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# Application Technologies for Harvested Rainwater in Farm Ponds

## Proceedings of National Consultation Meeting

19-20 March, 2012 - CRIDA, Hyderabad

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National Agricultural Innovation Project

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## Preface

Rainwater harvesting in farm ponds for supplemental irrigation is an important strategy for stabilizing yields of rainfed crops. Farm ponds are promoted in the integrated watershed programmes and under MGNREGS as a drought proofing strategy. More recently, farm ponds are integrated with micro-irrigation programmes under the National Horticulture Mission, particularly in states like Maharashtra and Andhra Pradesh. With continued over-exploitation of groundwater, it is important to use surface water harvested as surplus runoff in dug out ponds, either as stand alone resource or in conjunction with groundwater for enhancing water productivity, particularly in arid and semi-arid regions.

Dug out ponds both as community structures and on individual holdings is a key intervention in most land and water conservation programmes. The water stored in farm ponds is relatively small and seasonal. Due to runoff from cultivated fields, the water contains lot of sediment posing problems for micro-irrigation systems. Operational research by CRIDA found large number of dug out structures are created across the country under MGNREGS, but in very few cases the water is actually being used for supplemental irrigation during dry spells. This is mainly due to lack of appropriate lifting devices which can be used in remote areas where electric power is not available. Earlier research in AICRPDA network on ponds focused on optimizing the size, lining and choice of crops for highest returns. Several lessons are learnt on using pond water on farmers' fields in Component – III projects of NAIP across the country. Many options for lifting water from the ponds viz., pedal/ cycle powered pumps, low capacity diesel / electric motors are being used. Different conveyance systems like sub-surface drips, sprinklers and rain guns are being used to apply the water from the ponds. However, so far low lift pumps have not been properly standardized in terms of power source and capacity. Similarly, the ideal conveyance mechanism from pond water has not been standardized particularly in terms of efficiency of water distribution in the field and overcoming the problems of sediments clogging the micro-irrigation systems.

The Planning Commission in the XII Plan strategy has highlighted the importance of rainwater harvesting and supplemental irrigation as a key strategy for climate resilient agriculture. The Rainfed Area Development Programme (RADP) of Ministry of Agriculture also promoted ponds as a key component of IFS. Therefore, there is a need to bridge critical gaps in farm pond technology in terms of water lifting and conveyance.

Considering these issues, a two-day national consultation was organized at CRIDA, Hyderabad during 19-20 March, 2012 with the objective to take stock of all the available knowledge on the above subject and come out with a standard methodology which can be recommended for the development schemes.

**(B.Venkateswarlu)**
**Director, CRIDA**

# Proceedings of the national consultation on application technologies for harvested rainwater in farm ponds during March, 19-20, 2012

The national consultation was organised at CRIDA, Hyderabad with the following objectives.

1. Sharing the experience on energy efficient water lifting techniques for farm pond irrigated agriculture and related issues among scientific community, Govt. Department, NGOs and progressive farmers.
2. Understanding the technological and social constraints in utilizing water lifting technologies.
3. Identify different enterprises to be associated with existing farm pond based farming system for increased productivity and profitability.

The consultation meeting was attended by 60 participant representing various ICAR institutes (CRIDA Hyderabad, CAZRI Jodhpur, CSWCRTI Dehradun, IISS Bhopal, VPKAS Almora etc.); Agricultural Universities (Gujrat Agricultural University, JNTU Hyderabad, University of Agricultural Science, Dharwad, Bihar Agricultural University, Bhagalpur, TNAU Coimbatore, MPKV Parbhani , Dr PDKV Akola etc.); State government representatives (Andhra Pradesh, Odisha, Chhattisgarh), KVKs, Industries (Jain irrigation system pvt limited, Renewability solar system, Hyderabad), NGOs (WOTR Pune, WASSAN Hyderabad, HoneyBee, Hyderabad) and progressing farmers from Andhra Pradesh, Bihar and Madhya Pradesh.

The meeting was inaugurated by Dr. A K Singh, Deputy director General, ICAR, New Delhi, who emphasized that the supplemental irrigation augmented by farm pond technology plays a vital role in sustaining farm productivity particularly in rainfed agriculture. He stressed the need for developing a suitable water lifting techniques for small scale farm ponds in view of energy efficiency, portability and applicability for supplemental and pre sowing irrigation in order to sustain productivity of rainfed agriculture. Director CRIDA in his remark mentioned that the rainwater harvesting in farm ponds for supplemental irrigation is an important strategy for stabilizing yields of rainfed crops. Farm ponds are promoted in the integrated watershed programmes and under MGNREGS as a drought proofing strategy. With continued over-exploitation of groundwater, it is important to use surface water harvested as surplus runoff in dug out ponds, either as standalone resource or in conjunction with groundwater for enhancing water productivity, particularly in arid and semi-arid regions. Dug out ponds both as community structures and on individual holdings is a key intervention in most land and water conservation programmes. Director, CSWCRTI presented his view of water harvesting and utilization pertaining to hill and mountain agro-ecosystem where he impressed upon the utilization of niche potential of gravity for water utilization from farm ponds.

A total of 11 papers were presented in two sessions and along with sharing of experience by 8 farmers on their innovative methods of water lifting and utilization from farm ponds. The paper presented covered the generic issues of location specific water harvesting technologies and integration of water lifting methods such as Khadin in Rajasthan is linked with fuel based stationery pump whereas low head portable pumps were used for lifting shallow water in Odisha. The major recommendations on water lifting technologies and utilization are emerged as follows.

1 The difference between water lifting methods from bore well and open source lies in the fact that bore well requires minimum suction head of 40 m whereas open source pond require only 5 meter. The pump for pond water should have higher delivery/suction ratio to achieve higher system efficiency.

2 Pump sizes: Suitable pump sizes are needed to develop by keeping in view that the capacity of farm pond barely crosses 2000 m3, and hence higher capacity pump will brought mismatch causing low system efficiency and higher investment.

3 Standardization of command area under farm pond: The experiences suggest that most farm pond sizes practiced in the country are of dimension 10mX10mX3m to 30m X 30 m X 4. These have the storage capacity ranging from 200 m3 to 2000 m3 and are able to provide adequate irrigation upto 1 acre of land. Hence the pumping requirement needs to be selected accordingly. These needs to be standardize for different capacity of pond and respective command for optimal use efficiency. The optimal pump size would be 1.5 hp for upto 500 m3 pond, 3 hp for 500-1000 m3 pond and 5 hp for above 1000 m3 ponds.

4 The wastage occurring through storage, conveyance and distribution in traditional flood or ridge and furrow method of irrigating field ultimately result in delivery of 30 to 35 % of stored water for plant uptake and thus pressurized irrigation system should be utilized.

5 Presently water application method is supply driven rather than crop-demand driven causing mismatch between need of the crop and the quantity of water supplied.

6 Selection of Crop: The selection of crop is highly crucial to achieve the water productivity and profitability.

7 In view of utilizing non-conventional energy sources, use to solar based pumping system in accordance with pump capacity should be promoted.

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# Application Technologies for Harvested Rainwater in Farm Ponds

# Upscaling of Portable Pumpset for Water Lifting in Adilabad District of Andhra Pradesh : A Case Study

**R.V. Adake, M. Osman, P. Ramesh*, G.R. Chary, S. Dixit, Manoranjan Kumar, I. Srinivas, and B. Venkateswarlu**

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## Abstract

*Best use of harvested water in pond is possible through suitable pumpset. This paper is focused suitable portable pumpset and its use and up-scaling in farm pond based agriculture in project mode. Based on study and farmers feedback it has been concluded that portable pumpset of 1.5 hp is more appropriate for lifting of harvested water where depth of pond is from 2 to 4 meter. It is also observed that six raiser sprinklers (1.5 kg/cm$^2$) could be operated at a time covering an area of 700 m2. With this cost of irrigation is about 1/2 the cost of furrow irrigation and 1/3$^{rd}$ cost of pipe irrigation as prevailing practices.*

## Introduction

In India, about one third of the total geographical area is drought prone. The occurrence of drought and floods is showing an increasing trend over the recent decades. Extreme events of both droughts and floods damage the crops to an extent of 60-80% in different areas. The productivity of rainfed agriculture is low mainly due to erratic distribution of rainfall. Hence, rainwater harvesting and its management assume importance in minimizing risk and stabilizing productivity. Farm pond is a viable technology for harvesting and storing of rainwater and it's utilization to save crops from dry spells. In changing climatic scenario droughts and floods are recurring phenomenon.

Farm pond technology is gaining momentum as water harvesting structure are made under various government schemes. The digging of farm ponds is one of the major activities under Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGA) and Rashtriya Krishi Vikas Yojana (RKVY). The financial support is extended for creation of farm ponds either in the form of loan or subsidy in many States in India. Although farm pond technology is viable but there are certain technical issues that limits the efficient use of harvested water. The water harvested in farm ponds is relatively low and seasonal. Large number of ponds are created across the country under MGNREGS, but very few are being actually used for supplemental irrigation to rainfed crops during dry spells. This is mainly due to lack of appropriate water lifting devices which can be used in remote areas where electric power is not available. This chapter focuses on critical issues involved in efficient use of pond water, water lifting devices, and their merits and demerits. Studies at Central Research Institute for Dryland Agriculture (CRIDA) helped in identification of suitable pumpset for pressurized irrigation and later up-scaled in project area under National Agricultural Innovative Project on "Sustainable rural livelihoods through enhanced farming systems productivity and efficient support systems" in Adilabad district of Andhra Pradesh and this chapter also highlights strategic plan implemented for up-scaling of portable pumpset technology and its implication on profitability and livelihood of rainfed farmers.

## Critical issues for efficient use of harvested water

The optimum use of power is about 1.5 to 2.0 hp for lifting of water from ponds or shallow dug wells because suction head is very low. In general, the depth of farm pond is 2 to 4 meter, for this ideal solution would be 1.5-2.0 hp engine/electric motor. Low head electrical pumpsets are commonly available in local market but timely and non availability of electrical power is a major issue. In many locations, farm ponds are in remote areas and lack supply of electricity. Pumpsets operating on fossil fuel are one of the options. In market, pumpsets operating on kerosene are available, however, kerosene is available through public distribution system which is insufficient and outside cost of kerosene is equal to that of diesel.

Apart from availability of power and fuel, the drudgery involved during transport of pumpset from field to field or field to home is another issue. Unlike the water lifting from deep well, the use of farm pond water is limited only for supplemental irrigation. For limited use, portable pumpset that can easily be brought back after its use for safety and maintenance is a major requirement. At the same time, it is equally important to study the performance of low head pumping devices for ideal conveyance mechanism. Usually, sprinkler irrigation is preferred over furrow irrigation as water use efficiency is high. In market, different sizes of sprinkler sets are available operating on 0.7 to 2.5 $kg/cm^2$ working pressure. Size and efficiency of sprinklers need to be matched with low head pumpset. There is poor understanding of the performance of low head pumpset for pressurized irrigation. Above all, there is lack of entrepreneurship for farm pond based agriculture. Custom hiring is one option through which harvested water not only can be used for agriculture with minimum investment but also provides employment opportunity for unemployed rural youth.

## Innovations in Manual Operated Water Lifting Devices (Low head Pumpset)

Many innovations are made by farmers and scientists in order to improve water lifting devices; bicycle and pedal operated pumps are some of the examples. Bicycle operated pumpsets consists of bicycle, rim, pulley, flywheel, and impeller as main components (Fig-1). The human energy required for operation of such mechanical pump is simplified with flywheel and pulley mechanism. This is the innovation of Mr. Vikram Rathod, a farmer from Adilabad district of Andhra Pradesh, which he patented and received several national awards. However, further efforts are needed to upscale such technologies on commercial basis.

Pedal pump is shown in Fig-2 which has double acting reciprocating pump.

*Fig.1 Bicycle operated centrifugal pumpset*

*Fig.2 Pedal operated reciprocating pump*

Pumping capacity of these pumpsets is 2000 l/h. Although manual operated pumpsets are low cost, but are not adopted by the farmers on wider scale because of drudgery.

## Commercially Available Portable Pumpsets

Portable pumpsets are the suitable options for water lifting from farm ponds as these are easy to carry from one place to another. Commonly available and most popularized pumps are centrifugal type and these are operated by engines of 1.5-3.5 hp (Fig. 3). The common specifications of these pumps are given in Table 1. Farmers have wider choice of fuel as these pumpsets are operating on petrol, kerosene and diesel. Petrol-start-diesel engines are lighter weight than commonly available diesel engines for given horsepower. The essential components of centrifugal pumps are fast rotating impellor and casing. Total pressure head of these pumpsets varies from 15 to 30 m. Farmers have choice to select the pumpset depending upon discharge and pressure heads based on their need. For furrow irrigation, higher discharge and low head pumpsets are preferred, where as for pressurized irrigation, higher pressure head is required. One of the limitations of centrifugal pumps is that the suction head cannot be higher than 7 meter above the

**Table 1. Specifications of commonly available portable pump sets**

| Sr. No | Particulars | Specifications |
|---|---|---|
| 1 | Rated Power, Hp | 1.5-3.5 |
| 2 | Delivery range, $m^3$/h | 15-30 |
| 3 | Weight of Pumpset, kg | 20-45 |
| 4 | Fuel | Multifuel |
| 5 | Pressure head, m | 12-30 |

*Fig.3 Commonly available portable pumpsets in Indian market*

water level. However, depth of farm pond varies between 2-5 meter; therefore, such pumpsets can be recommended for lifting of water from farm pond.

Regarding operation and maintenance, it requires skill which calls for training and capacity building of pumpset user. Centrifugal pumps are designed for specific flow rate and operating pressure and it is important that pump characteristics and operating conditions are matched by technical personnel.

## Selection of Portable Pumpsets

It is commonly believed that portable pumpsets are suitable only for furrow irrigation and not for sprinklers. Commercially, there are wide range of sprinklers available for pressurized irrigation. The common sprinklers used by the farmers are raiser sprinklers. The working pressure of these sprinklers is 2 to 2.5 kg/cm$^2$. Testing and standardization of operational parameters of sprinklers on portable pumspet need to be evaluated before recommending it for use. To generate the information on sprinkler performance using portable pumpst the feasibility tests for lifting and distribution of harvested water from farm pond through sprinkler irrigation was conducted at CRIDA.

In Indian market, portable pumpsets of 1.5 to 2.0 hp size operating on petrol or kerosene are available on large scale; however, only few firms are manufacturing petrol-start-diesel pumpsets. Petrol-start-diesel pumpsets of 1.5 hp can be chosen as it is easily available and cost effective compared to petrol. Kerosene is cheaper than diesel but its availability is limited through Public Distribution System (PDS), hence, petrol-start-diesel engines are suggested (Fig 4). Detailed specifications of selected portable pump sets is given below,

1. Engine Model : HSMF, MK-12
2. Make : Greaves Cotton Ltd, Chennai
3. Rated RPM : 3000 rpm
4. Rated Power : 1.5 hp
5. Fuel : Petrol start & Diesel run
6. Pump : 2" X 2" Monoblock
7. Pressure Head : 12 meter
8. Discharge : 5 lps (liters per seconds)
9. Pumpset weight : 34 kg

*Fig.4 Portable diesel pumpset of 1.5 hp*

## Feasibility tests of Portable pumpset for sprinkler

Several tests and demonstrations of portable pumpset along with sprinklers were performed for lifting of water from pond and its distribution. In various cases, about one thousand cubic meter of water was lifted and used for supplemental irrigation with different irrigation methods such as furrow, sprinklers and pipes. On this context, the vegetables like brinjal, tomato were cultivated in 0.2 ha area near the pond (Fig 5). Sprinklers were operated at about 120 m away from the pond for giving supplemental irrigation of redgram

*Fig.5 Lifting of water through portable pump set and irrigation to crops near by pond*

*Fig.6 Conveying water through sprinklers*

crop as case study (Fig 6). It was observed that there was no difference between performance of sprinklers operating very near the pond (20-40 m) and away from the pond about up to 130 m. However, there may be a chance of low efficiency in the performance of sprinklers in undulating fields and loss in pressure head. During the evaluation it was observed that required working pressure of tested sprinkler was 2.5 kg/cm$^2$ but actual pressure observed at delivery side was 1.5 kg/cm$^2$. It indicated that pressure head provided by portable pumpset were not sufficient to give good output of sprinklers. Secondly, though rated speed of the engine was 3000 rpm (as mentioned in specifications) the actual operating speed was 2000 rpm. For these operating conditions, the performance of pumpset was found to be satisfactory. The details of sprinkler performance, area coverage and fuel cost is given in Table-2.

The spray radius of the each sprinkler was found to be 10 m compared to 12 m with working pressure of 3 kg/cm$^2$ as in 4.5 hp pumpset. Although, there was reduction in spray radius of 20% the saving in fuel cost was about 50% when compared with pumpset of higher horsepower. Hence,

**Table 2: Performance test of portable pump sets for sprinkler irrigation**

| Sr. No. | Particulars | Observations |
|---|---|---|
| 1. | Engine speed, rpm | 2000 |
| 2. | No. of sprinklers | 06 |
| 3. | Sprinkler spacing, m | 12 |
| 4. | Radius of spray obtained, m | 10 |
| 5. | Net Area Irrigated, m$^2$ | 714 |
| 6. | Discharge at delivery, m$^3$/hr | 09 |
| 7. | Irrigation yield, mm/hr | 10 mm |
| 8 | Fuel consumption, l/hr | 0.686 |
| 9, | Fuel cost for irrigation (10 mm), Rs/acre | 160 |

water lifting from pond with portable pumpset and irrigation through sprinkler was found to be satisfactory. Using identified pumpset, six sprinklers can be operated at a time covering an area about 700 m$^2$. Total cost of fuel was 400 Rs/ha or 160 Rs/acre for 10 mm irrigation. Study showed that one acre area can be irrigated in a day using portable pumpset. In brief, portable pumpsets are suitable for small-scale irrigation using sprinkler as improved method. Moreover, its overall weight is 34 kg, which can easy for transportation.

There is a scope to improve upon portability of this pumpset by selecting appropriate material.

## Economics of portable diesel pumpset

The economics of portable diesel pumpset of 1.5 hp with different irrigation methods for irrigation of 50 $m^3$/acre is worked out (Table 3). In many parts of India, mainly Odisha, Coastal Andhra Pradesh, West Bengal etc farmers use portable pumpset to lift water from shallow dugouts and ponds for irrigating vegetable crops with half inch pipe. This is a common practice for small scale irrigation. The economics of traditionally practiced irrigation method is compared with furrow irrigation and sprinkler irrigation as improved method.

The economic analysis for operation of identified diesel pump with different irrigation methods showed that the cost of sprinkler irrigation is 55% lower than that of furrow irrigation and 35 % of pipe irrigation. Consumption of fuel is about four times higher with pipe irrigation compared to sprinkler irrigation and hence operational cost is higher. In case of furrow irrigation, though fuel consumption per unit of delivery was three times higher than in sprinklers wages of labour was high due to more number of persons involved. Moreover, water use efficiency of furrow irrigation is lower than sprinkler. Overall, sprinkler irrigation is superior to furrow and pipe method of irrigation as it is cost effective and water use efficiency.

After conducting several evaluation studies, portable pumpset technology along with sprinkler set was up-scaled in project area of Adilabad district of Andhra Pradesh under National Agricultural Innovative Project (2007-12) for efficient use of harvested rainwater in farm pond.

## Water harvesting through farm ponds and up-scaling of portable pumpset technology: A case study in Adilabad (AP)

The study was undertaken in a cluster villages (Seetagondi, Pedamalkapur, Chinamalkapur, Kothwalguda, Garkampet, Arkapally, and Somwarpet) under Seetagondi Gram Panchyat of Gudihatnoor Mandal, Adilabad district of Andhra Pradesh during 2009-12. Total geographical area of cluster is 1912 ha out of which net cultivable area is 1296 ha (68%) of which 86% is rainfed. Very little area (less than 1%) is irrigated under bore wells. The average annual rainfall of the cluster is 1000 mm out of which 85% is received during southwest monsoon. The major rainfed crops are cotton, pigeonpea, sorghum, and soybean.

**Table 3. Economics of identified portable pumpset with different irrigation methods for 50 $m^3$/acre**

| Irrigation Method | Flow rate ($m^3$/hr) | Operation (hrs) | Fuel (l) | Fuel cost* (Rs) | Labour Wages* (Rs) | Total Cost, (Rs) |
|---|---|---|---|---|---|---|
| Pipes(1/2") | 2 | 25 | 17 | 714 | 600 | 1314 |
| Furrow | 14 | 3.5 | 2.4 | 100 | 750 | 850 |
| Sprinkler | 8 | 6 | 4 | 168 | 300 | 468 |

*Diesel@42 Rs/l and labour @ 150 Rs/day

The physiography is undulating with 2 to 20% and in the crop fields it is 2 to 3%.

Management interventions were introduced amongst which water harvesting through farm pond was the key. In total, thirty ponds were dug in project area and some of them in collaboration with District Water Management Agency (DWMA), Adilabad. The average capacity of pond is about 1000 to 1200 $m^3$ with depth of 4.5 m. The works under taken and water stored in ponds at various locations in the cluster are shown in Fig 7. The ponds constructed under MGNREGA were also taken for improvement as depth of pond constructed under scheme was only 2 m. These ponds were remodeled from 11 x 9 x 2 meter with storage capacity of (125-150 $m^3$) to 20 x 20 x4.5 m (1000 to 1200 $m^3$ storage capacity) by employing machines as it is difficult to dig beyond 2.0 m manually in black soil.

A reconnaissance survey was conducted for selection of suitable sites (based on soil type and runoff potential) for farm ponds. For enhancing the productivity of rainfed crops, many crop

## Portable pumpset for reusing harvested water – A Participatory approach

A strategy was worked out to utilize farm pond water for small scale irrigation for enhancing water productivity in the project area. A water user group was formed consisting of nine interested farmers (with farm ponds) and distributed 9 portable pumpsets and accessories including pipes on a participatory and cost sharing basis. The total investment on pumpset and accessories including pipes was Rs 15,000/-. Out of this, Rs 10,000/- towards purchase of pumpsets was borne from the project (CRIDA-NAIP) and contribution from each farmer was Rs. 5000/- towards purchase of accessories and sprinklers. A tripartite Memorandum of Understanding (MoU) was signed involving farmers, CRIDA and KVK, Acharya NG Ranga Agricultural

*Fig 7. The work undertaken for construction ponds and water stored in ponds at various places in cluster*

University (ANGRAU) officials with necessary terms and conditions.

## Capacity building

Demonstrations and training are essential components to promote any new technology. The portable pumpset system was new to the farmers in the NAIP cluster villages. Pumpset components mainly cranking, choke placement, turning of petrol to diesel, cleaning of spark plug, fuel jet adjustment and proper oiling are the important aspects that farmers should aware of these for ease of operation Although these are minor things for designers but it is difficult to understand by the farmers at initial stage when technology is introduced. In many cases, good designs may become apparently failure due to lack of timely training and demonstrations. This was taken care by conducting frequent demonstrations and providing training for operation of portable pumpset (Fig 8). We also felt that at least one skilled person or technician is required at cluster level to take care of any unforeseen problems and repair.

*Fig 8. Demonstration and training to farm pond user group*

## Impact of Harvested water in farm pond

Water harvesting technology and utilization of harvested water through portable pumpset made a significant contribution in increasing crop yield and income of farmers by extending crop growing period and cropping intensity. Usually, last picking of cotton is being done in mid January but because of water availability in the ponds and appropriate size of pump farmers could able to provide 2 to 3 supplemental irrigations and harvested two extra pickings. The farmers earned extra income due to increase in productivity of rainfed crops and cropping intensity by growing vegetable crops. The average increase in cotton yield due to supplemental irrigation is 1.5 quintal per acre. It yielded in additional income of Rs 6000/-. Area irrigated, number of supplemental irrigation, operational cost for irrigation, yield increased and additional returns of targeted farmers (Table 4). The pay back for farmer's contribution was found to be only one season. One of the farmers raised rabi sorghum for grain and fodder production. In addition to utilization of harvested water for supplemental irrigation, it was also made available for drinking purpose particularly for cattle.

## Need for technical improvement in portable pumpset

Although portable pumpsets are energy efficient for lifting pond water, the farmers experienced some operational difficulty in existing pumpset such as cranking with rope, start-to-run plug, chock direction, etc. Technical improvements are needed in the existing pumpset to make it farmers friendly.

## Conclusions

Water harvesting through farm pond is a viable technology but appropriate

**Table 4. Income from supplemental irrigation (SI) during 2011-12**

| Name of the farmer | Crop | No. of SI | Operational cost (Rs/acre) | Increase in yield (q/ac) | Additional return, Rs/ac |
|---|---|---|---|---|---|
| Shri. E. Mallesh | Cotton (1 acre) | 2 | 750 | 1.5 | 6000 |
| Shri. Ganga Reddy | Cotton (1 acre) | 3 | 1125 | 1.5 | 6000 |
| Shri K. Ramarao | Cotton (1 acre) | 3 | 1125 | 2.0 | 8000 |
| Shri S. Bheem Rao | Cotton (1 acre) | 2 | 750 | 1.0 | 4000 |
| Shri. M. Manthu | Sorghum (2 acre) | 3 | 2050 | 07q grain+ 12 q fodder = Rs 20,000/- | |
| Shri. N. Rajanna | Vegetables (0.5 acre) | 2 | 750 | -- | 6800 |
| Shri. K. Ramarao | Vegetables (0.5 acre) | 3 | 1125 | - | 9200 |

water lifting mechanism is required for effective use of pond water for enhancing water productivity in rainfed agriculture. A portable pumpset of 1.5 hp (Petrol-start-diesel run) was evaluated/ demonstrated for lifting of pond water and pressurized irrigation showed satisfactory performance in terms of both cost and energy. The utilization of harvested water using portable pumpset added significant contribution to farmer's income. The payback period of portable pumpset is just one year. Portable technology inspired the farmers to make effective use of harvested water.

# Rainwater Harvesting in Navsari Agricultural University Campus – A Case Study

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## Abstract

*With the advent of Navsari Agricultural University in May 2004, efforts were made to increase productivity and to find the reasons and ways to deal with the mounting 'water' problem. Apart from bringing more area under cultivation, availability of water for supplementary irrigation and improvement in irrigation efficiency, drainage, conjunctive use and rain water harvesting were some of the measures initiated during first few years. Well water quality observations were initiated from 2003 and construction of ponds / percolation pits on the micro watershed basis were started after 2006. The long term progressive development regarding rain water harvesting, increased use of pressurized irrigation methods along with other scientific watershed management practices clearly showed overall improvement or helped in maintaining the ground water quality in spite of increase in cropping intensity, human and animal population within and outside campus. Water quality of only those wells was found to be deteriorating which are catering larger cropped area and located on higher elevation and away from any water body. Farms which follow better method of irrigation, precision farming, organic cultivation, Agro - Horti – Forestry – Fishery – Dairy modules along with rain water harvesting by a pond / percolation pits / percolation wells / trenches / sub soiling have maintained or checked the previously declining ground water quality. Constructed ponds in the degraded lands have not only shown improvement in ground water quality but are being used for meeting the irrigation demands of neighboring fields, drinking water needs of animals, fisheries, and duckery.*

**Key words:** Farm pond, percolation pit, ground water recharge, conjunctive use, multiple uses

## Introduction

Navsari Agricultural University located at 72° 54′ E – Latitude, 20° 57′ N – Longitude and 10 m AMSL – Altitude is 13 Km from historical Dandi beach. The region receives more than 1500 mm torrential rains during monsoon. The soils are black cotton with the predominance of paddy, sugarcane, mango, sapota, banana, papaya, onion, castor, floriculture, fisheries, and dairying as major farming activities. Due to large scale industrialization of south Gujarat, problems of air and water pollution have arisen which have become more complex because of over exploitation of natural resources like ground water and deforestation – urbanization in neighboring areas. Most of the farms, therefore, suffer from deteriorating soil health, receding water tables, polluted ground water, soil erosion, and water scarcity during *rabi* and summer months, water logging during monsoon.

NAU Campus at Navsari, spreads in an area of about 400 ha. The campus has different experimental fields under the control of various departments and general fields under the control of college. The residential area, colleges, farm building, roads and other structures covers approximately 10 % of the total area. The campus had ample water availability till few years back but at the time of formation of new University water shortages were experienced during summer and water logging during monsoon. It had been observed that water levels receded by 5 to 7 m in a decade and most of the bores had become defunct as the water quality deteriorated drastically due to which many cultivable farm land became uncultivable and was lying as waste land. High intensity rains occur during monsoon allowing very little opportunity time for the water to infiltrate into the aquifers. All the rainwater during monsoon was directly carried through the drainage system in the campus. Although, there were two small ponds in the campus, one of the pond stored water during monsoon and also the excess water from bore well whereas another did not store much water, may be due its virtually no catchment area, rather it was filled by pumping ground water. The reason being it was designed for the purpose of cattle willowing. In many of the wells the water quality had deteriorated to such an extent that they cannot be used for drinking purposes or for irrigation of crop. With the advent of Navsari Agricultural University in May 2004, efforts were made to increase productivity and to find the reasons and ways to deal with the mounting 'water' problem. Apart from bringing more area under cultivation, availability of water for supplementary irrigation and improvement in irrigation efficiency, drainage, conjunctive use and rain water harvesting were some of the measures initiated during first few years.

## Methodology:

### Identification of reasons of water problems

- Previously the irrigation water in the campus was from the canal
- Bore well supplemented the short supplies in the past, became the only water source
- Cultivation of high water consuming crops like sugarcane and paddy crop in the region
- Introduction of cash crops such as banana and lily which also has high water demands
- Heavy ground water exploitation due to increase in residential area around the campus.
- Silting and choking of drains due to negligible expenditure on maintenance of drainage system
- Silting and chocking of culverts at crossing causing water stagnation
- Bowl shaped topography (*kyari* lands) at some places of farm, with virtually no drainage
- No efforts made to recharge the ground water, rather riding high in the myth that between Vapi to Tapi there cannot be any water shortages in this land of *Balram*

### Approach

- Documentation of pre development status
- Identification of micro watersheds
- Rainfall analysis
- Runoff estimation
- Site selection for construction of water bodies
- Execution of planned drainage, irrigation and water conservation activities
- Evaluating the improvement
- Documentation of current status

After identification of problem and the reasons for the problem, efforts were made to reshape and the design the surface drains for quick removal of stagnant water from the fields. To begin with, rainfall record of meteorological laboratory at college farm, Navsari was analyzed. Rainfall intensity and recurrence interval of high intensity of rains for South Gujarat was worked out for finding the peak runoff which is needed for the design of drains and water conservation structures. Drains were designed on the basis of rainfall – runoff analysis of contributing micro watersheds (Table 1) within the campus. Peak discharges (Table 2) were used for calculating drain dimensions. Based on demand, supply, topography and finance availability location of ponds, check dams, percolation pits, trenches, bore wells, recharge wells, erosion control structures, irrigation pipe line and surface drains, in the campus were planned for conserving soil and water and improving water use efficiency.

## Methods adopted for rainwater harvesting/ground water recharging

- Farm ponds
- Percolation pits
- Percolation wells

**Table 1: Micro watersheds in the University Campus**

| Watershed | Inside Campus (ha) | Outside campus (ha) | Total area (ha) | Remarks |
|---|---|---|---|---|
| A | 26 | 24 | 50 | Not contributing. Lying on the periphery on north eastern border (A Block) |
| B | 200 | 100 | 300 | Multiple uses when rain water is harvested |
| C | 150 | 20 | 170 | Multiple uses when rain water is harvested |
| D | 24 | - | - | Not contributing. Lying on the periphery on western border (west of canal), F Block |

**Table 2: Discharge rates in different watersheds of University campus**

| Estimation Model | Watershed--> | B | C | Test plot |
|---|---|---|---|---|
| | Area (ha)--> | 300 | 170 | 2 |
| CN method | Constant | 46.7 | 26.5 | 0.3 |
| Rational method | 0.6 | 41.3 | 22.1 | 0.3 |
| Dickens | 19.5 | 44.5 | 29.0 | 1.0 |
| Ryves | 6.8 | 14.1 | 9.7 | 0.5 |
| Cook's Method | - | 9.6 | 7.8 | 0.3 |
| Creager's Formula | 47 | 46.6 | 28.9 | 0.3 |
| Modified Meyers formula | 0.15 | 45.5 | 34.2 | 3.7 |
| Dredge and Burge formula | 19.5 | 24.9 | 13.2 | 0.7 |
| Burge formula | 19.6 | 25.0 | 13.2 | 0.7 |
| Fuller's formula | 8 | 45.5 | 28.9 | 0.8 |
| Baird and McIllwraith(1951) | 1200 | 44.3 | 25.2 | 0.3 |
| Empirical Formula for South Gujarat Coast | - | 46.7 | 26.5 | 0.3 |
| Observed | - | 46.7 | 28.4 | 0.3 |

- Check dams
- Sub soiling
- Surface drains
- Culverts on surface drains

Water harvesting is done at suitable locations, table 3 & 5, by draining the monsoon runoff for ground water recharge, irrigation, fisheries, duckery, and recreation and to improve ground water quality and check sea water ingress. Most of the ponds were made in either waste lands or in lands having poor crop productivity.

Development of water conservation activities in the University farm started from 2006 onwards. To assess the changes due to construction of drainage, ponds, percolation pits; apart from increase in productivity, net cultivable area, irrigation efficiency, the changes could be directly evaluated by monitoring the ground water quality. The water quality observations from different wells spread over 400 ha area of the University campus on monthly / seasonal frequency are being observed since 2003. Well code and its location are shown in table 4 and figure 1. Water table was also observed on the monthly basis from few open wells.

## Results and discussion:

After the formation of NAU in May 2004, drainage – land reclamation and creation of water bodies was taken up. Table 5 shows the water bodies created in the University farms. This development not only increased cropping intensity and provided much needed supplementary irrigation, aesthetic beauty to the campus, fisheries but also

**Table 3: Soil and Water conservation activities executed**

| Year | Activity | Remark |
|---|---|---|
| 2004 - 05 | De-silting and cleaning of surface drains / construction of new drains | Improved drainage |
| 2005 - 06 | Construction of higher capacity culverts & construction of new drains ; Percolation well, trenches, Percolation pits; Pond digging work started in Block D | Improved drainage & Water stagnation removed & Improvement in water quality Observed |
| 2006 - 07 | Digging of pond at two sites, de-silting of existing pond (Block C & D), Land reclamation | Rain / canal water harvesting |
| 2007 - 08 | Deepening of ponds (Block D); Construction of percolation pits, Laying of pipe lines for water conveyance – 2500 m | Rain / canal water harvesting Conversion of low lands to raise farm lands, Check on sea water ingress Improved water conveyance efficiency |
| 2008 - 09 | Construction of new pond in Horticulture Farm (Block D & E) & Extension of pond dug in waste land of Block B | Rain / canal water harvesting Conversion of low lands to raised farm lands |
| 2011 - 12 | Dug out pond constructed in Sugarcane farm, Block G | Harvest seeping canal water, Help in recharging and improving water quality of bore well |

**Table 4: Observations wells for evaluating ground water quality**

| S.No. | Well Code | Location |
|---|---|---|
| 1 | A | Plot No 10, Block-D, College Farm |
| 2 | B | Plot No 20, Block-C, Well adjacent to Dairy farm |
| 3 | C | Plot No 22, Block-C, Well at Dairy Farm (North Eastern Side) |
| 4 | D | Plot No 20, Block-D, Adjacent to Oil palm Block |
| 5 | E / N | Plot No 24, Block-D, Pulse research station Main bore |
| 6 | F | Plot No 13, Block-C, Sump Water from canal - Near Dairy |
| 7 | G | Campus Eng. Tank No. 3 |
| 8 | H / O | Plot No 9, Block-D, Vegetable farm bore |
| 9 | I | Plot No 15, Block-B, Class IV / Near PG Hostel |
| 10 | J | A/B Block Forestry Nursery Bore |
| 11 | K | Plot 18, Block E, Commercial Bore, SWMRU |
| 12 | L | Plot 16, Block C, New bore, Adjacent to PG Hostel Pond |
| 13 | P | Plot 14, Block E, Main Bore, SWMRU |
| 14 | Q | Plot 25, Block E, Jetropha - Chiku Bore |
| 15 | R | Plot No 18, Block-F, Organic Farm |
| 16 | S | Plot 20, Block B, PG Hostel Pond, |
| 17 | T | Plot 10, Block E, Border of SMRU & RHRS |
| 18 | U | Plot 5, Block E, Coconut - Horticulture Orchard |

put a check on fast deteriorating ground water quality. Water table data also shows marginal improvement in water table especially in the wells which are very near the water body or the wells which are topographically located on the sub surface flow channels. Further, coastal areas of South Gujarat receive incessant rains during monsoon and during later part of monsoon, water table comes very near the ground surface, which restricts rain water to infiltrate / percolate into the ground water aquifers thus underlining the preference of water body with larger surface area so that the standing water may get sufficient opportunity time to percolate. In fields where farmer / Research farm doesn't afford to allocate area for a pond, there use of percolation pit, percolation well, trenches are the options. Percolation well / pits will directly take the water to the aquifer, bypassing hard top soil layer having poor infiltration rate.

The water quality data shows trends of improvement in water quality in general, however the water quality has deteriorated in few wells which do not fall within the influence of any water body. Another reason for deteriorating water quality may be the increase in student – staff – animal population in the campus which is in addition to increased cropping intensity after formation of the University. The data also shows deceleration in otherwise fast deteriorating water quality in farms where pressurized irrigation system is used. The trend line show some ambiguity in water

**Table 5: Creation / rejuvenation of water bodies at NAU campus**

| S. No. | Location | Type of water body | Purpose | Remark |
|---|---|---|---|---|
| 1 | Block A, Master Plan | Dug out pond | Ground water recharge | Reshaping, desilting **(Mar. 2008)** |
| 2 | Block B, | Dug out pond | Use of waste land, Irrigation, Ground water recharge, Fisheries | Newly created **(Mar. 2008 Apr. 2009)** |
| 3 | Block C, LRS | Pond | Buffalo willowing | Reshaping, desilting **(Apr. 2009)** |
| 4 | Block D, Pulse | Dug out pond | Use of waste land, Irrigation, Ground water recharge, Fisheries | Newly created **(Mar. 2006 Mar. 2008 Apr. 2009)** |
| 5 | Block E, SWMRU | Pond | Fisheries | Newly created **(Mar. 2009)** |
| 6 | Block E, Horticulture | Dug out pond | Irrigation, Ground water recharge, | Newly created **(Apr. 2009)** |
| 7 | Block G, Diploma School | Dug out pond | Duckery | Newly created **(Apr. 2007)** |
| 8 | Block F | Dug out pond | Use of saline land having poor productivity, multipurpose use | Newly created **(Mar. 2010)** |
| 9 | Block G, Sugarcane farm | Dug out pond | Bore well recharge | Newly created **(Mar. 2012)** |

quality of few wells in spite of being located in the vicinity of ponds, may be because of location of well is in the opposite side of water body, higher elevation of well, sub surface channels, cultivation of high water requiring crops like sugarcane, banana and paddy and using surface method of irrigation. Annual water quality of all the wells shows lowest EC values immediately after monsoon which goes on to reach its peak during summer. It can also be inferred from the data that farms having tree crops i.e. Horticulture and Forestry farms show a constant or sustained water quality may be due to tree are helping in recharging and consuming less water. Monthly water table observations were taken from the open wells present in the farm. Increase in water table is observed in the wells near vicinity or maximum of 1 m rise, till 100 m from the water bodies.

## Conclusions:

The long term progressive development regarding rain water harvesting showed overall improvement or helped in maintain the ground water quality in spite of increase in cropping intensity, human and animal population within and outside campus. Water quality of only those wells was found to be deteriorating which are catering larger cropped area and located on higher elevation and away from any water body. Farms which follow better method of irrigation, precision farming,

**Table 6: Well water quality indicating temporal trends due to rain water harvesting**

| Well Code | Trend of EC (dS/m) | Remarks / Inferences |
|---|---|---|
| A | Rising<br>Though shows decrease in 2009 | Away from influence of any water body.<br>Highest topographic elevation of University campus.<br>Increase in cropping intensity – well covers big area due to its center place location. |
| B | Rising | Away from influence of any water body.<br>Increase in animal population and also increase in cropping.<br>Intensity (area under grass was increased to feed farm animals, previously grass was purchased from outside) Surface method of irrigation is still followed |
| C | Decreasing | Well was closed for irrigation due to poor water quality<br>It also got recharged due to construction of Pond / Check dam<br>Sea water ingress used to take place through creek of Purna river near Puneswar temple, during high tide. *Water quality could be further improved if direct recharging of well is done from the pond* which is at around 250 m from the pond. |
| D | Decreasing | Though the well is about 400 m from the pond but perhaps well falls in the sub surface channel leading to the pond due to which water quality has improved especially after construction of pond at Pulse started from 2006 onwards. Data from 2006 to 2009 show more or less constant water quality around 1dS/m. In addition to creation of water body area under micro irrigation increased after 2006 thus needing less application of water |
| E / N | Rising | Though the pond is at around 250 m in north west quality has not improved. Slight improvement is visible in 2009 as compared to 2008. Another reason being flow of ground water in also as per the surface flows, i.e. in north of pond thus clearly leaving the well situated in south east of pond. Increase in cropping intensity |
| F | Decreasing | Pond water is directly influencing – improving the water quality |
| G | Rising | Well located in higher elevation and away from pond influence Well caters to the domestic water demands as well and due to increase in human population (student strength and staff) it is withdrawing more water as compared to few years back. Well which are within the radius of influence of this well are irrigating high water requiring crops like sugarcane, banana and that too through surface method of irrigation. Well is not falling over the Sub surface flow channels During 2007 & 2008 there was some sustenance due to percolation pit but its impact diminished due to obstruction in flow in subsequent years. |
| H / O | Sustained | Horticulture crops (Mango – sapota Trees)<br>Percolation pits in the vicinity<br>Use of pressurized irrigation methods and cultivation in green houses |

| | | |
|---|---|---|
| I | Sustained & Decreasing | Water quality improved after construction of Pond i.e. after 2007 |
| J | Sustained & Decreasing | Water quality improved after construction of Pond i.e. after 2007 |
| L | Decreasing | Near pond |
| P | Sustained & Decreasing | In spite of high cropping intensity water quality is maintained due to the following reasons:<br>Impact of percolation pit<br>Use of pressurized irrigation methods / precision farming practices<br>Crop rotation<br>Plastic Mulching / Green houses |
| Q | Insufficient data | Influence of pond is not visible from one year data may be because of higher elevation of well and location at northern most border of the farm.<br>Away from the influence of pond |
| R | Insufficient data | Data is of only 1 yr (2009) but it shows that Water quality is medium perhaps due to use of drip method of irrigation and use of organic fertilizers |
| S | 1 year data | Pond water<br>Fit for irrigation |
| T | 1 year data (2009) | Water quality appears to be fit for irrigation may be because of use of pressurized irrigation, tree crops, and construction of pond in Horticulture farm |
| U | 1 year data (2009) | Medium water quality which is fit for irrigation purposes<br>Cultivation of Horti- Forestry crops |

**NAVSARI AGRICULTURAL UNIVERSITY CAMPUS**

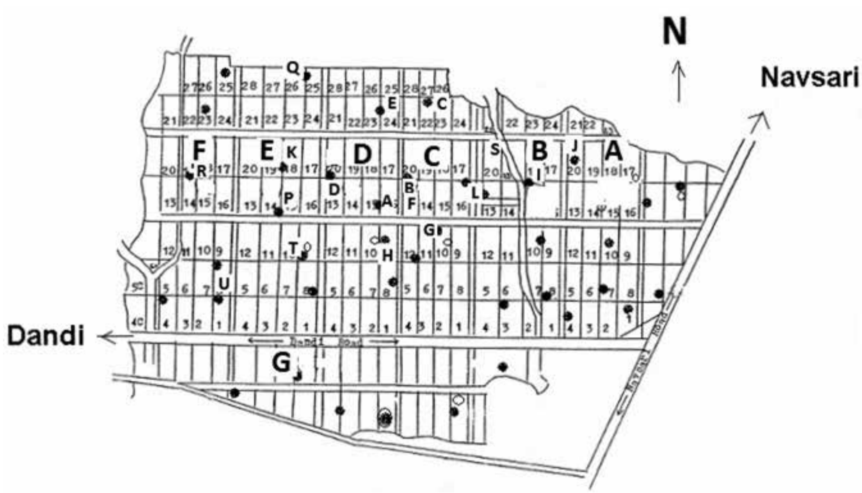


*Fig.1 Bore well / Open well locations*

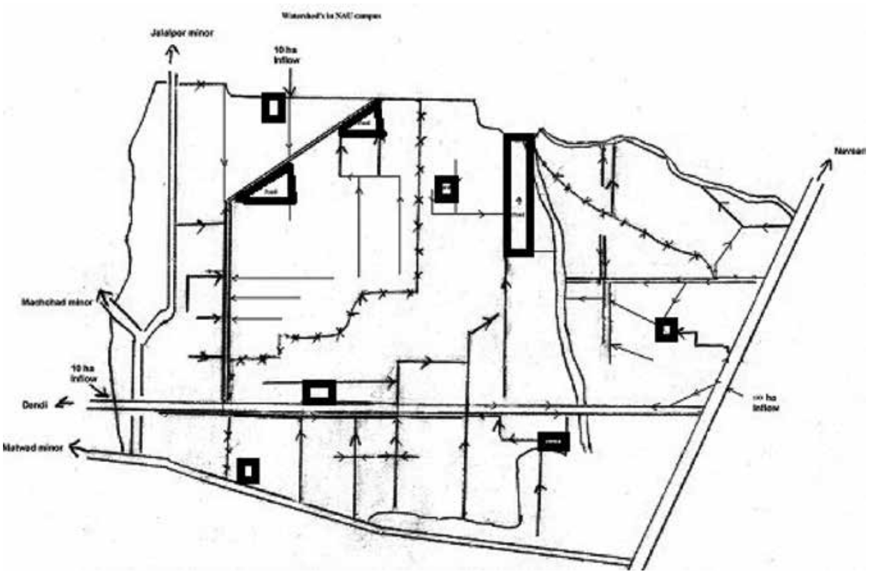


Fig.2 Farm pond created / rejuvenated

organic cultivation, Agro - Horti – Forestry – Fishery – Dairy modules along with rain water harvesting by a pond / percolation pits / percolation wells / trenches / sub soiling have maintained or checked the previously declining ground water quality. Ponds made in the degraded lands have also helped in meeting the irrigation demands of neighboring fields, drinking water needs of animals, fisheries, and duckery. Moreover, to maintain quality of water of University farm from further deterioration, the study clearly indicates to harvest as much rain / canal water, adopt efficient irrigation methods, crop rotation, use of organic fertilizers and tree plantation especially in northern strip of University farm and impose ban on new boring. Permission of boring should only be given after evaluating the monthly ground water quality for a year, of the existing bore well in the neighborhood and its distance from the proposed well.

# Rainwater Harvesting for Sustenance in Hot Arid Zone of Rajasthan

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## Abstract

*The hot and arid zone of India is spread over 31.7 m ha where water harvesting is of immense importance to sustain the agricultural production. Present paper deals with the proven methodology for water harvesting in these area. These methods include Nadi, Pond, Khadins Tanka etc. These systems of water harvesting were further integrated with water application system for efficient water management in agriculture using optimum water lifting and delivery system. The paper also discuss the rainwater harvesting from constructed catchment and its utilization in life saving irrigation.*

## Introduction

The arid ecosystem covers about one-eight of the world's land surface. Majority of these lands lies under hot arid eco-system. The hot arid zone of India is spread over 31.7 m ha. The hot arid region occupies major part of north-western India (28.57 m ha) covering western part of Rajasthan (19.6 m ha, 69%), north-western Gujarat (6.22 m ha, 21%) and south-western part of Haryana and Punjab (2.75 m ha, 10%). The region receives low rainfall (<100 mm to 500 mm) with highly erratic distribution over space and time (CV>60%). The region has high temperature regime and consequently high evapotranspiration demand. Groundwater is deep and often brackish. The western-central area is devoid of drainage system and surface water resources are meager. Due to low and erratic rainfall, replenishment of water resources is also very poor. The overall probability of drought for region is 47%. The weather condition even in average years for most part of the year remains too dry and inhospitable for successful growth of crops. The main cause of risk in arid agriculture is the variability of rainfall. Therefore, availability and redistribution of available water resources assumed prime importance in the sustainable development of hot arid regions.

## Water Resource Management in Arid Rajasthan

Rain is the principal source of water in this region, which augments soil moisture, groundwater and surface flows. Agriculture and several of the other economic activities in arid areas depend on rain. Under such circumstances every drop of water becomes very precious. Of the total water use about 85% of water is used for irrigation and remaining 15% is used for drinking, industrial and other purposes. About 65% of irrigation water and 30-40% of drinking water is subjected to serious losses. Hence, increasing water use efficiency coupled with increasing availability of water through rainwater harvesting and management is the key to survival on sustainable basis. Rainwater harvesting, its conservation and efficient utilization can solve problem of water scarcity to the greater extend. Rainwater harvesting in small ponds (*nadis*), under ground tanks (*tankas*), *Khadins* (Low lying areas) etc. is an age-old tradition in arid zone of Rajasthan. These traditional rainwater harvesting structures vary in design, shape and size. Central Arid Zone Research Institute, Jodhpur has worked over more than 4-5 decades to improve and refine these technologies.

## Rainwater Harvesting in Nadi and Ponds

The people of rural arid areas live in scattered settlements called *dhani's* distributed over sand dunes, interdunal plains and undulating landforms. Under such conditions it is inconceivable that organized water supply will be feasible option to fully meet the demand of thirsty land, human and livestock. Under such circumstances the system of rainwater harvesting in *Nadi* and farm ponds are viable proposition for a group of farm families or community. *Nadi* is a dugout pond used for storing runoff water from adjoining natural catchment during rainy season. High evaporation and seepage losses through porous sides and bottom, heavy sedimentation due to biotic interference in the catchment and contamination are major bottlenecks. Complete control of seepage and evaporation losses is very costly and not foolproof. Nadi can play a significant role in preventing complete crop failure (Mann and Singh, 1977; Singh, 1983). Singh (1986) reported better utilization of nadi water for raising nurseries, orchards and to support the initial establishment of trees observed instead of watering field crops. Chatterji *et al*., (1985) reported pollution of nadi water due to free access of human and livestock leading to the growth of many harmful bacteria and other water born diseases and therefore, not safe for human consumption in Nagaur district (Raj.). Sedimentation in pond is another major problem. Shankarnarayan and Singh (1979) observed that reduction in water surface area and drainage basin area up to 1.8 to 2.4 and 6 to 8 times, respectively, due to biotic interference. To overcome these problems CAZRI has developed designed *Nadis* with LDPE lining on sides and bottom keeping surface to volume ratio 0.28 and provision of silt trap at inlet (Khan, 1989). *Nadis* also help in recharging ground-water aquifers although their effect varies depending on the underlying soils and rocks. A study of a 2.25-hectare *nadi* with a storage capacity of 15,000 cubic meters in the north Gujarat alluvial area calculated that the pond contributed as much as 10,000 cubic meters of water to the groundwater aquifer in one rainy season.

Farm Pond is an improved version of *nadi* with treated catchment and surplus arrangement for removal of excess water. A farm pond of 20,000 $m^3$ capacity was constructed at Kukma watershed at Bhuj in Gujarat by CAZRI in year 2004. Construction of farm pond resulted in assured availability of 20,000 $m^3$ water even in as small as 150 mm rainfall region (Narain *et al.,* 2006). The collected water was used to provide irrigation to Date palm, ber, aonla and other fruits plants in nearby area. Construction of large number of rainwater harvesting nadis and farm ponds can solve the problem of uncertainty of occurrence of rainfall and can store water during heavy rainfall for non monsoon period for human, livestock and crops on sustainable basis. Therefore, construction/renovation and desilting of nadis/farm ponds during drought relief measures by state government and NGO's can be very beneficial.

## Rainwater Harvesting in Khadins

Recurring droughts and long dry spells are regular feature of arid zone of Rajasthan, which results in crop failures or severe reduction in crop growth and yield. A traditional practice of *khadin* farming in hyper arid region of Jaisalmer ensures better moisture conservation and cropping. The system is very effective even in hyper arid region of western Rajasthan where annual average rainfall is less than 200 mm.

Khadin farms were first constructed by Paliwal Brahmin of Jaisalmer district in the fifteenth century (Sehgal, 1973). The Paliwals connected most of the local catchments into well knit system of *khadin* farms for assured crop production even under low rainfall. Kolarkar *et al*., (1983) observed 2 to 16 times lower electrical conductivity (EC) of *khadin* soils compared to outside farms. The reduction in EC has been attributed to leaching of salts through seepage water in *khadin*. The *khadin* soils hold soil moisture to last up to growing season. The average yield of 20-30 q $ha^{-1}$ for wheat and 13-25 q $ha^{-1}$ for chick pea without any specific agronomical practices and fertilizers were also reported under *khadin*. CAZRI, Jodhpur has evolved a design package and guidelines for construction of khadins (Khan, 1992 a). Improved *khadin* has been constructed by CAZRI near village *Danta* in Barmer district. The catchment area of the *khadin* is 137 ha with 6.88 ha submergence. Provision of 40 m bed bar in 450 m long earthen embankment was provided for spilling over excess water in *khadin* bed. The total water storage capacity of *khadin* is $54.2 \times 10^4$ $m^3$ and beneficiaries are four farm families (Khan, 1998). At another site *khadin* of 20 ha areas was developed in Baorali-Bambore watershed with surplussing arrangements. Before construction of *khadin*, uncontrolled runoff from upper catchment used to wash away seeds, fertilizers, and standing crops besides loss of valuable water. After construction of Khadin, farmer could take excellent *Kharif* and *Rabi* crops (Narain and Goyal, 2005). Collecting water in a *khadin* aids the continuous recharge of groundwater aquifers. Studies of groundwater recharge through *khadins* in different morphological settings suggest that 11 to 48 per cent of the stored water contributed to groundwater in a single season. This replenishment of aquifers means that subsurface water can be extracted through bore wells dug downstream from the *khadin*. The average water-level rise in wells bored into sandstone and deep alluvium was 0.8 meters and 1.1 meters, respectively. There were 500 such *khadins* covering an area of 12,140 ha in Jaisalmer and the crop production from such areas was adequate to feed the people of Jaisalmer district. Large-scale development of *khadin* farms at suitable locations can enhance land productivity.

## Rainwater Harvesting From Constructed Catchment

Under this system, catchments are constructed in such a way that runoff is directed to a desired destination instead of spreading here and there. The desired destination may be crop/ tree to supplement the soil moisture or a reservoir for storage and subsequent utilization. Inter-row, inter-plot and micro-catchment are some of constructed catchments which can be used to enhance the availability of water. Runoff from micro-catchments was generally found to depend upon rainfall and catchment characteristics. The results of seven years field studies showed that micro-catchments produced 13 to 32 per cent of rainfall as runoff at 0.5 per cent slope; and even higher at 5 per cent (36 to 45%) and 10 per cent (26 to 44%) slopes. Runoff generally increased with decreasing slope length; runoff for 5 and 10 per cent slope were nearly equal but greater than for 0.5 per cent slope (Sharma, 1986). Apparently, there is a critical slope beyond which runoff is not affected by slope increases. A large part of the rainfall is absorbed by the sandy soil of the catchment, thereby reducing the total amount of runoff harvested water. Various surface covers and sealant were experimented to increase runoff. Plastic covered catchments were found to generate 95 per cent runoff while Janta emulsion (asphalt), pond sediment and compacted catchments yielded 91 per cent, 88 per cent and 66 per cent runoff, respectively (Sharma et al., 1986). The results of the studies at farmer's field in Kalyanpur (Barmer) showed very high efficiency of moisture conservation with stone and sand filled used polythene bags with associated improvement in growth and establishment of Ziziphus mauritiana (ber) seedlings (Ojasvi et al., 1999).

Inter-row water harvesting using ridge-furrow has also been found useful in raising dryland crops. Under this technique, 50-60 cm wide ridges alternated with 30-40 cm inside furrows (15 cm deep) are constructed using ridger equipment. Crops are planted in furrows adopting a paired row design. Ridges yield runoff to the furrows, thus enhancing the moisture regime in the root zone. Singh *et al.,* (1973) reported 210% increase in the yield of pearl millet with this system. They concluded that ridge-furrow technique has better adaptability for small holders, as no area of the field is lost to catchment construction. Singh (1982) suggested maintaining the furrows and ridges as permanent structures. Thus, if the tillage is restricted to furrows only, the energy input can be substantially reduced.

## Rainwater Harvesting through Tanka for Potable Water

Good quality potable water is a global issue, particularly in developing world because 80% of the diseases in the world are due to poor quality of drinking water. The problem of poor quality ground water used for drinking is more acute in the state of Rajasthan. Rainwater is the purest form of water. Appropriate harvesting of rainwater from roof top or open catchments and its utilization can alleviate problem of salts to great extent. Studies conducted at CAZRI have revealed that roof made of different materials can generate 50 to 80% runoff can be stored in underground cistern (*tanka*) which could provide excellent drinking water round the year. Surface rainwater can also be harvested in tanka using artificially prepared catchment. Till today, the most of the villages are depending on these structures as source of drinking water. Traditional *tankas,* constructed with lime plaster, typically have a life span of three to four years. They suffer from seepage and evaporation losses and in the absence of proper silt traps and pollutant-free inlets, the quality of the conserved water deteriorates over time making it unsafe for drinking.

CAZRI has designed improved *tankas* for individual family to community with capacities of 5,000 to 600,000 litres. Vangani *et al.*, (1988) have observed that an individual family tanka is better managed than a community tanka. The improved *tankas* include silt traps at the inlets to prevent pollutants from entering the *tanka*. The improved designs have a lifespan of more than 20 years. Planting of suitable tree species around the periphery of the catchment area of a *tanka* is recommended to improve the local environment (Khan, 1992 b, Bhati, *et al.*, 1997). CAZRI has constructed 17 improved *tankas* in village Kalyanpur (Distt. Barmer) and Baorali-Bambore (Distt. Jodhpur) under National Wasteland Development Board and National Agricultural Technology Projects (1998-2003). The improved *tanka* design developed at CAZRI has wide acceptability in the region, which has been widely replicated in large numbers under Rajeev Gandhi National drinking Water Mission. The number of improved tanka in different capacity ranges constructed in the region are 11,469 with a total storage capacity of 4,75,200 cubic meters and are sufficient to meet the drinking and cooking water requirements for a population of 1,32,000 throughout the year (Khan & Venkateswarlu, 1993). *Tanka* is highly economical compared to hauling of water from long distances.

## Rainwater Harvesting for Supplemental/Life Saving Irrigation

Studies conducted at CAZRI and elsewhere show that application of water at critical stages of trees/crops growth increases the yield substantially. Complete drought or long dry spells within a season are very common in this region. Harvested rainwater can be used to provide supplemental/life saving irrigation particularly to trees and crops. Khan (1995) observed that with supplemental irrigation the fruit yield of *ber* (*Ziziphus mauritiana*) and pomegranate increased substantially. In comparison to no irrigation, increase in fruit yield with 2, 4 and 6 irrigations (60 litres irrigation$^{-1}$ plant$^{-1}$) for ber was 46.4, 80.3 and 124%, whereas, in the case of pomegranate it was 69.8, 112.5 and 191.7%, respectively. At Jhanwar watershed (Jodhpur) harvested rainwater from a farm pond (271 m$^3$ capacity) was used to grow *ber* plantation and subsequently to provide supplemental irrigation, which resulted in increased fruit yield of ber (8 q ha$^{-1}$) with 1.67: 1 benefit: cost ratio (Goyal *et al.*, 1995, 2007). Katiyar *et al.*, (1999) reported a benefit to cost ratio of 2.5:1 with supplemental irrigation to wheat, mustard and gram with farm pond. The system of rainwater harvesting by way of farm ponds and subsequently its recycling for life saving irrigation can provide an effective check against dry spells and drought for economic yields (Goyal *et al.*, 1997a & b; Goyal and Sharma, 2000).

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# Water Harvesting in the Himalayan Region – Problems & Prospects

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## Abstract

*Development and efficient management of water resources, particularly in the Himalayan region, is an issue of utmost importance from national perspective. The present paper deals with the technology of constructing small rain water harvesting structures for micro level water resource development vis a vis its utilization techniques for life saving irrigation such as promotion of micro-irrigation system. Supplemental irrigations increased crop yields significantly when applied during critical stages of plant growth. The paper also stress upon the importance of creation of local institution to construct small water harvesting structure through community participation in a watershed development program. Appropriate soil conservation measures on watershed basis, groundwater recharge technology with active participation of the local community are described from success stories of different watershed projects.*

## Introduction

Enclosed within the arms of the Indus in the west and the Brahmaputra in the east, Indian Himalayas cover an area of about 50 millon hactares extending through a length of 2500 km from NW to SE and width of 250-300 km. The glaciers and catchments of Himalayan mountains are a source of water for the major rivers of northern India which are lifeline to millions of people downstream in the plains. However, the 'water towers' as the Himalayan mountains are aptly called, have been witnessing a diminishing trend in lean flow discharge due to degradation of catchments and climate change. The hilly region presents a paradoxical situation of scarcity amidst plenty on the water front. Though sufficient rainfall is received in most part of the region during monsoon season (June to September), most of it flows down the steep slopes as runoff and not available for practical use. The terraced cultivation is mostly rainfed and irrigation facilities are very limited mostly in valley areas. The issue of water availability in the mountain eco-system is complex since majority of the water resource available in the rivers flowing down below is not available for use in upper region. The problem of water resource development in the hilly area are typical since the topographical limitations and steep slopes prevent the laying of network of canals and also exploitation of groundwater is not feasible. Springs or rivulets frequently found on hill slopes and in the valleys, constitute the major source of water supply for drinking and irrigation. Watershed based water harvesting and its recycling in hilly areas is like a "liquid gold" which can boost the productivity of land tremendously and also augment the discharge of springs through groundwater recharge. A proper water harvesting strategy can also mitigate the problem of soil erosion and floods to a large extent.

## Water Resource Assessment

Springs constitute the major source of water supply in the hilly regions especially in uplands. Springs are the manifestations of the ground water hydrology of mountainous regions. These are frequently found on hill slopes and in the valleys and carry concentrated outflow of the underground water called base flow, sub-surface flow or lean period flow. Springs may be called small or large depending upon the discharge rate as temporary i.e. seasonal or permanent (perennial) depending on whether the water supply is for a short period or continuous throughout the year. Systematic studies to assess amount and duration of flows in such springs are rarely available. The investigations carried out at Almora in Kumaun Himalayas (Uttarakhand) on the flows of springs revealed discharge in the range of 2 lpm to 20 lpm (Srivastava, 1980) while in Tehri Garhwal region, average minimum discharge varying from 1 lps to 15 lps in summers was recorded (Annon., 1978). The hydrologic monitoring of few springs at Shillong in the Eastern Himalayan region also indicate a water yield of less than 1 lps to 5 lps with the annual water yield of 0.99 to 7.7 ha-m (Prasad *et al.*, 1987). Most of the springs in Garhwal and Kumaun Himalayas are perennial, indicating good potential for developing irrigation facilities for small land holdings through a network of small channels and tanks which needs to be fully explored.

Sub-surface runoff constitutes the major part of the water yield from forested watersheds in Himalayan region particularly the oak forest. Hydrological investigations in Sainji watershed in north-western Garhwal Himalayas revealed that sub-surface runoff component was as high as 89-95% of the total runoff and 44-47% of the rainfall (Sharda *et al.*, 2009). Of late, due to various developmental activities and degradation of catchments, water resources in the Himalayan region have been adversely affected. During a recent survey conducted by the water supply department in Uttarakhand State, it was found that the sources of 805 schemes out of 4719 drinking water schemes had experienced a reduction to the tune of about 50 per cent. The water sources of 121 schemes had completely dried up.

A classical example of declining discharge is Gaula river catchment in Uttarakhand Himalaya, where in 40 per cent of the villages, spring discharge has declined from 25-75 percent during the last 5 to 50 years. Consequently, the river flow has reduced from 12000 $m^3$/day to 5000 $m^3$/day in 15 years due to overexploitation of natural resources in spite of the fact that average annual rainfall remained static at about 2200 mm. The average annual runoff in the Himalayan watersheds is estimated to vary from 15 to 20 per cent in the valleys to as high as 50 per cent in the high hills.

## Water Harvesting and its Potential

Water harvesting is a system of collecting and storage of any form of water rainfall, runoff or sub-surface water for multiple uses such as drinking, irrigation, livestock, fisheries etc. An attempt should, therefore, be made firstly to retain as much rainwater in the soil as possible so as to create favorable moisture conditions for crop growth. The excess water that exceeds the infiltration and storage capacity of soil may then be harvested in the nearby field or at another convenient location in the watershed. In medium to high rainfall areas, in addition to following *in-situ* conservation practices, the surplus water can also be harvested and reused at appropriate locations. Rain harvesting technology is highly location specific depending on climatic, physiographical and socio-economic factors.

The estimated potential volume of rainwater storage through small scale water harvesting structures in different rainfall zones of India is shown in Table1. A total storage of about 24 million ha-m can be created through such structures depending upon annual rainfall.

As can be seen from Table-1, there is a high potential of rain water harvesting through small storage structures i.e. 17.87 M ha-m in the high rainfall zones of India (> 1000 mm rainfall). The high rainfall areas of the country generally comprise of hilly and undulating terrains such as north-west Himalayas (Jammu & Kashmir, Himachal Pradesh, Uttarakhand), north-eastern region, north-eastern part of Bihar, West Bengal, Orissa, Western and Eastern Ghats covering parts of Maharashtra, Karnataka, Kerala, Tamil Nadu and Andhra Pradesh states.

## Traditional Water Harvesting System

Water harvesting is an age old practice in India. It is a process of collection of runoff from treated or untreated land surface/ catchment and storing it in an open farm pond or closed water tank/reservoir or *in-situ* moisture storage in the soil.

Beautifully constructed *Naulas*, which harvest the natural sub-surface flow, were traditionally used for meeting the drinking water needs in the hill areas of Uttarakhand state and are still in use at some places. However, with the advent of governmental schemes of mass water supply, these are generally in a state of utter neglect. There is a well-defined and mutually agreed system of water sharing by the community from these *Naulas*. In the uplands, dugout tanks locally called *Khals* were traditionally made to harvest water from adjoining slopes (saddle area) for serving the water needs of cattle as well as groundwater recharge.

Small water storage tanks (*Hauj*) and irrigation channels (locally called *Guhls* or *Kuhls*) have been commonly used in hilly regions of Jammu & Kashmir, Himachal Pradesh and Uttarakhand states for tapping and conveying the water from the perennial springs for irrigation, domestic and livestock needs. However, most of the *Guhls* are now non-functional and in some cases more than

**Table 1: Estimated rainwater harvesting storage potential in different rainfall Zones of India**

| Rainfall zone (mm) | Geographical area (million hectare) | Rainfall for effective surface storage (%) | Harvestable runoff in water harvesting structure (M ha-m) |
|---|---|---|---|
| 100-500 | 52.07 | 5 | 0.78 |
| 500-750 | 40.26 | 6 | 1.51 |
| 750-1000 | 65.86 | 7 | 4.03 |
| 1000-2500 | 137.24 | 6 | 14.61 |
| >2500 | 32.57 | 4 | 3.26 |
| **Total** | | | **23.99** |

half of the water entering these *guhls* is lost through seepage.

Singh (1988) has reported about the indigenous technique of bamboo drip irrigation of the beetle leaf and arecanut plantation in Jaintia hill district of Meghalaya. In this system, water from natural streams located at higher elevation is conveyed and distributed with the use of bamboo channels, channel supports, water diversion pipes and then bamboo strips. The whole system enables distribution of 15 to 25 litres of water per minute entering the main channel to 10-80 drops per minute at the site of water application without leakage at any point.

An indigenous farming system popularly known as *Zabo* is practised in Nagaland, where land use, namely forest and agriculture in combination with animal husbandry with well founded conservation base, is developed in an integrated manner for water resource development and management for protection of environment and sustainable production (Samra *et al.*, 2002).

## Water Harvesting Measures – Present Status

The following water harvesting measures/ practices are useful in the hilly regions:

- *In -situ* retention of rainfall on the land itself by agronomic/ mechanical measures
- Harvesting the surface/sub-surface runoff and its storage for later use
- Diversion of perennial surface/ sub-surface water sources such as springs and streams into the storage structures
- Roof top water harvesting

Further according to the prevailing geo-morphological and geo-hydrological situations, the water harvesting practices and methods may be classified as those applicable for mid Himalayas and those for the foothills.

## *In-Situ* Water Conservation

In-situ retention of rainwater in the field itself is the most efficient method to recharge and store moisture in the root zone for optimal plant growth. This can be achieved by suitable agronomic measures such as crop geometry, crop combinations, mulching etc. and also by promoting moisture retention by mechanical measures such as bunding, terracing, basins or micro-catchments, contour furrows etc.

## Water Harvesting in Foot Hills

In the foothills, small embankment or dugout type farm ponds can be constructed to store excess runoff water for providing life saving irrigation to crops. About 16.5% of rainfall can be harvested in farm ponds in Doon Valley, Uttarakhand (Sastry *et al.*, 1985) and as much as 42% in the middle Himalayan region.

In Doon valley, 0.20 ha-m capacity farm pond can be constructed for every 1 ha of catchment area. The seepage and evaporation losses in Doon valley account for 70% and 30%, respectively. After cessation of monsoon, the pond loses about 50% of its storage capacity through seepage and evaporation and thus making only 50% and 30% capacity of reservoir available for supplemental irrigation at presowing and CRI stages of wheat, respectively. However, the storage losses tend to be 40% of the initial losses in a period of about 10 years due to sealing of pores by fine sediment.

**Table 2: Expected water yield into farm ponds located in different foot hill regions**

| Region | Soil | Monsoon Rainfall (mm) | Land slope (%) | Expected water yield (%) |
|---|---|---|---|---|
| Dehradun (Uttarakhand) (Himalayan foot hills) | Silty loam | 1600 | 2-4 | 16.5 |
| Fakot (Uttarakhand) (Mid Himalaya) | Loam, silty clay loam | 1900 | 72 | 42 |
| Shillong (NE Hill region) | Clay loam | 1400 | 35 | 27 |

## Water Harvesting Measures for Uplands

### Tanks and *Guhls*

Small irrigation channels locally called *guhls* have been conventionally used in the hilly areas to convey water from small perennial springs/sources to the fields. When the discharge is low, small water storage tanks (*hauj*) are used to store and regulate the water from *guhls* rather than applying it directly to the fields. In the uplands of mid Himalayas, the seepage losses are to the tune of 300-400 lit per sq m of the surface area (Ved Prakash *et al.*, 1979) and hence *kuchcha* ( unlined) tanks lose as much as 80% of their storage capacity through seepage losses. To check seepage losses, cement lined *guhls* have been conventionally used (normally with carrying capacity of 5-10 lit/sec.). Cement being a costly item, low density polyethylene (LDPE) film has been tried as a low cost lining material for guhls in hills (Juyal and Gupta, 1986). Even after taking into account the life of the two lining materials (LDPE film and cement), the cost of LDPE film lined *guhl* is 75% cheaper than the cement lined *Guhl*.

Small cement masonary tanks (20-50 cum storage capacity) have been commonly used to store water from small perennial sources for irrigation, drinking and domestic purposes. LDPE film (800 and 1000 gauge thickness) has been used as an alternative lining material for tanks in Uttarakhand hills (Srivastava, 1984; Juyal and Gupta, 1985). The cost of construction of such tanks varied from Rs.25 to Rs.110 per cum of water storage depending upon topography and availability of construction materials as against Rs. 450 for cement masonary tanks (Table 3). Taking into account the life of both type of materials, the cost of water storage in LDPE tanks was half than that of the cement lined ones. The LDPE tanks have been particularly found suitable for irrigation of orchards. The sides of such tanks are made slanting ( 1:1 slope) and the tank is covered with LDPE film. To protect the film from damage, it has been covered with loose stones, earth or stone masonry in mud mortar.

A reinforced polyethylene film (Geomembrane-200 gsm) has been successfully used at Research Farm, CSWCRTI, Dehradun for low cost lining of small farm ponds of trapezoidal shape ( 9m x 7m top, 5m x 3 m bottom with slanting side slope of 1:1). For covering the film from damage, natural geotextile (coir net and mat) were used. The cost of water storage was Rs. 500 per cum in the poly-lined ponds compared to Rs1350 per cum in case of conventional brick masonry tanks. The ponds are also being utilized for fisheries. Similarly, poly-lined tanks constructed in

**Table 3: Cost of construction of LDPE film lined tanks using different covering material on film at different topographical locations**

| Sl. No. | Location | Side slope | Cost per cum of water storage (Rs.) | Particulars | References and year of study |
|---|---|---|---|---|---|
| 1. | Vivekanand Parvatiya Krishi Anusandhan Shala (VPKAS), Almora (Uttarakhand) | 1:1 | 25.00 | 800 g film covered with round stones on mild slopes | Srivastava (1984) |
| 2. | -do- | 1:1 | 50.00 | 800 g film covered with 15 cm soil layer on mild slopes | Srivastava (1984) |
| 3. | -do- | 80 degree | 120.30 | 800 g film covered with stone wall 30 cm thick on steep slopes | Srivastava (1984) |
| 4. | Operational Research Project, Fakot, Uttarakhand, (CSWCRTI, Dehradun) | 1:1 | 110.00 | 1000 g. film covered with stone masonary in mud mortar (1:6) with 20 cm thickness | Juyal & Gupta (1985) |
| 5. | Research Farm, CSWCRTI, Dehradun | 1:1 | 500.00 | Geomembrane (200 gsm) covered by geotextile material | 2008 |

mountainous terrain of Himachal Pradesh state in India gave satisfactory performance and were low cost substitute to the costly RCC tanks (Rs.232 per cum of water storage in the former compared to Rs.2849 per cum in later).

Network of small storage tanks constructed to capture the storm runoff from the terraced lands could serve for conjunctive use of rainfall and harvested storm runoff to provide life saving irrigation both in *Rabi* and *Kharif* seasons (in case of dry spells). In the uplands, due to topographical limitations, it may not be possible to construct big tanks having sufficient command area of even say 1 ha. Instead several small size tanks (20-50 cum capacity) lined with LDPE film can be constructed in series and distributed to cover a larger area.

## Micro irrigation systems

The mountainous agro-ecosystem of Himalayas is characterized by undulating terrain coupled with limited water resource which needs to be utilized most judiciously and efficiently. The prevailing terraced cultivation in the area with perennial stream flow provides ample scope for gravity-fed efficient micro-irrigation systems (MIS) such as drip and sprinkler irrigation. Due to topographical advantage in the hilly areas, drip or sprinkler irrigation system can be pressurized by elevation difference without the need for pumping. Studies conducted in the hilly region on micro-irrigation systems have shown promising results in efficient water use and saving in precious water and drudgery. In a study conducted under Farmers' Participatory Action Research Programme (FPARP) by

CSWCRTI, Dehradun, it was found that under drip irrigation, the yield and water use efficiency (WUE) of potato increased by 51.4 and 15.3 per cent, respectively as compared to traditional furrow irrigation (Tripathi and Patra, 2009). The yield and WUE of wheat increased by 117 and 41 per cent, respectively under sprinkler irrigation as compared to rainfed conditions. The seasonal water use by potato was 268 m and 204 mm under drip and traditional method of irrigation, respectively whereas the water use by wheat was 296 mm and 192 mm under sprinkler and rainfed conditions, respectively. Though the water use by both crops was higher in case of efficient micro irrigation technique, the performance of these crops was better as compared to rainfed conditions and traditional irrigation techniques which was reflected in increase in yield and WUE. In addition to increased WUE and yield, the labour and time reduced considerably.

In another study in North Western Himalayas, Kumar *et al.*, (2009) found that integrating water harvesting and gravity-fed micro-irrigation system is a feasible option for efficient water management in terraced land for growing vegetables. The performance of the system was found satisfactory which saved 41.1% and 33.3% of irrigation water as compared to check basin irrigation in case of vegetable pea and French bean, respectively. The water use efficiency of the system was significantly higher than check basin irrigation. Economic indicators such as Net present value, Benefit cost ratio, Internal rate of return and Payback period for the gravity-fed MIS were INR 160, 523, 1.78, 12.2% and 3.38 years, respectively. It was recommended that the gravity-fed MIS should be integrated with the water harvesting system to effectively and economically utilize the water in vegetable cultivation in terraced land of the hill farming system. The climate change/ variability is very likely to reduce availability of irrigation water thus requiring saving in irrigation water. The efficient micro irrigation can come handy to resolve these crisis. It is thus concluded that these modern water management techniques have enormous potential in the mountainous Himalayan regions in saving water and increasing crop yield and need to be promoted for sustainable crop production and better management of water resources.

## Rooftop water harvesting

It is an effective means of runoff harvesting from roof tops. The rainwater falling on the roofs of buildings is collected and stored into the cisterns i.e. tanks constructed above or below the ground surface. The stored water may be used for domestic consumption after purification, if necessary. This kind of practice is prevalent in many parts of Rajasthan, Gujarat and North Eastern hill region to meet the domestic requirements (Samra *et al*., 2002). Gupta and Katiyar (1982) presented the scope for utilization of rainwater cistern systems in the North Western Himalayan region of the country. Such a system could also be used for community water supply by collecting runoff in a centralized tank and providing a network of distribution system near a cluster of houses.

It has been estimated that in the state of Uttarakhand (area – 53483 sq km) receiving an average of annual rainfall of 1250 mm, even if 50 per cent of the rain is harvested from only 1 per cent of the total area, it can fulfill the domestic water needs (100 litre per day) of the entire population of the state.

Roof top water harvesting has been prevalent in the eastern Himalayan, however, efforts are being made to popularise it in the western Himalaya also under various government programs. Many hills states including Uttarakhand are in the process of enacting legislations to make rain water harvesting mandatory in all the new buildings to be constructed.

## Hydraulic Ram (Hydram) Pumps

*Guhls* and tanks have limited potential since they can irrigate lands below the water source. Most of the surface water sources in the hilly regions lie below the agriculture fields. The conventional methods of lifting water by engine or electric motor pumps etc. have limited application due to erratic power supply, inadequate support and maintenance facilities and high operating cost. The hydraulic ram (hydram) is a self-powered impulse pump which uses the energy of the falling water which is abundantly available in the hilly areas to lift some portion of this water to a level much higher than the original source as a result of water hammer effect. The device can work for 24 hours a day for many years (expected life 30 years) and requires little attention except for change of rubber packing, when needed. The hydram pump generally lifts 1/7 to 1/10th of the water delivered to it and works at the best efficiency (66-70%) if the drive head to delivery head ratio is 1:3 to 1:4. The hydram pump can lift water upto as high as 152 m but a more common lift is 45 m. However, a minimum flow of 5 litres per minute in the drive pipe and a minimum fall (drive pipe) of one metre from the source to the ram is needed. Singh (1977) has summarized water lifting capacities for various sizes of hydram pumps against lift magnification factors ranging from 2 to 30.

Another effective means of judiciously applying this water for irrigation is through use of sprinklers (gravity fed) in conjunction with hydrams in hills. The water is raised and stored in the tanks at higher elevations. The fields located on lower elevations are irrigated using sprinklers through network of pipes. Number of hydrant points are located near the fields at convenient locations so as to connect them with sprinkler system whenever required.

## Ground Water Recharge

Presently, around half of the irrigation demands in India are met from ground water resources. Ground water is being over exploited in most of the Asian countries including India and its conservation as well as management is catching attention of scientists, technocrats, bureaucrats and policy makers. The component of rainfall contribution as infiltration to ground water varies from 3 to 25 per cent in different hydrological situations. This needs to be supplemented through artificial recharging as the extraction generally exceeds the natural rate of recharge. Recharging of ground water is one of the major activities of watershed management programmes. Various watershed studies have amply demonstrated that there is considerable increase in ground water recharge through adoption of soil and water conservation measures like percolation tanks, contour bunding, gully plugs, check dams, trenching, and other agronomic measures. Spectacular increase (0.2 to 2 m) in ground water table was recorded in different agro-climatic regions of the country as a result of soil and water conservation measures taken in the watersheds.

An increase of 50 to 150% in number of dry wells and an increase of over 14%

in the water yield of dug/open wells was registered as an impact of various watershed interventions.

## Enhancement of Lean Period Flow - Sahastradhara

The hilly regions face an acute water shortage after the monsoon period which usually lasts up to mid- September. The lean period flow available in the streams is the only source of water for the use of local people since ground water is very deep. In the Sahastradhara mined watershed (area-64 ha) undertaken for treatment in 1985 by CSWCRTI, Dehradun, the dry weather flow in the main drainage channels used to last by the end of December. The post treatment analysis indicated that there was not only a quantum jump in the dry weather flow at any given time but it also prolonged by 150-240 days (Fig. 1). This was possible due to increased sub-surface component of runoff water during the monsoon season as a result of various bio-engineering measures undertaken in the watershed. After treatment, the main drainage channels became perennial and some new water sources also appeared in the watershed. The farmers in the nearby area utilized this augmented water resource to meet their irrigation and domestic needs (Juyal *et al.*, 2007).

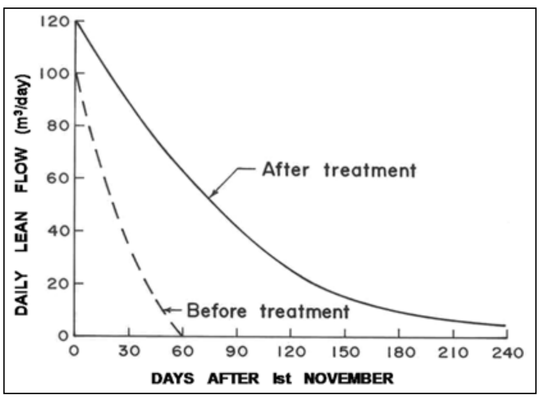


*Fig. 1: Increase in lean period flow due to treatment at Sahastradhara watershed*

## Drought Negotiation through Water Recharge

Water harvesting and other soil and water conservation (SWC) measures provide resilience in production against unfavourable weather conditions. Such measures adopted in Fakot watershed of Tehri Garhwal district (Uttarakhand) helped the farmers in sowing large percentage of their arable lands (96%) in time even during the drought year of 1991. On the other hand, there was about 18 percent reduction in the net sown area outside the watershed. The reduction in average productivity of arable land was only 5 percent in Fakot watershed as compared to 40 percent in the outside areas. Productivity of the non-arable land was worst affected by severe drought in the district. However, the groundwater recharging structures (trench, pits, gully plugs, check dams) helped the farmers to produce sufficient quantity of fodder. It is, therefore, established that sustainable production from treated watersheds can be achieved even under severe drought conditions.

## Use of Harvested Water

The harvested rain water is a scarce commodity and, therefore, should be utilized very judiciously. The recycling of water can be planned on the basis of weekly rainfall probability analysis and available soil moisture status for judicious use of harvested water. In addition to irrigation, this water can be used for multiple uses e.g. drinking, fisheries, cattle needs, groundwater recharge etc. Micro level water harvesting projects are much cheaper than the conventional major and medium irrigation projects. Moreover, small water harvesting structures can be better managed by the community following participatory approaches.

## Enhancement of Crop Productivity

Studies conducted in Doon valley indicate that one supplemental irrigation (5 cm) to wheat crop at presowing stage from the harvested pond water increased the wheat yield by 85% and an additional irrigation (5 cm) at crown root initiation (CRI) stage increased the yield by 128% (Singh *et al.*, 1981).

Similarly studies at VPKAS, Almora (Uttarakhand) have shown that the wheat crop does not suffer from moisture stress during the entire growth period if one pro-sowing irrigation of net 15 mm depth and one irrigation of net 40 mm depth at CRI stage is provided through rain water stored in small poly-lined tanks which provide an assured yield of about 30 q/ha against the present best average of 15-20 q/ha under rainfed conditions.

## Community Participation in Water Harvesting

A successful example of participatory water resource development has been demonstrated through a dugout pond constructed at village Kalimati in Raipur Block of Dehradun district (Uttarakhand). The pond of 260 cu m capacity harvests interflow and provides irrigation to 42 ha land in villages Kalimati and Bhopalpani benefiting 125 families through lifting as well as underground pipeline systems (Sharda *et al.*, 2006). Out of a total cost of about Rs.1.98 lakhs, the farmer's contribution was 35 percent in terms of labour and collection of local materials and the entire cost was recovered within a period of two years. Enthused with the benefits of sub-surface flow harvesting, another tank of 350 cum capacity was constructed in December, 2003 in a participatory mode at village Bhopalpani at a total cost of Rs.3.47 lakhs in which farmers contribution was as high as 51 percent. This technology motivated the farmers of non-adopted adjoining village Paw-Wala-Soda who managed funds from the State agencies and members of Parliament/Legislative Assembly for developing a water resource under the active guidance of CSWCRTI, Dehradun. A pipeline system of about 4.5 km length was laid out to divert water from a perennial source, 2.5 km away from the village to irrigate 25 ha agriculture land benefiting 44 farm families in which farmers' contribution was about 25 per cent. Water user societies have been constituted for equitable sharing of harvested water among the beneficiaries on mutually agreed payment basis covering the operational and maintenance cost of the system.

## Multiple Use of Water

The harvested water can be judiciously applied for multiple uses such as drinking, irrigation, livestock, fisheries, etc. to optimize water productivity. An integrated farming system (IFS) based on multiple uses of water, comprising of water- mill, fisheries, poultry, piggery and agriculture has been developed in mid-Himalayan region of Uttarakhand state to provide additional monetory benefits to small and marginal farmers who largely depend on watermills for their livelihood. The system would cost only about Rs. 1,20,000/- in addition to the existing set of water mill and terraces. The system yields a net profit of about Rs. 23,000/- annually against only Rs.10,000 earned from the watermill alone. The synergetic benefits such as remnants from watermill which would serve as a feed for fish, pigs and poultry birds and droppings of the poultry which would act as fish- feed can be mutually harvested in the system in addition to pig and poultry dung which can be utilized as a manure in the agriculture fields. Farmers can recover the initial investment within a period of 6 - 7 years.

## Economics of Water Harvesting

The cost of generating micro-irrigation through small water harvesting structures varies from Rs. 9000 to 30,000 per ha; while the cost of minor irrigation is estimated to be around Rs.70,000. The benefit cost ratio of various water harvesting structures in different regions was found to vary from 1.48 to 3.89.

The Benefit Cost (B: C) ratio in respect of unlined farm pond (1.65 ha-m capacity) in Doon valley with presowing irrigation and 50 kg nitrogen/ha to wheat crop was 1.85:1 for 30 years project life (Ram Babu, 1987). Economic evaluation of Sukhomajri Project where an embankment type pond (5.5 ha-m capacity) was constructed in a mini watershed, the B: C ratio worked out to be 1.63:1 for 30 years of project life at 10% discount rate.

In a water harvesting project constructed at Kalimati and Bhopalpani villages in Doon Valley of Uttarakhand where interflow was harvested in a pond and conveyed to fields through HDPE pipeline, the Net Present Value worked out to be Rs.23,55,261/- with benefit cost ratio of 1.42:1 considering project life as 30 years and discount rate as 10 per cent. The internal rate of return was as high as 94.5 per cent even under adverse situation. It may thus be concluded that water harvesting and recycling is an economically viable proposition.

## Watershed based Water Harvesting System

Water is an essential life sustaining service provided by Himalayan watersheds for which health of the watersheds need to be maintained properly. However, the current situation is not satisfactory. The potential erosion rate in the Himalayan region has been estimated to be very high with about 39 per cent area having erosion rate of more than 40 t/ha/year. Overall, about 68 per cent of the area has erosion rate more than the permissible rate of 10 t/ha/year. This calls for a massive program for treatment of watersheds.

Water harvesting has been given major thrust in the ongoing watershed development programmes such as NWDPRA, IWDP, Hariyali, etc. The recent Common Guidelines on Watershed Development Programmes in India have further added impetus to rain water conservation and harvesting. Some success stories of the watershed development programmes with special reference to water harvesting and groundwater recharge are presented below:

## Fakot Watershed (Tehri Garhwal, Uttarakhand)

In the middle Himalayan region at Fakot in Tehri Garhwal District of Uttarakhand, a small watershed of 370 ha area was treated with soil and water conservation measures including water resource development through small water harvesting structures and drainage line treatment. The measures included construction and repair of *guhls* (2310 m length), construction of cement lined and LDPE lined tanks of 150 cum capacity (24 nos.), renovation of bench terraces (27.4 ha), gully plugs (66 nos.) and landslide control measures (2 ha). In addition, fuel fodder and orchard plantation works were also carried out. Consequent to water resource development activities, paddy and wheat yields increased by 16.5 q/ha and 19.3 q/ha respectively. These measures considerably reduced runoff and soil loss from 42.0 to 14.2% and 11.9 to 2.5 t/ha, respectively. The benefit cost ratio considering 25 years project life has been worked out as 2.71 at 12 per cent discount rate (Dhyani *et al*., 1997).

## Sainji Watershed (mid-Himalayas)

In the Himalayan region, the water available for drinking, irrigation and other needs is either through rivers/streams as surface water or through springs as sub-surface flow. However, due to mismanagement of watersheds, there is a marked decline in the dry weather flow. Scientific information on the hydrology of mountainous watersheds is scanty and inadequate. Hence to bridge this gap, Sainji watershed (area-265 ha) situated in Aglar (Yamuna) basin in Tehri Garhwal Distt. of Uttarakhand was taken up by CSWCRTI, Dehradun during 2000 for hydrological investigations and improving water productivity following participatory approaches. The watershed has mixed land use comprising mostly of forest with agriculture to forest area ratio being 1:6.

Conservation measures for restoration of the ecosystem included i) contour trenching for intercepting overland flow, ii) plantation of multipurpose trees (fuel, fodder, timber), horticultural plants and grasses, iii) rehabilitation of landslide affected areas by bio-engineering measures, and iv) renovation of bench terraces for *insitu* rain water conservation. A R.C.C. tank of 80,000 litre capacity (size 10 m x 5 m x 1.6 m ) was constructed through community participation to store perennial flow from oak forest. Out of the total cost of Rs. 1,70,000, farmers contribution was Rs. 22,800 (13.4%).

The hydrological investigations revealed that sub-surface flow was the chief contributor (37 to 46% of rainfall) while surface flow comprised of only 1.6 to 5.2% of the total runoff in the mountainous watershed mainly during the rainy season. Sub-surface flow in Oak forest watershed was almost 9% higher than the scrub forest watershed. Hence, it is essential to maintain a well managed Oak forest for sustained water yield. Bio-engineering measures in degraded lands have resulted in increase in base flow from the watershed by about 15%, minimized the chances of occurance of landslides and improved seedlings growth. Development of water resources and storage of rain water for utilization in dry spells has ensured sustainable crop production. The R.C.C. tank was able to irrigate about 15 ha area on an average after the cessation of monsoon by harvesting flow from small streams (3-6 l/s).

## Land Degradation and Mass Erosion

The major mass erosion problems in the Himalayas are due to landslides, minespoils and torrents. About 10-20 landslides/slips may be observed per km on hill roads. Mining in Himalayas covers an area of 25,057 ha (mostly limestone mining) and an area of 2.73 million ha is affected by torrents in the country. Soil erosion can be expected at the rate of 320-4000 t/ha/year due to landslides and about 550 t/ha/year in the minespoil areas. Major landslides in Himalayas result in an annual loss or more than 50,000 man hours and 5000 vehicle hours/km on hill roads resulting in a loss of Rs.350 million annually. It is estimated that mining in Doon Valley alone reduced food production by 28%, water resources by 50% and livestock production by 35%, whereas hill torrents are estimated to damage 100 hectares of forest land every year with trees worth Rs.10 million. Land degradation results in loss of water quality, increase in peak discharge rate in the lower order streams, reduced subsurface water recharge and loss of perennial flow in the rivers. Restoration of these areas by bio-engineering measures improves the flow regime and water quality (Table 4 & 5).

## Gaps and Future Needs

Undoubtedly, rainwater harvesting and its judicious utilization and groundwater recharge are of utmost importance and concern particularly in the context of enhancing productivity of land and conservation of resources in the Himalayan region. Though massive watershed development programmes in the country have been in operation for the past many years, success stories are few and far between. In order to achieve the desired goals, a mass awareness programme in a mission mode involving the local community is highly desirable. Another lacuna in this respect is lack of appropriate technology and know-how as water harvesting and groundwater recharge measures are highly location specific and depend on a variety of factors. The impact of soil and water conservation measures on watershed basis has not been evaluated on the flow regimes at micro and macro-scales in a systematic manner. Therefore, upstream- downstream linkages in conservation and management of rainwater and groundwater recharge need to be critically analysed. Also impact of land use changes on the availability of water

**Table 4: Effect of bio-engineering measures on landslide (1964-1994) and minespoil rehabilitation (1984-1996) project**

| Particulars | Landslide project | | Minespoil project | |
|---|---|---|---|---|
| | Before treatment | After treatment | Before treatment | After treatment |
| Runoff, mm | 55 | 38 | 57 | 37 |
| Sediment load, t/ha/yr | 320 | 5.5 | 550 | 8 |
| Dry weather flow, days | 100 | 250 | 60 | 240 |
| Vegetative cover, % | < 5 | > 95 | 10 | 80 |

**Table 5: Water quality parameters (ppm) for treated and untreated minespoils**

| Item | Ca | Mg | $SO_4$ |
|---|---|---|---|
| Treated mine | 74 | 34 | 138 |
| Untreated mine | 188 | 39 | 240 |
| Water quality standard | 75 | 50 | 250 |

resources and perenniality of streams needs to be quantified in view of the rapid growth in urbanization and industrialization.

## Key Issues and Recommendation

- Traditional systems of water harvesting (e.g. *Chaal, Khaal* and *Naula*) be preserved, rejuvenated and further improved.
- Development of appropriate water harvesting technology suiting the typical hill situations.
- In the hills due to topographical limitations, small lined tanks for water storage can only be constructed. In view of fragile geology, RCC construction is recommended to prevent cracks due to unequal settlement of foundation. However, poly-lined tanks (20-50 cum capacity) constructed in series should be propagated as a low cost measure.
- In view of limited water resource availability in the Himalayan region, micro-irrigation systems such as drip and sprinkler need to be installed on a massive scale to improve the productivity and water use efficiency particularly for vegetable and horticulture crops. However, due to high initial cost of the system and poor economic condition of hill farmers, this needs to be heavily subsidized by the government. Integration of low cost water harvesting with low head micro-irrigation is desirable.
- An underground pipeline system is a viable alternative to conventional stone masonry open channels (*guhls*) for improving the conveyance efficiency and avoiding recurring maintenance.
- Roof top water harvesting as prevalent in the NE Himalayas should be propagated in NW Himalaya also to meet the domestic water needs and augment groundwater recharge.
- Multiple use of available water such as water mill, fisheries, poultry, piggery etc to realize optimum benefit from limited water resource and improve livelihood of farmers.
- Proper institutional mechanism (Water Use Society) and equitable sharing of water resource. Understanding upstream-downstream linkages, complementaries and conflict resolution.
- Application of hydrologic models, remote sensing and GIS techniques in assessing water harvesting potential and location of structures. Easy availability of high resolution imageries and their proper utilization by user agencies to be ensured.
- Scope of popularizing water harvesting and use under various programs (such as MNREGA) to realise desired benefits from multiple use of water.

## Conclusions

Development and efficient management of water resources, particularly in the Himalayan region, is an issue of utmost importance from national perspective. The technology of constructing small rain water harvesting structures for micro level water resource development provides a viable cost effective alternative to the major irrigation projects for which environmental stipulations are becoming very stringent. To make efficient use of limited available water, micro-irrigation systems (drip/ sprinkler) should be promoted. Creation of local institutions was much easier and success rate was found to be higher wherever some irrigation could be provided by constructing small structures through community participation in a watershed development programme. Supplemental irrigations increased crop yields significantly when applied during critical stages of plant growth. Appropriate soil conservation measures on watershed basis are urgently needed to replenish the declining water tables and sustaining flows in springs and rivers. The water harvesting and groundwater recharge technology needs to be propagated extensively with active participation of the local community. The impact of SWC measures and landuse changes on availability of water resources and changes in flow regimes needs to be studied systematically at micro and macro-watershed scales.

# Application Technologies for Harvested Rainwater in Ponds: Issues and Prospects

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## Abstract

*Rainwater harvesting in farm ponds for supplemental irrigation are considered as an important strategy in present day dryland farming. These are promoted through various development programs as a drought proofing strategies. However the lifting technologies for the shallow depth farm ponds are rarely discussed. The present paper takes the account of present status of application technologies; describe different prevailing water lifting techniques used in different part of India, discuses issues associated with current water utilization techniques.*

## Introduction

The rainfed agriculture is practiced in major part of the country. This accounts to 62% of net sown area (>90 m ha) that contributes to 44% of food grain production and supporting 40% of human population. These areas get an annual rainfall between 400 mm to 1000 mm which is unevenly distributed, highly uncertain and erratic. In certain areas the total annual rainfall does not exceed 500mm. The crop production, depending upon this rain, is technically called dry land farming and areas are known as dry lands. The productivity in this region is significantly low (< 1t/ha). The major ecological and economical factors that attributes to low productivity include rainfed cultivation, small and fractured land holdings, insufficient soil moisture for germination and limited scope to adopt intensive agriculture.

Rainwater harvesting in farm ponds for supplemental irrigation is an important strategy for stabilizing yields of rainfed crops. Farm ponds are promoted in the integrated watershed programmes and under MGNREGS as a drought proofing strategy. More recently, farm ponds are integrated with micro-irrigation programmes under the National Horticulture Mission, particularly in states like Maharashtra and Andhra Pradesh. With continued over-exploitation of groundwater, it is important to use surface water harvested as surplus runoff in dug out ponds, either as stand alone resource or in conjunction with groundwater for enhancing water productivity, particularly in arid and semi-arid regions.

Dug out ponds both as community structures and on individual holdings is a key intervention in most land and water conservation programmes. The water stored in farm ponds is relatively small and seasonal. Due to runoff from cultivated fields, the water contains lot of sediment posing problems for micro-irrigation systems. Operational research by CRIDA found large number of dug out structures are created across the country under MGNREGS, but in very few cases the water is actually being used for supplemental irrigation during dry spells. This is mainly due to lack of appropriate lifting devices which can be used in remote areas where electric power is not available. Earlier research in AICRPDA network on ponds focused on optimizing the size, lining and choice of crops for highest returns. Several lessons are learnt on using pond water on farmers' fields. Many options for lifting water from the ponds viz., pedal/cycle powered pumps, low capacity diesel /electric motors are being used for lifting water from shallow ponds. Different conveyance systems like sub-surface drips, sprinklers and rain guns are being used to apply the water from the ponds. However, so far low lift pumps have not been properly standardized in terms of power source and capacity. Similarly, the ideal conveyance mechanism from pond water has not been standardized particularly in terms of efficiency of water distribution in the field and overcoming the problems of sediments clogging the micro-irrigation systems.

The Planning Commission in the XII Plan strategy has highlighted the importance of rainwater harvesting and supplemental irrigation as a key strategy for climate resilient agriculture. The Rainfed Area Development programme (RADP) of Ministry of Agriculture also promoted ponds as a key component of IFS. Therefore, there is a need to bridge critical gaps in farm pond technology in terms of water lifting and conveyance.

## Irrigation and crop productivity:

Rainfall is the most significant climate factor that affects the crop growth and production from the rainfed areas in the country. A good example is the interaction between annual food grain production in India and the summer monsoon rainfall. The fall in production is usually observed during the years of deficit rainfall and vice versa i.e. during years of excess rainfall. The annual rainfall in the rain fed region is quite erratic with large spatial and temporal variations. The coefficient of variation increases with decreasing rainfall. While it is about 20% in dry sub-humid region, it is as high as 60% in the arid rain fed region. Besides water, other bio-physical and socio-economic constraints limit the productivity of crops and livestock. Progress has been quite slow in rain fed agriculture, which constitutes bulk of our agricultural land. The productivity of rain fed agriculture is less than half of the productivity of irrigated lands (Table 1). It may be seen that irrigation can lead to substantial improvements in the productivity of rain fed crops.

**Table 1. Yields of principal crops under irrigated and unirrigated conditions**

| Crop | Irrigated | Unirrigated | % increase expected over unirrigated |
|---|---|---|---|
| Rice | 1880.3 | 1220.4 | 54.1 |
| Sorghum | 1242.6 | 606.9 | 104.7 |
| Pearl millet | 1170.2 | 596.2 | 96.2 |
| Maize | 2040.5 | 1339.2 | 52.4 |
| Ragi | 1966.8 | 995.9 | 97.5 |
| Wheat | 2068.1 | 1100.1 | 88.0 |
| Barley | 1836.6 | 1127.2 | 62.9 |
| Gram | 830.0 | 548.5 | 51.3 |
| Groundnut | 1244.2 | 844.4 | 47.3 |
| Sugarcane | 70687.5 | 43161.2 | 63.8 |
| Rapeseed &mustard | 893.6 | 573.2 | 55.9 |
| Cotton | 440.3 | 195.1 | 125.7 |
| Jute | 1952.6 | 1502.8 | 29.9 |

1 Average of 1985-86 to 1991-92 over different states

Source: Central Water Commission (1995)

## Water Harvesting and utilization in agriculture : Indian Experience

In view of the agricultural scenario of Indian rural settings, there is a shift in paradigm from ground water recharge to small size surface water harvesting and recycling to agriculture to attain sufficient soil moisture for successful crop production. The intervention of water harvesting enables to increase the cropping intensity substantially and thus increase farm income. The average productivity of 1.0 t/ha of dryland agriculture could be doubled easily by providing 1 or 2 irrigation. The major impediments in realizing the potential of water harvesting and recycling in dryland agriculture is however, the economical and effective means to lift water and distribute the same at the field. The existing means of lifting pumps is grossly mismatched because its turns to be over designed in view of small size water harvesting ponds (usually of capacity up to 1000 $m^3$). Moreover the lifting pump depends upon the supply of either electricity or fossil fuels. Thus the affordability of this means to the small and marginal farmers is a major concern. To avoid the economic liabilities associated with lifting pump and increase the profitability from limited land and climate resources, this class of farmers usually goes for hand watering of crop by fetching water as head load. This consumes lot of time along with physical labour. The present innovation is proved as the economical and efficient alternative to the water lifting and high pressure requiring irrigation system. The present innovation is a perfect match between the water available and area under command can be extensively used for small scale vegetable production that improve quality of life by means of providing food and nutritional security alongwith income generation.

The empirical nature of soil-plant-water-atmosphere system and complex relationship among the various interacting factors of the water balance, simulation modeling has been carried out by several researchers in the past to determine the optimal design of the runoff recycling based systems for crop production (Srivastava, 1996). Ambast et al (1998) recommended that 20 % of the watershed area can be diverted to the water harvesting system based on the results from the soil water balance model for rice field. Islam et al (1998) based on his studies in low rainfall areas of Bangladesh, recommended 8 % of the farm area if put under water harvesting system, is economically feasible and reported 20 % increase in rice yield. Panigrahi et al (2005) recommended 12 % area under water harvesting system for the eastern region.

Several studies on supplemental irrigation using on farm water storage system has been carried out in the past (Rathore et al, 1996; Panigrahi et al 2005). Construction of small reservoir of capacity less than 200 $m^3$ is a good economical alternative for storage of excess rainwater and its reuse as supplemental irrigation to *kharif* crops during dry spell of monsoon season and pre-sowing irrigation to the crop of *rabi* season during November to April (Panigrahi et al 2005, Paul and Tiwari, 1994, Syamsiah et al, 1994,).

Sustainable management of water resources with due respect to ecological, economic and ethical blended with technical feasibility requires a holistic and integrated approach involving engineering, socio-economic and environmental aspects. Water resources development requires a judicious mix of large, medium and small reservoirs based on the integration of techno-economic feasibility and environmental capability along with regional demand. There seems to be no scope of any controversy in this respect since India lags far behind in meeting its demand for water. Therefore, any addition to its resource through any means big or small would contribute to the socio-economic upliftment of the people of India. It also seems that no single strategy such as reduction of losses to same water alone (Table 2) would work unless it is fully supported by development of additional sources of water and its multiple uses. Therefore, the focus must lie both on development and management.

## RKVY policy for new tanks and ponds

The farm ponds should be constructed and lined by plastic sheets of 500 microns such that water is available for 2-3 life saving irrigation. The construction of ponds/ tanks on the field of individual farmers for the storage of rain water may be of the size 20 m x 20 m x 3 m which would cost Rs.1.20 lakhs per tank including polythene lining (cost of lining Rs.0.40 lakh) as adopted in National Horticulture Mission. The site for the construction of ponds/ tanks would be carefully selected so that minimum earth work is required for construction and sufficient catchment area is available for runoff to fill the tank. The command area would be about 2 ha. Construction of farm ponds would be taken up in clusters of villages in a campaign mode, so that the execution of the work is expedited and close monitoring is facilitated for creating visible impact.

Small capacity farm ponds with storage capacity varying from 500 to 2000 $m^3$ are constructed and popularized at massive scale post introduction of employment guarantee scheme. These are constructed as a means to store surplus rainwater and to use to mitigate adversity of dry spell as well as pre sowing irrigation for post monsoon crop. The pond sizes are varying from 12m X 12m X 3m to 30mX30mX3m.

## Water Lifting Devices

According to power sources water lifts can be classified as manual, animal and power operated devices. The brief description of these devices is as in Table 3.

**Table 2. Water saving strategies in agriculture**

| Sr.No | Items |
|---|---|
| 1 | On farm land and water management that would include, land leveling, zero tillage, bed and furrow farming, precision farming, improved surface irrigation techniques and land drainage |
| 2 | Improved pressurized irrigation techniques |
| 3 | Improved agronomic practices that would include time of sowing, crop varieties, cropping systems, conjunctive use and mulching |
| 4 | Crop diversification |
| 5 | Rainwater management in agriculture including three tier system developed at CSSRI, Karnal |
| 6 | Irrigation regime in rice crop including shallow submergence, irrigation scheduling at hair cracking and dry seeding or irrigations at critical stages in other crops |
| 7 | Deficit irrigation particularly under high water table conditions |

**Table 3 Water lifting devices prevailing in India**

| Sl. No. | Devices | Capacity | Maximum lift | Maximum head at delivery | Possibility of attachment of modern irrigation system |
|---|---|---|---|---|---|
| **Human powered devices** | | | | | |
| 1 | Swing basket | 3500-5000 lph | 0.75 | Negligible | no |
| 2 | Counterpoise lift | 2000 lph | 2-3 m | Negligible | no |
| 3 | Don | 2500-4000lph | 0.8-1.2 m | Negligible | no |
| 4 | Archimedean screw | 1600 lph | 0.6 to 1.2 | Negligible | No |
| 5 | Paddle pump | 18000 lph | 0.45-0.60 | Negligible | no |
| **Animal powered devices** | | | | | |
| 6 | Rope and bucket lift | 9000 lph | 0.5 | Negligible | No |
| 7 | Self-emptying bucket | 8000 lph | 9m | | No |
| 8 | Two bucket lift | 14000lph | 5 m | | No |
| 9 | Persian wheel | 10000 lph | 9m | | No |
| 10 | Chain pump | - | 6m | 0.6-0.9m | No |
| **Mechanical powered devices** | | | | | |
| 11 | Hydraulic ram | 3000 lph | - | 3 m | Limited |
| 12 | Monobloc pump (2 hp) | 50000lph | 20-50 | 4-30 m | Yes |

## Some innovation in water lifting and utilization

### *Low energy water applicator (LEWA)*

Considering the overall farming situation in developing countries particularly India it has been observed that the available options of efficient irrigation technologies are unable to cover up small and marginal farm holders due to lack of the applicability and acceptability in terms of their needs, priorities and financial capabilities. This makes imperative to develop a substitute of existing technologies that could be cheap simple and less capital intensive as well as applicable for small farms. The ICAR Research Complex for Eastern Region, Patna developed LEWA device, which can be used in place of high pressure overhead sprinkling nozzles (Singh et al. 2009). Singh et al. (2009) The performances of a low cost water and energy efficient device called LEWA which can be used in place of overhead impact sprinklers to irrigate field and row crops efficiently at small farms were evaluated. LEWA can be operated at an operating pressure range 39 to 98 kPa at its nozzle head, with discharge rate 0.87–1.10 m3/h, and throw diameter 6–8 m. Since operating pressure at the nozzle head governs overall system pressure and reflects the total cost of the system, size of prime mover pump required and its operational cost; therefore the developed device holds greater promise in development of a cost effective water and energy efficient pressurized irrigation system for small and marginal farmers possessing small and fragmented land.

### *Small scale Solar based water lifting and application using micro-irrigation attachment*

The micro-irrigation system essentially employs principles of hydraulic characteristics of pressurized pipe flow. The micro-irrigation system is the assembly of several components that convert the continuous flow of water into drop flow to achieve higher water use efficiency. Conventionally, micro-irrigation system directly connected to delivery head of the pump and so this system requires high pressure at the delivery head for proper functioning. In most of the case the source of water being the ground water and therefore a pump of capacity of 5 hp or more running on either electricity or fossil fuels is essential for successful operation. Thus the conventional irrigation system prohibits the use of surface water and moreover the compulsory choice of higher capacity pump causes gross mismatch between size of pump and available plot size. The solar version for this configuration of irrigation system requires huge investment making this a costly preposition. In view of these facts, the present innovation was derived addressing the three major issues to substantiate the sustenance farming of dryland agriculture practiced by small and marginal farmer.

1. Utilization of surface water from small scale water harvesting.
2. Minimizing the dependency on energy either from electricity, fossil fuels or both and so enabling in reducing the carbon footprint.
3. Increasing the cropping intensity for food and nutritional security by enabling the farmer to intervene into vegetable cultivation after monsoon season.

Due consideration of the techno- socio-economic situation of the small and marginal farmers practicing agriculture in drylands were attended while developing this system. In present context, the average farm size is considerably small in case of small and marginal farmer and hence affordability and availability of irrigation (mostly ground water lifted using high capacity pumps) is a major concern. These leads to rainfed farming that limit the cropping intensity and thus profitability from agriculture. Considering these issues in the background the present water application system has been developed. The developed irrigation system includes three broad components namely, solar power generation system, water lifting system and water distribution using water emitting devices operated through gravity.

### *Solar power generation unit*

The solar power generation unit consists of solar panel, solar charge control unit, battery and inverter. These components were selected after considering the compatibility and optimality to achieve higher efficiency and better economics. The solar panel charges the battery through solar charge control unit. The solar panel of size 1.44 $m^2$ has the capacity to the generate 144 watt from solar energy. The energy stored in the battery is supplied to the small pump through inverter.

### *Water lifting system*

The small pump that is connected to the inverter operates with 110 watt input power and 0.06 kW shaft power lift water at the rate of 900 litre per hour at 4.5 m delivery head. The water is lifted to the elevated temporary water storage tank of 1000 litre capacity. This water storage tank is placed at elevation such that the water level in the tank is 3 meter above the ground. Hence in this process a gravity head of 3 m is obtained which is equivalent to 0.3kgf/cm$^2$ hydraulic pressure.

### Water distribution system

The water storage tank is attached with water distribution system. The attachment could be micro-sprinkler irrigation system (Attachment A) or micro-tube irrigation system (Attachment B). These water distribution systems however are most suitable for vegetable cultivation in small plot size of 0.5 acre or less. The attachment are designed such that the water application rate should be equal to the water inflow rate to the storage tank resulted from pump. In this way the water level in the storage tank could be stabilized and hence this could provide constant pressure to the attached irrigation system. In this way maximum uniformity in the water application through attached irrigation system could be achieved.

The attachment A were connected with the outlet of the storage tank through 75 mm main/submain PVC pipe that directed water flow to micro-sprinkler through 16 mm LDPE lateral pipe. The field placement of micro-sprinklers is carried out in such a fashion that it distributes water uniformly. The optimal spacing of micro-sprinkler is 2.5 meter by 2.5 meter. 20 such micro-sprinkler having discharge capacity of 45 litre/hr was operated. Similarly attachment B was also attached with the storage tank through 75 mm main/submain PVC pipe by means of 16 mm lateral pipe. The micro-tube of 1.2 mm diameter and 50 cm long was connected to lateral that directs water flow to small storage provision of 16 mm diameter and 10 cm long sealed at both end (made using 16 mm lateral pipe). This caused pressure dissipation due to hydraulic phenomena of sudden enlargement. This storage provision further distributed water to the star configuration of micro tubes (set of 4 microtubes of 1.2 mm diameter and 50 cm long) that placed to individual plants. This provision further dissipates the energy due to hydraulic phenomenon of sudden contraction. As a result, this mechanism transforms the continuous flow of water in to the drop flow. The resultant discharge thus obtained was 1.0 litre/hour.

The selection of attachment depends upon the choices of crops. The micro-sprinkler irrigation system is selected for dense growing vegetables such as vegetable pea, French bean, spinach, coriander, radish, carrot etc. Similarly the micro-tube irrigation system is selected for vegetable crops for which fixed row to row and plant to plant spacing is recommended. The present setup of micro-tube is configured for the vegetable crop which requires 50 cm spacing for both X and Y direction i.e. plant to plant and row to row.

## Issues associated to current water utilization techniques

The wastage occurring through storage, conveyance and distribution ultimately result in delivery of 30 to 35 % of stored water for plant uptake (Patil 1987). The traditional flood or ridge and furrow method of irrigating field suffers from numerous problems such as considerable seepage (Moolman 1985, Hodgson *et al* 1990, Kahlown and Kemper 2004), conveyance and evaporation loss (Singh *et al* 2006); higher energy cost; lower water productivity; irrigation-induced soil erosion (Gomez *et al* 2004), and leaching of costly agricultural inputs causing sub-surface water pollution (Humphreys *et al* 1989). Moreover, this method is supply driven rather than crop-demand driven causing mismatch between need of the crop and the quantity of water supplied. The decrease in the availability of water for agriculture, coupled with the requirement for the higher agricultural productivity, means that there is no option but to improve the water use efficiency. This has to include an efficient utilization of available water which otherwise would evaporate or percolate from the root zone of the soil.

The recent advances in irrigation technology have made inroads in the cultivation of vegetables and horticultural crops. The frontier technology of micro-irrigation system not only provides higher water productivity but also minimize the problems associated with the traditional irrigation system. However these irrigation systems work best with ground water and so its expansion concerns a lot. So there is a need to address the issue of suitable irrigation system for pond water. The issues are

- Water lifting techniques: The difference between water lifting methods from bore well and open source lies in the fact that bore well requires minimum suction head of 40 m whereas open source pond require only 5 meter. The pump for pond water should have higher delivery/suction ratio to achieve higher system efficiency.
- Pump sizes: Suitable pump sizes are needed to develop by keeping in view that the capacity of farm pond barely crosses 2000 $m^3$, and hence higher capacity pump will brought mismatch causing low system efficiency and higher investment.
- Standardization of command area under farm pond: The experience suggest that farm pond of size 30m X 30 m X 3 will be able to provide adequate irrigation to 1 acre of land. Hence the pumping requirement would not be more than 1.5 hp. These needs to be standardize for different capacity of pond and respective command for optimal use efficiency.
- Selection of Crop: The selection of crop is highly crucial to achieve the water productivity and profitability.

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# Micro Irrigation and Pump set Marketing Scenario for Irrigation Potential Development in Rainfed Areas of Odisha

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## Abstract

*Rain water use and retention has been a continuous activity of the researchers. In Odisha the irrigation potential was about 8% in 1995 bur by 2020 a target of 35% in each block has been fixed by government. Many small irrigation projects have been planned for this purpose as they are managed by farmers and the success rate is very high. Presently in Odisha, direct lift irrigation, shallow tube well, bore well, dug well and farm ponds are the means of creating micro irrigation structure. The water withdrawal, recharge, increase in water use efficiency has been tried through such projects. It has been also proposed to sell standalone pump sets for creation of the irrigation potential for small fragmented land holdings. Present paper analyses the sell trend, popular pump set in different terrain. It has been observed that due to non availability of power in farm land diesel pump sets are mostly preferred. Similarly light weight pump sets are preferred in hilly and riverbank location for ease of use.*

## Introduction

Odisha is the first state to announce the agricultural policy in 1996. Development of irrigation potential from 8% to 35% was one of the mandates of Agricultural Promotions and Investment Corporation Ltd. (APICOL). It has introduced 50% subsidy limited to 50000 INR per small irrigation project. These were dug well, filter point tube wells (Shallow tube well), Bore wells in hard rock aquifers and river lift projects using 1.5 hp to 5 hp pump sets. Subsequently funds were mobilized from Rural Infrastructure Development Fund (RIDF) instead of state resources. This has been now named as 'Jalanidhi'. Community lift irrigation as well as cluster bore wells is presently promoted by government departments. Farm pond is also considered as a recharge as well as life saving irrigation structure in addition to dug wells. Concept of use of poly vinyl chloride (PVC) pipes for distribution channel and drip / sprinklers (micro irrigation) has been promoted under this heading. It has been observed that due to less advertisement the message could not reach all the farmers. Although subsidy per project @ 50% limited to 50000 INR was provisioned at the beginning the progress was very slow. Now the subsidy amounts are limited to 20000, 40000 and 50000 INR for Shallow tube well / dug well / bore well, respectively.

These structure are made of PVC of GI pipes depending upon the climatic condition of the area (Saline / non saline). To mitigate the drought, pump sets are promoted under different central government schemes, Rastriya Krishi Vikas Yojana (RKVY). Last five year statistics is given in Figure 1. It has been observed that there is a steady increase in sale of pump set alone for Irrigation purpose. About 44,196 pump sets of various hp. It has been noted that

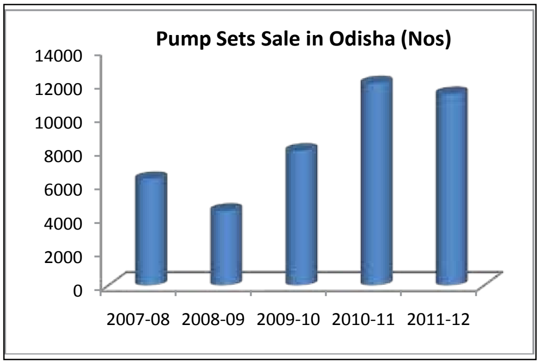


*Fig.1. Pump sets sold in Odisha to combat drought*

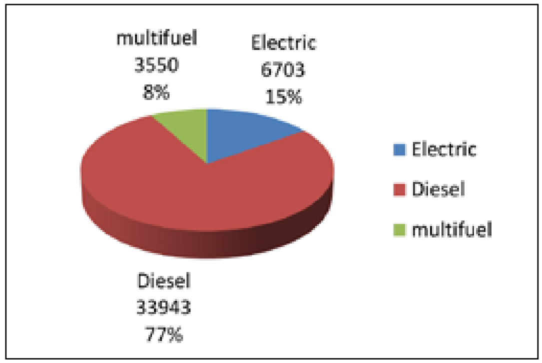


*Fig.2. Split up of pump sets used in Odisha*

the pumps are multi fuel operated / diesel operated / electric operated ones. Figure 2 shows that about 15 % of the pump sets are electrically operated, 8% of the pump sets are operated using multi fuels like starting with petrol and run with diesel or kerosene. The sale of these pump sets is purely based on farmer's choice. These farmers choose it as per the contingency of their use. In hilly (deleted area) and coastal area where frequently shifting of pump set is required, farmers prefer light weight pump set over heavy and stationary types. This is also true for tube wells. More numbers of STW where the water table is low, farmer use diesel pump sets. The percentage is about 95% and hardly 5% farmer has access to electricity.

It has been observed that the pump sets are often billed twice or more to obtain subsidy. Now this is promoted and the account maintained in e-governance model.

## Privately owned Irrigation sources

The duplication on the document has also been observed. The electric pump sets require electric line and with electrical connectivity it can be reduced. Proposal for promotion of more numbers of electrical pump sets with subsidized tariff will give a boost to development of irrigation potential. The use of non conventional energy like solar PV cell has a higher potential. The

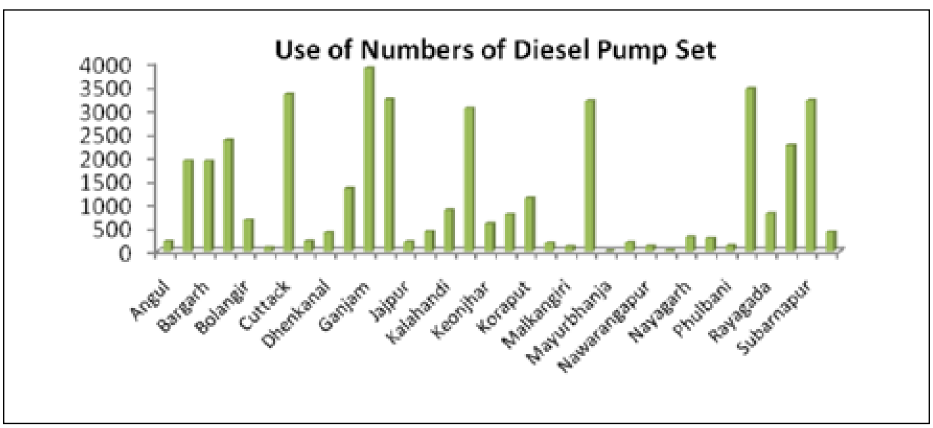


*Fig.3. Use of Diesel Pump sets in Odisha (2005)*

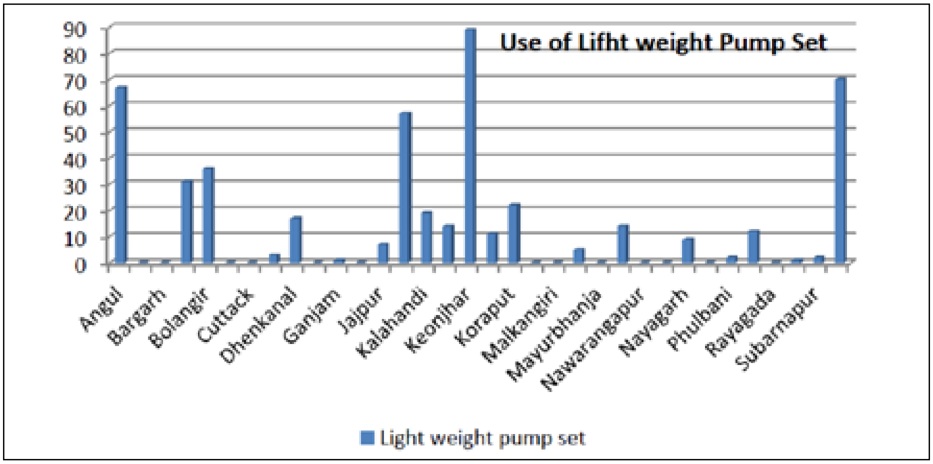


Fig.4. Light weight DP sets

dug wells use invariably DP sets of low hp and light weight. The model proposed by CRIDA with solar PV has a greater potential in Odisha. Odisha has average annual rain fall of about 1460 mm. The entire water moves away within 3 months from the land and most of the area the second crop is not taken up due to non availability of water. The water recharge can use structures like dug well and farm ponds are intervention to recharge the aquifer. Diesel pump sets are popular as they are portable and affordable by the common farmer. The water discharge from such a source can be used for life saving irrigation for the crops like paddy and vegetables. Figure 3 & 4 placed above shows the sale of DP sets in different districts of Odisha. Presently Odisha has 30 Districts; the use of DP sets in this district shows the development of agriculture in the state. The districts with higher population of DP sets are agriculturally resource rich districts. Among the district further an attempt has been made to find out the number of light weight pump set in these areas. It has been observed that districts like Angul Keonjhar, Sundargarh, Bolangir, Bargarh has more numbers of the light weight pump sets. This correlates to more vegetable grown in these areas. Further the details of the pump sets promoted under the RKVY schemes are given in Figure 5. It has been observed that the share of DP sets, light weight DP set, Heavy DP set and electrical pump set

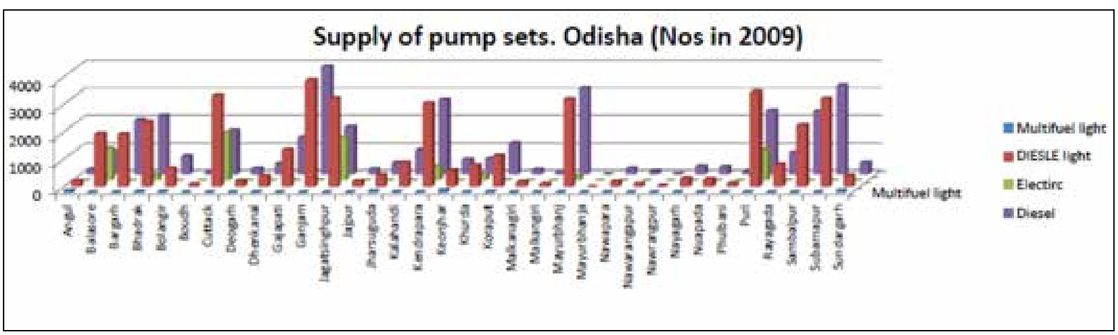


Fig.5. Different types of DP sets promoted under RKVY

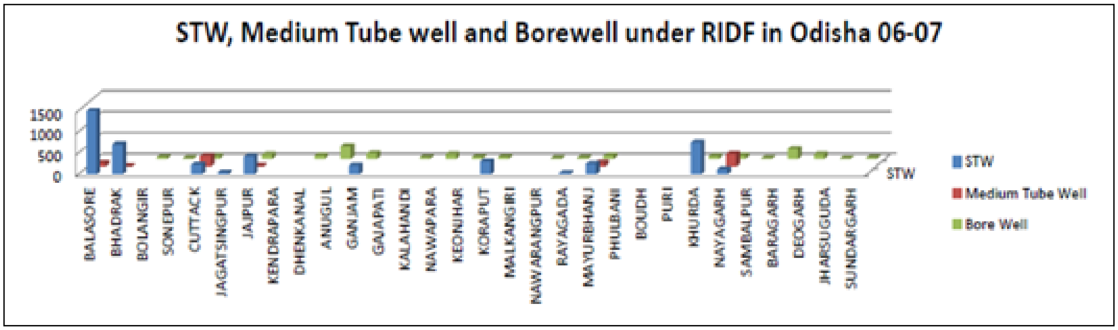


Fig.6. STW, MW and Bore well executed in year 2006

are popular in different district varies. They have no relation with the land marks. It may be inferred that major share in medium weight and electrical pump sets. On field verification it has been observed that the electrical pump sets are used when the farm land and farm house are very close. The same pump is used for domestic use as well as agricultural use. It is used for vegetable, sapling and orchard purpose.

## RIDF and LIPs Promotion

NABARD has allowed about 90000 minor irrigation structures through private initiatives. Starting from RIDV V till now RIDF SVII has been effectively used for promotion of LIPs. These LIPS has a command area of 2 hectares. In case of Dug well it is 0.5 hectare. The irrigation structures are bore well in the hard rock terrene. In coastal area as the formation is alluvial, the filter point tube well using PVC / GI pipe are constructed. It has been a rough and tough work to find out how the farmer will join hand with the government machinery to develop irrigation potential. Many schemes area lunched keeping the need of the farmers in to account. RIDF Xi was exclusively for the hard rock terrene. Other RIDF programs are lunched for area coving rain fed areas. Five types of irrigation structures are promoted under this scheme. The cost of LIPs is more compared to the DP sets. The costs of the wells are about a lakh of rupees. Comparative studies on acceptance of the LIPs by the farmers over years are given in Figure 7. Similar figures are available for different years. It has been observed that the farmers are not proactive in such a program. Government officials of agriculture department and the executants have to convince the farmers for such a work. On success of one farmer the usefulness of LIPs is understood by the farmers.

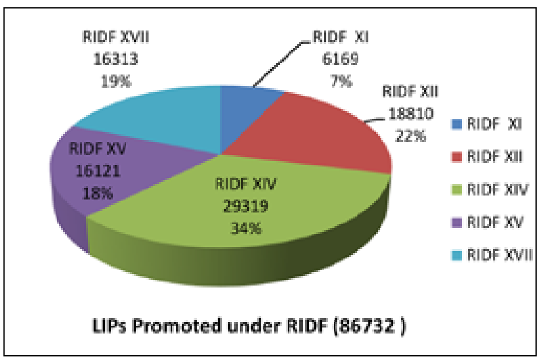


Fig.7. LIPs Promoted under RIFD Scheme

The kharif program of the entire state has been projected in the figure 8. It shows that there is considerable increase in the Rabi cultivation due to such intervention. All districts have some irrigation potential developed through the micro irrigation structures (LIPs). Unlike Major, Minor,

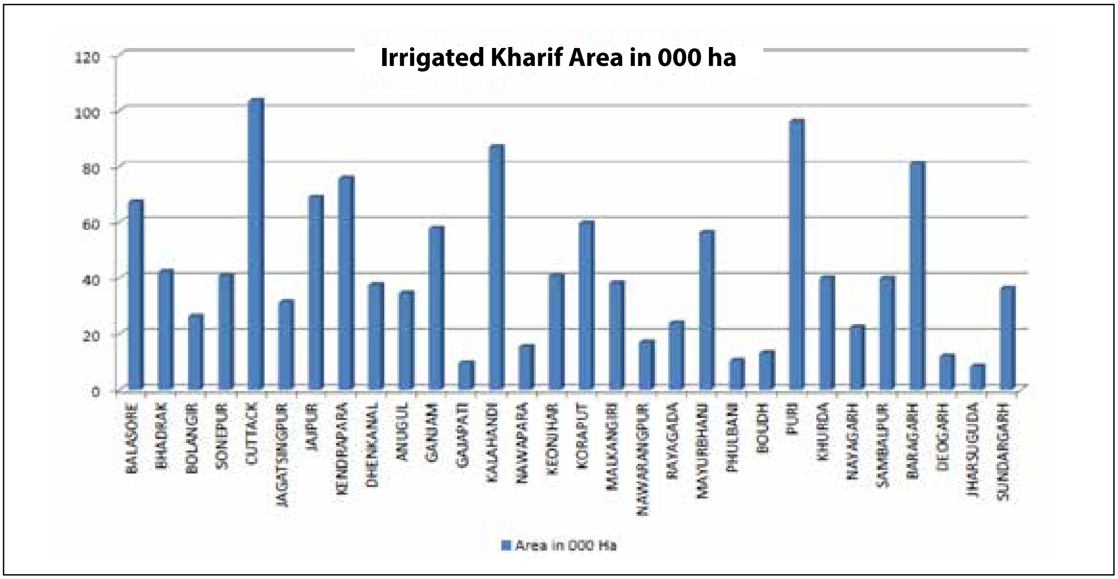


*Fig.8. Irrigated Kharif Area, 2010-11, in 000 Ha*

government owned LIPs. The use of Pani panchayat has been eliminated in such micro irrigation projects. The cost of irrigation is also less compared to the major and minor irrigation structures. The farmer is at liberty to sell excess water to nearby farmers for better use of water. The river lift irrigation projects, dug well and the farm ponds are the best sustainable irrigation structures. They use the temporary water storage for irrigation which replenishes every year after rain. Odisha has ample rain fall. More such irrigation structure with high water use efficiency will strengthen the farming community in growing cash crop and increase the standard of living. More a water recharge and efficient use of the water is presently required. With less volume of water available for such activity, it is desirable to use latest and most efficient irrigation techniques.

## Conclusion

The development of irrigation potential has many stake holders. All are interested to get it at a lesser cost. The service charge is also increasing day by day. Some standard path and process needs to be developed for the process.

## Abbreviations

RLIP- River Lift Irrigation Projects

LIP – Lift Irrigation Points

RKVY – Rastriya Krishi Vikas Yojana

RIDF – Rural Infra Structural Fund

DP – Diesel Pumps

PVC – Poly Vinyl Chloride

GI – Galvanized Iron

# Understanding the Implications of Farm Pond Strategy in Climate Change Scenario in Arid and Semi-arid Regions in Maharashtra

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## Abstract

*In India, though there are traditional roots for building big, medium, as well as small water storing structures, the trend and love for these structures (which increase surface water availability) is increasing day by day at the level of the government as well as international funding agencies. Briscoe and Malik's book[1] (India's Water Economy: braising for turbulent future, World Bank (2006)) illustrates and clearly takes a position in favour of creating larger water infrastructure, especially larger storages. It treats per capita surface water storage as an indicator of development. Quoting the book (p.30),*

*"Arid rich countries (like the United States and Australia) have built over 5000 m3 of water storage per capita, middle income countries like China has 2500 m3, … and India can store only about 200 m3".*

*Correlating per capita surface water storage with 'development' itself is problematic as it can have negative impacts on ecosystems and groundwater table. At the same time, under the climate change scenarios, precipitation forecasts for India suggest higher but more variable rainfall, except in the drier parts, where rainfall could decrease. At the same time, the changing patterns of rainfall and runoff are expected to significantly impact the surface water availability and groundwater recharge (Massachusetts Institute of Technology, 2008).*

*Farm ponds have been used traditionally as an economical and efficient way to retain water for livestock and irrigation. Harvesting of the rain water in ponds helps to preserve this water so that it can be put to varied uses later on. Farm ponds also offer the opportunity to rear fish and other aquatic organisms providing for diversification of farm enterprises and reduction in crop failure risks.*

## Introduction

Though farm pond as water harvesting activity has traditional roots, since the last few years it has been promoted by state, national and international donor agencies on large scale. MGNREGA and National Horticulture Mission have a major provision for farm pond implementation. Mainly farm ponds are promoted to focus as being water storage tanks for supplying water to the crop in the dry and needy days. Here, farm ponds are expected to harvest the rainwater of particular catchment. But in practice it is observed that, farmers are pumping groundwater to fill the farm ponds. This has major implication, because farm ponds which

[1] Briscoe and Malik, 2006, 'India's Water Economy: braising for turbulent future, World Bank', is available at http://www wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2008/06/25/000333037_20080625020800/Rendered/PDF/443760PUB0IN0W1Box0327398B01PUBLIC1.pdf

are designed for harvesting rainwater are leading towards the extraction from aquifers. The rate of evaporation in background to climate change scenario plays the critical role in the amount of water stored and actually used in dry period. Few studies and sources report that the rate of evaporation drastically differs in Maharashtra, depending on the local temperature and wind velocity. The annual evaporation rate in Marathwada region of Maharashtra reaches to around 44%, whereas around 25% in Vidarbha and 15% in Western Maharashtra.[2] It shows that there is much higher possibility of loss or waste of surface water stored in water harvesting structures due to evaporation. Climate change scenario is directly linked with the rate of evaporation, with the estimated further rise in average global temperature; it will definitely increase the rate of evaporation in these regions and surface water storages.

In this background, WOTR has initiated a study with two main concerns. First, farm ponds are implemented and planned government department to implement at larger level in WOTR's project area, where the Climate Change Adaptation (CCA) project is focusing on increasing the water availability with various water harvesting structures. In this area WOTR is also proposing farm ponds for protecting agriculture and supplement water to crops in dry days to increase the adaptive capacities of farmers to climate change. Secondly, it has been observed that in this area the extraction of groundwater for filling the farm ponds is a general practice. This groundwater extraction practice results in complex issues, such as depletion of groundwater table, community conflicts, use of electricity, etc. Thus, this scenario looks good till the water source for farm ponds as we have quoted is 'rain water'. In climate change context, the shift or change in this water source is leading to more vulnerable situation, which is dangerous. Hence to have more clarity, the study is being conducted in Sangamner clusters of Ahmednagar district. The study attempts to meet the following objectives:

1) To understand the changes in the farm pond water filling practices in semi arid region of Maharashtra.
2) To explore the emerging issues, consequences, and conflicts amongst farm pond owner and their non-farm pond owner neighboring farmers emerged through farm pond issues
3) To provide the insights for improvement of farm ponds in rain fed and semi arid areas in climate change scenario.

## Methodology

The study engages a multi-stakeholder approach. Between 20-25 farms ponds in Sangamner taluka is being physically verified with qualitative indicators. At the same time interviews is being conducted with these farm pond owners to know the details about farm ponds.

Three focused group discussions with farm pond owners and neighboring farmers will be conducted to know the implication of ground water extraction for filling the farm ponds. Few interactions with government officials at Taluka/Block level, who are engaged in farm pond implementations, will also be carried out to know their views, ideas, and experiences about farm pond intervention.

[2] *See Suhas Deshmukh, Dainik Loksatta, dated on Jan 25, 2012, 'Jalsathyatil sarvadhik bashpibhavanahi marahtwadyat'.*

## Primary Findings and Discussions (based on ongoing fieldwork)

### *Description of Area*

Sangamner taluka come under semi-arid zone, hence prone to groundwater stress. It falls in rain shadow zone of Western Ghats. In this region annual average rainfall is between in 500 and 750 mm. Further, even this scanty precipitation runs off as the rock formation and gradients do not permit much percolation. Low porosity of underlying rock formation and scanty rainfall mean poor underground water storages and uncertainty in location and capacity of subsoil aquifers.

Bore wells were introduced in Sangamner taluka in around 1970s to solve problem of drinking water scarcity. But the commercial farmers started taking advantage of this technology in reaching deep aquifers for irrigating farms, which resulted in excessive exploitation of groundwater. To address this issue or problem, government as well as many few NGOs promoted ground water recharge schemes in this region through various water harvesting programs. These are mainly watershed programs and integration of various soil and water conservation and employment generation programs. Farm pond is one of the major activities of these interventions since 2005-2006. The state government has planned to construct 200 farm ponds in every taluka of the state under the Maharashtra Rural Employment Guarantee Scheme (MREGS). According to the state government resolution, 352000 farm ponds are being planned to construct from 2009 to 2014, with annual target of 70400 farm ponds.[3] Through the Rashtriya Krishi Vikas Yojana (RKVY), in 25 districts from Marathwada, Vidarbha and north and south Maharashtra that are rain-fed and cotton-growing areas, 27,000 additional ponds are being constructed .The Maharashtra state agriculture department has been decided to construct over one lac farm ponds during calendar year 2010.[4]

## Discussion

To date, total 13 farm ponds in Sangamner taluka are being visited. The following are the major observations.

- Farm pond size of observed farm ponds varies from 1000 $m^3$ to 20,000 $m^3$. The average size as government norms should be 1,200 cubic meters, which is 20X20X3 size. A farm pond constructed 3 years back with no lining serves as percolation tank and is used to recharge downstream well by using bottom discharge pipe. (Village – Warudi Pathar)
- Farm pond Recharge: Farm pond recharge is the main concern. Because we observed that out of 13 farm ponds, 10 farm ponds were filled with water by either bore wells, dug wells or water from small dams (Dhorwadi dam). Only 3 farm ponds were recharged by rainwater, where there was no water during investigation. Dug well (50ft depth, 8ft dia) specially constructed to recharge one farm pond. 10Hp Electric motor installed. (Village – Sawargaon Ghule)

[3] *See 'Government Resolution Number-farm pond-2009/chapter272/EGS-5', is available at http://nagpur.nic.in/htmldocs/agri-dsao/20100101175646001.pdf*

[4] *Times of India, dated Jan 21, 2010, the news is available at http://articles.timesofindia.indiatimes.com/2010-01-21/pune/28140904_1_ponds-crop-scheme*

- Out of 13 farm ponds 5 farms ponds were without any plastic lining and 8 were having plastic lining to control the percolation of stored water.
- Water pumps used: Both diesel and electric pumps found at the farm ponds. 5 electric pumps and 2 diesel pumps were found at 7 farm ponds. Motors and pumps were used to lift water from water source (bore well, open well and tanks) to farm ponds, and also at the farm pond to lift water from it to for irrigation. Motor power of observed pumping devices found in range of 7.5 Hp to 10 Hp.
- Mode of irrigation: about effective and economic water use it was found that, 5 farm pond owners were using drip irrigation which is good indicators. This is necessary to promote in rest of farm pond owners.
- Government Subsidy on construction of 20m x 20m x 3m farm pond along with lining is 1.2 lakh. The farmer who constructs farm pond greater than this size has paid surplus amount.
- Also, in order to provide farmers with additional income sources, government is giving major thrust to the fisheries sector, particularly inland fisheries. But instead of solving the problem, it is observed that it is augmenting the problem. As region receives scanty rainfall (in current situation, there were no rains in field), farmer recharge those farm ponds by bore well, which results in further depletion of groundwater.

  Large number of fingerlings (3500) stocked in small sized pond (15m x15m x 6m); theoretically stocking density in such pond should be maximum 500. (Village – Bhojdari). Farm ponds are lined with plastic lining to avoid seepage loss, thus preventing ground water recharge. In addition to this surface stored water get lost due to evaporation. Now in such situation if aquaculture is promoted it will still worsen the problem, because farmer will then bound to maintain certain water level in farm pond to survive fish.
- **Evaporation:** we tried to understand the perceptions and experiences of the farm pond owners about the scale of evaporation. A farm owner who own 61m x 30.5m x 8m size of farm ponds said that, in period of 24 hrs, water level from farm pond reduces by 2 inch due to evaporation i.e. 2.1 mm/hr. It means water loss due to evaporation in this pond is 47.25 cubic meters = 47256 liters/ day. It shows if the water in the farm pond is stored in August and is used in the month of May (for period of 8 months), 11340 liters of water will be evaporated. It means almost 24% of water stored in this farm pond will evaporate.

## Recommendations

1. Size of farm pond which will be actually constructed should be decided by department experts than by farmer, considering various rainfall zones.
2. Before designing a farm pond, its purpose should be made clear i.e. whether it is going to be used for ground water recharge or for rain water harvesting. Topography should be taken into consideration before defining FP purpose.
3. Different environment friendly evaporation control mechanisms should be included in pond designing. One of such mechanism explored is Evaloc

(use of Ultra thin film), which is non-toxic and biodegradable and can retard evaporation column loss around 33% (Average). It is also economically viable which cost around Rs.3 for 1000 liters water.

4. Trainings and guidance should be provided about crop planning and water budgeting to the farm pond beneficiaries.

## Conclusion

As the project area is already facing the problem of groundwater table depletion, farm ponds should be filled mainly with the rainwater, and ground water extraction needs to be avoided. The structure of farm pond must be built within the sanctioned norms about the size. The farm ponds should be treated as farm ponds and not village tanks and percolation tanks (with increased size).

**Annexure: Summary table of collected data of 13 farm pond**

| Water Source | Duration of water availability in source | Pond Lining | Length | Breadth | Height | Surface area (Q.M) | Water hight (m) | Motor |
|---|---|---|---|---|---|---|---|---|
| Bore Well | 9 months | Plastic | 15 | 15 | 6 | 1350 | 1 | Diesel Pump |
| Bore Well | 12 months | Plastic | 13 | 13 | 5 | 845 | 4 | Electric Motor |
| Bore Well | *a | Plastic | 30.5 | 30.5 | 9 | 8372.25 | No Water | EM |
| Rainwater | *b | No | 30.5 | 30.5 | 9 | 8372.25 | No Water | |
| Dug W | 6 months | No | 45 | 30 | 8 | 10800 | No Water | Electric Motor |
| Dug W | 3 months | No | 15 | 15 | 4 | 900 | No Water | Electric Motor |
| Bore Well | 12 months | Plastic | 61 | 30.5 | 7.6 | 14139.8 | 4 | Electric Motor |
| Dhorwadi Pond | 12 months | Plastic | 40 | 30 | 11 | 13200 | 2 | Electric Motor |
| Rainwater | 3 months | No | 12 | 12 | 3 | 432 | No Water | |
| Rainwater | *b | No | 30.5 | 30.5 | 5.5 | 5116.375 | No Water | |
| Bore Well | *c | Plastic | 14 | 5 | 3 | 210 | 2 | Electric Motor |
| Dhorwadi Pond | Depends on rainfall, avg storage months = 9 | Plastic | 63 | 35 | *c | 19845 | 4 | Diesel Pump |
| Bore Well | No idea | Plastic | 38 | 38 | 9 | 12996 | No Water | |

*a= new bore wells hence no idea to farmer as well. *b = new farmponds *c = no uniform depth

# Protective Irrigation through Farm Pond for Enhancing Crop Productivity

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## Abstract

*A farm pond was constructed under RKVY program at Daryapur and Akot Talukas of Akola districts and was demonstration was conducted by university University in order to demonstrate the use of stored farm pond water to irrigate various crops. The micro irrigation systems like drip and sprinkler were used to apply protective irrigation to various crops. The protective irrigation using these farm ponds alongwith micro-irrigation systems was given to various crops during kharif and rabi season. It is observed that in all crops yield increased was observed in the range of 50-125% and water use efficiency was increased in the range of 1.48-3.59 kgha$^{-1}$mm$^{-1}$ over rainfed condition. Similarly, in village Ghusar the farmers who have given protective irrigation to their crops in kharif as well as in rabi had reported the yield increase by 30 to 40% in greengram and chickpea. It is observed that the yield increase was more than 50% in greengram, chickpea, cotton and safflower after protective irrigation over rainfed crops.*

## Introduction

Water is the part of the larger ecosystem in which the reproduction of the bio diversity depends. Scarcity of water is caused by low water storage capacity, low infiltration, larger inter annual and annual fluctuations of precipitation (due to monsoonic rains) and high evaporation demand. The available water resources are under pressure due to increasing demands and the time is not far when water, which we have always thought to be available in abundance and free gift of nature, will become a scarce commodity. Conservation and preservation of water resources is urgently required to be done. Water management has always been practiced in our communities since ancient times, but today this has to be done on priority basis. Due to population explosion, our country faces a serious threat to the management of water resources as the gap between demand and supply widens. There is a tendency to ignore the traditional water-harvesting systems. We should draw upon the wisdom of our ancient life sustaining systems and through better management, conserve our precious water resources. Harvesting of rainwater is of utmost important. Judicious mix of ancient knowledge, modern technology, public and private investment and above all, people's participation will go a long way in reviving and strengthening water harvesting practices throughout the country.

To meet the growing water supply demand, we are depending maximum on surface water, which is stored in the form of lakes and reservoirs. Availability and storage of water in reservoirs and lakes depends ultimately on yearly rainfall. If rainfall is inadequate or if there is draughts for successive years, surface water bodies get consumed and in such a case, we have no alternative than using the groundwater. Therefore we must guard against the depletion or spoiling of our most valuable groundwater storage. Natural conservation of water and efficient use of this natural storage and at the same time making arrangements for additional recharge of groundwater aquifer by one way or other, to replenish the used groundwater becomes our responsibility. We should make maximum use of the easily available normally wasted, local renewable source of water that is rainwater. The effective way to store rainwater is by allowing it to percolate into ground by enriching groundwater storage.

Scientific management of water conservation techniques such as water harvesting and moisture conservation can maximize productivity and increase water use efficiency of different agronomical crops. During drought years, supplemental irrigations at critical stages may be essential not only to prevent mortality of crops but also to maintain a required vigor for normal productivity. In Vidarbha region of Maharashtra State and most part of the country, occurrence of high intensity rainfall events may results in floods. In these areas dry spells even within the monsoon periods are not uncommon, resulting in fluctuation in crop production. In these areas it would be wise to harvest the runoff water for supplemental irrigation to different agronomical crops by constructing farm ponds to store and recycle it. Farm ponds hold great promise as a life saving device for rainfed crops in the areas characterized by low and erratic rainfall. The stored pond water can be used as protective irrigation during critical stages of crop growth depending upon the crop water requirement and availability of water. Vora *et al.,* (2008) reported the remarkable increment of 30 to 50% with one supplementary irrigation of 6 cm depth in cotton, wheat, gram and cumin crop.

## Rainwater Harvesting through Farm Pond

The demand for water is 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 3.3 M·hm to 7.00 M·hm in 2020/25. Similarly the demand of water for industries will be increased by 4 fold *i.e.* from 3.0 M·hm to 12.00 M·hm 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 groundwater table is depleting in most of the areas. In some areas the depletion is about 30-50 m in the last 30-40 years (Sivanappan, 2006). 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 rainwater efficiently. The theme paper on Water vision 2050 of India, prepared by Indian Water Resources Society (IWRS) has indicated that a storage of 60 M·hm is necessary to meet the demand of water for irrigation, drinking and other purposes. But the present live storage of all reservoirs put together is equivalent of about 17.5 M·hm which is less than 10% of the annual flow of the rivers in the country. The projects under construction (7.5 M·hm) and those contemplated (13 M·hm) are added, it comes only 37.50 M·hm and hence we have to go a long way in water harvesting to build up storage structures in order to store about 60 M·hm. Therefore there is an urgent need to take up the artificial recharge of the rainwater for which water harvesting and water conservation structures are to be build up in large scale. Generally, storage of rainfall in the soil profile is cheaper and more efficient than storage of runoff in excavated tanks. However, the major limitation of storage in the soil profile is its limited capacity. In most of the rainfed areas, rainwater conservation measures can not conserve all the rainwater and a certain amount of runoff is bound to occour. This runoff can be collected and stored in tanks for a life saving irrigation to rainfed crops (Bangar *et al.*, 2003). The ponds are mainly of two types. One is embankment type and other is dug out type. The embankment type pond is constructed across streams/ ravines and big gullies in order to impound certain quantity of runoff water which will otherwise find its way to rivers. The impounded water infiltrated into subsoil and recharges the groundwater table. The excess runoff is collected in dug out farm pond and the stored water can be used as a supplementary irrigation to the crops grown in adjoining areas. In vertisols and specially in saline tract of Vidarbha region in Amravati, Buldana and Akola districts collection of runoff into the farm ponds is most important and is need of the day to provide the protective irrigation at least to some part of the land holding of farmer.

## Protective irrigation in *kharif* and *rabi* season

The farm ponds were constructed in Daryapur and Akot Talukas of Akola districts by State Agriculture Department under RKVY. The sizes of farm pond are mainly 20X20X3 and 30X30X3 m. Demonstrations were conducted on farmers field by the University in order to demonstrate the use of stored farm pond water to irrigate various crops. The micro irrigation systems like drip and sprinkler were used to apply protective irrigation to various crops. The effect of protective irrigation on yield of various crops during *kharif* and *rabi* season is given in the Table1. It is observed that in all crops yield increased was observed in the

**Table 1. Effect of protective irrigation through Farm Pond on yield of various crops**

| Crop | Irrigation system | No. of protective irrigation | Yield, $qha^{-1}$ | | Increase over rainfed, % | Water use efficiency, $kgha^{-1}mm^{-1}$ | |
|---|---|---|---|---|---|---|---|
| | | | Rainfed | Irrigated | | Rainfed | Irrigated |
| Cotton | Drip | 02 | 12.75 | 22.50 | 76.47 | 1.99 | 3.04 |
| Cotton | Sprinkler | 02 | 12.75 | 21.50 | 68.62 | 1.99 | 2.90 |
| Soybean | Sprinkler | 01 | 15.00 | 23.00 | 50.00 | 2.34 | 3.59 |
| Pigeonpea | Pepsi drip | 01 | 8.00 | 12.00 | 50.00 | 1.25 | 1.73 |
| Greengram | Sprinkler | 01 | 5.00 | 11.25 | 125.00 | 0.78 | 1.63 |
| Safflower | Sprinkler | 01 | 9.50 | 15.00 | 57.89 | 1.48 | 2.17 |
| Chickpea | Sprinkler | 01 | 5.00 | 9.50 | 90.00 | 0.78 | 1.48 |

Note: Average rainfall 639.69 mm and per irrigation depth is 50 mm. (Source: FPARP, Dr. PDKV, Akola)

**Table 2. Success story of farmers of Ghusar village**

| | | | | |
|---|---|---|---|---|
| 1. | Name of the farmer | : | Shri. Pravin Vijayrao Pagrut | |
| 2. | Address | : | | |
| | i) Village | : | Ghusar | |
| | ii) Post | : | Ghusar | |
| | iii) Tehsil | : | Akola | |
| | iv) District | : | Akola | |
| | v) State | : | Maharastra | |
| 3. | Contact details | : | 9822708237 | |
| 4. | Details of the farm (size, location, water availability etc.) | : | 2.8 ha, Ghusar, Farm pond | |
| 5. | Names of the central sector / State Schemes utilized by the farmer and the period | : | National Horticulture Mission (NHM) 2007-08 | |
| 6. | Technologies / Good Agricultural Practices / facilities / Benefits obtained with details | : | Farm pond (lined)<br>Size- 82.0m X 26.0mX 3.0m<br>Sowing of crops across the slope | |
| 7. | Details of results obtained due to the adoption of technologies | : | Improved /Present production technologies | Traditional/past production practices |
| | i) Productivity per hectare | : | Greengram -5q<br>Chickpea- 15q | Greengram -3.75q<br>Chickpea- 10q |
| | ii) Cost of production per hectare | : | Rs. 22500 | Rs. 18000 |
| | iii) Net income per hectare | : | Rs. 39000 | Rs. 12500 |
| | iv) Price realized (Rs. Per ton) | : | Greengram: Rs. 54000<br>Chickpea: Rs.23000 | Greengram: Rs. 27800<br>Chickpea: Rs.16600 |
| | v) Natural resources saved / conserved | : | Water, soil | - |
| | vi) Product quality improvement | : | Improvement in grain size | - |
| 8. | Factors contributing to success | : | Protective irrigation from stored water in farm pond | |
| 9. | Any other relevant | : | Provides farm implements and sprinkler set and pump set to other farmers as per need. | |

range of 50-125% and water use efficiency was increased in the range of 1.48-3.59 kg $ha^{-1}mm^{-1}$ over rainfed condition.

In village Ghusar the farmers who have given protective irrigation to their crops in *kharif* as well as in *rabi* had reported the yield increase by 30 to 40% in greengram and chickpea. The information of the farmers is given in Table 2. It was also observed that the farmer had obtained 45% more yield in case of pigeonpea crop when one protective irrigation was given at the time of flowering. Some farmers had utilized the berms of farm ponds for growing the pigeon pea crop and they were benefited by obtaining the yield from that area which otherwise may be fallow besides their berms and the embankments were protected. The relevant photographs are depicted in the success stories.

The effect of protective irrigation through farm pond on yield and water use efficiency in different crops is shown in Fig.1. It is observed that the yield increase was more than 50% in greengram, chickpea, cotton and safflower after protective irrigation over rainfed crops. In case of soybean and pigeonpea the yield increase was below 50% over rainfed crops. The water use efficiency was found to be highest in soybean followed by cotton, safflower, pigeonpea, greengram and chickpea after protective irrigation through farm pond over rainfed crops.

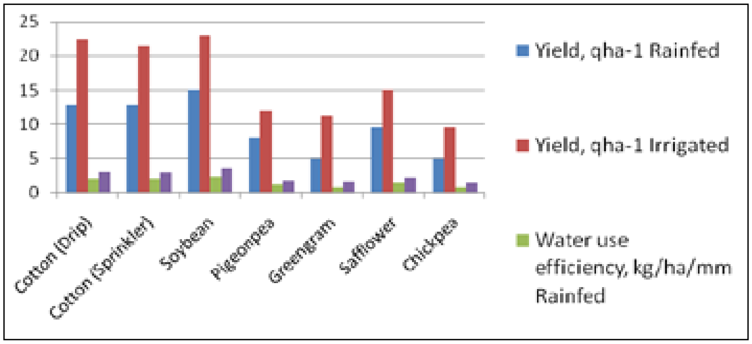


*Fig.1 Effect of protective irrigation on yield and water use efficiency in different crops*

*Water storage in pond during kharif*

*Pigeonpea cultivation on the berms*

*Crop condition during kharif*

*Pigeonpea after protective irrigation*

*Photographs of Shri Pundlik Lothe's field at village Ghusar Tq. and Dist. Akola*

## Conclusion

Pond water was used for providing supplementary irrigation (one or two as per requirement) to the field crops, which resulted in higher returns through greater yield of the crops. The increase in yield levels was in the range of 60-70% and water use efficiency was in the range of 1.28-3.47 $kgha^{-1}mm^{-1}$ over rainfed condition. It is possible for the farmers to go for the second crop in *rabi* season. In case of chickpea, when moisture in the soil was not adequate, irrigation provided from farm pond sustained the crop and increased the yield by 33 to 40% over rainfed chickpea. The available water was also used for livestock and field operations.

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# Rainwater Harvesting and Recycling for Protective Irrigation in Assured Rainfall Zone of Marathwada Region

**B.W. Bhuibhar, D.A. Chavan and M.R. More***

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## Abstract

*A study on assessment of farm pond with respect to rain water harvesting and recycling for protective irrigation during rabi season was conducted during 2010-11 on demonstration farm, Marathwada Krishi Vidyapeeth, Parbhani. Catchment area of the farm pond is 2.04 ha. Daily rainfall and pan evaporation data were collected from the Meteorological Observatory of the University. The inflow and depth of water stored in the farm pond was monitored daily throughout the growing season. Stage- storage and stage-water spread area calibration curves of the farm pond have been developed from the grid survey of the farm pond storage area. The water spread area at embankment top and bottom section of the farm pond was 309.491m$^2$and 674.736 m$^2$ respectively. The maximum depth of water storage and storage capacity of farm pond was observed as 2.193m and 1079.20m$^3$ respectively. During 2010, total evaporation and seepage loss through the farm pond during the season was 228.661 m$^3$ and 2775.554 m$^3$ respectively. The weight of silt deposited in the farm pond during monsoon season 2010 was observed as 17.14 tonnes. Consolidation of the peripheral embankments of farm pond over the period of season was found as 15.7083%. The harvested water in the farm pond was utilized for protectve irrigation to the safflower crop with the help of portable monoblock irrigation pumpset of 1.5 hp. The experiment was laid in randomized block design with treatments of; one protective irrigation, two protective irrigations and without any protective irrigation (Control). Treatment of two protective irrigations recorded significantly higher safflower grain yield (606.99 kg/ha) over other irrigation treatments.*

## Introduction

Fresh water scarcity is not limited to the arid climate regions only, but in areas with good supply, the access of safe water is becoming a critical problem. Despite accumulated flooding in high risk areas, a large part of the year remains dry leading to drought or drought like situations in major parts of the country. Even after good monsoon, water is not available only because of lack of proper rain water management and storage. Lacks of water is caused by low water storage capacity, low infiltration, and larger intra/ inter annual rainfall fluctuations and high evaporation demand. Drought prone areas have to be provided water not only for human and cattle consumption but also for irrigation. Harvesting every drop of rain water in-situ is very essential for promoting sustainable agriculture in semi-arid regions. It is therefore important that adequate supplies of water be developed. Rainwater management is the most critical component of rainfed farming. Water harvesting means conserving the excess runoff water from

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monsoon rain and utilizing for raising good crops in dry tracts, drinking and recharging purposes. 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. There are divergent views on the actual potential and scope of farm ponds for water harvesting 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. Considering this, the present project is being carried out with following objectives,

- To assess the surface runoff potential of vertisols and rainwater harvesting with farm pond.
- To assess the storage losses such as evaporation and seepage losses through dugout farm pond.
- To assess the erosion hazard in the catchment and its deposition in farm pond.
- To reutilize harvested rainwater for protective irrigation.

## Methodology

### Location

Dug out farm pond has been developed at Demonstration-cum-Mega Seed Production Farm, Marathwada Krishi Vidyapeeth, Parbhani. The soils are medium deep to deep black and mostly clay in texture with pH 7.5. The soil strata at the farm pond site comprises top clay soil layer 1.0 to 1.25 m, followed by 1.5 to 1.8m soft murum and then hard murum.

### Climate

Study area comes under assured rainfall zone with mostly kharif cropping. The

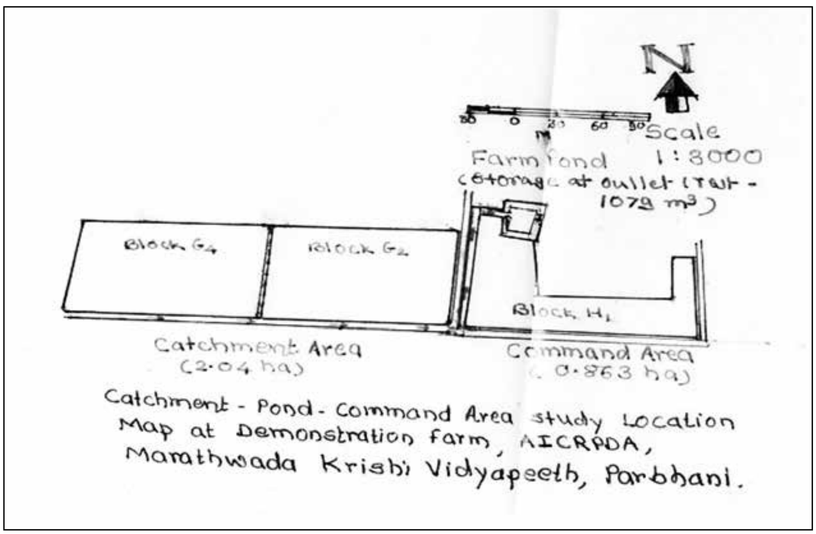


*Fig. 1. Location map of Farm Pond at demonstration farm, MKV, Parbhani*

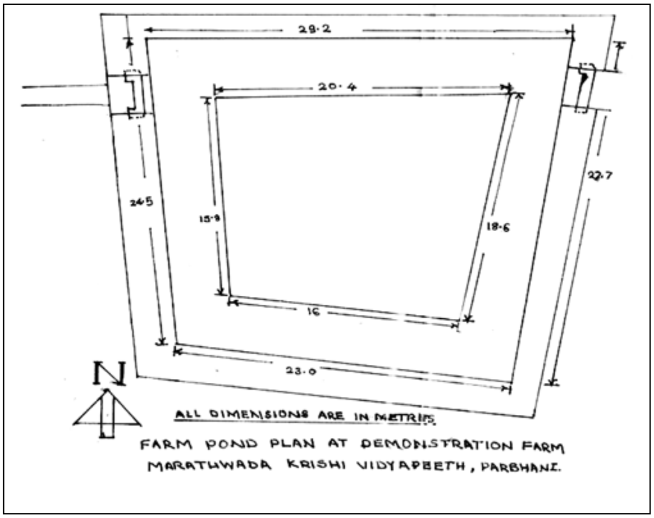


*Fig.-2: Components of Farm Pond, MKV, Parbhani.*

average rainfall of the Parbhani is 890 mm with average number of 48 rainy days. South-West monsoon is the major source of rainfall for the region. The region falls under semi-arid tropics having highest temperature of $43^0$C during the month of May, while the lowest temperature of $11^0$C during the month of December.

## Components of farm pond and catchment area

From the topographic map of demonstration farm, catchment area of the farm pond was determined as 2.04 ha. The components of the farm pond are shown in fig-2. The maximum depth of storage water impounding and storage volume in farm pond was 2.193m and 1079.20$m^{3.}$ respectively.

## Storage capacity of farm pond

Grid survey of the storage area of farm pond and its surrounding was conducted. Elevation and water spread area at the embankment top, farm pond bottom and outlet crest were determined. The storage capacity of the farm pond was calculated using Trapezoidal formula,

$$V = \frac{A_1 + A_2}{2} \; x \; D$$

In which,
V = Volume of water stored in farm pond, $m^3$
$A_1$ = Water spread area at embankment top section, $m^3$
$A_2$ = Water spread area at farm pond bottom, $m^2$
D = Depth of water stored in farm pond, m

## Losses from farm pond storage

Evaporation and seepage are the two major storage losses from farm pond stored water. For estimation of evaporation loss from the farm pond; daily pan evaporation data was used. The daily evaporation loss through farm pond was calculated by the following formula,

Daily Evaporation Loss ($m^3$)

$$= \frac{\text{Daily Pan Evaporation x 0.7 x Average Water Surface Area } (m^2)}{1000}$$

Seepage loss per day from the farm pond was estimated by subtracting evaporation loss from change in farm pond water storage ($m^3$). Daily seepage and evaporation losses were respectively added, over the period considered, to determine total loss.

## Silt deposition

Total silt deposited in the farm pond was determined from the depth of silt deposited in the farm pond with respect to farm pond side surface and bottom at a grid interval of 4 m and the area of silt deposition. Water content of the silt samples was determined to calculate bulk density of the deposition and the corresponding weight of silt deposited.

## Recycling of harvested water

Water harvested in the farm pond was utilized with the help of portable Monoblock Pump set of 1.5 hp for protective irrigation to safflower crop. The study on protective irrigation was conducted during *Rabi*-2010. The details of the experiment are as below,

**Season:** Rabi 2010-11

**Design:** R.B.D.

**Replications: 6**

**Treatments: 3**

$T_1$- One protective irrigation of 5 cm depth at branching stage,

$T_2$ – Two protective irrigations each of 5 cm depth at branching and capsule formation stage and

$T_3$ – Control i.e. without any protective irrigation.

**Plot size :** 3.6 x 4.05 m

**Crop:** Safflower

**Variety:** Parbhani-12

**Date of sowing :** 15.10.2010,
**Date of harvesting :** 18.3.2011

**First Irrigation:** 10.12.2010

**Second Irrigation:** 26.12.2010

## Results and Discussion

### Season 2010 (Rainfall)

During 2010, total of 1259.7 mm rainfall received during the period from June to December, with 58 rainy days. The onset of effective monsoon was during 26$^{th}$ MW. July was found wettest month with monthly total rainfall of 426.8 mm, followed by the month of August with monthly total rainfall of 380.7 mm rainfall.

## Runoff from catchment

Inflow data to the farm pond during 2010 indicated that from the catchment area of 2.04 ha with vertisol on 1 % land slope and cropped with soybean, runoff of 62.41 mm was generated due to rainfall of 468.80 mm which accounts on an average of 13.31 % and 1273.26 $m^3$ runoff volume.

## Stage- storage and stage-water spread area relationship

Stage- storage and stage-water spread area relationship of the farm pond have been developed in the form of calibration curve

**Table 1: Rainfall during 2010 at MKV, Parbhani.**

| Month | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|
| Rainfall, mm (Rainy Days) | 106.1 (5) | 426.8 (14) | 380.7 (15) | 221.1 (14) | 31.2 (5) | 93.3 (5) | 0.5 (0) |
| January-December | 1295.2 (60) | | | | | | |
| June-December | 1259.7 (58) | | | | | | |

**Table 2: Rainfall- runoff observed from catchment area ( 2.04 ha, Crop : Soybean) of farm pond during 2010 at MKV, Parbhani.**

| Date | Rainfall (mm) | Actual runoff volume,$m^3$ | Direct runoff, mm | Runoff as a per cent of rainfall, % |
|---|---|---|---|---|
| 1/7/2010 | 93.4 | 354.46 | 17.38 | 18.50 |
| 26/7/2010 | 28.0 | 43.75 | 2.15 | 7.68 |
| 29/7/2010 | 45.0 | 28.75 | 1.41 | 3.13 |
| 30/7/2010 | 14.4 | 22.89 | 1.12 | 7.78 |
| 31/7/2010 | 37.7 | 32.67 | 1.60 | 4.24 |
| 27/8/2010 | 30.2 | 100.00 | 4.90 | 16.23 |
| 28/8/2010 | 10.0 | 23.99 | 1.18 | 11.8 |
| 31/8/2010 | 32.6 | 248.75 | 12.19 | 37.39 |
| 17/9/2010 | 47.2 | 26.75 | 1.31 | 2.78 |
| 23/9/2010 | 40.7 | 266.25 | 13.05 | 32.06 |
| 23/10/2010 | 15.8 | 40.00 | 1.96 | 12.41 |
| 4/11/2010 | 36.2 | 81.25 | 3.98 | 10.99 |
| 19/11/2010 | 37.6 | 3.75 | 0.18 | 0.50 |
| **Total** | **468.80** | **1273.26** | **62.41** | **13.31** |

from the dimensions of components of the farm pond and contour map of storage area with reference to the bottom of farm pond. The values of water spread (surface) area and storage volume with respect to depth of water impounded in the farm pond have been used to establish stage- storage and

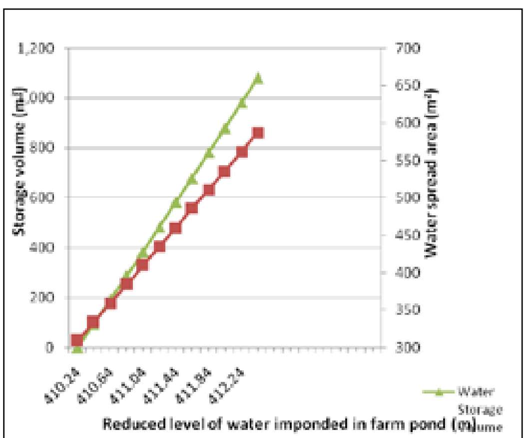

Fig.3- Stage-storage relationship of the farm pond

stage-water spread area relationship. The developed graph can be used to determine water surface area and volume of stored water in farm pond.

## Harvesting of rainwater

Data presented in table-3 indicated that total of 3022.60 $m^3$rain water was harvested during the period from July to December, 2010. The maximum rain water harvested was recorded as 854.20 $m^3$ on 8.8.2010 because of heavy rainfall (136.6 mm) on 7.8.2010. It was observed that the farm pond was filled to its full capacity on 2.7.2011 to 5.7.2011, 8.8.2010 and 14.8.2010. Considering the season-2010, inflow to the farm pond was maximum during the month of August (1544.65 $m^3$) followed by the month of July (1130.45 $m^3$). Considering monthly average of stored water it was observed that retention of harvested water was maximum during the month of September (893.84 $m^3$).

**Table 3: Runoff harvesting and assessment of losses through the farm pond during 2010 at MKV, Parbhani.**

| Month | Inflow,$m^3$ | Average monthly storage, $m^3$ | Evaporation loss, $m^3$ | Seepage loss, $m^3$ | Total storage losses, $m^3$ |
|---|---|---|---|---|---|
| July | 1130.45 | 601.15 | 37.838 | 821.164 | 859.002 |
| August | 1544.65 | 726.75 | 34.305 | 762.017 | 796.332 |
| September | 261.25 | 893.84 | 43.849 | 497.705 | 541.554 |
| October | 10.00 | 577.41 | 46.164 | 293.207 | 339.371 |
| November | 76.25 | 422.96 | 37.258 | 140.324 | 177.582 |
| December | -- | 208.87 | 29.247 | 261.137 | 290.384 |
| **Total** | **3022.60** | **--** | **228.661** | **2775.554** | **3004.215** |

## Storage losses through the farm pond

### *Evaporation loss*

Harvested rainwater lost by evaporation during the period from July to December indicated that maximum water loss through the farm pond was observed in the month of October (46.164 $m^3$), followed by the month of September (43.849 $m^3$). Total evaporation loss through the farm pond for the period July to December-2010 was observed as 228.661 $m^3$.

### *Seepage loss*

Harvested rainwater in the farm pond lost by seepage during the period from July to December indicated that maximum water loss was observed in the month of July (821.164 $m^3$) and subsequently the rate of seepage loss decreased continuously till the month of November. However, the the rate of seepage loss abruptly increased during the month December and may be due to withdrawal of the ground water from the surrounding area for irrigation. Total loss of stored water by seepage through the farm pond for the period July to December 2010 was observed as 2775.554 $m^3$ and thus average seepage loss per day through the farm pond works out as 5.83 $m^3$.

Total storage water losses for the period July to December 2010 was found as 3004.215$m^3$. Seepage losses comprise 92.39 % of total storage losses and the rest of evaporation losses.

**Table 3A: Average daily evaporation and seepage loss observed during 2010, at MKV, Parbhani.**

| Month | Av. daily Evaporation loss, $m^3$ | Av. daily Seepage loss, $m^3$ |
|---|---|---|
| July | 1.351 | 37.347 |
| August | 1.182 | 29.308 |
| September | 1.461 | 19.142 |
| October | 1.148 | 13.106 |
| November | 1.241 | 5.197 |
| December | 0.943 | 8.423 |

## Recycling of harvested water

The study on reutilizing the harvested rainwater for protective irrigation to safflower crop was conducted with treatments as ; $T_1$- One protective irrigation of 5 cm depth at branching stage, $T_2$ – Two protective irrigations each of 5 cm depth at branching and capsule formation stage and $T_3$ – Without any protective irrigation.

**Table 4: Safflower yield of as affected by protective irrigation during rabi-2010 at MKV, Parbhani.**

| Treatments | Total yield, Kg/ha | Increase over control, % | Grain yield, Kg/ha | Increase over control, % |
|---|---|---|---|---|
| $T_1$- One protective irrigation | 2201.64 | 76.29 | 541.49 | 100.64 |
| $T_{2-}$ Two protective irrigations | 2353.90 | 88.48 | 606.99 | 124.91 |
| $T_3$- Control without any protective | | | | |
| Irrigation | 1248.85 | -- | 269.88 | -- |
| **Mean** | 1934.798 | | 472.788 | |
| **SE** | 48.415 | | 8.823 | |
| **C.D at (p=5%)** | 152.688 | | 27.828 | |
| **CV%** | 6.129 | | 4.571 | |

*Protective irrigation through farm pond with 1.5 hp Honda pump*


*Safflower with protective irrigation through farm pond*

**Table 5: Silt deposition in the farm pond during 2010at MKV, Parbhani.**

| Particulars | Average depth of silt, m | Area of silt deposition, $m^2$ | Volume of silt deposition, $m^3$ | Actual volume of silt, $m^3$ | Weight of silt deposited, tonnes |
|---|---|---|---|---|---|
| Bottom section of farm pond | 0.0248 | 309.491 | 7.675 | 5.54 | 14.86 |
| Embankment inner section of farm pond | 0.0166 | 70.800 | 1.175 | 0.848 | 2.28 |
| **Total** | | | | | **17.14** |

Treatmentwise safflower grain yield and total yield were recorded. Safflower yield data presented in Table-4 indicated that treatment of two protective irrigations ($T_2$) recorded significantly higher grain yield (606.99 kg/ha) than treatment of one protective irrigation ($T_1$) and no protective irrigation ($T_3$). Treatment ($T_1$) also recorded significantly higher grain yield (541.49 kg/ha) than treatment ($T_3$). Treatment $T_2$ and $T_1$ recorded respectively; 124.91 % and 100.64 % higher safflower grain yield than that of treatment $T_3$.

## Silt deposition

Average moisture content of silt samples, collected at the time of silt deposition depth measurement was found as 27.81%. Similarly, the average bulk (dry) density of the silt deposited in the farm pond was found as 2.683 g/cm$^3$. The weight of silt deposited in the farm pond was thus found as 17.14 tonnes. The quantity of silt deposited in farm pond was collected from catchment area of 2.04 ha over the period of one season.

## Consolidation of the embankment of farm pond

The consolidation of peripheral embankment of farm pond over the period was determined by comparing the elevations of embankment top measured on May, 2010 and subsequently on February 2011. Average elevation of top of embankment of the farm pond recorded on May, 2010 and February, 2011 was 1.0 m and 0.85 m respectively. The decrease in average elevation thus worked out as 15.00 %.

## Irrigation Potential of farm pond

Quantity of harvested rainwater available in the farm pond during the season and probable irrigation potential by applying 5 cm of depth of irrigation; assuming 80 % conveyance efficiency have been presented in table-6. Harvested water volume to the tune of 1/2 to 3/4$^{th}$ of storage capacity of farm pond was available during September end to 15$^{th}$ of October and can be utilized for applying irrigation of 5 cm depth for about 0.916 ha area.

**Table 6: Probable irrigation potential depending on water availability in farm pond during the season, 2010.**

| Date | Water available in the farm pond, $m^3$ | Area to be irrigated (80% conveyance efficiency), ha |
|---|---|---|
| 15$^{th}$ July | 610.00 | 0.976 |
| 31$^{st}$ July | 277.50 | 0.444 |

| Date | Water available in the farm pond, m$^3$ | Area to be irrigated (80% conveyance efficiency), ha |
|---|---|---|
| 15$^{th}$ August | 1060.00 | 1.696 |
| 31$^{st}$ August | 1050.00 | 1.680 |
| 15$^{th}$ September | 840.00 | 1.344 |
| 30$^{th}$ September | 775.00 | 1.240 |
| 15$^{th}$ October | 572.50 | 0.916 |
| 31$^{st}$ October | 447.50 | 0.716 |
| 15$^{th}$ November | 422.50 | 0.676 |
| 30$^{th}$ November | 350.00 | 0.560 |
| 15$^{th}$ December | 230.00 | 0.368 |
| 31$^{st}$ December | 46.25 | 0.074 |

**Table 7: Comparison of portable low head mono-block pump sets for protective irrigation.**

| Characteristics | Pump Type | | | |
|---|---|---|---|---|
| Rated output | 1.5 hp | 1.5 hp | 3.0 hp | 3.0 hp |
| Head (Total), m | 38 | 20 | 20 | 17 |
| Discharge, l/min | 200 | 600 | 800 | 950 |
| Fuel : start/running | Petrol/Kerosene | Petrol/Kerosene | Petrol/Kerosene | Petrol/Kerosene |
| Weight, Kg | 14 | 23 | 35 | 37 |
| Carrying arrangement | Handle | Tubular frame | Tubular frame | Tubular frame |
| Material | Aluminum | | | |
| alloy | Cast Iron | Cast Iron | Cast Iron | |
| Priming | Self | Non-self | Non-self | Non-self |
| Fuel Consumption, l/hr | 0.7 | 0.7 | 1.25 | 1.25 |
| Pump price (Approx.) | Rs.14,500-15,000 | Rs.14,500-15,000 | Rs.17,500-18,000 | Rs.17,500-18,000 |
| Approximate cost of irrigation (excluding cost of pipes), Rs/ha | 3125 | 1060 | 990 | 840 |
| Approx. field capacity, ha/day | 0.13 | 0.38 | 0.51 | 0.61 |

# Efficient Rainwater Management Practices for Sustainable Productivity and Profitability of Rainfed Crops under Different Soil and Agro-climatic Conditions

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## Abstract

*Among different inputs used in rainfed agriculture, water is the most crucial input for attaining sustainable productivity and profitability of crops. In the All India Coordinated Research Project for Dryland Agriculture (AICRPDA) with 22 cooperating centers in different states, field experiments are being conducted every year to identify efficient methods of rainwater management practices under on-station condition. The rain water management practices comprise of in-situ and ex-situ moisture conservation practices are : (i) application of mulches to conserve soil moisture; (ii) ridges and furrows; (iii) compartment bunds; (iv) tied ridges; (v) conservation furrow; (vi) sowing across the slope; (vii) vegetative barriers; and (viii) rain water harvesting and re-use for providing life saving/protective irrigation to crops during stress. An attempt is made in this paper to assess the effects of rain water management practices on the productivity of crops; response of crops to supplemental irrigation; cost of different practices; gross returns; net returns; benefit-cost ratio; and rain water use efficiency under varying rainfall situations at different soil and agro-climatic conditions in rainfed areas. The effect of critical irrigation provided to crops at different stages was assessed for cotton, castor, groundnut, soybean, mustard, safflower, rice, wheat, maize, pigeonpea, green gram, chickpea, potato, tomato crops. The net monetary returns as influenced by the critical irrigation of 5 to 10 cm (depending on the water available in the farm pond) ranged from Rs.2769/ha with maize grown under semi-arid Inceptisols at Rakh dhiansar (Jammu & Kashmir) to Rs.28956/ha with wheat under sub-humid Vertisols at Rewa (Madhya Pradesh). The analysis indicated that the farmers practice (control) gave net monetary returns in the range of Rs.1176/ha with groundnut under semi-arid Vertisols at Rajkot (Gujarat) to Rs.25460/ha with wheat under sub-humid Vertisols at Rewa. The benefit-cost ratio of critical irrigation provided to the crops ranged from 1.22 with potato under per-humid Inceptisols at Jorhat (Assam) to 4.51 with wheat under sub-humid Vertisols at Rewa. The benefit-cost ratio of farmers' practice (no irrigation to crops) ranged from 0.80 for maize under dry sub-humid Inceptisols at Rakh dhiansar to 2.62 for castor under semi-arid aridisols at SK Nagar (Gujarat).*

*Different crop residue mulches were applied to conserve soil moisture and improve the crop productivity and profitability under erratic rainfall conditions. When mulches were applied, the net monetary returns were in a range of Rs.3799/ha when rice was grown under dry sub-humid Inceptisols at Varanasi (Uttar Pradesh) to a maximum of Rs.37803/ha for sorghum under semi-arid Vertisols at Akola (Maharastra).*

*Compared to this, the farmers practice gave monetary returns in the range of Rs.660/ha from maize grown under dry sub-humid Inceptisols at Ballowal Saunkhri (Punjab) to Rs.34012/ha from sorghum grown under semi-arid Vertisols at Akola. The benefit-cost ratio of application of mulches ranged from 1.30 for rice grown under dry sub-humid Inceptisols at Varanasi to 3.96 for soybean grown under semi-arid Vertisols at Akola. The benefit-cost ratio of farmers practice (no critical irrigation to crops) ranged from 0.86 for lentil under moist sub-humid Inceptisols at Ranchi (Jharkhand) to 3.82 for soybean under semi-arid Vertisols at Indore (Madhya Pradesh). The efficient rain water management practices which have provided sustainable productivity and profitability of crops grown at different AICRPDA centers are discussed in the paper. The efficient rain water management practices have also been tested under farmers' field conditions through Operational Research Project/On-farm trials in different years. A few case studies of the successful rainfed technologies related to rain water management practices are also discussed in the paper.*

## Introduction

The AICRPDA is a network program in Central Research Institute for Dryland Agriculture (CRIDA) under Natural Resource Management (NRM) Division of Indian Council of Agricultural Research (ICAR). The network has 22 centers viz., 20 centers in State Agricultural Universities and 2 in technical/other Universities. The mandate of the centers is to : (i) optimize the use of natural resources, i.e., rainfall, land and water, and to minimize soil and water loss and degradation of environment; (ii) to evolve simple technologies to increase crop productivity and viability; (iii) to increase stability of crop production over years by providing improvements in NRM, crop management systems and alternate crop production technologies matching weather aberrations; (iv) to develop alternate and sustainable land use systems; and (v) to evaluate and study transferability of improved dryland technology to farmers' fields. The AICRPDA network also has 8 Operational Research Projects (ORPs) with the main objectives of (i) evaluating the performance of each component of dryland technology under the farmers management conditions; (ii) to provide feedback to the research stations for refinement of the recommendations; (iii) to achieve first hand working experience in the development of micro-watersheds so that they may serve as models for extension agencies.

## Materials and Methods

### Distribution of rainfall at different centers

The rainfed areas are spread out widely in the country. They can be broadly classified into arid, semi-arid and dry and wet sub-humid regions. The arid areas forming 19.6% of the total geographical area (329 m ha) are characterized by low and erratic rainfall (< 500 mm) and sandy soil texture. The growing season is very short (up to 75 days) with millets and short duration pulses dominating the production systems. Livestock farming is an important component of production in the arid ecosystem. The semi-arid areas can be further classified into dry and wet areas. Dry semi-arid areas form 12% of geographical area and receive a mean annual rainfall ranging from 500–700 mm with a growing season of 75-199 days. The wet semi-arid region constituting 25.9% of geographical area receives mean annual rainfall ranging from 750–1100 mm with a growing season up to 120 days. The crops and cropping systems are quite diverse in the semi-arid part of the country depending on the length of growing season. Sorghum, cotton, soybean, groundnut and pulses are major crops grown in this zone. The dry sub-humid areas constitute 21.1% of geographical area and receive a mean annual rainfall ranging from 1100–1600 mm. The high rainfall in these areas provides opportunities for water harvesting which can be linked with advantage to control water congestion of soil on one hand and runoff driven soil erosion on the other.

Based on the mean normal rainfall occurred during the last 4 decades, one center at Hisar is under arid climate (< 500 mm); 8 centers viz., Bellary, Rajkot, Bijapur, Anantapur, Arjia, Agra, Solapur and Kovilpatti are under dry semi-arid climate (500-750 mm); 5 centers viz., S.K.Nagar, Akola, Rakh Dhiansar, Bengaluru and Indore are under wet semi-arid climate (750-1000 mm); 4 centers viz., Ballowal Saunkhri, Faizabad, Varanasi and Rewa are under dry sub-humid climate (1000-1250 mm); and 2 centers viz., Chianki and Phulbani are under wet sub-humid climate (1250-1500 mm) groups. The details of mean monthly rainfall received at different centers during the last 40 years are given in Table 1. About 80 to 90% of the rainfall is received during June to October at all the centers.

**Table 1. Rainfall (mm) received at different AICRPDA locations (mean of 40 years)**

| Center | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Arid (< 500 mm)*** | | | | | | | | | | | | | |
| Hisar | 13 | 16 | 12 | 6 | 20 | 47 | 122 | 126 | 40 | 5 | 0 | 4 | 411 |
| ***Dry semi-arid (500-750 mm)*** | | | | | | | | | | | | | |
| Bellary | 4 | 1 | 5 | 21 | 54 | 63 | 43 | 53 | 123 | 102 | 33 | 11 | 513 |
| Rajkot | 1 | 1 | 2 | 1 | 3 | 97 | 221 | 166 | 74 | 9 | 15 | 0 | 590 |
| Bijapur | 4 | 2 | 6 | 21 | 38 | 86 | 73 | 78 | 152 | 96 | 31 | 7 | 594 |
| Anantapur | 2 | 0 | 1 | 31 | 38 | 64 | 99 | 123 | 112 | 113 | 32 | 10 | 615 |
| Arjia | 4 | 3 | 5 | 4 | 6 | 73 | 196 | 249 | 97 | 10 | 7 | 4 | 658 |
| Agra | 15 | 12 | 11 | 3 | 11 | 51 | 186 | 262 | 90 | 24 | 2 | 2 | 669 |
| Solapur | 2 | 5 | 4 | 11 | 37 | 113 | 128 | 140 | 172 | 80 | 24 | 6 | 722 |
| Kovilpatti | 21 | 18 | 23 | 68 | 60 | 17 | 23 | 32 | 75 | 181 | 150 | 60 | 728 |
| ***Wet semi-arid (750-1000 mm)*** | | | | | | | | | | | | | |
| S.K.Nagar | 0 | 0 | 0 | 0 | 0 | 87 | 278 | 275 | 142 | 20 | 3 | 1 | 806 |
| Akola | 10 | 9 | 11 | 3 | 18 | 155 | 224 | 221 | 103 | 47 | 15 | 9 | 825 |
| R.Dhiansar | 0 | 0 | 0 | 0 | 0 | 73 | 329 | 278 | 119 | 15 | 13 | 33 | 860 |
| Bengaluru | 1 | 8 | 13 | 34 | 101 | 84 | 100 | 133 | 211 | 167 | 59 | 15 | 926 |
| Indore | 9 | 2 | 3 | 2 | 9 | 121 | 261 | 225 | 247 | 40 | 18 | 7 | 944 |
| ***Dry sub-humid (1000-1250 mm)*** | | | | | | | | | | | | | |
| B.Saunkhri | 1 | 0 | 4 | 4 | 0 | 79 | 328 | 345 | 188 | 32 | 1 | 30 | 1012 |
| Faizabad | 15 | 12 | 7 | 7 | 21 | 134 | 279 | 324 | 195 | 46 | 9 | 10 | 1057 |
| Varanasi | 26 | 18 | 10 | 4 | 12 | 87 | 338 | 312 | 210 | 49 | 7 | 5 | 1078 |
| Rewa | 22 | 19 | 15 | 6 | 10 | 120 | 309 | 337 | 199 | 32 | 10 | 8 | 1087 |
| ***Wet sub-humid (1250-1500 mm)*** | | | | | | | | | | | | | |
| Chianki | 19 | 30 | 29 | 32 | 40 | 187 | 315 | 283 | 271 | 77 | 8 | 9 | 1300 |
| Phulbani | 9 | 14 | 21 | 31 | 58 | 182 | 340 | 381 | 221 | 88 | 28 | 5 | 1378 |

### *Experiments on rain water management conducted at different centers*

Field experiments to manage rain water are being conducted at different centers every year from 1971 onwards. During 2011-12, there were 75 experiments (19.2%) out of 390 experiments on RWM conducted under on-station condition. Similarly, there were 16 (11.4%) trials out of 141 trials on RWM conducted under ORP in farmers' field condition. The experiments involved treatments of (i) *in-situ* moisture conservation; (ii) application of mulches for better management of soil moisture; (iii) *ex-situ* water harvesting and re-use for giving supplemental or critical irrigation to crops; (iv) vegetative barriers to control run off and soil loss and better management of rain water; (v) growing of crops based on the slope and water movement (upstream and downstream water management). The rain water management practices were also tested in combinations with fertilizer N, P, and K nutrients; organic sources of nutrients; mulches; different levels of tillage; intercropping systems; varying seed rates and other treatments depending on the soil type, crop, rainfall and other variables in a given situation (Vittal et al., 2003; Maruthi Sankar et al., 2011).

### *Rain water use efficiency and profitability of treatments*

Using the observations of yield attained by different fertilizer treatments, and cumulative rainfall from June to October, a comparison of the ratios of yield and cumulative rainfall was made for assessing the performance of treatments for RWUE in each year and were averaged over years (Rockstrom et al., 2003; Mingbin et al., 2003). The water use efficiency is affected by application of fertilizer and their interactions (Ogola et al., 2002). Based on the ANOVA, the treatments which gave significantly higher RWUE could be considered as superior compared to those with significantly lower RWUE under rainfed conditions. The productivity and monetary returns, water use efficiency would be affected by tillage and cropping systems in studies made by different authors (Nema et al., 2008; Maruthi Sankar et al., 2012; Peterson et al., 1996). The gross monetary returns could be computed as a product of the mean yield of each treatment attained over years and value of the crop. The net monetary returns (Rs/ha) is derived as a difference of the gross monetary returns and cost of cultivation for each treatment. The benefit–cost ratio could be derived as a ratio of the gross monetary returns and cost of cultivation for each treatment and could be compared for assessing the superiority of treatments.

## Results and Discussion

### *Effect of RWM practices on productivity of different crops*

#### *In-situ moisture conservation practices*

Under *in-situ* moisture conservation practices tested at different locations, ridges and furrows method was superior for castor at SK Nagar with yield of 1390 kg/ha compared to flat bed method with 1079 kg/ha with yield increase of 28.9%. This practice was also superior for lentil at Agra (together with 8 cm irrigation at 45 DAS); pigeonpea at Faizabad and soybean at Indore (together with seed rate @ 60 kg/ha) with yield of 1387, 2218 and 1921 kg/ha compared to flat bed sowing with yield of 1162, 1834 and 1159 kg/ha respectively. The yield increase with ridges and furrows method was 19.4, 21.0 and 65.8% at Agra, Faizabad and Indore respectively. The practice of 30 cm distance between rows having 3 rows on broad bed of 90 cm and furrow of 45 cm was superior for groundnut at Rajkot with a pod yield of 992 kg/ha (15.8% increase) compared to control spacing 45 cm (857 kg/ha). The method of sowing across the slope together with vegetative barrier with 'Rosha grass' was superior at Indore with significantly higher maize yield of 1725 kg/ha (30.4% increase) compared to farmers practice of sowing along the slope without any vegetative barrier (1323 kg/ha).

At Arjia, strip cropping of maize + blackgram with deep tillage and ridging after sowing was superior with significantly higher maize equivalent yield of 2262 kg/ha (yield increase of 98.3%) compared to maize + blackgram in 2:2 ratio (1141 kg/ha). At Hisar, deep ploughing was superior for mustard with yield of 1580 kg/ha (16.2% increase) compared to shallow ploughing (1360 kg/ha). At Agra, significantly higher pearlmillet yield of 2940 kg/ha (34.1% increase) was attained by adopting flat bed + line sowing + conservation furrow compared to 2192 kg/ha attained by flat bed + broadcast sowing method. At Parbhani, conservation furrow at 2.7 m interval was highly efficient with sorghum equivalent yield of 5688 kg/ha (40.4% increase) compared to control yield of 4052 kg/ha. The effect of *in-situ* moisture conservation practices on productivity of crops along with yield increase over control are given in Table 2.

### Application of different mulches

At Ballowal Saunkhri, paddy straw was superior for African sarson with yield of 1064 kg/ha compared to control of 'no mulch' with 750 kg/ha (yield increase of 41.9%). This was also superior for wheat with yield of 2060 kg/ha compared to control with yield of 1290 kg/ha (yield increase of 59.7%). At Ranchi, paddy straw together with 100% recommended seed rate was superior for lentil with yield of 955 kg/ha compared to control with yield of 702 kg/ha (yield increase of 36.0%). The crop residue mulch was superior for castor at SK Nagar (1387 kg/ha), pigeonpea at Indore (1309 kg/ha), and sorghum at Akola (5695 kg/ha) compared to control yield of 1079, 1204 and 5177 kg/ha respectively. The yield increase was 28.5, 8.7 and 10.0% at SK Nagar, Indore and Akola respectively.

At Anantapur, the crop residue mulch together with micro-catchments at 45 cm apart for every 4 lines was superior for groundnut with pod yield of 1026 kg/ha (increase of 7.9%) compared to control yield of 951 kg/ha. Application of straw mulch to overcome early season drought was superior for rice at Varanasi with yield of 1325 kg/ha (increase of 19.4%) compared to control of 1109 kg/ha. At Indore, application of polythene mulch was superior for soybean with yield of 2566 kg/ha (increase of 42.7%) compared to control of 1798 kg/ha. At Ballowal Saunkhri, sugarcane trash was superior for maize with yield of 3066 kg/ha (increase of 56.8%) compared to control of 1917 kg/ha; while subabul mulch was superior for lentil with yield of 654 kg/ha (increase of 35.2%) compared to control of 484 kg/ha. The effect of mulches on crop productivity and increase over control for rainfed crops at different locations are given in Table 3.

### Application of critical irrigation

At SK Nagar, two life saving irrigations + FYM @ 5 t/ha was superior for castor with yield of 981 kg/ha compared to control of 615 kg/ha (yield increase of 59.4%). At Jorhat, two life saving irrigations (one at stolon & one at tuber formation) was superior for potato with yield of 6839 kg/ha compared to control of 5745 kg/ha (increase of 19.0%).

At Rajkot, one irrigation at 40% soil moisture deficit was superior for groundnut with pod yield of 950 kg/ha compared to control of 303 kg/ha (yield increase of 213.5%). At Rakh dhiansar, two life saving irrigations (one at pre-sowing and one at branching stages) + 100% RDF was superior for mustard with yield of 1649 kg/ha compared to control of 625 kg/ha (increase of 163.8%). In case of maize at Rakh dhiansar, one life saving irrigation during stress + 100% RDF was superior with yield of 1912 kg/ha compared to control of 1033 kg/ha (increase of 85.2%). At Varanasi, one life saving irrigation during late season drought was superior for rice with yield of 1614 kg/ha compared to control of 1434 kg/ha (increase of 12.6%). At Phulbani, two irrigations from lined pond with soil : cement ratio of 6 : 1 (8 cm thickness) was superior for tomato with yield of 18076 kg/ha compared to control of 14578 kg/ha (increase of 24.0%). At Rewa, one pre-sowing irrigation was superior for wheat with yield of 2756 kg/ha compared to control of 2460 kg/ha (increase of 12.0%). The effect of critical irrigation on crop productivity and yield increase over control at different locations are given in Table 4.

#### *Vegetative barriers*

At Ballowal Saunkhri, kannah grass as a vegetative barrier was superior for blackgram for attaining yield of 793 kg/ha (increase of 23.9%) compared to control (640 kg/ha). The grass was also superior for maize with yield of 1746 kg/ha (increase of 42.9%) compared to control (1222 kg/ha); and sesame with yield of 551 kg/ha (increase of 27.5%) compared to control (432 kg/ha). At Bengaluru, nase grass live barrier was superior for finger millet with yield of 2690 kg/ha (increase of 47.9%) compared to control (1819 kg/ha). In case of horse gram, khus live barrier was superior with yield of 4616 kg/ha (increase of 52.9%) compared to control (3018 kg/ha). At Indore, vegetative bunding + sowing across the slope was superior for soybean for attaining yield of 2794 kg/ha (increase of 41.9%) compared to control (1969 kg/ha). The effect of vegetative barriers on productivity of crops along with increase in yield are given in Table 5.

## *Effect of RWM practices on profitability of crops*

#### In-situ *moisture conservation practices*

Under *in-situ* moisture conservation practices tested at different locations, ridges and furrows method was superior for castor at SK Nagar with net profit of Rs.20522/ha and BC ratio of 4.25 compared to flat bed method with Rs.16040/ha with BC ratio of 3.50. This practice was superior for lentil at Agra (together with 8 cm irrigation at 45 DAS); and soybean at Indore (together with seed rate @ 60 kg/ha) with net profit of Rs.44013/ha and Rs.31387/ha and BC ratio of 4.84 and 3.35 compared to flat bed sowing (net profit of Rs.35563/ha and BC ratio of 4.26 at Agra; and net profit of Rs.14486/ha with BC ratio of 2.09 at Indore). In case of groundnut at Rajkot, 30 cm distance between rows having 3 rows on broad bed of 90 cm and furrow of 45 cm was superior for attaining a net profit of Rs.17586/ha and BC ratio of 2.26 compared to control of 45 cm spacing (net profit of Rs.13347/ha and BC ratio of 1.98).

At Arjia, strip cropping of maize + blackgram with deep tillage and ridging after sowing was superior with significantly higher net profit of Rs.13171/ha and BC ratio of 2.72 compared to maize + blackgram (2:2) (net profit of Rs.6227/ha and BC ratio of 1.18). At Hisar, deep ploughing was superior for mustard with net profit of Rs.14806/ha and BC ratio of 1.86 compared to shallow ploughing (net profit of Rs.9898/ha and

BC ratio of 1.56). In pearl millet at Agra, maximum net profit of Rs.18559/ha with BC ratio of 2.68 was attained by adopting flat bed + line sowing + conservation furrow compared to Rs.11962/ha with BC ratio of 2.09 attained under flat bed + broadcast sowing method. At Parbhani, conservation furrow at 2.7 m interval was highly effective for sorghum with net profit of Rs.21420/ha and BC ratio of 2.84 compared to control (net profit of Rs.12265/ha and BC ratio of 2.09). The effect of *in-situ* moisture conservation practices on gross and net monetary returns and BC ratio of crops are given in Table 2.

### Application of different mulches

At Ballowal Saunkhri, paddy straw was superior for African sarson with net profit of Rs.9820/ha and BC ratio of 1.96 compared to control (net profit of Rs.4453/ha and BC ratio of 1.46). This was also superior for wheat with net profit of Rs.12358/ha and BC ratio of 2.05 compared to control of Rs.3505/ha and BC ratio of 1.30. At Ranchi, paddy straw together with 100% recommended seed rate was superior for lentil with net profit of Rs.8929/ha and BC ratio of 1.80 compared to control (negative net returns of Rs. -1130/ha and BC ratio of 0.86). At SK Nagar, crop residue mulch was superior for castor (net profit of Rs.16594/ha and BC ratio of 3.51) compared to control (net profit of Rs.12595/ha and BC ratio of 3.01). The crop residue mulch was superior for pigeonpea at Indore (Rs.23812/ha), and sorghum at Akola (Rs.37803/ha) compared to control. At Anantapur, the crop residue mulch together with micro-catchments at 45 cm apart for every 4 lines was superior for groundnut with net profit of Rs.19879/ha and BC ratio of 2.66 compared to control of Rs.18145/ha and BC ratio of 2.53. Application of straw mulch at early season drought at Varanasi was superior for rice with net profit of Rs.3799/ha and BC ratio of 1.30 compared to control of Rs.1802/ha and BC ratio of 1.15.

At Indore, application of polythene mulch in soybean gave maximum net profit of Rs.34839/ha and BC ratio of 3.87 compared to control of Rs.23666/ha and BC ratio of 3.82. At Ballowal Saunkhri, sugarcane trash was superior for maize with net profit of Rs.8359/ha and BC ratio of 1.67 compared to control (net profit of Rs.660/ha and BC ratio of 1.06); while subabul mulch was superior for lentil with net profit of Rs.9042/ha and BC ratio of 2.03 compared to control (net profit of Rs.4462/ha and BC ratio of 1.51). The effect of mulches on gross and net returns and BC ratio are given in Table 3.

### Application of critical irrigation

At SK Nagar, two life saving irrigations + FYM @ 5 t/ha was superior for castor with net returns of Rs.17049/ha and BC ratio of 3.01 compared to control (net returns of Rs.9725/ha and BC ratio of 2.62). At Jorhat, two life saving irrigations (at stolon & one at tuber formation) was superior for potato with net returns of Rs.12224/ha and BC ratio of 1.22 compared to control of Rs.8850/ha and BC ratio of 1.19. At Rajkot, irrigation at 40% soil moisture deficit was superior for groundnut with net returns of Rs.22058/ha with BC ratio of 2.41 compared to control (net returns of Rs.1176/ha and BC ratio of 1.09). At Rakh dhiansar, two life saving irrigations (one at pre-sowing and one at branching stages) + 100% RDF was superior for mustard with net returns of Rs.19879/ha (BC ratio of 3.71) compared to control (net returns of Rs.3413/ha and BC ratio of 1.49). In maize at Rakh dhiansar, one life saving irrigation during stress + 100% RDF was superior with net returns of Rs.2769/ha and BC ratio of 1.24 compared to control (net returns of Rs.-1739/ha and BC ratio of 0.80). At Varanasi, one life saving irrigation during late season drought was superior for rice with net returns of Rs.3311/ha and BC ratio of 1.27 compared to control of Rs.2217/ ha with BC ratio of 1.18. At Phulbani, two irrigations from lined pond (soil : cement ratio of 6:1 with 8 cm thickness) was superior for tomato with net returns of Rs.146380/ha and BC ratio of 2.79 compared to control of Rs.85910/ha and BC ratio of 1.76. At Rewa, one pre-sowing irrigation was superior for wheat with net returns of Rs.28956/ha and BC ratio of 4.51 compared to control of Rs.25460/ha with BC ratio of 4.29. The effect of critical irrigation on monetary returns and BC ratio of crops are given in Table 4.

#### *Vegetative barriers*

At Ballowal Saunkhri, vegetative barrier with kannah grass was superior for blackgram gave net returns of Rs.14883/ha (BC ratio of 2.09) compared to control (net returns of Rs.10045/ ha and BC ratio of 1.78). This grass was also superior for maize with net profit of Rs.4012/ ha (BC ratio of 1.26) compared to control of Rs.-1098/ha (BC ratio of 0.93); and sesame with net profit of Rs.10813/ha (BC ratio of 1.96) compared to control of Rs.6691/ha (BC ratio of 1.63). At Indore, vegetative bunding + sowing across the slope for soybean gave maximum net profit of Rs.43705/ha (BC ratio of 4.97) compared to control of Rs.27839/ha (BC ratio of 3.53). The superior vegetative barriers for monetary returns and BC ratio of crops are given in Table 5.

## Rain water management technologies developed by AICRPDA centers

### Technology-1 : Water harvesting and supplemental irrigation to rainfed groundnut under shallow arid alfisols in Andhra Pradesh

**Domain districts :** Kurnool, Anantapur (except south-eastern part) western part of Prakasam, southern part of Mahaboobnagar and north– western parts of Kadapa covering scare rainfall zone (Rayalaseema) of Andhra Pradesh.

#### Technology

- Protection of groundnut crop during dry spells by giving supplemental irrigation from harvested water in farm ponds.
- A pond of 250 $m^3$ capacity (10 m x 10 m with 2.5 m depth) with side slopes of 1.5:1 is recommended for catchment area of 1 ha. Soil + cement lining in 6:1 ratio is done for reducing seepage losses.
- The cost of farm pond is about Rs. 12000/-. Supplemental irrigation of 1 cm through sprinklers at 45 DAS (pod formation stage) will increase pod yield by 25%. Sprinklers are run through diesel pump.
- A sprinkler unit costs about Rs.12000/- & 5 HP oil engine costs about Rs. 17500/-.

#### Performance

- Application of 1 cm irrigation to groundnut during stress at pod development stage gave 1023 kg/ha compared to control of 820 kg/ha.
- There is yield increase of 24.8% with supplemental irrigation.
- The capital (Rs. 41500/-) recovery can be made over a period of 4 to 5 years by adoption of this technology with yield increase of 20 to 30% annually.

#### Impact and up-scaling

- Adoption of this technology will increase pod yield in drought years & reduce farmers' distress.
- By adopting this practice, there will be an additional pod yield of 25500 tons (worth about Rs. 7.65 crores) in the target domain.

- Part of the capital cost of farm pond can be met from NREGS, which can help in faster upscaling of technology.
- The remaining capital expenditure has to be provided as soft loan to small & marginal farmers who cannot afford to invest money.

### Technology-2 : Higher mustard productivity in rainfed regions of Agra through supplemental irrigation with harvested rain water

**Domain districts :** Agra, Aligarh, Mathura, Mainpuri, Etah districts in south-western semi-arid zone of Uttar Pradesh.

#### Technology

- Out of annual rainfall of 665 mm received in the region, 80% is received during *kharif.*
- The entire *kharif* rain is received in two or three events. About 30% of rainfall goes as runoff.
- This runoff water is harvested in a farm pond (20 m X 20 m X 2m of size (with storage capacity of 800 $m^3$) and used as pre or post sowing irrigation for mustard.
- Depending on water availability, 8 cm irrigation can be given in two splits i.e. 4 cm at flowering and 4 cm at siliqua formation for better productivity and profitability.
- The cost of farm pond is Rs. 40000/-.

#### Performance

- Supplemental irrigations at flowering & siliqua formation stages of mustard give yield of 2076 kg/ha compared to 1459 kg/ha under farmers practice.
- The yield advantage is about 42.3% with a net income of Rs. 10000/ha & BC ratio of 3.80.

#### Impact and up-scaling

- Mustard is grown on about 79000 ha in Agra district.
- By giving supplemental irrigation to rainfed mustard, additional production valued at 79 crores could be realized by farmers.
- The capital cost of farm ponds can be minimized by convergence with NREGS. Coordination between departments is necessary for successful adoption of such technologies.
- Soft loans can be provided to farmers to meet material cost and labour cost can be met from NREGS.

### Technology-3 : Use of harvested rain water for production of short duration leafy vegetables in Jharkhand

**Domain districts :** Ranchi, Hazari bagh, Giridhi, Santhal Paraganas, Dhanbad, & North East of Ranchi in Central & North East plateau zone; Palamau, Gumla, part of Hazaribagh, Hilly Southern part of Gaya, Aurangabad, Rohtas in western plateau zone of Jharkhand.

#### Technology

- Runoff from cropped fields is stored in a dugout pond of size 6m x 6m x 3m in the lower end.
- About 5000 $m^3$ of water can be stored in the pond in a season from the runoff colleted from one ha farm land. Cost of farm pond with stone pitching is Rs. 30000/-
- Using this water, leafy vegetables can be grown on 2500 sq. m area with 5 irrigations with 3 cm irrigation each (border method).
- Short duration vegetables like Palak

(Pusa Jyothi), Coriander Selection-81) and Radish (Chetki) are recommended for this type of cultivation. Cost of each irrigation is Rs. 700/-

**Performance**

- A yield of 2238 kg/ha of Palak, 2206 kg/ha of Coriander & 1245 kg/ha of Radish is realized in one season.
- It gives net returns of Rs.17904/ha for Palak, Rs.66180/ha for Coriander & Rs.39836/ha for Radish with BC ratio of 1.28, 1.89 & 1.99 respectively.

**Impact and up-scaling**

- About 15% farmers in the area have adopted recycling of harvested water for vegetable crops.
- More area can be brought under this technology by popularizing through KVK, State Department of Agriculture NHM schemes for realizing more economic returns.

**Technology-4: Ridge–furrow planting of pigeonpea + rice in Eastern Plain Zone of Uttar Pradesh**

**Domain districts :** Varanasi, Chandauli, Sant Rabidas Nagar, Jaunpur, Ghazipur, Mirzapur and Sonbhadra districts in Eastern Plain and Vindhyan Zone of Uttar Pradesh.

**Technology**

- Ridge-furrow planting of pigeonpea (Bahar) and rice (NDR-97) in uplands and medium lands helps in minimizing risk and harvesting bonus yield of component crop i.e., either rice in case of pigeonpea based or pigeonpea in case of rice based system.
- Pigeonpea is planted on ridge and rice in furrows. The ridge-forming machine makes ridges 60 cm apart & 15 cm wide on the top. The cost of machine is Rs. 2000/-

**Performance**

- Ridge-furrow planting helps in runoff modulation, crop diversification, soil fertility build up, risk reduction & disruption of pest cycle.
- This system produces rice equivalent yield of 8866 kg/ha (2200 kg/ha of rice & 2000 kg/ha of pigeonpea) against 3500 kg/ha of rice with farmers' practice of sole rice under flat planting.
- This system gives 1.6 times higher biomass, 18% reduction in cost & 47% higher income over farmers' practice.

**Impact and up-scaling**

- About 25% area in the region has come under ridge-furrow planting system. With introduction of ridge forming machine and its availability through custom hiring, large area under this diversified system is expected in future.
- Continued extension efforts are needed through KVKs, ATMA, & other development schemes.

**Technology-5 : Ridges and furrows for in-situ moisture conservation in scarce rainfall zone of Maharashtra**

Domain districts : Solapur and Ahmednagar districts and western part of Beed, Osmanabad, Aurangabad, Eastern part of Pune, Sangli, Kolhapur and southern part of Dhule, Jalgaon, Nandurbar and Jalna in Maharashtra.

**Technology**

- Ridges and furrows are made with bullock drawn *Baliram* wooden plough across the slope in June at the onset of monsoon. The width of furrow is 45 cm and height is 20 cm.

- The effective field capacity of the wooden plough for making ridges and furrows is 1 to 1.5 ha/day.
- The cost of opening of ridges and furrows with *Baliram* wooden plough is Rs.1000/ha. The main purpose of making ridges and furrows is to capture rainfall during *kharif*, avoid soil erosion and store more water in profile, which is useful for *rabi* crop.

**Performance**

- The practice of ridges & furrows conserves 45% more moisture than farmers practice (two harrowings) & retains it for longer period (up to 60 days) & increases *rabi* sorghum yield (826 kg/ha) by 53%.
- This gives net returns of Rs. 8500/ha with BC ratio of 1.76 compared to farmers' practice (yield of 540 kg/ha, net returns of Rs.3850/ha & BC ratio of 1.48).

**Impact and up-scaling**

- This practice is widely adopted in 60% of *rabi* sorghum area in Solapur district.
- Further upscaling of this practice can be done in other districts of the target domain with similar agro-ecological features through more extension efforts and linkage with line departments, demonstrations by ATMA, KVKs, and NGOs etc.

**Technology-6 : Ridge planting of pearl millet for higher productivity in Agra region**

**Domain districts :** Agra, Aligarh, Mathura, Mainpuri, Etah districts in south-western semi-arid zone of Uttar Pradesh.

**Technology**

- Pearl millet is sown on ridges by ridger seeder with ridge size of 75 cm.
- The excess rainwater is safely drained out from field or conserved in the furrows.
- It provides more opportunity time for the water to infiltrate into soil. It also provides better physical environment to the crop both during normal & sub-normal rainfall situations.
- It reduces crust formation at the time of germination.
- The operational cost by using ridger seeder is Rs. 600/ha.

**Performance**

- Pearl millet performs better on ridges with grain yield of 2288 kg/ha compared to farmers practice (1586 kg/ha).
- The increase in yield is 44.3% & net returns is Rs.13761/- with BC ratio of 2.23 over farmers' practice of broadcasting seed.
- Ridge planting provides enough aeration & porosity to soil for enhanced root growth, apart from safe disposal of excess rainwater and reduced soil loss.

**Impact and up-scaling**

- Pearl millet is grown on 1.07 lakh ha in the region with average yield of 1407 kg/ha. This can be enhanced to 2016 kg/ha by adoption of this technology.
- This technology can be upscaled by making available ridger seeder through custom hiring centers and demonstrations by KVK & State dept. of Agriculture

### Technology-7 : Cover crops for in-situ moisture conservation in black soils of Northern dry Zone of Karnataka

**Domain districts :** Bijapur, Bagalkot, Gadag, Koppal, Bellary, part of Dharwad, Belgaum, Raichur and Davangere districts in medium to deep black soils of Northern dry zone of Karnataka

#### Technology

- Involves cover cropping with quick growing species to reduce run-off and splash erosion.
- These crops include sunhemp, greengram, cucumber, ridge gourd for *kharif.*
- These species quickly cover the ground surface by 45 days and reduce run off, conserve rain water *in-situ.*
- Legume cover crops improve soil fertility by adding N, benefiting succeeding crops when incorporated at harvest or during vegetative stage as in case of sunhemp (at 45 DAS) days).

#### Performance

- With cover cropping in *kharif*, yield advantage in various *rabi* crops varies from 43 to 300% with BC ratio up to 5.47.

#### Impact and up-scaling

- This technology is practiced in 500 ha in Bijapur, Gadag & Bagalkot & has potential for upscaling in peri-urban areas with good market.
- Further upscaling can be done with demonstrations by line departments, KVKs, ATMA, NGOs.
- Incentives under NHM can be designed as it results in enhanced vegetative production.

### Technology-8 : Land management practices for higher soybean productivity in Malwa region in Madhya Pradesh

**Domain districts :** Dhar, Indore, Ujjain, Dewas, Ratlam, Rajgarh, Mandsaur, Neemach Jhabua, Sehore and Shajapur in Madhya Pradesh

#### Technology

- It involves planting soybean either on broad beds (90 cm) or ridges (45 cm).
- The ridges can be made with bullock-drawn ploughs. Provision of SWEEP between furrow openers of tractor drawn seed drill facilitates ridge planting of soybean.
- Soybean can be grown on the broad beds or ridges with 25% less than the recommended seed rate.
- Growing soybean on broad beds or ridges improves soil physical environment, better root growth, water use efficiency and higher crop yields.

#### Performance

- Soybean on BBF or ridge system gives yield of 1600 kg/ha against flat planting (1235 kg/ha).
- Better crop growth & yield coupled with reduced seed rate gives higher BC of 2.5 with this practice over farmers' practice (2.2).
- WUE with ridge furrow system is 27.3 against 21 kg/ha/cm with farmers' practice.

#### Impact and up-scaling

- Farmers in Malwa region adopted this technology on fairly large area.
- Availability of improved farm implements will help in spreading this

technology faster along with creating more awareness with farmers through training & demonstrations.

- Farmers realized higher profitability due to better drainage, moisture conservation and reduced seed rate.

### Technology-9 : Compartment bunding and balanced nutrition for higher productivity of rainfed cotton in Southern Tamil Nadu

**Domain districts** : Thoothukudi, Tirunelveli, Virudhanagar and Madurai districts in Southern zone of Tamil Nadu.

### Technology

- Compartment bunds are formed either manually with spade or with tractor drawn bund former during first fortnight of September before onset of north-east monsoon.
- The size of bund is 8 x 5 m with 0.3 m height, 0.3 m base width with cross section of 0.045 $m^2$.
- The cost of making compartment bunds is Rs.750/ha if manually made and Rs.500/ha with tractor drawn bund former.
- Cotton (KC-3) is sown by dibbling in the bunded fields before onset of monsoon.
- The longevity of bunds depends on rainfall intensity & remain intact up to 30 days i.e. up to end of October.
- Balanced nutrition in cotton comprises basal application of 40 kg N, 20 kg $P_2O_5$, $ZnSO_4$ @ 25 kg/ha (soil application) & two foliar sprays of 1% $MgSO_4$ at 40 & 60 DAS. The cost of application of $ZnSO_4$ and MgSO4 is Rs.1200/ha.

### Performance :

- Compartment bunds increase soil moisture storage by 5% & along with balanced nutrition gives seed cotton yield of 637 kg/ha with net returns of Rs.3299/ha compared to farmers' practice of no bunding & no balanced nutrition (Rs.497/ha).
- This represents 28% increase in yield & BC ratio of 1.35 & gives assured yield in sub-optimal rainfall years.

### Impact and up-scaling

- This practice is adopted in 500 ha in Toothukudi district.
- With further upscaling in the remaining 4500 ha of cotton area in the district through demonstrations by KVK, NGOs, line departments and other agencies, production of 6750 bales of lint with net returns of Rs.1.48 crores could be attained.

### Technology-10 : Compartment bunds for moisture conservation in Northern dry Zone of Karnataka

**Domain districts :** Bijapur, Bagalkot, Gadag, Koppal, Bellary, part of Dharwad, Belgaum, Raichur & Davangere districts in medium to deep black soils of Northern dry zone of Karnataka.

### Technology

- It involves making square compartments on the field to retain rainwater and arrest soil erosion. After receipt of early rains in June and July, land is harrowed to remove germinating weeds. Then compartment bunds (0.15 m height) are formed using bullock drawn bund former.
- The size of bunds varies from 3 m x 3 m to 4.5 m x 4.5 m depending on slope. The cost of compartmental bunds is Rs.150/ha. These bunds are retained till sowing of *rabi* crops with seed-cum-ferti drill

during 2nd fortnight of September to 1st fortnight of October.

- Compartment bunds provide more opportunity time for water to infiltrate into soil & help in conserving moisture.

**Performance**

- *Rabi* sorghum, sunflower, safflower & chickpea gave seed yields of 870, 675, 620 & 450 kg/ha, respectively with yield advantage of 40, 35, 38 & 50% respectively with net returns of Rs. 2475, Rs.3700, Rs. 3250 & Rs.2850 with compartment bunds over flat planting.
- The practice has more impact during sub-optimal rainfall years & also significantly controls run off.

**Impact and up-scaling**

- This practice is adopted on 800 ha in Bijapur, Bagalkot and Raichur districts of northern Karnataka. Further upscaling can be done through demonstrations by line departments, KVKs, ATMA, and NGOs etc.
- There is large scope to implement this through NREGS where land development works can be undertaken on private lands also. This activity can be included in the shelf of works of the Gram Panchayat every year.

**Technology-11 : Deep tillage & compartment bunds for enhanced pearl millet productivity in Agra region**

**Domain districts :** Agra, Aligarh, Mathura, Mainpuri, Etah districts in south-western semi-arid zone of Uttar Pradesh.

**Technology**

- Deep tillage (20-25 cm) by mould broad plough is done in alternate year in summer (April-May).
- This facilitates better rainwater infiltration into soil and effective weed control.
- The compartment bunds (6.0 m X 4.5 m) are formed either manually or with tractor drawn ridge maker after proper germination to conserve more moisture.
- The operational cost for deep tillage & compartmental bunding is Rs. 1000/ha.

**Performance**

- Deep tillage + compartment bunds conserves moisture up to 5% & gives pearl millet (WCC-75) yield of 1875 kg/ha which is 31% higher than farmers' practice (1230 kg/ha).
- This technology gives net returns of Rs. 10045/ha with BC ratio of 3.23 compared to farmers practice even during sub-normal rainfall situations

**Impact and up-scaling**

- Deep tillage in summer & compartment bunds after germination can support up to 1.5-2 t/ha of pearl millet yield.
- About 20% farmers in the region are adopting this technology.
- There is great scope for further adoption by strengthening extension activities & linkages with programs of line departments & NGOs.

**Technology-12 : Gravel and sand mulching in sodic soils for moisture conservation in Northern dry Zone of Karnataka**

**Domain districts :** Bijapur, Bagalkot, Gadag, Koppal, Bellary, part of Dharwad, Belgaum, Raichur & Davangere districts in medium to deep black soils of Northern dry zone of Karnataka

### Technology

- This technology involves sand application to sodic vertisols during summer.
- Before application of sand, perennial weeds like *Cynodon dactylon, Cyperus rotundus etc.*, are removed. FYM @ 5 t/ha is applied, followed by deep ploughing.
- After bringing soil to fine tilth, nearly 275-300 tractor loads/ha of gravel & sand mixture is uniformly applied & spread manually using spades to ensure uniform thickness of 10-15 cm on soil surface.
- The cost of application of gravel sand is Rs.77500/ha (Rs.2500 for labour cost spreading + Rs.75000/- for transport @ Rs 250/tractor loads).
- This is a capital investment technology of land development & mulching but is effective for 15-20 years. Therefore, the cost of sand/ gravel application /ha/year comes to Rs. 3875 to Rs. 5160.
- However, gravel & sand should be applied once in 5 years in patches where sand is lost due to runoff. Gravel & sand mulching helps in conserving rainwater *in-situ*.

### Performance

- This practice enables double cropping of groundnut or green gram in *kharif,* followed by *rabi* sorghum or sunflower or chickpea in *rabi.*
- This technology gives yield advantage up to 125% in groundnut (1400 kg/ha), 214% in *rabi* sorghum (2200 kg/ha), 300% in sunflower (2000 kg/ha), 300% in chickpea (1500 kg/ha) & 366% in green gram (1400 kg/ha) with additional net returns from Rs.5300 to Rs. 33000, BC ratio of 2.83 to 5.69.
- The cost of sand application can be recovered within 2 years of cropping.

### Impact and up-scaling

- This technology is adopted in 30000 ha in sodic soils of Koppal & Gadag districts in northern Karnataka.
- Further upscaling can be done in this region where gravel and sand are easily available within the reach of the farmers at affordable transport cost.
- This technology also can be undertaken partly through NREGS, where the labour component can be met under land development works.

## Technology-13 : Earthing up in maize for higher productivity in deep black soils of Malwa region in Madhya Pradesh

**Domain districts :** Indore, Dhar, Ujjain, Dewas, Ratlam, Rajgarh, Mandsaur, Jhabua, Sehore & Shajapur districts in Malwa plateau of Madhya Pradesh

### Technology

- Sowing of maize in deep black soils with 45 cm row spacing on flat beds and earthing up 25 DAS with bullock drawn small blade harrow (Doura/ Kulpa) having 23 cm blade width tied with coir rope at both side ends of the blade.
- Earthing up helps in *in-situ* moisture conservation within the rows by retaining rainwater and also facilitates draining out excess water & controls weeds.
- The cost of this practice is Rs 500/ha.

### Performance

- This practice increases maize grain yield by 11% & gives additional yield of 338 kg/

ha & net returns of Rs. 1325/ha with BC ratio of 1.6 over farmers' practice (3558 kg/ha & net returns of Rs. 9859/ha with BC ratio of 1.34).

- This provides anchorage to roots & prevents lodging.

### Impact and up-scaling

- This practice is adopted on considerable area under rainfed maize in Malwa region.
- With further extension efforts, this practice can be upscaled through demonstrations by KVKs, ATMA under special schemes like ISOPOM & RKVY.
- Maize production can be enhanced to 3.34 lakh tons from existing 3.05 lakh tons in the region.

### Technology-14 : Vegetative barrier and in-situ incorporation of horse gram for higher finger millet productivity in semi-arid alfisols of Karnataka

**Domain districts :** Tumkur, Bangalore, Kolar, Chitradurga, Mysore and Mandya districts of central, eastern and southern dry zone of Karnataka.

### Technology

- Fall ploughing and sowing of horse gram (PHG-9) for *in-situ* green manuring at pre-flowering stage (40-45 DAS) followed by sowing of finger millet (GPU-28).
- Establishment of *Nase* grass (*Pennisetum hohenekere*) as live barrier on contours as inter-terrace land treatment is part of this technology.

### Performance

- The live barrier *Nase* grass with *in-situ* incorporation of horse gram biomass gives finger millet grain yield of 2500 kg/ha & straw yield of 3800 kg/ha with BC ratio of 1.95 compared to 1.74 under farmers practice.

### Impact and up-scaling

- Fall ploughing coupled with establishment of vegetative barrier of *Nase* grass & horse gram raised as cover crop gives marginally higher BC ratio for finger millet farmers due to additional costs involved in raising & incorporation of horse gram, but it controls soil loss and maintains soil fertility.
- Finger millet is cultivated in 1 m ha with production of 1.8 m tons in Karnataka.
- By adoption of this technology, it is possible to enhance production to 2.5 m tons.

### Technology-15 : Drought management in rainfed castor in Telangana

**Domain districts :** Ranga Reddy, Mahabubnagar, Nalgonda and parts of Medak of Telangana region of Andhra Pradesh

### Technology

Involves management of drought through package of practices covering :

- Sowing of drought tolerant cultivars like Jyothi, Kranti and 48-1 during June 15th –July 1st week across the slope
- Formation of conservation furrows for every 2 rows planted at 90 cm apart
- Operation of blade harrow in between castor rows during early growth stage.
- Additional N @ 10 kg/ha after relief of dry spells either at early (up to 45 DAS) or mid (45-90 DAS) growth stages.

### Performance

- Adoption of drought management practices as a package gives 35-50%

higher yield of castor over farmers practice with BC ratio of 1:8.

**Impact and up-scaling**

- Since these practices do not involve much investment, about 30% farmers in the area are adopting one or other components.
- Small farmers prefer no-cost options, while medium to large farmers tend to adopt additional N application also.
- KVK & ATMA should popularize this technology widely.

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# Water Resource Management in Hill Farming for Environment and Economic Security

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## Abstract

*In rainfed hill agriculture, where water storage is a major constraint, assured availability of water may help in increasing the farm production exponentially. This not only leads to the conservation of water but efficient distribution in the field. Since, the cost of developing water resources in hills is very high, there is strong need to minimize the storage and application losses and to utilize scarce water efficiently. Recent advances in irrigation and protected cultivation technology have made inroads in the cultivation of horticultural and vegetable crops. The present study envisages to successful implementation of these technology through realistic demonstration. The study finds that integrated low cost LDPE film lined tanks and protected cultivation technology can resulted into the economic transformation of rural settings of the Hill and Mountain agro-ecosystem of India.*

## Introduction

The criticality of water as natural resource in hill farming becomes self- evident because of terrain factor and issues involved in their development. The NW Himalaya (NWH) which consists of J&K, HP and UA, spreads to 33 million ha and habited by 25 million humans and 19 million livestock. The livelihood scenario in the region is highly critical. Availability of cultivable land per family in 5 selected districts was 0.4 to 0.6 ha (Srinivas *et al*, 2009). Agriculture, a major livelihood in hills, is faced with the challenges of extreme variation in agro-ecosystems, poor management and over-exploitation of natural resources. This has resulted in poor productivity, degradation of water sheds, economic unviability and poverty (Srivastva, 2006). Ecologically, the Himalayan ecosystem is estimated to need at least 5 unit of forest cover to sustain one unit of hill farming (Singh, J.S., 2004). Water is considered to be most critical natural resource for future growth of agriculture (Paroda, 2009). The habitation and settlements in hill region have developed along with *gadheras* (hill streams) and *naulas or dharas* (emerging water springs). Any strategy of improving water resource utilization cannot be seen in isolation with hill agro eco-system, integrated farming type and level of management including skill and capacity building of farming community. Not much work on on-farm water resources research and still less on their development is reported. In fact there has been insufficient work not only in itself but considering the extreme variation in agro eco systems and natural resources having very small mapping units.

## Context

The population pressure on farm land is very high in hills, being 1047/km$^2$ compared to national figure of 704/km$^2$. Four out of the eight Millennium Development Goals, being Eradication of poverty and hunger, Gender equality and women empowerment, Environment protection and Development of a global partnership for Development, concern directly to the people of Himalaya. The goal of ensuring economic security, supported by food and employment security is dependent on environmental security. Priority to comprehensive water resource management is expected to have strong positive impact on these factors. Water, its availability, competing demand, management and prevention of its pollution are major issues for the humanity.

North-west Himalayas are characterized by high attitude (1000m to >3500 m amsl), steep slope ((15% to >100%), high intensity rainfall (>100 mm/hr), dominance of shallow and gravelly soil (7.5-15 cm depth and > 40% gravel), severe degradation, loss of forest cover and inaccessibility (8.6 km length of roads compared to 37km/100km$^2$ in India). The mountain hydrology is adversely affected due to steep slopes, declining vegetative cover, gravelly soil with shallow depth and poorly developed cultivable terraces.

**Integrated Mountain farming system**: An integrated hill farming systems leads to improved factor productivity and reduced soil erosion. Employment Generation could be achieved because of, diversified food production including fruits, vegetables and allied activities including milk, poultry, fisheries and mushrooms.

**Climate resilience:** The IHR is noticeably impacted by climate change. The average annual rainfall received in NW Himalaya is 1336 mm, whereas Almora (UK) receives around 1150 mm rainfall. After accounting for runoff, the contribution from upstream and deep percolation losses, the estimated availability of rain water for plants was only 411, 363 and 316 mm. The region can be grouped into Water sufficient, Water excess and Water stressed situation.

**Major impact:** Loss of seeds, planting materials, Greater erosion due to poor vegetation cover, Greater exploitation and decline in natural resources.

## Approach

- Knowledge based site specific action plan
- Defined implementation mechanism.
- Integration of water resource management as a way of hill farming.
- Policy support.

## Major efforts in Water resource development

**Water harvesting and surface storage:** Monsoon rains characterized by high intensity of around 50 mm and more per hour which often far exceeds the infiltration rate, offer huge opportunity for water harvesting and storage.

i. Managing surface runoff

ii. Harnessing available distant resources

iii. Harnessing hill streams ( *gadheras* )

iv. Harnessing emerging water resources

v. Harnessing surface runoff

**Non arable land management:** This aspect is very important particularly for hill as the region has predominance of forest. Hence for improvement of moisture regime, its conservation in forest area (65%) is a must. Concerted efforts were made under the NAIP-SRLS project in the 5 districts of N W Himalaya. The non- arable land, which was owned by both individuals and community constituted 1312 ha being 28 % of the total area. Efforts made included treatment of 380 ha (30%) with bio engineering measures, 37 water harvesting ponds and 105 ha under perennial vegetation. Thus 485 ha were covered with different treatments.

**Arable land management:** Managing water resources in mountains as well as accommodating onsite/offsite stake-holders has always been a big challenge. Assuming that annual rainfall being 1000 mm and the runoff being 30%, and accounting for upstream contribution and deep percolation losses, only 582, 510 and 440 mm of water remains available to crops. Reduced tillage improved water productivity by 30 to 50 %, without affecting the food production. Establishment of crops was ensured by seed priming, deeper sowing to moist layer and dew harvest, resulting 13 to 50 % higher production without enhancing the water demand. *Insitu* on-farm water harvesting in ¼ th area raised production by 75%.Similarly, sunken bed farming resulted in 20% higher production from rice-wheat (>6 t/ha/yr) under rainfed agriculture. Recycling of harvested water resulted in 20 to 50 t/ha/yr of vegetable production in open to 80 to 120 t/ha/yr under protected cultivation. Water conservation by planting pits and trenches has improved survival and growth of fodder plantation by 25 and 75% in non-arable lands.

The food production in India is estimated at 254 million tonnes (Dept. of Ag, GOI). Water and its efficient management is central to the food production. There is growing realization of the importance of water harvesting both for environment protection and enhancement of food production. It is estimated that around 3-5 million of productive land get flooded. The major issues related to water harvesting revolves around managing rain water, increasing retention by vegetation canopy, soil profile and surface storage. The nature of hill and mountain ecosystem is quite distinct in this regard.

Micro-irrigation is necessary in the hill agriculture, not only due to efficient application and maximizing water use, but due to following reasons:

Slopy terrain (6 to > 100 %), limited soil depth (7.5 to 30 cm), and high gravel content (15 to > 50%).

## Grid based water harvesting ponds

Giving thrust to sustainable water resource development will entail due emphasis to perennial vegetation. The improved vegetative cover will not only reduce splash erosion but also result in reduced tillage. This will positively influence soil erodibility. In turn, the process will lead to better positioning of farming system to wards climate resilience.

The plantation of fruits under "On farm integrated farming system" and NAIP-SRLS project with 20,000 surviving fruit trees is estimated to have minimized tillage in > 20 ha area. Interface is very important. Albeit the primary need is domestic fulfillment and mitigation of hunger. Next to that the market, pricing, social and policy interface issues often dominate and greatly influence the farmer's incentives to farming. Thus, water resource development is very crucial for hill region.

**Water harvesting:** Because of terrain condition, which limits large scale canal or tube well irrigation. The small irrigation channels (Guls or Kuhls) face perpetual problem of repairs due to unstable terrains.

**Micro-irrigation:** Micro0irrigation is essential for hills not only for maximizing the water use but its efficient application. This is required due to steep slopy terrain, limited soil depth and high content of gravel.

**Protected cultivation:** this technology is appropriate because of very limited holding of around 0.4 to 0.6 ha/family. It has district advantage of 3 to 4 times higher production per year. It facilitates year round cropping even during harsh winters. The physical damage to fruits and plants due to hail storm and excess rains are also prevented. It works as excellent tool for carbon sequestration Apiary associated with polyhouse adds to the advantages.

**Multiple use of water:** water harvesting in ponds improves availability in vicinity of house hold for farming, Livestock and domestic chores. Thus it helps reduce drudgery to farm women. The ponds retaining water for longer period with depth of 1.5 m were successfully used for fish farming.

## Water resource development and climate resilience

Water resource development will help to reduce peak runoff. In one of the programme in village Bhagartola Almora more than 3,000 $m^3$ storage was developed. Similarly under NAIP-SRLS in 5 disticts more than 25,000 $m^3$ of storage of rain water and stream water was developed. Higher productivity based on moisture conservation and life saving irrigation directly contributed to higher carbon sequestration. Enhancement of water retention, considering sink (soil texture, gravels and depth) will be important strategy in imparting resilience to stress.

## Integrated Farming Systems- Replicable research information generation:

### Farm holding scale:

The productivity conditions of three sits at farm holding level and within micro-watershed were quantified. The selected micro-watershed were quantified. The selected micro-watersheds represented 0.4 ha area, which is the commonly prevailing size of a farm holding. The high, medium and low productivity conditions were quantified by i. run off (23, 30 and 37%), ii. soil loss (<10 t, 10-15 t and > 25t/ha/yr), iii soil nitrogen (0.21, 0.18 and 0.13 kg N/m3, and iv. the rain water available for crops (411, 363 and 316 mm/yr). Natural resource management on micro-watershed scale could raise the prevailing productivity of integrated farming system from 2.9 t/ha/yr to 4.3 under appropriate system. This productivity was further raised to 6 to 8 t/ha/yr with inclusion of water harvesting and vegetable cultivation; 11t of fruits and 12 t/ha/yr of fodder on micro-watershed basis. Thus, the carrying capacity of 1 ha could be raised from 8 humans and 0.3 cattle to more than 15 humans and 1 cattle. Adoption of strategy and the technology developed will not only result in food security but also help to reduce the twin problems of degradation and poverty. This approach promises to provide basis for successful action plan aimed at food and water security.Thus, it was possible to raise the carrying capacity of one hectare of land in hill region to 15 humans and 1 unit of livestock against the existing level of only 8 and 0.3, respectively.

**Village scale:** Diversification of traditional farming effectively supported by water harvesting and its multiple utilization at the farmer's field were undertaken as major research and development strategy. Water harvesting tanks consisted of 68 numbers with 3,060 $m^3$ one storage and poly houses of 97 numbers 8,245 $m^2$ area, respectively. The shift from traditional farming, which consisted of 63% cereals and pulses followed by only 30% vegetables and only 7% fruits to diversified integrated farming system consisted of 50% under cereals and pulses, 36% under vegetables, 12% under fruits, 1.3% under protected and 0.3% under fisheries. The introduction of water harvesting tanks and greenhouse changed the cropping system substantially. The area under traditional cereals and pulses were reduced to 44% from 55%. The reduction was resulted into the increase in area under vegetable (37% from 30%), fruits (18% from 15%). Fisheries could also been introduced after creation of water bodies in 0.1% area.

This could be achieved in a phased manner over three years period. Improved farming system included the components of traditional crops, plantations of *kharif* and *rabi* season vegetables including French bean, tomato, capsicum, squash, okra and cabbage, Vegetable pea and cauliflower resulting Rs 13 lakh income from 7.5 ha area (Rs. 1.95 lakh/hs) from vegetables alone, averaging around Rs 2 lakh/ha.

**Regional scale:** Similarly in NAIP Districts of Kupwara, Doda, Chamba, Tehri Garhwal and Champawat, the vegetable area and production was raised from from 600ha to 700 ha, and production from 1,685 t to 3516 t , respectively. This was largely supported by generating water resource of more than 25,000 $m^3$ through 268 farm ponds and 296 no of poly houses.

## Multiple use of harvested water

### Gaps and Constraints

There is closed cycle of water resource management and its utilisation in hills. On one hand, the technologies have been developed but its integration into mountain farming development programmes have been insufficient. In view of the terrain conditions, large scale development of water resources like canal irrigation and tube well irrigation is not feasible. Hence mega efforts are required for conservation, development and efficient utilisation of water resources.

## Water resource management at Regional, Community and Individual Level

Water resource development and irrigation development has been very limited in hill region. Hence tntegrated water resource development, protected cultivation and multiple use of water is very much pertinent in hill and mountain agro-ecosystem.

## Contingency plan

- Well planned field and controlled conditions to evolve contingency planning

## Issues in Implementable and Replicable technologies

Water Resource development as pre condition for vegetable farming and influenced by following factors

- Availability of resources including land in a farmers household farming systems. Eg :- sowing Transplanting time of crops and vegetables have to be integrated with the prevailing cropping of a farm household.
- The entire cropping and components sequence are hardly worked out in conjunction with the dynamic availability pattern of water.

**i.** Implementable techniques include gradual induction of compatible technologies.

**ii.** Technological orientation of the farmers in a graded and gradual way; with complete infrastructure, knowledge and input support. The examples are:

- Protected and surface covered cultivation
- Hybrid Napier in Oliya gaon
- Fruit plantations on terraces
- Establishing farmers link with inputs and knowledge support agencies.
- Financial and credit functional linkage
    - o not for namesake but functional credit card,

## Looking ahead

**Researchable Issues:** The VPKAS attempted convergence of implementable and replicable technologies as its outreach activities at village Bhagartola and Darim of District Almora and Nainital respectively. However there are several researchable issue which needs to be addressed for further translation of technologies at the farmer field. These are

- Moisture regime and availability pattern of Water
- Time scale management: Gradual induction of technology, cyclic improvement and build up skill improvement.
- Space scale management: Individual farm family, Village Community Watershed and Regional scale.

Realization of water resource development as core to sustainable hill farming supported by environmental security should define development of Hill Region. Grid based development of water resources covering the agro eco-region in a phased manner should form major agenda for water secured hill agriculture and its community in future.

Though there is enough knowledge base but intensive efforts are needed to address the diverse eco systems. The situation on on-farm research, technology transfer and adaptation is highly unsatisfactory. Hence, concerted efforts on mega scale are needed.

## Summary and Conclusion

The success of the water resource development and its efficient utilisation in hill farming may be credited to

- Need based interventions and convergence.
- Inclusive approach
    - o Agro eco system and farming systems.
    - o Involving entire community and village watershed.
- Robust technology and effective implementation Mechanism

There is a need for dedicated efforts on hill streams and springs: conservation, management, development and utilisation. Effective water resource management is essential not only for environment security but for imparting climate resilience.

Successful implementation of these technologies through realistic demonstration, integrated low cost LDPE film lined tanks and protected cultivation technology has resulted into the economic transformation of rural settings of the Hill and Mountain agro-ecosystem of India.

Mountain farming holds promise to meet the future requirements of the population it supports, and in addition to the market. However, the precondition is support of appropriate technology, implementation mechanism along with investment and support of encouraging policies. There are several success stories both at farm and watershed level in India. Adoption of the same will go long way to ensure food, environment, economic and livelihood security in the hill region

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**Annexure**

## Central Research Institute for Dryland Agriculture
## Hyderabad

# National Consultation on Application Technologies for Harvested Rainwater in Farm Ponds

## 19-20 March, 2012
## Venue : New Conference Hall

## PROGRAMME

**19 March 2012**

| | | |
|---|---|---|
| 0930 hrs | Registration | |
| | **Inaugural Session** | |
| 1000 hrs | Welcome | Dr.G.R.Korwar, Head, DRM, CRIDA |
| 1005 hrs | Background for the Consultation | Dr.B.Venkateswarlu, Director, CRIDA |
| 1010 hrs | Remarks | Dr.P.K.Mishra, Director, CSWCRTI |
| 1015 hrs | Inaugural Address | Dr.A.K.Singh, DDG (NRM), ICAR |
| 1025 hrs | Vote of Thanks | Dr.K.V.Rao, Sr.Scientist, CRIDA |
| | **Technical Session I** | **Chair – Dr.A.K.Singh, DDG (NRM)**<br>**Co-Chair – Dr.P.K.Mishra** |
| 1030 hrs | Application technologies for lifting water from shallow ponds – issues and strategies | Dr.Manoranjan Kumar |
| 1045 hrs | Upscaling low lift pumps for micro irrigation in Orissa | Dr.P.K.Paikaray |
| 1100 hrs | **TEA** | |
| 1130 hrs | Low energy water applicator (LEWA) - issues in upscaling | Dr.Ajay Kumar |
| 1145 hrs | Jain Jeevan – a solar pumping and drip irrigation system developed by Jain Irrigation | Mr.M.B.Reddy |
| 1200 hrs | Upscaling of portable pump technology in Adilabad district under NAIP | Dr.Ravikant Adake |
| 1215 hrs | Use of manual lift pump for irrigating agricultural crops in mine spoiled reclaimed areas of Jharkhand | Mr.Vinod |
| 1230 hrs | **Experience of farmers on innovative lifting devices (5 minutes each)**<br>Bicycle operated pump for low head water lifting<br>Innovative portable pumpset used for using farm pond water | <br><br>Mr.Vikram Rathod, Adilabad, AP<br>Mr.Rama Rao/Mr.Chandrasekhar, Adilabad, AP |

| | | |
|---|---|---|
| | Pond water utilization by diesel pump for high value vegetables cultivation<br>Experiences of other farmers<br><br><br><br>Demonstration of solar based water lifting devices | Mr.Namdev, Adilabad, AP<br><br>Two farmers from Orissa<br>One farmer from Bhagalpur<br>One farmer from Bhopal<br>One farmer from Jharkhand<br>Mr.Sekhar, Industry Representative |
| 1330 hrs | **LUNCH** | |
| | **Technical Session II** | **Chair : Dr.A.K.Singh**<br>**Co-Chair: Dr.B.Venkateswarlu** |
| 1430 hrs | Water harvesting in Himalayan regions – Problems and prospects | Dr.P.K.Mishra |
| 1450 hrs | Dug-out farm ponds for water harvesting and sustainable agriculture in low rainfall region of AP | Dr.B.Venkateswar Rao |
| 1520 hrs | Rainwater harvesting strategies in hot arid zone of Rajasthan | Dr.R.K.Goyal |
| 1540 hrs | Rainwater harvesting and use of low lift pumps in Marathwada region of Maharashtra | Dr.M.Bhuibar |
| 1600 hrs | Water harvesting in hill farming systems of North-West Himalaya | Dr.A.K.Srivastava |
| 1620 hrs | Rain water harvesting system and reuse in NAU campus – a case study | Dr.P.K.Srivastava |
| 1640 hrs | Environmentally sound technologies for water use efficiency | Mr.J.Koteswar Rao |
| 1700 hrs | Water harvesting in ponds to cope with climate change | Mr.Eswar Kale |
| 1720 hrs | Close | |

## 20 March 2012

| | | |
|---|---|---|
| 0900-1300 hrs | Visit to Gunegal Research Farm to see the water harvesting structures | Dr.K.S.Reddy/Dr.Manorajan Kumar/ Dr.Ravikant Adake |
| 1300 hrs | Lunch | |
| 1400 hrs | Plenary Session | Chair : Dr.B.Venkateswarlu |
| | Discussion and road map for development of farm pond technologies in the country | **Discussants**<br>Mr.M.P.Jain<br>Dr. A.K.Shukla<br>Mr.S.P.Gupta<br>Dr.M.B.Nagdeve<br>Dr.Rajeswari<br>Dr.Sahadeva Reddy<br>Dr.R.E.Lotha<br>Dr.K.M.Hati and<br>Other participants |
| 1600 hrs | Close | |

Indian Society of Dryland Agriculture thankfully acknowledges the financial assistance received from Indian Council of Agricultural Research (ICAR), New Delhi for organizing the National Consultation Meeting.

Indian Society of Dryland Agriculture thankfully acknowledges the financial assistance provided out of National Agricultural Innovation Project (NAIP) for organizing the National Consultation Meeting.

## Indian Society of Dryland Agriculture (ISDA)

This is a registered society (Regd. No. 1486 of 1986) with the main objective as to provide an opportunity to agricultural scientists from different disciplines to address problems confronting dryland agriculture in a concerted and integrated manner. It has about 400 members. The Society publishes a journal entitled 'Indian Journal of Dryland Agricultural Research and Development' bi-annually in June and December. The papers published in the journal are covered by CAB International, U.K., Indian Science Abstracts, India, The Indian Agricultural Sciences Abstracts, India.

**Subscription details:**

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| Annual member | Rs. 400/- |
| Life member | Rs. 2500/- |
| Organizations | Rs. 2000/- |

## Brief about CRIDA

CRIDA is a National Research Institute under the Indian Council of Agricultural Research (ICAR) established in 1985 with a mandate to carry out basic and applied research in rainfed farming. The Institute also undertakes National/ International Collaborations and Consultancy Projects. All India Coordinated Research Programmes (AICRPs) of ICAR on Dryland Agriculture and Agrometeorology with 25 partners each are in CRIDA. This is the lead Institute and the National Nodal point for the National Initiative on Climate Resilient Agriculture (NICRA) which is being implemented at large number of Research Institutes of ICAR, State Agricultural Universities and 100 KVKs.

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