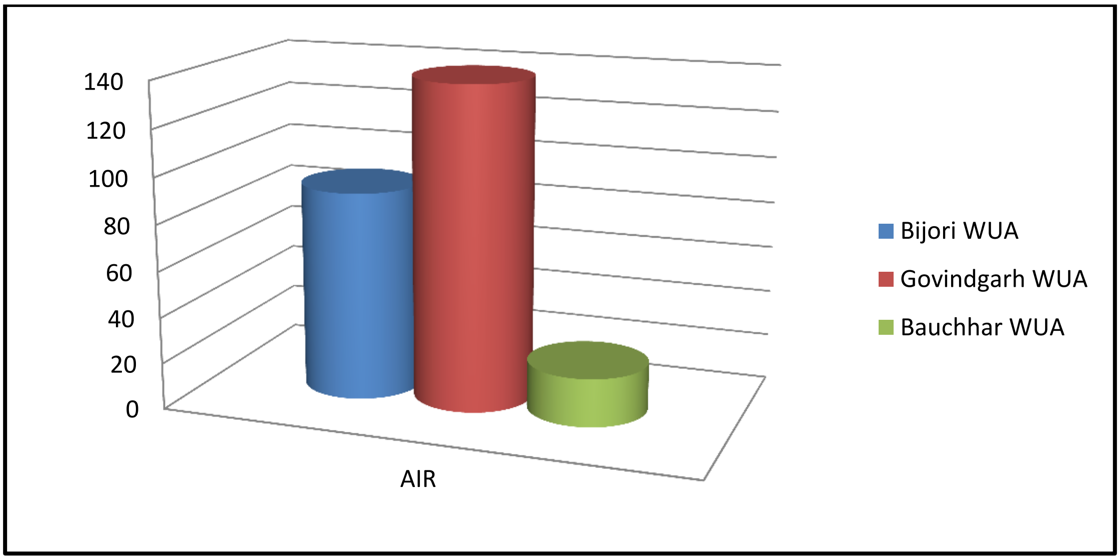


Fig 4.6 Area/Infrastructure ratio in different WUAs.

4.3.2 Water productivity

4.3.2.1 Wheat productivity

Table 4.8, Table 4.9 and Table 4.10 shows water productivity of wheat, gram and pea crop in different reaches in different category in three WUAs.

Fig 4.7 shows water productivity of wheat in head reach in different WUA's. Highest water productivity was found in Govindgarh WUA medium farmers of 1.14 kg/m^3 and lowest in Bijori and Bauchhar WUA marginal farmers are 0.31 kg/m^3 as shown in Table 4.8. Govindgarh WUA has shown maximum water productivity in all four category and Bijori WUA has minimum water productivity. Table 4.9 shows maximum water productivity of wheat in middle reach is also in Govindgarh WUA with small farmers (1.41 kg/m^3).

Table 4.10 shows maximum water productivity of wheat in tail reach is shown by Govindgarh WUA in medium farmers (1.93 kg/m^3) and the minimum in Bijori WUA large farmers is 0.39 kg/m^3. Fig 4.9 shows average of all category farmers is maximum water productivity in Govindgarh WUA and minimum in Bijori WUA.

Water productivity of wheat is highest in Govindgarh WUA and lowest in Bijori WUA in head, middle and tail reaches in all four farmers category as compare to other WUA's.

Table 4.8 Water productivity at head reaches in different WUA's.

WUA Name	Farmer Category	Water Productivity (kg/m^3)		
		Wheat	Gram	Pea
Bijori WUA	Marginal	0.31	-	-
	Small	0.38	0.97	-
	Medium	0.59	1.88	-
	Large	0.52	1.83	0.36
Govindgarh WUA	Marginal	0.55	-	-
	Small	0.99	1.11	-
	Medium	1.14	1.39	-
	Large	0.81	1.37	-
Bauchhar WUA	Marginal	0.31	-	-
	Small	0.57	0.64	-
	Medium	0.56	0.70	-
	Large	0.51	0.74	0.12

Table 4.9 Water productivity at middle reaches in different WUA's.

WUA Name	Farmer Category	Water Productivity (kg/m^3)		
		Wheat	Gram	Pea
Bijori WUA	Marginal	0.45	-	-
	Small	0.50	-	-
	Medium	0.64	1.22	0.14
	Large	0.44	2.23	0.29
Govindgarh WUA	Marginal	0.83	-	-
	Small	1.41	1.16	-
	Medium	1.04	0.83	-
	Large	1.30	1.31	-
Bauchhar WUA	Marginal	0.49	-	-
	Small	0.98	-	-
	Medium	1.20	0.98	-
	Large	1.06	1	0.11

Table 4.10 Water productivity at tail reaches in different WUA's.

WUA Name	Farmer Category	Water Productivity (kg/m^3)		
		Wheat	Gram	Pea
Bijori WUA	Marginal	0.46	-	-
	Small	0.58	0.62	-
	Medium	0.52	1.62	0.54
	Large	0.39	4.18	0.49
Govindgarh WUA	Marginal	0.63	-	-
	Small	1.07	1.86	-
	Medium	1.93	2.11	-
	Large	1.79	2.22	-
Bauchhar WUA	Marginal	1	-	-
	Small	0.83	0.59	-
	Medium	1.32	-	0.11
	Large	1.35	1.20	0.13

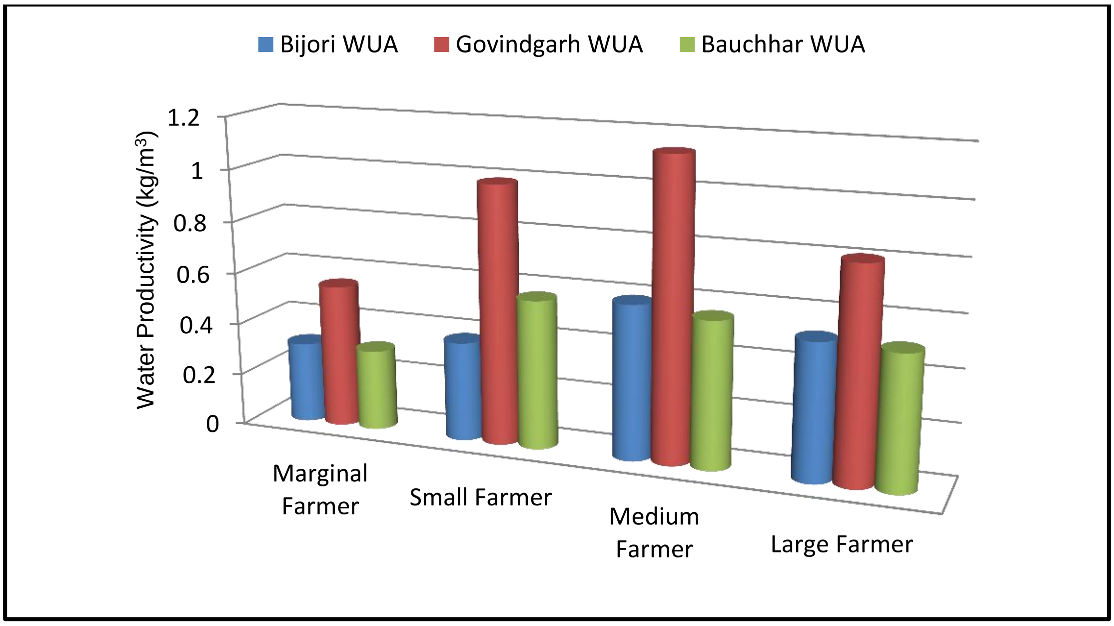


Fig. 4.7 Water productivity of wheat at head reach in different WUA's.

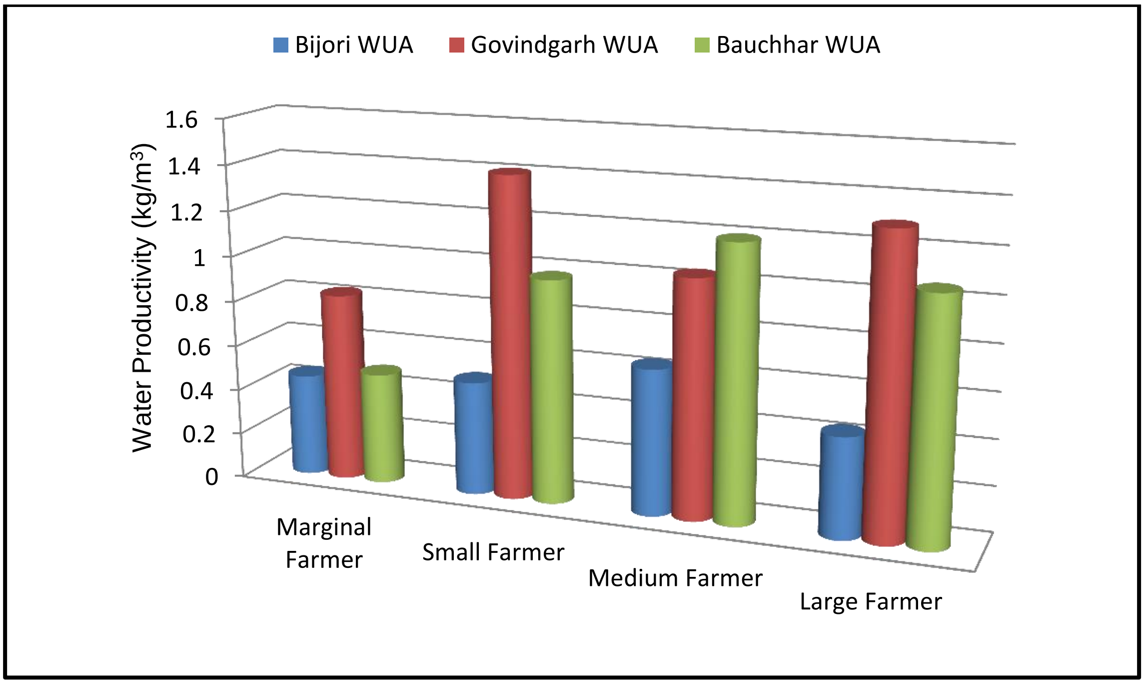


Fig. 4.8 Water productivity of wheat at middle reach in different WUA's.

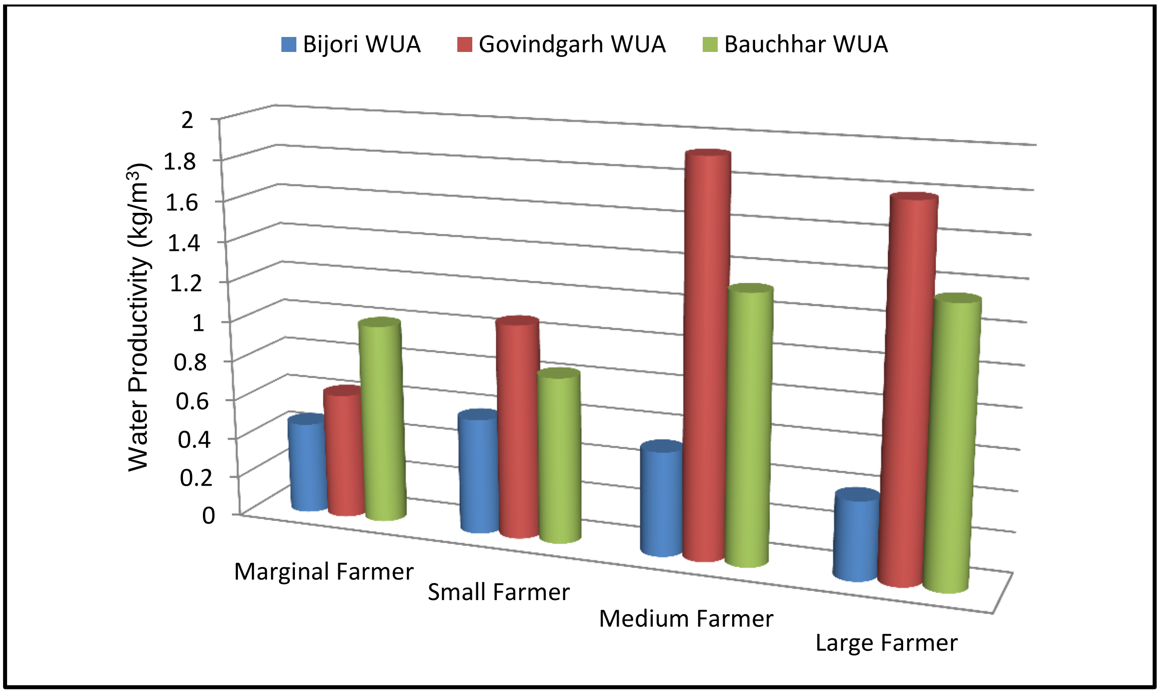


Fig. 4.9 Water productivity of wheat at tail reach in different WUA's.

4.3.2.2 Gram productivity

Water productivity of gram in head reach in different WUAs is shown in Table 4.6 and highest water productivity was obtained in Bijori WUA in medium farmers (1.88 kg/m^3). The lowest was in Bauchhar WUA (0.64 kg/m^3) (Fig 4.10).

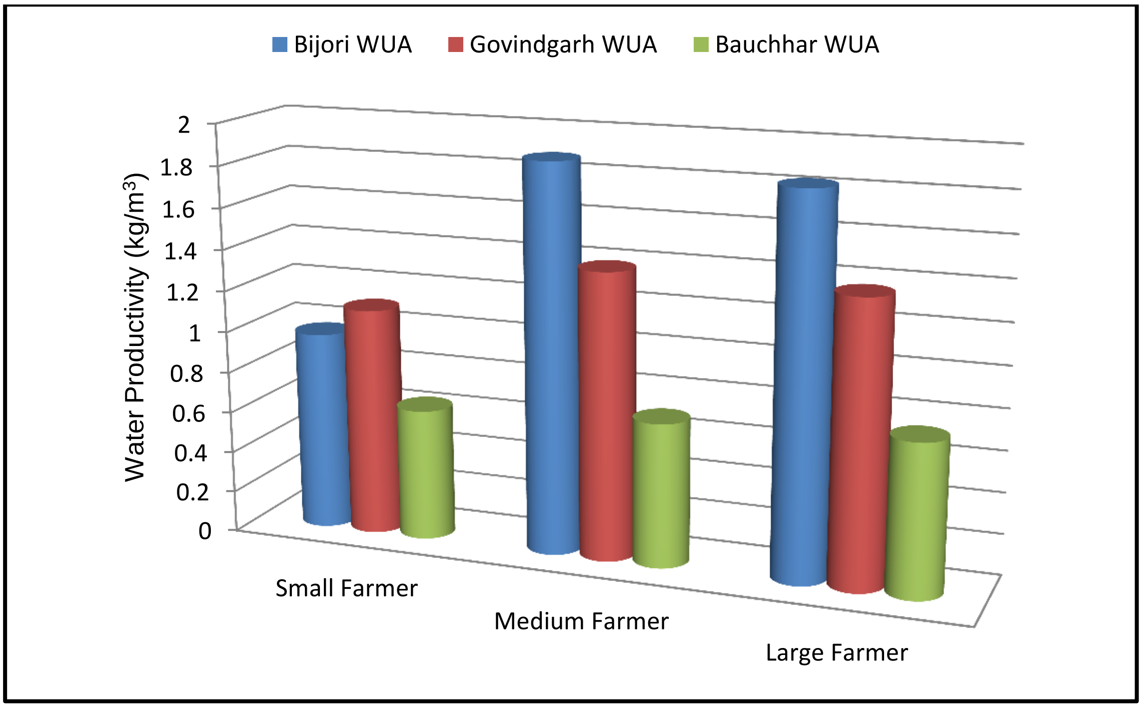


Fig. 4.10 Water productivity of gram at head reach in different WUA's.

Water productivity of gram in middle reach is maximum in Bijori WUA with large farmers with 2.23 kg/m^3 and the minimum was in Govindgarh WUA with medium farmers is 0.83 kg/m^3 as shown in Table 4.9. Fig 4.11 shows water productivity in medium and large farmer category was found highest in Bijori WUA. In small category only Govindgarh WUA farmers have sown gram crop.

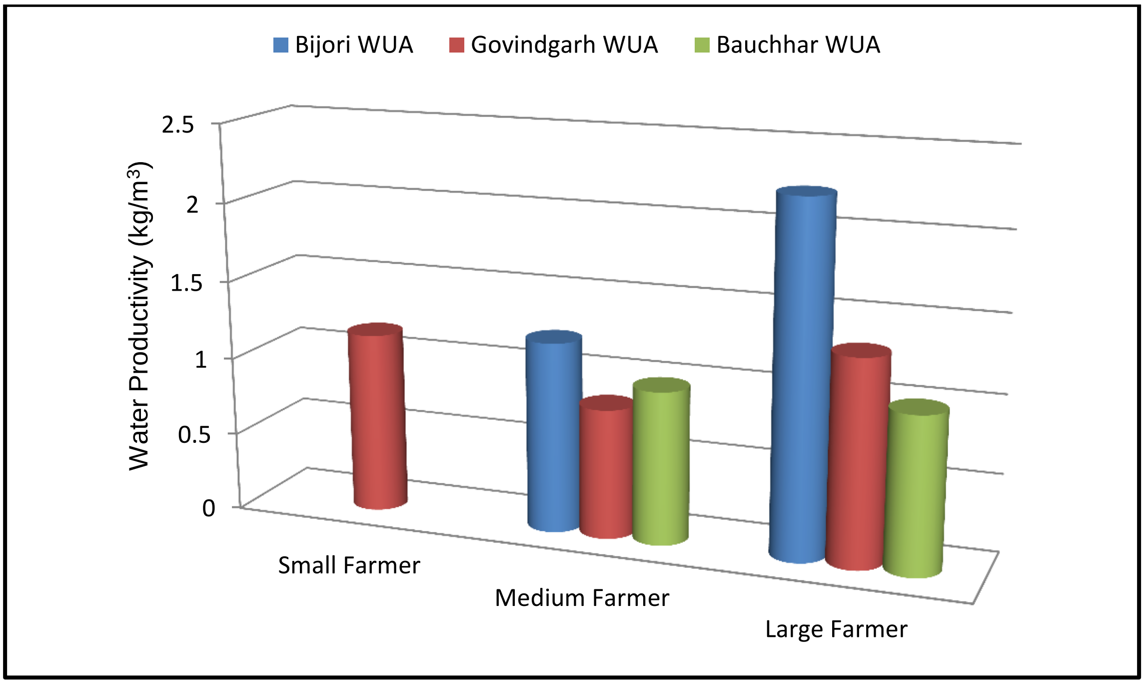


Fig. 4.11 Water productivity of gram at middle reach in different WUA's.

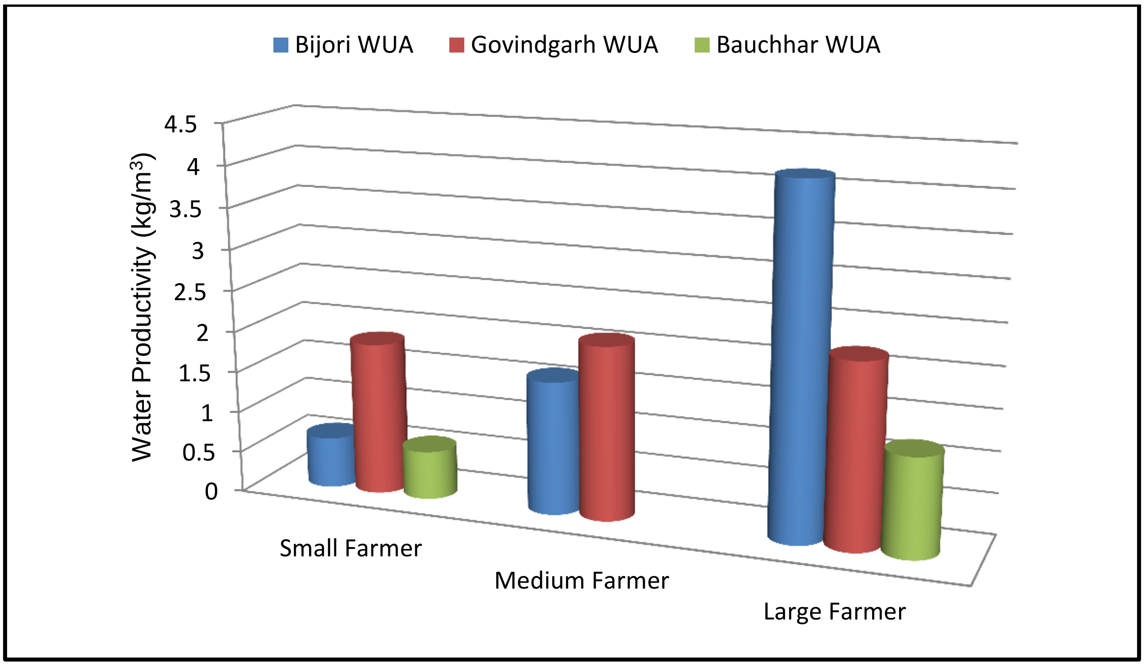


Fig. 4.12 Water productivity of gram at tail reach in different WUA's.

Water productivity of gram in tail reach was found as high as 4.18 kg/m^3 with Bijori WUA in large farmers and minimum of 0.59 kg/m^3 in Bauchhar WUA in small farmers. Fig. 4.12 shows that small farmer category has less water productivity as compared to medium and large category farmers.

Gram crop is not sown by all WUAs in marginal farmer category and in middle reach Bijori and Bauchhar WUAs small farmers are not sowing gram crop, wherever in tail reach Bauchhar WUA farmers are not growing gram crop in command area.

4.3.2.3 Pea productivity

Pea crop is grown only by large category farmers in Bijori WUA and Bauchhar WUA. As shown in Fig. 4.13. Water productivity as 0.36 kg/m^3 of pea in head reach is maximum in Bijori WUA, Bauchhar WUA has 0.12 kg/$m^{3.}$ Fig. 4.14 shows water productivity in the middle reach. Bauchhar WUA farmers are not growing pea crop. In this reach highest water productivity in Bijori WUA was 0.29 kg/m^3 and lowest was Bauchhar WUA is 0.11 kg/m^3 (Fig. 4.15). Maximum water productivity in tail reach in Bijori WUA with medium farmers was 0.54 kg/m^3 and minimum was in Bauchhar WUA with medium farmers (0.11 kg/m^3).

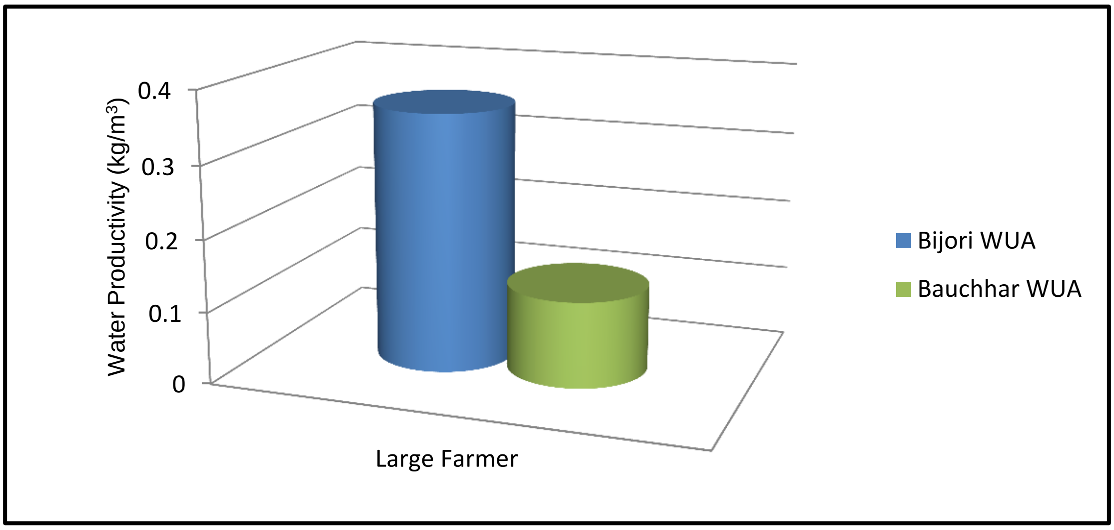


Fig. 4.13 Water productivity of pea at head reach in different WUA's.

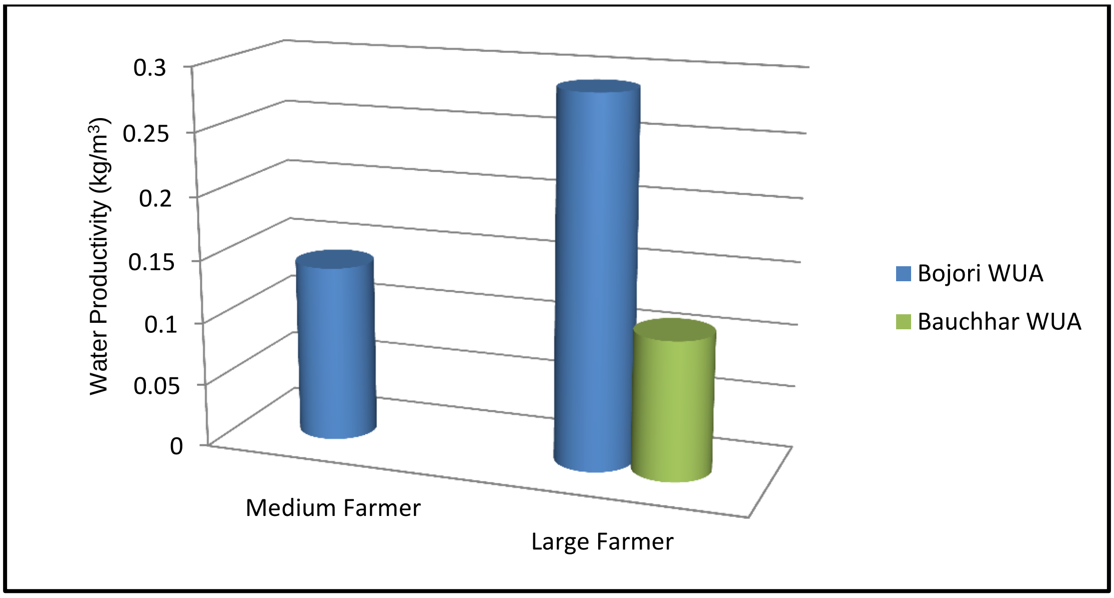


Fig. 4.14 Water productivity of pea at middle reach in different WUA's.

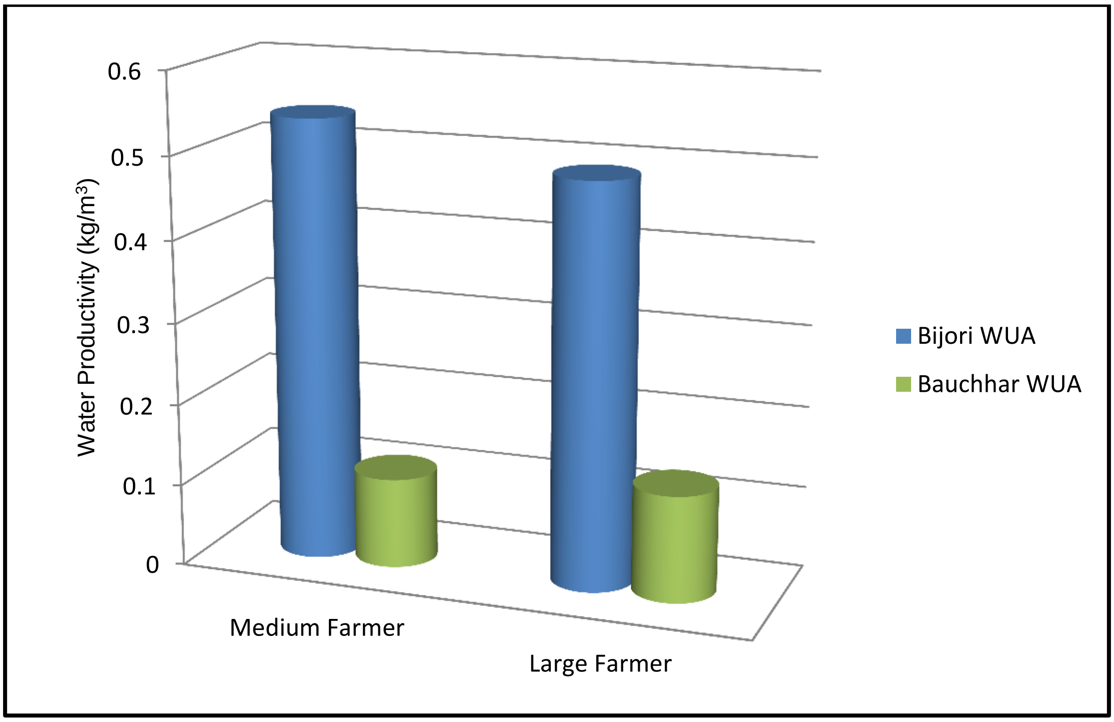


Fig. 4.15 Water productivity of pea at tail reach in different WUA's.

4.3.3 Social Organizational Indicator

The social organizational indicators were determined in terms of farmer's satisfaction and farmer involvement and farmer's contribution in different WUA's.

4.3.3.1 Farmer's satisfaction and involvement

Fig. 4.16 shows that 86.9% Govindgarh WUA farmers are satisfied with working process of WUA and living standard has increased. In Bijori and Bauchhar WUA only 71.4% & 61.1% farmers are satisfied.

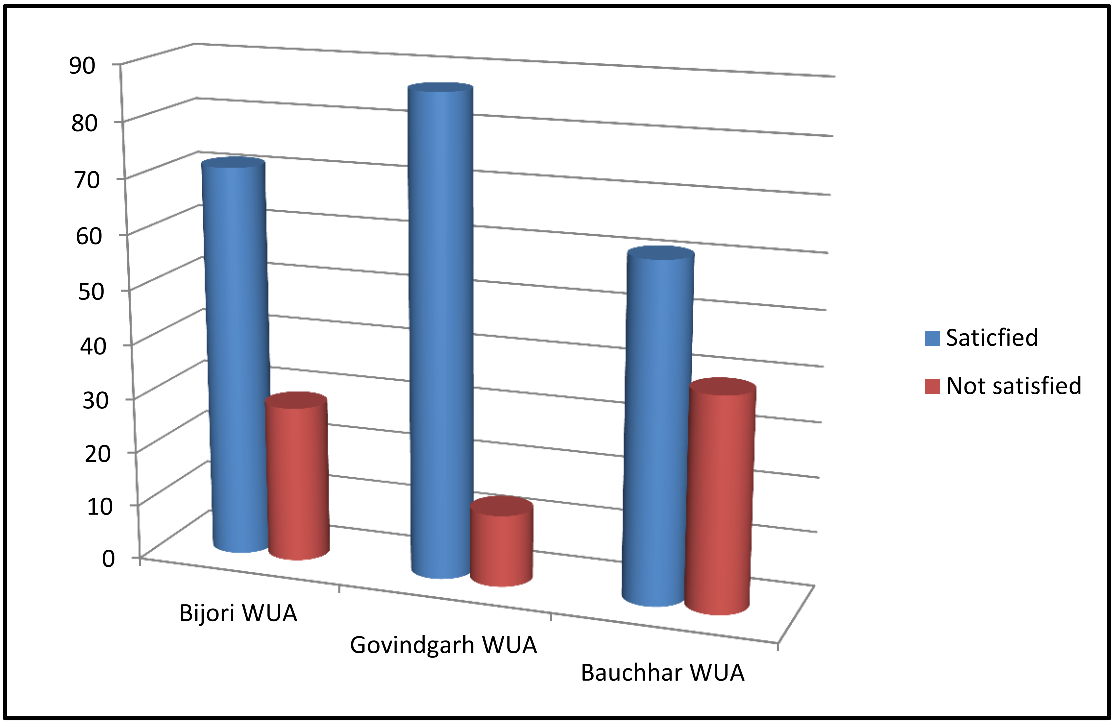


Fig. 4.16 Farmer satisfaction and involvement at different WUA's

4.3.3.2 Farmer's Contribution

Farmer's contribution towards regular maintenance of the canal system was analysed. Fig. 4.17 shows that 55.6%, 91.7% and 41.7% farmer are contributing for maintenance in the irrigation system in Bijori WUA, Govindgarh WUA and Bauchhar WUA respectively. Govindgarh WUA farmer contributes highest, so this WUA was better in command area.

4.3.4 Analysis of variation of water productivity with in each WUA.

Water productivity as obtained with wheat, gram and pea crop varies with respect to canal reach and also with the categories of farmer's i.e. marginal, small, medium and large farmer. It also attains different value as per water management, canal management and water distribution works under taken by WUA's. Wheat productivity data were used to find out the impact of all these variation statistically.

In this analysis, ANOVA used is randomized complete block design with many observation units. Water productivity of wheat crop in different reaches was assessed for four categories of farmers. Appendix F presents the data of wheat productivity as observed in Bijori, Govindgarh and Bauchhar WUA and its analysis.

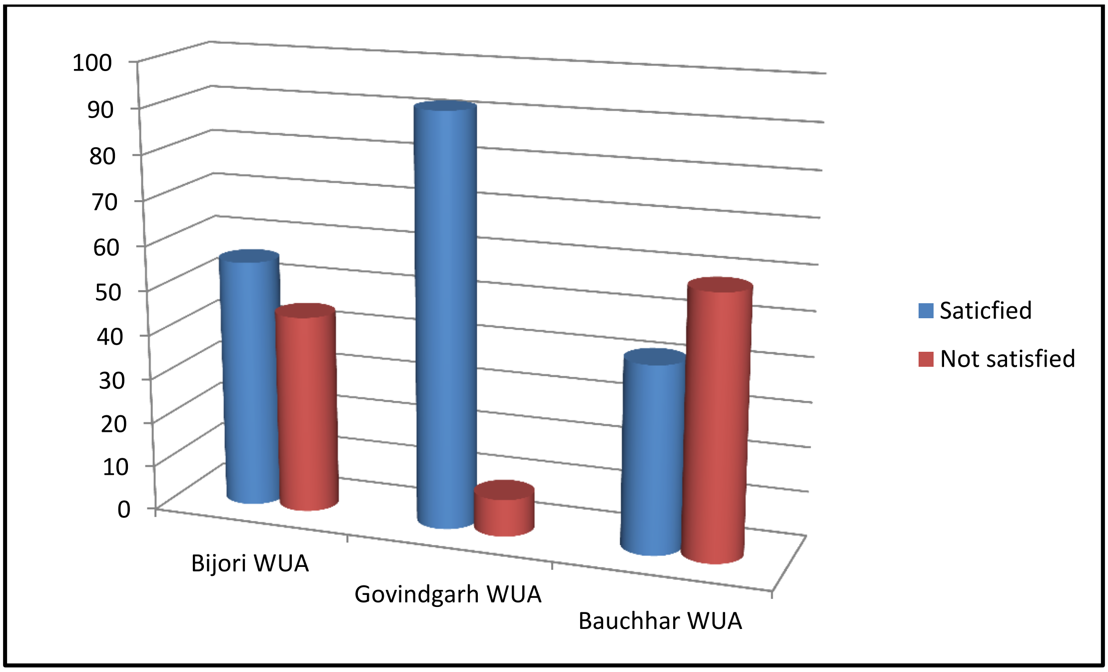


Fig. 4.17 Farmer's contribution at different WUA's

4.3.4.1 Bijori WUA

In Bijori WUA mean water productivity obtained under three replications of wheat crop in different categories of farmers is presented in Table 4.11. Average water productivity in Bijori WUA has been found to be maximum (0.58 kg/m^3) with medium category of farmers. The minimum of 0.41 kg/m^3 was with the marginal farmers. Overall variation of water productivity in Bijori WUA is from 0.31 to 0.64 kg/m^3. Mean values for head, middle and tail reach of canal are almost in the same range (0.45 to 0.51 kg/m^3).

Table 4.11 Mean water productivity of wheat (kg/m^3) in Bijori WUA.

Farmer category	Water productivity in kg/m^3			
	Head reach	Middle reach	Tail reach	Average
Marginal	0.31	0.45	0.46	0.41
Small	0.38	0.50	0.58	0.49
Medium	0.59	0.64	0.52	0.58
Large	0.51	0.44	0.39	0.45
Mean	0.45	0.51	0.49	

Table 4.12 reveals that the calculated value of F statistics for experimental error is 1.255 which is less than the corresponding table value $F_{5\% \, (6,24)}$ = 2.5082. It indicates that the experimental error of the data for Bijori WUA is found statistically non-significant. Hence pooled experimental error was worked out by combining the experimental error with sampling error of the data as described in section 3.13 of material and methodology chapter.

Table 4.12 Analysis of variance for Bijori WUA

Source of variation	df	ss	ms	fc	$F_{5\%}$	Significance
Reach,(r = 3)	2	0.02	0.01	0.552	19.46	NS
Category, (t=4)	3	0.15	0.05	2.771	2.9223	NS
Experimental error	6	0.128	0.022	1.255	2.5082	NS
Sampling error	24	0.425	0.017			
Total number	35	0.723				
Common error			0.0184			

Finally calculated value of F statistic for treatment Fc for category (2.771) was found less than the corresponding tabulated value $F_{5\% \, (3, \, 30)}$ (2.9223). Therefore for it can be concluded that the different reaches in four categories of farmers have statistically equal water productivity in Bijori WUA.

4.3.4.2 Govindgarh WUA

In Govindgarh WUA mean of water productivity obtained under three replications of wheat crop in different categories of farmers is presented in Table 4.13. Average water productivity in Govindgarh WUA has been found to almost same in medium and large category i.e. 1.37 kg/m^3 and 1.3 kg/m^3 and the minimum water productivity in marginal category was 0.68 kg/m^3. Overall range is 0.55 kg/m^3 to 1.93 kg/m^3. Calculated value of F statistics for experimental error is 6.901 which is greater then the corresponding table value $F_{5\% \ (6,24)}$ = 2.5082 as shown in Table 4.14.

Table 4.13 Mean water productivity of wheat (kg/m^3) in Govindgarh WUA.

Farmer category	Water productivity in kg/m^3			
	Head reach	**Middle reach**	**Tail reach**	**Average**
Marginal	0.55	0.83	0.63	0.67
Small	0.99	1.41	1.07	1.16
Medium	1.14	1.04	1.93	1.37
Large	0.81	1.30	1.79	1.30
Mean	0.87	1.15	1.35	

Table 4.14 Analysis of variation for Govindgarh WUA

Source of variation	df	ss	ms	fc	$F_{5\%}$	Significance
Reach	2	1.63	0.814	1.739	6.1631	NS
Category	3	2.65	0.882	1.885	4.7571	NS
Experimental error	6	2.808	0.468	6.901	2.5082	S
Sampling error	24	1.628	0.068			
Total number	35	8.71				

It indicates that the experimental error of the data for Govindgarh WUA is found statistically significant. Calculated value F_c for category is 1.885

which is less than the corresponding tabulated value $F_{5\%\ (3,\ 6)}$ = 4.7571. Variation of water productivity in different category is non-significant.

4.3.4.3 Bauchhar WUA

In Bauchhar WUA mean of water productivity obtained under three replications of wheat crop in different categories of farmers is presented in Table 4.15. Calculated value of F statistics for experimental error is 1.61 which is less than the corresponding table value $F_{5\%\ (6,24)}$ = 2.5082 shown in Table 4.16.

Table 4.15 Mean water productivity of wheat (kg/m^3) in Bauchhar WUA.

Farmer category	Water productivity in kg/m^3			
	Head reach	Middle reach	Tail reach	Average
Marginal	0.31	0.49	1	0.60
Small	0.57	0.98	0.83	0.80
Medium	0.56	1.20	1.32	1.03
Large	0.51	1.06	1.35	0.98
Mean	0.49	0.93	1.13	

Table 4.16 Analysis of variation for Bauchhar WUA

Source of variation	df	ss	ms	fc	$F_{5\%}$	Significance
Reach	2	2.57	1.285	19.407	19.462	NS
Category	3	1.02	0.34	5.136	2.9223	S
Experimental error	6	0.57	0.095	1.61	2.5082	NS
Sampling error	24	1.416	0.059			
Total number	35					
Common error			0.066			

It indicates that the experimental error of the data for Bauchhar WUA is found statistically non-significant. Calculated value F_c for treatment is 5.136 which is greater than the corresponding tabulated value $F_{5\%\ (3,\ 30)}$ = 2.9223.

Hence, the four categories of farmers in Bauchhar WUA have statistically different water productivity. Calculated critical difference (least significant difference) is 0.1995. Average water productivity in marginal, small, medium and large category is 0.6, 0.8, 1.03 and 0.98 kg/m^3. The medium farmer has the maximum water productivity among all four categories of farmer considered in this investigation and highest water productivity in medium farmers in Bauchhar WUA. Mean water productivity is maximum in tail reach (1.13 kg/m^3) which may be because of the reason that in this reach wheat yield is high and total water delivered in field is low as compared to other reach.

4.3.4.4 Variability of water productivity with different WUA's

Water productivity of wheat crop was studied in head, middle and tail reach in all categories of farmers in three WUA's commands. The water productivity achieved at the head reach in three WUA has already been presented in Table 4.8. It also included productivity for Gram and Pea. The data for middle reach and tail reach have been included Table 4.9 and Table 4.10. Variation of water productivity in different WUA commands has been depicted and presented in section 4.3.2.1. Govindgarh WUA has been found giving higher water productivity in all four categories of farmer in head reach. However in middle and tail reach maximum productivity observed in small and medium farmers. Marginal farmers are getting best water productivity in Bauchhar WUA.

The data on wheat productivity achieved in different reaches in different categories where pooled for three WUA separately. The statistical analysis subjected to this data set shows that it has significant variation within WUA's, within reaches of canal (replication) and within different category of farmers (Treatment). The details of statistical analysis are presented in Table 4.17. However the variation is not-significant in WUA's, replication interaction and within the three farmers in each reach. Overall mean productivity of 108 observed farmer's field in all three WUA's area is 0.819 kg/m^3. Water productivity in tail reach was maximum at 0.99 kg/m3 and is was significantly higher than head (0.904 kg/m3) and middle reach (0.863 kg/m3) mean productivity level. The productivity level in middle reach was also significantly higher then head reach, hence it can be concluded that if the data of all the three WUA's are pooled the mean water productivity increases from head to tail reach significantly. As shown in Fig. 4.18 and Fig. 4.19 less productivity in head reach may be attributed to over utilization of water. The obvious reason for this availability of water in canal operation time and the flat rate of irrigation charges @300 Rs/ha. Further excess water in root zone affected the crop performance and resulted in reduced yields as shown in Fig. 4.20, which further reduces the water productivity level. Total number of irrigation applied in head, middle and tail reach also vary in different reach (Appendix – E).

Table 4.17 Variation of water productivity in different WUA's.

Source of variation	**df**	**ss**	**ms**	**fc**	**Pr > F**	**Significance**
Sample	2	0.219	0.109	1.49	0.229	NS
WUA	2	7.512	3.756	51.03	<0.001	S
Replication	2	2.786	1.393	18.92	<0.001	S
Treatment	3	2.881	0.961	13.04	<0.001	S
WUA x Replication	4	1.184	0.296	4.02	0.005	NS
Error degrees of freedom = 94		Error mean square = 0.073		Least significant difference = 0.127		

WUA	**Mean**	**Interaction**	**Significance**
Head	0.604	T – M	Significant
Middle	0.863	T – H	Significant
Tail	0.991	M – H	Significant
Average	0.819		

This fact is stabilised in the Fig. 4.20 where the trend line of yield level obtained has been shown with the water utilization figures. The trend line shows that in head reach of canal the yield level decrease as the water utilization increases in x- axis. The reverse trend was observed in middle and tail reach shows that the yield level are higher and higher when water utilization was more.

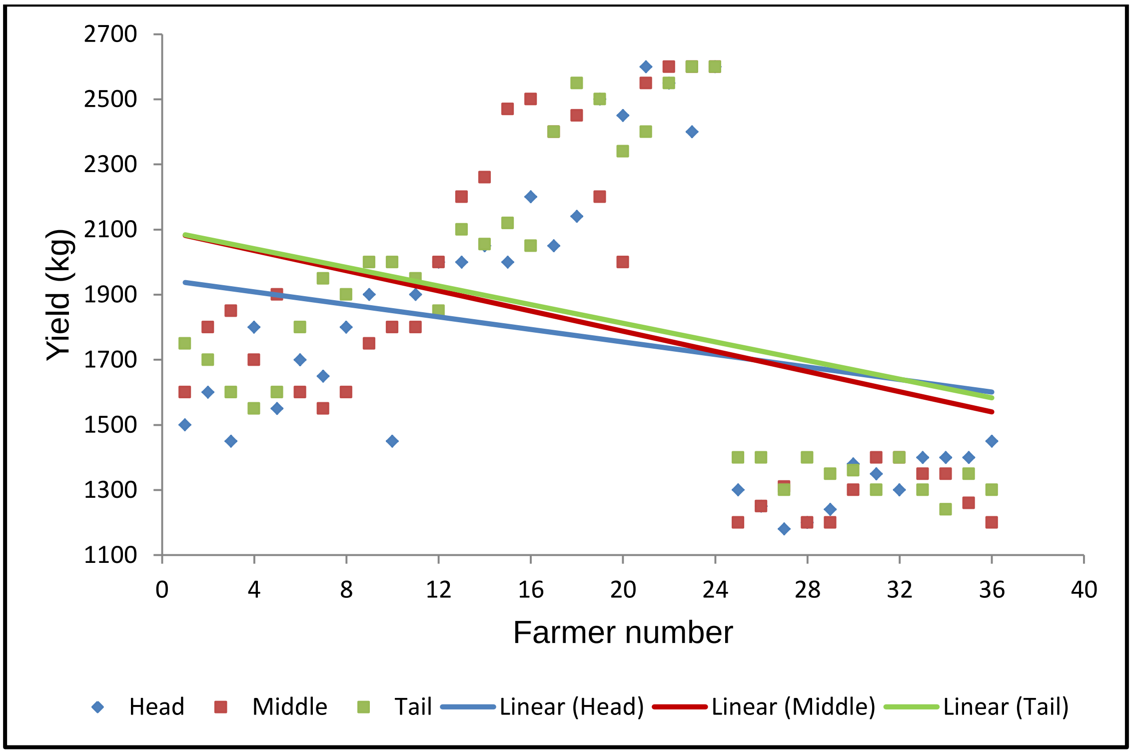


Fig. 4.18 Yield in all WUA's in different reaches

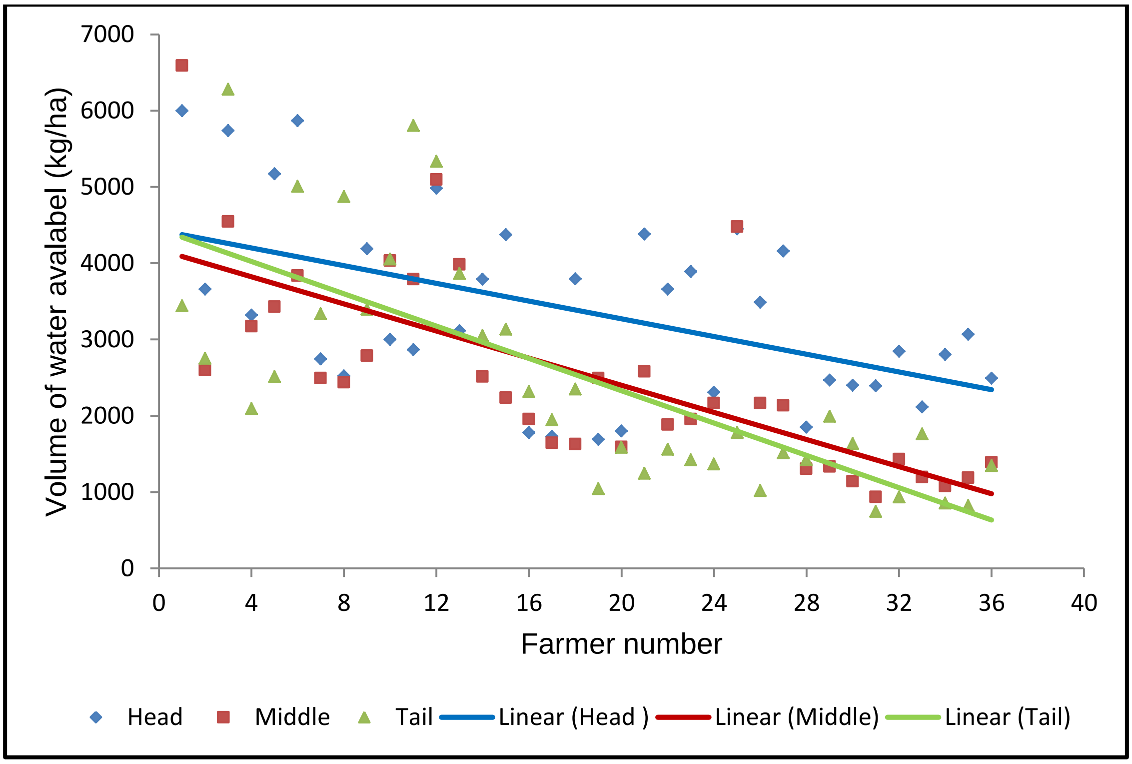


Fig. 4.19 Volume of water applied in all WUA's in different reaches

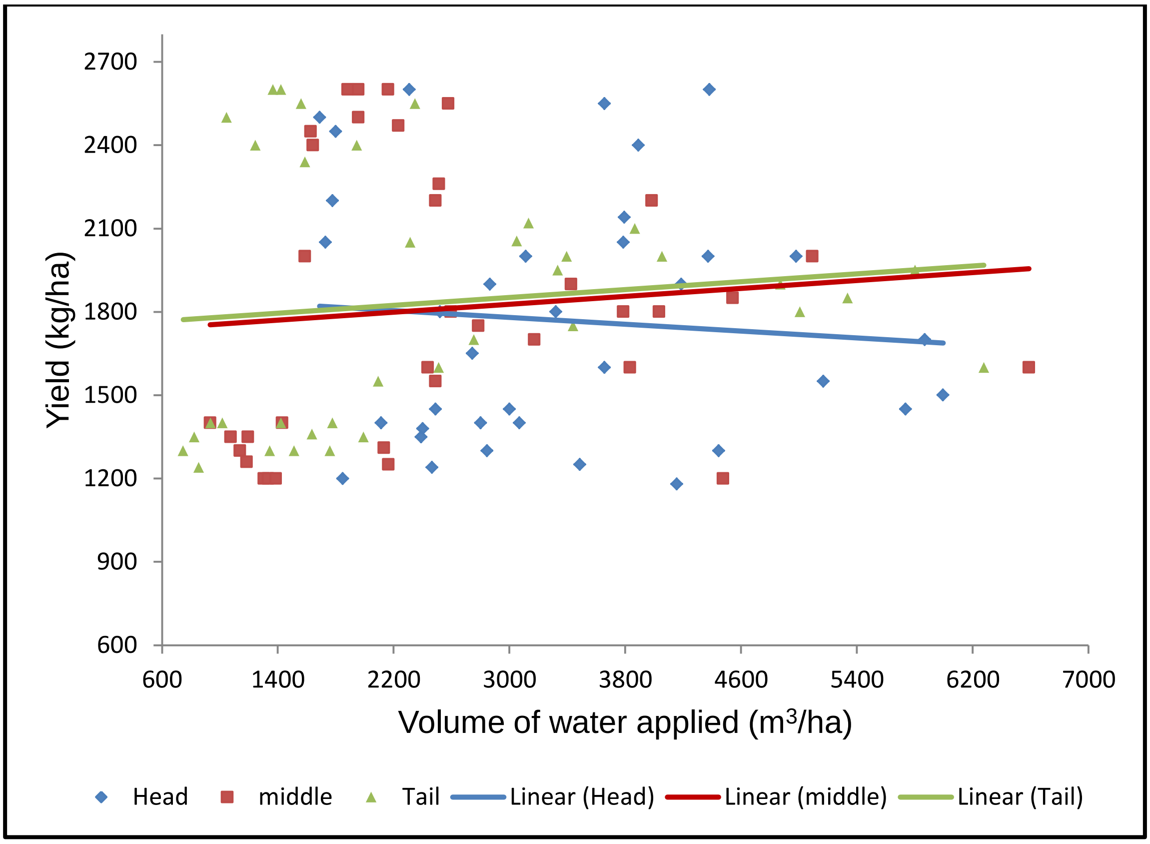


Fig. 4.20 Variation of wheat yields with water utilization.

A fact can be observed in the figure that water utilization in overall three WUA's is minimum around 747 m^3/ha in tail reach, 933 m^3/ha in middle reach and 1689 m^3/ha in head reach. Which again show that head reach has got over utilization of water. The respective yield in minimum water utilization in tail, middle and head reach are 1300 kg/ha, 1400 kg/ha and 2500 kg/ha respectively, it shows that the yield is increasing from tail to head reach but it is not able to compensate the head reach water productivity level due to higher water utilization with less increase in yield. Therefore it can concluded that there is need of improving water management in head reach. Also improved water availability in tail end may further improve yield level and water productivity level to appreciable limit.

4.3.4.5 Spatial variability of water productivity in canal reaches.

Reach wise details of statistical analysis is presented in Table 4.18. Mean water productivity in head reach for all WUA's is 0.604 kg/m^3. However water productivity of Govindgarh WUA was maximum at 0.87 kg/m^3 and it was significantly higher as compared to Bauchhar WUA and Bijori WUA. The difference in Bauchhar WUA and Bijori WUA is statistically non-significant.

Table 4.18 Variation of water productivity in head reach in different WUA's.

Source of variation	df	ss	ms	fc	Pr > F	Significance
Sample	2	0.134	0.067	1.61	0.217	NS
WUA	2	1.331	0.665	15.99	<0.001	S
Treatment	3	0.659	0.219	5.28	0.005	NS
Error degrees of freedom = 28		Error mean square = 0.042		Least significant difference = 0.1706		

WUA	Mean	Interaction	Significance
Govindgarh	0.875	Govindgarh – Bauchhar	Significant
Bauchhar	0.490	Govindgarh – Bijori	Significant
Bijori	0.447	Bauchhar – Bijori	Non - Significant
Average	0.604		

Statistical analysis shows that water productivity in middle reach for all WUA's is significantly different (Table 4.19). Mean water productivity is 0.862 kg/m^3. Water productivity of 1.146 kg/m^3 at Govindgarh WUA was maximum and it was significantly higher than Bauchhar (0.935 kg/m^3) and Bijori WUA (0.505 kg/m^3). The productivity in Bauchhar WUA was also significantly higher than Bijori WUA.

Table 4.20 presents the details of statistical analysis of water productivity levels in tail reach. Mean of water productivity in all WUA's is 0.99 kg/m3. Water productivity of Govindgarh WUA and Bauchhar WUA are statistically similar (1.35 kg/m3 and 1.13 kg/m3) and the productivity level of Bijori WUA was 0.49 kg/m3 which is significantly lower than Govindgarh and Bauchhar WUA.

Table 4.19 Variation of water productivity in middle reach in different WUA's.

Source of variation	df	ss	ms	fc	Pr > F	Significance
Sample	2	0.034	0.0171	0.35	0.705	NS
WUA	2	2.558	1.279	26.5	<0.001	S
Treatment	3	0.917	0.305	6.34	0.002	NS
Error degrees of freedom = 28		Error mean square = 0.048			Least significant difference = 0.1838	

WUA	Mean	Interaction	Significance
Govindgarh	1.146	Govindgarh – Bauchhar	Significant
Bauchhar	0.935	Govindgarh – Bijori	Significant
Bijori	0.505	Bauchhar – Bijori	Significant
Average	0.862		

Table 4.20 Variation of water productivity in tail reach in different WUA's.

Source of variation	df	ss	ms	fc	Pr > F	Significance
Sample	2	0.227	0.113	0.90	0.419	NS
WUA	2	4.806	2.403	18.93	<0.001	S
Treatment	3	1.973	0.657	5.18	0.006	NS
Error degrees of freedom = 28		Error mean square = 0.1269		Least significant difference = 0.2979		

WUA	Mean	Interaction	Significance
Govindgarh	1.35	Govindgarh – Bauchhar	Non – Significant
Bauchhar	1.13	Govindgarh – Bijori	Significant
Bijori	0.49	Bauchhar – Bijori	Significant
Average	0.99		

SUMMARY AND CONCLUSIONS

Considering the importance of canal irrigation system and the water user association's participation in increasing its performance and the development of existing irrigation command area, this study was carried out to assess the working status of water user association and prospect of farmer contribution through water user association's to improve crop production as well as water productivity in irrigation command area.

The performance of Water User Associations (WUA's) was evaluated on the basis of different indicators, which includes physical indicator, bio-economical indicator and social organizational indicator. The study was conducted on the command area in Jabalpur and Narsinghpur districts under Left Bank Canal of RABSP as well as in Govindgarh Tank command area of Rewa district. The survey was conducted among the water users in the command area of three Water User Associations Bijori WUA, Govindgarh WUA and Bauchhar WUA. The selection of farmers for survey was based on random sampling and farmer interview schedule was also used to collect more precise information on various aspects to characterize and evaluate the working of selected Water User Association's.

Physical indicators, such as Tail-end supply ratio, Area uniformity ratio, Delivery timeliness ratio, Carrying capacity ratio, Poor structure ratio, Fee collection ratio, Maintenance budget ratio, Personnel cost ratio, manpower number ratio, sustainability of irrigated area and area/infrastructure ratio were evaluated for different WUAs. Bio-economical indicator, on water productivity, social organizational indicator, effectiveness of farmers and WUAs, their contribution and level of satisfaction was evaluated. Water application methods, discharge delivered and yield of the crops were observed in each of the three selected farmers field in each head, middle and tail reach of canal command area. The survey work was conducted for all four categories namely marginal, small, medium and large farmer. The observation were compiled for each category and for each reach and analysis of variance was studied for their variability and spatially at three different locations. The WUA's were characterised with the help of the indicators enumerated.

Water productivity of 36 samples in each of head, middle and tail reach was computed and used to compare these spatial change with respect to distance from main canal along the minor. Analysis was further made to sort out variation in head, middle and tail reach of different location and also to note the variability of overall water productivity at three WUA's.

Summary of the results obtained in the study is presented below:

Characteristics of Water User Association

1. Bijori WUA has highest area followed by Govindgarh and Bauchhar WUA. Highest total number of farmers present in Bijori WUA in marginal category is 450 and lowest in Bauchhar WUA in large category is 16 but highest total area covered by Bijori WUA in small category farmers is 843 ha and lowest in in Bauchhar WUA in marginal category farmers is 47ha.
2. Total survey area highest covered in Bauchhar WUA in large category farmers is 57.03 ha because these category percentage of total farmers is 56.25% and lowest in Bijori WUA in marginal category farmers is 4.56 ha.
3. Highest discharge obtained in Bijori WUA, Govindgarh WUA and Bauchhar WUA is 0.443 m^3/s, 0.572 m^3/s and 0.408 m^3/s and it decreases in tail reach to 78.33%, 62.76% and 87.01% respectively. The lowest discharge obtained for Bijori WUA, Govindgarh WUA and Bauchhar WUA was 0.025 m^3/s, 0.246 m^3/s and 0.189 m^3/s respectively. It decreases to 84%, 67.48% and 60.32% respectively in tail reach. Govindgarh WUA highest discharge in canal and percentage of canal water discharge is less as compare to other two WUAs.

Physical indicators:

1. In Tail-end supply ratio in Bijori WUA, Govindgarh WUA and Bauchhar WUA is 0.58, 0.67 and 0.37. This ratio was highest in Govindgarh WUA because sufficient canal water available for irrigation in tail reach.
2. Area uniformity ratio was 0.96, 0.79 and 0.99 in Bijori WUA, Govindgarh WUA and Bauchhar WUA respectively. This ratio is lowest in

Govindgarh WUA because tail end farmers are wasting less canal water compared to other two WUAs.

3. Delivery timeliness ratio in Bijori WUA, Govindgarh WUA and Bauchhar WUA are 1, 1 and 0.75 respectively. This ratio was lowest in Bauchhar WUA. The canal water is not available in irrigation time.
4. Carrying capacity ratio is 0.92 in Bijori WUA, 0.96 in Govindgarh WUA and 0.89 in Bauchhar WUA. Carrying capacity ratio is highest in Govindgarh WUA because canal water discharge is near to design discharge.
5. Poor structure ratio is 0.667, 0.50 and 0.85 in Bijori WUA, Govindgarh WUA and Bauchhar WUA respectively. In Bauchhar WUA poor structures is more as compare to other two WUAs so poor structure ratio is high in Bauchhar WUA.
6. Fee collection performance is 0.667, 0.751 and 0.576 in Bijori WUA, Govindgarh WUA and Bauchhar WUA respectively. Fee collection performance is highest in Govindgarh WUA as compare to other two WUAs. This was possible due to awareness among farmers.
7. Maintenance budget ratio is 0.661, 0.625 and 0.417 in Bijori WUA, Govindgarh WUA and Bauchhar WUA respectively. In Bijori WUA more expenditure in maintenance so this ratio is more in this WUA.
8. Personnel cost ratio is 0.50, 0.56 and 0.47 in Bijori WUA, Govindgarh WUA and Bauchhar WUA respectively. Govindgarh has personnel cost ratio as more because expenditure in personnel activity like training, wages etc. was more in this WUA.
9. Manpower number ratio in Bijori WUA, Govindgarh WUA and Bauchhar WUA is 0.011, 0.009 and 0.006 respectively. In Bauchhar WUA number of staff is less and cultivable command area is more as compare to other WUAs.
10. Sustainability of irrigated area in Bijori WUA, Govindgarh WUA and Bauchhar WUA is 0.88, 0.84 and 0.35 respectively. In Bijori WUA sustainability of irrigated area is higher as compared to other WUAs because irrigated area is more than other WUAs.
11. Area/infrastructure ratio is 90.37, 139.27 and 20.83 in Bijori WUA, Govindgarh WUA and Bauchhar WUA respectively. Govindgarh WUA

has more Area/infrastructure ratio because in this WUA, number of structure and length of structure is less and irrigated area is more as compared to other two WUAs.

Bio-economical indicator

1. The range of water productivity of wheat in Bijori WUA, Govindgarh WUA and Bauchhar WUA was found to be 0.25-0.71kg/m^3,0.46-1.7 kg/m^3 and 0.28-0.66 kg/m^3 in head reach, 0.24-0.69 kg/m^3, 0.55-1.51kg/m^3 and 0.27-1.5 kg/m^3 in middle reach and 0.26-0.74 kg/m^3, 0.55-2.39 kg/m^3 and 0.68-1.74 kg/m^3 in tail reach.
2. The range of water productivity of gram in Bijori WUA, Govindgarh WUA and Bauchhar WUA was found to be 0.53-3.2 kg/m^3, 0.32-2.67 kg/m^3 and 0.53-0.9 kg/m^3 in head reach, 0.35-2.76 kg/m^3, 0.73-1.56 kg/m^3 and 0.87-1.44 kg/m^3 in middle reach and 0.62-6.25 kg/m^3, 1.58-2.98 kg/m^3 0.59-1.7 kg/m^3 in tail reach.
3. Govindgarh WUA command area has no pea crop. Water productivity of pea crop in Bijori WUA and Bauchhar WUA is 0.3-0.43 kg/m^3 and 0.12 kg/m^3 in head reach, 0.14-0.32 kg/m^3 and 0.09-0.14 kg/m^3 in middle reach and 0.3-0.68 kg/m^3 and 0.1-0.13 kg/m^3 in tail reach.

Social organizational indicator

1. From the local inspection point of view, it was observed that 71.4% farmers were satisfied in the command area of Bijori WUA and in the Govindgarh WUA 86.5% satisfied and in Bauchhar WUA, 61.1% are satisfied. The results showed that Bauchhar WUA farmers are not satisfied with the system and in Govindgarh WUA farmers are satisfied with the working of canal.

2. It was found that the 55.6%, 91.7%, 41.7% farmers in the command of Bijori WUA, Govindgarh WUA and Bauchhar WUA respectively participated for making better irrigation system. They regularly maintain the canal system by cleaning it from vegetation and silt deposits for better production.

3. As per survey conducted on effectiveness of origination, it was observed in all selected WUAs that, the Govindgarh WUA farmers thinks that water users association is effective, while the Bauchhar WUA farmers thinks that it is useless.

Conclusions

1. Out of the total 11 indicators evaluated for characterising WUA's, nine are in acceptable range in all three WUA's.
2. Tail end supply ratio was 0.37 in Bouchhar which is below the acceptable limit and shows poor availability in Bauchhar WUA.
3. Bauchhar WUA has highest manpower number ratio of 0.06 followed by 0.011 in Bijori and 0.009 in Govindgarh WUA. It proves the superiority of Govindgarh WUA among all three WUA's.
4. It terms of water productivity, Govindgarh WUA has shown highest performance in all reaches. This is also indicated by farmer satisfaction.
5. Statistical analysis of data shows the superiority of Govindgarh WUA among three WUA's.
6. Govindgarh WUA is having best performance among three WUA's under study.
7. Farmer's categories with different canal reach are also responsible for significant variation in the crop as analysed statistically.
8. There is a significant variation in water productivity in head, middle and tail reach. Tail reach has higher water productivity level as compared to head and middle reach. Even higher water utilisation at head reach of canal could not achieve higher water productivity as compared to tail reach.
9. There is need of proper water management to improve water utilisation in head reach and water available in tail reach for further enhancing water productivity in all the command areas.

SUGGESTIONS FOR FUTURE WORK

Based on the result obtained for the selected objectives following suggestion for the future work are proposed.

1. The study may be done considering more farmers in the command area.
2. As per the present scenario, there are no measuring devices at the outlets to check the discharge and there are no means to account for the seepage losses. Therefore measuring devices should be installed in order to calculate the discharge and water use efficiency so that farmer's may plan crop accordingly.
3. A study should be performed on analysis of canal irrigation system for both seasons i.e. Kharif and Rabi covering the entire crop seasons.

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Appendix - A

Water User Association Survey

1) नहर मरम्मत पर खर्च जल उपभोक्ता संस्था द्धारा :– ....

2) नहर संचालन पर खर्च जल उपभोक्ता संस्था द्धारा :–..

3) ट्रेनींग एवं दुसरे कार्यो पर खर्च :– ....

4) कुल सालाना खर्च :– ....

5) कुल कितने दिन नहर से पानी छोडा गया :–...

6) नहर से पानी रीसाव होता हे क्या :– हॅा / नही

अगर हॅा तो खेत के कितने क्षेत्र पर प्रभाव पडा :– पुरा /आधा /एक तीहाई /

7 वाराबंदी कि जाती हे क्या (हॅा / नही)

8 आने वाली फसल के लीये कोई योजना तेयार करते है क्या (हॅा / नही)

9 कमांड क्षेत्र मे आने वाले किसानो कि सुची है क्या (हॅा / नही)

10 नहर का पानी उपयोग करने वाले किसानो कि सुची है क्या (हॅा / नही)

11 नहर से पानी लेने कि योजना बनाई है क्या (हॅा / नही)

12 हा तो लागु हुई है क्या (हॅा / नही)

13 जल के बहाव का नाप करते है क्या (हॅा / नही)

14 जल उपभोक्ता के बीच विवाद का निराकरण करते है क्या (हॅा / नही)

15 वार्षिक लेखा जोखा रखते है क्या (हॅा / नही)

16 सोसल आडीट वर्ष मे कितनी बार होता है (हॅा / नही)

Appendix- B

Farmers Field Survey

1) जल उपभोक्ता संस्था का नाम ....

2) गांव ....

3) किसान का नाम ....

4) खेत की स्तिथि नहर के किस रीच में आता है।

हेड मिडल टेल

5) खसरा नं .... रकबा नं ....

6) कुल भूमि ....

फसल			
किस्म			
रकबा			
बुवाई का समय			
बीज की मात्रा/एकड			
उपज			
सिचाईं की संख्या			
स्त्रोत			
तरीका			
उपज का मुल्य			

7) सिंचाई क्रम :— फसल...

	दिन	कितने घंटे	डिसचार्ज	सिचाईं की गहराई	सिचाईं कब की समय
1 सिंचाई					
2 सिंचाई					

3 सिंचाई					
4 सिंचाई					
5 सिंचाई					

फसल...

	दिन	कितने घंटे	डीसर्चाज	गहराई	सिचाईं कब की समय
1 सिंचाई					
2 सिंचाई					
3 सिंचाई					
4 सिंचाई					
5 सिंचाई					

फसल...

	दिन	कितने घंटे	डीसर्चाज	गहराई	सिचाईं कब की समय
1 सिंचाई					
2 सिंचाई					
3 सिंचाई					
4 सिंचाई					
5 सिंचाई					

8) पानी का बटवारा :– पुरा /आधा /एक तीहाई /कितने लोग एक साथ पानी लेते है

9) नहर मे 1) पानी का शुल्क देते है   (हॅा / नही)

2) कितनी शुल्क देते है (रूपये) ....

10) सिंचाई का अन्य स्त्रोत :–   कुंआ / नलकूप / नाला / तालाब

11) सिंचाई के लीये साधन :– डीजल पंप / मोटर पंप

12) बिजली का शुल्क :– ....

13) कितने HP कि मोटर है :– ....

14) योजना के अनुसार सिंचाई क्रम :– 20 दिन /15 दिन /7 दिन /4 दिन

15) वास्तवीक सिंचाई क्रम क्या निभाया गया :–

हॅा	नही	हॅा	नही	हॅा	नही	हॅा	नही	हॅा	नही
1 सिंचाई		2 सिंचाई		3 सिंचाई		4 सिंचाई		5 सिंचाई	

16) पास के कुए में पानी की गहराई :–

सिंचाई क्रम	1 सिंचाई	2 सिंचाई	3 सिंचाई	4 सिंचाई	5 सिंचाई
गहराई (से.मी.)					

17) नहर का पानी कही पर इकटठा करते हे क्या :– (हॅा / नही)

हॅा तो कहां पर :– तलाब / निचला इलाका / खेत

18) क्या नहर का पानी सही मात्रा मे मिलता है :– (हॅा / नही)

Appendix - C

Social Capacity

1) क्या आप जल उपभोक्ता संस्था के कार्य से संतुष्ट है (हॅा / नही)

2) क्या आप जलकर से संतुष्ट है (हॅा / नही)

3) क्या नहर मे पानी हमेशा रहता है (हॅा / नही)

4) क्या आपके खेत मे बराबर मात्रा मे पानी आता है (हॅा / नही)

5) क्या जल उपभोक्ता संस्था नहर का रखरखाव करती है (हॅा / नही)

6) क्या आप नहर के रखरखाव मे मदद करते है (हॅा / नही)

7) क्या आप नहर की साफ सफाई मे मदद करते है (हॅा / नही)

8) क्या आप फसल के अनुसार पानी की मात्रा जानते है (हॅा / नही)

9) क्या फसल की पैदावार बडी है (हॅा / नही)

10) क्या पहले से अब आपके रहन सहन में बदलाव है (हॅा / नही)

Appendix- D1

Bijori WUA farmers water delivery data:-

S.No.	Farmer Name	Reach	Category	Area(ha)	Village	Motor (hp)	Velocity (m/s)	Area (m3)	Discharge (m3/s)
1	Kalash Prashad	H	Marginal	0.46	Pipriya	No	1.022	0.027	0.0275
2	Soni bai	H	Marginal	0.8	Zanshi	No	1.391	0.016	0.0226
3	Sitaram	H	Marginal	0.81	Bichuva	No	2.302	0.011	0.0258
4	Vishal singh	H	Small	1.9	Jamuniya	3	1.748	0.018	0.0320
5	Chetu	H	Small	1.01	Pipriya	No	0.865	0.034	0.0291
6	Chotelal Patel	H	Small	1.21	Bichuva	No	2.290	0.014	0.0330
7	Ramchand	H	medium	2.01	Pipriya	3	1.429	0.021	0.0300
8	Ramdash	H	medium	2.43	Chapra	4	2.302	0.015	0.0354
9	Omkar Rai	H	medium	3.47	Chapra	4	1.345	0.021	0.0283
10	Shivram	H	Large	4.05	Nunpur	4	2.179	0.014	0.0300
11	Rabbu Pahlvan	H	Large	12.15	Nunpur	5	1.000	0.029	0.0290
12	Badidash visvkarma	H	Large	4.45	Nunpur	4	1.544	0.018	0.0280
13	Nanhu Zhukkam	M	Marginal	0.34	Jamuniya	No	1.768	0.018	0.0311
14	Santibai	M	Marginal	0.45	Pipriya	No	1.493	0.018	0.0270
15	Pram lal	M	Marginal	0.7	Zanshi	No	1.498	0.016	0.0246
16	Gaya Prashad	M	Small	1.09	Jamuniya	2	1.353	0.022	0.0300
17	Govind Prashad	M	Small	1.22	Pipriya	No	1.982	0.015	0.0290
18	Bhojraj Chadar	M	Small	1.21	Chapra	No	1.459	0.018	0.0258
19	Kishori	M	medium	3.2	Pipriya	No	2.018	0.014	0.0280
20	Dasai Vrandavan	M	medium	2.13	Dolakheda	No	1.616	0.017	0.0274
21	Suresh Zariya	M	medium	2.51	Chapra	No	1.236	0.021	0.0263
22	Santosh Yadav	M	Large	4.09	Chapra	No	1.741	0.018	0.0310
23	Raman Kishan	M	Large	6.07	Nunpur	No	2.050	0.015	0.0298
24	Bilochi	M	Large	4.05	Nunpur	4	1.513	0.017	0.0255
25	Dasrath Yadav	T	Marginal	0.37	Jamuniya	No	1.454	0.015	0.0220
26	Sukhdev Prashad	T	Marginal	0.55	Zanshi	No	1.082	0.022	0.0234
27	Nanhelal	T	Marginal	0.07	Pipariya	No	1.345	0.015	0.0200
28	Sunil Nanhelal	T	Small	1.98	Pipariya	No	0.919	0.020	0.0180
29	Narmadaprashad	T	Small	1.78	Zanshi	3	0.884	0.023	0.0206
30	Hakkibai Premlal	T	Small	1.35	Jamuniya	No	2.093	0.012	0.0250
31	Omkar singh	T	medium	4	Pipariya	5	0.840	0.018	0.0150
32	Rajaram	T	medium	2.43	Bijori	No	0.613	0.028	0.0171
33	Bhagvandas	T	medium	2.02	Bichuva	No	0.928	0.016	0.0149
34	Dhursingh	T	Large	4.03	Pipariya	4	1.190	0.016	0.0190
35	Raju Maharaj	T	Large	4.05	Bichuva	4	1.215	0.014	0.0174
36	Ramfal	T	Large	6.58	Pipariya	5	1.220	0.015	0.0180

Appendix- D2

Govindgarh WUA farmers water delivery data:-

S.No.	Farmer Name	Reach	Category	Area(ha)	Village	Motor (hp)	Velocity (m/s)	Area (m3)	Discharge (m3/s)
1	Yasvant singh	H	Marginal	0.97	Mohni	No	1.004	0.030	0.0300
2	Omkar jagdish	H	Marginal	0.89	Govindgarh	No	1.015	0.028	0.0284
3	Ravisankar	H	Marginal	0.97	Govindgarh	No	1.485	0.020	0.0295
4	Rajendra Siyasaran	H	Small	1.42	Parsiya	No	1.711	0.018	0.0300
5	Mohanlal	H	Small	1.82	Nakta	No	1.382	0.023	0.0324
6	Sashisekhar	H	Small	1.98	Govindgarh	No	2.169	0.015	0.0320
7	Niraj Ramsurat	H	Medium	3.04	Parsiya	4	1.374	0.021	0.0285
8	Rajesh harivansh	H	Medium	3.06	Kapurhai	4	1.557	0.017	0.0270
9	Umasankar	H	Medium	2.43	Amin	5	1.875	0.016	0.0308
10	Markandy Pandy	H	Large	4.05	Parsiya	5	2.314	0.014	0.0329
11	Badrisingh	H	Large	4.05	Amin	5	1.098	0.032	0.0350
12	Ashok kumar	H	Large	4.86	Nakta	5	1.173	0.025	0.0295
13	Hanuman Ramsrvan	M	Marginal	0.61	Mohni	No	1.329	0.021	0.0280
14	Chandmoli jagdish	M	Marginal	0.98	Govindgarh	No	1.593	0.018	0.0284
15	Vasudev jagdish	M	Marginal	0.81	Mohni	No	1.528	0.016	0.0250
16	Anurag Ramrasile	M	Small	1.62	Amin	No	1.852	0.015	0.0275
17	Ramnath	M	Small	1.62	Nakta	3	1.616	0.016	0.0264
18	Shyamlal ramdulare	M	Small	1.86	Mohni	No	1.442	0.019	0.0267
19	Prashant Gayanarayan	M	Medium	2.43	Parsiya	4	2.439	0.011	0.0280
20	Rajesh Ramjas	M	Medium	2.02	Kapurhai	No	1.758	0.014	0.0248
21	Rajendra Dinesh	M	Medium	2.43	Amin	No	1.475	0.020	0.0290
22	Amratlal	M	Large	4.25	Nakta	4	1.727	0.016	0.0278
23	harivansh badriprshad	M	Large	6.07	Kapurhai	5	1.339	0.022	0.0300
24	Lalman molai	M	Large	8.10	Parsiya	5	1.708	0.018	0.0304
25	Ramvisvas	T	Marginal	0.86	Nakta	No	1.571	0.018	0.0288
26	Puspendra gangasingh	T	Marginal	0.97	Mohni	3	2.093	0.014	0.0294
27	Kiran suryabhan	T	Marginal	0.97	Mohni	No	1.793	0.017	0.0302
28	Narendra singh	T	Small	1.62	Mohni	3	1.149	0.021	0.0244
29	Badriprashad Somnath	T	Small	1.92	Kapurhai	No	1.737	0.015	0.0260
30	Raviprashad	T	Small	1.70	Nakta	No	1.132	0.019	0.0220
31	Tejbhan singh	T	Medium	3.24	Mohni	4	0.909	0.023	0.0210
32	Vijay Sobhnath	T	Medium	2.43	Kapurhai	3	2.158	0.012	0.0255
33	Ramgopal	T	Medium	3.24	Kapurhai	3	1.175	0.018	0.0210
34	Samaylal	T	Large	5.26	Amin	5	0.824	0.028	0.0231
35	Sudamaprshad	T	Large	5.12	Nakta	4	1.264	0.016	0.0200
36	Prassn ramsujavan	T	Large	7.29	Mohni	5	1.216	0.015	0.0180

Appendix- D3

Bauchhar WUA farmers water delivery data:-

S.No.	Farmer Name	Reach	Category	Area(ha)	Village	Motor (hp)	Velocity (m/s)	Area (m3)	Discharge (m3/s)
1	Mohan kachi	H	Marginal	0.405	Bouchhar	No	0.863	0.029	0.025
2	Arvind patel	H	Marginal	0.810	Basanpani	3	1.039	0.027	0.028
3	Krasn kumar	H	Marginal	0.360	Mekh	No	1.431	0.018	0.026
4	Sardar patel	H	Small	1.619	Bouchhar	3	1.689	0.015	0.026
5	Annilal Rai	H	Small	1.619	Bouchhar	3	1.238	0.021	0.026
6	Surendra saxena	H	Small	1.619	Karakbel	No	1.833	0.015	0.027
7	Vijay patel	H	Medium	2.429	Basanpani	4	1.163	0.024	0.028
8	Ganesh patel	H	Medium	2.834	Devri	5	1.316	0.019	0.025
9	Sitaram	H	Medium	3.239	Bouchhar	3	1.593	0.016	0.026
10	Ajeet patel	H	Large	4.049	Bouchhar 2	4	1.754	0.017	0.03
11	Purshottam	H	Large	4.372	Mekh	3	0.859	0.035	0.03
12	Hariram	H	Large	9.717	Bouchhar 2	5	1.571	0.019	0.03
13	Chekdilal	M	Marginal	0.360	Mekh	No	1.463	0.019	0.028
14	Ghashyam	M	Marginal	0.931	Devri	No	1.944	0.014	0.028
15	Munna singh	M	Marginal	0.810	Basanpani	No	1.565	0.015	0.024
16	Lotan patel	M	Small	1.619	Bouchhar	3	1.435	0.015	0.022
17	Shivkumar Visvkarma	M	Small	1.619	Basanpani	3	1.538	0.016	0.025
18	Shirikant Tiwari	M	Small	1.215	Basanpani	3	1.314	0.018	0.024
19	Styanarayan Tiwari	M	Medium	2.024	Karakbel	No	1.871	0.011	0.021
20	Tofan singh	M	Medium	2.429	Devri	5	1.622	0.014	0.023
21	Harilal nanhelal	M	Medium	2.024	Mekh	3	1.194	0.018	0.021
22	Arun nema	M	Large	4.049	Bouchhar	4	1.341	0.016	0.022
23	Santosh kumar	M	Large	8.502	Mekh	5	1.083	0.022	0.024
24	Tikaram	M	Large	6.478	Devri	5	1.473	0.018	0.026
25	Kunjilal	T	Marginal	0.405	Devri	No	1.473	0.017	0.025
26	Lakhanlal	T	Marginal	0.891	Bouchhar 2	3	1.447	0.015	0.021
27	Omprakash	T	Marginal	0.381	Mekh	No	1.325	0.015	0.02
28	Gokul Nema	T	Small	1.619	Karakbel	3	0.925	0.022	0.02
29	Sunil sahu	T	Small	1.619	Karakbel	3	1.413	0.015	0.021
30	Narendra patel	T	Small	1.619	Basanpani	3	1.173	0.020	0.023
31	Sanju nema	T	Medium	3.239	Bouchhar	4	0.773	0.023	0.018
32	Omprakash sudama	T	Medium	2.632	Mekh	3	1.590	0.012	0.019
33	Jagdish	T	Medium	3.644	Devri	3	1.231	0.018	0.022
34	Mohan singh	T	Large	6.478	Basanpani	5	0.754	0.028	0.021
35	Shiv dayal	T	Large	7.287	Bouchhar	4	1.129	0.016	0.018
36	Ganpat singh	T	Large	6.073	Devri	5	1.220	0.015	0.018

Appendix- E1

Bijori WUA water available and irrigation in field data

S.No.	Farmer Name	No. of day water available in canal	Total no. of day canal start	Total no. of order	Sufficient water order	Crop area (ha)			Total irrgation time (h)		
						W	G	P	W	G	P
1	Kalash Prashad	85	120	4	4	0.46			28		
2	Soni bai	120	120	4	4	0.80			36		
3	Sitaram	120	120	4	4	0.81			50		
4	Vishal singh	85	120	4	4	1.21	0.68		35	8	
5	Chetu	85	120	4	4	0.81	0.20		40	8	
6	Chotelal Patel	120	120	4	4	0.81	0.40		40	8	
7	Ramchand	120	120	4	4	1.42	0.59		36	8	
8	Ramdash	120	120	4	4	2.02	0.40		40	6	
9	Omkar Rai	120	120	4	4	2.43	1.04		100	12	
10	Shivram	120	120	4	4	3.24	0.81		90	8	
11	Rabbu Pahlvan	120	120	4	4	7.29	1.62	3.24	200	18	144
12	Badidash visvkarma	120	120	4	4	2.02	0.40	2.02	100	4	132
13	Nanhu Zhukkam	70	120	4	4	0.34			20		
14	Santibai	75	120	4	4	0.45			12		
15	Pram lal	75	120	4	4	0.70			36		
16	Gaya Prashad	70	120	4	4	1.09			32		
17	Govind Prashad	75	120	4	4	1.22			40		
18	Bhojraj Chadar	100	120	4	4	1.21			50		
19	Kishori	75	120	4	4	2.43	0.77		60	8	
20	Dasai Vrandavan	95	120	4	4	2.02	0.11		50	8	
21	Suresh Zariya	100	120	4	4	1.70		0.81	50		88
22	Santosh Yadav	90	120	4	4	1.66	0.81	1.62	60	4	100
23	Raman Kishan	95	120	4	4	2.83	1.62	1.62	100	12	200
24	Bilochi	95	120	4	4	3.24	0.81		180	8	
25	Dasrath Yadav	60	120	4	4	0.37			16		
26	Sukhdev Prashad	64	120	4	4	0.55			18		
27	Nanhelal	65	120	4	4	0.07			6		
28	Sunil Nanhelal	65	120	4	4	1.98			64		
29	Narmadaprashad	64	120	4	4	1.62	0.16		55	8	
30	Hakkibai Premlal	60	120	4	4	1.35			75		
31	Omkar singh	65	120	4	4	2.43		1.57	150		120
32	Rajaram	80	120	4	4	2.02	0.40	0.00	160	8	
33	Bhagvandas	75	120	4	4	2.02			128		
34	Dhursingh	65	120	4	4	2.02	0.79	1.21	120	8	132
35	Raju Maharaj	75	120	4	4	1.62	0.81	1.62	150	6	120
36	Ramfal	65	120	4	4	2.43	1.62	2.53	200	10	176

Appendix- E2

Govindgarh WUA water available and irrigation in field data

S.No.	Farmer Name	No. of day water available in canal	Total no. of day canal start	Total no. of order	Sufficient water order	Crop area (ha)		Total irrgation time (h)	
						W	G	W	G
1	Yasvant singh	120	120	4	4	0.97		28	
2	Omkar jagdish	120	120	4	4	0.97		36	
3	Ravisankar	120	120	4	4	0.97		40	
4	Rajendra Siyasaran	110	120	4	4	1.21	0.20	20	8
5	Mohanlal	120	120	4	4	1.62	0.20	24	8
6	Sashisekhar	120	120	4	4	1.21	0.77	40	4
7	Niraj Ramsurat	110	120	4	4	2.43	0.61	40	6
8	Rajesh harivansh	105	120	4	4	2.43	0.63	45	6
9	Umasankar	120	120	4	4	2.02	0.40	80	8
10	Markandy Pandy	110	120	4	4	3.24	0.81	100	9
11	Badrisingh	120	120	4	4	3.24	0.81	100	9
12	Ashok kumar	120	120	4	4	4.05	0.81	88	8
13	Hanuman Ramsrvan	95	120	4	4	0.61		24	
14	Chandmoli jagdish	110	120	4	4	0.98		24	
15	Vasudev jagdish	95	120	4	4	0.81		20	
16	Anurag Ramrasile	110	120	4	4	1.21	0.81	24	8
17	Ramnath	100	120	4	4	1.62		28	
18	Shyamlal ramdulare	95	120	4	4	1.42	0.45	24	10
19	Prashant Gayanarayan	95	120	4	4	2.02	0.40	50	8
20	Rajesh Ramjas	95	120	4	4	2.02		36	
21	Rajendra Dinesh	110	120	4	4	2.02	0.40	50	6
22	Amratlal	100	120	4	4	4.25		80	
23	harivansh badriprshad	95	120	4	4	4.86	1.21	88	18
24	Lalman molai	95	120	4	4	6.07	2.02	120	24
25	Ramvisvas	85	120	4	4	0.86		32	
26	Puspendra gangasingh	80	120	4	4	0.97		28	
27	Kiran suryabhan	80	120	4	4	0.97		28	
28	Narendra singh	80	120	4	4	1.21	0.40	32	4
29	Badriprashad Somnath	70	120	4	4	1.92		40	
30	Raviprashad	85	120	4	4	1.21	0.49	36	4
31	Tejbhan singh	80	120	4	4	2.02	1.21	28	8
32	Vijay Sobhnath	70	120	4	4	1.62	0.81	28	8
33	Ramgopal	70	120	4	4	2.43	0.81	40	10
34	Samaylal	95	120	4	4	4.05	1.21	76	14
35	Sudamaprshad	85	120	4	4	2.83	2.29	56	24
36	Prassn ramsujavan	80	120	4	4	6.07	1.21	128	14

Appendix- E3

Bauchhar WUA water available and irrigation in field data

S.No.	Farmer Name	No. of day water available in canal	Total no. of day canal start	Total no. of order	Sufficient water order	Crop area (ha)			Total irrgation time (h)		
						W	G	P	W	G	P
1	Mohan kachi	95	120	4	4	0.40			20		
2	Arvind patel	80	120	4	4	0.81			28		
3	Krasn kumar	70	120	4	4	0.36			16		
4	Sardar patel	95	120	4	4	1.62			32		
5	Annilal Rai	95	120	4	4	1.21	0.40		32	6	
6	Surendra saxena	70	120	4	4	1.62			40		
7	Vijay patel	80	120	4	4	2.02	0.40		48	6	
8	Ganesh patel	85	120	4	4	2.02	0.81		64	9	
9	Sitaram	95	120	4	4	2.83	0.40		64	6	
10	Ajeet patel	95	120	4	4	3.24	0.81		84	12	
11	Purshottam	70	120	4	4	3.24	1.13		92	12	
12	Hariram	95	120	4	4	6.07	1.62	2.02	140	21	270
13	Chekdilal	55	120	4	3	0.36			16		
14	Ghashyam	70	120	4	3	0.93			20		
15	Munna singh	55	120	4	3	0.81			20		
16	Lotan patel	65	120	4	3	1.21	0.40		20	6	
17	Shivkumar Visvkarma	55	120	4	3	1.62			24		
18	Shirikant Tiwari	55	120	4	2	1.21			16		
19	Styanarayan Tiwari	60	120	4	3	1.62	0.40		20	6	
20	Tofan singh	70	120	4	3	1.62	0.81		28	9	
21	Harilal nanhelal	55	120	4	2	2.02			32		
22	Arun nema	65	120	4	3	3.24	0.81		44	9	
23	Santosh kumar	55	120	4	3	7.29		1.21	100		180
24	Tikaram	70	120	4	2	4.86	0.81	0.81	72	9	180
25	Kunjilal	55	120	4	2	0.40			8		
26	Lakhanlal	40	120	4	3	0.89			12		
27	Omprakash	30	120	4	3	0.38			8		
28	Gokul Nema	45	120	4	2	1.62			32		
29	Sunil sahu	45	120	4	2	1.21	0.40		32	9	
30	Narendra patel	30	120	4	2	1.62			32		
31	Sanju nema	45	120	4	3	2.43		0.81	28		224
32	Omprakash sudama	30	120	4	2	2.63			36		
33	Jagdish	55	120	4	2	1.62	0.81	1.21	36	12	240
34	Mohan singh	30	120	4	3	5.67	0.81		64	12	
35	Shiv dayal	45	120	4	2	5.67	1.62		72	15	
36	Ganpat singh	55	120	4	3	4.05	0.81	1.21	84	12	256

Appendix- F1

Bijori WUA water productivity in different crops

S.No.	Farmer Name	Total amount of water m3			Yield (kg/ha)			Production (kg)			Water productivity (kg/m3)		
		W	G	P	W	G	P	W	G	P	W	G	P
1	Kalash Prashad	2766.96			1500			692.31			0.25		
2	Soni bai	2931.552			1600			1282.59			0.44		
3	Sitaram	4644			1450			1174.09			0.25		
4	Vishal singh	4032	460.8		1800	900		2186.23	615.79		0.54	1.34	
5	Chetu	4184.64	418.464		1550	1100		1255.06	218.22		0.30	0.52	
6	Chotelal Patel	4752	475.2		1700	1250		1376.52	501.01		0.29	1.05	
7	Ramchand	3888	432		1650	1050		2338.06	620.65		0.60	1.44	
8	Ramdash	5103.36	510.336		1800	1300		3643.72	526.32		0.71	1.03	
9	Omkar Rai	10170	406.8		1900	1250		4615.38	1300.61		0.45	3.20	
10	Shivram	9720	432		1450	1100		4696.36	890.69		0.48	2.06	
11	Rabbu Pahlvan	20880	939.6	15033.6	1900	1300	2000	13846.15	2105.26	6485.83	0.66	2.24	0.43
12	Badidash visvkarma	10080	403.2	12196.8	2000	1250	1800	4048.58	506.07	3643.72	0.40	1.26	0.30
13	Nanhu Zhukkam	2240.64			1600			544.13			0.24		
14	Santibai	1166.4			1800			808.91			0.69		
15	Pram lal	3181.68			1850			1295.75			0.41		
16	Gaya Prashad	3456			1700			1851.42			0.54		
17	Govind Prashad	4176			1900			2315.38			0.55		
18	Bhojraj Chadar	4640.4			1600			1936.84			0.42		
19	Kishori	6048	403.2		1550	1100		3765.18	846.15		0.62	2.10	
20	Dasai Vrandavan	4933.8	394.704		1600	1200		3238.87	126.32		0.66	0.32	
21	Suresh Zariya	4735.8		11460.636	1750	1200	1950	2975.71		1578.95	0.63		0.14
22	Santosh Yadav	6696	446.4	11160	1800	1200	1750	2987.85	971.66	2834.01	0.45	2.18	0.25
23	Raman Kishan	10717.2	964.548	10717.2	1800	1050	2100	5093.93	1700.40	3400.81	0.48	1.76	0.32
24	Bilochi	16498.08	366.624		2000	1250		6477.73	1012.15		0.39	2.76	
25	Dasrath Yadav	1267.2			1750			644.74			0.51		
26	Sukhdev Prashad	1516.32			1700			936.03			0.62		
27	Nanhelal	432			1600			110.12			0.25		
28	Sunil Nanhelal	4147.2			1550			3068.62			0.74		
29	Narmadaprashad	4068.9	295.92		1600	1150		2591.09	186.23		0.64	0.63	
30	Hakkibai Premlal	6750			1800			2426.72			0.36		
31	Omkar singh	8100		5400	1950		1850	4736.84		2906.07	0.58		0.54
32	Rajaram	9861.12	246.528		1900	1000		3846.15	404.86		0.39	1.64	
33	Bhagvandas	6861.312			2000	950		4040.49			0.59		
34	Dhursingh	8208	273.6	8276.4	2000	950	2050	4048.58	750.00	2489.88	0.49	2.74	0.30
35	Raju Maharaj	9396	250.56	6264	1950	1100	1900	3157.89	890.69	3076.92	0.34	3.55	0.49
36	Ramfal	12960	259.2	7840.8	1850	1000	2100	4493.93	1619.43	5313.77	0.35	6.25	0.68

Appendix- F2

Govindgarh WUA water productivity in different crops

S.No.	Farmer Name	Total amount of water m3		Yield (kg/ha)		Production (kg)		Water productivity (kg/m3)	
		W	G	W	G	W	G	W	G
1	Yasvant singh	3024		2000		1943.32		0.64	
2	Omkar jagdish	3680.64		2050		1991.90		0.54	
3	Ravisankar	4248		2000		1943.32		0.46	
4	Rajendra Siyasaran	2160	864	2200	1400	2672.06	283.40	1.24	0.33
5	Mohanlal	2799.36	933.12	2050	1550	3319.84	313.77	1.19	0.34
6	Sashisekhar	4608	460.8	2140	1600	2599.19	1230.77	0.56	2.67
7	Niraj Ramsurat	4104	615.6	2500	1560	6072.87	947.37	1.48	1.54
8	Rajesh harivansh	4374	583.2	2450	1740	5951.42	1098.95	1.36	1.88
9	Umasankar	8870.4	887.04	2600	1640	5263.16	663.97	0.59	0.75
10	Markandy Pandy	11844	1065.96	2550	1600	8259.11	1295.55	0.70	1.22
11	Badrisingh	12600	1134	2400	1650	7773.28	1336.03	0.62	1.18
12	Ashok kumar	9345.6	849.6	2600	1800	10526.32	1457.49	1.13	1.72
13	Hanuman Ramsrvan	2419.2		2200		1336.03		0.55	
14	Chandmoli jagdish	2453.76		2260		2205.10		0.90	
15	Vasudev jagdish	1800		2470		1990.00		1.11	
16	Anurag Ramrasile	2376	792	2500	1530	3036.44	1238.87	1.28	1.56
17	Ramnath	2661.12		2400		3886.64		1.46	
18	Shyamlal ramdulare	2306.88	961.2	2450	1600	3471.66	712.55	1.50	0.74
19	Prashant Gayanarayan	5040	806.4	2200	1580	4453.44	639.68	0.88	0.79
20	Rajesh Ramjas	3214.08		2000		4048.58		1.26	
21	Rajendra Dinesh	5220	626.4	2550	1450	5161.94	587.04	0.99	0.94
22	Amratlal	8006.4		2600		11052.63		1.38	
23	harivansh badriprshad	9504	1944	2600	1800	12631.58	2186.23	1.33	1.12
24	Lalman molai	13132.8	2626.56	2600	1800	15789.47	3643.72	1.20	1.39
25	Ramvisvas	3317.76		2100		1802.43		0.54	
26	Puspendra gangasingh	2963.52		2055		1996.76		0.67	
27	Kiran suryabhan	3044.16		2120		2059.92		0.68	
28	Narendra singh	2810.88	351.36	2050	1400	2489.88	566.80	0.89	1.61
29	Badriprashad Somnath	3744		2400		4615.38		1.23	
30	Raviprashad	2851.2	316.8	2550	1370	3097.17	665.59	1.09	2.10
31	Tejbhan singh	2116.8	604.8	2500	1490	5060.73	1809.72	2.39	2.99
32	Vijay Sobhnath	2570.4	734.4	2340	1520	3789.47	1230.77	1.47	1.68
33	Ramgopal	3024	756	2400	1560	5829.96	1263.16	1.93	1.67
34	Samaylal	6320.16	1164.24	2550	1800	10323.89	2186.23	1.63	1.88
35	Sudamaprshad	4032	1728	2600	1800	7368.42	4117.41	1.83	2.38
36	Prassn ramsujavan	8294.4	907.2	2600	1800	15789.47	2186.23	1.90	2.41

Appendix- F3

Bauchhar WUA water productivity in different crops

S.No.	Farmer Name	Total amount of water m3			Yield (kg/ha)			Production (kg)			Water productivity (kg/m3)		
		W	G	P	W	G	P	W	G	P	W	G	P
1	Mohan kachi	1800			1300			526.32			0.29		
2	Arvind patel	2822.4			1250			1012.15			0.36		
3	Krasn kumar	1497.6			1180			425.18			0.28		
4	Sardar patel	2995.2			1200			1943.32			0.65		
5	Annilal Rai	2995.2	561.6		1240	900		1506.07	364.37		0.50	0.65	
6	Surendra saxena	3888			1380			2234.82			0.57		
7	Vijay patel	4838.4	604.8		1350	800		2732.79	323.89		0.56	0.54	
8	Ganesh patel	5760	810		1300	900		2631.58	728.74		0.46	0.90	
9	Sitaram	5990.4	561.6		1400	950		3967.61	384.62		0.66	0.68	
10	Ajeet patel	9072	1296		1400	1000		4534.41	809.72		0.50	0.62	
11	Purshottam	9936	1296		1400	1000		4534.41	1133.60		0.46	0.87	
12	Hariram	15120	2268	29160	1450	1000	1700	8805.67	1619.43	3441.30	0.58	0.71	0.12
13	Chekdilal	1612.8			1200			432.39			0.27		
14	Ghashyam	2016			1250			1163.97			0.58		
15	Munna singh	1728			1310			1060.73			0.61		
16	Lotan patel	1584	475.2		1200	950		1457.49	384.62		0.92	0.81	
17	Shivkumar Visvkarma	2160			1200			1943.32			0.90		
18	Shirikant Tiwari	1382.4			1300			1578.95			1.14		
19	Styanarayan Tiwari	1512	453.6		1400	1000		2267.21	404.86		1.50	0.89	
20	Tofan singh	2318.4	745.2		1400	1000		2267.21	809.72		0.98	1.09	
21	Harilal nanhelal	2419.2			1350			2732.79			1.13		
22	Arun nema	3484.8	712.8		1350	1000		4372.47	809.72		1.25	1.14	
23	Santosh kumar	8640		15552	1260		1800	9182.19		2186.23	1.06		0.14
24	Tikaram	6739.2	842.4	16848	1200	900	1800	5829.96	728.74	1457.49	0.87	0.87	0.09
25	Kunjilal	720			1400			566.80			0.79		
26	Lakhanlal	907.2			1400			1246.96			1.37		
27	Omprakash	576			1300			494.74			0.86		
28	Gokul Nema	2304			1400			2267.21			0.98		
29	Sunil sahu	2419.2	680.4		1350	1000		1639.68	404.86		0.68	0.60	
30	Narendra patel	2649.6			1360			2202.43			0.83		
31	Sanju nema	1814.4		14515.2	1300		1800	3157.89		1457.49	1.74		0.10
32	Omprakash sudama	2462.4			1400			3684.21			1.50		
33	Jagdish	2851.2	950.4	19008	1300	1000	1800	2105.26	809.72	2186.23	0.74	0.85	0.12
34	Mohan singh	4838.4	907.2		1240	1000		7028.34	809.72		1.45	0.89	
35	Shiv dayal	4665.6	972		1350	1000		7651.82	1619.43		1.64	1.67	
36	Ganpat singh	5443.2	777.6	16588.8	1300	1000	1800	5263.16	809.72	2186.23	0.97	1.04	0.13

VITA

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