RAINWATER MANAGEMENT FOR SUSTAINABLE CROP PRODUCTION IN KANDHAMAL DISTRICT OF ORISSA

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CERTIFICATE-I

This is to certify that the thesis entitled "**Rainwater management for sustainable crop production in Kandhamal district of Orissa"** submitted in partial fulfillment of the requirements for the award of the degree of **Doctor of Philosophy in AGRICULTURAL ENGINEERING (Soil and Water Conservation Engineering)** to the Orissa University of Agriculture and Technology is a faithful record of *bonafide* and original research carried out by ***SRI CH. RAJENDRA SUBUDHI*** (Admn. No. 01 Ag. Engg. / Ph.D. (Trad.) / 2008) under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

It is further certified that the assistance and help received by him from various sources during the course of investigations have been duly acknowledged.

CHAIRMAN

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CERTIFICATE-II

This to certify that the thesis entitled "**Rainwater management for sustainable crop production in Kandhamal district of Orissa"** submitted by **SRI CH. RAJENDRA SUBUDHI (**Admn.No. 01 Ag. Engg. / Ph.D (Trad.) / 2008) to the Orissa University of Agriculture and Technology, Bhubaneswar, in partial fulfillment of the requirements for the degree of **Doctor of Philosophy in AGRICULTURAL ENGINEERING (Soil and Water Conservation Engineering)** has been approved by the student's advisory committee and the external examiner.

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Date (Ch. Rajendra Subudhi)

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LIST OF SYMBOLS

Symbol	Nomenclature
$\in$	Thresh hold value
B	Benefit
Bt	Benefit of subscribed years
C	Cost
χ^2	Chi-square
Ct	Cost of subscribed years
C_w	Cost of earth work
γ	Locationparameter
Γ	Gammafunction
I	Discount rate
Kg/ha-mm	Kilogram per hectare millimeter
L	Litre
M	Rank number
μ	Mean
N	Number of years
O	Observed value
P	Predicted value
PW	Present worth
Q_e	Volume of water loss as evaporation,
Q_i	Volume of water utilized for irrigation
Q_p	Volume of water received directly from the rainfall
Q_r	Volume of runoff collected from the field
Q_s	Volume of water lost due to seepage
P	Probability
R	Internal rate of return
R^2	Co-efficient of determination
σ	Standard deviation
t	Tonne

Symbol	Nomenclature
T	Treatments
WUE	Water use efficiency
x	Multiplication
X	Rainfall
X	Variate
Y	Runoff
Z	Soil loss

LIST OF ABBREVIATIONS

ASCE	American Society of Civil Engineers
BCR	Benefit cost ratio
c.e.w.	Cost of earth work
CEW	Cauliflower equivalent yield
c.l.	Cost of lining
C.T.	Cumulative total
D.H.	Date of harvesting
D.P.	Date of plantimg
D.S.	Date of sowing
Dwb	Dry weight basis
Fig	Figure
Ha	Hectare
IRR	Internal rate of return
Kg	Kilogram
Kg/ha-mm	Kilogram per hectare millimetre
LP	Lined pond
M	Meter
m. ha	Million hectare
m. ha-m	Million hectare meter
M.T.	Monthly total
N	North
NPW	Net present worth
OFR	On farm reservoir
OMR	Operation maintenance and replacement

PBP	Payback period
PET	Potential evapo transpiration
PW	Present worth
RBD	Randomized block design
REY	Rice equivalent yield
Rs	Rupees
ULP	Un lined pond

ABSTRACT

Land, water and vegetation are the most important natural resources on which the living beings rely, need proper planning in development, management and optimal utilization of these resources for sustainable production and economic enhancement of the rural people. Sustainability in production, improvement in the standard of living of the poor families and restoration of ecological balance, require different measures on agricultural land and common property resources, involve the measures on agricultural lands and the common property resources. Pentad rainfall analysis will help to determine the dry pentads. This will help the farmers of Kandhamal district to provide life saving irrigation to the crop by constructing water harvesting pond at the lower side of their land.

The highest runoff was obtained in cultivated fallow i.e. 400.93 mm and lowest runoff is in pigeon pea + groundnut intercropping (T_7) i.e. 309.25 mm. This is followed by pigeon pea + rice intercropping system (319.58 mm) which is 2.9 % lower than pigeon pea + rice strip cropping system (T_4). About 7.4 % of rainfall as runoff was saved in case of pigeon pea + groundnut intercropping system (T_7) over cultivated fallow (T_9).

Less soil loss to a tune of 8.03 t/ha is observed in groundnut + pigeon pea intercropping (T_7). Field under rice + pigeon pea intercropping is the second lowest soil loss producer followed by pigeon pea + rice strip cropping. Highest quantity of soil loss (8.94 t/ha) was obtained from pigeon pea.

Amongst sole crops, groundnut yielded less soil loss (9.42 t/ha) which is 3.2% and 5.52% less than sole crop of rice and pigeon pea respectively. When sole crop of ground nut, strip cropping of pigeon pea + groundnut and intercropping of pigeon pea + groundnut are taken in to consideration, less soil loss is obtained from pigeon pea + groundnut intercropping field followed by pigeon pea + groundnut strip cropping and sole crop of groundnut. The soil loss in the cases of pigeon pea + rice strip cropping (T_4) and pigeon pea + groundnut (T_5) showed at par. The highest soil loss amongst all the treatments is obtained from cultivable fallow land followed by uncultivated fallow. Pigeon pea + rice (T_6) intercropping allow soil loss of 8.5 t/ha which is 9.41% less than the pigeon pea + rice strip cropping.

Intercrop system of groundnut and pigeon pea (4:2) gave significantly higher rice equivalent yield than other intercrop and sole crops systems. Mean rice equivalent yield was 3.862 t/ha. Introduction of pigeon pea + groundnut (2:4) increased the yield by 158 %, 97% and 21% when compared with sole crop of rice, pigeon pea and groundnut respectively.

The mean yield in last three years shows that the yield of vegetables (Cauliflower equivalent) in lined pond is highest (4.84 t/ha), which is 19.21 % more than the unlined pond (4.06 t/ha) due to more number of irrigation is given to lined pond (4.84t/ha) and 41.1 % higher than no pond system (3.43 t/ha) as no irrigation was given in no pond system. The mean *rabi* radish yield in lined pond was 23.77 t/ha. The mean yield of radish crop was obtained 23.77 t/ha from lined pond only during *rabi*, by using water from the water harvesting tank. The other two systems (unlined and no pond system) crop could not be grown due to want of irrigation water. The water loss in unlined pond was highest (28,600, lit/day or 831 lit/day/m^2) where as lowest is found in lined pond (235.8 lit/day or 17.06 lit/ day/ m^2).

The cost of lined pond was Rs 9.967=00 and that of unlined pond was Rs 2,993=00. The water use efficiency was highest in lined pond (8.6 kg/ha/mm).The cost of lining per square meter was Rs 88.50. It is observed that tomato yield was better than the cauliflower yield. The rich farmers can go for water harvesting pond based technology as higher cost benefit ratio (2.25) is obtained in lined pond compared to 2.12 in unlined pond and 1.97 in no pond treatment plots. The payback period for both lined pond (soil cement plaster 6:1 of 8 cm thickness) and unlined pond were estimated as 2 years.

CHAPTER- I

INTRODUCTION

CHAPTER- I

INTRODUCTION

Rainfed agriculture occupies a prominent place in Indian economy and rural livelihood. It is pivotal to the economy and food security of India. The geographical area of India is 328 m ha. About 60% of the total cultivated area is rainfed, supporting 40% of India's food demand of 1.2 billion people. India ranks first among countries that practice rainfed agriculture in terms of extent and value of production. Even if full irrigation potential is achieved, about half of the 142 m. ha cultivated area will most likely remain dependent on rainfall (Dar, 2011). The state Odisha, having geographical area of 155.4 lakh hectares, about 63 lakh hectares of land have been put under cultivation. About 44% of cultivated area is coming under rain fed and this is also decreasing day to day due to variation in production. Similarly, the district Kandhamal of Odisha state with the total geographical area of 7.54 lakh ha, 1.77 lakh ha. area is put under cultivation, out of which 81 per cent of area is under rainfed agriculture.

Besides land and other inputs water contributes one of the principal constituents to increase food production. Erratic and uneven rainfall distribution and subsequent soil loss through runoff are the two major problems prevalent in the rainfed regions causing reduction in the production of upland crops. Even short term dry spells can reduce production significantly and prolonged drought can cause total failure and mass starvation. Also water stress at some critical stage of crop growth can greatly reduce the yield. Sustainable production depends on health, vitality and purity of production environment of which land and water are important constituents. The need for proper planning in development, management and optimal utilization of the natural resources is of great importance for the economic up-gradation of the poor rural people of the state. So the need for conservation of the natural resources land, soil and water are of great importance for increasing the fuel, fodder and fiber for future generation.

Kandhamala district is a drought prone area. So rainfall analysis is required for crop planning to mitigate drought spell and drought situation for benefit of poor tribal farmers of the district.

1.1 Importance of rainfall analysis

Rainfall is one of the most important natural input resources to crop production in semi arid region. In India, the gross irrigated area has been rapidly increasing from 28 m ha in 1960-1961 to 58.13 m ha in 2011. Despite this progress, marginal and small farmers constituting 80% of agricultural income group, still depend on rain fed farming. The early or delay in onset of monsoon, early or late withdrawal of monsoon, breaks in monsoon period, unusual heavy rainfall during the critical phenological phase of crops may disturb the normal crop growth and development. To exploit the available rainfall effectively, crop planning and management practices must be followed based on the rainfall amount and distribution at a place. Most of the hydrological events occurring as natural phenomena are observed only once. One of the important problems in hydrology deals with the interpretation of past records of hydrological event in terms of future probabilities of occurrence. The procedure adopted for estimating of the frequency of occurrence of the rainfall event in known as frequency analysis. Though the rainfall is erratic and varies with time and space, it is commonly possible to predict return period using various probability distributions.

1.2 Runoff management techniques (*in - situ*)

Improvement in soil conditions (maintenance of infiltration capacity by mechanical manipulation and addition of organic manure) and soil-water regime to optimize crop production can be accomplished by runoff management techniques which vary with the situation, depending on existing conservation problems on soil in the ecological region. The various types of run-off management may be classified are those which:

- increase water intake and storage and so reduce runoff
- control water movement over the soil surface
- dispose safely of the excess rainfall as runoff and storage in harvesting pond.

Soil and water conservation are the two interrelated parameters. Methods that control and conserve water on hillsides also conserve the soil and control erosion.

In the arid and semi-arid regions, the choice of management is clear; all rainfall must be retained by techniques that reduce storm-water runoff, improve infiltration and increase the water storage capacity of the soil. In the humid and sub-humid areas, a balance has to be struck between conservation of soil and water by runoff control and the avoidance of surface water logging, so the options are not as straight forward. In general, runoff is best minimized by ensuring high infiltration of rainwater into the soil through biological conservation measures. Where this cannot be done to full effect, particularly in areas of high-intensity storms or where there are periods of poor crop cover, earth works (physical control measures) can provide surface protection by holding water to give it time to soak by the soil. Such physical conservation measures involve land shaping, construction of contour bunds, terraces and ridges. These require considerable technical design, supervision, proper construction and maintenance costs. In contrast, the biological methods include some soil management and agronomic cultural practices that are normally the companion of profitable agriculture such as appropriate land use and preparation, fertility maintenance, crop residue management, the use of cover crops and appropriate crop husbandry. Much research on rainfall-runoff management and its influence on erosion and soil-water conservation have been accumulated over the years. Some of the successful practices are briefly described in the following section.

Fragmented and small land holdings of small and marginal farmers restrict for construction of water harvesting structures / ponds in their lands. Further to mitigate the drought and to earn more profit, Government of India implemented the 2^{nd} green revolution and crop diversification programme in the uplands. Small farmers have affinity to grow paddy in uplands, because rice is their staple food. But the less yield obtained due to occurrence of drought, irregular rainfall pattern and loss of top fertile soil with runoff water from such type of lands make the farmer less profit. Therefore it is necessary for these type of farmers to select the cropping systems, so that it will retain more moisture, will conserve soil, simultaneously will reduce the loss of plant nutrients and overall will give more economical yield. This system is in-situ management.

1.3 Need for rainwater harvesting

Water is becoming a scarce commodity and it is considered as a liquid gold in all the parts of the country especially in Coimbatore, Erode and Salem Districts of Tamil Nadu. The demand of water is also increasing day by day not only for agriculture, but also for household and Industrial purposes. It is estimated that water need for drinking and other municipal uses will be increased from 3.30 m-ha-m to 7.00 m-ha-m in 2020-25. Similarly the demand of water for industries will be increased by 4 fold i.e. from 3.00 to 12.00 m-ha-m during this period. At the same time more area should be brought under irrigation to feed the escalating population of the country, which also needs more water. But we are not going to get one litre more water than we get at present though the demand is alarming. The perennial rivers are becoming dry and ground water table is depleting in most of the areas. Country is facing floods and drought in the same year in many states. This is because, no concrete action was taken to conserve, harvest and manage the rain water efficiently. The rainfall is abundant in the world and also in India. But it is not evenly distributed in all places. India being the monsoonal country, the rain falls only for 3 to 4 months in a year with high intensity, which results more runoff and soil erosion. Total rain occurs only in about 100 hours out of 8760 hours in a year. It is also erratic and falls once in 3 or 4 years. This is very common in many parts of the country. It is suggested that the cropping system should be based on hydrologic events considering water management and water harvesting potential of upland crop fields. Panda (2009) carried out a study for eastern India, and found the concept of on-farm reservoir system to mitigate the ill effect of drought on agriculture.

1.3.1 History of rain water harvesting

Many techniques now in use today for water harvesting is not new. It is practiced as early as 4500 B.C. by the people of Urope, also by the Nabateans and the people of the Middle East. Evenari and his colleagues of Israel have described water harvesting system in the Negve desert. The system involved clearing hill sides to smooth the soil to increase runoff and then building contour ditches to collect the water and carry it to low lying fields where the water was used to irrigate crops. By the time of the Roman Empire, these runoff farms had evolved into relatively sophisticated systems. The next significant development was the construction of roaded catchments as described by the public works Department of Western Australia in 1956. They are so called because the soil is graded into ditches. These ditches convey the collected water to a storage reservoir. Lauritzan, USA has done pioneering work in evaluating plastic and artificial rubber membranes for the construction of catchments and reservoirs during 1950's. In 1959, Mayer of water conservation laboratory, USA began to investigate materials that will make the soil to become hydrophobic or water repellent. Then gradually expanded to include sprayable asphalt compounds, plastic and metal films bounded to the soil compaction and dispersion and asphalt fiber glass membranes.

The light textured and well-drained upland soils classified under sandy loam (0-30 cm depth) in North Eastern Ghat Zone provide scope for cultivation of vegetables during rainy season. The intermittent dry spells and terminal drought affect the performance of these high value crops in most of the years. About 36 to 50 % of the rainfall which is lost in the form of run-off (Dhruvnarain, *et al*. 1986). Harvesting of this run-off water in constructed farm tank with proper lining and reuse of this water for life-saving irrigation will protect the crop from dry spell occurred during *kharif*. If possible the harvested runoff water will be helpful for supplemental irrigation to a second crop after harvest of the first crop. This system is ex-situ management of water.

The medium and big farmers who can afford for construction of water harvesting pond in upland situations, high value remunerative vegetable crops with ex-situ management is suggested. This will also make to grow a second crop in that area, by utilizing the stored water in the pond.

Keeping these points in view, the present experiment involving two water management systems *in-situ* and *ex-situ* (pond and no-pond based system) have been designed with the following objectives.

Objectives:

1. Rainfall analysis and crop planning of Kandhamal district
2. Rainwater management through different cropping systems and estimation of runoff, soil loss and crop productivity
3. Water harvesting and its reuse for better rain water management, sustainability in production and increase of economy
4. Economic analysis of *in-situ* and *ex- situ* management

CHAPTER- II

REVIEW OF LITERATURE

CHAPTER-II

REVIEW OF LITERATURE

This chapter deals with review of some of the works done in the past by the researchers on the issue of rainfall analysis and rainwater management.

2.1. Rainfall analysis

Analysis of meteorological events of a region over a number of years is very useful for crop planning, designing water harvesting structures, scheduling of irrigation etc. The random nature of rainfall occurrence needs its sound statistical analysis and logical interpretation.

In this direction, different workers such as Singh *et al.* (2002) carried out probability analysis of monthly rainfall at Jhansi and suggested the need for harvesting surplus water.

Singh *et al*. (2005) analyzed the 28 years of rainfall data, suggested that, months from July to August are suitable for transplanting of paddy. In uplands situation, with three crops sequence, they suggested that the third crop should be sown before the end of October.

Jat *et al.* (2006) predicted the rainfall for Rajastan through log-person type-III distribution for prediction of water deficit of Jaipur and Kota. Rainfall is one of the most important natural input resources to crop production in semi arid region. To exploit the available rainfall effectively, crop planning and management practices must be followed based on the rainfall amount and distribution at a place. Most of the hydrological events occurring as natural phenomena are observed only once. One of the important problem in hydrology deals with the interpreting past records of hydrological event in terms of future probabilities of occurrence. The procedure adopted for estimation of the frequency of occurrence of the rainfall event in known as frequency analysis.

Frequency analysis of rainfall data has been attempted for different places in India (Aggarwal, 2008) to find out the rainfall amount at different probability level for design of soil and water conservation structures and crop planning. Probability and frequency analysis of rainfall data enables us to determine the expected rainfall at various chances. Weekly, monthly and seasonal probability analysis of rainfall data for crop planning has been attempted by different authors. Prediction of rains and crop planning can be done analytically which proves a significant tool in the hands of farmers for better economic returns.

Reddy *et al.* (2008) analyzed the rainfall for water harvesting structures and suggested that surplus *kharif* water can be harvested in water harvesting structures in Bangalore region of Karnataka.

Subbaiah and Prajapathi (2013) applied SMEMAX transformation its modified version and power transformation to weekly rainfall records tested previously for independence, homogeneity and completeness for their capabilities of predicting rainfall amount at various probability levels. It was found that power transformation the most suitable among all three versions of SMEMAX transformation in transforming the rainfall data to a normal distribution.

2.1.1 Probability distribution functions

The random natures of rainfall occurrence need its sound statistical analysis and logical interpretation. The analysis of annual rainfall and monthly rainfall pattern of a region over a number of years is very useful for crop planning, designing water harvesting structures, scheduling of irrigation, etc.

Fisher (1924) studied the influence of rainfall on the yield of wheat in Rothamasted and concluded that distribution of rainfall during a season is the determining factor rather than total amount of rainfall which influences the crop yield.

In Chhattisgarh state, there are large variations in annual rainfall and these variations often result in reduced crop productivity especially rice crop. Rice is grown in approximately 3.6 million hectares area and farmers take tall and photo-sensitive varieties for some reasons which flower by mid-October and mature by mid-November. Terminal drought is a recurring feature for rice crop in this region. Also intermittent dry spells make the crop operations delayed as 80 per cent of the area in this region is under rainfed conditions. Thus, the success of rice crop not only depends upon the monsoonal rainfall but also on the October rainfall which occurs due to cyclonic activity in the Bay of Bengal. As the Chhatisgarh plains in central India are mainly dependant on monsoon rains (south-west), the precise knowledge of amount of rainfall that can be expected at different probability levels will go a long way in helping farmers to plan their agricultural operations.

Another useful line of work relating to the study of rainfall distribution was introduced by Manning (1950) and a transformation of the skew frequency distribution of rainfall was performed to close down to the theoretical normal distribution.

Therefore, an attempt has been made for probability analysis of long term rainfall data of Labandi station for developing risk proof technologies for rainfed agriculture of Raipur district (Rao et al. 1968).

Similarly weekly rainfall analysis gives more useful information in crop planning (Sharma *et al.*, 1979). Different techniques for determining probability distribution on rainfall analysis and best fit probability distribution function such as normal, log-normal, Gumbel, Weibull and Pearson type etc. have been identified as per different research studies.

Earlier workers Ray *et al*. (1980) and Agnihotri *et al*. (1986) have worked out the weekly rainfall probabilities for different agro climatic regions, suggested that the rainfall at 80 per cent probability can safely be taken as assured rainfall. While that of 50 per cent probability is the medium limit for taking dry risk.

Kumar (1999) analyzed the rainfall through different probability distribution function and found that Log-Normal distribution is the best for predicting annual maximum daily rainfall at Pantnagar for planning of soil conservation and drainage measures.

Research works in this direction by Mishra *et al*. (1999) used the probability analysis of weekly rainfall for irrigation scheduling and found the different models for Assam region.

Kumar (2000) analyzed the weekly probability of rainfall and suggested the crop planning for Garhwal Himalayan region.

Tomar and Ranade (2001) predicted a model between probability of rainfall occurrence and mean monthly rainfall for irrigation scheduling in black clay soil of Indore region of Madhya Pradesh. Analysis of annual, seasonal and monthly rainfall of a region is useful to design water harvesting structure.

According to Mulat *et al.*(2004), the quantum of rainfall during crop growing season and temporal distribution of rainfall is a crucial factor deciding inter annual fluctuations in national crop production security.

Jat and Singh (2005) obtained that Log Pearson Type -III is suitable for prediction of rainfall at Rajastan.

Singh *et al*. (2005) used the probability analysis of weekly rainfall for irrigation scheduling and found the different models for Bihar region.

Jat *et al*. (2006) analyzed the rainfall data on weekly basis through Gamma distribution to predict the minimum assured rainfall at different probability of exceedence. The study revealed that chance of drought are more at critical stage of Sorghum crop which indicated that, there is a scope for supplemental irrigation.

2.1.2 Importance of probability analysis

Recently, the severe drought conditions have disrupted human societies in Bundelkhand region of central India and got the attention of India on reality of climate variability and its significance.

The information on annual and seasonal rainfall of a region is useful to design water harvesting structure for agricultural operations, field preparation, seeding, irrigation, fertilizer application and overall in field of crop planning (Sharma, *et al.*, 1979).

Several studies have been undertaken in India to assess the rainfall variability. Parthasarthy and Mooley (1981) for Karnataka and Dhar *et al.*(1982) for Tamilnadu have found the significant evidence for the presence of different cycles ranging from 2 years to short periods in the rainfall series of different regions of India.

Blandford (1886) was the first meteorologist to made extensive studies on Indian rainfall. Detailed analysis of long-period rainfall data over different sub divisions of India and also over India as a whole does not indicate any long-term climatic change, but only indicate year-to-year random fluctuations during 100 years (1871-1978).

Also, some significant cycles of 2 (quasi-biennial) - 15 years periods were noted only in some regions of India (Lal *et al.,* 1992).

Recent studies indicate that increase in temperature with rainfall uncertainties may lead to loss of 10% - 40% crop production in India due to its large population and limited resources (Parry, 1994).

Climatic variability, particularly rainfall is the major factor influencing the agricultural productivity and sustainability in the tropics (Virmani, *et al.,* 1994). Around 60% of the Indian agriculture is rain-dependent, distress-prone and vulnerable to climate. Constant increase in green house gas concentrations, since pre-industrial times, has led to positive radioactive forcing of the climate, tending to warm the surface.

There is also a global trend for increased frequency of drought as well as heavy precipitation events, posing potential threat to ecosystem especially agricultural production and productivity (Watson *et al.*, 1996).

The rainfed agro-ecology is characterized as vulnerable for agricultural operations which revolve around moisture availability due to rainfall pattern, amount, intensity and its uses for crop production (Deka and Nath, 2000).

In most of the studies the research workers have suggested the cropping pattern considering the rainfall amount at different probability levels (Hundal and Kaur, 2002).

The information on annual and seasonal rainfall of a region is useful to design water harvesting structure for agricultural operations, field preparation, seeding, irrigation, fertilizer application and overall in field of crop planning (Kar, 2002).

Recent studies indicate that increase in temperature with rainfall uncertainties may lead to loss of 10% - 40% crop production in India due to its large population and limited resources (Fischer *et al.,* 2002 and Parry *et al.,* 2004).

Uncertainties and seasonal migrations have been further compounded due to high frequency of the extreme rainfall and weather events like droughts due to global warming (Aggarwal, 2008).

In most of the studies the research workers have suggested the cropping pattern considering the rainfall amount at different probability levels (Ahmed *et al*., 2009 and Rabindrababu *et al*., 2010).

Historically, Bundelkhand region of Central India used to have one drought in 16 years in 19th century which increased by three times during the period 1968 to 2000 and in last 10 years, region have witnessed five drought years (Rai *et al.*,2012).

The current changing climatic scenarios are projected to have a major impact on the rainfall pattern and its intensity which would directly affect the ecosystem, agricultural production practices, water resource management and the crop planning (Rai *et al.*2012).

2.2 Rainwater management

2.2.1 *In-situ* soil and water management

In-situ management of runoff, soil loss and its effect on crop productivity have been studied by several authors and are described below

Mathan (1996) observed that soil loss (416.3kg/ha) was minimum in banana cultivated watershed compared to farmers' practice in Tamil Nadu.

Vetiver bunding by planting vetiver in three rows with row to row spacing of 10 cm and bunding interval 6metre across the slope, the runoff (16.6% of rainfall and soil loss (2.22 t/ha) was lowest amongst the bunding measures bermuda, sabai, napier and stylo, for Kandhamal district of Odisha (Subudhi and Senapati, 1996).

Hadda *et al.* (2000) found the different in situ soil and water conservation measures in North Western tract of India. Amongst the different conservation measures, improved land form treatment, the raised and sunken bed reduced runoff by 6% and soil loss by 42% compared to the traditional flat bed landform treatment.

Determinations carried out on a 9% slope Luvisol, in the Centre of Croatia, have shown that ploughing on the upstream-downstream direction has resulted in losing soil due to erosion amounting between 5.10 to 38.18 t/ha, with different crops. In case of deep ploughing on the direction of level curves, the loss was between 5.25 and 0.18 t/ha (Kisic *et al.,* 2006).

The favorable influence of reduced tillage system and of crop residues on soil erosion was also signaled by Lal (2006). He showed that in no-tillage system, soil losses by erosion were close to the one found in case of soil protection with 6 t/ha of mulch of crop residue. In Romania, soil erosion is the most expensive degradation process, which affects almost 63% of the total area and 56% of the arable land. Investigations on soil erosion process were conducted in very few zones, compared to the diversity of geomorphologic, soil, and climatic factors from our country. Investigations on the potential erosion, conditioned by geomorphologic, soil and climatic factors, have shown that in NE Romania, the mean soil losses by erosion were of 18.3 t/ha/year.

The studies carried out on the effective erosion, based on direct determinations and complex analyses, have shown that in the entire NE zone, the effective erosion had a mean value of 4.8 t/ha/year. Investigations carried out until today give information on the anti-erosion effect of different crop rotations with breeding plants and the hydro-ameliorative works on the present rate of shallow erosion. Soil losses by erosion on the fields ploughed on the upstream-downstream direction, which are cultivated with maize, are of 7.48 t/ha. In sunflower, cultivated with the conventional soil tillage system, the annual eroded soil was of 3.04 t/ha. Incorporation of wheat straw and green fertilizer into soil, erosion has decreased to 2.327 t/ha and 0.937 t/ha, respectively (Mitova *et al.,* 2006).

In maize cultivated LAND with no-till system, the total phosphorus losses on loam soils of N Alabama by erosion was varying from 2.4 to 2.1 kg/ha (Nyakatawa *et al.,* 2006). Singh and Khera (2006) observed that barren soil produced higher soil loss (1.75t/ha) compared to forest soil (1.29 t/ha) in Punjab.

On 8.5% slope fields from SW Finland, annual soil losses by erosion are of 5-6 t/ha and leached nitrogen and phosphorus amounts are of 15.0 and 1.1 kg/ha/year, respectively (Muukkonen *et al.,* 2007).

Incorporation into soil of 2471, 4942 and 9884 kg/ha of crop residues has resulted in diminishing the amount of eroded soil by 64, 85 and 98%, respectively, compared with the areas where no crop residues were applied. (Kumar *et. al.,* 2013), developed a dynamic sediment yield model of Jharkhand, Giridih watershed a soft catchment of Barakar river basin considering present day runoff and past values of runoff sediment yield as the input variables to estimate the sediment yield from a catchment on daily basis.

Adimassu *et al.* (2014) in Ethiopia documented that Barley protected with soil bund gave less soil loss (47%) and annual runoff by 28 % compared to no bund.

Kathamale *et al.* (2014) conducted an experiment during *kharif* for 5 years from 2008-12 to evaluate pigeon pea based intercropping system under vertisols in scarcity zone of Maharastra. The intercropping of pigeon pea + groundnut (1+3) was found superior with mean maximum pigeon pea yield 1425 kg/ha. Mean maximum water use efficiency of 3.19 kg/ ha-mm and maximum net return of 30,307 Rs / ha. Further this intercropping system also recorded higher land equivalent ratio of 1.29 and yield advantage of 29 % compared to sole crop.

The rainfall and runoff model; were developed using mike 11 name for Vinayakpur intercepted catchment, Chhattisgarh RMSE and R^2 values were found out which were 0.79 and 0.75 respectively (Singh *et.al*, 2014).

Amin *et al.* (2015) developed a linear model was used to measure the runoff and sediment yield at outlet of Dachigam watershed, situated in the catchment area of exhibited Dal lake in Kashmir valley, India. The validation of the model was also carried out by evaluating the quantitative test through the weekly data for 5 years from 2005-09. The performance of the model was evaluated using statistical and graphical method to assess the capability of the model.

2.2.2 *Ex-situ* soil and water management

Ex situ water management is one type of management of land and conservation of rainfall excess which not only helped the havoc at the lower side but also provides life saving irrigation to the monsoonic crop during moisture stress condition and also to the second. Many authors have focused on On Farm Reservoir (OFR) with lined and unlined system for increasing the yield and economic condition of the farmers.

Panigrahi and Panda (2003) reported that an average increase in yield of rice and mustard yield due to supplemental irrigation from the OFR is found to be 29.2% and 22.3% more over the average yield of corresponding crops under rain fed condition.

The effect of rain water harvesting and ponds in different parts of the countries were suitable for soil and water conservation and increasing crop yield and economics of the farming communities. (Sharma et al., 2004).

Panigrahi *et al.* (2005) found the optimum size of OFR was found to be 12 % of the land area and side slope of OFR system is 1:1. This OFR system gave benefit cost ratio, internal rate of return and payback period of 1.22, 16.1% and 13 years respectively with rice mustard cropping system.

The benefit-cost value of lined and unlined OFRs occupying 10% of the farm area becomes 1.65 and 2.70, respectively (Sethy *et al*., 2005).

The effect of rain water harvesting and ponds in different parts of the countries were suitable for soil and water conservation and increasing crop yield and economics of the farming communities. (Kumar *et al*., 2006).

Reddy *et al*., (2008) analyzed the rainfall for water harvesting structure. They mentioned that surplus *Kharif* water can be harvested in water harvesting structures in Bengaluru region of Karnataka.

Yemenu and Chemed, (2013) mentioned in their article that the harvested water can be used for double cropping or other domestic uses.

A field experiment was conducted by Hijam *et al*. (2014) at AICRP for dryland agriculture UAS, GKVK, Bangalore during *kharif* 2012 to assess the effect of protective irrigation and mulching to mitigate dry spell with integrated nutrient management in maize production. Three protective irrigation of 2, 46, 926 litre / hectare were given through harvested water collected in the farm pond. Higher growth parameter, yield attributes, cornel yield and stover yield of maize were observed significantly in the plots under protective irrigation from farm pond and mulching.

One protective irrigation of 5 cm to soya bean at maturity stage was given from the dugout farm pond which increased the yield by 30.87 %. (Pandke *et al.*, 2014).

There was a significant difference in the cropped area, cropping intensity and irrigation intensity among the farmers with rain water harvesting structures in comparison with farmers without rain water harvesting structures. (Badiger *et al.*, 2016).

Activity of excavation of water harvesting tank in the individual farmer's field was extremely useful in arresting runoff, it also enhanced the water availability and turned the mono crop area into multi-cropped area (Ranade *et al*., 2016).

CHAPTER- III

MATERIALS AND METHODS

CHAPTER-III

MATERIALS AND METHODS

This chapter deals with the physical features of experimental site and materials and methods used for the conduct of the experiment to obtain the final result.

3.1 Location map of experimental site

The trial was conducted for three consecutive years (2007 to 2009) at AICRPDA farm, Phulbani, (OUAT) in Kandhamal district of Odisha, India. It is located at $20^{0}27'01.98''$ N latitude and $84^{0}14'15.92''$ E longitude and 553 m above MSL. (Fig 3.1). The district is coming under North Eastern Ghat agro climatic zone of Odisha with tropical moist sub-humid climate. The soil of the district is classified as alfisols.

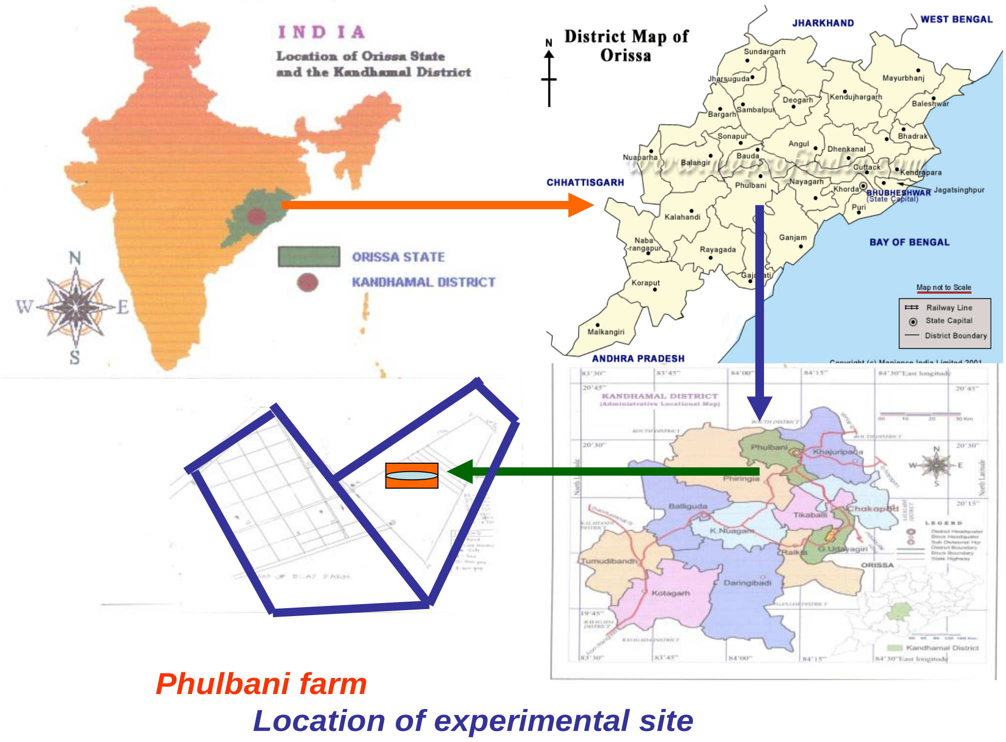


Fig 3.1 Location map of experimental site

3.2 Geographical features:

Kandhamal district is located in the central part of Odisha stretching between $83^{0}30'$ E to $84^{0}48'$ E longitude and $19^{0}34'$ N to $20^{0}54'$ N latitude with an area of 8,021 sq. km. It is surrounded with Boudh district in the north, Rayagada district in the south, Ganjam and Nayagarh district in the East and Kalahandi district in the west. Kandhamal district comes under the North-Eastern Ghats Agro-Climatic Zone (Zone No. 5) of the state and the altitude ranges from 300 m to 1100 m above mean Sea level (MSL). The terrain of the district is hilly and highly inaccessible. Kandhamal District has Sub-tropical climate characterized by hot and dry summer, medium to high rainfall and prolonged cold and dry winter. The soil is mostly red-lateritic group, which is porous having low organic matter contents. As such, the water holding capacity is very low. The pH value of the soil varies from 5.3 to 6.5, which is acidic in nature.

3.3 Land use pattern and cropping area in Kandhamal district

Kandhamal district is having a geographical area of 8021 thousand ha (Table 3.1), comprising of 18.45 % arable land and 81.55% non arable land. With an arable land area of 1, 48, 100 ha upland area consisting about 1, 16, 600 ha. Out of 654 thousand ha non arable

Table 3.1 Land use pattern of Kandhamal district

Sl. No	Land use type	Area (ha)	*Percentage of geographical area and Percentage of area
1	Arable land	1,48,100	18.45 *
(i)	Up land	1,16,608	78.73
(ii)	Medium land	20,624	13.93
(iii)	Low land	10,868	7.34
	Total (arable)	1,48,100	100.00
2	Non arable land	6,54,000	81.55*
(i)	Forest	5,41,000	82.72
(ii)	Land under non agricultural use	9,000	1.37
(iii)	Permanent pastures	10,000	1.53
(iv)	Cultivable wasteland	14,000	2.14
(v)	Land under misc. tree crops and groves	34,000	5.20
(vi)	Barren and uncultivable land	30,000	4.59
(vii)	Current fallows	10,000	1.53
(viii)	Other fallows	6,000	0.92
	Total (non arable)	6,54,000	100.00
	Grand total (arable + non arable)	8,02,100	100.00

Source-Internet Odisha Portal, Year 2012

land 82.72 % of the area (541 thousand ha) is forest land. Out of 1, 48,100 ha of arable land, 78.73% area is *up* land (Upland is such type of land where rain water does not retain for days.

Farmers have usually designed the land as high land which are somehow situated in a higher altitude comparing to other surrounding lands. Drainage is not at all a problem in such type of land.), *medium* land (According to the local concept is such type of land where water is retained for few days but not water logging condition can be prevailed.) and *low* land (Low lands are truly low comparing to other surroundings land situations where water can be retained for several days and drainage is a problem for paddy cultivation these lands are suitable.)occupying 13.93 % (20,624 ha) and 7.34 % (10,868 ha) of the area under arable land respectively. Table 3.1 shows the land use pattern and the cropping area in the district is shown in Table 3.2. Paddy occupies the highest percent arable area (45.1 %), followed by maize (13.4 %), niger (10.1 %) and p. pea (4.2 %). During *kharif* and *rabi*, paddy occupies 98.6 % and 1.4 % respectively.

Table 3.2 Area under different crops ('000 ha) and their percentage in Kandhamal district of Odisha during *Kharif* and *Rabi*.

Crop	**Area ('000 ha)**			**Percentage of total area**
	***Kharif* (Rainfed)**	***Rabi* (Irrigated)**	**Total area**	
Paddy	53.1	0.66	53.76	45.10
Maize	15.8	0.17	15.97	13.40
Arhar	5.0	0	5.00	4.20
Blackgram	4.5	0.20	4.70	3.90
Niger	12.0	-	12.00	10.10
Potato	0.56	-	0.56	0.50
Sweet potato	2.02	-	2.02	1.70
Cabbage	2.51	-	2.51	2.10
Cauliflower	3.42	-	3.42	2.90
Tomato	3.03	-	3.03	2.50
Turmeric	11.40	-	11.40	9.60
Ginger	4.29	-	4.29	3.60
Garlic	0.10	-	0.10	0.10
Coriandor	0.34	-	0.34	0.30
Total	118.07	1.03	119.10	100.00

Source-Internet Odisha Portal, Year 2012

al district

Different cropping systems practiced in Kandhamal district are given in Table 3.3. It is observed that most of the farmers practiced paddy-horse gram and paddy-mustard.

Horsegram and mustard are sown after harvest of paddy under residual soil moisture condition. In mono cropping and in mixed cropping system, they follow maize + cowpea, paddy + pigeon pea, paddy + maize in the uplands. Small patches of vegetables, pulses and oilseeds crops are seen near small water storage structures available in the district.

Table 3.3 Cropping systems in Kandhamal district of Odisha

Land type		***Kharif***	***Rabi***	**Summer**
(A)	Uplands	I. Mono crops of Paddy, Ragi, maize, Jowar, pigeopea, Mung, Biri, G.nut, Niger, sesamum, Turmeric, Zinger or off season vegetables. II. Mixed cropping of Maize+Cowpea, Paddy+pigeonpea, Paddy+Maize	Horse gram, mustard	
(B)	*Medium* lands	Paddy	Mustard	
(C)	*Low* lands	Paddy	Fieldpea (Piara)	
(D)	Irrigated *up*lands	Paddy,	vegetables	
		Maize	vegetables	
		Paddy	mustard	vegetables
		Paddy	wheat	Pulses /oilseeds
(E)	*Medium l*ands	Paddy	Wheat	Vegetables
		Paddy	Mustard	Pulses
		Paddy	Vegetables	Pulses
		Paddy	Potato	Sesamum
(F)	*Low* lands	Paddy	-	Paddy

3.5. Distribution of farm families in Kandhamal district

The district is having 1, 08, 263 farm families, out of which big and medium farmers constituting 6.97 per cent. Marginal and small group consisting 17.23 and 42.08 % respectively (Table 3.4). About 15.54 % of the total rural families are agricultural laborers and 2.27 % occupied by the rural artisans.

Table 3.4 Farm families in Kandhamal district of Odisha

Sl. No.	Farmer group	Number of farm families	Percent
1	Medium and large farmers	7548	6.97
2	Small farmers	18652	17.23
3	Marginal farmers	45558	42.08
4	Agricultural laborers	16823	15.54
5	Non agricultural labourers	16612	15.34
6	Rural artisans	2461	2.27
7	Others	609	0.56
	Total	108263	100.00

Source-planningcommission.nic.in/plans/stateplan/sdr_orissa/sdr_orich8.doc

3.6. Rainfall Analysis

Daily rainfall data were collected from the district office representing Kandhamal district from 1968 to 2010 (43 years) for analysis of rainfall.

3.6.1 Pentad rainfall analysis

Rice is the staple food of the people of Kandhamal district. Most of the uplands are covered under rice except few areas under non rice crops. In rainfed farming, mainly for upland condition rice crop which is more prone to the drought was taken as standard crop for planning propose. A survey work was conducted in the nearby areas in Sudreju and Gaudapada villages of Khajuripada block and Keredi and Lahabadi villages of Phulbani block of Kandhamal district. As per the survey with the farmers in the region, it was revealed that, rice can sustain continuously for 5 days with the available moisture in the soil without rainfall. So pentad rainfall and evaporation analysis were done for the crop planning using different distributions. Rainfall data of 45 years (1966-2010) were collected from collectorate office Kandhamal district of Odisha.

Pentad, rainfall of Kandhamal district of Odisha were analyzed using Normal distribution, Lognormal distribution, Log-normal (3-parameter) distribution, Gamma distribution, Pearson distribution, Log-Pearson Type III distribution, Generalized Pareto distribution, Generalized extreme value distribution, Gumbel's method and Weibull distribution, were tried to best fit by chi-square test.

3.6.1.1 Probability Distribution Functions

A lot of researches have been done to fit a distribution to precipitation data.

i) Normal Distribution:

This is symmetrical, continuous distribution, theoretically representing the distribution of accidental errors about their mean, or the so called *Gaussian law of errors*. The probability density is

$$p(x) = (1/\sigma\sqrt{2\pi})\ e^{-(x-\mu)^2/2\sigma^2}$$

Where, x is the variate, μ is the mean value of variate and σ is the standard deviation. In this distribution, the mean, mode and median are the same. The cumulative probability of a value being equal to or less than x is

$$p(x \leq) = 1/\sigma\sqrt{2\pi} \int_{-\infty}^{x} e^{-(x-\mu)^2/2\sigma^2} dx$$

This represents the area under the curve between the variates of $-\infty$ and x.

ii) Lognormal (2-parameter) Distribution:

This is transformed normal distribution in which the variate is replaced by its logarithmic value. This distribution represents the so called *law of Galton* as it was first studied by Galton in 1875. The probability density is

$$p(x) = (1/\sigma_y\, e^y\sqrt{2\pi})e^{-(y-\mu_y)^2/2\sigma_y}$$

Where, $y = ln\ x$ and x is the variate, μ_y is the mean of y and σ_y is the standard deviation of y.

iii) Log-normal (3-parameter) distribution:

A random variable X is said to have three parameter log-normal probability distribution if its probability density function (pdf) is given by:

$$f(x) = \begin{Bmatrix} \frac{1}{(x-\lambda)\sigma\sqrt{2\pi}} exp\left\{-\frac{1}{2}\left(\frac{\log(x-\lambda)-\mu}{\sigma}\right)^2\right\}, \lambda < x < \infty, \mu > 0, \sigma > 0 \\ 0, \text{otherwise} \end{Bmatrix}$$

where μ, σ and λ are known as location, scale and threshold parameters, respectively

i) Log-logistic distribution:

The pdf of three parameter log-logistic probability distribution is given by:

$$f(x) = \begin{Bmatrix} \dfrac{e^{\left\{\log(x-\lambda)-\frac{\mu}{\sigma}\right\}}}{\sigma\left[1+e^{\left\{\log(x-\lambda)-\frac{\mu}{\sigma}\right\}}\right]^2} \; x > \lambda, \mu > 0, \sigma > 0 \\ 0, otherwise \end{Bmatrix}$$

where μ, σ and λ are known as location, scale and threshold parameters, respectively.

ii) Gamma distribution:

Probability density of this distribution is

$$p(x) = x^a e^{-x/b} / b(a+1)\Gamma(a+1)$$

with *b>0, a>-1* for *x=0*

and *p(x)* = 0 for $x \leq 0$

where, a & b are constants and $\Gamma(a+1) = a!$ is a gamma function. The cumulative probability being equal to or less than $x(< \infty)$ is known as incomplete gamma function. The statistical parameters are Mean=b (a+1) and variance= b^2*(a+1)*

iii) Pearson Distribution:

Karl Pearson has derived a series of probability function to fit virtually any distribution. The general and basic equation to define the probability density of a Pearson distribution

$$p(x) = e \int_{-\infty}^{x} \frac{a+x}{b_0+b_1x+b_2x^2} dx$$

where a, b_0, b_1 and b_2 are constants.

The criteria for determining types of distribution are β_1, β_2 and k.

Where,

$$\beta_1 = \frac{\mu_3^2}{\mu_2^3}$$

$$\beta_2 = \frac{\mu_4}{\mu_2^2}$$

$$k = \frac{\beta_1(\beta_2+3)^2}{4(4\beta_2-3\beta_1)(2\beta_2-3\beta_1-6)}$$

Where, μ_2, μ_3 and μ_4 are second, third and fourth moments about the mean.

When $\beta_1 = 0, \beta_2 = 3$ and $k = 0$, the Pearson distribution is identical to the normal distribution. *Chow* (1964) suggested that Type-I and III distributions are often used in hydrologic frequency analysis.

vi (a) Pearson Type-I distribution:

For Type-I, k<0. Its probability density is

$$p(x) = p_0\left(1+\frac{x}{a_1}\right)^{m_1}\left(1-\frac{x}{a_2}\right)^{m_2}$$

Where, ${}^{m_1}/_{a_1} = {}^{m_2}/_{a_2}$ and the origin is at the mode.

The values of m_1 and m_2 are given by

$$m_1\ or\ m_2 = \frac{1}{2}\left[r-2 \pm r(r+2)\frac{\sqrt{\mu_2\beta_1}}{2(a_1+a_2)}\right]$$

when μ_2 is positive, m_2 is the positive root and m_1 is the negative root and $r = \frac{6(\beta_2-\beta_1-1)}{6+3\beta_1-2\beta_2}$

$$a_1 + a_2 = {}^1/_2\sqrt{\mu_2[\beta_1(r+2)^2 + 16(r+1)]}$$

and $p_0 = \frac{N}{a_1+a_2}\frac{m_1{}^{m_1}m_2{}^{m_2}}{(m_1+m_2)^{(m_1+m_2)}}\frac{\Gamma(m_1+m_2+2)}{\Gamma(m_1+1)\Gamma(m_2+1)}$

where N is the total frequency.

vi. (b) Pearson Type-III distribution:

For Type-III distribution,

$$k = \infty \text{ or } 2\beta_2 = 3\beta_1 + 6$$

The probability density with the origin at mode is

$$p(x) = p_0(1 + {}^x/_a)^c e^{-cx/a}$$

Where, $c = \frac{4}{\beta_1} - 1$

$$a = \frac{c}{2}\frac{\mu_3}{\mu_2}$$

$$p_0 = \frac{Nc^{c+1}}{ae^c\Gamma(c+1)}$$

iv) Log-Pearson Type III distribution:

This distribution is extensively used in USA for projects sponsored by the US Government. In this the variate is first transformed into logarithmic form (base 10) and the transformed data is then analyzed. If X is the variate of a random hydrologic series, then the series of Z variates where,

z = log x

are first obtained for this z series, for any recurrence interval T and the coefficient of skew C_s,

σ_z =standard deviation of the z variate sample

$= \sqrt{\sum (z - \bar{z})^2/(N-1)}$ and

C_s =coefficient of skew of variate z

$= \frac{N\sum(z-\bar{z})^3}{(N-1)(N-2)\sigma_z{}^3}$

$\bar{z}$=mean of z values

N= sample size = number of years of record

iv) Generalized Pareto distribution:

The family of generalized Pareto distributions (GPD) has three parameters μ, σ and ξ. The cumulative distribution function is

$$F_{(\varepsilon,\mu,\sigma)}(x) = \begin{Bmatrix} 1-\left(1+\frac{\xi(x-\mu)}{\sigma}\right)^{\frac{-1}{\xi}} \; for\; \xi \neq 0 \\ 1-\exp\left(-\frac{x-\mu}{\sigma}\right) \quad for\; \xi = 0 \end{Bmatrix}$$

for $x \geq \mu$ when $\xi \geq 0$ and $x \leq \mu - \frac{\sigma}{\xi}$ when $\xi < 0$,where $\mu \in \mathbb{R}$ is the location parameter, $\sigma > 0$ the scale parameter and $\xi \in \mathbb{R}$ the shape parameter.

The probability density function is

$$f_{(\xi,\mu,\sigma)}(x) = \frac{1}{\sigma}(1+\frac{\xi(x-\mu)}{\sigma})^{\left(-\frac{1}{\xi}-1\right)}$$

Or,

$$f_{(\xi,\mu,\sigma)}(x) = \frac{\sigma^{\frac{1}{\xi}}}{(\sigma+\xi(x-\mu))^{\left(\frac{1}{\xi}+1\right)}}$$

again, for$x \geq \mu$, and $x \leq \mu - \frac{\sigma}{\xi}$ when $\xi < 0$

ix) Generalized Extreme value distribution:

Generalized extreme value distribution has cumulative distribution function

$$F(x;\mu,\sigma,\xi) = \frac{1}{\sigma}\left[1+\xi(\frac{x-\mu}{\sigma})\right]^{\left(-\frac{1}{\xi}-1\right)} exp\left\{-\left[1+\xi(\frac{x-\mu}{\sigma})^{\frac{-1}{\xi}}\right]\right\}$$

For 1+$\xi(x-\mu)/\sigma > 0$, where, $\mu \in \mathbb{R}$ is the location parameter, $\sigma > 0$ the scale parameter and $\xi \in \mathbb{R}$ the shape parameter. The density function is, consequently

$$f(x;\mu,\sigma,\xi) = \frac{1}{\sigma}\left[1+\xi(\frac{x-\mu}{\sigma})\right]^{\left(-\frac{1}{\xi}-1\right)} exp\left\{-\left[1+\xi(\frac{x-\mu}{\sigma})^{\frac{-1}{\xi}}\right]\right\}$$

again, for $1+\xi(x-\mu)/\sigma > 0$

x) Gumbel's method:

The extreme value distribution was introduced by *Gumbel* (1954) and is commonly known as Gumbel's distribution. It is one of the most widely used probability-distribution functions for extreme values in hydrologic and meteorological studies. According to this theory of extreme events, the probability of occurrence of an event equal to or larger than a value x_0 is

$$P(X \geq x_0) = 1 - e^{-e^{-y}}$$

in which *y* is a dimensionless variable and is given by

$$y = \alpha(x-a)$$

$$a = \bar{x} - 0.45005\sigma_x$$

Thus, $y = \frac{1.2825(x-\overline{x})}{\sigma_x} + 0.577$…….. (i)

where $\bar{x}$= mean and σ_x= standard deviation of the variate *X*. In practice it is the value of *X* for a given *P* that is required and such Eq. (i) is transposed as

$$y_p = -ln[-\ln(1-P)]$$

Noting that the return period $T = {}^{1}/_{P}$ and designating y_T =the value of *y*, commonly called the reduced variate, for a given *T*

$$y_T = -\left[ln.ln\frac{T}{T-1}\right]$$

Or, $y_T = -\left[0.834 + 2.303\, log\, log\frac{T}{T-1}\right]$

Now rearranging Eq. (i), the value of the variate X with a return period *T* is

$$x_T = \bar{x} + K\sigma_x$$

Where, $K = \frac{(y_T - 0.577)}{1.2825}$

The above equations constitute the basic Gumbel's equations and are applicable to an infinite sample size (i.e. $N \rightarrow \infty$).

xi) Weibull distribution:

The Weibull distribution, also known as the Extreme Value Type III distribution, first appeared in his papers in 1939. The two-parameter version of this distribution has the density function

$$f(x) = \frac{\alpha}{\beta}(\frac{x}{\beta})^{\alpha-1}\exp(-(\frac{x}{\beta})^{\alpha})$$

The Weibull distribution is defined for $x > 0$, and both distribution parameters (α-shape,β-scale) are positive. The two-parameter Weibull distribution can be generalized by adding the location (shift) parameter γ:

$$f(x) = \frac{\alpha}{\beta}(\frac{x-\gamma}{\beta})^{\alpha-1}\exp(-\left(\frac{x-\gamma}{\beta}\right)^{\alpha})$$

In this model, the location parameter γ can take on any real value, and the distribution is defined for $x > \gamma$.

3.6.1.2 Plotting position

Subramanya (1990) has stated that the purpose of frequency analysis of an annual series is to obtain a relation between the magnitude of the event and its probability of exceedence. A simple empirical technique is to arrange the annual extreme series in descending order of magnitude and to assign an order number, *m*. The probability, p of an event equalled to or exceeded is given by Weibull formula

P = m/(N+1)

Where,

m= rank number

N= number of years

The recurrence interval is given by

T=1/P = (N+1)/m

3.6.1.3. Goodness of fit Test

Chi-square test of goodness of fit of observed values is calculated by the following equation:

$$\chi_c^2 = \sum_{i=1}^{K}\frac{(O_i - E_i)^2}{E_i}$$

Where, K is the number of class interval, O_i *and* E_i are the observed and expected rainfall values in the i^{th} class, respectively. The distribution with least sum of χ_c^2 values will be adjudged the best. This distribution has been applied by *Subudhi* (2007)

Where, χ^2 = value of Chi-square, O = observed value and P = predicted value and summation is done from i = 1 to 9 i.e. 10 to 90% PE.

3.6.2 Pentad evaporation at 20 % probability of exceedence

In the absence of evaporation data in the district, the data of Bhubaneswar under sub humid condition as that of Kandhamal district were taken into consideration for crop planning. The pan evaporation data for the year 1991 to 2006 were collected from the meteorological observatory station of OUAT, Bhubaneswar.The probability analysis of pentad evaporation value was done through probability distribution and plotting position were evaluated by Weibull equation. Evaporation at 20 % probability was used for crop planning.

3.7 *In- situ* soil and water management

Experimental design

The experiment field was divided into three large plots indicating three replicated plots. The replicated plots were separated by forming bunds of 30 cm wide. Similarly each replicated plot was divided into 9 subplots equal with number of treatments and separated by bunds of width 30cm. Crops were grown as per the recommended cultivation practices. The layout of the treatments is given in Fig. 3.2

The runoff and soil loss were observed by installing multi slot divisor (25 slots) and runoff collection tank (drum-50 litre capacity) at the end of each plot (Fig 3.3). Runoff from each day rain storm was estimated by measuring the depth of water in the runoff collection tank connected with the central slot. Depth of water in each collection tank was measured every day at 8 a.m. Water collected in each drum were stirred properly and three samples each of one litre were collected in collection bottles separately from each treatment plots for estimation of soil loss carried by the runoff water. Chemical analysis of runoff water collected from each treatment plot was also done for estimation of loss of plant nutrients transported along with runoff water. The rain water collected in the open drum were deducted.

The details of the experimental design (Fig 3.7) for the present work under the situation of in-situ soil and water management are given below

i) Treatments: 9 (Nine) .The details of the treatment is given below(Table 3.5)

Table 3.5 Treatment details of the experiment (*in situ*)

Treatment	Crop system
T1	Sole rice crop
T2	Sole pigeon pea crop
T3	Sole groundnut crop
T4	Pigeon pea and rice in alternate strips. (6m : 6m)
T5	Pigeon pea and groundnut in alternate strips. (6 m : 6 m)
T6	Intercrop of pigeon pea and rice (2:5).
T7	Intercrop of pigeon pea and groundnut (2:4).
T8	Uncultivated fallow.
T9	Cultivated fallow.

ii) Replication: 3 (Three),

iii) Design- Randomized block design

iv) Gross study area-62.0 x 27.0 m^2=1684.8 m^2,

v) Net treatment area-50.0 x 27.0 =1350 m^2

vi) Gross treatment plot area-25.0 m x 2.0 m = 50 m^2

vii) Net treatment plot area-21.8 mx1.5 m=32.7 m^2

viii) Recommended practices for cultivation of different crops (Table 3.6):

Table 3.6 Recommended practices for cultivation of different crops

Crop	Culture variety	Seed rate (kg/ha)	Spacing		Fertilizer (kg/ha)
			R/ R (cm)	P / P (cm)	
Rice	ZHU-11-26	75	15	-	60:30:30 :: $N-P_2O_5-K_2O$ 30kg N in two equal splits (at 20days and 35 days after sowing)
Pigeon pea	Upas 120	25	45	30	20:40:20:: $N-P_2O_5-K_2O$
Groundnut	Smruti	150 (pod)	30	13	20:40:40 :: $N-P_2O_5-K_2O$

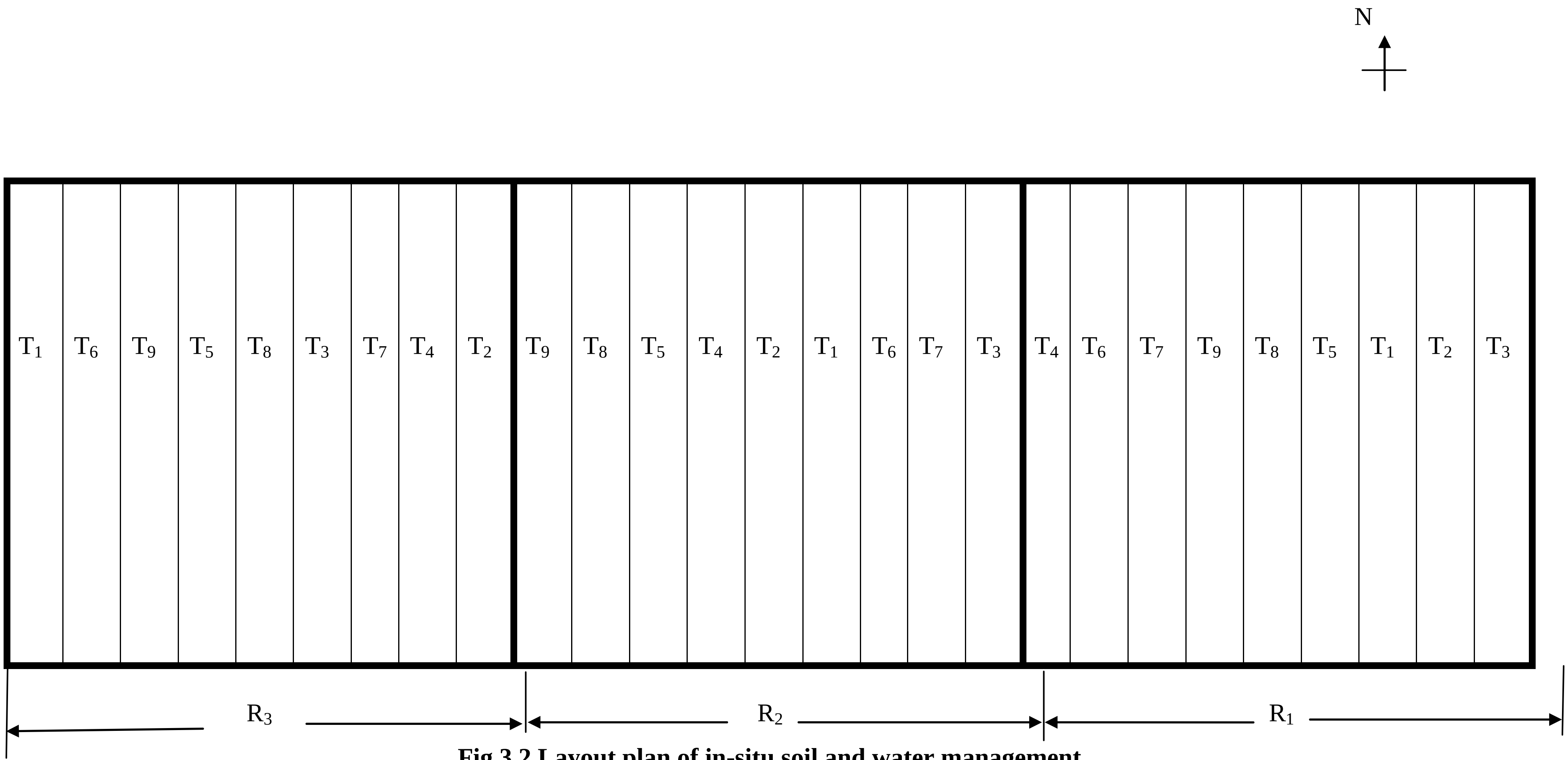


Fig 3.2 Layout plan of in-situ soil and water management

Fig.3.3 Multislot divisor with runoff collection tank

3.8 *Ex- situ* soil and water management

Cropping pattern of cauliflower/ tomato during rainy season and radish during pre-rabi season was chosen in uplands with OFR system. This management practice was taken for the second type of farmers (medium and large farmer group) who are capable of constructing the OFR. The land area for the OFR approach was taken as 10 percent (Panigrahi *et.al*., 2005) for harvesting runoff water. The storage water in 10 % area is utilized to supply water to the rest of the 90 % area utilized for planting of crops

3.8.1 Experimental details

The details of the experimental design for the present work under the situation of *ex-situ* soil and water management are given below (Table 3.7)

i) Treatments: 3 (Three) .The details of the treatment are given below

Table 3.7 Treatment details of the experiment (*ex situ*)

Treatment No.	Treatment details
T_1	Lined pond (8 cm thickness) with soil: cement (6:1) plaster
T_2	Unlined pond
T_3	No pond (control)

ii) Replication: no

iii) Design: single plot

iv) Gross study area-1,924 m^2

v) Net treatment area-1500 m^2

vi) Gross treatment plot area: 30.0 m x 16.67m = 500 m^2

vii) Cropped area: 450 m^2

viii) Dimension of the pond

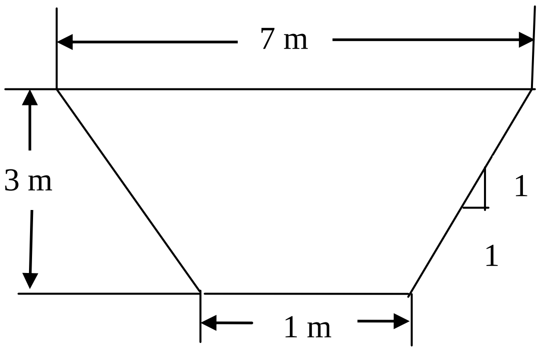
Pond area = 7.0m x 7.0 m (49 m^2)

Top width = 7.0 m x 7.0 m

Bottom width =1.0 m x 1.0 m

Height = 3.0 m

Side slope = 1:1



ix) Recommended Practices for cultivation of different crops: Recommended practices are presented in Table 3.8.

The experiment field was divided into three large plots indicating three treatment plots. All the treatments are separated by drainage channel of 1 m width. The layout of the plots was shown in Fig 3.4. The two ponds, one lined pond (Fig 3.5), and the other unlined pond (Fig 3.6) were constructed at end of the plot. Ponds were constructed in 10% of the gross area and rest 90% area was taken for cultivation under OFR system. (Panigrahi *et al.*, (2005) found the optimum size of OFR was found to be 12 % of the land area and side slope of OFR system is 1:1.for Eastern India). Varity, seed rate and spacing are shown in Table 3.8.

Table 3.8 Variety, seed rate and spacing of different crops in ex-situ soil and water management

Crop	**Culture variety**	**Seed rate (kg /ha)**	**Spacing**	
			R/R(cm)	**P/P (cm)**
Cauliflower	Hemlata	0.35	45	45
Tomato	B.T.-10	0.15	60	45
Radish	Pusa Chetki	6.00	45	05

x) Fertilizer application to different crops at different stages is given in Table 3.9

Table 3.9 Fertilizer application to different crops in ex-situ soil and water management

Application time	**Crop**								
	Cauliflower			**Tomato**			**Radish**		
	N	**P_2O_5**	**K_2O**	**N**	**P_2O_5**	**K_2O**	**N**	**P_2O_5**	**K_2O**
Basal (kg/ha)	25	40	60	31.25	80	20	25	50	75
1st top dressing (kg/ha)	50			31.25		40	25		
2nd top dressing (kg/ha)	50			31.25		40			
3rd top dressing (kg/ha)				31.25					
Total	125	40	60	125	80	100	50	50	75

Depth of water at each pond was measured at 8 a.m. each day. Volume of water supplied to the crop was also measured. Water was applied to the crop manually through mug and bucket.

Estimation of soil moisture (dry wt. basis) which is an indicator for absorption and retention of moisture in the soil by a crop / cropping system was done by gravimetric methods. Layout plan of *ex-situ* management is shown in Fig 3.4. Lined pond and unlined pond was shown in Fig 3.5 and 3.6 respectively.

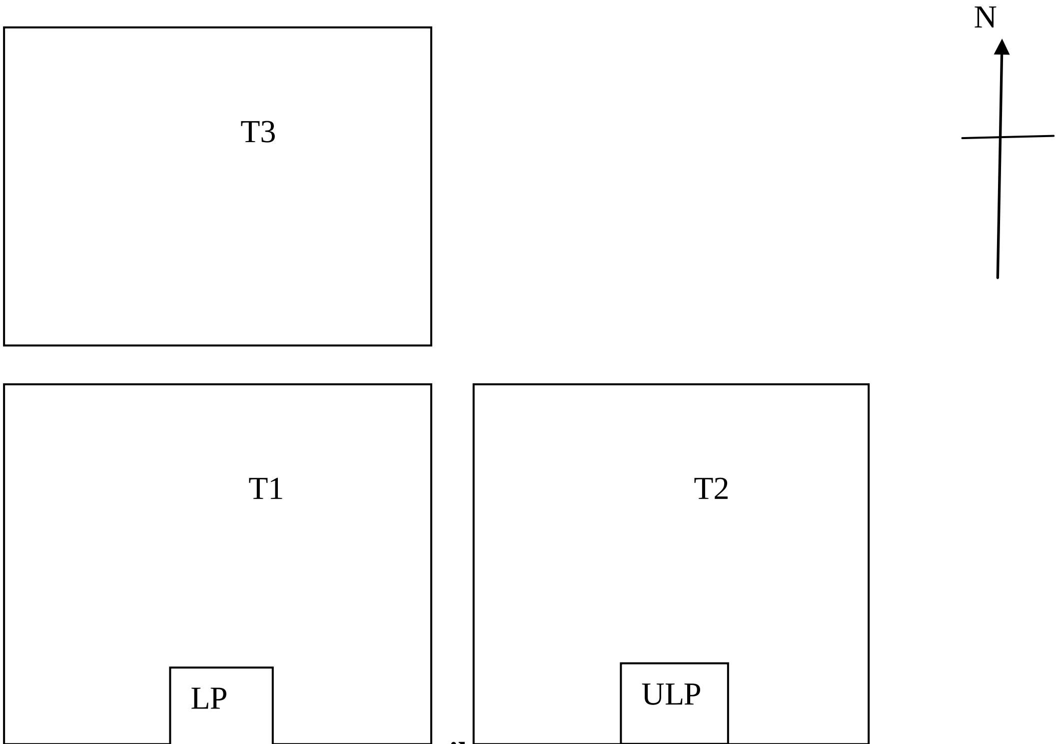


Fig 3.4 Lay out plan of *ex-situ* soil and water management

Fig 3.5 On farm reservoir with soil cement (6:1) plaster lining

Fig 3.6 On farm reservoir without lining

3.9 Water balance of OFR

The water balance of the OFR was estimated considering inflows into the OFR and outflows from the OFR. The inflows are the direct rainfall reached the OFR and surface runoff from the field. The outflows are evaporation, seepage, percolation and supplemental irrigation applied to the crop in the field. The evaporation, seepage and percolation losses are here considered as the total losses from the OFR. The water balance model is considered with the change in storage and can be written as

Change in storage = Inflow - Outflow

Thus the various components of OFR water balance model are,

$$Sn-S_{n-1}=\Delta S_n=Qrn+Qpn-(Qen+Qin+Qsn) \quad (3.1)$$

Where

S=Storage volume in the OFR,

Q_r = Volume of runoff collected from the field

Q_p = Volume of water received directly from the rainfall,

Q_e=Volume of water loss as evaporation,

Q_i=Volume of water utilised for irrigation,

Q_s=Volume of water lost due to seepage

n and n-1 represents nth and (n-1) th day

$Q_{rn}=S_{rn}XA_{cp}$

A_{cp}=Total field area- area of OFR

The loss due to seepage and evaporation were estimated from the out flow volume from the OFR due to irrigation, seepage and depth of water lowered between $(n-1)^{th}$ and n^{th} day. Multiplied with average of the top area of the OFR on $(n-1)^{th}$ and n^{th} day. Q_{pn} is calculated as the product of direct precipitation and area of OFR on n^{th} day.

3.10 Economic analysis

3.10.1 Benefit-cost method

The economic feasibility of a project is based on the benefit –cost relationship. The total benefit B should be more than the total cost C. A project is economically feasible under the following conditions.

$B > C$

$B — C > 0$

Or $B/C > 1$

It is essential to take into consideration the time element of both benefits and costs. The costs include the fixed cost (cost of planning and design installation and commissioning), which are incurred in the initial stages.

The second is the annual cost usually termed OMR (operation, maintenance and replacement) and the expenditure on taxes and insurances. Annual benefits are always considered. For a comparison of benefits and costs, both are expressed in the same terms, namely, present worth values or annual values, which include amortization on the initial investment.

In situations where several competing projects are to be considered within a limited budget, or alternative proposal are available, they are to be compared and ranked in a series of decreasing values, such as decreasing benefits or decreasing returns on the money invest.

In comparing benefits to costs, two alternative criteria are available, namely the expression of net benefit-cost ratio, provides the relative returns from each unit of the money invested. When funds are limited, it is advisable to use the B:C criterion which will allocate the available funds to a combination of smaller, efficient projects rather than one or two large ones.

3.10.2. The present worth method (PW)

In this method, the algebraic sums of benefits minus costs over the life of the project are converted into their present worth. The present worth is defined as follows:

$$PW = \sum_{t=i}^{n} \left(\frac{P}{F},\ I\%, t \right) \left(B_t - C_t \right) \tag{3.2}$$

Where,

B_t = benefit in subscribed year, Rs

C_t = Cost in subscribed year, Rs

i = discount rate

t = period of analysis varying from 1 to n years

(P/F, i%, t) is the abbreviation for the single payment present worth factor. The notation P and F imply future and present amounts, based on discount rate and period of analysis. For a given value of discount rate i and period n, the present worth factor is

$$(P/F, i\%, t)=P/F \tag{3.3}$$

Which is defined as

$$P/F=1/(1+i)^n \tag{3.4}$$

In eqn.(3.3) the value of i is taken as a fraction

When the annual net benefit

$$B = B_t - C_t \qquad (3.5)$$

remains constant over the project life, except the initial first cost K,Eq 3.2 may be modified to

$$PW = -K + B\ (P/A) \qquad (3.6)$$

Where

K=initial first cost, Rs

B =annual net benefit, Rs

(P/F, i%, n) is the abbreviation for the series present worth factor. A denotes equal amounts at the end of each of n years. For a given value of discount rate i and period n, the series present –worth factor is

$$(P/A,\ i\%,\ n) = P/A \qquad (3.7)$$

Which is defined as

$$P/A = \{(1+i)^n - 1\}/i(1+i)^n \qquad (3.8)$$

In eqn.(7) the value of i, is taken in fraction.

3.10.3 Internal rate of return (IRR)

The profitability of a project may be measured by means of a comparison between its benefit and costs, through the use of the internal rate of return. The internal rate of return, r is defined as the interest rate which will provide the equalization of total cost to benefit. Considering the annual values of benefits and costs, the internal rate may be expressed mathematically as

$$K \times C_{rf} = B \qquad (3.9)$$

Where,

K=initial investment,Rs

B=annual net benefit, Rs

C_{rf}=capital recovery factor=$\{r(1+r)^n\}/\{(1+r)^n-1\}$ (3.10)

r=initial rate of return, fraction

Alternatively,

$$C_{rf} = B/K \qquad (3.11)$$

The internal rate of return, r, is the rate of interest which will satisfy the relationship

$$C_{rf(r,n)} = B/K \qquad (3.12)$$

Conversely

$$\{r(1+r)^n\}/\{(1+r)^n-1\} = B/K \qquad (3.13)$$

If the value of r is higher than the market value of interest on investments, the project is economically feasible. When projects are ranked in order of merit, the internal rate of return r will give a different series than that obtained by the benefit-cost ratio criterion. The method is suitable when the money for the initial investment is limited. Both criteria will however result in similar ranking when comparing projects with similar benefit-cost ratios.

CHAPTER- IV

RESULTS AND DISCUSSION

CHAPTER-IV

RESULTS AND DISCUSSION

This chapter includes the, pentad analysis, moving average analysis of rainfall data, soil loss, runoff and yield under different in-situ soil and water management system. It also includes the crop yield, water loss and other related parameters of ex-situ management practice along with the analysis of economic parameters.

4.1 Rainfall analysis

4.1.1 Rainfall analysis of Kandhamal district

The monthly and annual rainfall of the experimental site during the years of 2007-2009 are given in Table 4.1 and the same has been depicted in Fig 4.1 and 4.2 respectively. The rainfall analysis indicates annual rainfall of all the three experimental years along with mean annual rainfall.

Table 4.1 Monthly and annual rainfall (mm) at Phulbani from 2007-09

Month	2007	2008	2009	Mean
January	0	61.40	0	20.5
February	21.60	2.40	0	8.0
March	5.40	12.60	1.00	6.4
April	21.60	12.60	0	11.4
May	86 .00	4.60	44.80	95.1
June	424 .00	270 .00	124.80	272.9
July	188.40	263.00	881.60	444.3
August	363.80	422.40	321.40	369.2
September	465.40	449.30	220.20	378.3
October	1 .00	31.00	76.60	36.2
November	0	2.50	19.00	7.2
December	0	0	0	0
Total (Annual)	1577.2	1531.8	1689.4	1599.5

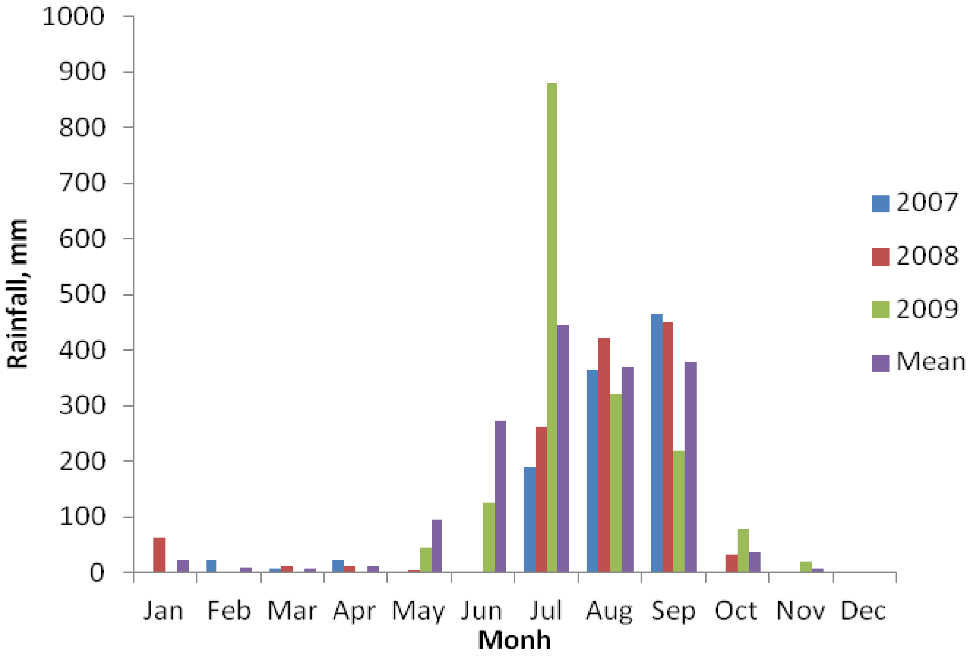


Fig 4.1 Rainfall pattern in different months during study period 2007-09

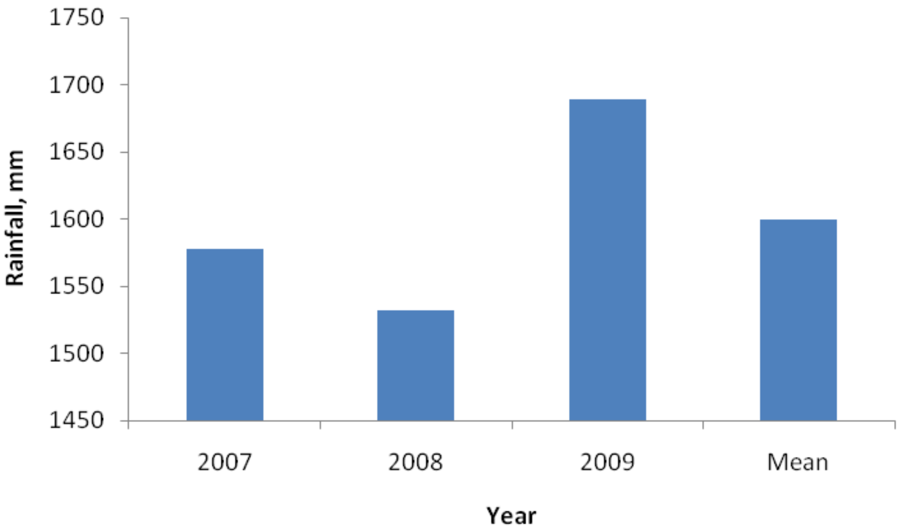


Fig 4.2 Annual rainfall pattern during 2007-09

It is observed that maximum amount of rainfall is received in the month of September during the experimental year 2007 and 2008. However the year 2009, maximum amount of rainfall is occurred during the month of July. But this is not in the case of normal year, in the normal year August receives maximum amount of rainfall.

In the year 2007, maximum amount of rainfall is received in the month of September (465.4 mm) followed by June (424.0 mm) and August (363.8 mm). The first, second and third highest rainfall in the year 2008 is occurred in the months September, August and June. Whereas, the month received maximum rainfall in the year 2009 is July (881.6 mm). In the same year, high rainfall occurred next to July is August (321.4 mm) and September (220.2 mm). This showed the, variation of rainfall in the experimental site in all the years.

The pentad rainfall is shown in Table 4.2 for the experimental years 2007-09. It is observed that 54th pentad received highest mean pentad rainfall of 102.3mm followed by 40th pentad which received 100.9 mm of rainfall. The pentad rainfall for the experimental year 2007-09 (Table 4.2) showed that, 34th, 39th, 46th and 55th pentads are receiving less rainfall (less than 12.5 mm per pentad).

Table 4.2 Pentad rainfall at Phulbani from 2007-09

Pentad No.	Rainfall (mm)			
	Year			
	2007	2008	2009	Mean
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	25	0	8.3
6	0	36.4	0	12.1
7	0	0	0	0
8	0	1.0	0	0.3
9	21.6	1.4	0	7.7
10	0	0	0	0
11	0	0	0	0
12	0	0	0	0
13	0	0	0	0
14	2.6	0	0	0.9
15	2.8	0	1.0	1.3
16	0	0	0	0
17	0	12.6	0	4.2
18	0	0	0	0
19	0	8.6	0	2.9
20	0	2.4	0	0.8
21	7.4	1.6	0	3
22	1.0	0	0	0.3

23	13.2	0	0	4.4
24	0	0	0	0
25	38.2	0	1.0	13.1
26	7.4	0	0	2.5
27	26.2	0	12.0	12.7
28	14.2	0	13.0	9.1
29	0	0	18.8	6.3
30	0	0	0	0
31	0	27.6	2.0	9.9
32	0	63.0	68.6	43.9
33	38.0	4.8	5.0	15.9
34	3.4	89.2	0	30.9
35	23.0	29.2	6.6	19.6
36	185.6	60.8	42.6	96.3
37	176.0	0	99.4	91.8
38	72.0	39.6	15.2	42.3
39	1.0	0	282.4	94.5
40	13.2	18.4	271.2	100.9
41	36.0	41.8	197.0	91.6
42	62.4	81	15.4	52.9
43	79.2	111.4	1.0	63.9
44	126.0	119.4	0	81.8
45	57.6	145.8	64.4	89.3
46	3.2	14.8	104.8	40.9
47	36.6	55.4	24.2	38.7
48	14.2	46.0	101.0	53.7
49	55.8	43.0	27.0	41.9
50	50.2	55.0	130.0	78.4
51	43.0	40.0	1.0	28.0
52	55.0	139	1.6	65.2
53	60.8	128.7	62.4	84
54	245.4	55.4	6.0	102.3
55	4.0	0	64.0	22.7

56	1.0	15.0	31.8	15.9
57	0	16	0	5.3
58	0	0	0	0
59	0	0	0	0
60	0	0	0	0
61	0	0	0	0
62	0	0	0	0
63	0	2.5	2.0	1.5
64	0	0	0	0
65	0	0	17.0	5.6
66	0	0	0	0
67	0	0	0	0
68	0	0	0	0
69	0	0	0	0
70	0	0	0	0
71	0	0	0	0
72	0	0	0	0
73	0	0	0	0
Total	1577.2	1531.8	1689.4	1599.5

4.1.2 Pentad rainfall and evaporation analysis of Kandhamal district:

Pentad rainfall at different probabilities of exceedance was analyzed through different distribution functions and is given in Table 4.3 with their chi-square values. Pan evaporation data were also analyzed for 20 percent probability of exceedence for the purpose of crop planning. Assuming average crop coefficient 1.0, the PET values for different pentads were estimated as the product of pan evaporation and the average crop coefficient and is given in Table 4.4. The pentad rainfall and PET at different probability of exceedence is shown in Fig 4.4. The pentad rainfall and PET at different probability of exceedence are shown in Fig 4.3 and 4.4 respectively.

A day of 2.5 mm is considered a rainy day. For a pentad, it should be 12.5 mm. Based on pentad value, rainfall close to 12.5 mm is observed in 75% probability. As observed the Kandhamal district is suffering from drought in every year, so rainfall at 75% probability is considered. Rice is the main crop grown in up lands. So in upland situation, rice can be sustained for five days with the moisture available in the soil. So for a pentad, the rainfall amount should be 12.5 mm which is considered as the base for crop planning for the Kandhamal district of Odisha.

Table 4.3 Pentad probability analysis of rainfall at Kandhamal district

Pentad No	**Best Fitted to distribution**	**Rainfall at different probability of exceedence (mm)**					**χ^2Calcu- lated**	**χ^2Tabu -lated**
		90	**75**	**50**	**25**	**10**		
1	No suff. data	0	0	0	0	0		
2	EV-III	0	0	0	0	2.51	Not fitted	
3	Log pearson	0	0	0	0	20.34	Not fitted	
4	Log pearson	0	0	0	0	0	Not fitted	
5	Gen Pereto	0	0	0	0	0	Not fitted	
6	Gen Pereto	0	0	0	0	0	Not fitted	
7	Gen Pereto	0	0	0	0	0	Not fitted	
8	Log pearson	0	0	0	0.95	12.39	Not fitted	
9	Log Normal	0	0	0	0	4.27	Not fitted	
10	Log Normal-3 Parameter	0	0	0	2.85	17.91	Not fitted	
11	No suff data							
12	Generalized Extreme Value	0	0	0	0	7.08	Not fitted	
13	Gen Pereto	0	0	0	0	29.50	Not fitted	
14	Gen Pereto	0	0	0	0	7.25	Not fitted	
15	Log pearson	0	0	0	0	5.97	Not fitted	
16	Gen Pereto	0	0	0	0	13.25	Not fitted	
17	Log Normal	0	0	0	1.10	10.54	1.00	1.07
18	Log Normal	0	0	0	0	11.83	0.40	0.46
19	Exponential	0	0	0	3.75	29.36	0.50	0.58
20	Extreme Value Type-III	0	0	0	4.40	14.24	0.67	0.71
21	Log pearson	0	0	0	0	5.19	Not fitted	

22	Extreme Value Type-III	0	0	0	7.56	26.25	1.33	1.64
23	Extreme Value Type-III	0	0	0	0.24	15.77	0.5	0.71
24	Exponential	0	0	0	7.38	17.88	1.50	1.87
25	Extreme Value Type-III	0	0	0	7.61	12.73	0.25	0.28
26	Log Normal	0	0	0	8.14	35.75	1.00	1.02
27	Log pearson	0	0	0	16.90	39.44	1.62	1.64
28	Generalized Extreme Value	0	0	0	8.37	15.95	6.53	6.63
29	Generalized Extreme Value	0	0	0	7.14	21.96	2.00	2.71
30	Log pearson	0	0	0	9.78	29.09	0.74	1.07
31	Gen Pereto	0	0	4.68	16.00	26.05	0.68	0.71
32	Log pearson	0	0	3.58	20.10	47.46	1.00	1.02
33	Log-Pearson	0.58	1.56	5.06	17.65	58.07	1.33	1.39
34	Pareto	3.23	12.73	32.49	62.33	95.18	2.00	2.41
35	Gamma	4.2	11.34	27.16	54.54	87.69	4.54	4.64
36	Pareto	6.44	16.47	37.80	71.36	110.62	0.8	1.02
37	Log-normal	13.06	22.82	42.45	78.95	138.08	0.84	1.00
38	Log-normal (3-p)	-	11.87	42.53	86.83	143.38	4.51	4.61
39	Pareto	10.00	22.07	66.45	262.14	-	1.11	1.39
40	GEV	11.30	21.63	38.60	66.00	107.80	0.28	0.44
41	Gamma	1.43	7.95	32.97	76.65	149.20	5.60	6.25
42	Gamma	6.31	17.85	44.30	91.28	147.68	5.10	6.25
43	Pareto	9.66	24.31	55.23	103.14	157.95	5.46	5.99
44	Log-normal (3-p)	4.46	24.35	55.64	100.71	158.08	3.20	3.22
45	Pareto	8.07	17.83	41.06	85.99	157.25	5.10	5.99
46	Gamma	6.46	17.44	41.76	83.82	134.75	2.30	2.37

47	Pearson	4.81	22.10	51.83	94.82	146.33	5.65	5.99
48	Log-normal (3-p)	4.83	19.07	41.22	72.75	112.43	2.74	2.77
49	GEV	5.32	17.24	38.74	77.99	147.29	2	2.41
50	Pareto	2.51	11.42	30.39	60.29	95.42	2.38	2.41
51	Pareto	1.13	11.14	34.25	76.69	138.98	7.7	9.21
52	Pareto	2.63	13.56	37.5	77.30	127.79	1.43	1.83
53	Log-normal (3-p)	-	9.61	29.26	59.81	101.60	1.17	1.39
54	Log-Pearson	0.67	1.58	4.14	10.9	26.27	4.35	4.61
55	Pareto	4.80	13.83	31.26	54.14	74.65	1.00	1.02
56	Log-Pearson	0.67	1.57	4.22	12.08	32.93	3.25	4.61
57	Log-normal	4.57	8.56	17.19	34.51	64.66	3.00	3.67
58	Log-Pearson	0.63	1.45	3.90	11.17	30.45	0.66	0.71
59	Log pearson	0	0	0	20.76	57.95	2.32	2.71
60	Log pearson	0	0	0	2.93	22.33	2.43	2.71
61	Gen Pereto	0	0	0	4.62	11.08	1.00	1.07
62	Extreme Value Type-III	0	0	0	0	32.82	Not fitted	
63	Log Normal	0	0	0	2.40	13.29	0.50	0.57
64	Log pearson	0	0	0	0	5.07	Not fitted	
65	Log Normal	0	0	0	0	4.87	0.67	0.70
66	No suff. data	0	0	0	0	0	Not fitted	
67	Log pearson	0	0	0	0	0	Not fitted	
68	No suff. data	0	0	0	0	0		
69	No suff. data	0	0	0	0	0		
70	No suff. data	0	0	0	0	0		
71	No suff. data	0	0	0	0	0		
72	No suff. data	0	0	0	0	0		
73	No suff. data	0	0	0	0	0		

Table 4.4. Evaporation (PET) at 20 % probability of exceedence (mm)

Pentad number	Evaporation ≈ PET (mm)	Pentad number	Evaporation ≈ PET (mm)	Pentad number	Evaporation ≈ PET (mm)
1	14.80	26	44.20	51	21.40
2	17.80	27	42.30	52	16.50
3	17.30	28	47.10	53	18.30
4	15.70	29	41.70	54	16.00
5	16.60	30	37.50	55	23.40
6	19.70	31	40.50	56	18.60
7	22.90	32	29.80	57	21.00
8	21.20	33	29.20	58	16.60
9	22.00	34	36.20	59	23.30
10	23.00	35	30.20	60	21.70
11	28.50	36	24.40	61	17.10
12	33.70	37	24.30	62	14.40
13	34.10	38	24.20	63	24.00
14	25.60	39	21.80	64	18.20
15	27.30	40	18.70	65	14.80
16	28.60	41	12.60	66	16.90
17	31.30	42	11.00	67	16.90
18	34.40	43	23.90	68	15.40
19	36.90	44	14.90	69	14.80
20	33.30	45	13.70	70	14.70
21	34.60	46	13.60	71	14.50
22	37.00	47	16.80	72	18.10
23	39.10	48	17.20	73	15.80
24	35.00	49	13.30		
25	45.10	50	15.90		

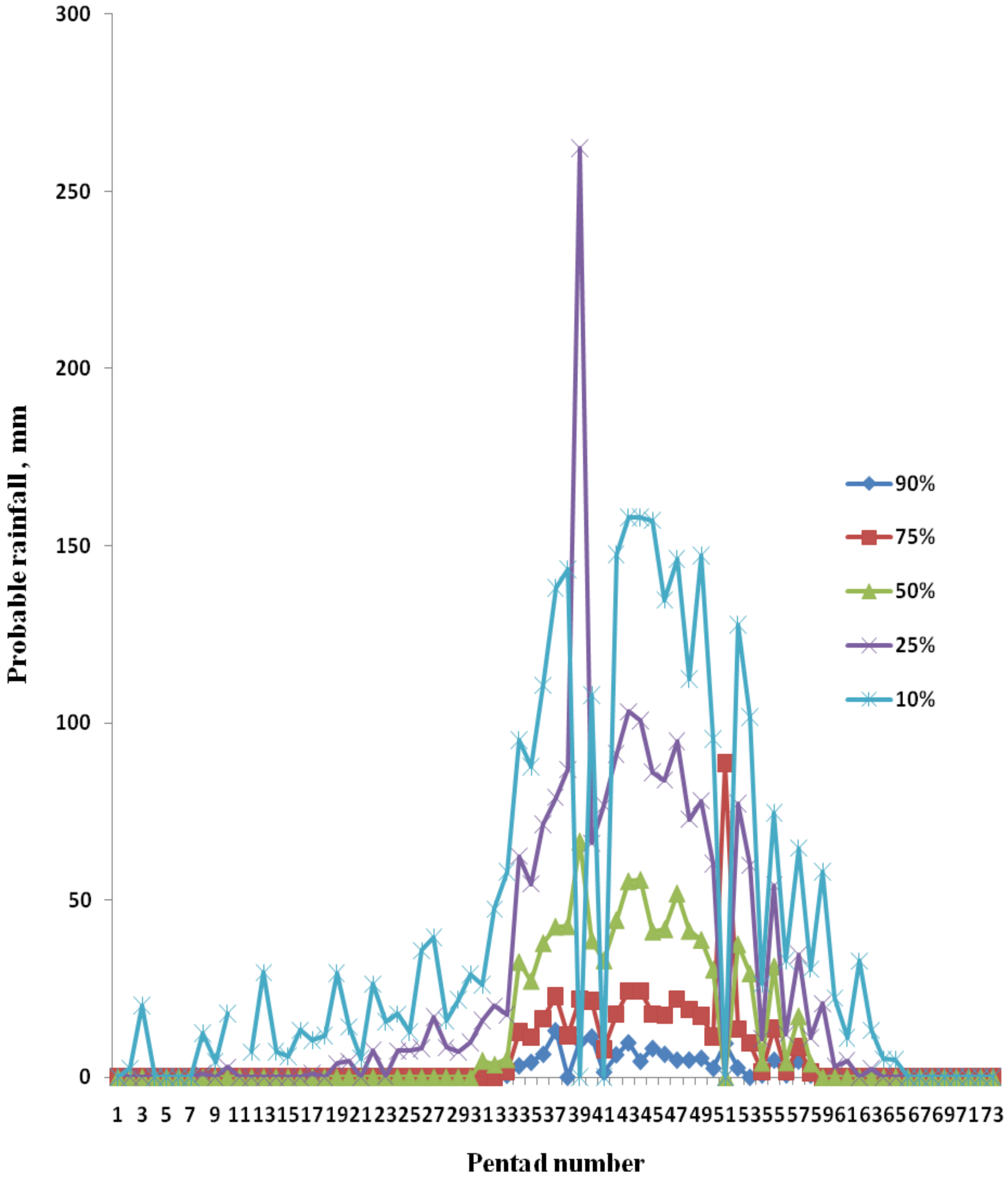


Fig 4.3. Probable pentad rainfall of Kandhamal district (Odisha)

A day of 2.5 mm rain is considered a rainy day. For a pentad it should be 12.5 mm. Based on pentad value of rainfall close to 12.5 mm is observed at 75% probability (Table 4.3).

Rice is the main crop grown in up lands by the farmers of the district. In upland situation, rice can be sustained for 5 days from the available moisture in the soil. So for a pentad, the rainfall amount should be 12.5mm which is considered as the base for crop planning during *kharif*. From Table 4.3, the pentad rainfall values very close to 12.5 mm for various pentads are observed at 75% probability of exceedence.

The best fitted distribution in different pentads and probability values at 90, 75, 50, 25, 10 % were calculated and shown in the Table 4.3. Table 4.4 and Fig 4.4 show the 20% probable evaporation values for different pentads. It is increasing up to 28th pentads 47.1mm which is the highest and lowest (11.00 mm) being observed in 42nd pentad.

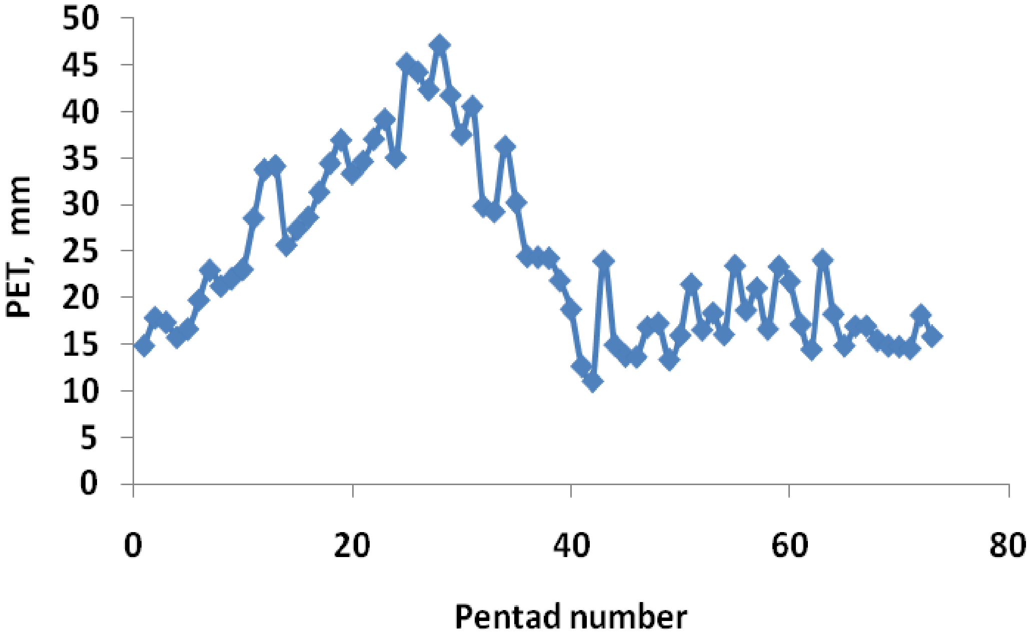


Fig 4.4 PET in different pentads

Onset of monsoon starts in the middle of 33rd pentad. Before 33rd pentad no rain is occurred at 90 and 75 % probability level. From the Fig 4.3, it is observed that certain amount of rainfall is occurred in 31st and 32nd pentads at 50 % probability.

4.1.3 Crop planning

4.1.3.1 *Kharif* crop planning

According to India Meteorological Department for Indian region, a day with rainfall amount equal to or more than 2.5 mm considered as a rainy day. So for a pentad the total rainfall will be 12.5 mm or more of this amount. Based on the pentad value, rainfall pentad close to 12.5mm is observed at 75% probability of exceedance. Rainfall at 75% probability and PET at 20% probability (product of evaporation at 20% probability and assumed crop coefficient 1.0) were considered for crop planning of the zone/district. Considering rainfall at

75% probability and PET at 20% probability (Fig 4.4) showed that during monsoon period rainfall amount is more than PET value, which indicates surplus moisture is available in the soil. The onset of monsoon starts on 12th June and withdraws on 5th October (Annual Report, DLAP, Phulabani 2008). The duration between the onset and the withdrawal is about 116 days. So a crop is to be selected which can be harvested within a period of 90 days or a maximum of 120 days, especially in upland situations. Hence paddy crop viz. Hira, Zhu, Pathara, Vandana, Khandagiri and Annapurna of duration 90days are suitable for the area in uplands. Now Government has given emphasis for diversification of up lands with non-rice crops. So under this situation vegetable and spices crops such as brinjal, okra, sweet potato, cowpea, runner bean, maize, groundnut and chilly with proper soil management practices can be taken up in uplands for higher economic value. Besides these now vegetables like cabbage and cauliflower have been started cultivation in uplands which will give high remunerative value to the farmers of the area.

Medium and *low* lands paddy will not suffer much from intermediate drought, if at all it is occurred. From the Table 4.3 it is also observed that the rainfall amount is equal to 12.5mm or more is observed at 75% probability. There is a variation of rainfall less than 12.5mm in all the pentads except the 37th pentad at 90% probability during monsoon period. If 75% probability is considered there is a moisture stress (less than 12.5 mm) is observed in 38th, 41st and 50th pentads during monsoon period. In these pentads even if there is a moisture stress in the soil, this can be overcome, as the air is in humid condition or the crop can be given life saving irrigation from storage ponds constructed in the field. Monsoon recedes towards the middle of 56th pentad. From the table it is observed that the upland crops will suffer from moisture stress towards the end of the crop period (during 53rd to 54th pentads) as PET is more than the expected rainfall at 75 and 90% probabilities.

During other pentads, the rainfall is sufficient by which crop will not suffer from drought. The rainfall at other probabilities is more than 12.5 mm, which will be sufficient to wet the 15cm depth of soil and there after it increases. Immediately after the harvest of first crop the land must be ploughed with well pulverization and a second crop of mustard/ horse gram should be sown in the field with proper leveling of the soil. The residual moisture available in the soil will help for the germination of seed. Pulverization of soil and leveling will help in retention of moisture for a longer period because of breaking of the soil capillary tube and increasing the evaporative path length. As most of the uplands are sloppy soil must be added with sufficient amount of organic manure in the form of compost or F.Y.M. along with bunding for better absorption of moisture if any rain occurs. Application of Farm Yard Manure and bunding should be made for further absorption and retention of moisture if any rain occurs. Upland being of low water holding capacity, paddy crop with low depth rooting system will suffer more than other crops; moisture from top surface will be evaporated more quickly than sub-surface layer.

Again low income from paddy crop is another factor. Therefore diversified cropping system of short duration and high remunerative crops like oilseeds, pulses, vegetables etc. can also be taken up for that eco - system. Deep rooted crops like pigeon pea can also be taken up in the uplands which can sustain under drought condition. Other crops like maize and intercropping of maize + cowpea, pigeon pea + green gram and pigeon pea + groundnut (2:4) can be also taken up in this area. Further vegetable crops like cowpea, runner bean, okra, pumpkin, tomato, cauliflower and cabbage may be practiced for high return. The pentad rainfall for the experimental year 2007-09 (Table 4.3) showed that, 34^{th}, 39^{th}, 46^{th} and 55^{th} pentads are receiving less rainfall (less than 12.5mm per pentad) , but crop can sustain due to humid condition and rainfall received from previous pentads. The excess water during kharif can be harvested in a pond or any water harvesting structures to reuse that water for a second crop as after September the rainfall at 75% is less than 100mm.

According to India Meteorological Department for Indian region, a day with rainfall amount equal to or more than 2.5 mm considered as a rainy day. So for a pentad the total rainfall will be 12.5 mm or more of this amount. Based on the pentad value, rainfall pentad close to 12.5mm is observed at 75% probability of exceedance. Rainfall at 75% probability and PET at 20% probability (product of evaporation at 20% probability and assumed crop coefficient 1.0) were considered for crop planning of the zone/district. Considering rainfall at 75% probability and PET at 20% probability (Fig. 4.4), during monsoon period, amount is more than PET value, which indicates that surplus moisture is available in the soil. The onset of monsoon starts on 12^{th} June and withdraws on 5^{th} October (Annual Report, DLAP, Phulabani 2008).

The duration between the onset and the withdrawal is about 116 days. So a crop is to be selected which can be harvested within a period of 90 days or a maximum of 120 days, especially in upland situations. Hence paddy crop viz. Hira, Zhu, Pathara, Vandana, Khandagiri and Annapurna are suitable for the area in uplands. Now Government has given emphasis for diversification of up lands with non-rice crops. So under this situation vegetable and spices crops such as brinjal, okra, sweet potato, cowpea, runner bean, maize, groundnut and chilly with proper soil management practices can be taken up in uplands for higher economic value. Besides these now vegetables like cabbage and cauliflower have been started cultivation in uplands which will give high remunerative value to the farmers of the area. Further, if at all intermittent drought occurs due to erratic distribution, can be overcome by recycling the water from the harvesting storage structure.

Medium and low lands paddy will not suffer from drought. If at all it is occurred the crop can be saved by recycling of storage water from the water harvesting pond. From the Table 4.3 it is also observed that the rainfall amount is equal to 12.5mm or more is observed at 75% probability. If 75% probability is considered there is a moisture stress (less than 12.5 mm) is observed in 38^{th}, 41^{st} and 50^{th} pentads during monsoon period. In these pentads even if there is a moisture stress in the soil, this can be overcome, as the air is in the humid condition or the crop can be given life saving irrigation from storage ponds constructed in the field. Monsoon recedes towards the middle of 56^{th} pentad. From the table it is observed that the upland crops will suffer from moisture stress towards the end of the crop period (during 53^{rd} to 55^{th} pentads) as PET is more than the expected rainfall at 75 and 90% probabilities. During other pentads, the rainfall is sufficient by which crop will not suffer from drought. The rainfall at other probabilities is more than 12.5 mm, which will wet the 15cm depth of soil and there after it increases.

As most of the uplands are sloppy for better retention of moisture the soil must be added with sufficient amount of organic manure in the form of compost or Farm Yard Manure and bunding should be made to retain moisture if any rain occurs. Upland being of low water holding capacity, paddy crop with low depth rooting system will suffer more than other crops; moisture from top surface will be evaporated more quickly than sub-surface layer. Again low income from paddy crop is another factor. Therefore diversified cropping system of short duration and high remunerative crops like oilseeds, pulses, vegetables etc. can also be taken up for that eco - system. Deep rooted crops like pigeon pea can be taken up in the uplands which can sustain under drought condition. Other crops like maize and intercropping of maize + cowpea, pigeon pea + green gram and pigeon pea+ groundnut (4:2) can be taken in upland situation. Further vegetable crops like cowpea, runner bean, okra, pumpkin, tomato, cauliflower and cabbage may also be practised.

The observation of rainfall for the year 2007-2009 (Table 4.3) revealed that there is no or negligible rainfall observed for the pentads 34^{th}, 39^{th}, 46^{th}, 55^{th} to 58^{th} pentads in the year 2007; and 37^{th}, 39^{th}, 55^{th} and 58^{th} pentad in the year 2008 and 43^{rd} ,44^{th} , $51^{st,}$ 52^{nd}, 54^{th}, 57^{th} and 58^{th} in the year 2009; during monsoon season.

The excess water during *kharif* can be harvested in a pond or any water harvesting structures to reuse that water for a second crop as after September the rainfall at 75% is less than 100mm.

4.1.3.2 *Rabi* crop planning

As observed from Table 4.3 towards the end of *kharif*, there is a rainfall in the region at 75% probability, which indicated that still moisture is available in the soil, so immediately after the harvest of first crop the land must be ploughed with well pulverization and a second crop of mustard/ horse gram/ niger should be sown in the field with proper leveling of the soil. The residual moisture available in the soil will help for the germination of seed. Pulverization of soil and leveling will help in retention of moisture for a longer period because of breaking of the soil vertical capillary tubes and increasing the evaporative length. If possible one or two irrigation may be given before flowering and at pod-formation stage from water harvesting pond. Some of the cropping patterns may be followed as mentioned below in Kandhamal district.

Un irrigated area

***Up*land area**

Short duration Paddy-Mustard

Short duration Paddy-Horse gram

Short duration paddy-Niger

Short duration paddy-Black gram

Short duration paddy-Green gram

Maize-Mustard

Pigeon pea

***Medium* land**

Medium duration paddy-Mustard

Medium duration paddy-Horse gram

***Low* land**

Long duration paddy-green gram

Irrigated land

Long duration paddy – vegetables-vegetables

Medium duration paddy-vegetables-vegetables

Vegetables – maize-vegetables

Rainfall in the region at 75% probability indicated that still moisture is available in the soil towards the end of *kharif*. So immediately after harvest of first crop, under residual soil moisture condition, crops of low water requirement such as mustard, horse gram, niger can be sown under rain fed situation, if possible one or two irrigations may be given before flowering and at pod-formation stage from water harvesting pond. The pentad rainfall for the experimental year 2007-09 (Table 4.2) showed that, 34^{th}, 39^{th}, 46^{th} and 55^{th} pentads are receiving less rainfall (less than 12.5mm per pentad) , but crop can sustain due to humid condition and rainfall received from previous pentads.

The farmers may use their 10 % of area and construct a lined pond, if they are planning to grow high value crops like, vegetables which will irrigate their crops when there is no rainfall and for a short duration vegetable crops during *rabi*

4.2 *In-situ* soil and water management

Runoff and soil loss, were measured installing multi slot divisor and collection tank at the end of the each treatment plot. Biometric observation and soil moisture content were taken fortnightly.

4.2.1 Rainfall, runoff and soil loss

Runoff was measured from the collection tank, collected during rain storm each day from each treatment plots under different copping systems (Figs. 4.5 to 4.9). Runoff collected from the storage tanks were analyzed for nutrient loss and sediment yield and are given in Table 4.5.

In the experimental years (2007-2009), rainfall was maximum in the year 2009. The runoff and soil loss were also maximum in the same year in all the treatments. In all the years the runoff was lowest in the treatment T_7 (Fig 4.10) and highest in T_9. Amongst the cropping system treatments, highest amount of runoff (346.45 mm) is produced from the field grown with pigeon pea only (T_2). The runoff is 27.84% of rainfall (Table 4.5). This may be due to wide spacing compared to close spacing crops like paddy and groundnut. Because of close spacing and soil covering, rainfall excess flowing over the soil is resisted by the plant system of paddy crop and foliage of groundnut crop as compared to the pigeon pea crop. Lowest runoff of 309.25 mm (25 % of rainfall) is occurred from the field of intercropping of groundnut and pigeon pea (T_7) as compared to other cropping systems. The reason being, firstly, intercropping of groundnut in between the two rows of pigeon pea helped in retarding the velocity of runoff flow, thus increasing the retention time and decreasing the runoff volume at the outlet. Secondly, though pigeon pea is an erosion permitting crop but the crop

Fig 4.5 Multi slot divisor with runoff collection tank

Fig4.6 Multi slot divisor along with rice

Fig 4.7 Multi slot divisor along with groundnut and pigeon pea with strip cropping

Fig.4.8 Multi slot divisor with pigeon pea and groundnut intercrop

Fig 4.9 Multi slot divisor along with groundnut crop

groundnut an erosion resisting crop covering the soil surface which helped in increasing the intake of runoff water into the soil.

When comparison is made between pigeon pea and groundnut intercropping and sole crop of groundnut, intercrop system produced less runoff than sole crop of groundnut. This may be due to, groundnut is grown in between two rows of pigeon pea. Pigeon pea is a deep rooted crop which makes cracking of underneath soil which helped for entering of more runoff water into the soil thus reducing the runoff yield. Groundnut crop as an intercrop helped in increasing the retention time of runoff water and increase the intake of soil incorporated with the breaking of underneath soil.

Table 4.5 Rainfall, runoff and soil loss under different cropping systems during 2007 - 09.

Treatments	**Rainfall (mm)**				**Runoff (mm)**				**Soil loss (t/ha)**			
	2007	**2008**	**2009**	**Mean**	**2007**	**2008**	**2009**	**Mean**	**2007**	**2008**	**2009**	**Mean**
T_1 – Rice sole	1011.60	1060.6	1380.90	1151.03	221.27 (21.87)	295.34 (27.84)	514.00 (37.22)	343.53 (29.84)	6.72	10.01	12.60	9.77
T_2 – P. pea sole	1019.60	1168.2	1544.80	1244.20	226.92 (22.25)	296.43 (25.37)	516.00 (33.40)	346.45 (27.84)	7.11	10.06	12.65	9.94
T_3 – G. nut sole	941.60	1064.5	1439.00	1148.36	221.94 (23.57)	284.03 (26.68)	508.00 (35.30)	337.99 (29.43)	6.49	9.35	12.43	9.42
T_4 – P. pea & rice strip cropping	1019.60	1168.2	1544.80	1244.20	221.10 (21.68)	279.48 (23.92)	487.00 (31.52)	329.19 (26.45)	6.47	9.59	11.84	9.30
T_5 – P. pea & g. nut Strip cropping	1019.60	1168.2	1544.80	1244.20	220.00 (21.57)	275.85 (23.61)	482.00 (31.20)	325.95 (26.19)	6.70	9.47	11.75	9.31
T_6 –P. pea+ rice (2:5) Intercropping	1019.60	1168.2	1544.80	1244.20	217.72 (21.35)	270.03 (23.11)	471.00 (30.48)	319.58 (25.68)	6.35	9.32	9.81	8.49
T_7 –P. pea+ g. nut (2:4) Intercropping	1019.60	1168.2	1544.80	1244.20	213.37 (20.92)	258.38 (22.11)	456.00 (29.52)	309.25 (24.85)	6.23	8.61	9.25	8.03
T_8 – Uncultivated Fallow	1019.60	1168.2	1544.80	1244.20	234.17 (22.96)	347.72 (29.76)	555.00 (35.92)	378.96 (30.45)	7.40	11.92	17.84	12.38
T_9 – Cultivated Fallow	1019.60	1168.2	1544.80	1244.20	250.12 (24.53)	364.67 (31.21)	588.00 (38.06)	400.93 (32.22)	9.77	15.99	19.82	15.19
SEm (0.05)					8.991	29.287	34.097	23.907	0.893	1.843	2.85	1.82
CD (0.05)					19.06	62.089	72.286	50.682	1.89	3.91	6.04	3.86

N.B.: Values in the parenthesis indicate per cent of rainfall In the experimental years (2007-09), rainfall was maximum in the year 2009 and so also the runoff and soil loss was also maximum in all the treatments.

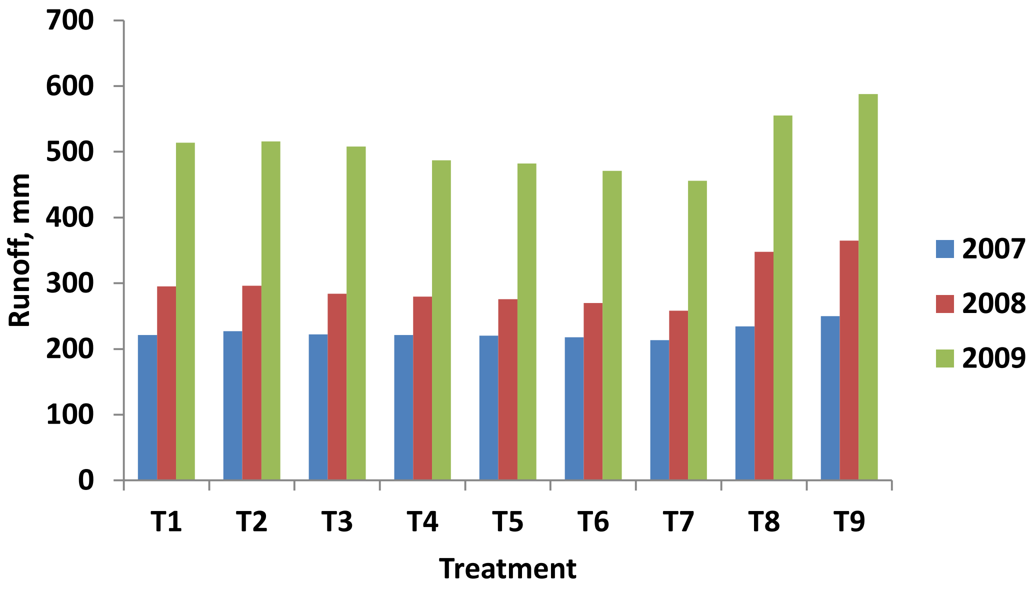


Fig 4.10 Runoff in different years as affected by different treatments

In case of single crops, growing groundnut in the field, yielded less runoff (338 mm) compared to sole crop of rice and pigeon pea. Sole crop of pigeon pea and rice gave 2.66 and 1.77 per cent higher runoff than ground nut respectively.

Strip cropping of pigeon pea + rice produced 0.98% higher runoff than pigeon pea + groundnut strip cropping. The intercropping of pigeon pea+ groundnut (2:5 rows) produced 3.2% less runoff than pigeon pea+ rice (2:5) intercropping. Pigeon pea and rice strip cropping produced runoff 329.19mm which is more than the pigeon pea + rice intercropping (319.58 mm). In case of p.pea and groundnut strip cropping, though p.pea is a deep rooted crop, the vegetative growth was poor at initial phase. The foliages covered the soil surface towards the middle of August, later than the groundnut crop. The open space is more in the area of p.pea strips. On the other side, the wide spacing, impact of raindrops directly and intercepted water drops falling on the open ground surface causing closing of vertical capillary pores, thus more runoff is occurred from the strip of pigeon pea. This high runoff occurred when flowing to the groundnut strip, may not resist the flow occurred from the pigeon pea strip. Thus higher runoff is observed at the outlet point of the p. pea + g.nut strip field.

Similarly 16.56% higher runoff is obtained from cultivated fallow (401.00 mm) when compared with uncultivated fallow land, yielding 379.00 mm runoff. More runoff in cultivated fallow is due to late grown and less density of vegetation at the initial stage as compared to uncultivated fallow.

Fig 4.11 shows that the soil loss was highest in the year 2009 and lowest in 2007 due to the rainfall was lowest in 2007 and highest in 2009. The soil loss was minimum in T_7 and

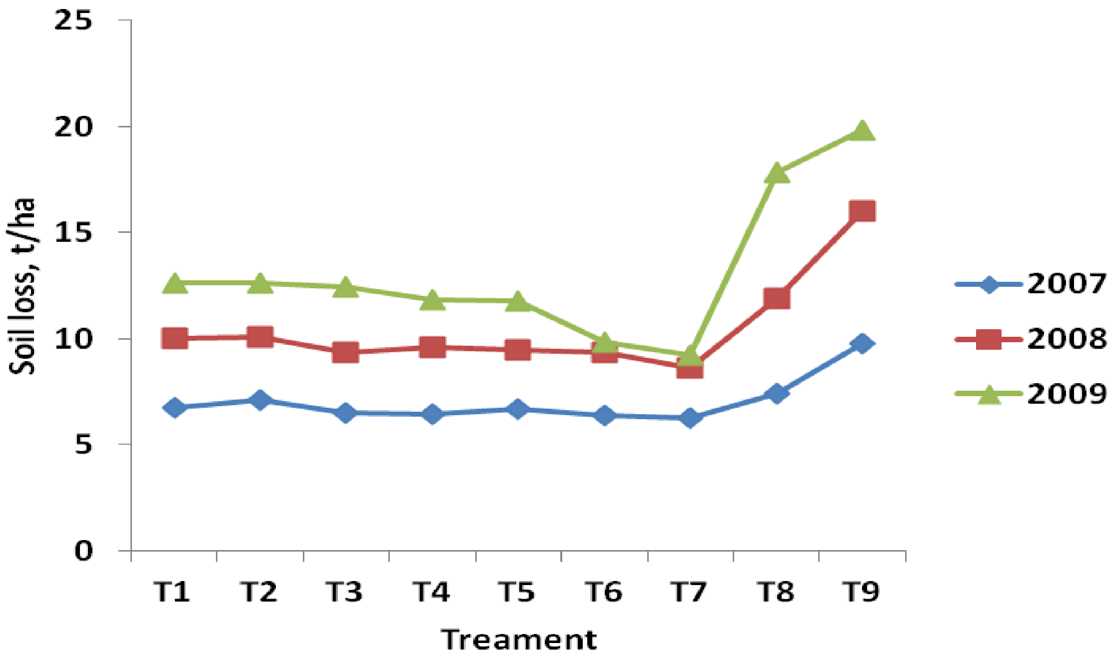


Fig.4.11 Soil loss in different treatments

highest in T_9. Fig 4.12 shows the runoff (% of rainfall), soil loss (q/ha/season) and R.E.Y (q/ha) of all the treatments. The soil loss and runoff were lowest in T_7 and highest in T_9. Less soil loss to a tune of 8.03 t/ha is observed in p.pea+ g.nut intercropping (T_7). Field under p.pea + rice intercropping is the second lowest soil loss yielder followed by p. pea + rice strip cropping (Fig 4.7). Highest quantity of soil loss (9.94 t/ha) was obtained from p.pea.

Amongst sole crops, field covered with groundnut crop (Fig 4.9) yielded less soil loss (9.42 t/ha) which is 3.2% and 5.52% less than the field with sole crop of rice (Fig 4.6) and p.pea respectively. When sole crop of ground nut, strip cropping of p.pea + g.nut and intercropping of p.pea + groundnut are taken in to consideration, less soil loss is obtained from intercropping of p.pea + g.nut field followed by p.pea + g.nut strip cropping and sole crop of g.nut. The soil loss in the cases strip cropping of p.pea + rice (T_4) and p.pea + g.nut (T_5) showed at par. The highest soil loss amongst all the treatments is obtained from cultivable fallow land followed by uncultivated fallow. Intercropping of p.pea + rice (T_6) allows soil loss of 8.5 t/ha which is 9.41% less than the strip cropping p.pea +rice.

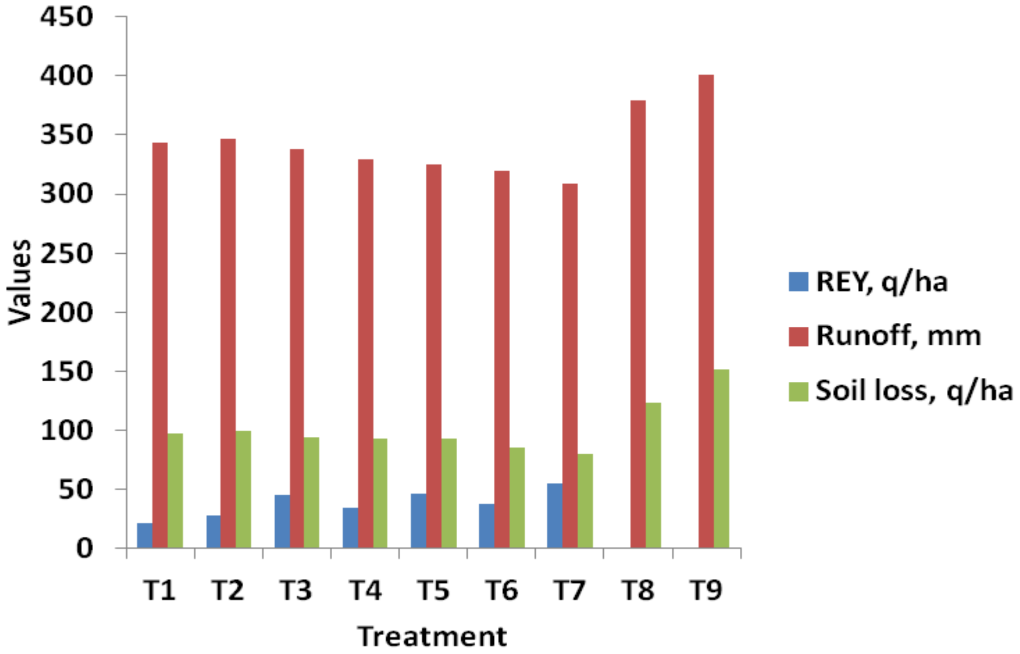


Fig 4.12 Mean REY, runoff and soil loss in different treatments from 2007-09

Less soil loss to a tune of 8.03 t/ha is observed in p.pea + g.nut intercropping (T_7) over p.pea + groundnut strip cropping (T_5) (Fig 4.11). Similarly intercropping of p.pea + rice is more beneficial over p.pea + rice strip cropping. Field under rice + p.pea intercropping is the second lowest soil less yielder followed by p. pea + rice strip cropping. Highest quantity of soil loss (9.94 t/ha) was obtained from p.pea. Amongst sole crops, groundnut yielded less soil loss (9.42 t/ha) which is 3.2% and 5.52% less than sole crop of rice and p.pea respectively. When sole crop of ground nut, strip cropping of p.pea + g.nut and intercropping of g.nut + p.pea are taken in to consideration, less soil loss is obtained from p.pea + g.nut field followed by p.pea + g.nut strip cropping and sole crop of g.nut. The soil loss in the cases of p.pea + rice strip cropping (T_4) and p.pea + g.nut (T_5) showed at par. The highest soil loss amongst all the treatments is obtained from cultivable fallow land as the land is exposed to rain followed by uncultivated fallow. p.pea + rice (T_6) intercropping allow soil loss of 8.5 t/ha which is 9.41% less than the p.pea +rice strip cropping.

4.2.2 Relation between rainfall, runoff and soil loss

The relationship between rainfall (mm), runoff (mm) and soil loss (t/ha) are presented in Fig 4.13 to 4.39 of all the treatments and the mathematical equations are given in Table 4.6. The correlation coefficient is also found out. The relationship between rainfall and runoff and Rainfall and soil loss followed quadratic equation where as runoff and soil loss followed linear equation. Table 4.6 and shows that the mean relationship between rainfall, runoff and

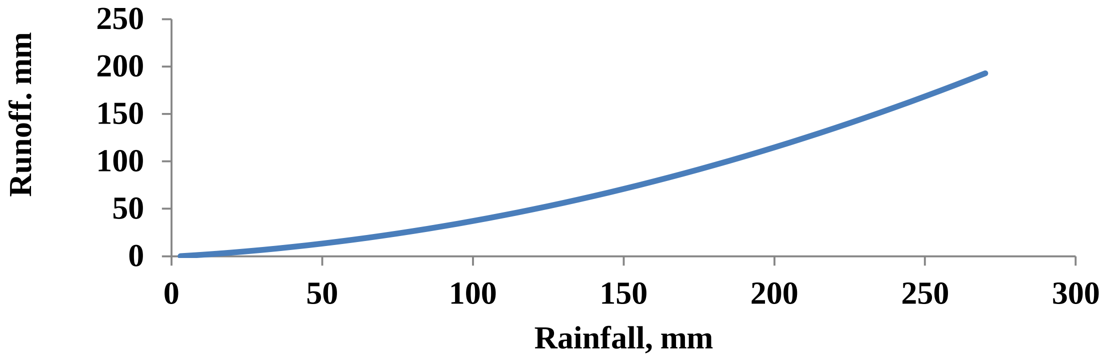


Fig 4.13 Relation between rainfall and runoff for sole crop rice (T_1)

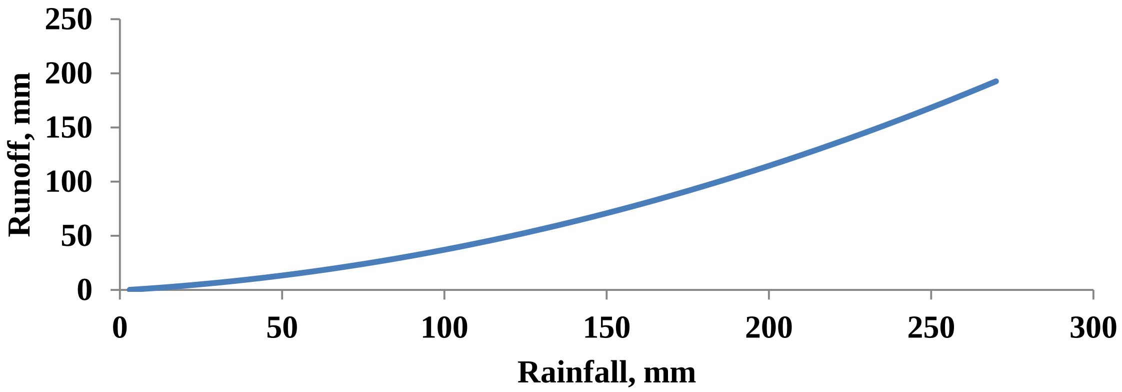


Fig 4.14 Relation between rainfall and runoff for sole crop pigeon pea (T_2)

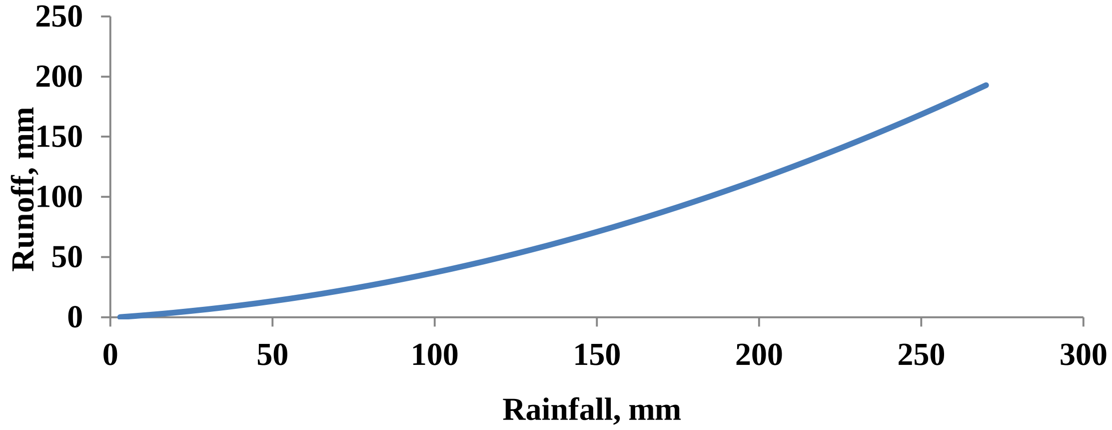


Fig 4.15 Relation between rainfall and runoff for sole crop groundnut (T_3)

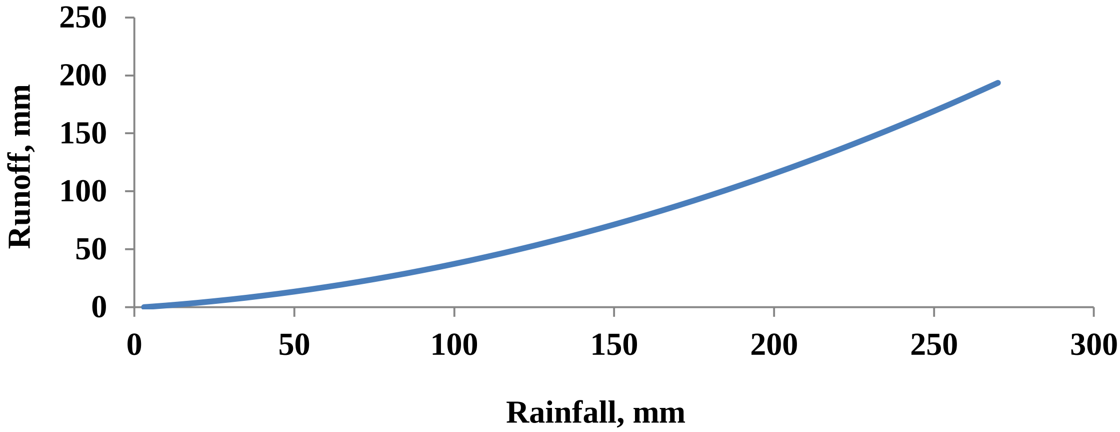


Fig 4.16 Relation between rainfall and runoff for strip cropping of pigeon pea + rice (T_4)

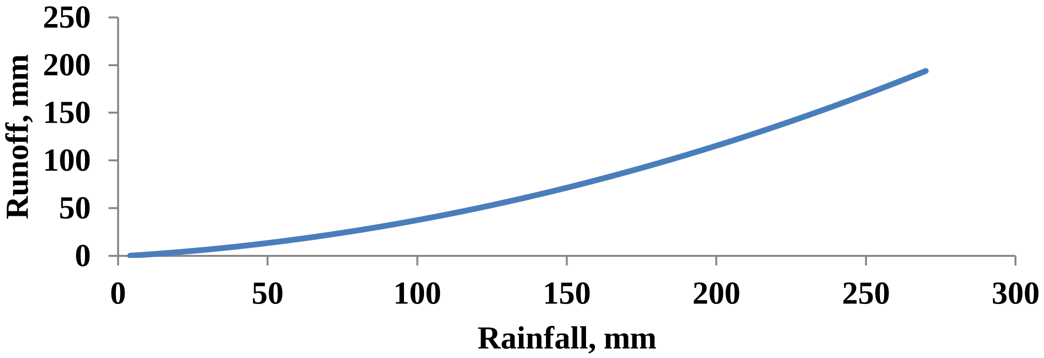


Fig 4.17 Relation between rainfall and runoff for strip cropping of pigeon pea + groundnut (T_5)

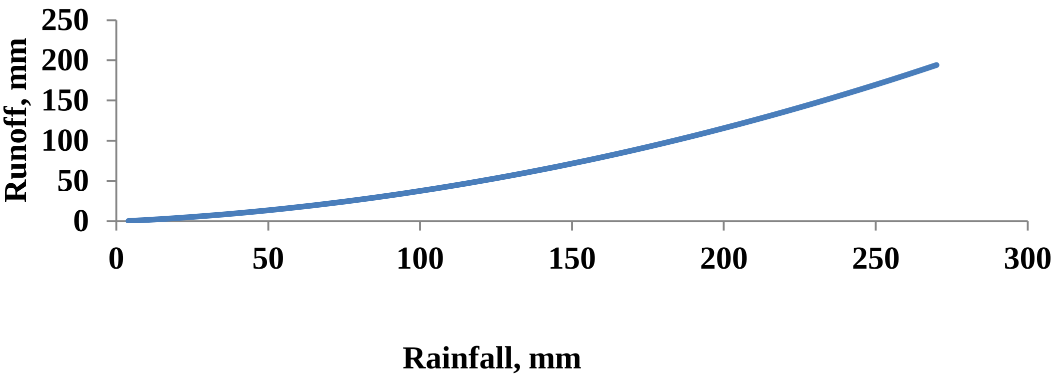


Fig 4.18 Relation between rainfall and runoff for intercropping of pigeon pea + rice (T_6)

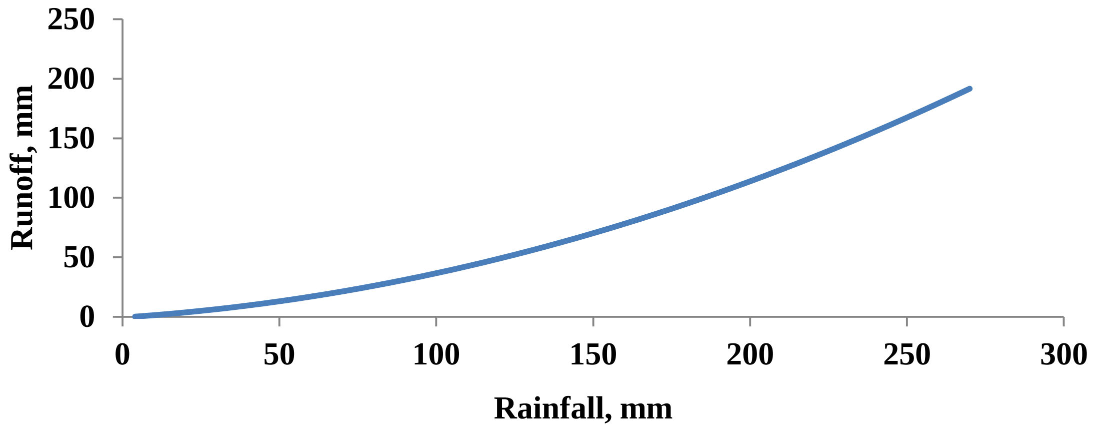


Fig 4.19 Relation between rainfall and runoff for intercropping of pigeon pea + groundnut (T_7)

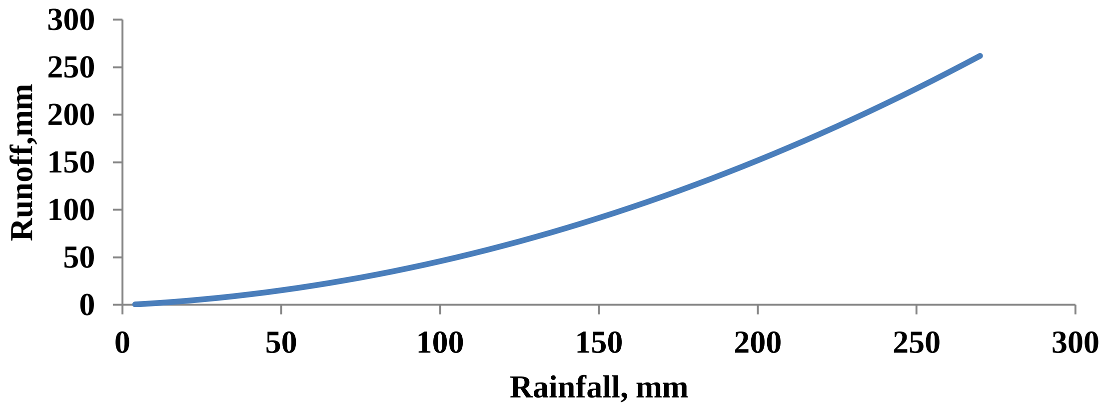


Fig 4.20 Relation between rainfall and runoff for uncultivated fallow (T_8)

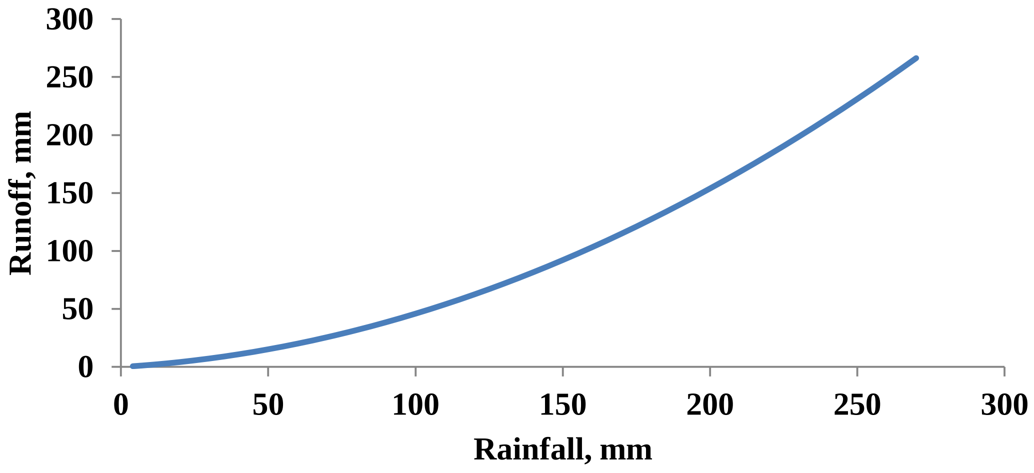


Fig 4.21 Relation between rainfall and runoff for cultivated fallow (T_9)

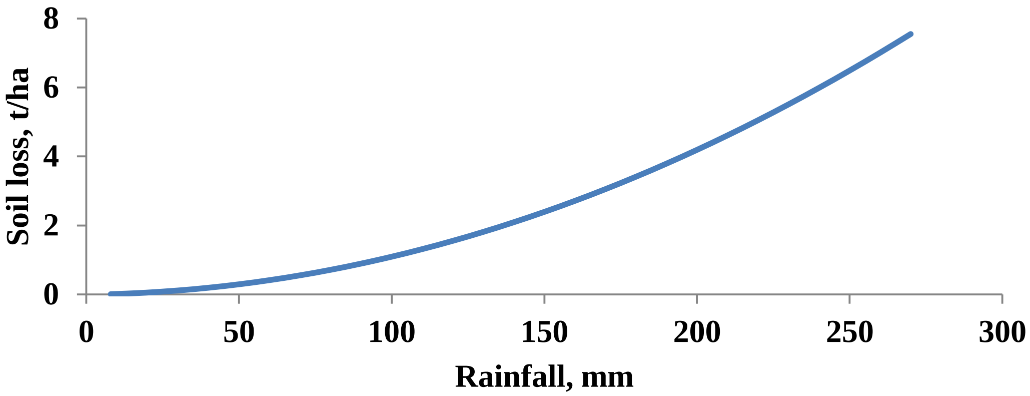


Fig 4.22 Relation between rainfall and soil loss for sole crop rice (T_1)

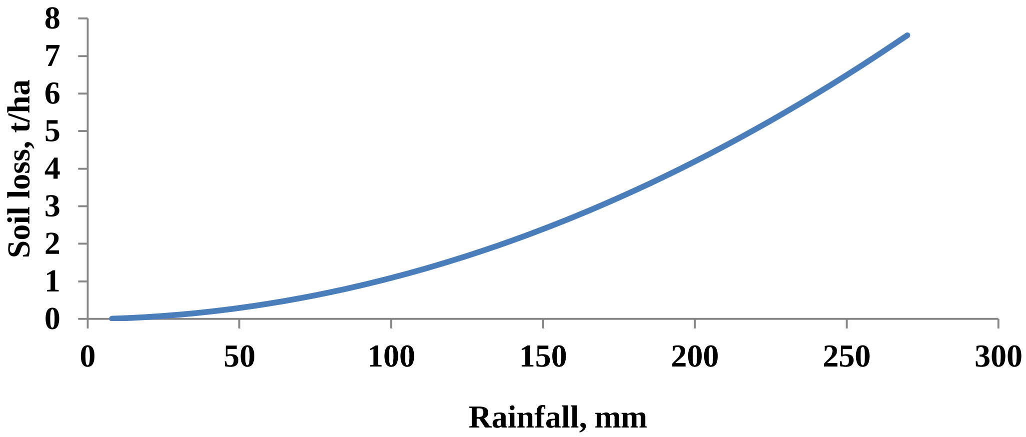


Fig 4.23 Relation between rainfall and soil loss for sole crop pigeon pea (T_2)

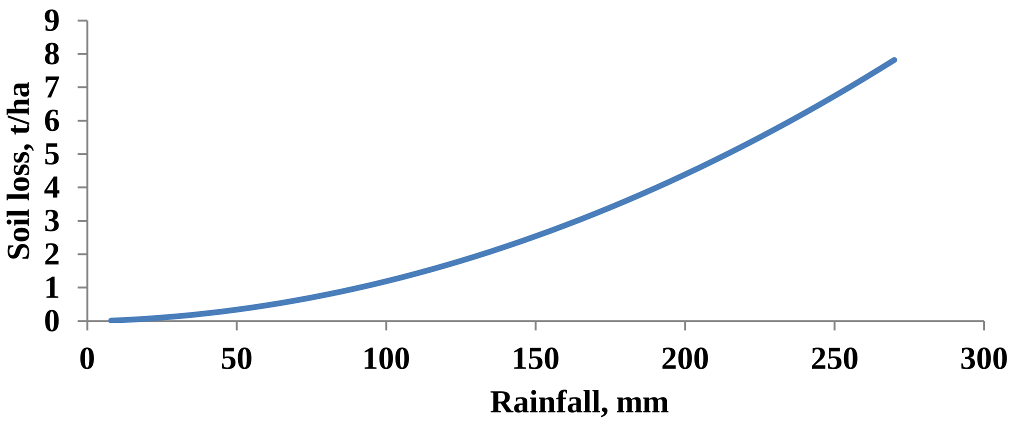


Fig 4.24 Relation between rainfall and soil loss for sole crop groundnut (T_3)

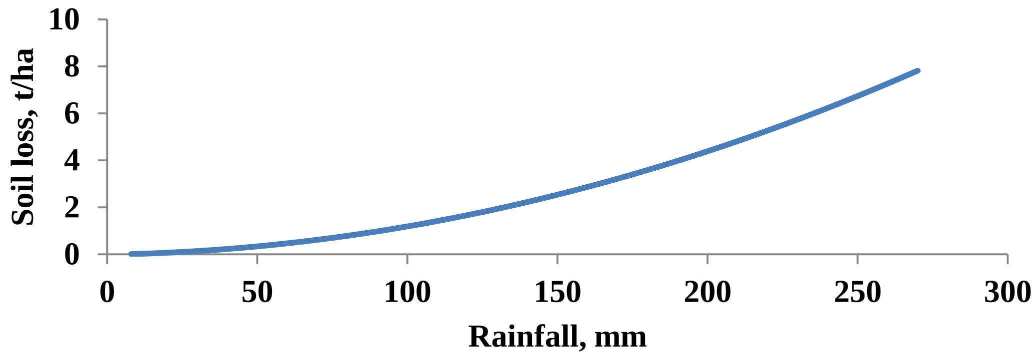


Fig 4.25 Relation between rainfall and soil loss for strip cropping of pigeon pea + rice, (T_4)

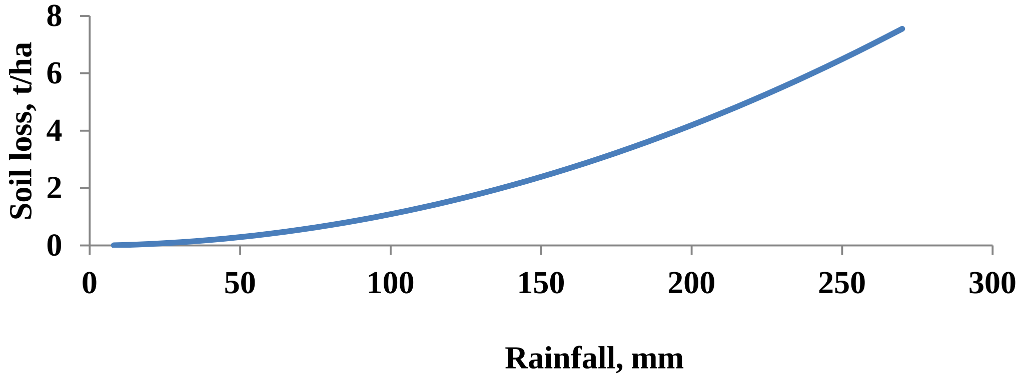


Fig 4.26 Relation between rainfall and soil loss for strip cropping of pigeon pea + groundnut (T_5)

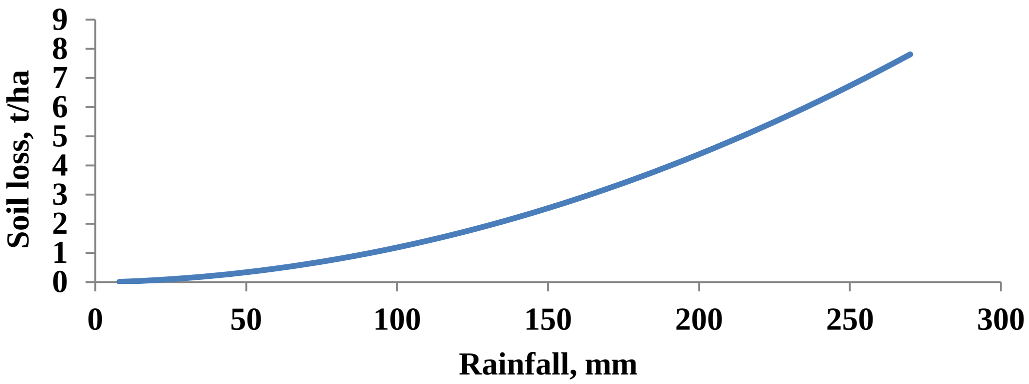


Fig 4.27 Relation between rainfall and soil loss for intercropping of pigeon pea +rice (T_6)

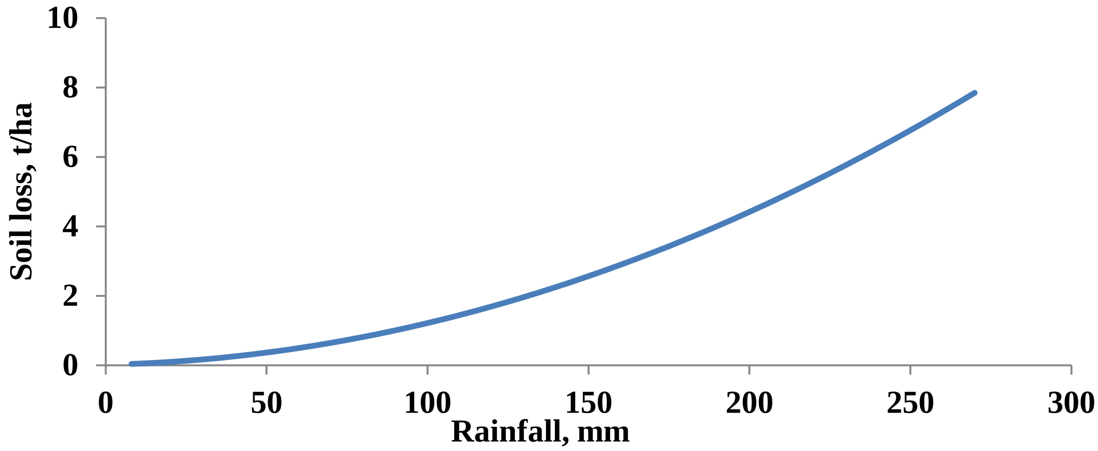


Fig 4.28 Relation between rainfall and soil loss for intercropping of pigeon pea + groundnut (T_7)

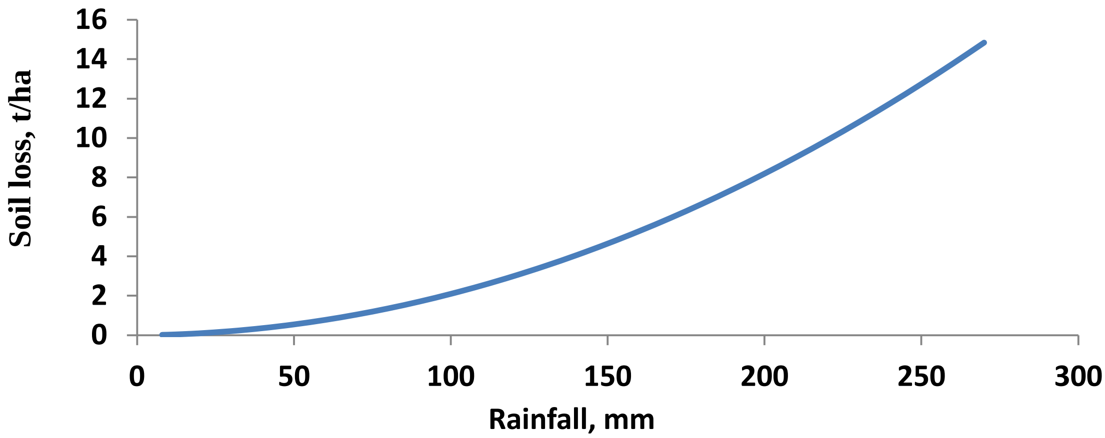


Fig 4.29 Relation between rainfall and soil loss for, uncultivated fallow (T_8)

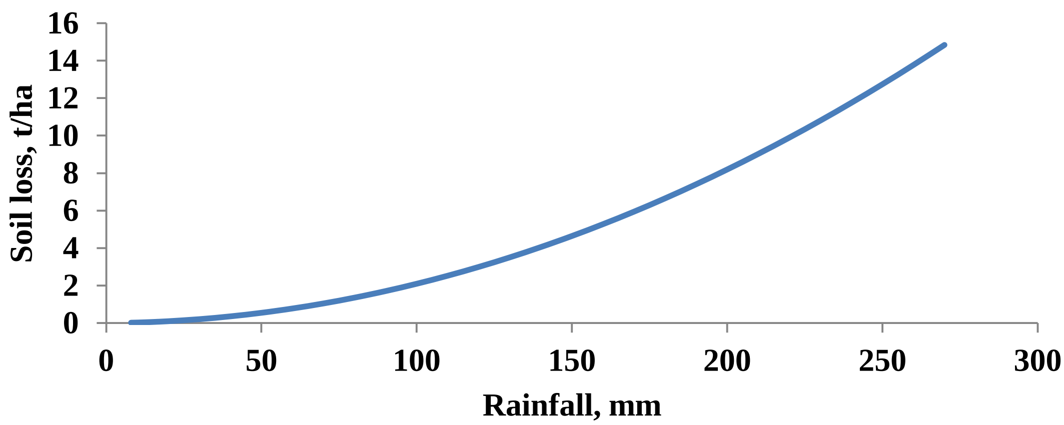


Fig 4.30 Relation between rainfall (x) and soil loss (z) for cultivated fallow (T_9)

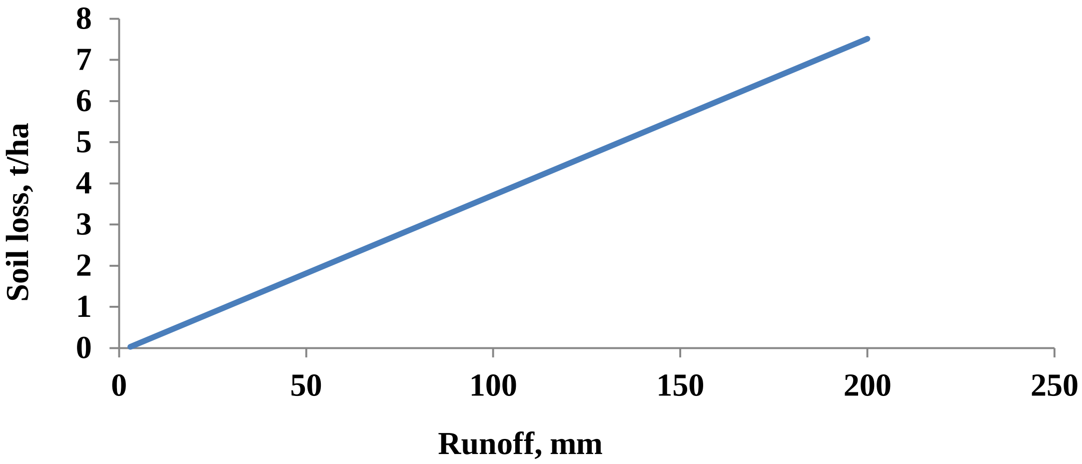


Fig 4.31 Relation between runoff and soil loss for sole crop rice (T_1)

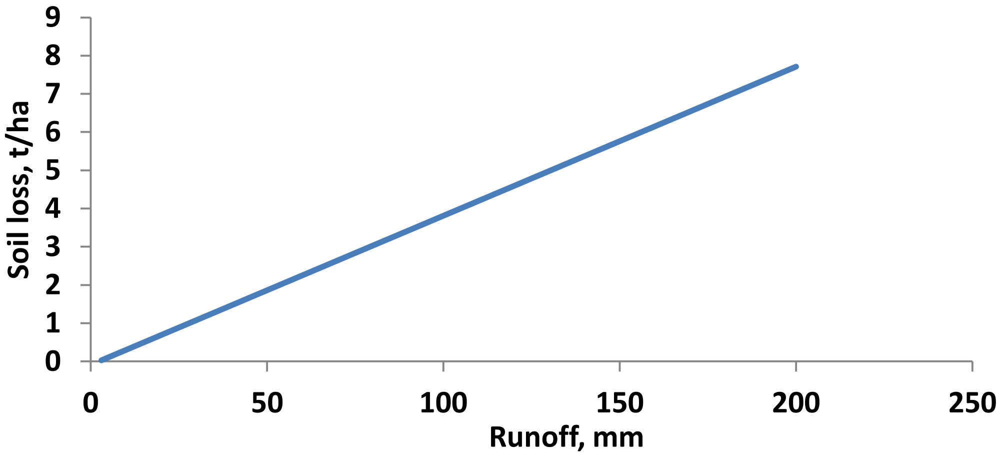


Fig 4.32 Relation between runoff and soil loss for sole crop pigeon pea (T_2)

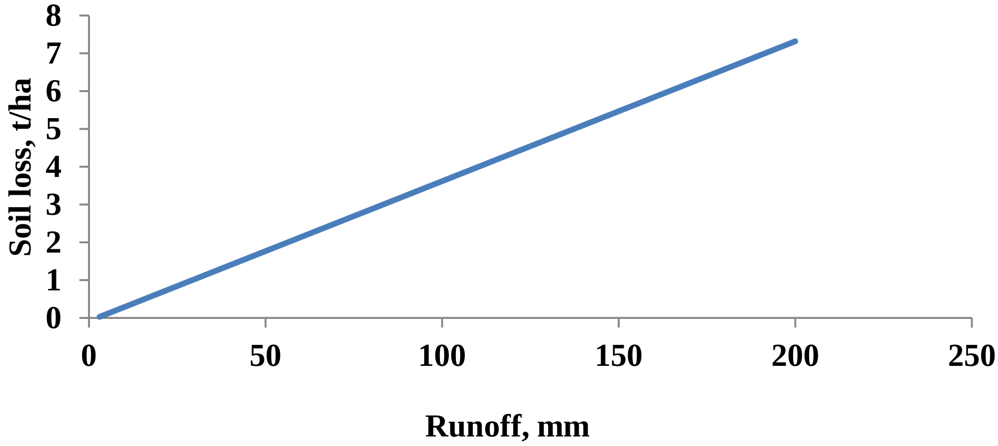


Fig 4.33 Relation between runoff and soil loss for sole crop groundnut (T_3)

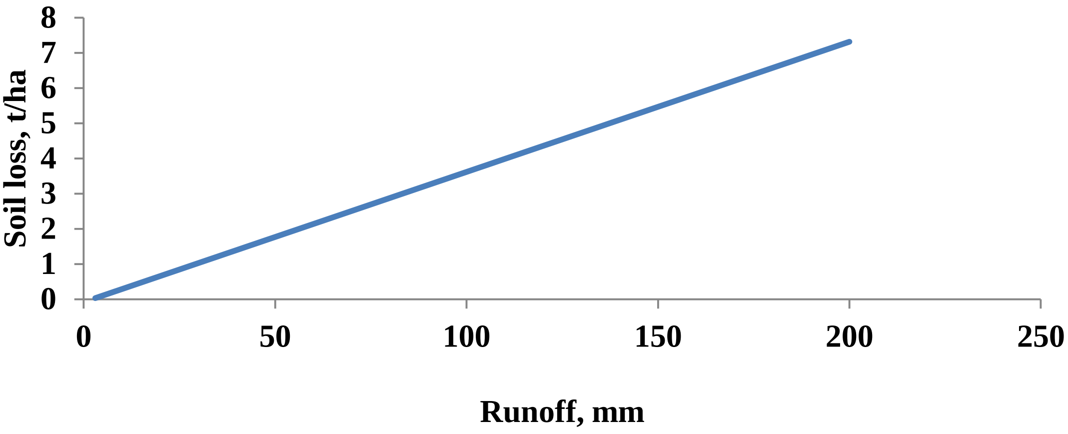


Fig 4.34 Relation between runoff and soil loss for strip cropping of pigeon pea + rice (T_4)

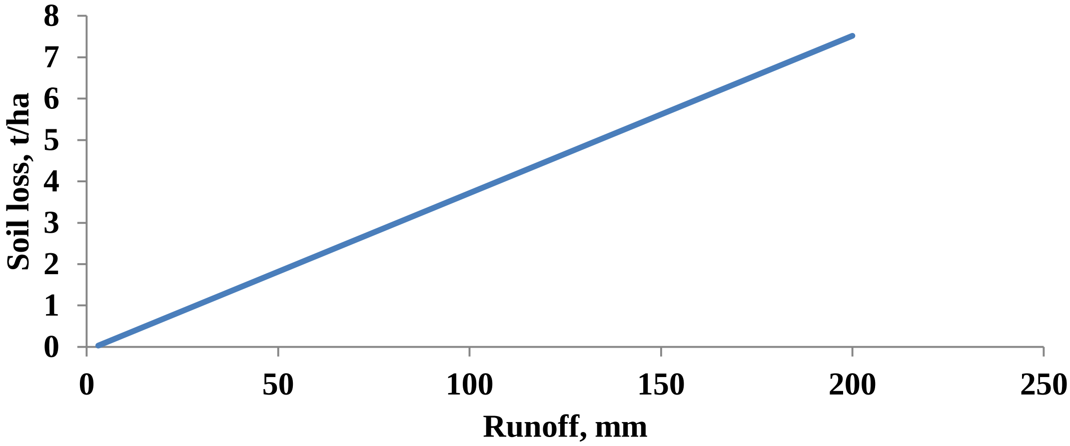


Fig 4.35 Relation between runoff and soil loss for strip cropping of pigeon pea + groundnut (T_5)

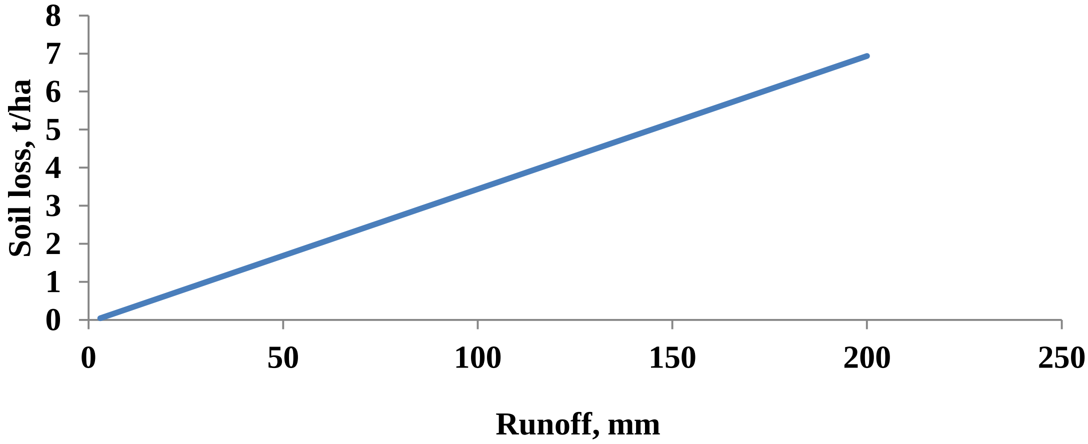


Fig 4.36 Relation between runoff and soil loss for intercropping of pigeon pea + rice (T_6)

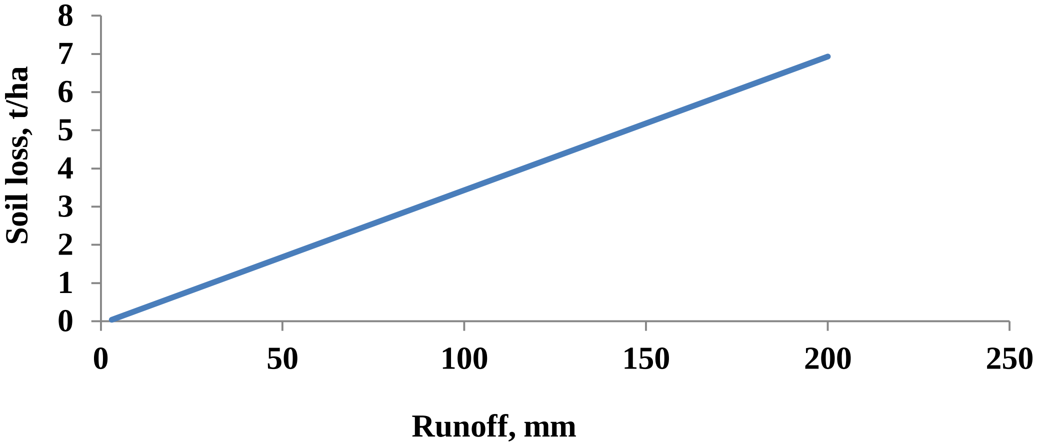


Fig 4.37 Relation between runoff and soil loss for intercropping of pigeon pea + groundnut (T_7)

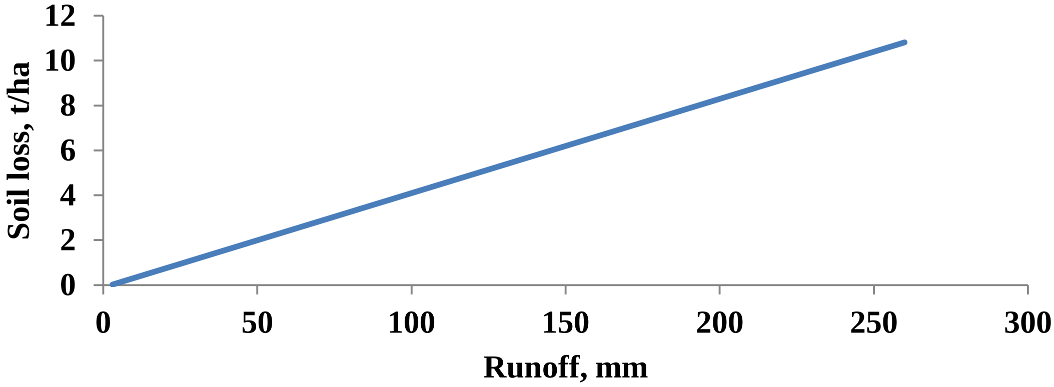


Fig 4.38 Relation between runoff and soil loss for uncultivated fallow (T_8)

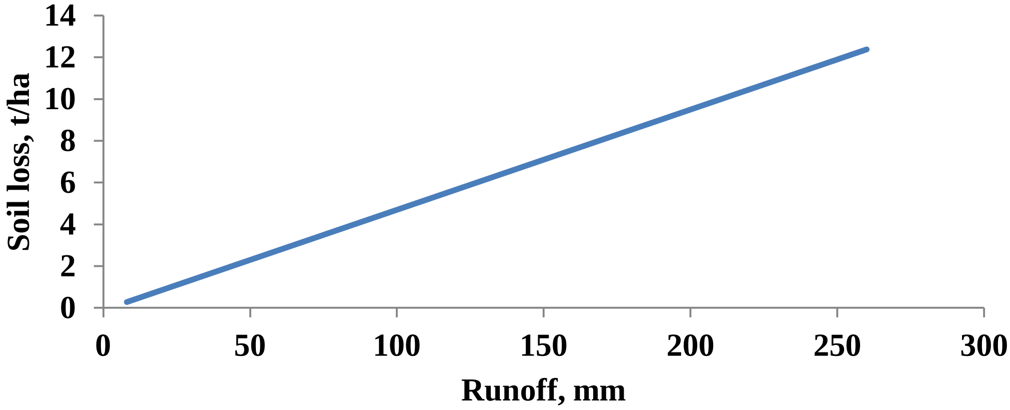


Fig 4.39 Relation between runoff and soil loss for cultivated fallow (T

Table 4.6 Relation between Rainfall (X), Runoff (Y) and Soil loss (Z) in different treatments along with co-efficient of determination (2007-09)

Treatments	**Rainfall (mm) and Runoff (mm)**	**Rainfall (mm) and Soil loss (t/ha)**	**Runoff (mm) and Soil loss (t/ha)**
T_1 – Rice sole	$Y=-0.490+0.176X+0.002X^2$ (0.975)	$Z= -0.008+0.001X+0.0001X^2$ (0.972)	Z= -0.086+0.038Y (0.983)
T_2- P. pea sole	$Y=-0.430+0.175X+0.002X^2$ (0.975)	$Z= -0.007+0.001X+0.0001X^2$ (0.973)	Z= -0.088+0.039Y (0.983)
T_3-G. nut sole	$Y=-0.460+0.176X+0.002X^2$ (0.975)	$Z= -0.010+0.002X+0.0001X^2$ (0.972)	Z= -0.081+0.037Y (0.986)
T_4- P. pea & Rice strip cropping (6 m:6 m)	$Y= -0.525+0.179X+0.002X^2$ (0.973)	$Z= -0.009+0.002X+0.0001X^2$ (0.972)	Z= -0.082+0.037Y (0.987)
T_5- P. pea & G. nut strip cropping	$Y= -0.567+0.18X+0.002X^2$ (0.974)	$Z= -0.009+0.001X+0.0001X^2$ (0.971)	Z= -0.083+0.038Y (0.982)
T_6- P. pea + Rice intercropping (2:5)	$Y= -0.586+0.181X+0.002X^2$ (0.972)	$Z= 0.016+0.002X+0.0001X^2$ (0.949)	Z= -0.064+0.035Y (0.967)
T_7- P. pea + G. nut intercropping (2:4)	$Y= -0.586+0.172X+0.002X^2$ (0.97)	$Z= 0.014+0.002X+0.0001X^2$ (0.943)	Z= -0.068+0.035Y (0.966)
T_8- Uncultivated fallow	$Y= -0.227+0.161X+0.003X^2$ (0.974)	$Z= -0.007+0.001X+0.0002X^2$ (0.97)	Z= -0.105+0.042Y (0.985)
T_9-Cultivated fallow	$Y= -0.153+0.15X+00003X^2$ (0.965)	$Z= -0.007+0.001X+0.0002X^2$ (0.872)	Z= -0.104+0.048Y (0.993)

N.B. –Values in the parenthesis indicate the coefficient of determination soil loss for 3 years from 2007 to 2009. This relationship may be used to predict the runoff and soil loss in similar slope and soil condition.

4.2.3 Moisture content

Observation on soil moisture content in different treatment plots showed that p.pea + g.nut (2:4) intercropping retained higher moisture content in comparison to other in comparison to other cropping system treatments may be due to one runoff permitting and other runoff conserving crop (Table 4.7). Intercropping of p.pea + g.nut showed 1.67, 4.47,

Table 4.7 Soil moisture content under different treatments during 2007-09

Treatments	Moisture Content (% dry wt. basis)			
	2007	**2008**	**2009**	**Mean**
T_1- Rice Sole	15.10	14.90	16.50	15.50
T_2- P.pea Sole	15.2	14.30	15.80	15.10
T_3- G.nut Sole	16.30	15.20	16.50	16.00
T_4- P.pea & Rice strip cropping (6m:6m)	16.20	16.00	16.40	16.20
T_5- P.pea & g.nut strip cropping (6m:6m)	17.00	16.90	17.40	17.10
T_6- P.pea + rice (2:5) intercropping	17.40	17.50	17.90	17.60
T_7- P.pea + g.nut (2:5) intercropping	17.80	17.80	18.10	17.90
T_8- Uncultivated fallow	15.70	15.20	15.90	15.60
T_9- Cultivated fallow	14.90	14.90	15.80	15.20
SE (m)±	0.25	0.93	0.95	0.86
CD(0.05)	0.90	1.99	2.03	1.84

9.50, 10.61, 13.4, and 15.64 per cent higher moisture content over p.pea +r ice intercropping p.pea + g.nut strip cropping, p.pea & g.nut strip cropping, and sole crop of g.nut, rice and p.pea respectively (Table 4.7). Because of deep rooting of the system, sole crop of p.pea retained 3.87% higher moisture in the soil than sole crop of rice and is at par with g.nut. Amongst sole crops higher moisture (16.00 %) is retained in field of groundnut followed by rice and pigeon pea. Strip cropping of p.pea and g.nut (T_5) retained 5 % higher moisture content over p.pea and rice strip cropping (T_4). Similarly intercropping of p.pea + g.nut (T_7) retained more moisture (17.8%) in comparison to p.pea + rice (T_6), which retained 17.60 % moisture content. When comparison is made between strip cropping and intercropping system p.pea + g.nut (T_7) retained more moisture over all other intercropping and strip cropping system. The increase was 1.67 %, 4.47 % and 9.5 % over intercropping of p.pea + rice (T_6), p.pea and g.nut strip cropping (T_5) and p.pea and rice strip cropping (T_4) respectively. Observing all the treatments, less moisture is retained in T_9 i.e., cultivated fallow land. Moisture content of T_1 and T_8 are at par.

Uncultivated fallow retained more moisture (2.63% higher) over cultivated fallow. This is due to more density of weeds in the case of uncultivated fallow. Moisture retention in uncultivated fallow land and rice field treatment are observed to be at par which increased the retention period of runoff plot. This caused more entry of water in to the soil.

This soil moisture increase has increased the crop yield of the treatments when we compare with the crop yield.

4.2.4 Nutrient loss

Nutrient loss in different treatments is presented in Table 4.8. Highest total nutrient loss was observed in treatment T_9 i.e. cultivated fallow land. Least nutrient loss (42.21 kg/ha) was observed in p.pea + g.nut (2:4) intercropping system (T_7) followed by 42.46 and 44.36

Table 4.8 Nutrient loss under different cropping system treatments

Treatments	**Nutrient loss from different treatments (kg/ha)**			**Total nutrient loss (kg/ha)**
	N	**P_2O_5**	**K_2O**	
T_1 – Rc Sole	11.50	10.14	29.70	51.34
T_2- Pp Sole	11.50	13.24	35.62	60.36
T_3-Gn Sole	13.13	12.00	28.76	53.89
T_4-P.pea & Rice strip cropping	11.13	9.69	23.52	44.34
T_5-P.pea & G.nut strip cropping	11.50	7.16	27.42	46.08
T_6-P.pea+Rice(2:5) intercropping	10.38	6.14	25.94	42.46
T_7-P.pea+G.nut (2:4)intercropping	12.25	4.62	25.34	42.21
T_8- Uncultivated fallow	11.50	4.17	36.02	51.69
T_9- Cultivated fallow	16.25	2.82	45.43	64.50

kg/ha in p.pea + rice (2:5) intercropping system (T_6) and p.pea & rice strip cropping system respectively. Sole crop of pigeon pea (T_2) will not help in protecting the land from soil loss as well as nutrient loss (60.36 kg/ha) as is indicated from the tables 4.5 and 4.8. Nutrient loss is more from pigeon pea field then from rice and groundnut field and is 14.9 % and 10.7 % higher respectively. Field with intercropping of p.pea + rice produced less nutrient loss which is 4.4% and 8.5 % less when the field is grown with strip cropping of p.pea and rice and p.pea and g.nut respectively. Even p.pea + g.nut intercropping gave less nutrient loss (42.21 t/ha) then p.pea + rice intercropping and other cropping systems. The nutrient loss from rice field was at par with uncultivated follow land. Nutrient loss is lowest (42.21 kg/ha) in $T_{7.}$This may be the reason to increase the yield in this treatment.

Because of high runoff and the corresponding high soil loss which obviously made highest total nutrient loss in treatment T_9 i.e. cultivated fallow land. This might be due to the reason that soil was cultivated and the surface was exposed without any crop. Least nutrient loss (42.21 kg/ha) was observed in p.pea + g.nut (2:4) intercropping system (T_7) followed by 42.46 and 44.36 kg/ha in p.pea + rice (2:5) intercropping system (T_6) and p.pea & rice strip cropping system respectively. Sole crop of pigeon pea (T_2) will not help in protecting the land from soil loss as well as nutrient loss (60.36 kg/ha) which is followed in the same manner as that of runoff and soil loss.

4.2.5. Yield attributes

The yield attributing characteristics of different crops under different treatments are given in Table 4.9. From the Table 4.9, it is observed that the intercropping of p.pea + g.nut (2:4) gave highest plant height and other yield attributing characters compared to other treatments. In intercropping system, plant height of rice (78.1 cm) is more in comparison to strip cropping and as sole crop systems. The increase of rice plant height was 4.5 % and 8.6 % higher over strip cropping of p.pea and rice and sole crop of rice respectively. So also the panicle length and number of tillers/ m run.

Plant height, no. of branches and spreading of branches in the case of pigeon pea are higher in intercropping system of p.pea + g.nut than the intercropping system of p.pea + g.nut, strip cropping of p.pea + g.nut and p.pea + rice and sole crop of p.pea. The same type of characteristics is also observed in case of g.nut. Similarly plant height (76.0 cm), number of branches (9.0) and number of pods per plant (42.1) were higher in intercropping of p.pea + g.nut when compared with strip cropping of p.pea and g.nut and sole crop system. In intercropping system, plant height of rice is more in comparison to strip cropping and as sole crop. So also panicle length and number of tillers per m. run.

In the case of pigeon pea, plant height, no. of branches and spreading of branches are higher in intercropping system of p.pea + g.nut than the intercropping system of p.pea + rice, strip cropping of p.pea & g.nut and p.pea + rice and sole crop of p.pea. The same type of

Table 4.9 Yield attributing characteristics of the crops in different treatments during 2007-09

Treatments	Rice			Pigeon pea			Groundnut		
	Plant height (cm)	No of effective tillers / m run	Panicle length (cm)	Plant height (cm)	No of branches	Spread (cm)	Plant height (cm)	No of branches	No. of pods per plant
T_1 – Rc Sole	71.4	51.5	17.0						
T_2- Pp Sole				186.6	22.1	93.2			
T_3-Gn Sole							65.4	8.0	35.2
T_4-Pp & Rc strip cropping	74.6	53.8	17.4	191.6	22.2	99.4			
T_5- Pp & Gn strip cropping				198.0	23.1	106.0	74.5	8.6	37.9
T_6—Pp + Rc (2:5) inter cropping	78.1	61.2	18.2	201.7	21.9	97.9			
Mean	74.7	55.5	17.5	197.5	22.5	100.7	72.0	8.5	38.4

characteristics are observed in case of groundnut. This is occurred because of higher retention of runoff water and better uptake of nutrients from the soil by the plants. More uptake of nutrients as is indicated by the loss of nutrients from the soil by the runoff water.

4.2.6 Effect of treatments on yield of crops

Intercrop of p.pea + g.nut (2:4) gave significantly higher rice equivalent yield (5.557 t/ha) as compared to other cropping systems (Table 4.10). Introduction of p.pea + g.nut (2:4) intercropping system increased the yield by 158 %, 97% and 21% when compared with sole crop of rice, pigeon pea and groundnut respectively. Though better growth and high moisture retention was observed in intercropping of p.pea + rice (T_6), strip cropping of p.pea + rice (T_4), the selling cost of rice made the variation in rice equivalent yield. This is resulted due to retention of more moisture and better growth of the plants in this cropping system as compared to other systems. Also p.pea + g.nut intercropping increase the yield by 16,32 and 38 % over strip cropping of p.pea & g.nut, intercropping of p.pea + rice and strip cropping of p.pea & rice respectively over. The intercropping of p.pea + rice, strip cropping of p.pea + rice and strip cropping of p.pea & g.nut affected the yield of the crops varies depending on the type of crop and its management in the field. This is attributed due to the presence of moisture, yield of soil loss and the biometric characteristics of the crops and the loss of nutrients from the field of different cropping systems in the sequence.

4.2.7 Economics of the cropping systems under different treatments (*in-situ* management)

The Economics of the cropping systems under different treatments is given in Table 4.11. From the table, it is observed that the of p.pea + g.nut (2:4) intercropping gave highest mean B: C ratio i.e. 2.06 amongst all the cropping system treatments. Rain water use efficiency was also highest in this treatment i.e. 3.35 compared to other treatments. Among single crops ground nut has got highest benefit: cost ratio (1.82) compared to others. Strip cropping of p.pea and groundnut has got highest Benefit-cost ratio compared to Pigeon pea and rice strip cropping. Comparison between inter cropping and strip cropping showed that intercropping of pigeon pea and groundnut gave higher benefit cost ratio than strip cropping system. So also the rainwater use efficiency. Higher rain water use efficiency (3.35) is obtained from pigeon pea+ groundnut intercropping system followed by p.pea and groundnut strip cropping (2.18). It is further observed that, where groundnut is grown as sole crop or intercrop or strip crop, in all the cases it gave high benefit cost ratio compared to other cropping systems.

Table 4.10 Yield (t/ha) of different cropping systems during 2007-09

Treatment / Year	2007				2008				2009				Mean			
	Rice	**P.pea**	**G.nut**	**REY**	**Rice**	**P.pea**	**G.nut**	**REY**	**Rice**	**P.pea**	**G.nut**	**REY**	**Rice**	**P.pea**	**G.nut**	**Mean REY**
T_1 – Rice sole	2.105			2.105	2.117			2.117	22.48			2.238	2.156			2.153
T_2- P.pea sole		1.056		3.340		1.081		2.544		1.109		2.585		1.082		2.823
T_3-G.nut sole			1.931	5.418			1.950	4.130			1.971	4.187			1.951	4.579
T_4-P.pea & rice strip cropping	1.386	0.748		3.753	1.398	0.790		3.258	14.48	0.832		3.370	1.411	0.790		3.460
T_5- P.pea & g.nut strip cropping		0.779	1.024	5.378		0.852	1.057	4.245		0.893	1.109	4.425		0.841	1.063	4.683
T_6- P.pea + rice (2:5) intercropping	1.777	0.822		4.043	1.796	0.796		3.584	18.48	0.801		3.708	1.807	0.806		3.778
T_7- P.pea + g.nut (2:4) intercropping		0.902	1.333	6.600		0.883	1.335	4.904		0.924	1.355	5.168		0.903	1.341	5.557
T_8- Uncultivated fallow				-				-				-				-
T_9 - Cultivated fallow				-				-				-				-
SEm$\pm$				0.096				0.006				0.006				0.006
CD(0.05)				0.291				0.188				0.182				0.178

N.B.: Selling price of Pigeon pea – Rs 20.00/kg, Groundnut - Rs 18.0/kg, Rice- Rs 9.50/kg

Table 4.11 Economics and rain water use efficiency during 2007-09 as affected by different *in- situ* conservation practices

Treatments	Cost of cultivation (Rs/ha)	Gross income (Rs/ha)	Net income (Rs/ha)	Benefit: cost	Rain water utilized (mm)	Rain water use efficiency (kg/ha-mm)
T_1- Rice sole	14,000	17,933	3,933	1.28	1329	1.62
T_2- P.pea sole	14,200	23,391	9,191	1.65	1690	1.67
T_3- G.nut sole	21,721	39,582	17,861	1.82	1573.5	2.91
T_4- P.pea & Rice strip cropping	17,861	28,866	11,005	1.62	1587.2	2.18
T_5- P.pea & G. nut strip cropping	19,294	38,839	19,545	2.01	1637.4	2.86
T_6- P.pea + Rice (2:5) intercropping	19,166	32,222	13,056	1.68	1574.2	2.4
T_7- P.pea + G.nut (2:4) intercropping	22,577	46,411	23,834	2.06	1658.8	3.35

This may be due to the yield difference obtained under different cropping system treatments as equal amount of water received by all the treatments occurred from the rain.

4.3 *Ex-situ* soil and water management

4.3.1 Yield as affected by different soil and water management system.

In the water harvesting pond based technology, cauliflower was grown in first two years during *kharif* followed by radish in *rabi*. Where as in the third year the cropping system was tomato-radish. The yields of the crops with different water harvesting pond based treatments are given in Table 4.12. It is revealed from the table that yield of cauliflower (Fig 4.45) was maximum (4.60 t/ha) in lined pond as compared to unlined pond (3.82 t/ha) and no pond system (3.27 t/ha) treatments. The yield increase in lined pond is 20.42 and 40.67% more over unlined and no pond system respectively. Similarly, the tomato yield (Fig 4.42,4.46 and 4.48) (13.32 t/ha) was maximum in lined pond which is 17.35 % higher than unlined pond and 42.76 % more over no pond system respectively. The mean yield of three experimental years showed that cauliflower equivalent yield was obtained to be the highest (4.84 t/ha) in lined pond (Fig 4.40 and 4.41) based system followed by 4.06 t/ha in unlined

Table 4.12 Yield of different crops in *kharif* and *rabi* season during 2007-08 to 2009-10

Treatment	*Kharif* (t/ha) Cauliflower 2007-08	*Kharif* (t/ha) Cauliflower 2008-09	*Kharif* (t/ha) Cauliflower Mean	*Kharif* (t/ha) Tomato (CEY) 2009-10	Mean CEY	*Rabi* (t/ha) Radish 2007-08	*Rabi* (t/ha) Radish 2008-09	*Rabi* (t/ha) Radish 2009-10	Mean
T_1-Lined pond with soil cement (6:1) plaster 8cm thickness	4.40	4.80	4.60	13.32 (5.33)	4.84	22.50	25.50	23.32	23.77
T_2-Unlined pond	3.82	3.82	3.82	11.35 (4.54)	4.06				
T_3-No pond	3.53	3.02	3.29	9.33 (3.732)	3.43				
Mean	3.92	3.88	3.90	11.33 (4.533)	4.11				

N.B.: Selling price of Cauliflower - Rs 20.00/ kg (2007-09); Tomato - Rs 12.00/ kg (2007-09), Radish - Rs 6.00/ kg during (2007-08) and (2008-09) and Rs 4.00/ kg during (2009-10).

Fig.4.40 Water harvesting pond without water

Fig 4.41 Water harvesting pond with water

ig 4.42 Cauliflower irrigated from water harvesting pond

Fig 4.43 Water harvesting pond with tomato crop

Fig 4.44 Tomato crop irrigated from water harvesting pond

Fig 4.45 Tomato crop in lined pond

Fig 4.46 Radish crop after harvesting of tomato

Fig 4.47 Close view of radish irrigated from water harvesting pond

Fig 4.48 Crop radish after harvest from water harvesting pond

pond and 3.43 t/ha in no pond system. The mean yield of radish in lined pond using water from lined pond was 23.77 t/ha (Table 4.12; Fig 4.43, 4.44 and 4.47). Application of more number of irrigation conversely the quantity of water applied affected the biometric characteristics. This is an indicator of higher yield of cauliflower and tomato in lined pond based system.

4.3.2 Soil moisture content

The mean moisture content (Table 4.13) was observed and was found that the yield may be high in T_1 due to high moisture content as irrigation was given frequently as per the

Table 4.13 Mean soil moisture content (%) in different treatments

Treatments	2007-08	2008-09	2009-10	Mean
T_1- Lined pond with soil cement (6:1) plaster 8cm thickness	19.6	18.8	19.9	19.4
T_2- Unlined pond	18.6	17.5	19.2	18.4
T_3- No pond	17.5	16.8	18.5	17.6
Mean	18.6	17.7	19.2	18.5

need in T_1 and T_2 and the T_3 received lowest moisture content as there was no irrigation given to that treatment.

4.3.3 Water loss in different treatments

The loss of water was found to be the lowest i.e., 235.8 lit/day (17.06 lit/day/m^2) in lined pond (Table 4.14). The seepage loss of 28.6 m^3/day (831lit/day/m^2) was observed i.e.

Table 4.14 Water loss in different treatments

Treatments	Total cost of the pond (Rs)	Cost of lining (Rs/m^2)	Water loss from the pond (lit/day)	Water loss (lit/day/m^2)	Time taken to dry up the pond, (days)	Economic loss due to seepage (Rs/day)	Cost of storage (Rs/m^3)
1	2	3	4	5	6	7=2 / 6	8=(7/4) x 1000
T_1-Lined pond with soil cement (6:1) plaster 8cm thickness	9,967 (6974cl+ 2993cew)	88.5	235.8	17.06	318	31.34	133
T_2-Unlined pond	2,993	0	28,600	831	2.62	1142.37	40
T_3-No pond	-	-	-	-	-	-	-

Cl - cost of lining, cew - cost of earth work

highest in unlined pond. The cost of lined pond was Rs 9.967.00 and that of unlined pond was Rs 2, 993. 00 (Table 4.14). The cost of lining per square meter was Rs 88.50. The economic loss due to seepage was calculated and was found lowest (Rs 31.34/ day) in lined pond, where as in case of unlined pond it was Rs 1142.37 / day.

4.3.4 Biometric observations in different treatments

Biometric observation during *kharif* and *rabi* are shown in Tables 4.15 and 4.16. The data showed that highest plant height and spread is observed in the field provided with lined pond compared to the field with unlined pond and no pond system in the case of cauliflower. Whereas, the number of leaves were observed to be same for both the years 2007 and 2008 but higher than the other two systems. This is due to availability of more quantity of water which was utilized to the crop for production. The plant height, spread, and number of branches in case of tomato crop were observed higher with lined pond and the increase were 13.2 %, 4.7 % and 6.5 % over unlined pond (Table 4.15). Similarly considering year wise result , observations on plant height, spread and number of leaves were observed in the year 2007-08 and 2008-09 with cauliflower grown in the ex-situ field system were higher over the no pond and unlined pond system. So also same tendency happened for tomato crop.

In unlined pond loss due to seepage and percolation is more than lined pond. Thus the biometric characteristics such as plant height, number of branches, number of leaves etc were less as less water was available for application to the crop in required amount in this treatment.

Table 4.15 Biometric observations of *kharif* crops

Treatments	Plant height (cm)				Spread (cm)				No of leaves			No of branches
Crop	Cauliflower			Tomato	Cauliflower			Tomato	Cauliflower			Tomato
Year	2007	2008	Mean	2009	2007	2008	Mean	2009	2007	2008	Mean	2009
T1	39	45	42	110.2	51.6	61.6	56.6	71.6	17.6	17.6	17.6	6.2
T2	37.5	38.5	38	95.6	43.8	53.8	48.8	68.2	16.4	16.4	16.4	5.8
T3	31.2	32.2	31.7	94.6	36.8	46.8	41.8	66.2	13.2	14.2	13.7	5.2

Table 4.16 Biometric observations of *rabi* (radish) crop

Treatment No.	Plant height (cm)				Spread (cm)				No. of leaves			
	2007	2008	2009	Mean	2007	2008	2009	Mean	2007	2008	2009	Mean
T1	20.8	25.8	25.5	24.03	44.4	45.4	44.4	44.7	20.8	26.8	24.8	24.1

4.3.5 Irrigation given in different treatments

Irrigation given in different treatments are presented in Table 4.17. It is observed that more number of irrigation was given from lined pond in all the years because of availability of water. More water is available due to less loss of water due to seepage, percolation and evaporation which made the lined pond dry in 318 days. Where as in unlined pond, the loss was high (831 lit/day/m^2.). So retention of storage water is only 2.62 days. Availability of more storage water helped for irrigation of 600 litres of water in each irrigation in lined pond whereas 300 litres of water was given in unlined pond in each irrigation due to less water available in unlined pond.

The number of irrigations given from lined pond in the year 2007-08, 2008-09 and 2009-10 were 18, 5 and 13 respectively. Water supplied from the unlined pond once each in the year 2007-08 and 2008-09. Whereas six irrigation were given to the crop during the year 2009 - 10.

The total number of irrigations given to the crops during *khari*f was 6, 1 and 6 and during *rabi* were 12, 4 and 7 from lined pond in the year 2007-08, 2008-09 and 2009-10 respectively.

Table 4.17 Number of irrigations and water applied in different years

Treatment	No. of irrigation			Quantity of water applied in each irrigation, (lit)	Quantity of water applied (lit)		
	2007-08	2008-09	2009-10		2007-08	2008-09	2009-10
T_1-Lined pond with soil cement (6:1) plaster 8cm thickness	18 (6* + 12**)	5 (1* + 4**)	13 (6* + 7**)	600	10,800 (24)***	3,000 (6.7)***	7,800 (17.33) ***
T_2-Unlined pond	1*	1*	6*	300	300 (0.7) ***	300 (0.7) ***	1,800 (4) ***

N.B.: *No. of irrigations during *kharif*, ** No. of irrigations during *rabi*, *** quantity of water applied in mm

Similarly the number of irrigations were 1, 1 and 6 supplied from the unlined pond. The water application from the unlined pond was during *kharif* only. During *rabi*, no crop was grown in the field provided with unlined pond as there was no water in the storage.

4.3.6 Soil test of different treatments

The soil characteristics analysis is shown in Table 4.18, it is observed that the organic content in lined pond treatment is increasing as depth is increasing. The soil type was taken in

Table 4.18 Soil test of different treatments

Treat. No.	Depth (cm)	Sand (%)	Silt (%)	Clay(%)	Text-ure	pH (1:2)	E.C. (%)	O.C. (%)	Available nutrient (kg/ha)		
									N	P_2O_5	K_2O
T_1	0-15	82.0	6.2	11.8	Sandy Loam	5.28	0.027	0.273	125.00	73.81	181.44
	15-30	79.0	6.2	14.8	Sandy Loam	4.80	0.044	0.312	130.00	18.59	255.36
	30-45	77.0	8.2	14.8	Sandy Loam	4.84	0.037	0.331	141.25	11.27	268.80

T_2	0-15	74.0	9.2	16.8	Sandy Loam	4.83	0.044	0.253	150.00	69.31	215.04
	15-30	70.0	7.2	22.8	Sandy Loam	4.94	0.032	0.214	111.25	12.39	208.32
	30-45	66.0	9.2	24.8	Clay loam	4.91	0.034	0.292	126.25	4.51	145.56
T_3	0-15	74.0	9.2	16.8	Sandy Loam	4.80	0.047	0.253	110	40.00	235.20
	15-30	68.0	8.2	23.8	Sandy Loam	5.01	0.031	0.253	97.5	88.46	241.92
	30-45	64.0	10.2	25.8	Clay loam	5.10	0.024	0.195	120	52.96	201.6

three different depths and it is observed that the soil type in all the depths and treatment were sandy loam except in 30-45 cm depth of T_2 and T_3 where treatments the textured class is clay loam. It is observed that the available K_2O is plenty in all the depths. The pH of soil is acidic in nature as it is less than 6 in all the cases.

4.3.7 Nutrient loss in different treatments

The nutrient loss from the three treatments presented in Table 4.19, Table shows that, nutrient loss from the plot provided with lined pond (T1) was less in comparison to unlined and no pond systems. This may be due to the fact that during intermittent dry spell more number of irrigation were given to crop, which was helping more uptake of nutrients by the plants, hence during the event of rain storm, less nutrient loss from the field was observed carried by the runoff water.

Table 4.19 Nutrient loss from different treatment plots

Treatments	Nutrient loss from different treatments (Kg/ha)			Total nutrient loss (kg/ha)
	N	P_2O_5	K_2O	
T_1-Lined pond with soil cement (6:1) plaster 8cm thickness	11.5	10.14	29.7	51.34
T_2-Unlined pond	13.13	12.0	28.76	53.89
T_3 -No pond	11.5	13.24	35.62	60.36

4.3.8 Water use efficiency

The water use efficiency was estimated under different treatments and is given in Table 4.20 and 4.21 for *kharif* and *rabi,* respectively. The water use efficiency during *kharif* was highest (3.26 kg/ha/mm) in the area irrigated by lined pond (Table 4.20). It is observed that tomato yield was better than the cauliflower yield. It is observed that water use efficiency was highest in crops irrigated by lined pond compared to other treatments. In no pond water use efficiency is lowest i.e. 2.49. The water use efficiency was highest irrespective of crops and season in pond based treatment provided with soil-cement (6:1) lining. It was 3.26 kg/ha-mm for cauliflower during *kharif* and 790.92 kg/ha-mm during *rabi* for radish crop. Whereas water use efficiency was highest (1500 kg/ha-mm) for radish in the year 2007-08 as less water was consumed by the crop. The water use efficiency obtained from cauliflower grown in the field with unlined pond is 2.96 and that of no pond system is 2.49 during *kharif.* During *rabi,* no crop was grown due to non-available of water in unlined and no pond system. Less water was applied during *kharif* compared to *rabi* in lined pond due to good rainfall in all the years from 2007-09.

4.3.9 Water balance in lined pond

One water balance study of lined pond is presented in Table 4.22. Lined pond showed that 21.6% of the total flow into the pond is lost due to over flow and 74.5% due to seepage and evaporation. Only 3.9% of the total inflow was utilized for irrigation to crops. Water balance in the lined pond date wise is presented in Appendix K.

Table 4.21 shows the water use efficiency during *rabi*. It is observed that the mean water use efficiency was 790.92 kg/ha/mm, the highest water use efficiency was during 2007-08 (1500 kg/ha/mm) as less rainfall was occurred during that year. Similarly for unlined pond only 0.9 % of the total quantity of water entered in to the tank was utilized for irrigation to crops. About 99.1 % of the total quantity of water entered in to the tank was undergone for storage is lost due to seepage, percolation through the soil and evaporation from the free water surface stored in the tank.

Table 4.20 Water use efficiency in different crops during *kharif*

Treatments	Cauliflower											Tomato					Mean WUE (Kg/ha-mm)
	2007					2008					Mean of 2007 and 2008	2009					
	Yield (kg/ha)	Rainwater utilized (mm)	Irrigation water utilized (mm)	Total consumption of water (mm)	WUE (kg/ha-mm)	Yield (kg/ha)	Rainwater utilized (mm)	Irrigation water utilized (mm)	Total consumption of water (mm)	WUE (kg/ha-mm)	WUE (kg/ha-mm)	Cauliflower eq. yield (kg/ha)	Rainwater utilized (mm)	Irrigation water utilized (mm)	Total consumption of water (mm)	WUE (kg/ha-mm)	
T1	4400	1390	8 (3.6)	1398	3.15	4800	1195.1	1.33 (0.599)	1196.43	3.2	3.18	5,330	1,549	8.0 (3.6)	1,557	3.42	3.26
T2	3820	1390	0.67 (0.302)	1391.33	2.75	3820	1195.1	0.67 (0.302)	1195.77	3.2	3.2	4,540	1,549	4.0 (1.8)	1,553	2.92	2.96
T3	3530	1390	-	1390	2.54	3020	1195.1	-	1195.1	2.53	2.53	3,732	1,549	-	1549	2.41	2.49

NB-Figures in the parenthesis indicate volume (m^3) of irrigation water applied

The total volume of water received by the unlined tank is 201.753 m^3 including direct rainfall over it. Out of this amount 99.1 % were lost due to overflow and seepage loss. Only 0.9 % was utilized for irrigation. So for Kandhamal hilly areas ponds dug for the sandy loam soil should be lined (Table 4.23).

Table 4.21 Water use efficiency during *rabi (*Radish) crop

Treatment	Year	Yield (kg/ha)	Rainwater (mm)	Irrigation water utilized (mm)	Total consumption of water (mm)	WUE (kg/ha-mm)
T_1	2007-08	22,500	3.0	12.0 (5.4)	15.0	1500
	2008-09	25,500	515.8	5.33(2.399)	521.13	49.44
	2009-10	23,320	19	9.33(4.199)	28.33	823.33
	Mean					790.92

N.B.: Figures n the parenthesis indicate irrigation water utilized in m^3

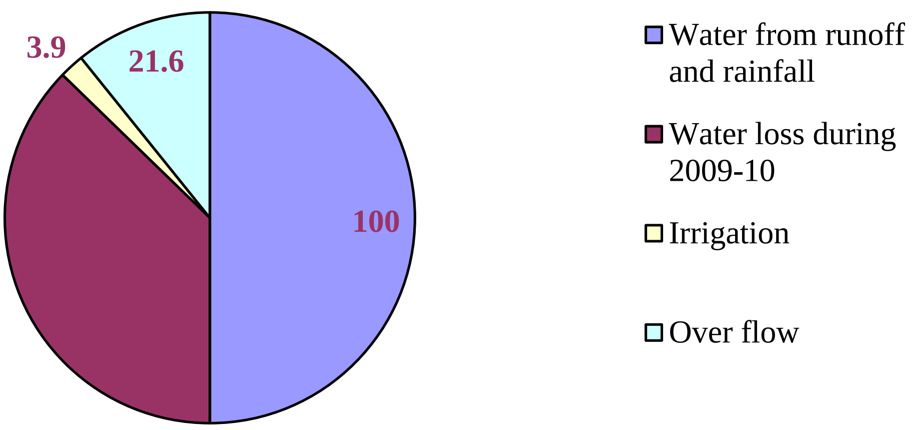


Fig 4.49 Water balance in percentage during 2009-10 in lined pond

Table 4.22 Water balance in the lined pond during 2009-10 in lined pond

Item	Quantity (lit)	(%)
Water in the tank as on 1.04.2009	Nil	
Water from runoff and rainfall entered into the tank	2,01,753	100
Water discharged out from the tank	43,615	21.6
Water loss during 2009-10	1,50,338	74.5
Water utilized for irrigation (*rabi and kharif*)	7,800	3.9
Storage of Water in the structure as on 31.03.2010	Nil	
Rain fall volume (entire year)	7,60,140	100
Runoff volume	1,17,293	15.4

Table 4.23 Water balance in the unlined pond during 2009-10

Item	Quantity (lit)	(%)
Water in the tank as on 1.04.2009	Nil	
Water from runoff and rainfall entered into the tank	2,01,753	100
Water discharged out from the tank and water loss during 2009-10	1,99,953	99.1
Water utilized for irrigation	1,800	0.9
Storage of Water in the structure as on 31.03.2010	Nil	
Rain fall volume (entire year)	7,60,140	100
Runoff volume	1,17,293	15.4

4.3.10 Techno-economic analysis

The techno economic parameters such as net present worth, benefit cost ratio ,internal rate of return and payback period were calculated and are presented below

4.3.10.1 Net present worth (NPW) and Benefit cost ratio (BCR)

The net present worth (Table 4.24) of investment made on lined pond was Rs. 40,487.00, whereas it was Rs 15,279.00 for unlined pond and Rs 8,935.00 for no pond system

Table 4.24 Techno economic parameters in different treatments

Treatment	NPW (Rs)	IRR (%)	Benefit-cost ratio	Payback period (years)	PW cash outflow (Rs)	PW cash inflow (Rs)
Lined pond	40,487	66	2.25	2	32,390	72,877
Unlined pond	15,279	12	2.12	2	18,866	43,291
No pond	8,935	-	1.97	-	9,201	18,136

against an investment (total PW Cash inflow) of Rs 72,877.00, Rs 28,873.00 and

Rs 18,136.00, respectively. The net present worth of investment in case of lined pond was more than the unlined pond because of extra cost involvement for provision of lining material.

The benefit cost ratio for lined pond was 2.25 (Table 4.24) where as it was 2.12 in case of unlined pond. It indicates that the BCR is high in lined pond in comparison with unlined pond and no pond has lowest BCR ratio (1.97).Hence it is worth constructing the lined pond. Based on the NPW and BC ratio it was concluded that the lined pond is economical and there is substantial increase in income of farmer by making lined pond and using the water of lined pond for raising a second crop.

The techno economic parameters such as NPW, BC ratio, IRR and PBP are computed in details for the case lined, unlined and no pond systems are given in Appendix P, Q and R respectively and in brief is given in Table 4.24

4.3.10.2 Internal rate of return (IRR)

The internal rate of return is 66% in lined pond. Internal rate of return is more than the present interest rate i.e., 12 %., because of high benefit and two crops in one year was harvested where as in other two systems only one crop was harvested.

4.3.10.3 Payback period

The table was prepared to calculate the NPP, IRR and payback period. Payback period for both lined and unlined pond were found to be two years because of good rainfall was received during the study period (Table 4.24).

CHAPTER V

SUMMARY AND CONCLUSIONS

CHAPTER-V

SUMMARY AND CONCLUSION

The pentad probability analysis of rainfall shows that most of the pentads the rainfall were fitted to log pearson and perreto type of distribution. Further it is observed that rainfall during June to September is more than 100 mm in each month and cropping pattern like paddy (110 days) may be grown followed by mustard is suitable to this region. Also if the *kharif* rain can be harvested and can be reused for *rabi* crop by using sprinkler or drip irrigation, which will give benefit to the farmers. As per the State Government programme, diversification of upland crops of paddy to non-paddy crops, like oil seed crop such as groundnut and pulse crop like green gram and black gram can be grown for high remuneration. Vegetable crops grown/ planted on ridges should be taken in uplands for retention of more moisture and control of soil erosion. The pentad analysis shows that the pentads which received less than 12.5 mm may be looked into at 75% probability level and different steps may be made to irrigate during that period from pond or irrigation department may be instructed accordingly. The rainfall analysis may be used to design irrigation structures and for watershed management of the district

Intercrop of pigeon pea+ groundnut (2:4) may be followed to check the soil loss (47 %) and to conserve more water (23 %) compared to cultivated fallow. This will also give more rice equivalent yield 55.57 q/ha (158 %) with benefit cost ratio of 3.35 compared to field grown with sole crop of rice in the North Eastern Ghat zone of Odisha. This is followed by strip cropping of p.pea and g. nut (46.83 q/ha) and sole groundnut (45.76q/ha). The mathematical equations between rainfall and runoff; rainfall and soil loss and runoff and soil loss have been developed for all the cropping systems under consideration.

The mean *kharif* cauliflower equivalent yield in last three years shows that lined pond gave highest yield (4.843 t/ha) which is 19% higher than the unlined pond treatment due to more number of irrigation was given to unlined pond (4.06 t/ha) and 42 % higher than the no pond (3.427 t/ha) as no irrigation was given in no pond. Also it gave extra income by irrigating radish during *rabi*. The mean *rabi* radish yield in lined pond was 23.78 t/ha. The loss of water due to seepage, percolation and evaporation was lowest (0.236 m^3/day or 17.06 lit/day/m^2) in lined pond. The seepage loss in unlined pond was highest (28.6 m^3/day) over the last three years. The payback period for the lined and unlined pond is 2 years. So to check the losses due to seepage and percolation and get higher yield and BC ratio, water harvesting pond in 10% area of the field should be constructed at the downstream side to get the benefit for sustainable crop yield. During the dry spell period they can irrigate the crop. The farmers of Kandhamal district grow rice but if they will dug pond than they can go for vegetable crops and get two crops instead of one. The soil loss also can be checked substantially.

The mean of first two years yield of cauliflower produced from the field of lined pond was 4.60 t/ha against the average yield of 3.82 t/ha in unlined pond and 3.29 t/ha in case of no pond treatment (control), which is an increase of 20.42 % and 39.82 % over the yield obtained from the field provided with unlined pond and control (without water harvesting pond). This is occurred due to supply of required amount of water at the time of need (more number of irrigation) available from the storage of lined pond. Similarly the production for tomato crop was 13.32 t/ha in the field of lined pond which is 17.35 % and 42.76% more than the field of unlined pond and no pond system, respectively. During the *rabi* season, due to availability and application of water from lined pond, the quantum of radish production was 23.77 t/ha, whereas, in the other two treatments crops could not be able to sustain after germination in the field because of non availability of water. Lining of 8 mm thick soil and cement (6:1) plaster reduced the loss of water due to evaporation, percolation and seepage. The loss was 17.06 lit/day/m^2 of seepage surface area. This value is increased to 831 lit/day/m^2 in case of water harvesting pond without lining.

The WUE of cauliflower in lined, unlined and no pond system were estimated to be 3.18, 2.98 and 2.54 kg/ha- mm, respectively. Similarly the WUE of tomato crop are calculated as 3.42, 2.92 and 2.41 kg/ha-mm, respectively in cases of lined, unlined and no pond system. Considering the cauliflower equivalent yield for the three years, the mean water use efficiency were estimated to be 3.26, 2.96, and 2.49 in lined, unlined and no pond systems respectively.

The payback period for both lined and unlined pond is 2 years.

CONCLUSIONS

Based on the results obtained from the field experiment, the following conclusions were drawn.

1. It is observed that rainfall during June to Sep is more than 100 mm in each month. The duration between the onset and with drawl of monsoon is 116 days. So crops of duration 90 days should be chosen to grow in upland situation. As most of the farmers are taking rice as their staple food of their daily life, high yielding rice varieties such as, Banaprava, Subhadra, Annada of duration ranging from 90-100 days should be considered for growing in uplands situations. Towards the end of harvest, residual moisture is available in the soil. So a second crop of mustard, linseed, horse gram of low water requiring crops can be taken under residual soil moisture condition.
2. Intercrop of pigeonpea and groundnut (2:4) may be followed to check the soil loss (47 %) and to conserve more water (23 %) compared to cultivated fallow and to give more rice equivalent yield (158 %) compared to sole rice treatment in the North Eastern Ghat zone of Odisha. This is followed by strip cropping of Pigeon pea and Groundnut (46.83 q/ha) and sole groundnut (45.76q/ha) .
3. Provision of water harvesting pond in 10 % area of the field at the downstream side and lined with 8 cm thickness soil-cement plaster (6:1) gave 41% and 19 % higher cauliflower equivalent yield in compared to no pond and unlined pond respectively. The B: C ratio is found to be 2.25 in lined pond as compared to 2.12 and 1.97 in unlined and no pond system respectively.
4. The payback period for both lined pond (lined with 8 cm thickness soil-cement plaster of 6:1) and unlined pond was estimated as 2 years.
5. If the rainfall excess can be harvested during *kharif* season and it can be reused for another *rabi* crop, which will give benefit to the farmers.
6. The recommended dimensions of dugout farm ponds of different design capacities with side slope of 1: 1 are given in Appendices L, M, N and O for Kandhamal district of Odisha under different cropping patterns.

SUGGESTIONS FOR FUTURE WORK

1 The in-situ management i.e. different cropping systems has given in section 3.7 and ex-situ management (pond based technology) along with control may be undertaken for different locations and different soil types for the study of seepage, runoff, soil loss and yield.

2 The trial on water harvesting may be taken considering a large plot as well as by giving irrigation by drip or sprinkler irrigation.

3 Measurement of runoff and soil loss in the experiment may be taken by using Coshocton wheel.

MESSAGES (ENGLISH)

Messages to the farmers:

- In sloppy lands farmers should grow pigeon pea and groundnut as intercrop in the row ratio of 2 : 4, strip crop of pigeon pea and groundnut with strip width of 6 m for up lands to reduce runoff, soil loss and to obtain better economic yield.
- Farmers, who can afford for construction of water harvesting pond, should go for pond based technology. Water harvesting ponds should be constructed in 10 % of the area at the lower side of their plot to store runoff water and re-use of this storage water for life saving irrigation to *kharif* crops, during *kharif* season and to grow a second crop during *rabi* season. For this type of technology farmers should grow high remunerative vegetable crops such as cauliflower and tomato.
- The pond should be lined with 8 cm thickness and soil cement plaster ratio of 6: 1.

Message to the scientists:

- Water harvesting pond in 10 % area lined with 8 cm thickness soil cement plaster of 6: 1 , should be tested for different agro climatic zones of Odisha.
- The intercropping of pigeon pea + groundnut (2:4) ratio or strip cropping of p.pea and groundnut should be tested in high lands of small slope (2 to 4%)
- Measurement of runoff and soil loss may be considered using Coshocton wheel

Messages to the entrepreneur/ Agri-business people:

- Water harvesting pond lining with 8 cm thickness soil cement plaster may be constructed in 10 % area at the lower side of their crop field to reduce losses due to seepage and percolation of storage water, for sustainable crop yield. The storage water collected in the water harvesting pond can save crop from intermittent drought during *kharif* season and to grow a second crop during *rabi*. This will increase the cropping intensity of the area/zone.
- Vegetable crops such as cabbage, cauliflower, tomato and radish should be grown in pond based technology for high return.
- Intercrop of p.pea and groundnut in mild sloppy high lands increase the crop yield and gave high rice equivalent yield (5.55 t/ha) which is significantly

higher compared to the field grown with other sole crop (p.pea, groundnut, rice). The alternate cropping system of strip cropping of p.pea and groundnut should be taken in high lands of small slope (3 to 4 %) for better control of runoff and soil loss and obtain economic yield.

ବା□

କୃଷକଙ୍କ ପାଇଁ ବା□ :-

ଯଦି ପାଣି ଜମିରୁ ଶୀଘ୍ର ବାହାରିଯାଉଥାଏ ତାହାହେଲେ ଚାଷୀମାନେ ସେମାନେ ଯେତେ ଜାଗା ପାଣିମଡାଇବେ ତାହାର ଶତକଡ଼ା ୧୦ଭାଗ ଜମିର ନିମ୍ନଭାଗରେ ଗୋଟାଏ ଜଳାଶୟ କରି ସେଥିରୁ ବଳକା ୯୦ ଭାଗ ଜମିରେ ପାଣିମଡାଇ, ଚାଷକୁ ବର୍ଷାଦିନରେ ମରୁଡି ଦାଉରୁରକ୍ଷା କରିବା ସଂଗେ ସଂଗେ ଅନ୍ୟଗୋଟାଏ ଫସଲ, ରବି ଋତୁରେ ପାଇପାରିବେ । ପୋଖରୀରେ ମାଟି ଓ ସିମେ□ ୬:୧ ଭାଗ ଅନୁପାତରେ ୩ ଇ□ବହଳରେ ଚାରିପାଖରେ ଲଗାଇବେ ।

ଚାଷୀମାନେ ଯଦି ପୋଖରୀ ଖୋଳନ୍ତି ତାହାହେଲେ ପନିପରିବା ଓ ମୂଳା ଏହିପରି ଫସଲ ଖ ସଡା କରି ଚା ଷ କରିବେ । ଯ ଦି ପେ । ଖ ରୀ ନକରନ୍ତି ତା ହେଲେ ହରଡ+ଚିନାବାଦାମ (୨:୪) ଅନ୍ତଃଚାଷ କରିପରିବେ । ଏହା ମରୁଡିଦାଉରୁ ଗୋଟାଏ ଫସଲ ନଷ୍ଟ ହୋଇଗଲେ ଚାଷୀ ଆଉ ଗୋଟାଏ ଫସଲ ପାଇପାରିବେ ।

ବୈଜ୍ଞାନିକଙ୍କ ପାଇଁ ବା□ :-

୧- ଏହି ବୈଜ୍ଞାନିକ ଉପଲବ୍ଧ କୌଶଳ ଯଥା ଜମିର ୧୦ ଭାଗ ଅ□ଳରେ ପୋଖରୀ ଖୋଳି, ପୋଖରୀରେ ମାଟି ଓ ସିମେ□ ୬:୧ ଅନୁପାତରେ ୩ଇ□ବହଳରେ ଦେଲେ ତାହା ଜଳର ଅପଚୟକୁ ରୋକିପାରିବ । ଏହାକୁ ବିଭିନ୍ନପ୍ରକାର ଜାଗା ଓ ବିଭିନ୍ନପ୍ରକାର ମାଟିରେ ପରୀକ୍ଷା କରାଯାଇ ପାରିବ ।

୨- ଏହି ଗବେଷଣାରେ ବ୍ୟବହୃତ ମଲଟିସ୍ଲଟ ଡିଭିଜର ବଦଳରେ କସକ୍ଟନ୍ ହୁଇଲ୍ ମାଟିପାଣିକୁ ସଂଗ୍ରହ କରିବାପାଇଁ ବ୍ୟବହାର କରାଯାଇପାରେ ।

୩-ଏହି ଗବେଷଣାରୁ ଉପଲବ୍ଧ ଜ୍ଞାନ କୌଶଳ ଯଥା :- ହରଡ+ଚିନାବାଦାମ (୨:୪) ଅନ୍ତଃ ଚାଷକୁ ବିଭିନ୍ନ ଗଡାଣିଆ ଯାଗା ଓ ଅନ୍ୟ ପ୍ରକାରର ମୃ□କାର ବ୍ୟବହାର କରାଯାଇପାରେ ।

ଉଦ୍ୟୋଗୀ ମାନଙ୍କ ପାଇଁ ବା□ :-

ଓଡ଼ଶାର ଗଡାଣିଆ ଓ ପାହାଡିଆ ଅ□ଳରେ ଅମଳ ବୃଦ୍ଧିପାଇଁ ଜମି ନମ୍ନିଭାଗର ୧୦ ଭାଗ ଜାଗାରେ ଗୋଟିଏ ପୋଖରୀ କରି ସେହି ପୋଖରୀରେ ମାଟି ଓ ସିମେ□ (୬:୧) ଭାଗ ଅନୁପାତରେ ୩ ଇ□ ବହଳରେ ଲେପନ କଲେ ପାଣି ପୋଖରୀରେ ରଖାଯାଇ ସେହପାଣିକୁ ବର୍ଷାଦିନେ ମରୁଡିରୁ ଚାଷକୁ ରକ୍ଷା କରିବା ସଂଗେ ସଂଗେ ରବି ଋତୁରେ ଆଉ ଗୋଟାଏ ଫଷଲ ପାଇ ପାରନ୍ତେ । ଏହାର ଲାଭ ଓ ଖର୍ଚ୍ଚର ଅନୁପାତ ୨.୨୫ ଅଟେ । ଏହି ଗବେଷଣା ଲବ୍ଧ ଜ୍ଞାନ ଯଥା ହରଡ+ଚିନାବାଦାମ (୨:୪) ଅନୁପାତରେ ଚାଷକଲେ ଏହା ଅମଳ ବଢାଇବା ସଂଗେ ସଂଗେ (R.E.Y-୫.୫୫୭ ଟ/ହେ) ଲାଭ ଓ ଖର୍ଚ୍ଚର ଅନୁପାତ (୨.୦୬) ସମସ୍ତଙ୍କଠାରୁ ଅଧିକ ହୋଇଥାଏ । ଯାହାଫଳରେ ଚାଷୀଲାଭବାନ ହୋଇଥାଏ ।

ଭବିଷ୍ୟତ ଗବେଷଣା ଉପଲକ୍ଷେ ଗବେଷକ ମାନଙ୍କ ପାଇଁ କିଛି ବା□ :-

ଏହି ପ୍ରକାର ଗବଷଣା ଅନ୍ୟ ଯାଗା ଓ ଅନ୍ୟ ପ୍ରକାର ମୃ□କାରେ ପରୀକ୍ଷା କରି ସିପେଜ୍, ରନ୍ଅଫ ଓ ମୃ□କା କ୍ଷୟ କିପରି ହୋଇଥାଏ ତାହା ବାହାର କରିପାରିବେ । ଏହି ଗବେଷଣାରେ ବ୍ୟବହୃତ ଡ୍ରମ ଗୁଡିକର ଆକାର ବଢାଇଲେ ବହୁତ ବର୍ଷା ହେଲେମଧ କିଛି ଅସୁବିଧା ହେବନାହିଁ । ଜଳ ସଂରକ୍ଷଣ ପୋଖରୀରୁ ବୁନ୍ଦା ଓ ସି□ନ ଜଳସେଚନ ପ୍ରଣାଳୀରେ ଜଳସେଚନ କରାଯାଇପାରେ ।

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APPENDIX

Appendix-A

Monthly rainfall (mm) at Phulbani from 1968-2010

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1968	28.4	26.0	48.4	30.3	1.4	99.2	295.6	275.9	284.7	135.7	0.8	0	1226.4
1969	0.6	0	0	21.5	55.1	175.7	551.5	246.7	168.9	5.4	17.4	17.6	1260.4
1970	4.1	0.8	94.0	60.6	34.4	378.7	440.4	243.3	221.6	61.5	0	0	1539.4
1971	14.8	0	0	63.9	104.0	321.4	198.5	303.3	117.7	169.1	2.8	0	1295.5
1972	0	23.4	0	0	1.8	155.8	521.9	242.9	266.5	29.0	101.8	0	1343.1
1973	0	0	0	0	31.6	124.1	453.9	489.4	112.5	227.5	5.9	0	1444.9
1974	0	0	7.9	11.4	56.8	68.1	150.7	169.9	146.1	125.4	0	0	736.3
1975	3.2	28.0	7.9	18.6	18.2	132.0	364.1	207.6	178.4	97.3	6.6	0	1062.1
1976	0	14.8	0	0	43.7	74.0	324.6	320.8	167.0	27.0	14.0	0	985.9
1977	0	0	0	70.4	122.2	122.9	314.6	340.1	451.8	29.6	101.4	5.2	1558.2
1978	0.3	67.8	46.5	23.8	0	158.2	347.4	625.8	204.6	98.5	9	0	1581.9
1979	0	0	0	0	0	155.6	336.8	290.8	158.8	11.6	0	0	953.6
1980	13.4	0	2.6	72.0	39.6	248.2	462.0	213.8	302.6	24.6	0	0	1378.8
1981	31.8	1.0	54.5	30.6	198.4	123.4	248.5	395.8	222.4	1.1	0	0	1307.5
1982	0	0.8	115.7	27.2	65.7	38.6	234.0	1167.2	58.4	2.4	3	0	1713.0
1983	0	47.4	11.4	27.2	65.7	139.6	223.9	287.7	333.1	35.2	0	3	1174.2
1984	4.2	7.5	0	45.0	69.0	463.5	276.0	420.3	58.2	13.5	0	0	1357.2
1985	30.3	66.9	1	0	19.2	52.5	380.1	587.4	514.6	186.7	0	0	1838.7
1986	18.0	42.1	16.0	14.0	18.6	369.0	580.0	377.6	119.0	81.5	106.0	62.0	1803.8
1987	20.0	0	14.0	0	18.0	72.1	270.2	80.3	141.4	88.8	159.3	0	864.1
1988	0	15.4	71.0	104.5	12.8	190.6	216.0	163.8	295.0	72.5	0	0	1141.6
1989	0	0	0	0	0	427.5	279.8	493.8	338.6	38.8	0	0	1578.5
1990	0	20.0	65.0	36.0	168.0	202.0	185.0	721.0	297.0	407.0	183.0	0	2284.0
1991	0	0	7.0	34.0	0	155.0	531.0	820.2	225.6	120.5	28.0	0	1921.3
1992	0	11.0	0	71.0	19.0	244.0	597.0	284.0	156.1	42.0	0	0	1424.1
1993	0	0	0	69.0	70.0	227.0	191.0	354.0	218.0	138.0	0	0	1267.0
1994	3.5	32.0	0	32.0	68.0	220.0	608.0	645.0	378.0	130.0	0	0	2116.5
1995	81.0	20.0	5.0	45.0	274.0	56.7	272.8	312.0	134.2	57.0	91.0	0	1348.7
1996	0	0	16.2	0	16.0	131.1	185.0	255.0	244.0	21.0	4.0	0	872.3
1997	59.0	0	0	109.0	15.0	250.0	304.0	640.2	171.0	80.0	35.0	64.0	1727.2
1998	0	50.0	62.0	11.0	146.0	84.0	218.6	199.5	227.0	121.0	57.0	0	1176.1
1999	0	4	0	6.0	99.0	206.0	367.8	134.2	269.4	202.4	2.0	0	1290.8
2000	0	0	35.0	0	55.0	144.0	279.0	273.0	125.0	31.0	0	0	942.0
2001	0	0	56.0	0	48.0	504.9	797.6	300.1	124.7	111.5	6.9	0	1949.7
2002	13.0	0	20.0	32.0	70.0	149.0	129.0	329.0	134.9	11.0	0	0	887.9
2003	0	23.5	12.5	59.0	7.0	117.0	237.0	358.1	350.1	216.0	0	42.0	1422.2
2004	16.0	38.0	14.0	42.0	30.0	188.0	364.0	242.0	229.0	218.0	0	0	1381.0
2005	28.0	7.0	0	0	34.0	94.0	500.3	139.8	572.4	251.2	2.0	0	1628.7
2006	0	0	0	2	139.2	297.7	412.5	987.2	176.0	13.0	3.0	0	2030.6
2007	0	21.6	5.4	21.6	86.0	424.0	188.4	363.8	465.4	1.0	0	0	1577.2
2008	61.4	2.4	12.6	12.6	4.6	270.0	263.0	422.4	449.3	31.0	2.5	0	1531.8
2009	0	0	1.0	0	44.8	124.8	881.6	321.4	220.2	76.6	19.0	0	1689.4
2010	15.0	2.0	0	0	133.8	154.0	281.9	281.9	194.2	51.6	35.0	48.0	1197.4
Mean	10.4	13.3	18.7	28.0	58.2	193.8	355.0	379.7	237.8	90.5	23.2	5.6	1414.2

Appendix-B

Daily rainfall data (mm) at Phulbani during 2007

Date	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1.	0	0	0	0	0	0	0	65.0	0	0	0	0
2.	0	0	0	0	0	0	0	3.4	7.0	0	0	0
3.	0	0	0	0	0	0	0	9.0	22.8	0	0	0
4.	0	0	0	0	38.2	0	2.0	0	4.4	0	0	0
5.	0	0	0	0	0	0	0	0	8.8	0	0	0
6.	0	0	0	0	0	0	2.0	78.2	12.2	1.0	0	0
7.	0	0	0	0	0	0	69.0	47.8	2.0	0	0	0
8.	0	0	0	0	0	0	0	0	0	0	0	0
9.	0	0	0	0	7.4	0	1.0	0	17.6	0	0	0
10.	0	0	2.6	0	0	0	0	0	5.0	0	0	0
11.	0	0	0	0	0	38.0	0	8.2	20.4	0	0	0
12.	0	21.6	0	4.4	0	0	0	42.2	0	0	0	0
13.	0	0	2.8	0	26.2	0	1.0	7.2	0	0	0	0
14.	0	0	0	0	0	0	0	0.6	21.0	0	0	0
15.	0	0	0	3	0	0	1.6	0	33.0	0	0	0
16.	0	0	0	0	9.2	0	7.4	1.4	1.0	0	0	0
17.	0	0	0	0	5.0	0	1.4	0	0	0	0	0
18.	0	0	0	1.0	0	3.4	2.8	1.2	9.2	0	0	0
19.	0	0	0	0	0	0	0	1.0	20.0	0	0	0
20.	0	0	0	0	0	0	5.6	12.2	1.0	0	0	0
21.	0	0	0	13.2	0	0	30.4	7.6	10.6	0	0	0
22.	0	0	0	0	0	11.2	0	9.6	20.0	0	0	0
23.	0	0	0	0	0	6.8	0	6.2	116.4	0	0	0
24.	0	0	0	0	0	5.0	0	2.0	59.0	0	0	0
25.	0	0	0	0	0	45.5	17.0	1.2	0	0	0	0
26.	0	0	0	0	0	86.0	2.4	4.0	0	0	0	0
27.	0	0	0	0	0	0.8	1.0	3.2	70.0	0	0	0
28.	0	0	0	0	0	16.3	0	3.8	4.0	0	0	0
29.	0		0	0	0	37.0	42.0	10.0	0	0	0	0
30.	0		0	0	0	174.0	1.8	34.0	0	0	0	0
31.	0		0		0		0	4.8		0	0	0
M.T.	0	21.6	5.4	21.6	86.0	424.0	188.4	363.8	465.4	1.0	0	0
C.T.	0	21.6	27.0	48.6	134.6	558.6	747.0	1110.8	1576.2	1577.2	1577.2	1580.2

M.T. –Monthly Total
C.T. – Cumulative Total

Appendix-C

Weekly rainfall distribution at Phulbani during 2007

Standard week	Period	Rainfall (mm)		No. of rainy days	
		Normal	2007	Normal	2007
1.	1-7 Jan.	1.22	0	0.08	0
2.	8-14	4.21	0	0.23	0
3.	15-21	2.2	0	0.18	0
4.	22-28	1.44	0	0.13	0
5.	29-4 Feb	2.0	0	0.1	0
6.	5-11	4.41	0	0.3	0
7.	12-18	6.0	21.6	0.53	1.0
8.	19-25	1.1	0	0.13	0
9.	26-4 Mar	5.5	0	0.3	0
10.	5-11	3.23	2.6	0.3	1.0
11.	12-18	2.8	2.8	0.33	1.0
12.	19-25	4.0	0	0.3	0
13.	26- 1 Apr	5.7	0	0.33	0
14.	2-8	11.7	0	0.68	0
15.	9-15	2.4	7.4	0.28	2.0
16.	16-22	8.3	14.2	0.63	1.0
17.	23-29	7.7	0	0.58	0
18.	30-6 May	10.6	38.2	0.65	1.0
19.	7-13	18.3	33.6	0.95	2.0
20.	14-20	12.6	14.2	0.83	2.0
21.	21-27	11.3	0	0.73	0
22.	28-3 June	10.9	0	0.85	0
23.	4-10	21.3	0	1.03	0
24.	11-17	60.1	38.0	2.45	1.0
25.	18-24	51.1	26.4	2.7	4.0
26.	25-1 Jul	64.0	359.6	2.8	5.0
27.	2-8	83.6	73.0	3.15	1.0
28.	9-15	62.0	3.6	3.18	0
29.	16-22	74.5	47.6	3.8	4.0
30.	23-29	83.1	62.4	3.35	2.0
31.	30-5 Aug	93.1	79.2	3.65	3.0

32.	6-12	85.8	176.4	3.45	4.0
33.	13-19	88.3	11.4	3.28	1.0
34.	20-26	61.4	42.8	2.85	5.0
35.	27-2 Sep	102.7	62.8	3.43	6.0
36.	3-9	55.9	67.8	2.9	5.0
37.	10-16	78.2	80.4	2.93	4.0
38.	17-23	44.2	177.2	2.25	5.0
39	24-30	35.7	133.0	2.05	3.0
40	1-7 Oct	32.9	1.0	1.65	0
41	8-14	21.8	0	1.28	0
42	15-21	26.6	0	1.15	0
43	22-28	12.2	0	0.6	0
44	29-4 Nov	9.1	0	0.7	0
45	5-11	8.8	0	0.48	0
46	12-18	2.9	0	0.25	0
47	19-25	4.4	0	0.13	0
48	26-2 Dec	1.11	0	0.1	0
49	3-9	0.05	0	0	0
50	10-16	1.94	0	0.1	0
51	17-23	1.03	0	0	0
52	24-31	1.9	0	0.08	0
Total		1407.34	1577.2	65.19	64.0

Appendix-D

Maximum and minimum temperature (^{o}C) at Phulbani during 2008-09

Date	Apr 08		May 08		June 08		July 08		Aug 08		Sept 08	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
1	20.8	34.0	23.4	39.6	22.4	32.2	23.6	28.0	22.4	27.4	21.8	30.2
2	17.2	32.0	23.6	41.0	20.0	38.6	23.6	30.0	22.2	29.6	22.2	28.4
3	20.6	35.4	20.0	40.0	25.0	36.4	23.4	30.6	23.0	27.8	20.4	29.4
4	18.8	33.2	19.8	41.0	22.4	35.0	24.8	31.4	22.8	29.8	21.0	28.4
5	19.4	33.0	23.6	41.2	24.2	34.0	22.6	30.0	23.2	29.6	21.8	30.4
6	16.2	27.0	25.6	41.2	21.4	37.4	23.6	29.0	22.4	30.4	21.8	31.2
7	16.8	31.8	22.4	40.0	21.4	32.0	22.2	29.2	23.4	29.4	22.8	31.4
8	17.8	33.2	23.4	40.4	24.0	31.8	21.8	25.0	22.2	28.4	21.8	31.0
9	16.6	34.6	23.8	40.2	23.4	31.4	20.6	25.2	22.0	27.0	21.6	30.4
10	15.4	34.0	26.0	40.0	23.2	31.0	23.2	28.4	21.4	28.0	22.2	30.4
11	16.2	35.2	21.4	40.0	23.4	28.4	22.8	28.4	23.4	27.4	22.4	27.8
12	17.4	37.0	23.8	40.2	23.2	30.8	22.8	29.4	22.4	30.2	21.6	27.4
13	17.6	38.6	21.6	39.2	23.6	31.2	23.6	28.0	22.6	30.4	22.4	29.0
14	21.0	38.4	14.5	38.6	24.6	30.2	23.4	31.8	23.6	30.4	21.8	29.4
15	22.4	37.6	23.4	40.2	22.2	30.4	22.2	31.2	21.8	29.4	23.2	31.2
16	23.2	38.8	25.0	40.0	21.6	26.0	21.6	31.0	22.4	30.0	21.2	26.0
17	22.4	39.6	23.3	40.4	21.2	25.0	22.4	31.6	22.2	29.2	21.2	25.4
18	21.4	40.0	22.4	41.4	21.0	23.6	20.6	31.4	21.6	29.4	21.0	23.6
19	20.4	40.0	26.4	40.2	21.0	24.4	22.6	31.8	21.0	27.4	20.6	27.4
20	17.4	40.6	26.6	41.4	23.2	31.0	22.2	30.4	21.8	29.2	20.6	31.0
21	17.2	40.4	26.0	41.2	23.2	33.2	22.2	31.2	21.2	26.2	22.4	31.4
22	18.0	40.4	24.4	39.6	21.0	31.2	22.4	31.0	20.2	28.4	21.6	29.4
23	20.2	40.2	25.4	38.6	23.0	28.0	22.6	30.2	22.2	26.6	20.6	27.8
24	22.4	4.0	23.6	37.6	22.6	28.6	21.2	31.0	22.0	27.4	21.8	29.0
25	21.0	40.0	24.0	37.2	23.6	27.6	22.8	28.8	22.4	27.2	21.8	30.4
26	21.4	40.0	24.8	38.0	23.0	28.4	22.6	29.4	22.4	30.4	21.4	29.8
27	22.2	39.8	26.2	38.8	23.0	26.0	22.0	29.2	20.4	31.6	21.8	30.8
28	23.8	40.0	23.4	39.6	21.6	27.2	22.4	26.8	24.0	33.0	21.0	30.6
29	23.8	39.8	24.8	39.6	21.0	28.0	21.6	26.2	21.0	33.2	20.8	30.4
30	22.6	38.6	23.8	40.0	23.0	27.2	21.6	29.0	21.2	32.4	20.2	30.6
31	-	-	24.2	40.0	-	-	22.2	26.0	21.8	26.4	-	-
Mean	19.7	35.9	23.6	39.9	22.6	30.2	22.5	29.4	22.2	29.1	21.6	29.3

Appendix-E

Maximum and minimum temperature (^{0}C) at Phulbani during 2008-09

Date	Oct 08		Nov 08		Dec 08		Jan 09		Feb 09		Mar 09	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
1	20.6	31.0	13.4	29.4	12.0	29.2	8.4	27.8	17.0	32.8	14.4	36.6
2	20.6	31.0	11.6	30.0	13.2	28.6	8.2	27.6	17.6	32.6	11.6	35.4
3	21.6	32.0	11.4	28.4	14.8	28.8	8.6	26.6	11.8	30.2	13.4	34.4
4	21.2	32.0	11.8	29.6	14.2	27.2	8.2	26.8	9.4	32.4	12.6	36.6
5	21.0	31.0	12.2	29.2	10.0	28.2	9.2	27.8	10.4	32.4	13.4	36.6
6	20.6	31.8	11.6	29.4	11.0	28.6	10.8	28.4	12.4	32.8	12.8	35.4
7	20.2	26.8	12.4	29.2	10.0	27.6	11.0	27.8	14.0	32.4	12.8	36.2
8	22.4	30.2	12.6	28.4	11.0	27.2	11.8	28.2	12.8	31.8	14.4	36.8
9	20.6	31.6	12.8	28.2	13.6	27.8	11.0	27.6	10.8	31.6	17.8	37.2
10	20.0	30.4	12.8	28.8	14.4	27.4	10.2	27.6	9.8	31.8	19.4	37.2
11	18.8	30.6	13.0	28.4	15.4	28.8	9.8	28.4	11.6	32.2	14.8	37.0
12	19.6	30.6	13.8	28.6	13.4	29.0	10.0	28.4	14.8	31.6	14.8	34.4
13	18.0	31.2	12.4	29.2	15.0	29.6	10.4	27.4	10.4	31.4	11.8	34.6
14	18.2	31.6	9.0	24.8	12.0	29.4	10.0	27.2	9.2	31.0	13.4	35.0
15	18.0	31.2	12.6	26.8	11.6	28.8	10.0	27.4	9.8	32.0	13.6	34.8
16	18.8	31.4	17.0	23.6	10.4	28.6	9.8	27.8	10.8	32.4	13.8	34.6
17	18.6	30.6	19.2	22.0	8.2	28.4	8.6	28.0	12.6	32.2	14.4	33.0
18	19.4	31.2	18.0	29.4	8.0	29.4	8.6	28.0	11.8	32.8	13.6	35.4
19	19.2	30.8	18.6	29.8	8.0	28.2	9.2	28.6	11.6	32.6	14.8	36.0
20	18.8	29.8	18.2	30.0	8.4	29.2	9.6	29.0	11.6	32.8	14.8	36.6
21	18.4	29.0	17.8	31.4	10.8	28.8	9.2	29.6	11.6	33.4	16.4	35.8
22	17.0	30.2	16.6	31.6	11.6	29.8	7.2	28.6	11.2	34.0	16.2	32.4
23	18.6	29.8	17.6	24.6	13.6	28.8	7.4	23.4	13.0	34.2	16.8	34.4
24	17.8	28.0	13.6	28.4	12.0	28.2	7.4	30.6	15.0	34.0	17.2	35.4
25	19.4	27.4	9.2	27.2	12.4	27.4	8.0	32.4	14.6	35.0	17.2	36.0
26	19.2	27.2	10.0	28.2	9.2	25.2	10.0	32.4	13.0	35.8	17.2	35.6
27	12.8	25.2	10.0	27.6	6.8	26.4	10.6	33.4	12.8	35.4	17.2	35.4
28	13.8	28.8	11.4	26.8	6.4	27.2	8.2	34.2	14.2	37.4	14.6	35.4
29	13.6	30.0	13.6	28.6	7.0	27.4	12.0	33.4	-	-	19.2	38.2
30	12.4	29.4	12.8	29.6	7.4	27.4	14.8	32.4	-	-	19.2	38.8
31	12.8	29.1	-	-	7.8	27.4	13.0	31.4	-	-	19.2	39.0
Mean	18.5	30.0	13.6	28.2	11.0	28.2	9.7	29.0	12.3	32.9	15.3	35.8

Appendix-F

Relative Humidity (%) at Phulbani during 2008-09

Date	Apr 08	May 08	June 08	July 08	Aug 08	Sept 08	Oct 08	Nov 08	Dec 08	Jan 09	Feb 09	Mar 09
1	63	67	64	80	89	98	93	92	92	91	96	82
2	68	55	73	82	89	95	92	83	94	93	98	78
3	82	56	75	79	95	98	92	90	98	91	98	77
4	84	49	65	72	95	98	88	90	98	91	87	74
5	82	71	53	95	95	90	90	92	89	86	91	75
6	83	72	95	83	93	90	93	92	98	91	85	67
7	80	69	89	92	97	89	95	90	85	91	90	70
8	77	66	77	97	100	86	97	88	93	94	90	70
9	74	69	68	97	97	93	92	83	90	91	89	87
10	64	51	86	88	98	87	97	89	94	93	96	79
11	67	57	84	89	83	92	91	90	94	85	84	75
12	65	58	80	85	89	87	95	88	94	87	90	71
13	62	50	76	71	94	92	93	90	94	87	87	76
14	79	58	77	85	94	89	93	76	94	93	79	68
15	78	55	97	95	89	92	95	88	96	91	81	64
16	72	70	100	92	94	97	95	98	87	95	85	71
17	89	49	100	89	92	100	96	96	93	95	88	80
18	66	49	100	92	92	100	95	95	93	95	88	68
19	67	39	95	83	93	95	95	95	93	83	82	73
20	67	57	83	86	90	95	93	94	93	98	84	70
21	66	71	85	94	95	90	95	93	91	79	74	77
22	68	40	95	97	97	97	93	92	96	90	78	54
23	66	61	76	98	100	97	91	78	96	90	82	68
24	74	59	81	98	100	97	91	96	94	93	84	71
25	56	56	90	87	94	89	81	93	96	89	87	56
26	61	52	100	85	89	84	86	93	95	91	80	71
27	46	45	100	100	87	87	96	93	93	89	72	65
28	80	57	90	98	84	84	91	93	93	90	74	56
29	69	48	95	95	83	93	89	92	93	89	-	55
30	74	72	87	92	87	95	86	96	95	94	-	67
31	-	65	-	100	93	-	96	-	91	86	-	72
Mean	71.0	57.8	84.5	89.5	92.5	92.5	92.4	90.6	93.4	90.4	85.7	70.5

Appendix-G

Maximum temperature (^0C) at Phulbani during the year, 2009

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	27.8	32.8	36.6	38.4	43.0	36.6	33.0	30.0	31.0	27.4	29.4	26.6
2	27.6	32.6	35.4	37.0	43.2	38.4	31.4	29.4	31.4	26.6	29.0	27.2
3	26.6	30.2	34.4	38.0	42.6	37.4	29.4	30.4	31.6	26.8	28.6	25.4
4	26.8	32.4	36.6	38.4	42.0	36.4	26.4	29.8	31.0	27.4	30.4	26.8
5	27.8	32.4	36.6	40.0	39.0	38.2	29.4	31.4	32.4	30.0	29.0	25.6
6	28.4	32.8	35.4	40.0	38.4	35.6	28.2	31.6	28.4	30.0	29.0	26.6
7	27.8	32.4	36.2	39.0	41.0	34.4	28.8	31.2	28.0	30.2	29.4	27.0
8	28.2	31.8	36.8	39.4	40.0	35.2	27.4	32.0	29.4	30.4	29.6	27.0
9	27.6	31.6	37.2	35.8	41.0	37.2	28.4	32.6	31.2	28.6	29.2	27.6
10	27.6	31.8	37.2	34.0	41.6	35.6	27.2	31.0	31.6	31.0	30.8	27.4
11	28.4	32.2	37.0	37.0	37.6	38.8	26.8	28.4	33.2	28.0	31.0	27.4
12	28.4	31.6	34.4	38.6	36.8	38.4	26.8	28.4	33.0	31.0	30.6	27.0
13	27.4	31.4	34.6	39.0	40.0	35.2	25.6	29.4	32.2	31.6	26.2	27.4
14	27.2	31.0	35.0	39.6	40.0	25.0	26.2	32.4	32.6	30.6	30.6	29.0
15	27.4	32.0	34.8	39.0	38.2	37.4	25.6	28.4	33.4	30.4	32.0	28.4
16	27.8	32.4	34.6	38.4	39.2	35.4	25.6	28.0	32.4	31.0	32.4	28.0
17	28.0	32.2	33.0	35.6	38.4	39.2	27.2	30.2	31.6	30.4	33.8	28.2
18	28.0	32.8	35.4	38.4	40.0	39.4	27.2	31.2	32.0	30.6	28.4	28.8
19	28.6	32.6	36.0	40.0	37.4	39.6	27.4	31.8	30.0	30.0	25.6	28.8
20	29.0	32.8	36.6	40.8	37.6	38.4	24.0	30.6	30.0	31.4	23.4	27.8
21	29.6	33.4	35.8	41.2	38.8	38.0	26.4	28.6	29.4	31.6	27.4	28.0
22	28.6	34.0	32.4	42.4	35.0	36.4	27.6	26.0	31.4	30.6	27.0	26.4
23	23.4	34.2	34.4	42.0	35.6	39.8	28.4	29.0	31.4	30.0	27.0	24.6
24	30.6	34.0	35.4	40.6	36.4	39.0	29.0	29.2	30.2	29.0	26.6	25.0
25	32.4	35.0	36.0	40.0	35.0	39.0	31.6	28.8	32.0	28.8	25.6	24.8
26	32.4	35.8	35.6	40.4	34.0	33.4	30.6	28.6	31.0	29.4	25.6	25.0
27	33.4	35.4	35.4	40.0	38.2	34.0	29.0	28.4	31.4	28.6	25.6	24.8
28	34.2	37.4	35.4	40.2	39.6	33.4	27.0	29.0	31.0	29.0	26.4	24.0
29	33.4	-	38.2	41.6	40.6	34.4	27.0	28.0	31.0	29.4	26.8	24.4
30	32.4	-	38.8	42.6	40.0	33.2	30.4	30.6	28.4	30.2	25.4	25.6
31	31.4	-	39.0	-	37.0	-	28.8	29.6	-	30.4	-	23.4
Mean	29	32.9	35.8	39.2	38.9	36.4	28	29.8	31.1	29.7	28.4	26.6

Appendix-H

Minimum temperature (^oC) at Phulbani during the year, 2009

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	8.4	17.0	14.4	19.6	23.8	23.4	23.4	23.4	23.4	22.8	14.2	8.4
2	8.2	17.6	11.6	18.4	24.0	24.0	23.0	24.6	23.0	22.4	13.0	10.0
3	8.6	11.8	13.4	18.0	23.8	23.2	21.6	24.8	23.6	22.8	12.2	9.6
4	8.2	9.4	12.6	18.0	25.6	23.6	23.2	24.0	23.2	23.0	17.8	11.0
5	9.2	10.4	13.4	22.0	21.8	30.0	24.0	24.2	22.2	22.4	17.4	10.4
6	10.8	12.4	12.8	19.4	21.6	21.0	24.2	23.6	21.8	22.2	17.6	11.6
7	11.0	14.0	12.8	18.6	21.6	21.0	22.6	23.4	21.8	23.0	20.0	9.4
8	11.8	12.8	14.4	18.6	21.4	24.2	23.4	24.6	23.6	22.6	19.6	9.4
9	11.0	10.8	17.8	22.4	24.0	24.4	23.4	25.4	23.6	19.4	20.0	10.6
10	10.2	9.8	19.4	19.4	24.0	25.2	22.4	22.2	23.4	19.4	18.4	12.2
11	9.8	11.6	14.8	19.8	24.2	24.6	22.6	23.4	23.0	19.0	16.8	12.0
12	10.0	14.8	14.8	17.2	24.2	25.6	22.8	24.0	22.6	17.6	16.4	11.6
13	10.4	10.4	11.8	17.8	24.6	24.4	22.4	24.4	23.0	18.2	21.6	11.4
14	10.0	9.2	13.4	18.4	22.2	37.0	22.6	23.0	23.6	18.4	21.4	11.0
15	10.0	9.8	13.6	18.6	23.8	25.0	22.6	23.2	23.4	17.8	21.4	10.6
16	9.8	10.8	13.8	24.6	24.6	25.2	22.4	24.0	24.2	18.4	19.6	10.6
17	8.6	12.6	14.4	22.6	24.8	25.4	22.4	23.0	23.2	18.2	19.2	15.0
18	8.6	11.8	13.6	22.4	21.6	25.8	22.4	24.0	24.0	18.2	19.0	12.6
19	9.2	11.6	14.8	23.0	26.4	25.6	22.6	24.0	22.0	17.6	20.6	12.8
20	9.6	11.6	14.8	18.4	26.4	19.4	22.0	22.4	22.4	18.2	17.2	14.0
21	9.2	11.6	16.4	21.2	21.6	27.2	22.0	21.6	22.0	15.4	18.2	12.6
22	7.2	11.2	16.2	22.2	21.8	26.4	22.2	22.4	22.2	15.6	15.0	10.4
23	7.4	13.0	16.8	20.2	24.8	27.8	22.6	23.4	23.2	12.4	10.6	7.6
24	7.4	15.0	17.2	17.6	25.2	25.4	22.6	22.0	22.6	12.6	10.0	7.2
25	8.0	14.6	17.2	17.4	25.4	23.0	24.8	21.8	23.2	11.8	9.6	6.4
26	10.0	13.0	17.2	20.2	24.0	23.2	24.6	22.4	23.4	12.2	10.6	6.2
27	10.6	12.8	17.2	20.6	25.6	24.0	24.2	22.0	22.6	11.8	8.5	7.6
28	8.2	14.2	14.6	17.8	23.6	24.6	22.6	23.4	22.4	11.4	8.2	6.6
29	12.0	-	19.2	21.0	24.0	24.0	22.6	23.6	23.0	11.8	8.0	6.6
30	14.8	-	19.2	23.2	23.2	24.4	23.2	24.0	23.4	14.2	8.0	10.4
31	13.0	-	19.2	-	24.4	-	23.4	23.0	-	14.0	-	11.4
Mean	9.7	12.3	15.3	20	23.8	24.9	22.9	23.4	23	17.6	15.7	10.2

Appendix-I

Relative humidity (%) at Phulbani during the year, 2009

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	91	96	82	56	56	69	82	82	92	95	87	89
2	93	98	78	61	62	63	84	86	98	98	94	91
3	91	98	77	59	49	60	98	85	92	92	96	98
4	91	87	74	63	73	52	85	86	92	95	95	100
5	86	91	75	54	77	49	83	82	100	92	82	100
6	91	85	67	48	62	84	92	75	94	92	93	93
7	91	90	70	50	60	81	97	76	92	89	96	93
8	94	90	70	59	60	72	92	74	95	90	91	91
9	91	89	87	48	51	75	92	83	92	95	88	89
10	93	96	79	64	55	75	98	98	94	95	88	91
11	85	84	75	47	59	51	82	95	97	95	89	100
12	87	90	71	55	59	69	98	90	94	96	88	100
13	87	87	76	52	73	63	100	94	84	96	92	100
14	93	79	68	55	73	62	100	92	94	95	88	91
15	91	81	64	42	79	62	100	94	90	93	87	93
16	95	85	71	47	91	61	100	94	90	94	86	95
17	95	88	80	80	76	55	92	97	87	93	96	94
18	95	88	68	72	75	68	93	92	87	93	98	89
19	83	82	73	68	87	70	100	88	97	95	90	98
20	98	84	70	49	79	65	100	97	89	98	89	77
21	79	74	77	47	76	65	98	97	97	87	89	98
22	90	78	54	54	75	56	85	93	97	96	90	98
23	90	82	68	47	70	63	77	93	85	85	83	91
24	93	84	71	47	69	50	82	95	92	86	95	93
25	89	87	56	42	71	70	82	97	85	84	98	88
26	91	80	71	68	65	78	78	100	90	90	95	91
27	89	72	65	63	61	64	83	100	97	86	87	95
28	90	74	56	62	52	76	98	97	95	90	91	93
29	89	-	55	61	75	82	87	95	95	94	89	88
30	94	-	67	63	65	85	97	92	97	82	95	83
31	86	-	72	-	78	-	87	93	-	87	-	88
Mean	90	86	71	56	68	67	91	91	93	92	91	93

Appendix J

Date of sowing, planting, harvesting and duration of different crops grown during 07-09 *in situ* and *ex-situ* plots

Crop	Year								
	2007-08			2008-09			2009-10		
	D.S./ D.P.	D.H.	Dura-tion	D.S./ D.P.	D.H.	Duraio n	D.S./ D.P.	D.H.	Durat ion (days)
Paddy	05.07.07	10.10.07	98	02.07.08	20.09.08	81	22.06.09	18.09.09	89
Groundnut	05.07.07	22.09.07	80	02.07.08	18.09.08	79	22.06.09	21.09.09	92
Pigeon pea	05.07.07	23.11.07	142	02.07.08	21.11.08	143	22.06.09	4.11.09	136
Cauliflower	23.06.09 /20.07.07	09.09.07 to 25.10.07	79-125	25.06.08 /19.07.08	02.09.08 to 26.09.08	66-94	-	-	-
Tomato	-	-	-	-	-	-	19.06.09 /22.07.09	11.9.09 to 23.10.09	83-127
Radish	07.10.07	22.11.07 to 31.12.07	46-85	20.08.08	03.10.08 to 28.10.08	45-70	14.10.09		46-54

Appendix K

Water balance in lined pond date wise

2008-09 Date	Water in the Tank (l)	Rainfall (mm)	Runoff vol (l)	Water loss (l)	Irrigation (l)	Bala, in the Tank (l)
1/04/08	0	0	0	0	0	0
2/04/08	0	0	0	0	0	0
3/04/08	0	0	0	0	0	0
4/04/08	0	5.2	702	120	0	582
5/04/08	582	3.4	459	102	0	939
6/04/08	939	2.4	324	150	0	1113
7/04/08	1113	0	0	160	0	953
8/04/08	953	0	0	143	0	810
9/04/08	810	0	0	142	0	668
10/04/08	668	0	0	130	0	538
11/04/08	538	0	0	124	0	414
12/04/08	414	0	0	102	0	312
13/04/08	312	0	0	95	0	217
14/04/08	217	1.6	216	85	0	348
15/04/08	348	0	0	97	0	251
16/04/08	251	0	0	86	0	165
17/04/08	165	0	0	74	0	91
18/04/08	91	0	0	50	0	41
19/04/08	41	0	0	41	0	0
20/04/08	0	0	0	0	0	0
21/04/08	0	0	0	0	0	0
22/04/08	0	0	0	0	0	0
23/04/08	0	0	0	0	0	0
24/04/08	0	0	0	0	0	0
25/04/08	0	0	0	0	0	0
26/04/08	0	0	0	0	0	0
27/04/08	0	0	0	0	0	0
28/08/04	0	0	0	0	0	0
29/04/08	0	0	0	0	0	0
30/04/08	0	0	0	0	0	0

1/05/08	0	0	0	0	0	0
2/05/08	0	0	0	0	0	0
3/05/08	0	0	0	0	0	0
4/05/08	0	0	0	0	0	0
5/05/08	0	0	0	0	0	0
6/05/08	0	0	0	0	0	0
7/05/08	0	0	0	0	0	0
8/05/08	0	0	0	0	0	0
9/05/08	0	0	0	0	0	0
10/05/08	0	0	0	0	0	0
11/05/08	0	0	0	0	0	0
12/05/08	0	0	0	0	0	0
13/05/08	0	0	0	0	0	0
14/05/08	0	0	0	0	0	0
15/05/08	0	0	0	0	0	0
16/05/08	0	0	0	0	0	0
17/05/08	0	0	0	0	0	0
18/05/08	0	0	0	0	0	0
19/05/08	0	0	0	0	0	0
20/05/08	0	0	0	0	0	0
21/05/08	0	0	0	0	0	0
22/05/08	0	0	0	0	0	0
23/05/08	0	0	0	0	0	0
24/05/08	0	0	0	0	0	0
25/05/08	0	0	0	0	0	0
26/05/08	0	0	0	0	0	0
27/05/08	0	0	0	0	0	0
28/05/08	0	0	0	0	0	0
29/05/08	0	0	0	0	0	0
30/05/08	0	0	0	0	0	0
31/05/08	0	4.6	621	130	0	491
1/06/08	491	0	0	120	0	371
2/06/08	371	18.0	2430	110	0	2691

3/06/08	2691	0	0	140	0	2551
4/06/08	2551	5.0	675	150	0	3076
5/06/08	3076	0	0	160	0	2916
6/06/08	2916	19.4	2619	160	0	5375
7/06/08	5375	43.6	5886	170	0	11091
8/06/08	11091	0	0	220	0	10871
9/06/08	10871	0	0	215	0	10656
10/06/08	10656	3.8	513	214	0	10955
11/06/08	10955	1.0	135	215	0	10875
12/06/08	10875	0	0	214	0	10661
13/06/08	10661	0	0	221	0	10440
14/06/08	10440	0	0	218	0	10222
15/06/08	10222	8.0	1080	214	0	11088
16/06/08	11088	46.0	6210	216	0	17082
17/06/08	17082	20.2	2727	218	0	19591
18/06/08	19591	11.0	1485	300	0	20776
19/06/08	20776	4.0	540	305	0	21011
20/06/08	21011	1..0	135	310	0	20836
21/06/08	20836	0	0	308	0	20528
22/06/08	20528	20.6	2781	306	0	23003
23/06/08	23003	0	0	350	0	22653
24/06/08	22653	7.6	1026	340	0	23339
25/06/08	23339	0	0	330	0	23009
26/06/08	23009	35.0	4725	330	0	27404
27/06/08	27404	19.2	2592	310	0	29686
28/06/08	29686	6.6	891	390	0	30187
29/06/08	30187	0	0	402	0	29785
30/06/08	29785	0	0	395	0	29390
1/07/08	29390	0	0	394	0	28996
2/07/08	28996	0	0	384	0	28612
3/07/08	28612	0	0	380	0	28232
4/07/08	28232	0	0	370	0	27862
5/07/08	27862	6.0	810	364	0	28308

6/07/08	28308	1.0	135	380	0	28063
7/07/08	28063	2.0	270	380	0	27953
8/07/08	27953	5.6	756	370	0	28339
9/07/08	28339	25.0	3375	380	0	31334
10/07/08	31334	0	0	402	0	30932
11/07/08	30932	0	0	401	0	30531
12/07/08	30531	0	0	400	0	30131
13/07/08	30131	0	0	402	0	29729
14/07/08	29729	0	0	394	0	29335
15/07/08	29335	10.8	1458	394	0	30399
16/07/08	30399	7.6	1026	406	0	31019
17/07/08	31019	0	0	410	0	30609
18/07/08	30609	0	0	402	0	30207
19/07/08	30207	0	0	401	600	29206
2007/08	29206	0	0	396	600	28210
21/07/08	28210	1.0	135	394	600	27351
22/07/08	27351	6.2	837	394	0	27794
23/07/08	27794	12.4	1674	380	0	29088
24/07/08	29088	22.2	2997	390	0	31695
25/07/08	31695	0	0	406	0	31289
26/07/08	31289	0	0	405	0	30884
27/07/08	30884	34.0	4590	405	0	35069
28/07/08	35069	6.0	810	450	0	35429
29/07/08	35429	41.0	5535	460	0	40504
30/07/08	40504	17.2	2322	500	0	42326
31/07/08	42326	65.0	8775	510	0	50591
01/08/08	50591	15.0	2025	601	0	52015
02/08/08	52015	6.4	864	602	0	52277
03/08/08	52277	7.8	1053	621	0	52709
04/08/08	52709	6.8	918	621	0	53006
05/08/08	53006	5.2	702	611	0	53097
06/08/08	53097	38.6	5211	630	0	57678
07/08/08	57678	5.6	756	670	0	57764

08/08/08	57764	63.2	8532	678	0	65618
09/08/08	65618	69.8	9423	756	0	74285
10/08/08	74285	0	0	843	0	73442
11/08/08	73442	71.0	9585	834	0	75000
12/08/08	75000	0	0	862	0	74138
13/08/08	74138	5.0	675	0	0	0
14/08/08	0	0	0	0	0	0
15/08/08	0	3.0	405	0	0	0
16/08/08	0	3.4	459	0	0	0
17/08/08	0	4.4	594	0	0	0
18/08/08	0	4.0	540	0	0	0
19/08/08	0	3.6	486	0	0	0
20/08/08	0	3.8	513	0	0	0
21/08/08	0	4.8	648	0	0	0
22/08/08	0	14.0	1890	0	0	0
23/08/08	0	29.2	3942	0	0	0
24/08/08	0	44.6	6021	0	0	0
25/08/08	0	1.0	135	0	0	0
26/08/08	0	0.4	54	0	0	0
27/08/08	0	0	0	0	0	0
28/08//08	0	0	0	0	0	0
29/08/08	0	0	0	0	600	0
30/08/08	0	0	0	0	0	0
31/08/08	0	11.8	1593	0	0	0
01/09/08	0	29.2	3942	0	0	0
02/09/08	0	2.0	270	0	0	0
03/09/08	0	37.0	4995	0	0	0
04/09/08	0	18.0	2430	0	0	0
05/09/08	0	0	0	0	0	0
06/09/08	0	0	0	0	0	0
07/09/08	0	0	0	0	0	0
08/09/08	0	0	0	0	0	0
09/09/08	0	20.0	2700	0	0	0

10/09/08	0	3.0	405	0	0	0
11/09/08	0	6.0	810	0	0	0
12/09/08	0	11.0	1485	0	0	0
13/09/08	0	0	0	0	0	0
14/09/08	0	0	0	0	0	0
15/09/08	0	0	0	0	0	0
16/09/08	0	15.0	2025	0	0	0
17/09/08	0	124.0	16740	0	0	0
18/09/08	0	110.0	14850	0	0	0
19/09/08	0	0	0	0	0	0
20/09/08	0	3.9	526.5	0	0	0
21/09/08	0	3.0	405	0	0	0
22/09/08	0	11.8	1593	0	0	0
23/09/08	0	55.4	7479	0	0	0
24/09/08	0	0	0	0	0	0
25/09/08	0	0	0	0	0	0
26/09/08	0	0	0	0	0	0
27/09/08	0	0	0	0	0	0
28/09/08	0	0	0	0	600	0
29/09/08	0	0	0	0	0	0
30/09/08	0	0	0	0	0	0
1/10/08	0	0	0	0	0	0
2/10/08	0	0	0	0	0	0
03/10/08	0	0	0	0	600	0
04/10/08	0	0	0	0	0	0
05/10/08	0	2.0	270	0	0	0
0610/08	0	11.0	1485	0	0	0
07/10/08	0	2.0	270	0	0	0
08/10/08	0	9.0	1215	0	0	0
09/10/08	0	7.0	945	0	0	0
10/10/08	0	0	0	0	0	0
11/08/08	0	0	0	0	0	0
12/10/08	0	0	0	0	0	0

13/10/08	0	0	0	0	0	0
14/10/08	0	0	0	0	0	0
15/10/08	0	0	0	0	0	0
16/10/08	0	0	0	0	600	0
17/10/08	0	0	0	0	0	0
18/10/08	0	0	0	0	0	0
19/10/08	0	0	0	0	0	0
20/10/08	0	0	0	0	0	0
21/10/08	0	0	0	0	600	0
22/10/08	0	0	0	0	0	0
23/10/08	0	0	0	0	0	0
24/10/08	0	0	0	0	0	0
25/10/08	0	0	0	0	0	0
26/10/08	0	0	0	0	0	0
27/10/08	0	0	0	0	0	0
28/10/08	0	0	0	0	0	0
29/10/08	0	0	0	0	0	0
30/10/08	0	0	0	0	0	0
31/10/08	0	0	0	0	0	0
01/11/08	0	0	0	0	0	0
02/11/08	0	0	0	0	0	0
03/11/08	0	0	0	0	0	0
04/11/08	0	0	0	0	0	0
5/11/08	0	0	0	0	0	0
06/11/08	0	0	0	0	0	0
07/11/08	0	0	0	0	0	0
08/11/08	0	0	0	0	0	0
09/11/08	0	0	0	0	0	0
10/11/08	0	0	0	0	0	0
11/11/08	0	0	0	0	0	0
12/11/08	0	0	0	0	0	0
13/11/08	0	0	0	0	0	0
14/11/08	0	0	0	0	0	0

15/11/08	0	0	0	0	0	0
16/11/08	0	2.5	337.5	0	0	0
17/11/08	0	0	0	0	0	0
18/11/08	0	0	0	0	0	0
19/11/08	0	0	0	0	0	0
20/11/08	0	0	0	0	0	0
21/11/08	0	0	0	0	0	0
22/11/08	0	0	0	0	0	0
23/11/08	0	0	0	0	0	0
24/11/08	0	0	0	0	0	0
25/11/08	0	0	0	0	0	0
26/11/08	0	0	0	0	0	0
27/11/08	0	0	0	0	0	0
28/11/08	0	0	0	0	0	0
29/11/08	0	0	0	0	0	0
30/11/08	0	0	0	0	0	0
01/12/08	0	0	0	0	0	0
02/12/08	0	0	0	0	0	0
03/12/08	0	0	0	0	0	0
04/12/08	0	0	0	0	0	0
05/12/08	0	0	0	0	0	0
06/12/08	0	0	0	0	0	0
07/12/08	0	0	0	0	0	0
08/12/08	0	0	0	0	0	0
09/12/08	0	0	0	0	0	0
10/12/08	0	0	0	0	0	0
11/12/08	0	0	0	0	0	0
12/12/08	0	0	0	0	0	0
13/12/08	0	0	0	0	0	0
14/12/08	0	0	0	0	0	0
15/12/08	0	0	0	0	0	0
16/12/08	0	0	0	0	0	0
17/12/08	0	0	0	0	0	0

18/12/08	0	0	0	0	0	0
19/12/08	0	0	0	0	0	0
20/12/08	0	0	0	0	0	0
21/12/08	0	0	0	0	0	0
22/12/08	0	0	0	0	0	0
23/12/08	0	0	0	0	0	0
24/12/08	0	0	0	0	0	0
25-Dec	0	0	0	0	0	0
26/12/08	0	0	0	0	0	0
27/12/08	0	0	0	0	0	0
28/12/08	0	0	0	0	0	0
29/12/08	0	0	0	0	0	0
30/12/08	0	0	0	0	0	0
31/12/08	0	0	0	0	0	0
01/01/09	0	0	0	0	0	0
02/01/09	0	0	0	0	0	0
03/01/09	0	0	0	0	0	0
04/01/09	0	0	0	0	0	0
05/01/09	0	0	0	0	0	0
06/01/09	0	0	0	0	0	0
07/01/09	0	0	0	0	0	0
08/01/09	0	0	0	0	0	0
09/01/09	0	0	0	0	0	0
10/01/09	0	0	0	0	0	0
11/01/09	0	0	0	0	0	0
12/01/09	0	0	0	0	0	0
13/01/09	0	0	0	0	0	0
14/01/09	0	0	0	0	0	0
15/01/09	0	0	0	0	0	0
16/01/09	0	0	0	0	0	0
17/01/09	0	0	0	0	0	0
18/01/09	0	0	0	0	0	0
19/01/09	0	0	0	0	0	0

20/01/09	0	0	0	0	0	0
21/01/09	0	0	0	0	0	0
2201/09	0	0	0	0	0	0
23/01/09	0	0	0	0	0	0
24/01/09	0	0	0	0	0	0
25/01/09	0	0	0	0	0	0
26/01/09	0	0	0	0	0	0
27/01/09	0	0	0	0	0	0
28/01/09	0	0	0	0	0	0
29/01/09	0	0	0	0	0	0
30/01/09	0	0	0	0	0	0
31/01/09	0	0	0	0	0	0
01/01/09	0	0	0	0	0	0
02/02/09	0	0	0	0	0	0
3/02/09	0	0	0	0	0	0
4/02/09	0	0	0	0	0	0
5/02/09	0	0	0	0	0	0
6/02/09	0	0	0	0	0	0
7/02/09	0	0	0	0	0	0
8/02/09	0	0	0	0	0	0
9/02/09	0	0	0	0	0	0
10/02/09	0	0	0	0	0	0
11/02/09	0	0	0	0	0	0
12/02/09	0	0	0	0	0	0
13/02/09	0	0	0	0	0	0
14/0209	0	0	0	0	0	0
15/02/09	0	0	0	0	0	0
16/02/09	0	0	0	0	0	0
17/02/09	0	0	0	0	0	0
18/02/09	0	0	0	0	0	0
19/02/09	0	0	0	0	0	0
20/02/09	0	0	0	0	0	0
21/02/09	0	0	0	0	0	0

22/02/09	0	0	0	0	0	0
23/02/09	0	0	0	0	0	0
24/02/09	0	0	0	0	0	0
25/02/09	0	0	0	0	0	0
26/02/09	0	0	0	0	0	0
27/02/09	0	0	0	0	0	0
28/02/09	0	0	0	0	0	0
01/03/09	0	0	0	0	0	0
02/03/09	0	0	0	0	0	0
03/03/09	0	0	0	0	0	0
04/03/09	0	0	0	0	0	0
05/03/09	0	0	0	0	0	0
06/03/09	0	0	0	0	0	0
07/03/09	0	0	0	0	0	0
08/03/09	0	0	0	0	0	0
09/03/09	0	0	0	0	0	0
10/03/09	0	0	0	0	0	0
11/03/09	0	0	0	0	0	0
12/03/09	0	0	0	0	0	0
13/03/09	0	0	0	0	0	0
14/03/98	0	0	0	0	0	0
15/03/09	0	0	0	0	0	0
16/03/09	0	0	0	0	0	0
17/03/09	0	0	0	0	0	0
18/03/09	0	0	0	0	0	0
19/03/09	0	0	0	0	0	0
20/03/09	0	0	0	0	0	0
21/03/09	0	0	0	0	0	0
22/03/09	0	0	0	0	0	0
23/03/09	0	0	0	0	0	0
24/03/09	0	0	0	0	0	0
25/03/09	0	0	0	0	0	0
26/03/09	0	1.0	135	0	0	0

27/03/09	0	0	0	0	0	0
28/03/09	0	0	0	0	0	0
29/03/09	0	0	0	0	0	0
30/03/09	0	0	0	0	0	0
31/03/09	0	0	0	0	0	0
Total		1456.4	196614		4800	

Appendix L

Dimensions of best section (square) of dugout farm ponds for different design capacities and depths in sandy loam soils with a recommended side slope of 1:1, for low depth

Cropping pattern – Vegetable -Radish

Design capacity (m^3)	For 2 m depth		For 2.5 m depth	
	Bottom side of square section (m)	Top side of square section (m)	Bottom side of square section, (m)	Top side of square section (m)
50	2.6	6.6	1.2	6.2
75	3.8	7.8	2.4	7.4
100	4.8	8.8	3.3	8.3
250	9.0	13.0	7.2	12.2
500	13.7	17.7	11.4	16.4
750	17.3	21.3	14.6	19.6
1000	20.3	24.3	17.3	22.3
1250	22.9	26.9	19.7	24.7
1500	25.3	29.3	21.9	26.9
1750	27.5	31.5	23.8	28.8
2000	29.6	33.6	25.7	30.7
2250	31.6	35.5	27.4	32.4
2500	33.3	37.3	29.0	34.0
2750	35.0	39.0	30.6	35.6
3000	36.5	40.5	32.1	37.1
3250	38.3	42.3	33.5	38.6
3500	39.8	43.8	34.8	39.8
3750	41.3	45.3	36.1	41.1
4000	42.7	46.7	37.4	42.4
4250	44.1	48.1	38.7	43.7
4500	45.4	49.4	39.9	44.9
4750	46.7	50.7	41.0	46.0
5000	48.0	52.0	42.1	47.1

Appendix M

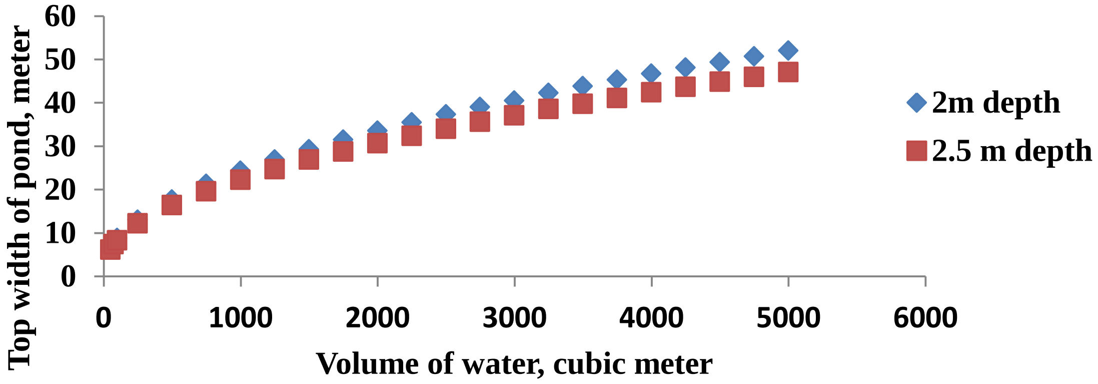
Dimensions of best section (square) of dugout farm ponds for different design capacities and depths in sandy loam soils with a recommended side slope of 1:1, for high depth

Cropping pattern –Vegetables-Radish / vegetables (short duration)

Design capacity, cubic meter	For 3 m depth		For 3.5 m depth	
	Bottom side of square section (m)	Top side of square section (m)	Bottom side of square section, (m)	Top side of square section (m)
100	2.1	8.1	0.5	7.5
250	5.6	11.6	4.2	11.2
500	9.6	15.6	7.9	14.9
750	12.5	18.5	10.7	17.7
1000	15.0	21.0	13.0	20.0
1250	17.2	23.2	15.1	22.1
1500	19.2	25.2	16.9	23.9
1750	21.0	27.0	18.6	25.6
2000	22.6	28.6	20.2	27.2
2250	24.2	30.2	21.6	28.6
2500	25.7	31.7	23.0	30.0
2750	27.1	33.1	24.3	31.3
3000	28.5	34.5	25.6	32.6
3250	29.8	35.8	26.8	33.8
3500	31.0	37.0	27.9	34.9
3750	32.2	38.2	29.0	36.0
4000	33.4	39.4	30.1	37.1
4250	34.5	40.5	31.2	38.2
4500	35.6	41.6	32.2	39.2
4750	36.7	42.7	33.2	40.2
5000	37.7	43.7	34.1	41.1

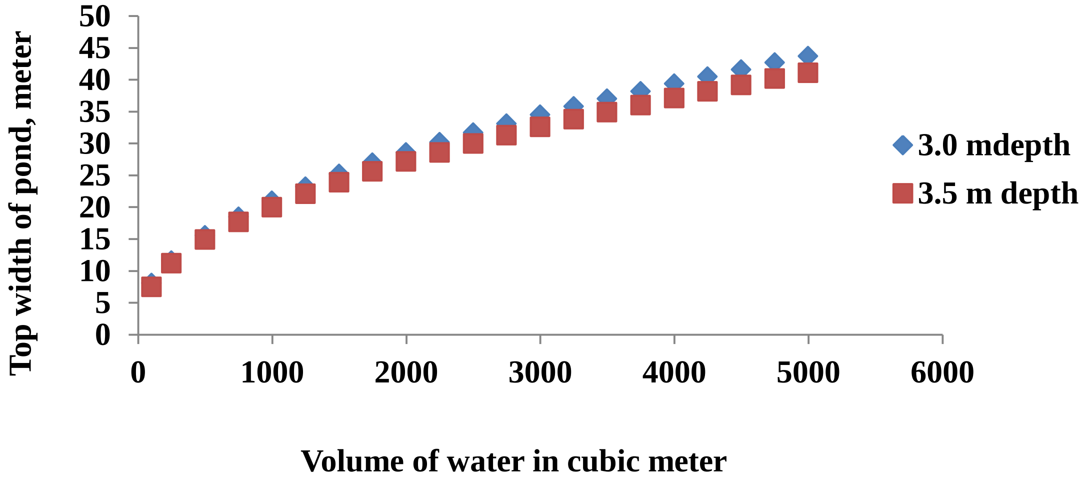
Appendix: N

Relation between volume of water and top width of square section of the pond, for low depth



Appendix O

Relation between volume of water and top width of square section of the pond, or high depth



Appendix P

Techno economic analysis of water harvesting pond

Year	No of Year	Lined pond				
		Cash outflow (Rs)	**PW Cash outflow (Rs)**	**Cash inflow (Rs)**	**PW Cash inflow (Rs)**	**NPW (Rs)**
	0	9969	9969		0	-9969
2007--08	1	3426	3172	10035	9292	6120
2008--09	2	2680	2298	11205	9606	7308
2009--10	3	3808	3023	11392	9043	6020
2010--11	4	3304	2429	10887	8002	5573
2011--12	5	3304	2249	10887	7410	5161
2012--13	6	3304	2082	10887	6801	4719
2013--14	7	3304	1928	10887	6352	4424
2014--15	8	3304	2057	10887	5882	3825
2015--16	9	3304	1653	10887	5446	3793
2016--17	10	3304	1530	10887	5043	3513
	Total	43011	32390	108841	72877	40487

Appendix Q

Techno economic analysis for unlined pond

Year	No of Year	Cash outflow (Rs)	PW Cash outflow (Rs)	Cash inflow (Rs)	PW Cash inflow (Rs)	NPW (Rs)
	0	2993	2993		0	-2993
2007--08	1	1491	1381	3420	3167	1786
2008--09	2	1502	1288	3440	2949	1661
2009--10	3	1610	1278	6128	4865	3587
2010--11	4	1610	1183	4329	3182	1999
2011--12	5	1610	1096	4329	2946	1850
2012--13	6	1610	1015	4329	2728	1713
2013--14	7	1610	939	4329	2526	1587
2014--15	8	1610	870	4329	2339	1469
2015--16	9	1610	805	4329	2166	1361
2016--17	10	1610	746	4329	2005	1259
Total		18866	13594	43291	28873	15279

Appendix R

Techno economic analysis for no pond

Year	**No of Year**	**No pond**				
		Cash outflow (Rs)	**PW Cash outflow (Rs)**	**Cash inflow (Rs)**	**PW Cash inflow (Rs)**	**NPW (Rs)**
	0		0		0	0
2007--08	1	1463	1355	2700	2500	1145
2008--09	2	1473	1263	2526	2166	903
2009--10	3	1170	929	2812	2232	1303
2010--11	4	1368	1006	2719	1999	993
2011--12	5	1368	931	2719	1851	920
2012--13	6	1368	862	2719	1713	851
2013--14	7	1368	798	2719	1587	789
2014--15	8	1368	739	2719	1469	730
2015--16	9	1368	684	2719	1360	676
2016--17	10	1368	634	2719	1259	625
	Total	13682	9201	27071	18136	8935

CURRICULUM VITAE

1. Name : CH.RAJENDRA SUBUDHI
2. Designation : Associate Professor
3. Place of posting : Department of Soil and Water Conservation Engineering, CAET, (OUAT), Bhubaneswar-751 003
4. Examination passed:

Sl. No.	Degree	Institution from which degree obtained	Year of passing
1	B.Sc.(Agril.Engg. & Tech.)	College Of Agricultural Engineering And Technology Orissa University of Agriculture And Technology, Bhubaneswar-751003 (Orissa)	1983
2	M.Tech.(Water Resources Development and Managemen)	Indian Institute of Technology, Kharagpur-721302 (W.B.)	1984-85

5. Service particulars :

Post Held	Name of the institution and Department	Period
Junior Scientist	Regional Research Station, National Agricultural Research Project, Bhawanipatna, OUAT ,Odisha	26.02.1985 to 16.04.1986
Junior Agricultural Engineer	All India Co-ordinated Research Project on Dryland Agriculture, Bhubaneswar, OUAT , Odisha	17.04.1986 to 27.05.1987
Training Associate (Water Management)	K.V.K., Baliapal, (OUAT), Odisha	28.05.1987 to 11.12.1990
Senior Scientist (Soil and Water Management)	Regional Research Station, Ranital, NARP-II,(OUAT), Odisha	12.12.1990 to 31.12.1993

Agricultural Engineer	All India Co-ordinated Research Project on Dryland Agriculture, (OUAT) Bhawanipatna,	01.01.1994 to 31.03.1994
Agricultural Engineer	All India Co-ordinated Research Project on Dryland Agriculture, (OUAT), Phulbani, Odisha	01.04.1994 to 04.07.2008
Chief Scientist (I/C)	All India Co-ordinated Research Project on Dryland Agriculture, (OUAT) Phulbani, Odisha	05.07.2008 to 17.04.2010
Associate Professor	Deptt. of Soil and Water Conservation Engineering, CAET (O.U.A.T.),Bhubaneswar, Odisha	18.04.2010 to continuing

6.Publications

A. No. Of Papers (Journals)	78
B. No. Of papers (Presented/Accepted in Symposium)	230
C. No. Of Books (Oriya)	01
D. No. Of Books (English)	01
E. No. Of English popular article	01
F. No. Of Oriya booklet	10
G. No. Of English booklet	10
H No of Oriya popular article	36
I. No of Books as contributor	46
Total	413

LIST OF PUBLICATIONS RELATED TO THESIS

Award

C.R.Subudhi received the best poster paper award in the National conference hald at OUAT from 5-7 April 2012 organised by Indian Association of Soil Conservationists.

Publications in International and national journals

1. **Subudhi, C.R**.(2011) Water harvesting through farm pond and utilization of conserved water for vegetable crops. International Jour. Contemporary Management and Research Application.1(01):14-19
2. **Subudhi C.R**.(2011) Effect of different cropping systems on runoff, soil loss and productivity in north eastern Ghats of Orissa Indian Journal of Soil Conservation.39(2):124-127
3. **Subudhi, C.R.** & Senapati,S.C. (2011) Effect of cropping system on runoff,soil loss and crop productivityin NEGZ of Odisha. Research Journal of Agricultural Science.2(4):1027-1029.
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6. **Subudhi C.R**. & Senapati S.(2012) Effect of cropping system on runoff, soil loss and crop productivity. Indian Journal of Dryland Research and Development. 27(1):74-77.
7. **Subudhi, C.R.** & Senapati,S. (2016) Relationship between rainfall, runoff, soil loss and productivity in north eastern ghat zone of Odisha. Biometrics & Biostatstics International Journal.Vol-4, Issue-2, pp-1-6.