STUDIES ON RAINWATER HARVESTING AND REUTILIZATION FOR PROTECTIVE IRRIGATION WITH FARM POND

By

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STUDIES ON RAIN WATER HARVESTING AND REUTILIZATION FOR PROTECTIVE IRRIGATION WITH FARM POND

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submitted to

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MORE RAM MANIKRAO
B.Tech. (Agril. Engg.)

UNDER THE GUIDANCE

OF

PROF. M.R. MORE

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2017

AFFECTIONATELY

DEDICATED

TO

MY BELOVED

PARENTS

CANDIDATE'S DECLARATION

I, HEREBY DECLARE THAT THE DISSERTATION

OR PART THEREOF HAS NOT BEEN SUBMITTED

BY ME TO ANY OTHER UNIVERSITY OR

INSTITUTION FOR A DEGREE

OR DIPLOMA.

Place : Parbhani **(Mr. More Ram Manikrao)**

Date : / /2017 **(Reg.No.2015AE/09M)**

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CERTIFICATE-I

This is to certify that the dissertation entitled **"STUDIES ON RAINWATER HARVESTING AND REUTILIZATION FOR PROTECTIVE IRRIGATION WITH FARM POND"** submitted to Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani in partial fulfillment of the requirement for the award of the degree of **Master of Technology (Agril. Engineering**) in **Soil and Water Conservation Engineering** embodied the results of the bonafied study carried by **Mr. More Ram Manikrao** under my guidance and supervision. I also certify that the dissertation has not been previously submitted by him for the award of Degree or Diploma of any University or Institute.

Place : Parbhani. **M.R. More**
Date : / /2017 **(Research Guide)**

CERTIFICATE-II

This is to certify that the dissertation entitled **"STUDIES ON RAINWATER HARVESTING AND REUTILIZATION FOR PROTECTIVE IRRIGATION WITH FARM POND"** submitted by **Mr. MORE RAM MANIKRAO** to the Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani in partial fulfillment of the requirement for the degree of **MASTER OF TECHNOLOGY (Agril. Engg.)**in the subjects of **Soil and Water Conservation Engineering** has been approved by the Students Advisory Committee after oral examination in collaboration with external examiner.

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Place: Parbhani

Date : / /2017 ***(More R. M.)***

ABBREVIATIONS

Agric.	:	Agriculture
Agril.	:	Agricultural
B.W.	:	Bottom width
CAET	:	College of Agricultural Engineering and Technology
cm	:	Centimeter
Cons.	:	Conservation
Dev.	:	Development
et al.	:	and others
Fig.	:	Figure
gm/cc	:	Gram per cubic centimeter
Govt.	:	Government
H	:	Height
ha	:	Hectare
i.e.	:	that is
J.	:	Journal
kg	:	Kilogram
m	:	Meter
M.K.V.	:	Marathwada Krishi Vidyapeeth
m^2	:	Meter square
m^3	:	Meter cube
m^3/p/y	:	Meter cube per person per year
mm	:	Milimeter
N	:	North
Res.	:	Research

RL	:	Reduced Level
Sci.	:	Science
Sr. No.	:	Serial number
T.W.	:	Top width
t/ha/yr	:	tonnes per hectare per year
viz.	:	Namely
GDP	:	Gross Domestic Product
HDPE	:	High Density Polyethylene
LDPE	:	Low Density Polyethylene
MSL	:	Mean Sea Level

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CHAPTER-I

INTRODUCTION

Agriculture is the back bone of the Indian economy. Agriculture and allied sector contribute nearly 22 per cent of gross domestic product (GDP) while about 65-70 per cent of the population is dependent on agriculture output. India has 16 per cent of world is population and holds 2.41 per cent of the world's land and 4 per cent of the world is water resource. Recent World Bank study indicated that per capita availability of water, which was in the order of 5000m^3 per year at the time of independence, has drastically come down to 2000m^3 per year. Contribution of ground water is so significant that more than 70 per cent population uses ground water for its domestic needs and more than half of irrigation needs are met form it.(Hadda and Yadav , 2009).

The average annual rainfall of India is about 119.4 cm considered over the geographical area of 328M ha, amounts to 392 M ha-m surface water. But 150 M ha-m flows as surface and subsurface runoff, and is not useful for the type of production. (Mathur et.al, 1997)

There is spatial and temporal variation in the rainfall. Nearly 60 per cent of area sown in country is dependent on rainfall, but erratic nature of monsoon increases the need of irrigation for assured agriculture production. Water availability can be assumed in tropical, sub-tropical and temperate areas where rainfall pattern is irregular, much of this rainfall flow as surface runoff; as a result there is scarcity of water and result into the risk of human being. Although in this situation artificial supply of water fulfills the demand.

A major source of water is rainfall. Fortunately India get heavy rain, but this occurs for short duration and typically in a span of 2-3 months. These rains should be used to recharge the ground water table.

The heavy rainfall should be utilized to collect water in ponds and reservoirs and this may help to fulfill the water requirement or increasing the water level. The main purpose of storing water is to provide irrigation to the crops. However; suitability of such water storage bodies is justified only if the

water is made to store at a specific location for a longer period of time. Storage changes in surface water sources are affected by a number of factors and therefore it is necessary to work out the water balance of such bodies to check out the future strategies for efficient and judicious management of available water.

In most parts of the Indian sub-continent, extraction of water from rivers and underground aquifers is causing severe environmental problems. In addition, runoff due to heavy rain can lead to accumulated flooding in high risk areas such as Eastern Utter Pradesh, Bihar, West Bengal and Assam. Despite this, due to the peculiar monsoonic climate in India, a large part of the year remains dry leading to drought or drought like situations in major parts of the country. The harnessing of excess rainfall from rooftops, catchments and protection of freshwater resources must therefore, be improved to ensure the required supplies of water for various purposes. It is therefore important that, adequate supplies of water be developed to sustain such life. Development of water supplies should, however, be undertaken in such a way as to preserve the hydrological balance and the biological functions of all ecosystem. At certain times during lean period or in rainy season when water is not needed for irrigation, it can be stored in secondary reservoir and used effectively during critical periods (Mann and Ramana Rao 1981). Crop failure is common event for want of pre-sowing irrigation, if rain is not received at sowing time of the crops. (Srivastava , 1997).

Rainwater management is the most critical component of rainfed farming. The successful production of rainfed crops largely depends on how efficiently soil moisture is conserved in *situ* or the surplus runoff is harvested, stored and recycled for supplemental irrigation. India has a long history of rainwater harvesting through a variety of structures and systems built by the Government or local bodies and managed by the community or village level institutions. However, after independence, with the availability of electricity and pumping technology, private investment on tube wells has enormously

increased and the tank systems were gradually ignored. The emphasis shifted from community based surface water storage structures, to individual investments which exploited ground water.

There are divergent views on the actual potential and scope of farm ponds for water harvesting in the country and its likely impact on enhancing food production. This is because of the uncertainty on availability of surface water for harvesting due to varied geographical features, soil types, slopes, rainfall and high capital investment on construction of ponds. The economic returns from small-scale water harvesting structures depend on end use of the water and the reliability of water availability through runoff.

Pigeon pea is a tropical grain legume grown mainly in India. Though largely considered an orphan crop, pigeon pea has a huge untapped potential for improvement both in quantity and quality of production. More than any other legume adapted to the region, pigeon pea uniquely combines optimal nutritional profiles, high tolerance to environmental stresses, high biomass productivity and most nutrient and moisture contributions to the soil. The legume can be utilized in several diverse ways while the high genetic variability that exists within the cultivated and wild relatives remains to be explored for further uses. This article highlights the need for popularizing pigeonpea as a major legume crop in india.

Benefits of farm pond:

Ponds can provide following benefits in addition to the provision of irrigation water.

Ponds are commonly used on ranches for stock watering. Cattle and horse required 45-57 litre of water per day. Rather than allow the stock to drink directly from the pond, a more environmentally friendly innovation is to fence the pond and use solar pump to move water into through for the cattle.

Ponds helps to recharge groundwater. Whether filled with water diverted from a stream or with tail water from irrigation , clay-lined ponds seep water into the ground at highly variable rates.

Ponds can assist in flood control by capturing and slowing the flow of water through a watershed. Particularly as climate change leads to greater storm flows, a distributed network of farm ponds could play an important role in attenuating peak flow and reducing flooding.

A more localized and distributed water supply can offsets water transported from distance reservoirs, reducing the energy needed for water conveyance. The harvested water in farm ponds is being used for providing life saving irrigation to dry land crops by lifting and applying to the fields. In the semi-arid region like Marathwada, the evaporation from water storage structures are generally high due to high temperature and low relative humidity.

Therefore, the present study is undertaken with following objectives,

1. To determine the storage losses from farm pond.
2. To study the effect of protective irrigation on the yield of pigeon pea.
3. To study the economic feasibility of farm pond harvested water for protective irrigation.

CHAPTER-II

REVIEW OF LITERATURE

This chapter deals with review of literature related to the present investigation. The research on rainwater harvesting and reutilization with a dugout farm pond is reviewed and presented under the following sub heads,

2.1 Importance of water harvesting

Mann and Ramana Rao (1981) conducted study on rain water harvesting management and its implications. The study revealed that the better rainwater utilization by harvesting and recycling increased the efficiency of available land and water resources. The potential productivity of treated regions appeared to be two to three times higher than what was attained by the traditional system of production.

Tiwari (1991) conducted a study on rainwater harvesting technology. The study revealed that there was great scope for improving agricultural productivity of arid and semi arid regions through efficient utilization of rainwater. He further stated that, if storage ratio was less than 6 the structure become uneconomical.

Goyal *et al. (1995)* carried out a study on evaluation of water harvesting pond in Hangar watershed during 1988-1994. The study revealed that water harvesting by means of farm pond of 271m^3 capacity coupled with ber (zizy phusmouritione) in the adjoining area could sustain the system even very low rainfall situation. The benefit cost ratio of the system worked out is 1.672 which indicated that, in order to import stability to agriculture productions of rain fed land in arid and semi arid areas farm pond seem to hold the key.

Hadda and Yadav (2009) conducted study on impact of small rain water harvesting tanks on agriculture and livehood. The study was undertaken to evaluate the impact of these water harvesting tanks on agriculture and ground water improvement in the region. Effect on improvement in cropping

intensity and crop yield have been observed after construction of these water harvesting tanks. Due to availability of irrigation water during the water scarce period, there has been a diversification in agriculture too. Before the project period, 52.1 per cent of the population was in medium income group whereas after the project period, 47% of the population was in high income group category. The depth of water table in these water harvesting tanks has risen from 0.5 m to 1.7 m after construction of the water harvesting tanks and renovation of existing village ponds

Rana *et al.* (2009) conducted study on rainwater harvesting through silpaulin lined tanks in hilly areas. The onetime cost of Rs. 0.50 per litre, whereas it is Rs. 1.00 per litre for brick lined cemented tanks and Rs. 2.00 per litre for R.C.C. tanks. The life of silpaulin sheet was approximately 15-20 years as per ISI code number 14611 : 1998, whereas the life of cemented tanks if constructed in completely rainfed areas was less due to alternate drying and wetting, and earthquake tremors thus, silpaulin lined tanks should be preferred over cemented tanks due to its low initial cost and longer life.

Rana and Gupta (2010) conducted study on impact assessment of rainwater harvesting tanks in hilly areas. Rainwater harvesting remains only feasible option to meet the minimum irrigation needs of the crops. By adopting the tomato-garlic crop rotation the farmers of the watershed could earn up to Rs. 2.50 lakh ha^{-1} $annum^{-1}$. Comparison on various parameters have shown that, silpaulin tanks were most suitable for hilly conditions as they can be constructed with lower initial cost and also offered flexibility of maintenance and longevity aspects.

2.2 Storage losses from farm pond

2.2.1 Evaporation loss

Sastry *et al.*, (1982) has worked on the structural measures for efficient control of seepage from dugout ponds. They concluded that the storage efficiency of the ponds mainly depends on storage losses i.e. seepage, evaporation and evapotranspiration and storage/ excavation ratio. They also

observed that the seepage losses tend to stabilize after 8 to 10 years of the construction of the farm ponds.

Verma *et al*., (1984) studied the feasibility of three dugout tanks constructed on individual farms and/ or on community basis in typical Kandi area of the Punjab state. The study revealed that, it was possible to collect at least 8 to 10 cm of runoff even during the drought year which was sufficient to provide for one supplemental irrigation to the donor area or its equivalent. One irrigation at pre sowing or 30 to 40 days after sowing increased wheat yield significantly and gave greater stability of yield over the years. Dug ponds undoubtedly hold lot of promise for storing excess runoff. But because of the previous nature of the Kandi soils, bulk of the stored water is lost by seepage. It appears that on these sandy and loamy sand soils it was necessary to line the tanks. It was found that 800 gauge polythene film was quite suitable for lining the tank bottoms. For lining the sides of the tank, brick and cement (7.5 cm thick) was found suitable, but the seepage losses through brick pores were above the tolerable limits.

Grewal *et al.*, (1982) conducted a study on effect of some soil and site properties on seepage losses from three small storage reservoirs developed in the Kalka area of Siwalik region for rain water harvesting and supplemental irrigation. It was observed that, on average 16-42 per cent of the total stored monsoon rainwater was lost through evaporation and seepage before it was utilized for 'Rabi' crop irrigation. The seepage loss on an average varied from 6.2 to 20.0, 0.4 to 1.2 and 2.0 to 10.1 mm/day in Sukhomadry reservoir numbers SM-I, II and III with the corresponding heads varying from 2.0 to 3.4, 3.4 to 3.3 and 2.5 to 4.1 meters respectively, the seepage losses decreased with the decrease in hydraulic head in each case.

Khan (1992) conducted a study on influence of climatic parameter on rate of evaporation from free water surface. The results revealed that air temperature was the major factor affecting evaporation, water temperature affected by evaporation indirectly by conveying humidity of the air

seemed to be far out weighted by other climatic factors. At tanks wind had a marked effect on evaporation climatic factors under the conditions prevailing test site complemented each other in increasing or decreasing evaporation.

Satpute *et al*., (2012) studied the storage losses from farm pond in saline tract of Vidarbha region in Maharashtra state. For quantification of evaporation and seepage losses, water level in one unlined and three polyethylene lined ponds of same size (82 m x 26 m x 3 m) were monitored in Ghussar village in Akola taluka of Akola district in saline tract area during October to December of 2009. The storage loss in unlined pond during October to December was found to be 71.42 cm which includes both evaporation and seepage loss where as the evaporation loss from three lined ponds was found to be 58.23, 61.18, 62.61 cm with an average of 60.64 cm. Result of study indicated that evaporation and seepage losses from dugout type pond in clayey soils of saline tract area was found to be 60.64 cm and 10.78 cm respectively during three months of water storage. One protective irrigation using harvested runoff water from dugout type farm ponds resulted in increasing dry land productivity of cotton and chickpea crops to 47.3 to 55.3 per cent and 43.5 to 58.5 per cent respectively.

2.2.2 Seepage loss

Kale *et al.*, (1986) studied on effect of various sealant materials on seepage losses in tanks in lateritic soil in Konkan region of Maharashtra having bulk density 1.02 g/cc, field capacity 34.1 and permanent wilting point 18%. The study revealed that polythene + cement + soil plaster (3:10) could be considered for lining purpose in the tanks to reduce the seepage losses in lateritic soil.

Juyal and Gupta *(1985)* reported that development of resources play an important role in hilly agriculture. The water storage tank constructed with cement masonry being costly, low cost LDPE film line tank were tried at the operational research project on watershed management a fact were tried at the operational on farmer’s field. The cost LDPE lined tanks was found to be

less than the half cement masonry ones cum water stored per year of expected life period.

Ranade *et al*. (1993) studied the performance of different sealant material for seepage control. Relative performance of the different sealant material viz. soil cement (8:1); soil-straw –cow dung paste (10:1:1); low density polyethylene film (LDPF), plastic film (Silpaulin sheet) and bentonite clay was evaluated in dugout ponds constructed in black clay soil. It was observed that sipaulin plastic film was most effective in controlling seepage followed by LDPE film and soil-straw-cow dung paste. The study indicated that even the thinner silpaulin sheet of 60 gsm may effectively control the seepage loss and also reduces cost of lining.

Singh *et al*. (1998) conducted study on performance of different sealant for seepage control. A large quantity of stored water was lost from unlined ponds due to seepage and percolation. The sealant play an important role in reducing seepage loss and different sealants were found suitable in different regions. Therefore, material should be selected based on local availability, its cost, and soil type of that region and sealant which not cause deterioration in the water quality.

Yadav *et al.,* (2006) conducted a study on partial polythene lining for reducing seepage losses from farm ponds. A pond of 1.70 ha-m capacity was excavated in 2001 at village Johranpur in Solan district of Himachal Pradesh to collect runoff from 4.5 ha area and to recycle it for supplemental irrigation in wheat crop. The presence of bouldery layer of 30 cm thickness at 100 cm height above the bottom of pond caused heavy seepage losses of 0.04 to 0.07 m^3 m^{-2} wetted area day^{-1}. A 140 m x 4.5 m polythene (HDPE) sheet of 300 μ thickness was laid out in 2002 in the down side embankment of pond having bouldery layer. Comparison of data on seepage loss, water availability and water use revealed that laying of polythene sheet reduced the seepage loss by 60 and 48% at water levels in the range of 125-150 cm and 175-200 cm, respectively. The amount of water used was increased from 0.17 ha m before

polythene lining in 2001 to 0.29 and 0.35 ha-m after lining in 2002 and 2003, respectively.

Samindre *(2011)* conducted a study on Assessment of farm pond with respect to water harvesting and recycling. Result shows total rain water harvested in the farm pond for during the study period was found to be 3022.60 $m^{3.}$ The result revealed that total water loss from tank in the form of seepage, evaporation and water lifted for irrigation was 2775.554 m^3, 228.661 m^3 and 18.38 m^3 respectively.

Pendke *et al. (2014)* conducted study on rainwater harvesting and recycling for sustainable agriculture in assured rainfall zone of marathwada region, during 2010-11 to 2013-14. On an average, runoff of 12.43% and harvesting potential of 11.10% of rainfall was observed from the catchment area of 1.60 ha during experimentation period. An average total storage loss of 1718.10 m3 was observed during the period from July to December comprising an evaporation and seepage losses of 150.59 m3 (8.67%) and 1567.51 m3 (90.29%), respectively. One protective irrigation of 5 cm to soybean at maturity stage during prevailing critical dryspell, increased soybean grain yield by 30.87%. An average irrigation potential, on the basis of monthly storage volume of farm pond during 2010 and 2013, was observed as 0.87 ha.

2.3 Impact of supplementary irrigation on yield

Desai *et al. (2007)* conducted a study on impact assessment on farm ponds in Dharwad District of Karnataka state. The present revealed that construction of farm ponds had brought about a perceptible change in cropping pattern by increasing area under *rabi* crop by about 30.18 per cent in areas in case with farm pond (13.05). the yield and returns of the all the crops were higher with farm pond over without farm pond. The household income (48.21) and employment level (4.08) were higher with farm pond than without farm pond.

Sulochanamma and Reddy *(2008)* studied the response of groundnut to supplemental irrigation through sprinklers. Different depth of

irrigation (0, 5,10, 15, 20 mm) were applied as a protective irrigation during pod filling phase of rainfed irrigation were closed for the entire day due to moisture stress except for short period of 1.8 hours, while leaflets were in open condition for 10.7 hours/day at four days after irrigation (DAI) with 20 mm irrigation.

Srinivasulu *et al. (2010)* reported that south coastal Andhra Pradesh is prone to both droughts and floods and receives rainfall from South-West and North-East Mansoon. This study was initiated to overcome prolong dry spell by providing life saving irrigation to improve the yield of flue cured Virginia (FCV) tobacco. Nine farm pond were dug for rain water harvesting and recycling. The yield of cured leaf improved in all the six years of study period and ranged between 12 and 31 per cent with one life saving irrigation over a control (rainfed). This translated to an additional net income irrigation from Rs. 2255/- to Rs. 17049/-per hectare. The BC ratio for lined pond was workout to be 1.34, while net present value (NPV) and IRR was estimated as Rs. 21938/- and 1.6 per cent, respectively. The payback was estimated as 12 years for lined pond after discounting the cost and returns.

Bhandarkar *(2010)* observed that for sustainable agriculture in rainfed vertisols water harvesting and recycling is almost important. Water harvesting pond is constructed in 10-12 per cent of watershed area. Minimum depth of pond should be 3m. the runoff received is 300 mm to fill up pond every year. About 60-70 per cent of stored water can be utilized for irrigation crop. Entire kharif and 50 per cent of rabbi crop can be irrigated twice with two field increase in yield. Additional benefits obtained through irrigation net benefits-cost ratio was work out to be 1.13.the benefit cost ratio works out of to be 2.03 considering total benefit-cost ratio under irrigation condition. Increase in yield was 6 q/ha (RS. 1000/q), 15.9 q/ha (Rs. 700/q), 15.6 q/ha (800/q), and 13.9 q/ha (Rs. 1200/q) in case of soyabean , Rice , Wheat and chickpea respectively.

Ranade *(2014)* reported that during a three year study period, it was observed that only during 2005 the soyabean crop needed supplementary irrigation due the long dry spell. It was observed that the provision of supplementary irrigation from these tank during kharip season increased the overall productivity of wheat, Gram, Pigeon pea, Maize, Garlic, Barseem, Potato, Mung, and Vgetables.

2.4 Economic Evaluation

Palanisami (1991) conducted study on economic evaluation of percolation ponds in Tamil Nadu State. The results indicated that the number of wells benefited was only 14 per cent of the total target wells. Wells located within 0.25 km radius from pond were more benefited. The water level increase due to pond less than 1 m. Both ground water recharge and cropping intensity influenced the gross income of farmer.

Mishra *et al.* (1998) conducted study on economic evaluation of farm pond in micro watershed. The investment incurred on farm pond get repaid in 10 years. the net present value (NPV) of pond was high at about 30,000/- and the BCR was 1.57. the IRR was about 19 per cent was higher than th bank rate of the interest both on short term and long term loan. Thus, all the parameters establish the economic viability of the farm pond. The value of BCR of 1.57 obtained was based on conservative estimate of returns. The BCR will certainly be higher if intangible benefits were also considered and quantified.

Rana *et al*. (2006) conducted study on economic evaluation for four year water harvesting structures under integrated watershed development project in Himachal Pradesh. The study revealed that the productivity of crops was increased and the cropping pattern was changed due to availability of irrigation water. Beneficiaries shifted due to high value of crops like tomato , ginger , garlic , onion , frence bean etc. which in turn increased per capita income in command area. The rearing of fish from two structures of samur khurd and labour further increased the income of user groups. Berseem

production resulted in higher milk yield by one liter per lactating animal per day. There were large number of intangible benefits like saving in land from degradation due to excessive runoff, increased vegetative cover and production of Bhabar grass from the catchments. All the project were found economically viable as the benefits cost ratio (BCR) was more than unity both at 10 to 12 per cent discount rates. Net present worth (NPW) was higher for labour and least for nanowal. Though full benefit yet to be harvested, yet even at this production level, only increase in area under cultivation has worked as magic in increasing the income of the farm families and building confidence in the people as well as the Goverment agencies for investing in water harvesting project for judicious use of scares water resources.

Vora *et al.* (2008) studied on utilizing farm pond technology for enhancing crop productivity in Bhal and coastal zone of Gujrat over a period of 10 years. Study revealed 30to 50 % increment in production of wheat, Gram, Cumin crops with one supplementary irrigation of 6 cm depth. It was estimated that the initial investment in form of cost on farm pond can be recovered within 4 year only. Net additional income generated from pond water irrigation was three times higher than the additional cost. An additional income of Rs. 4,325 per ha was insured from irrigating convectional crop only.

CHAPTER-III

METHODOLOGY

The study entitled 'Studies on rainwater harvesting and reutilization for protective irrigation with farm pond" was conducted at Crop Demonstration Farm, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, during the year 2016-2017. The methodology adopted during this study is presented under the following sub heads,

3.1 Location and Climate

Parbhani is one of the districts of Marathwada region, falls under assured rainfall zone, semi-arid tropics having highest temperature of 43 ^{0}C during month May; while the lowest temperature of 11 ^{0}C during December. Parbhani is situated in between 19^0 16' North latitude and 76^0 47' East longitudes, with MSL of 405.8 m. The average annual rainfall of the region is 898.7 mm with average of 52 rainy days. South West monsoon is the major source of rainfall for the region. The rainfall is uneven, erratic and varies from year to year. About 90 % of total rainfall is received during the season from June to September.

3.2 Details of farm pond

Demonstration farm of 25.93 ha was developed during 2005-2006 at Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani for demonstration of crop production technologies developed by the University. For water harvesting purpose number of dug out farm ponds have been developed and one of the farm ponds with catchment area of 1.90 ha was selected for the present study.

The cross sectional area at bottom and top section of the farm pond was found to be 279.75 m^2 and 516.82 m^2 respectively. The mean R.L. of embankment top was 413.130m. The average R.L. of bottom of farm pond was 410.210m. The R.L. of the outlet was 412.437m. The maximum depth of water

impounded and storage capacity of pond was 2.227 m and 933.99 m^3 respectively.

Table 3.1 Dimensions of components of farm pond, VNMKV, Parbhani

Sr.No..	Particular	Magnitude
1.	R.L. at embankment top	413.169 m
2.	Farm pond bottom depth	2.925 m
3.	R.L. at farm pond bottom with soil depth	410.21 m
4.	R.L. of inlet crest	412.22 m
5.	R.L. of outlet crest	412.437 m
6.	Water spread area at outlet crest	516.82 m^2
7.	Pond bottom area	279.75 m^2
8.	Storage volume at outlet crest (full)	933.99 m^3
9.	Maximum water storage depth (outlet crest)	2.223 m

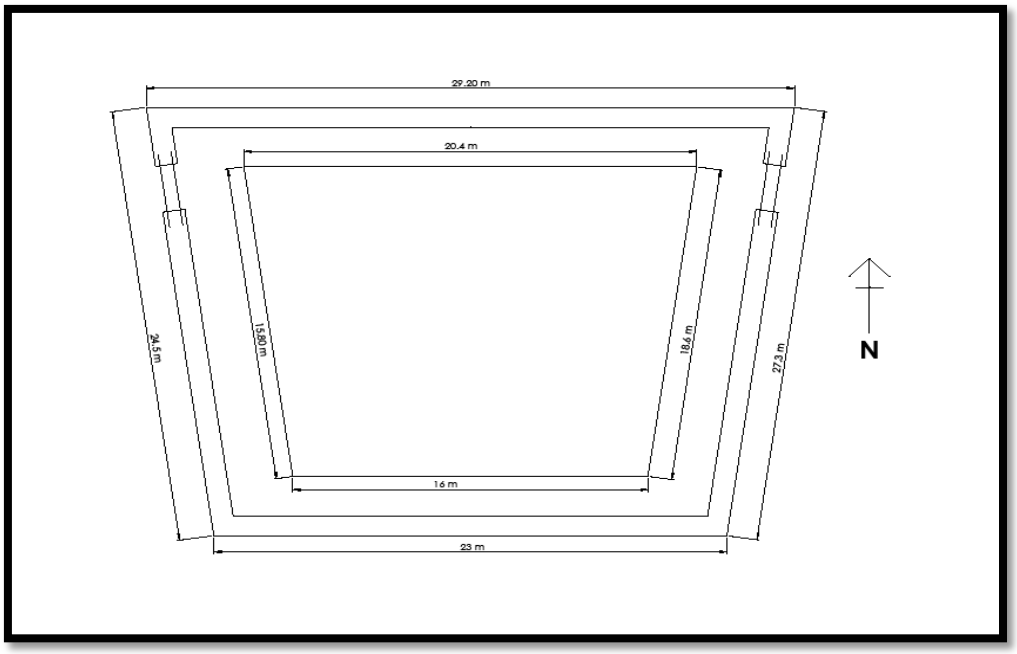

Fig 3.1: Layout Plan of Farm pond at demonstration farm, VNMKV, Parbhani

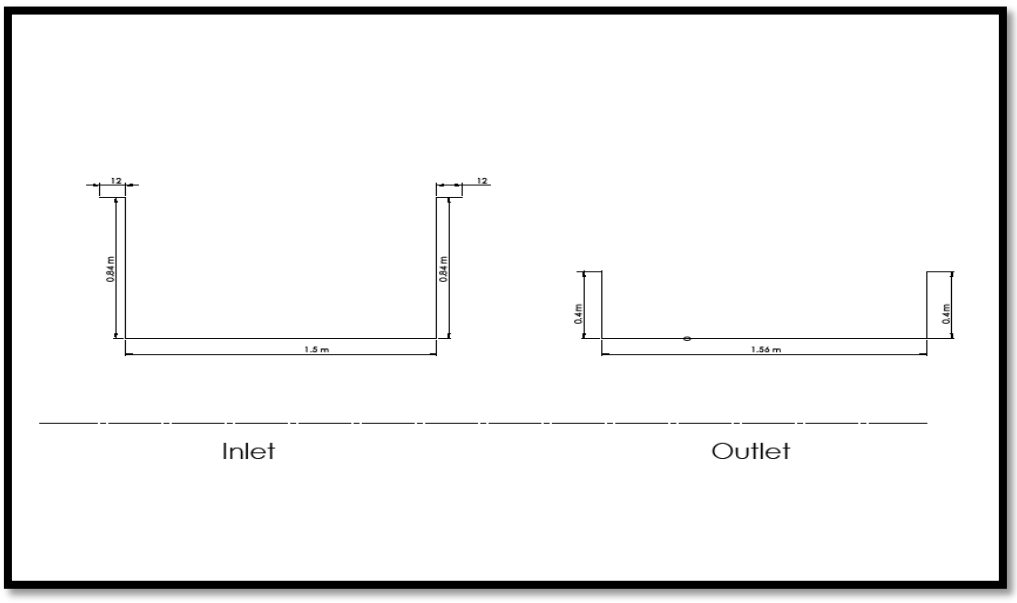

Fig 3.2:Farm pond components at demonstration farm, VNMKV, Parbhani

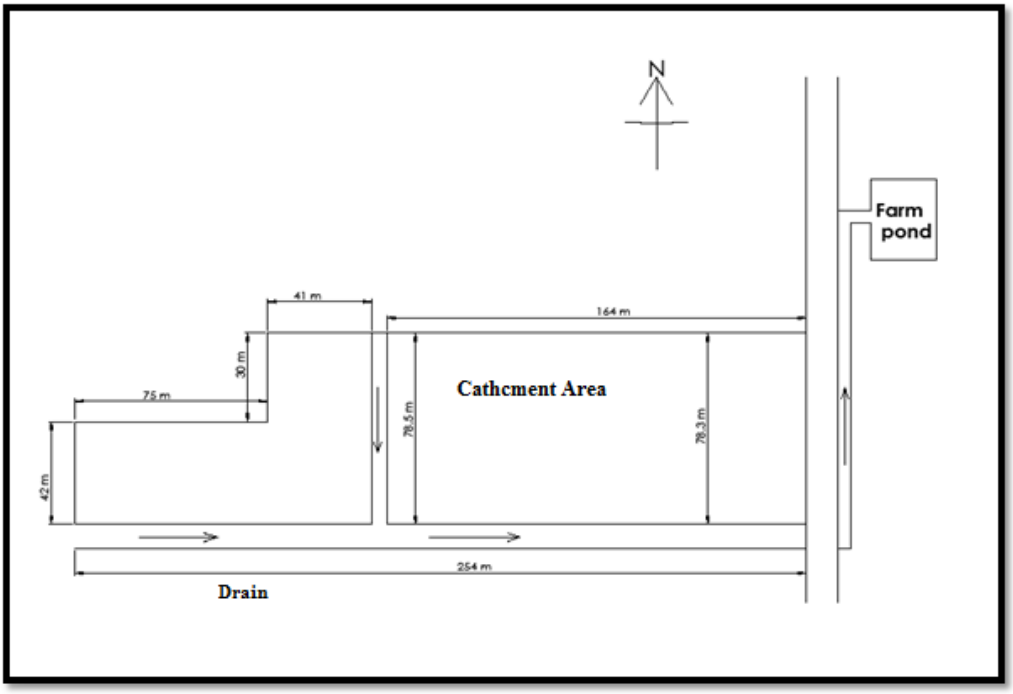

Fig 3.3: Location of farm pond and its catchment area

3.3 Water surface area

For determination of water surface area, R.L.s will be recorded at an interval of 0.25 m interval starting from the top of embankment, to develop water spread area- stage relationship. Lateral measurements on inside side slope of the farm pond were simultaneously recorded with respect to each vertical interval. Actual water surface area in farm pond at each vertical interval will determined by using Bramhaguptas formula. The formula is

$$A=\sqrt{(S-a)(S-b)(S-c)(S-d)}$$

$$S=\frac{a+b+c+d}{2}$$

Where,

a, b, c, d= length of four sides of the farm pond (lateral measurement), m

S= perimeter, m,

A= water spread area m^2.

3.4 Storage volume

Storage volume with respect to each vertical interval in farm pond will be determined by using Trapezoidal formula,

$$V = \frac{A1+A2}{2} \times h$$

Where,

V=Volume of water stored in the farm pond, m^3

A_1= water spread area at first vertical interval, m^2,

A_2= water spread area at second vertical interval, m^2,

h=vertical interval, m.

Incremental storage volume will be determined for each vertical interval and respectively added to get total storage volume with respect to farm pond bottom Graphical relationship will be developed by plotting stage of water above the farm pond bottom as an ordinate against water surface area and storage volume as an abscissa.

3.5 Storage Volume

Water stage in the farm pond will be measured with the help of staff gauge installed in the farm pond. Observations on depth of water impounded in the farm pond will recorded daily. The corresponding storage volume was determined by developing stage-storage relationship of the farm pond.

3.6 Storage losses

3.6.1 Evaporation loss:

Major storage losses from stored water in the farm pond are evaporation and seepage. For estimation of evaporation loss; daily pan evaporation data recorded at Meteorological Observatory, VNMKV, Parbhani,

was used. The evaporation loss through farm pond was calculated by using following formula,

$$\text{Evaporation loss} = \frac{\text{Daily pan evaporation (mm)} \times 0.7 \times \text{Avg.Water surface area, } m^2}{1000}$$

(m^3 /day)

3.6.2 Seepage loss

Seepage loss was estimated by substracting evaporation loss from change in storage volume. Seepage loss from the farm pond was estimated on daily basis and added over the period. The (-) ve sign indicate the loss in storage volume while (+) ve sign indicates the increase in storage volume.

3.7 Irrigation to pigeon pea

The harvested water was utilized as source for protective irrigation for pigeon pea and accordingly study was planned. The treatment of recycling study includesone protection irrigation in pod development stage of pigeon pea and compared with treatment without irrigation.

3.8 Reutilization of harvested water

Water harvested in the farm pond was utilized with the help of 1.5 hp portable petrol start-diesel runpump set for protective irrigation to pigeon pea crop in one of the field plots demonstration farm, VNMKV, Parbhani, as part of study on reutilization of harvested water. The experimental details are given as below,

1. Design :CRD (Completely Randomized Design)
2. Plot size :2×2 m
3. Replications: 6
4. Treatments : 2

   T_1 – Single protective irrigation at pod development stage

T_2 – Without any Protective irrigation,

5. Crop : Pigeon pea (Cajanus cajan)
6. Variety: BDN-779
7. Date of sowing :20/06/2016
8. Date of harvesting :25/12/2016
9. Date of protective irrigation :30/11/2016 (pod development stage)
10. Depth of protective irrigation : 10cm
11. Stage of pigeon pea crop : pod development

3.9 Economics of protective irrigation

For economic evaluation of the treatments, cost of cultivation, cost of cultural operations, fixed and operational costs of pump and accessories were calculated. These total cost was be used to determine the gross monetary returns (GMR), net monetary returns (NMR) and benefit cost ratio (B:C ratio).

3.9.1 Gross monetary returns

The total monetary value of economics produce obtained from the crop was calculated based on the prevailing market prices.

3.9.2 Net monetary returns

Net monetary returns of treatments wereobtained by subtracting cost of cultivation of treatments from gross monetary returns.

3.9.3 Benefits-cost ratio :

It is the ratio of net monetary returns to the cost of cultivations.

3.10 Statistical analysis

The design of the experiment was prepared considering completely Randomized Design. The statistical analysis was carried out with MAUSTAT, standard statistical software for the comparison between the treatment means of growth using F test, standard error of means and the critical differences (CD).

CHAPTER-IV

RESULTS AND DISCUSSION

The study entitled, Studies on rainwater harvesting and reutilization for protective irrigation with farm pond' was carried out during the 2016-17 at Demonstration Farm, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. The harvested rain water in the farm pond was reutilized for applying protective irrigation to the pigeon pea crop during pod development stage. Results of the study have been presented under the following subheads.

4.1 Season 2016.

The data on weather parameter recorded at Meteorological Observatory V.N.M.K.V. Parbhani during 2016 have been collected.(Appendix-I). The month-wise rainfall during June to December 2016 has been presented in Table 4.1.

Table 4.1: Rainfall during July-December 2016 at Parbhani.

Month	July	August	September	October	November	December
Rainfall, mm (Rainy Days)	407.2 (15)	93.7 (07)	171.6 (13)	166.6 (05)	--	--
July – December (2016)	839.1 (40)					
January – December (2016)	1159.5 (54)					

Data presented in Table 4.1 indicated that, onset of effective monsoon at Parbhani was observed on 12 July 2016. Total rainfall received during January to December 2016 was 1159.5 mm in 54 rainy days, whereas the total rainfall received during July to December 2016 was 839.1 mm in 40 rainy days. With respect to the distribution of rainfall during the season, it was

observed that July was found as wettest month with 407.2 mm rainfall, followed by the month of September with 171.6 mm rainfall.

4.2 Month wise water balance of farm pond:

The stage storage relationship was developed for farm pond and presented in Fig 4.1

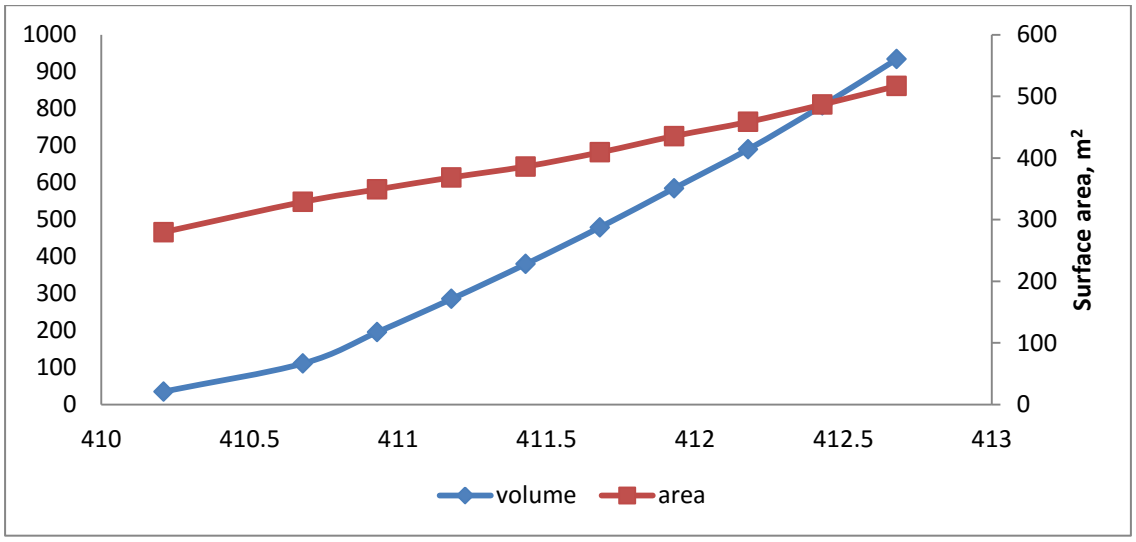

Fig 4.1: Stage storage relationship of the farm pond VNMKV, Parbhani

Farm pond water balance components the period from December-2016 has been presented in Table 4.2 to Table 4.7.

Data presented in Table 4.2 revealed that the quantity of water harvested on 12/07/2016 was 419.3m^3 due to rainfall 92.7 mm on that day. Water harvested was 39.34 m^3due to rainfall of 19.2 mm on 26/07/2016. The total evaporation loss for the month July-2016 was observed as 19.10m^3.the total seepage loss for the month July 2016 was observed as 632.60 m^3.

Table 4.2 Water balance components of farm pond for the month July 2016, VNMKV, Parbhani.

Date	R.L. of impounded water (m)	Rainfall (mm)	Storage volume (m^3)	Change in change in storage volume (m^3)	Average water surface area (m^2)	Evaporation loss (m^3)	Seepage loss (m^3)
10.07.2016	411.21	38.6	325.92	-	325.93	-	-
11.07.2016	411.21	8.8	325.92	0	325.93	0.87	-
12.07.2016	412.21	92.7	744.95	419.03	372.48	0.64	0.00
13.07.2016	412.01	1.3	655.06	-89.89	363.93	0.00	0.00
14.07.2016	411.81	0.0	564.68	-90.39	352.93	0.66	89.22
15.07.2016	411.71	0.0	519.69	-44.99	346.46	0.99	89.40
16.07.2016	411.61	0.0	479.39	-40.30	342.43	1.33	43.66
17.07.2016	411.51	0.0	440.017	-39.38	338.48	1.39	38.90
18.07.2016	411.41	2.0	415.75	-24.27	346.46	1.56	37.81
19.07.2016	411.31	0.5	360.22	-55.53	327.48	1.26	23.00
20.07.2016	411.31	3.2	360.22	0.00	327.48	0.94	54.59
21.07.2016	411.21	0.0	322.92	-37.30	322.93	0.62	0.00
22.07.2016	411.26	7.2	341.17	18.25	324.93	1.13	36.17
23.07.2016	411.31	8.4	360.22	19.05	327.48	0.84	0.00
24.07.2016	411.21	1.0	325.92	-34.30	325.93	0.92	0.00
25.07.2016	411.11	0.5	286.58	-39.34	318.43	0.68	33.61
26.07.2016	411.21	19.2	325.92	39.34	325.93	0.80	38.54
27.07.2016	411.21	0.5	325.92	0.00	325.93	0.87	0.00
28.07.2016	411.31	36.0	360.22	34.30	327.48	0.78	0.00
29.07.2016	411.01	0.0	252.74	-107.48	315.93	0.87	0.00
30.07.2016	410.81	44.0	210.58	-42.16	350.98	1.02	106.47
31.07.2016	411.81	59.2	561.56	350.97	325.93	0.93	41.22
Total						**19.14**	**634.88**

Data presented in Table 4.3 revealed that the quantity of water harvested on 01/08/2016 was 7.12 m^3due to rainfall 6.4 mm on that day. Also on 28/08/2016 4.71 m^3 water was harvested. The total quantity of water harvested on 29/08/2016 and 31/08/2016 was 50.18 m^3 and 17.77 m^3respectively of rainfall of 24.7 mm and 9.0 mm on corresponding days.Maximum seepage loss 84.23 m^3 was observed on 02/08/2016. The total evaporation and seepage loss observed for the month of August-2016 was 32.6m^3 and 358.05m^3 respectively.

Data presented in Table 4.4 indicated that the quantity of water harvested on 01/09/2016 was 52.74 m^3 due to rainfall of was 12.0 mm on that day. The water harvested in the farm pond on 14/09/2016 was 179.26 m^3 due to rainfall of 21.4 mm on that day. The quantity of water harvested on 15/09/2013 was 34.09 m^3due to rainfall of 11.0 mm on that day.The water harvested on 16/9/2016 was 146.37due to rainfall of 69.2 mm on that day. The quantity of water harvested on 22/09/2016, 23/09/2016 and 24/09/2016was110.71, 37.50, 252.20 due rainfall of 11.0 , 21.5, 17.4 and 64.2 on corresponding days. The total evaporation and seepage loss observed for the month Septeber-2016 were 25.40m^3 and 651.80 m^3 respectively. It is clear from 4.4 that daily seepage loss per day was decreased as the depth of water in the farm pond was decreased gradually as compared to previous months July and August, 2016.

Table 4.3 Water balance component of farm pond for the month August - 2016, VNMKV, Parbhani

Date	R.L. of impounded water (m)	Rainfall (mm)	Storage volume (m^3)	Change in change in storage volume (m^3)	Average water surface area (m^2)	Evaporation loss (m^3)	Seepage loss (m^3)
01.08.2016	411.83	6.4	568.68	7.12	352.13	0.59	
02.08.2016	411.63	1.0	483.82	-84.86	341.93	0.62	84.24
03.08.2016	411.58	4.4	463.38	-20.44	339.48	0.67	19.78
04.08.2016	411.57	2.0	459.31	-4.07	338.98	0.57	3.50
05.08.2016	411.52	0.0	441.63	-17.68	337.13	0.85	16.83
06.08.2016	411.49	0.0	427.43	-14.20	334.98	0.96	13.24
07.08.2016	411.43	0.0	405.17	-22.26	332.93	1.17	21.10
08.08.2016	411.38	0.0	385.73	-19.44	330.53	1.23	18.21
09.08.2016	411.34	0.0	370.25	-15.48	328.53	1.26	14.22
10.08.2016	411.29	0.0	351.13	-19.12	326.03	1.26	17.86
11.08.2016	411.23	0.0	332.22	-18.91	324.43	1.18	17.73
12.08.2016	411.20	0.0	320.77	-11.45	324.99	1.36	10.09
13.08.2016	411.17	0.0	309.41	-11.35	322.98	1.36	9.99
14.08.2016	411.17	11.2	309.41	0.00	322.98	0.90	0.00
15.08.2016	411.13	0.0	294.34	-15.08	320.98	0.94	14.13
16.08.2016	411.11	0.0	286.52	-7.81	319.43	1.07	6.74
17.08.2016	411.09	0.0	279.70	-6.83	318.93	1.03	5.80
18.08.2016	411.07	0.0	272.89	-6.81	318.43	1.20	5.60
19.08.2016	411.06	0.0	269.28	-3.61	317.93	1.29	2.32
20.08.2016	411.05	0.0	265.58	-3.71	317.68	1.18	2.53
21.08.2016	411.03	0.0	259.96	-5.62	317.03	1.29	4.33
22.08.2016	411.02	0.0	256.30	-3.66	316.43	1.40	2.26
23.08.2016	411.01	7.0	252.34	-3.96	315.43	1.10	2.86
24.08.2016	410.96	0.0	235.29	-17.05	314.98	1.19	15.86
25.08.2016	410.96	6.0	236.57	1.28	315.43	0.93	0.00
26.08.2016	410.89	0.0	212.79	-23.78	312.93	1.01	22.78
27.08.2016	410.86	0.0	202.56	-10.23	311.63	1.05	9.19
28.08.2016	411.01	22.0	252.74	50.18	315.93	0.80	0.00
29.08.2016	411.11	24.7	288.43	35.69	320.48	1.46	0.00
30.08.2016	411.06	0.0	270.66	-17.77	318.43	0.89	16.87
31.08.2016	411.11	9.0	288.43	17.77	320.48	0.81	0.00
Total						**32.61**	**358.05**

Table 4.4 Water balance components of farm pond for the month September-2016 , VNMKV, Parbhani

Date	R.L. of impounded water (m)	Rainfall (mm)	Storage volume (m^3)	Change in change in storage volume (m^3)	Average water surface area (m^2)	Evaporation loss (m^3)	Seepage loss (m^3)
01.09.2016	411.26	12.0	341.17	52.74	324.93	0.80	
02.09.2016	411.31	3.8	360.22	19.05	327.48	0.73	0.00
03.09.2016	411.11	0.0	286.58	-73.64	318.43	1.03	72.61
04.09.2016	411.01	0.0	252.34	-34.24	315.43	1.04	33.20
05.09.2016	410.81	0.0	185.69	-66.66	309.48	1.17	65.49
06.09.2016	410.76	0.0	168.56	-17.12	306.48	1.18	15.94
07.09.2016	410.66	0.0	136.32	-32.25	302.93	1.23	31.02
08.09.2016	410.56	0.0	104.64	-31.68	298.98	1.19	30.48
09.09.2016	410.52	1.5	90.75	-13.90	297.53	1.12	12.77
10.09.2016	410.47	0.0	76.94	-13.80	295.93	1.08	12.73
11.09.2016	410.45	0.0	70.91	-6.03	295.48	0.93	5.10
12.09.2016	410.43	0.0	63.33	-7.58	294.58	1.07	6.51
13.09.2016	410.41	0.0	57.31	-6.03	293.88	0.95	5.08
14.09.2016	410.96	21.4	236.57	179.26	315.43	0.66	0.00
15.09.2016	411.06	11.0	270.66	34.09	318.43	0.53	0.00
16.09.2016	411.46	69.2	417.03	146.37	333.63	0.00	0.00
17.09.2016	411.71	57.2	519.69	102.66	346.46	0.00	0.00
18.09.2016	411.61	0.0	479.40	-40.30	342.43	0.67	39.62
19.09.2016	411.51	2.0	440.02	-39.38	338.48	0.95	38.43
20.09.2016	411.51	0.0	440.02	0.00	338.48	0.90	0.00
21.09.2016	411.41	11.0	415.75	-24.27	346.46	0.73	23.54
22.09.2016	411.71	21.5	526.46	110.71	350.98	1.08	0.00
23.09.2016	411.81	17.4	563.96	37.50	352.48	0.62	0.00
24.09.2016	412.38	64.2	816.16	252.20	376.98	0.00	0.00
25.09.2016	412.26	17.5	764.78	-51.38	373.98	0.47	50.91
26.09.2016	412.08	4.2	681.24	-83.54	365.28	0.36	83.18
27.09.2016	411.98	0.0	635.44	-45.79	360.03	1.26	44.53
28.09.2016	411.92	0.0	607.70	-27.74	356.43	1.15	26.59
29.09.2016	411.86	0.0	581.55	-26.16	353.53	1.29	24.87
30.09.2016	411.79	11.0	551.13	-30.42	349.93	1.22	29.19
Total						**25.41**	**651.80**

Table 4.5 Water balance of farm pond for the month October -2016, VNMKV, Parbhani

Date	R.L. of impounded water (m)	Rainfall (mm)	Storage volume (m^3)	Change in change in storage volume (m^3)	Average water surface area (m^2)	Evaporation loss (m^3)	Seepage loss (m^3)
01.10.2016	411.76	6.3	538.63	-12.51	348.63	0.61	
02.10.2016	412.38	65.8	816.16	277.54	376.98	0.00	0.00
03.10.2016	412.38	37.4	816.16	0.00	376.98	0.58	0.00
04.10.2016	412.13	0.0	705.63	-110.53	368.48	0.85	109.68
05.10.2016	412.08	0.0	681.52	-24.11	365.43	1.33	22.78
06.10.2016	411.99	0.0	640.74	-40.78	360.98	1.26	39.51
07.10.2016	411.87	0.0	590.09	-50.65	355.48	1.37	49.28
08.10.2016	411.79	0.0	555.25	-34.84	351.43	1.43	33.41
09.10.2016	412.06	45.2	676.13	120.88	365.48	1.07	0.00
10.10.2016	411.98	0.0	635.36	-40.77	359.98	0.96	39.82
11.10.2016	412.07	11.7	679.41	44.06	365.28	0.87	-44.92
12.10.2016	411.98	0.0	638.04	-41.37	360.48	1.26	40.11
13.10.2016	411.86	0.0	584.80	-53.24	354.43	1.39	51.85
14.10.2016	411.79	0.0	552.04	-32.76	350.50	1.20	31.56
15.10.2016	411.73	0.0	526.35	-25.69	347.43	1.17	24.52
16.10.2016	411.67	0.0	501.07	-25.28	344.38	1.08	24.20
17.10.2016	411.61	0.0	476.36	-24.71	341.48	1.10	23.61
18.10.2016	411.57	0.0	459.31	-17.05	338.98	1.26	15.79
19.10.2016	411.53	0.0	443.06	-16.25	336.93	1.32	14.93
20.10.2016	411.48	0.0	423.78	-19.28	335.00	1.55	17.73
21.10.2016	411.45	0.0	411.85	-11.93	333.48	1.59	10.34
22.10.2016	411.42	0.0	399.49	-12.36	331.53	1.49	10.87
23.10.2016	411.40	0.0	391.79	-7.70	330.63	1.55	6.15
24.10.2016	411.38	0.0	384.95	-6.85	330.43	1.30	5.55
25.10.2016	411.35	0.0	373.61	-11.33	329.18	1.22	10.11
26.10.2016	411.30	0.0	353.09	-20.53	325.43	1.18	19.34
27.10.2016	411.23	0.0	326.70	-26.38	321.88	1.22	25.17
28.10.2016	411.20	0.0	320.12	-6.59	324.99	1.50	5.09
29.10.2016	411.18	0.0	308.25	-11.87	319.43	1.16	10.71
30.10.2016	411.18	0.0	311.14	2.90	322.43	1.02	0.00
31.10.2016	411.17	0.0	307.49	-3.65	321.98	1.10	2.55
Total						**35.99**	**611.64**

Table 4.6 Water balance of farm pond for the month November -2016

Date	R.L. of impounded water (m)	Rainfall (mm)	Storage volume (m^3)	Change in change in storage volume (m^3)	Average water surface area (m^2)	Evaporation loss (m^3)	Seepage loss (m^3)
01.11.2016	411.15	--	301.05	-6.43	321.97	1.15	5.29
02.11.2016	411.12	--	289.98	-11.06	320.42	1.21	9.85
03.11.2016	411.10	--	282.51	-7.47	319.22	1.18	6.29
04.11.2016	411.07	--	274.40	-8.11	319.07	1.21	6.90
05.11.2016	411.05	--	267.06	-7.35	317.92	1.02	6.32
06.11.2016	411.05	--	265.22	-1.84	317.62	1.02	0.82
07.11.2016	411.04	--	261.55	-3.67	317.02	0.98	2.69
08.11.2016	411.02	--	253.92	-7.63	315.42	1.04	6.59
09.11.2016	411.00	--	246.98	-6.94	314.62	0.97	5.97
10.11.2016	410.96	--	236.57	-10.41	315.42	0.86	9.55
11.11.2016	410.95	--	231.73	-4.84	315.27	0.84	4.00
12.11.2016	410.93	--	224.46	-7.27	313.92	0.79	6.48
13.11.2016	410.90	--	214.35	-10.10	312.92	0.79	9.31
14.11.2016	410.89	--	210.93	-3.42	312.49	0.74	2.68
15.11.2016	410.87	--	205.61	-5.32	311.52	0.81	4.52
16.11.2016	410.86	--	202.43	-3.18	311.42	0.83	2.35
17.11.2016	410.86	--	200.27	-2.16	310.49	1.17	0.99
18.11.2016	410.85	--	196.87	-3.40	310.03	1.09	2.31
19.11.2016	410.83	--	190.60	-6.27	309.92	1.11	5.16
20.11.2016	410.81	--	183.23	-7.37	307.95	0.91	6.47
21.11.2016	410.79	--	176.48	-6.75	306.92	0.97	5.78
22.11.2016	410.77	--	171.85	-4.63	306.87	0.90	3.73
23.11.2016	410.76	--	166.50	-5.35	305.5	1.07	4.28
24.11.2016	410.74	--	159.93	-6.57	304.62	1.04	5.52
25.11.2016	410.73	--	156.80	-3.12	304.47	1.02	2.10
26.11.2016	410.70	--	149.14	-7.66	304.37	1.04	6.62
27.11.2016	410.69	--	144.53	-4.61	304.27	1.00	3.61
28.11.2016	410.67	--	137.85	-6.68	302.97	1.06	5.62
29.11.2016	410.65	--	131.34	-6.52	301.92	1.06	5.46
30.11.2016	410.62	--	123.41	-0.93	301.00	0.99	0.07
					Total	29.87	141.92

Data presented in Table 4.5 indicated that the quantity of water harvested on 02/10/2016 was 277.53 m^3 due rainfall of 65.8 mm on that day. The quantity of water harvested on 09/10/2016 was 120.87m^3 due to rainfall of 45.2 mm on 09/10/2016. The net water harvested on 11/10/2016 was 44.0556 m^3 due rainfall of 11.7 mm that day. It is clear from Table 4.4 that daily seepage loss per day was decreased as the depth of water in the farm pond was decreased gradually as compared to previous months July, August and September 2016. The total evaporation and seepage loss observed for the month October-2016 wererecorded as 35.98 m^3 and 611.64 m^3 respectively.

Data presented in Table 4.6 revealed that, the quantity water harvested in the farm pond in the month of November was nil. The total evaporation and seepage loss observed for the month November 2016 were recorded as 29.8620 m^3 and 147.33 m^3 respectively.

On 30/11/2016, the quantity of water utilized for applying protective irrigation to pigeon pea was 55 m^3 which showed drastic reduction in reduced level in farm pond on next day (i.e. 01/12/2016).

Table 4.7 Water balance components of farm pond for the month December -2016, VNMKV, Parbhani

Date	R.L. of impounded water (m)	Rainfall (mm)	Storage volume (m)	Change in change in storage volume (m^3)	Average water surface area (m^2)	Evaporation loss (m^3)	Seepage loss (m^3)
01.12.2016	410.44	--	67.83	--	294.93	0.12	
02.12.2016	410.43	--	64.86	-2.97	294.83	0.10	2.87
03.12.2016	410.42	--	61.82	-3.04	294.38	0.11	2.93
04.12.2016	410.41	--	58.83	-2.99	294.13	0.10	2.89
05.12.2016	410.4	--	55.84	-2.99	293.88	0.09	2.90
06.12.2016	410.39	--	52.83	-3.01	293.48	0.10	2.91
07.12.2016	410.38	--	49.70	-3.12	292.38	0.09	3.03
08.12.2016	410.37	--	46.71	-3.00	291.93	0.08	2.92
09.12.2016	410.36	--	43.73	-2.98	291.53	0.08	2.90
10.12.2016	410.35		40.73	-3.00	290.93	0.07	2.93
11.12.2016	410.34		37.74	-2.99	290.33	0.07	2.92
12.12.2016	410.33		34.73	-3.02	289.38	0.06	2.95
13.12.2016	410.32		31.79	-2.94	288.98	0.06	2.87
14.12.2016	410.31		28.86	-2.92	288.63	0.06	2.87
Total						**1.20**	**37.89**

Data presented in Table 4.7 revealed that quantity of water harvested in the farm pond for the period 1st December to 14th December was nil. There was no rainfall during December-2016. The total evaporation and seepage loss observed from farm pond for the month of December-2016 were found to 1.20 m^3 and 37.90m^3 respectively.

Table 4.8- Average daily evaporation and seepage losses through farm pond Observed during the year-2016,VNMKV, Parbhani.

Month	Total evaporation loss (m^3)	Av. Daily evaporation loss (m^3/d)	Total seepage loss (m^3)	Av. Seepage loss (m^3)
10^{th}- 31^{st}July	19.10	1.66	632.60	30.12
1^{st} - 31^{st}August	32.61	1.05	358.05	11.93
1^{st} - 30^{st}September	25.41	0.84	651.80	22.47
1^{st}- 31^{st}October	35.99	1.16	611.64	19.73
1^{st} - 30^{st} November	29.87	0.99	147.33	4.91
1^{st}-14^{th}December	1.20	0.09	37.89	2.91
Total	144.18	4.13	2439.31	92.07

4.3 Storage losses

4.3.1 Evaporation losses

From analysis of water balance components of farm pond, evaporation losses were estimated on daily basis using pan evaporation data and has been presented in Table 4.8. Data presented in Table 4.8 revealed that during the period from July-December 2016 water loss due to evaporation through the farm pond was maximum of 35.98 m^3 during the month of October followed by 32.60 m^3 during the month of August. Evaporation losses were 19.14, 25.40, 29.86 and 1.19 m^3 for the month of July, September, November and December respectively. Thus, total storage water loss due to evaporation through the farm pond during July to December was observed as 144.17 m^3, which was accounted as 5.57 per cent of total storage losses.Average daily evaporation loss through the farm pond for the months, July, August, September, October, November and December, 2016 was 1.66, 1.05, 0.84, 1.16, 0.99 and 0.085 m^3 respectively (Table 4.8).

4.3.2 Seepage losses

From the observation of Table 4.8 with respect to seepage loss through the farm pond, it indicated that, during the season July to December 2016, maximum seepage loss of 651.80 m^3 was observed in the month of

September ,whereas minimum of 37.89 m^3 was observed in the month of December. The seepage losses for the month of July, August, October and November were 634.88, 358.05, 611.64 and 147.33 respectively. Thus, total storage water loss due to seepage from July to December 2016 was observed 2441.59 m^3, which accounted 94.42 per cent of total storage losses. Average seepage loss for the month of July, August, September, October, November and December, 2016 was observed as 30.12, 11.93, 22.47, 19.73 and 4.91 , 2.91 m^3 respectively(Table 4.8).

4.4 Reutilization of harvested water for protective irrigation

The rain water harvested in the farm pond was utilized for applying protective irrigation to pigeon pea during its pod development stage.Protective irrigation of 10 cm depth was applied to the pigeon pea on 30/11/2016 using with 1.5 hp, portable mono- block engine which start with petrol and run with diesel.

4.3 Protective irrigation using water harvested in farm pond

4.3.1 Grain yield

Table 4.9: Pigeon pea grain yield affected by protective irrigation during *rabi* 2016 - 17

Treatments	Pigeon pea grain yield (Kg/ ha)	Increase in grain yield over control(%)
T_1- One protective irrigation at pod development stage	2204.41	27.30
T_2- Control (without any protective irrigation)	1602.57	
SE	5.29	
C. D at (P= 5%)	16.88	
Mean	1903.49	
CV %	1.70	

Pigeon pea grain under different irrigation treatments is presented in Table 4.3. It is clear from Table 4.3 that treatment T_1 (one protective

irrigation at pod development stage) gave significantly higher grain control (T_2). It was observed from Table 4.3 that treat T_1recorded pigeon pea grain yield 881.76 Kg per hectare as compared to treatment T_2 (641.03 Kg per hectare). It was also seen from Table 4.3 that treatment T_1 showed 27.30 % increase in pigeon pea grain yield over control (i.e. Treatment T_2).

4.3.2 Diesel run portable pump set

The characteristics of diesel run portable pump set utilized for applying protective irrigation to safflower is given in Table 4.10.

Table 4.10: Characteristics of Diesel run portable pump set

Parameters	Range
Rated output	1.5 hp
Head (Total), m	38 – 20
Discharge, l/min	200-600
Fuel : start/running	Petrol/ Diesel
Weight, Kg	14 – 23
Carrying arrangement	Handle/ Tubular frame
Material	Aluminum alloy/ Cast Iron
Priming	Self / Non-self
Fuel Consumption, l/hr	0.4
Pump price (Approx.)	Rs.15,000
Approx. field capacity, ha/day	0.2 - 0.4

The details of components of for protective irrigation through farm pond water with portable low head pump are presented in Table 4.11

Table-4.11Details of components considered for calculation of cost of irrigation per hectare with Diesel run portable pump set

Particulars	Capacity/Unit	Cost(Rs)
Portable pump set, 1.5 hp (Petrol-start/ Diesel-run)	0.2 ha/day	Depreciation cost (for initial cost of Rs. 15,000) 750/ha
91.4 m PVC pipe & accessories	--	650/ha
Fuel Consumption	15 *l*/ha diesel	1100/ha
Labour	10/ha	1500/ha
Total operating cost of one protective irrigation	33 ha	Rs 4000

4.3.3 Cost of cultivation of pigeon pea

The cost of cultivation of pigeon pea was determined and has been presented in Table 4.12.

Table- 4.12: Cost of cultivation of pigeon pea per hectare

Sr. No.	Particulars	Cost, Rs/ha
1.	Land preparation (Two Harrowing and land cleaning)	4000.00
2.	Seed material	2150.00
3.	Fertilizer and its application	2700.00
4.	Sowing	1250.00
5.	Hoeing (including labour charges)	1000.00
6.	Hand Weeding	1000.00
7.	Plant protection (including labour charges)	3000.00
8.	Harvesting and threshing (including labour charges)	2500.00
9.	Other items, Rental value of land, depreciation of far, implements, land revenue and taxes, interest on loan etc	12400.00
	Total	30000.00

The cost of protective irrigation per hectare was determined considering fixed cost of pump, system components, accessories and operating cost of pump system. The cost of irrigation operation is presented in Table 4.13

Table- 4.13: Cost of protective irrigation from harvested rain water through farm pond with Diesel run portable pump set.

Sr. No.	Particulars	Cost, Rs
Fixed costs / year		
1.	Depreciation cost of portable pump set, 1.5 hp	750
2.	Depreciation cost of PVC pipes and accessories	650
Variable costs/ ha		
1.	Fuel consumption (15 liter diesel)	1100
2.	Labour (10 man days)	2500
Cost of irrigation operation/ ha Rs.5000		

*Excluding the cost of excavation of farm pond

It could be seen from Table 4.13 that the cost of one protective irrigation per hectare by surface method was worked out to be Rs. 5000/- Fixed and variable costs incurred have been considered while calculating cost of one protective irrigation.

4.3.4 Gross Monetary Returns (GMR), Net Monetary Returns (NMR) and B:C ratio

Table- 4.14: Pigeon pea yield and cost economics as affected by protective irrigation

Treatment	Pigeon pea grain yield, kg/ha	Gross Monetary Returns, Rs/ ha	Net Monetary Returns, Rs/ ha	B:C ratio
T_1- One protective irrigation at pod development stage	2204.41	111302.00	76302.00	2.18
T_2- Control (without any protective irrigation)	1602.57	80926.00	50926.00	1.69

The economics of protective irrigation to pigeon pea under different irrigation treatments are estimated and presented in Table 4.14. The cost of irrigation for each treatment is estimated per season considering the life and depreciation cost of pump set, PVC pipes and accessories given in Table 4.13. The cost of cultivation is calculated considering the input and labour

charges (Table 4.12). Then, the additional cost of one protective irrigation over control is estimated. In table 4.14, the selling or market rate of pigeon pea is considered and the GMR (Gross monetary returns) is estimated under each treatment. The NMR (Net monetary returns =GMR- (cultivation cost + additional cost of protective irrigation)) is also estimated. The benefit- cost ratio is estimated by dividing the net monetary returns with cost of cultivation.

Data presented in Table 4.14 shows that, treatment T1 *i. e*. one protective irrigations at pod development stage recorded highest GMR (111302.00Rs/ha) and NMR (76302.00) as compared to control (T2) *i. e.* without protective irrigation. Data presented in Table 4.14 shows that, the benefit- cost ratio (2.18) is found to be higher under the treatment t1*i. e*. one protective irrigation pod development stage The lowest B:C ratio (1.69) is estimated under the treatment T_2 (without protective irrigation).

CHAPTER-V

SUMMARY AND CONCLUSIONS

The research on, 'Studies on rainwater harvesting and reutilization for protective irrigation with farm pond' was conducted during the year 2016-17 at demonstration farm of the Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. The daily depth of water impounded in the farm pond was recorded for developing stage-storage relationship of the farm pond. Daily rainfall and pan evaporation data was collected from the Meteorological Observatory of the Vasantrao Naik Marathwada KrishiVidyapeeth, Parbhani. For estimation of the loss of water through evaporation from farm pond, daily pan evaporation data was multiplied by pan co-efficient (0.70). The daily water loss through evaporation (m^3) from the farm pond was calculated by multiplying daily depth of water evaporated from the farm pond to the water storage area for a particular day. The daily water storage area and volume of water impounded was estimated for particular depth of impounding of water from stage storage relationship of the farm pond.

The harvested water in the farm pond was utilized for applying protective irrigation to the pigeon pea crop. The experiment consisted six replications and two treatments. One protective irrigation for pigeon pea at pod development stage (T_1) was applied on 30.11.2016. The treatment T_2 consisted without protective irrigation to pigeon pea. The grain yield of pigeon peawas recorded plot wise.The grain yield data was analyzed using MAUSTAT software and results obtained were compared treatment wise.

For economic analysis of the treatments, cost of cultivation, cost of cultural operations, fixed and operational costs of pump and accessories were calculated. These total cost was be used to determine the gross monetary returns (GMR), net monetary returns (NMR) and benefit cost ratio (B:C ratio).

The area of top section and bottom section of the farm pond was 279.75 m^2 and 516.82 m^2 respectively. The average elevation of embankment at top was 413.130m. The average elevation of bottom of pond was 410.210m. The elevation at the bottom of outlet was 412.437m. The maximum depth of water impounded and maximum storage volume in the farm pond was 2.165m and 933.99m^3 respectively.

The total water evaporated through farm pond for the month of July, August, September, October, November and December 2016 was found to be 19.14 m^3, 32.60m^3, 25.40 m^3, 35.9882$m^{3,}$29.8620 m^3 and 1.1965 m^3 respectively. The maximum water evaporated through the farm pond was recorded in the month of October-2016. Total evaporation loss through the farm pond recorded was144.17 m^3.The seepage loss through the pond for the month of July August, September, October, November and December 2016 was found to 634.88, 358.05 m3, 651.80 m^3, 611.64 m^3, 147.33 $m^{3,}$ and 37.89 m^3 respectively. The maximum water seepage through the farm pond was recorded in the month of September -2016.The total seepage loss recorded through the farm pond was 2441.59 m^3.

The harvested water in the farm pond was utilized for irrigating the pigeon pea crop at its pod development stage. One of protective irrigation (T_1) recorded significantly higher pigeon pea grain yield than treatment of without protective irrigation (T_2). Due to the one protective irrigation, 27.30 per centgrain yield increased over or control was observed.

The study revealed that the treatment T_1 *i. e.* one protective irrigations at pod development stage recorded highest GMR (111302.00Rs/ha) and NMR (76302.00) as compared to control (T_2) *i. e.* without protective irrigation. The benefit- cost ratio (2.18) is found to be higher under the treatment T_1*i. e.* one protective irrigation pod development stage. The lowest B:C ratio (1.69) is estimated under the treatment T_2 (without protective irrigation).

Conclusions:

It is very clear that, the farm pond constructed at the demonstration farm of Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani provided sufficient water during 2016 season.From the results obtained in present study, following conclusions are drawn,

1. The evaporation and seepage loss component from unlined dug out type farm pond was found to be144.18 m^3 and 2439.31 m^3respectively during the water storage period (10^{th}July to 14^{th}December).Total rain water harvested in the farm pond for the period 10^{th} July to 14^{th} December2016 was found to be 2585.76 $m^{3.}$ Seepage losses comprise 94.33 % of storage losses indicating the need to line the farm pond. Seepage losses weredecreased as the storage time elapsed. The were found maximum in the month of July.

2. Treatment of one protective irrigation (T_1) recorded significantly higher grain yield (2204.41 Kg/ha) than treatment of without protective irrigation (T_2)(1602.57 Kg/ha). The study thus, has been able to throw the light on, advantages of protective irrigation through farm pond.

3. In case long duration *kharif*crop like pigeon pea, when the conserved moisture in the soil was not adequate, one irrigation provided from the farm pond increased the pigeon pea crop yield by 27.30 per cent.The benefit- cost ratio was found to be higher under the treatment T_1 *i. e.* one protective irrigation pod development stage than T_2 (without protective irrigation).

4. The observations and the results of the study showed that farm pond is an effective technology for harvesting and recharging the runoff thereby providing water for protective irrigation.

5. The study has been useful for further development of farm pond technology to make it more profitable.

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ANNEXURE-I

Monthly rainfall data during the year 2016

Date / Month	July 2016	Aug 2016	Sept 2016	Oct 2016	Nov 2016	Dec 2016
1	1.5	6.4	12.0	6.3	--	--
2	5.8	1.0	3.8	65.8	--	--
3	12.6	4.4	--	37.4	--	--
4	--	2.0	--	0.0	--	--
5	34.8	--	--	0.0	--	--
6	19.3	--	--	0.0	--	--
7	0.0	--	--	0.0	--	--
8	7.7	--	--	0.0	--	--
9	2.4	--	1.5	45.2	--	--
10	38.6	--	--	0.0	--	--
11	8.8	--	--	11.7	--	--
12	92.7	--	--	0.0	--	--
13	1.3	--	--	0.0	--	--
14	--	11.2	21.4	0.0	--	--
15	--	--	11.0	0.0	--	--
16	--	--	69.2	0.0	--	--
17	--	--	57.2	0.0	--	--
18	2.0	--	--	0.0	--	--
19	0.5	--	2.0	0.0	--	--
20	3.2	--	--	0.0	--	--
21	--	--	11.0	0.0	--	--
22	7.2	--	21.5	0.0	--	--
23	8.4	7.0	17.4	0.0	--	--
24	1.0	--	64.2	0.0	--	--
25	0.5	6.0	17.5	0.0	--	--
26	19.2	--	4.2	0.0	--	--
27	0.5	--	--	0.0	--	--
28	36.0	22.0	--	0.0	--	--
29	--	24.7	--	0.0	--	--
30	44.0	--	11.0	0.0	--	--
31	59.2	9.0	--	0.0	--	--
Total (R.D.)	**407.2** (15)	**93.7 (07)**	**171.6 (13)**	**166.6 (05)**	--	--

ANNEXURE –II

Daily evaporation data during the year 2016

Date / Month	July 2016	Aug 2016	Sept 2016	Oct 2016	Nov 2016	Dec 2016
1	3.8	2.4	3.5	2.5	5.1	4.7
2	4.2	2.6	3.2	of	5.4	4.1
3	3.4	2.8	4.6	2.2	5.3	4.8
4	4.7	2.4	4.7	3.3	5.4	4.7
5	3.3	3.6	5.4	5.2	4.6	4.3
6	2.8	4.1	5.5	5.0	4.6	4.8
7	4.7	5.0	5.8	5.5	4.4	4.8
8	3.5	5.3	5.7	5.8	4.7	4.4
9	2.3	5.5	5.4	4.2	4.4	4.6
10	3.8	5.5	5.2	3.8	3.9	4.5
11	2.8	5.2	4.5	3.4	3.8	4.6
12	--	6.0	5.2	5.0	3.6	4.7
13	2.6	6.0	4.6	5.6	3.6	4.9
14	4.0	4.0	3.0	4.9	3.4	5.0
15	5.5	4.2	2.4	4.8	3.7	4.5
16	5.8	4.8	--	4.5	3.8	
17	6.6	4.6	--	4.6	5.4	
18	5.2	5.4	2.8	5.3	5.0	
19	4.1	5.8	4.0	5.6	5.1	
20	2.7	5.3	3.8	6.6	4.2	
21	5.0	5.8	3.0	6.8	4.5	
22	3.7	6.3	4.4	6.4	4.2	
23	4.0	5.0	2.5	6.7	5.0	
24	3.0	5.4	--	5.6	4.9	
25	3.6	4.2	1.8	5.3	4.8	
26	3.8	4.6	1.4	5.2	4.9	
27	3.4	4.8	5.0	5.4	4.7	
28	3.8	3.6	4.6	6.6	5.0	
29	4.6	6.5	5.2	5.2	5.0	
30	3.8	4.0	5.0	4.5	4.7	
31	--	3.6		4.9		

ANNEXURE –III

Water impounded in farm pond in the month of July , 2016.

Date	Depth of water level in farm pond (mm)	Variation in depth of water in farm pond (mm)
10.07.2016	1000	--
11.07.2016	1000	0
12.07.2016	2000	1000
13.07.2016	1800	-200
14.07.2016	1600	-200
15.07.2016	1500	-100
16.07.2016	1400	-100
17.07.2016	1300	-100
18.07.2016	1200	-100
19.07.2016	1100	-100
20.07.2016	1100	0
21.07.2016	1000	-100
22.07.2016	1050	50
23.07.2016	1100	50
24.07.2016	1000	-100
25.07.2016	900	-100
26.07.2016	1000	100
27.07.2016	1000	0
28.07.2016	1100	100
29.07.2016	800	-300
30.07.2016	600	-200
31.07.2016	1600	1000

ANNEXURE – IV

Water impounded in farm pond in the month of August, 2016.

Date	Depth of water level in farm pond (mm)	Variation in depth of water in farm pond (mm)
01.08.2016	1615	
02.08.2016	1415	-200
03.08.2016	1365	-50
04.08.2016	1355	-10
05.08.2016	1310	-45
06.08.2016	1276	-34
07.08.2016	1217	-59
08.08.2016	1167	-50
09.08.2016	1127	-40
10.08.2016	1077	-50
11.08.2016	1024	-53
12.08.2016	987	-37
13.08.2016	958	-29
14.08.2016	958	0
15.08.2016	917	-41
16.08.2016	897	-20
17.08.2016	877	-20
18.08.2016	857	-20
19.08.2016	847	-10
20.08.2016	836	-11
21.08.2016	820	-16
22.08.2016	810	-10
23.08.2016	800	-10
24.08.2016	747	-53
25.08.2016	750	3
26.08.2016	680	-70
27.08.2016	650	-30
28.08.2016	800	150
29.08.2016	900	100
30.08.2016	850	-50
31.08.2016	900	50

ANNEXURE –V

Water impounded in farm pond in the month of September 2013.

Date	Depth of water level in farm pond (mm)	Variation in depth of water in farm pond (mm)
01.09.2016	1050	150
02.09.2016	1100	50
03.09.2016	900	-200
04.09.2016	800	-100
05.09.2016	600	-200
06.09.2016	550	-50
07.09.2016	450	-100
08.09.2016	350	-100
09.09.2016	305	-45
10.09.2016	260	-45
11.09.2016	240	-20
12.09.2016	215	-25
13.09.2016	195	-20
14.09.2016	750	555
15.09.2016	850	100
16.09.2016	1250	400
17.09.2016	1500	250
18.09.2016	1400	-100
19.09.2016	1300	-100
20.09.2016	1300	0
21.09.2016	1200	-100
22.09.2016	1500	300
23.09.2016	1600	100
24.09.2016	2165	565
25.09.2016	2045	-120
26.09.2016	1865	-180
27.09.2016	1765	-100
28.09.2016	1705	-60
29.09.2016	1645	-60
30.09.2016	1575	-70

ANNEXURE –VI

Water impounded in farm pond in the month of October 2016.

Date	Depth of water level in farm pond (mm)	Variation in depth of water in farm pond (mm)
01.10.2016	1545	-30
02.10.2016	2165	620
03.10.2016	2165	0
04.10.2016	1915	-250
05.10.2016	1865	-50
06.10.2016	1775	-90
07.10.2016	1660	-115
08.10.2016	1580	-80
09.10.2016	1850	270
10.10.2016	1765	-85
11.10.2016	1860	95
12.10.2016	1770	-90
13.10.2016	1650	-120
14.10.2016	1575	-75
15.10.2016	1515	-60
16.10.2016	1455	-60
17.10.2016	1395	-60
18.10.2016	1355	-40
19.10.2016	1315	-40
20.10.2016	1265	-50
21.10.2016	1235	-30
22.10.2016	1205	-30
23.10.2016	1185	-20
24.10.2016	1165	-20
25.10.2016	1135	-30
26.10.2016	1085	-50
27.10.2016	1015	-70
28.10.2016	985	-30
29.10.2016	965	-20
30.10.2016	965	0
31.10.2016	955	-10

ANNEXURE –VII

Water impounded in farm pond in the month of November 2016.

Date	Depth of water level in farm pond (mm)	Variation in depth of water in farm pond (mm)
01.11.2016	935	-20
02.11.2016	905	-30
03.11.2016	885	-20
04.11.2016	860	-25
05.11.2016	840	-20
06.11.2016	835	-5
07.11.2016	825	-10
08.11.2016	805	-20
09.11.2016	785	-20
10.11.2016	750	-35
11.11.2016	735	-15
12.11.2016	715	-20
13.11.2016	685	-30
14.11.2016	675	-10
15.11.2016	660	-15
16.11.2016	650	-10
17.11.2016	645	-5
18.11.2016	635	-10
19.11.2016	615	-20
20.11.2016	595	-20
21.11.2016	575	-20
22.11.2016	560	-15
23.11.2016	545	-15
24.11.2016	525	-20
25.11.2016	515	-10
26.11.2016	490	-25
27.11.2016	475	-15
28.11.2016	455	-20
29.11.2016	435	-20
30.11.2016	410	-25

Date	Depth of water level in farm pond (mm)	Variation in depth of water in farm pond (mm)
01.12.2016	935	-10
02.12.2016	905	-10
03.12.2016	885	-10
04.12.2016	860	-10
05.12.2016	840	-10
06.12.2016	835	-10
07.12.2016	825	-10
08.12.2016	805	-10
09.12.2016	785	-10
10.12.2016	750	-10
11.12.2016	735	-10
12.12.2016	715	-10
13.12.2016	685	-10
14.12.2016	675	-10