Rainwater Harvesting and Reuse through Farm Ponds

Experiences, Issues and Strategies

Proceedings of National Workshop-cum-Brain Storming

Editors

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21-22 April 2009
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rainwater/ water harvesting/ farm pond/ ponds/ tank/ lining material/ harvestable surplus/ runoff/ supplemental irrigation/ livelihoods/ water storage structures/ on-farm reservoir/ optimum size/ networking/ reuse/ economic analysis/ rainfed region/ vetisols/ alfisols/ shivaliks/ malwa/ hill region/ north east region

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Preface

Rainfed farming will remain the main stay for the livelihood support of millions of small and marginal farmers across the country even after realizing the complete irrigation potential. Rainwater management is the most critical component of rainfed farming. The successful production of rainfed crops largely depends on how efficiently soil moisture is conserved in situ or the surplus runoff is harvested, stored and recycled for supplemental irrigation.

Research by ICAR and State Agricultural Universities has resulted in designing of efficient water harvesting structures for different rainfall regions and soil types, effective storage of harvested water and methods of its efficient use. Outside the main stream research system also, several non-governmental organizations (NGOs) have come up with models of simple and low cost water harvesting structures, evolved water sharing methods, community regulation of water use, which helped in up-scaling the models to certain extent. Different state governments (Maharastra, Madhya Pradesh, Gujarat etc) have initiated special programmes on farm ponds/small storage structures in order to ensure the sustainability and to improve the livelihoods of people.

Despite these experiences, the adoption of farm ponds at the individual farm level has been very low, particularly for drought proofing through life saving irrigation of kharif crops. A number of technological and socio-economic constraints are cited for this poor adoption and up-scaling. With climate change posing a major challenge for rainfed agriculture and the constraints in further expansion of irrigated area in the country, rainwater harvesting and efficient water use are inevitable options to sustain rainfed agriculture in future. The rainfall extremes and high intensity rain events witnessed in recent years are likely to cause large spatial and temporal variations in the amount of surplus runoff available for harvesting. In some areas, there could be increased runoff and more potential for harvesting, while in other areas it might decrease.

Considering these issues, a two-day National Workshop-cum-Brain storming session on farm pond technology was organized at CRIDA during 21-22 April,20009 with the objectives of (a) Sharing of experiences on water harvesting and reuse through farm ponds and related issues, among scientific institutions, Govt. departments, NGOs, civil society organizations and progressive farmers. (b) to Understand the biophysical, technological and social constraints in adoption and up-scaling. and (c)Identify critical research gaps and policy initiatives for wider adoption of farm pond technology in the country.

The workshop was primarily sponsored by National Agricultural Innovation Programme (NAIP) of ICAR under Sustainable Rural Livelihoods Programme. The workshop was attended by about 80 members representing scientific community (both ICAR and state agricultural universities), central and state government departments and NGOs. The present volume presents the practices being followed in different states and recent technological advances made, the role being envisaged for farm ponds in rainfed agriculture.

B.Venkateswarlu

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Rainwater Harvesting and Recycling: Current Status and Issues

Rainwater Harvesting through Farm pond and Well Recharging Structures to Support Rainfed Agriculture

Sandeep Khanwalkar

Madhya Pradesh Rural Livelihoods Project (MPRLP), Bhopal, Madhya Pradesh

Abstract

Even in high rainfall areas also, agriculture is not sustainable in the absence of water storage structures. Realising the fact that livelihoods in tribal areas can be improved with water resources augmentation, Madhya Pradesh Rural Livelihoods Programme (MPRLP) initiated a program in watershed mode with emphasis on farm level water resource augmentation through farm ponds, recharging of dug wells, stop dams etc. The paper presents a detailed account of the efforts made in Mandla district and lessons learnt while implementation of the program.

Introduction

Since time immemorial, water conservation and harvesting have been practiced in India and other parts of world. The production process depends on the timely water conservation in *Talab, pokhar, johad, khet talab*, and *bandha.* Rajasthan is famous for its traditional water conservation and harvesting practices. Madhya Pradesh, the *Pat Bandhna* is an age-old practice adopted by tribal families. *Chandela* tanks are good example of water conservation and harvesting, constructed by the *Chandelas rulers*.

In Madhya Pradesh, agriculture is mainly rainfed and the cropping pattern developed was also based on total quantum of rains received and type of soil. For example, in *Malwa,* which was known for good soil quality and depth had different cropping pattern historically (now it is completely changed due to technology) compared to the *Haveli* area (Mahakoshal or Jabalpur region) where crops were grown using water collected in big *talabs,* which exist in the area. This practice is similar to the practice adopted in Rajasthan where it is termed *Khadin.*

But still there is a need to implement water conservation practices in view of erratic rainfall in vast tracts of India. The pattern of water has changed drastically due to the availability of improved water lifting technologies. Consequently, crop production has intensified in larger areas.

There is requirement is to conserve rainwater adopting various conservation practices like farm pond, recharge structure for open well, field bunding, diversion drain to collect more water in farm ponds and open wells. This will lead to increased availability of water for agricultural purposes, leading to higher production. It is proven that farm ponds not only store water but also contribute to conserving soil moisture and sub-surface water. It is important to increase awareness at the field level on the usefulness of farm pond and well-recharging structures even though they are constructed at the cost of productive land.

About the Project

The philosophy behind the Madhya Pradesh Rural Livelihoods Project (MPRLP) is to lead a fight against the rural poverty along with the rural poor through bottom-up approach. The rural poor could be the real agents of economic change if given opportunities to realise their inner strengths and build confidence among them to rise above the poverty. The decision for the disposal of untied funds by the gram sabha stems from this philosophy.

With the area-specific strategies and flexible approaches to rural livelihoods options, the MPRLP helps the poor to explore and harness local opportunities of livelihoods, sharpen skills to avail such opportunities and march on with self-motivated entrepreneurship. The fulcrum of all development activities and capacity building is the gram sabha or the village assembly.

MPRLP is operating in 4000 villages of 9 tribal districts of Madhya Pradesh (Figure 1) namely Anuppur, Dindori, Mandla, and Shahdol in the eastern parts, Aalirajpur, Barwani, Dhar, and Jhabua in the south-western parts and Sheopur is in the northern part of Madhya Pradesh.

Figure 1. MPRLP districts in Madhya Pradesh

The project strengthens the programmes like watershed management and joint forest management and attempts to create livelihoods through the creation of micro-enterprises, drawing on the agricultural, forest and livestock resource base and skill endowments of the people.

The project is working on water conservation in all the project villages. National Rural Employment Guarantee Scheme (NREGS) provided an opportunity to work on these issues. The project being an implementing agency for the NREGS is involved in constructing farm ponds, open wells with recharging structures, field bunding, and undertaking plantation by adopting watershed approach. Since 2006, the project is working as the implementing agency for the NREGS in project districts. Concept of Technical Support Team was introduced to take watershed programme to the project districts. Apart from this, the project is also implementing various sub-schemes developed under NREGS by the Department of Panchayat & Rural Development, Government of Madhya Pradesh. These sub-schemes were mainly conceptualised to support and strengthen natural resource base activities at the village level.

A total of 64 farm ponds and 1001 open wells were constructed spending Rs. 442.81 lakhs under the *Kapildhara* sub-scheme of NREGS in the project districts by December 2008. Farm Ponds and Open well construction in the Mandla district was taken up at a large scale. For implementation of these activities, the project also involved two of its partner organisations as Technical Facilitation Team at the cluster level. This concept showed good results to undertake focused activities at a large scale. In this paper, experiences from the Mandla district are shared. The project also conducted detailed outcome analysis of the activities with respect to water availability to support rainfed agricultural production.

Brief Profile of Mandla District

The district Mandla is situated in the catchments of river Narmada and its tributaries.

Mandla is richly endowed with dense forests. The world famous Kanha National Park is the pride of Mandla and of the state. The majestic tigers add to the beauty of Kanha forests. The geographic area is 8771 km^2 spanned over and the length of the district is about 133 km from north to south and 182 km east to west and the population is 8,94,236. There are 9 blocks, 4 Tehsils and 1247 villages. Mandla district is part of the Deccan trap, which forms the most important aquifers. The weathered, fractured, jointed and vesicular units of basalts in Deccan traps form moderate to good aquifers.

Table 1. Land use classification of Mandla (in '000 ha)

Forest	593
Fallow Land	62
Cultivable Waste Land	20
Land not Available for Cultivation	53
Other Uncultivated Land Excluding both Fallow Land and Cultivable Waste Land	20
Net Sown Area	218

Groundwater situation in Mandla district comes under safe zone. With good rainfall, the Mandla district is known for its wild life, the forest cover and *Kanha Tiger Safari*. Paddy is the main crop in the *kharif* season. Rainfall ranges between 1200 to 1600 mm annually (Table 2). Mandla's eastern region receives about 157.00 cm rainfall. Even with good rainfall, water conservation is needed across the district.

Potential and Constraints

Good forests cover on upper ridge, black cotton soil in the plains, perennial streams etc., with a rainfall of 1200-1600 mm make the district rich in terms of natural resources, which provide opportunity for better management and use of these resources. District is also rich in bio-diversity. These all are potential sectors, which contribute to the overall growth including livelihoods of the tribal families. There is a need to manage these resources involving the community.

Poverty, irregular cash flow, low production, lack of infrastructure, lack of market support, no updated information on improved practices of crops production, livestock rearing, fish production etc are the most common constraints for the overall growth and development of the tribal region. Within district also, the impact of these constraints varies in different areas (Table 3).

Water Conservation and Rainfed Agriculture

Livelihoods of the tribal families mainly depend on agriculture & allied sector, Non-Timber Forest Produce (NTFP) and labour. Entire market system and cultural practices are framed around agriculture, allied activities and forestry activities. One needs to understand it from the tribal perspective to address the issues logically.

Sustainable agriculture can be possible when management of the natural resources is done on a sustainable basis. Agriculture requires good quality and improved seed, healthy and productive soil and water. The results in Table 4 help in assessment of the relationship between availability of water, soils and crop factors on crop production.

Table 2. Rainfall Data (mm)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5.2	17.8	23.5	4.1	13.4	149.4	61.1	412.2	144.1	57.1	1.2	0

Present requirement is to understand how we can promote and facilitate water conservation using various methods to ensure that the groundwater is not polluted and not over exploited, sub surface water availability increased, soil moisture retention capacity enhanced and over all water availability is increased.

We tried to work on these issues by adopting watershed approach and construction of farm pond and open well supported by the recharging structures. To increase the life of these structures, the catchment treatment and field bunds were also built so that the silt deposition in farm ponds can be reduced and rainwater can be diverted in to the open wells.

Table 3.

Particulars	Constraint	Opportunity
Production	Low and low rate of adoption of improved practices	Good soil, improved crop varieties
Rainfall	Short duration, high intensity	Overall quantum is good, availability of moisture for longer duration, area available for water harvesting structure
Soil depth	High rate of top soil erosion	Traditional conservation practice and good soil depth in plains
Soil type		Good quality soil, traditional conservation practices
Market support	No or poor market support, market not poor sensitive	Linkages can be developed if organic farming is promoted
Information	No proper information dissemination mechanism according to farmer demand, Low literacy rate.	Various government programme which provides information in different mode/mediums.
	Dependency only on traditional knowledge	
Cash flow	Irregular, high debt, limited cash crops, no banking services	SHG movement, NREGS, Government schemes
Infrastructure	Remote location	BRGF, PMGSY, NREGS

Table 4.

Water availability	Soil	Crop
Quantity per day	Texture	Type of root system
Rotation or turn period	Structure	Life-span
System and method of irrigation	Depth up to the water-table	Consumptive water needs in relation to climate
Water quality class	Infiltration and permeability	Critical periods with respect to moisture
	Slope of land	Yield response in relation to water-supply

Watershed and Agricultural Development

Poor soil and water management is one of the root causes of poor productivity of the tribal household farms. The traditional dependence on rainfed agriculture causes fluctuations in production levels and imparts instability to the tribal economy. Lessons within Madhya Pradesh and in other states have shown that the creation of water harvesting structures, as a community movement, is an effective approach to stabilise peoples' incomes and reduce their vulnerability. The increase in soil fertility and water availability achieved through watershed management contributed to increased productivity and production to enable farmers to take two or more crops per year, with both food security and cash income benefits.[1] The present low-level of irrigation underscores the need to take up more interventions to enhance crop production and soil water conservation in the Mandla district.

Watershed development is very important approach for the tribals given the twin benefits that it leads to. In the short-term outputs, it leads to income transfers through wage employment given its labour intensive nature and in the medium term outputs, it is leading to creation of assets that contribute to the sustainability of livelihoods.

The process of creating sustainable livelihood starts with livelihood analysis. The focus should be on the following:

- A good quality land
- Good quality seed
- Knowledge on crop management practices of a crop and
- Water requirement and management (critical stages of irrigation)

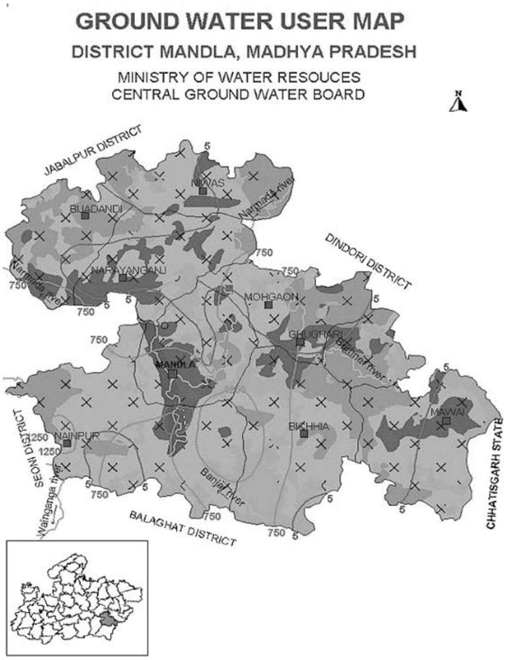
The focus is to build water harvesting structures on community land as well as private farm lands. The creation of these structures has helped to improve productivity of rainfed farming. The project is working on increasing the cropped area as well as through diversification of cropping systems. For this, the watershed development activities are helping the community to adopt improved agricultural practices leading to increased incomes through higher productivity.

To insure agricultural production *'water'* is very crucial as a large area of agriculture in Mandla district is rainfed. Scarcity of water, especially sub surface water was not a constraint earlier but in last few years this has become a problem. The reason is very simple it is assumed that if there is good rainfall, the water scarcity should not be there. Therefore, the conservation of water was never a priority.

To work on water conservation in this district, it is important to understand the groundwater status in the district and potential areas for water harvesting and using it for production purposes. This analysis will help in identification of water conservation activities and promotion of new crops which require more water.

District groundwater user map (Figure 2) proved clear picture of availability of water and groundwater status of Mandla district. If activities are planned according to this map entire groundwater scenario will improve within district. It clearly explains that dark green zone are appropriate for open well and bore well, light green area are suitable for open well and orange colour area is suitable for conservation activities only.

1 MPRLP Phase II project document



LEGEND

Aquifer	Well Feasible	Rig Suitable	Depth of Well (m)	Discharge (lpm)	Suitable Artificial Recharge Structure
Soft Rock Aquifers	Dug well Tubewell	Manual Rotary	20 - 30 50 - 100	60 - 240 100 - 500	Recharge shaft
	Dug well Tubewell	Manual Rotary	10 - 15 30 - 60	60 - 180 30 - 90	Recharge shaft
	Dug well Bore well	Manual DTH	10 - 15 30 - 75	60 - 180 30 - 120	Nala-Bund Check Dam
Hard Rock Aquifers	Dug well Bore well	Manual DTH	10 - 15 30 - 200	60 - 240 30 - 200	Check Dam

750 Electrical Conductivity Contour (micro mhos/cm at 25°C)	Drainage	District Headquarters
10 Water Level Contour (m.bgl) (Pre-monsoon decadal mean 1993-2002)	Spring	Block Headquarters
	Hilly Area	

Figure 2. Groundwater user Map, Mandla District, Madhya Pradesh.
Source: Ministry of water resources, Central Groundwater Broad

The Process

Developing Village Profile

Detailed household survey was conducted to asses the need and available resource to develop a village profile at ward level involving *Ward Panch.* Problem analysis and prioritisation revealed that water was primary and most crucial requirement of the tribal community as most of the rainfall received during two months and for rest of the season is received less rains, all goes into drains and water is not used for productive purpose. After that, all the issues were compiled and prioritized at the village and Gram Panchayat level too. This helps in developing yearly plan under various schemes.

In majority of the villages, soil erosion, water conservation, and agricultural development were identified as priorities by majority of the households. At the village level, special planning exercise to work on watershed programme and soil water conservation activities was carried out. This was an opportunity utilised to seize and strengthen resource base to sustain livelihoods of tribal families. Through NREGS, infrastructure was created to conserve rainwater, which can be used for productive purposes which includes drinking water for cattle, life saving irrigation for agriculture and irrigation to improved livelihoods. With these objectives, work started in nine tribal districts of Madhya Pradesh.

In Madhya Pradesh, Department of Panchayat and Rural Development developed sector-wise sub-schemes under the NREGS. To implement the sub-schemes under NREGS special activity, planning was done after developing village profile and submitted to three tier PRI systems for approval as per the act. After approval of the plans by PRI, the funds were released to the MPRLP. In Mandla district, we prepared special plan to implement these activities in two clusters. Focus was mainly to create water harvesting structure and take up water conservation activities. *Kapil Dhara* sub-scheme of NREGS mainly focuses on creating structures to conserve and harvest rainwater for productive purpose with focus on agriculture.

Table 5. Cross section analysis

Hilly area is covered with good forest in some part and some parts it is degrading	Upland	Upland	Mid up Land	Medium land	Low land
Black cotton and loamy	Loamy and Muram with some gravels in some area	Loamy, muram with, and clay	Loamy and clay in some parts	Clay, black cotton soil in majority of area	Clay and black cotton soil in majority of area
Mix of good, shallow and average	Shallow	Shallow to moderate	Moderate	Good soil depth	Good soil depth
Good up to October	Good up to October	Good up to November	Good up to Mid Feb	Good throughout year	Good throughout year
Moderate	Not very good	Not very good	Moderate	Good to high	High
Forest crops, grasses, some degrades patches	Grasses, shrubs, fallow land, niger, minor millets, upland paddy single crop fallow land system is being practiced	Double crop system: mostly rice- based system: rice/maize, lentil, gram, pea: mostly traditional varieties	Double crop system: rice- based farming system mostly Rice, lentil/wheat	Mono crop Rice, on bund pigeon pea	Mono crop rice bund pigeon pea
Soil erosion in degraded area, Shallow soil depth with poor soil quality	Soil erosion Poor quality soil Shallow soil depth High rate of moisture loss Poor management of nutrients received from forest	Soil erosion High rate of moisture loss Limited availability of nutrients in soil Low productivity	Low production Small plot size Use of traditional practices for production	Low production Small plot size Use of traditional practices for production Waterlogging	Low production Small plot size Use of traditional practices for production Waterlogging Poor drainage
Rich biomass from forest Availability of nutrients from forest if managed properly Support in maintaining eco system	Receives good quantity of nutrient and bio mass from upper ridges If proper conservation practices are adopted than production can be enhanced Fodder for livestock	Bio mass Labour Traditional conservation practices Fodder for livestock	Bio mass Labour Traditional conservation practices Fodder for livestock	Bio mass Labour Traditional conservation practices Fodder for livestock Moisture availability	Bio mass Labour Traditional conservation practices Fodder for livestock Good quality soil and land Round the year availability of moisture and water

Kapildhara Scheme for Construction of Water Conservation Structures

It is a scheme to conserve and harvest sub-surface flow of water mainly rainwater by creating structures like *dug wells with recharging structure, farm pond, stop dam,* and *small pond etc*. It is seen that due to the presence of basalt layer, the groundwater recharge capacity of the region is very low. Wells provide an opportunity to extract sub-surface flow of the region without exploiting its groundwater reserve.

Criteria for beneficiary selection: 1. Scheduled tribe and scheduled caste families, 2. BPL families (not mandatory for SC & ST families), 3. Beneficiary of land improvement activities and 4. Indira Awas Yojana families. Apart from these families, farmers have criteria to fulfil like they should not have any source for irrigating their crops, should have at least 1 ha land and one member from family should be educated up to 5th standard. For some tribes like *Baiga*, *Sahariy* and *Bharia,* this criterion is not applicable. These activities can be taken in groups also. Areas where construction of open well is not possible due to deep groundwater and dark zone there only conservation activities like construction of farm pond were allowed.

Steps in the implementation of Kapildhara sub-scheme:

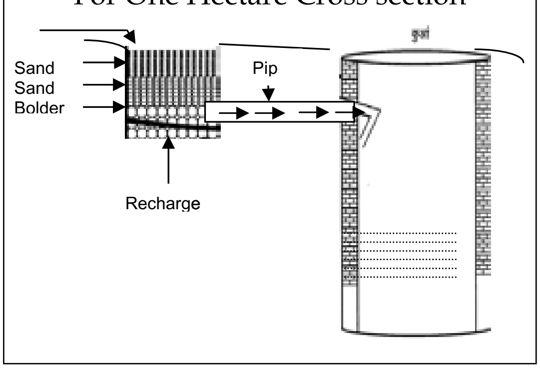
1. Selection of the beneficiary
2. Selection, recommendation and approval of work
3. Preparation of the estimates and approval
4. Construction of structures

For each activity, the villagers prepare proposal and get it approved by the Gram Sabha. After that, the funds were transferred to them through by cheque or in cash, depending on amount to ensure transparency at village level.

Design and Cost Estimates

Open well

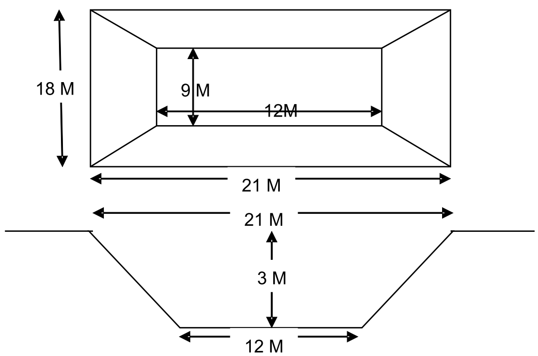
Type of land strata	Diameter in Meter	Depth in Meter	Lining in Meter
Basalt	5.00	12.00	3.00
Rocks other than Basalt	4.00	12.00	3.00
Brick linking in Alluvium	2.5	20.00	20.00
RCC Lining in Alluvium (Ring Well)	2.00	10.00	10.00
Well recharge pit for open well: 3X3X3 meter; cost estimate Rs. 3500/ RP			



Farm Pond

Sr.No.	Details	Length	Width	Depth	Quantity
1	Excavation work	15X15+6X6		3.00 meter	391.5 M^3
2	Hard soil (50%)	391.5X1/2			196.75 M^3
3	Hard Murram (50%)	391.5X1/2			196.75 M^3
4.	Inlet - outlet				

of Farm Land



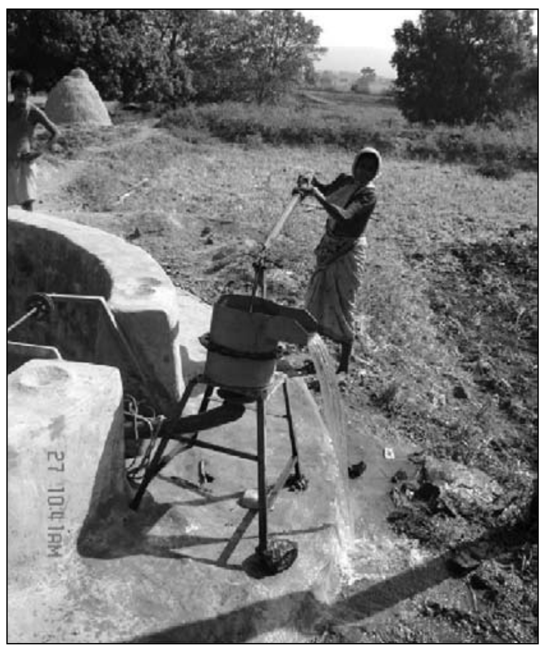
Farm Pond size was determined based on the total area and water availability. Different sizes of farm ponds are as given:

1. For 0.5 ha farm area, the pond size is 15X15X3 M
2. For 1 ha Farm area , the pond size is 18X21X3 M
3. For 1 ha Farm area, the pond size is 21X23X3 M

Results

Water conservation by farm pond and open well with recharging structures helped in creating additional source for sub-soil water for production purpose. The total additional irrigation potential created 903.57 $m^{3.}$ By constructing a total of 64 farm ponds (Table 6) is roughly 25056 $M^{3.}$ This will help in conserving more water within the village boundary and increase duration of sub soil moisture which will definitely contribute to production of crops.

All these ponds are meeting its purpose and there is increased demand for construction of farm ponds by the tribal farmers. Most of the ponds are not lined with any



material. Grasses were sown in the inner side of the pond and on top bund *pigeon pea* crop is planted. This way overall pigeon-pea production in the area increased, which provides farmers additional income.

In most of the open wells, farmers were provided water lifting devices like low lift pump, diesel pump with pipe line. As part of the strategy we are linking all farmers in our project villages that have any water resource to provide them support to have water lifting devices. This is now changing the cropping patterns in these villages.

All farmers, who got support through these interventions, are now taking two crops with assured irrigation. This is not only sustaining their livelihoods but contributing to overall production of the state. The initiative taken under NREGS produced varied degree of outcomes mainly increased areas for water conservation and harvesting which can be used for agriculture production.

Lessons Learnt

It was a good experience in implementing these activities in a cluster. Entire approach created awareness within these villages to conserve water adopting soil and water management practices to enhance agricultural production.

- The most important learning is how to convince community in the high rainfall areas to adopt conservation measures. Second thing we need to immediately work on is to enhancing awareness on the conservation of surface water during good or bad rainfall years.
- Need-based and available resource-based planning to improve livelihoods enhanced community participation and sustainability.
- Short-duration crops like papaya, vegetables, flowers, onion, garlic, etc. are grown as intercrops for additional income.
- All the activities related to conservation should be done on a cluster basis for preparing logical plans as per requirement of the area.
- All resource development should be linked with production activities which

Table 6. Details of various soil and water conservation activities taken under NREGS

Sub scheme	Particular/ sub scheme	No. of villages	No. of families covered	Quan-tity	Area	Expenditure in Rs.
Kapil-dhara	No. of Farm ponds	59	64	64	32 ha irrigation at least once	2070129
	No. of Wells		23	23	23 Ha	
Bhumi Shilp	Area coverage under bunding		256		91.48 ha	790109
	CPW constructed				7988 running meters.	966566
	Gulley plugging				660 no.s and 1387.10rm.	672746.5
Nandan Falodyan	Aonla, Guava, Lemon, Custurd apple, Jack Fruit		209 HH	12270	78 Ha.	24,000,00

Outcome

- Increased irrigation area in the district.
- Farmers who have got farm pond or well are taking at least two assured crops in a year.
- Farmers risk bearing ability increased. Shift in vegetable cultivation is one strong indicator
- It helps in the introduction of new crops i.e. mulberry based sericulture, vegetable farming, etc.
- It also generates more wage employment in the district

are directly related to livelihoods of the family.

- After construction and repair of these resources, additional support to use them for productive purpose is must.
- Productive link analysis is must. After this analysis, we must discuss this with beneficiaries to make them understand the importance of input made on it.

Strategies for Upscaling

The activities promoted by MPRLP are already accepted by the government. Funds are available to take us these activities at the individual and cluster level. Our approach to upscale is as follow:

- Prepare shelf of project for construction of farm ponds, open well, well recharging structures. Make presentation in the gram sabha for approval. After that get approval from three tier PRI system. Ensure fund release as per demand and time plan from zila panchayat.
- Capacity building of stakeholders on productive aspect related to this activity.
- Orientation of field functionaries
- Ensuring funds at village level
- Sharing of learning at various forums for wider circulation.
- Documentation of success stories.

References

1. http://www.krishiworld.com/html/soils4.html
2. http://www.nrega-mp.nic.in/ NREGA MP web site
3. Frank Peacock, Ritu Bharadwaj and Sandeep Khanwalkar: Land and Water Resource, MPRLP study document
4. Project document Madhya Pradesh Rural Livelihood Project Phase II

Water Harvesting Structures in Naturally Water Scarce Regions: Hydrological Opportunity and Economic Viability

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Abstract

This paper assesses the effectiveness of runoff harvesting in naturally water-scarce regions of India from the point of view of improving both local hydrological regimes, and basin water balance; discusses the various considerations involved in analyzing economics of runoff harvesting, and their imperatives for determining the optimum level of water harvesting in water-scarce basins; and identify the sets of conditions under which rainwater harvesting structures (RWHS) generate the intended benefits.

Methodology

The methodology involved analysis of: macro level hydrological and geo-hydrological data of the country, including data on annual rainfalls, rainfall variability, no. of rainy days, soil infiltration, potential evaporation (PE); data on rainfall, runoff and reference evapo-transpiration (ET_0) for selected basins viz., Narmada, Cauvery, Pennar, Krishna and Sabarmati; and data on effects of water harvesting on stream flows and groundwater levels for Ghelo river basin in Saurashtra, Gujarat.

Naturally Water-scarce Regions and Physical Scarcity of Water

From an anthropogenic perspective, water-scarce regions are those where the demand for water for various human uses far exceeds the total water available from the natural system, or the technology to access it is economically unviable. This includes the surface water, water stored in the aquifers, and that held in the soil profile. Water scarcity can be physical (where the demand for water for various human uses far exceeds the total water available or the technology) or economic i.e. also be felt when the resources are available in plenty in the natural system in a particular region, but adequate financial resources to access available water due to unfavorable economic situation it are not available with the populations living in there. The former is called physical scarcity, and the latter economic scarcity. In this article we are concerned with regions facing physical scarcity of water.

Physical scarcity of water occurs in the regions which experiences low to medium rainfalls and high evaporation rates, which are otherwise called naturally water-scarce regions. Most parts of Western, North-western Central and Peninsular India fall under this category. They have low to medium rainfalls and high potential evaporation (PE) rates. The mean annual rainfall ranges from less than 300 mm to 1000 mm, where as the PE ranges from less than 1500 mm in some pockets in the north east to more than 3500 mm in some pockets in Gujarat and Maharashtra.

In the subsequent section, we would explain the process which determine the supplies and demand for water, which in turn induces water scarcity in those regions. As regards natural water supplies, the runoff available from rainfall precipitation and groundwater recharge from a unit land area in such regions is generally low. This is because runoff is the amount in excess of the soil moisture storage and infiltration. Since evaporation rates are high, soil moisture generated from precipitation gets depleted during the rainy season fall itself, increasing infiltration of water which fulfills the soil moisture deficit. This leaves much less chance for water to runoff.

As regards the demand for water, crop evapo-transpiration mainly determines the requirement of water for agriculture, as agriculture is the largest source of water demand for human uses in all major river basins in India.

Analysis shows that for five river basins falling in the above mentioned regions, annual reference evapo-transpiration is many times more than effective renewable water resources. But, what is available for crop production includes the soil moisture storage as well. But since the soil moisture storage is a small fraction of the rainfall even in very high rainfall regimes, the potential evapo-transpiration (PET) for the entire year would be much higher than the sum of soil moisture storage--which is a fraction of rainfall--, and effective renewable water resources.

In that case, the imbalance between effective water availability and water demand for agricultural uses is very high for all the five basins. In addition to the agricultural water, there are demands for water from other sectors such as domestic and industrial uses. But, for the time being, we can ignore this. This gap between demand and renewable supplies can be reduced if we have very less arable land, and very large amount of land serving as natural catchments for supplying runoff water. But, unfortunately, the amount of virgin catchment left out in water-scarce regions of India is very small. It varies from 58.6% in case of Pennar basin to 28% in case of Sabarmati basin.

The increasing cropping intensity of crop production in the rich upper catchments of river basins and watersheds has two major negative impacts on available renewable water resources. Firstly, *First*: it captures a share of the runoff generated from the area, and therefore reduces the available surface water supplies. Secondly, *Second*: increase in cultivated land increases the water requirement for irrigation. This way, large regions in India are facing shortage of water to meet the existing demands.

Downstream Impacts of Upstream Water Harvesting

The states, viz., Gujarat, Rajasthan, Madhya Pradesh and Maharashtra took up intensive water harvesting during the past 20 years. The first decentralized modern water harvesting intervention in India was dug well recharging, and was started in Saurashtra region after the three-year consecutive droughts during 1995-987. This involved diverting field runoff and runoff in the local streams and nallas into open wells, which are characteristic of hard rock regions. Grass root level NGOs, spiritual and religious institutions, private agencies and social activists participated in this programme, which later on came to be known as Saurashtra dug-well recharge movement.

The argument was that the seven lakh open wells in the region could be recharged using monsoon runoff, which was all flowing waste into the sea. The people, who were behind this movement, did not consider the fact that approximately 110 medium and a few large reservoirs, which were located downstream, and were not getting sufficient flows even in normal rainfall years to supply for irrigation and drinking. The dependable runoff of the entire Saurashtra peninsula, generated from 91 small river basins, is 3613 MCM. Whereas all the major and medium reservoirs in the region have sufficient storage capacity to capture up to 5458 MCM water annually. This clearly shows that dug well recharging if carried out in the upper catchments of these basins, would only help reduce the inflows into these reservoirs.

But, the general belief is that because these structures are too small that they are benign (Batchelor *et al.*, 2002) though present in large numbers in most cases. The primary reason for such an outlook is that the agencies which are concerned with small water harvesting (in the upper catchment) and those which are concerned with major head- works are different and they do not act in a coordinated fashion at the basin level of the basin. Building of small water harvesting systems such as tanks, check dams is often the responsibility of minor irrigation circles of irrigation department or district arms of the rural development departments of the states concerned. This *ad hoc* approach to planning often leads to over-appropriation of the basin water, with negative consequences for large reservoir schemes downstream (Kumar *et al.*, 2000). As regards the quality of implementation of the programme, it came under severe attack from Public Accounts Committee, which found poor quality of construction, and mis-appropriation of funds. While the work was expected to be carried out by *Panchayats*, the entire construction work was awarded to a few big contractors.

Data collected from Ghelo river basin shows that the inflows into Ghelo-Somnath reservoir had significantly reduced after intensive water harvesting work was undertaken in the upper catchment. The total number of structures in the upper catchment area of 59.57 sq. km is around 100. A close look at the catchment rainfall and runoff in Ghelo-Somnath shows that after 1995, the year which saw intensive water harvesting work, the reservoir overflowed only in 2005 when the rainfall recorded was 789 mm. Regressions of rainfall and runoff, carried out for two time periods i.e., 1969-1995 and 1995-2005, clearly show that the relationship between rainfall and runoff had changed after water harvesting (WH) interventions. The amount of rainfall required for filling the reservoir had now increased from 320 mm to 800 mm. Though the curves intersect at higher rainfall magnitudes, this is not a problem as such as high rainfall does not occur in the basin.

Many large and important river basins in India, which are also facing water scarcity, are now "closed" or do not have uncommitted flows that are utilizable through conventional engineering interventions. Some of them are Pennar, Cauvery and Vaigai in the South (based on GOI 1999: pp 472-477), and Sabarmati, Banas in the west, which are "closed". In addition to these, all the west-flowing rivers in Saurashtra and Kachchh in Gujarat are also "closed". While Krishna basin is on the verge of closure, one basin which is still "open" is Godavari in the east (based on GOI 1999: pp 466-469).

In nutshell, water harvesting interventions in the "closed basins" located in the naturally water-scarce regions would have adverse impacts on stream-flow availability for downstream uses. One could always argue that in wet years, the runoff would be much higher than the normal rainfall. While harvesting this water would mean huge investments for the structures, the aquifers in hard rock areas lack the storage capacity to absorb the runoff diverted into the system. On the other hand, in low rainfall years, the downstream impact of intensive water harvesting systems in the upper catchments would be severe as evident from the analysis of runoff data of Ghelo river basin in Saurashtra.

Rainfall-Runoff Variability and their Implications for Reliability of Water Supplies and Economic Viability

Regions with semi arid and arid climate experience extreme hydrological events (Hurd *et al.*, 1999). Regions with high variability in rainfall in India coincide with those with low magnitudes of rainfall and high PE, which also have high dryness ratio (Kumar et al., 2006). In such areas, a slight variation in precipitation or PE can substantially magnify the water stress on biological systems as compared to humid regions (Hurd *et al.*, 1999). Rainfall variability induces higher degree of variability in runoff. We take the example of the catchments of Banas basin in North Gujarat of western India to illustrate this.

In Palanpur area of Banaskantha district in north Gujarat, which has semi arid to arid climatic conditions, the rainfall records show a variation from a lowest of 56 mm in 1987 to 1584 mm in 1907. The runoff estimated on the basis of regression equation developed for a sub-basin, named, Hathmati of Sabarmati basin in north Gujarat, which is physiographically quite similar to Palanpur area of Banaskantha, shows that the runoff can vary from a lowest of 0.6 mm to 541 mm. Thus the lowest runoff is close to 1/1000th of the highest runoff. This means, in drought years, when the actual water demand for irrigation increases, the amount of runoff that can be captured becomes almost negligible. Hence, the systems become unreliable. Though what can occurs at the sub-basin level may not be representative of that in small upper catchments, the difference cannot be drastic.

When there is a high inter-annual variability in the runoff a catchment generates, a major planning question which arises is "for what capacity the water harvesting system should be designed". When scarcity is acute, highest consideration is given to capturing all the water that is available. If all the runoff which occurs in a high rainfall year is to be captured, then the cost of building the storage system would be many hundred times more than what is required to capture the one which occurs during the lowest rainfall. But, the system would receive water to fill only a small fraction of its storage capacity in the rest of the years. This could make it cost-ineffective. The issue of variability is applicable to the design of large head works as well. But, in large systems, the water in excess of the storage capacity could be diverted for irrigation and other uses to areas which face water shortages during the same season, thereby increasing the effective storage.

In order to illustrate this point, we use the data generated from Ghelo river basin in Saurashtra. The basin has a total catchment area of 59. 20 sq. km. It had a medium irrigation reservoir with a storage capacity of 5.68 MCM and has been functional since 1966. On the basis of inflow data of the reservoir for the period 1969-95, showed that the total runoff generated in the basin varied from zero in the year corresponding to a rainfall of 39 mm to a maximum of 17.78 MCM in the year corresponding to a rainfall of 1270 mm. Today, the total capacity of water harvesting systems built in the upstream of Ghelo reservoir is 0.15 MCM. During the period from 1969 to 2005, the reservoir showed overflow for 13 years with a total quantum of 60.936 MCM. If one million cubic metres of runoff had to be captured in addition to the 5.89 MCM that would be captured by the medium irrigation reservoir, it would cost around 0.09 X/m^3 of water, while capturing 3 MCM would cost 0.11 X/m^3 of water. If the maximum runoff observed in the basin, i.e., 17.785 MCM has to be captured, the total volume of water captured would be only 60.91 MCM, in which case the unit cost of water harvesting would be around 0.21 X/m^3 of water. Here, "X" is the cost of storage structures for creating an effective storage space of one MCM. Here, again, we are not considering the incremental financial cost of .the special structures for capturing high magnitudes of runoff, which cause flash flood.

Economics of Water Harvesting

In the planning of large water resource systems, cost and economics are important considerations in evaluating different options. But unfortunately, the same does not seem to be applicable in the case of small systems.

Part of the reason for the lack of emphasis on "cost" is the lack of scientific understanding of the hydrological aspects of small scale interventions, such as the amount of stream flows that are available at the point of impoundment, its pattern, the amount that could be impounded or recharged and the influence area of the recharge system. Even though simulation models are available for analyzing catchment hydrology, there are great difficulties in generating the vital data at the micro level on daily rainfall, soil infiltration rates, catchment slopes, land cover and PET which determine the potential inflows; and evaporation rates that determine the potential outflows. Further for small water harvesting project, implemented by local agencies and NGOs with small budgets, the cost of hydrological investigations and planning is hard to justify. Often, provision for such items is not made in small water harvesting projects.

That said, the amount of runoff which a water harvesting structure could capture, depends on not only the total quantum of runoff, but also how it occurs. A total annual runoff of 20 cm occurring over a catchment of one sq. km. can generate a surface flow of 0.20 MCM. But the amount that could be captured depends on the rainfall pattern. The low rainfall, semi arid and arid regions of India, which experience extreme hydrological events, have annual rains occurring in a fewer number of days as compared to sub-humid and humid regions with high rainfalls regions (Kumar et al., 2006). As a result, in these regions, high intensity rainfalls of short duration are quite common. These runoffs generate flash flood. If the entire runoff occurs in a major rainfall event, the runoff collection efficiency would reduce with reducing capacity of the structures built. If large structures are built to capture high intensity runoff thereby increasing the runoff collection efficiency, that would mean inflating cost per unit volume of water captured. In fact, authors such as Oweis, Hachum and Kijne (1999) have argued that runoff harvesting should be encouraged in arid area only if the harvested water is directly diverted to the crops for use.

Given the data on inflows and runoff collection efficiencies, predicting the impacts on local hydrological regime is also extremely complex, requiring accurate data on geological and geo-hydrological profiles, and variables. In lieu of the above described difficulties in assessing the effective storage, unit costs are worked out on the basis of the design storage capacity of the structures and thumb rules about the number of fillings. In order to get projects through, proponents show them as low cost technology, under-estimating the costs and inflating the recharge benefits.

The government of India report (GOI, 2007) bases its arguments for rainwater harvesting on the pilot experiments conducted by CGWB in different parts of India using five different types of structures (see GOI, 2007: pp 13-15 for details). While the estimated costs per cubic metre of water were one-time costs (see Column 6 of Table 3), the report assumes that the structures would have a uniform life of 25 years. Two things in these figures are very striking. First: the costs widely vary from location to location and from system to system, and the range is wide, which the report duly acknowledges. Second: even for a life of 25 years, the upper values would be extremely high, touching Rs.7.7/m^3 of water for percolation tank and Rs. 18.2/m^3 for sub-surface dyke. But, such a long life for recharge system is highly unrealistic. Considering an active life of 10 years for a percolation tank, 5 years for check dam and sub-surface dyke, and 3 years for recharge shaft, we have worked out the unit cost of recharging using these systems.

The results show that the costs are prohibitively high for sub-surface dyke and check dam, and very high for percolation tanks. Added to the cost of recharging, would be the cost of pumping out the water from wells. The size of returns from crop production should justify such high investments. A recent study in nine agro-climatic locations in Narmada river basin showed that the gross return ranged from Rs. 2.94/m^3 to Rs.13.49/m^3 for various crops in Hoshangabad; Rs. 1.9/m^3 to Rs. 10.93/m^3 for various crops in Jabalpur; Rs. 2.59/m^3 to Rs. 12.58/m^3 for crops in Narsingpur; Rs. 1.33/m^3 to Rs. 17/m^3 for crops in Dhar; and Rs. 3.01/m^3 to Rs. 17.91/m^3 for crops in Raisen (Kumar and Singh, 2006). The lower values of gross return per cubic metre of water were found for cereals, and high values were for low water consuming pulses, and cotton. This means that the net returns would be negative if recharge water is used for irrigating such crops. Contrary to this, the report argues that the costs are comparable with that of surface irrigation schemes (GOI, 2007: pp 13). Such an inference has essentially come from over-estimation of productive life of the structures.

Now, scale considerations are extremely important in evaluating the cost and economics of water harvesting/groundwater recharge structures because of the hydrological integration of catchments at the level of watershed and river basins. The economics of water harvesting systems cannot be performed for individual systems in isolation, when the amount of surplus water available in a basin is limited, as interventions in the upper catchments reduce the potential hydrological benefits from the lower systems (Kumar *et al*., 2006; Ray and Bijarnia, 2006). In the case of Arwari basin it was found that while the irrigated area in the upper catchment villages increased (where structures were built), that in the lower catchment village significantly reduced (Ray and Bijarnia, 2006). What is therefore important is the incremental hydrological benefit due to the new structure.

In any basin, the marginal benefit from a new water harvesting structure would be smaller at higher degrees of basin development, while the marginal cost higher. The reason being: 1] higher the degree of basin development, lower would be the chances for getting socially and economically viable sites for building water impounding structures, increasing the economic and financial cost of harvesting every unit of water; and 2] with higher degree of development, the social and environmental costs of harvesting every unit of water increases (Frederick, 1993), reducing the net economic value of benefits. Therefore, the cost and economic evaluation should move from watershed to basin level. The level at which basin development can be carried out depends on whether we consider the flows in a wet year or dry year or a normal year. Nevertheless, there is a stage of development beyond which the negative social, economic and environmental benefits starts accruing, reducing the overall benefits.

But, it is important to keep in mind that the negative social and environmental effects of over-appropriation of basin's water resources may be borne by a community living in one part of the basin, while the benefits are accrued to a community living in another part. Ideally, water development projects in a basin should meet the needs and interests of all stakeholders. Therefore, optimum level of water development should not aim at maximizing the net basin level benefits, but rather optimizing the net hydrological and socio-economic benefits for different stakeholders and communities across the basin.

The potential impacts of the water harvesting projects of the government have to be seen from this perspective. Even if recharging of millions of wells and tanks and ponds in the region becomes successful in creating an additional recharge in the order of magnitude, it is unlikely to create equivalent additional economic benefits from agriculture production. As per official estimates, the total storage capacity created in the river basins of South and Central India, viz., Cauvery, Pennar, Krishna, Narmada, east flowing rivers between Pennar and Cauvery, and east flowing rivers south of Cauvery is 57.11 BCM, against utilizable water resources of 100.32 BCM (GOI, 1999: pp 37, Table 3.5 and 3.6). Now, the actual volume of water being effectively diverted by the reservoirs/diversion systems in these basins would be much higher due to diversion during the monsoon, and additional water stored in the dead storage. This apart, the traditional minor irrigation schemes such as tanks are also likely to receive inflows during monsoon. It is estimated that South India Peninsula had nearly 135000 tanks, which cater to various human needs of water, including irrigation. Thus, the existing storage and diversion capacities in the region would be close to the utilizable flows. Hence, the livelihoods of farmers, who do not have access to groundwater, will be at stake at least in normal rainfall years and drought year.

To improve the economics of RWH, it is critical to divert the new water to high-valued uses. Yield losses due to moisture stress are extremely high in arid and semi-arid regions and that providing a few protective irrigations could enhance yield and water productivity of rainfed crops remarkably, especially during drought years (Rockström *et al.*, 2003). The available extra water harvested from monsoon rains should therefore be diverted to supplementary irrigation in drought years.

Key Learning

As detailed analysis provided in Kumar et al., (2006) and Kumar et al. (2008) show, in high rainfall, and medium evaporation regions which experience high reliability in rainfall such as parts of Orissa, Jharkhand, Chattisgarh, the north eastern hill region, and the western Ghat, the overall potential and reliability of water supplies from RWHS would be high. The naturally water-scarce regions in India, which are characterized by low and low to medium rainfalls and high evaporation, are facing physical scarcity of water. The renewable water resources availability falls far short of the total water demand from agriculture alone.

The poor water supplies from the catchments, and the high inter-annual variability, and the high evaporation rates increase the cost of individual water harvesting systems in the naturally water-scarce regions.

The scale considerations are extremely important in evaluating the cost and economics of water harvesting structures because of the hydrological integration of catchments at the level of watershed and river basins. This is particularly important for basins in the naturally water-scarce regions of South Indian peninsula, Western India, Northwestern India and parts of Central India, that are either closed or on the verge of closure.

In closed basins, the net economic value of the benefits from water harvesting would be either too low or negative, due to the very low or zero net incremental hydrological gain at the basin level, and the high incremental cost.

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Practical Suggestions for Efficient Water Harvesting

Enhancing Knowledge of Catchment Hydrology: in water harvesting, what is least understood is the catchment hydrology. Most small rivers in India are not gauged for stream flows and siltation. Example is Narmada river basin. It has a total of 56 gauging sites of which 25 collect data on siltation load. Data on siltation rates are often available for large reservoirs from siltation studies done by Central Board of Irrigation and Power (CBIP). But applying this to small catchments can lead to either under-estimation of siltation rates as siltation rates are generally high for hilly upper catchments. On the other hand, applying rainfall-runoff relationships of large basins for small upper catchments would result in under-estimation of runoff, as small upper catchments would normally have steeper slopes. The scale problems in water harvesting are well-documented (Sivapalan and Kalma, 1995; Wood *et al*., 1990).

Though runoff data can be generated for streams which otherwise are not gauged, through runoff modeling, scientific data on hydrological parameters such as soil infiltration rates, land use characteristics, catchment slopes are essential to arrive at reliable results (Jakeman et al., 1994). Managing hydrological data for small catchments is a major challenge in India.

Research to Focus on Green as well as Blue Water: The central focus of any rainwater harvesting project in India is about capturing the excess water which flows out of the domain of interest, storing and subsequently diverting it for beneficial uses. But, green water is an important component of the hydrological system and the harvested water in tanks and ponds. The focus has never been on improving the efficiency of utilization of this green water. For any basin, it is crucial to know how much of the total precipitation falling on the basin is available as green water and how much of it gets used up in crop production; how much of it is lost in non-beneficial evaporation from the soil.

In high rainfall regions like Kerala, the utilizable surface water resources are much less in comparison to the runoff generated. Here, effective strategies to capture runoff in situ for crop production through proper land use planning--including increasing area under paddy-, would help improve green as well as blue water use, and alter the hydrology positively.

Basin Water Accounting and Water Balance: For any water scarce river basin in India, water accounting is the first and the most important step to begin with before planning any water harvesting and recharge project. It is important to know whether the basin has any surplus flows, which goes into the natural sink, or significant amount of water that is lost in evaporation from natural depressions. This can be followed by water balance studies to examine what percentage of the water could be captured without causing negative effects on the downstream uses. Needless to say, both water accounting and water balance studies should be carried out for typical rainfall years so as to capture hydrological variability. Such studies can provide critical inputs to basin-wide water resource planning for optimal water harvesting to ensure sound economic viability.

Wet Water Saving: In river basin which experience high aridity during the summer months, the water stored in tanks, pond and other small reservoirs can lead to heavy losses through evaporation. If this is prevented, it can lead to wet water saving, through increase in output per unit of evaporated water. Directly diverting the harvested water from the RWH system to the crop land is critical to maximizing the net hydrological gain, especially in areas with poor groundwater storage or areas experiencing high inter-annual variability in runoff (Oweis, Huchum and Kijne, 2002). Allocation of blue water harnessed to rainfed crops to avoid moisture stress during critical stages of crop growth would increase the yield of crops remarkably (Seckler, 1996), thereby increasing the productivity of green as well as blue water. In the case of Sub-saharan Africa, Rockström *et al*. (2002) showed that yield could be doubled in certain cases through hydro-climatic alterations.

References

Batchelor C, Ashok Singh, Rama Mohan Rao MS and Johan Butterworth. (2002) Mitigating the Potential Unintended Impacts of Water Harvesting, paper presented at the IWRA International Regional Symposium 'Water for Human Survival', 26-29 November, 2002, Hotel Taj Palace, New Delhi.

Evans JP and Jakeman AJ (undated) Development of a Simple, Catchment-Scale, Rainfall - Evaporation - Runoff Model, Centre for Resource and Environmental

Studies, The Australian National University, Canberra ACT 0200: http://earth.geology.yale.edu/~je84/mystuff/research/ems_paper.pdf.

Frederick KD. (1993) Balancing Water Demand with Supplies: The Role of Management in a World of Increasing Scarcity, Technical Paper 189, Washington D. C: World Bank.

Government of India (1999) Integrated Water Resource Development: A Plan for Development, Report of the National Commission for Integrated Water Resources Development Vol. I, Ministry of Water Resources, Government of India, New Delhi.

Government of India (2007) Report of the Expert Group on "Groundwater Management and Ownership," Planning Commission, Yojana Bhawan, New Delhi.

Hurd B, Neil Leary, Russell Jones and Joel Smith (1999) Relative Regional Vulnerability of Water Resources to Climate Change, Journal of the American Water Resources Association, 35 (6): 1399-1419.

Jakeman AJ, David A, Post and Beck MB. (1994) From data and theory to environmental models, Environmetrics, 5, 297-314.

Kumar M, Dinesh M, Shantanu Ghosh, Ankit Patel, Singh OP and Ravindranath R. (2006) Rainwater harvesting in India: Some critical issues for basin planning and research, Land Use and Water Resources Research, 6 (2006): 1-17.

Kumar M, Dinesh M, Ankit Patel, Ravindranath R and Singh OP. (2008) Chasing a Mirage: Water Harvesting and Artificial Recharge in Naturally Water Scarce Regions, Economic and Political Weekly, 43 (35): 61-71.

Oweis T, Hachum A and Kijne J. (1999) Water Harvesting and Supplementary Irrigation for Improved Water Use Efficiency in Dry Areas. SWIM Paper, Colombo, Sri Lanka.

Rockström J, Jennie Barron and Patrick Fox. (2002) Rainwater management for improving productivity among small holder farmers in drought prone environments, Physics and Chemistry of the Earth, 27 (2002): 949-959.

Seckler, David J. (1996) The New Era of Water Resources Management: From Dry to Wet Water Savings, Research Report # 1, International Irrigation Management Institute, Colombo, Sri Lanka.

Sivapalan M and Kalma JD. (1995) Scale problems in hydrology: Contributions of the Robertson Workshop, Hydrological Processes, 9 (3-4): 1995.

Wood EF, Sivapalan M and Beven K. (1990) Similarity and scale in catchment storm response. Rev. Geophysics, 28, 1-18.

Water Seepage Control through Novel Sheet Materials

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Abstract

The paper describes the novel material developed at Indian Institute of Technology, Delhi for lining of farm ponds and water storage structures. The material was used as lining material in farm ponds, conveyance channels in agricultural fields. Field evaluation was carried out at different national level institutes.

Introduction

A major source of water is rains. Fortunately, in this part of the world, we have heavy rains, but this occurs for short durations and typically in a span of two to three months. For the rest of the period, there is very little rain. Ideally these rains should be used to recharge the aquifers. Due to limited surface water availability, we try to use the groundwater leading to decreasing water table. The efforts in recharging the groundwater have been rather limited. In many cases, we may have a situation where water table is too deep to have a meaning full recharge. Thus, the heavy rain should be utilized to collect water in ponds and reservoirs and this may help to fulfill the water requirement. Excess surface water in these water bodies may be diverted to recharge the groundwater.

The most efficient way of storing the water locally is to create reasonably sized ponds consistent with the catchment area. There may be substantial water seepage loss in an unlined pond and this depends on the type of soil. In USA, seepage rates of soil groups measured in Idaho using ponding tests are given in Table 1.

Table 1. Seepage rate with different soil types

Soil Types	Seepage
Clayey	7 cm/day
Silty	23 cm/day
Loamy	29 cm/day
Sandy	48 cm/day

The water lost through seepage from ponds is priceless, as we may not be able to find any alternate source of getting the same. The typical approach for seepage control is lining the pond. Generally, cement/concrete lining used for this purpose is subject to crack with time, leading to significant water seepage. This relates to sub grade settlement and inability of the cover to adjust to the settlement. If the soil is wet then it gives limited support to the cover, leading to the cracks. The intrinsic limitation of the cement/concrete type of cover is its poor performance in tensile/bending. There are also issues related to thermal expansion/ contractions, affecting the performance of the cement/concrete cover material.

Geomembranes

To overcome these limitations of the traditional cover material, geomembranes are used as lining material and are generally covered with a layer of cement/concrete, tiles, soil etc. Geomembranes[1] are plastic sheet/film material, being highly extensible; these sheets readily adjust to the sub grade settlement. These sheets are highly impermeable to water and have lifespan of 30+ years. The existing method of lining canals, ponds using 150-200 micron low density poly ethylene (LDPE) sheet with/without a cement/concrete cover is quite outdated, as these sheets are punctured and damaged during installation itself.

The first applications of polymeric and rubber-like sheets, as linings of canals and ponds, were introduced about forty years ago. Since then these materials have played an increasingly important role in civil engineering and especially in water conservation, agricultural and industrial water pollution control. A large number of various types of linings have been experimented with a growing number of applications, for large covered surfaces, as well as in some new fields of use such as earthen dams.

High Density Poly Ethylene (HDPE) Geomembranes

The most common types of geomembranes are HDPE sheet materials[2-3]. HDPE is well-understood geomembranes in terms of applications and lifetime predictions. However, there are a lot of limitations of these sheets as given below:

- Due to its susceptibility to stress cracking, it requires well-compacted smooth sub grade and with minimal differential settlement. It may not be easy to meet these requirements in a large number of cases as this could lead to significant cost escalations. In many cases, and particularly in expansive soils, it may not be easy to predict the differential settlement.
- HDPE sheets are typically used in the thickness range of 1.5 to 2 mm to achieve suitable puncture resistance and thus have very low ductility. Thus, the conformability of these sheets to the sub grade is very limited and this in turn requires very smooth sub grade. Thicknesses lower than 1.5 mm for HDPE sheets are not recommended due to low puncture resistance.
- Low ductility of these sheets also requires elaborate arrangements for transportation and installation. Further, these sheets must remain flat over the soil without folds.
- HDPE and similar polyethylene based geomembranes are available in limited widths of 5m to 9 m and thus requires extensive field sealing. This adds on the time for implementation of the project. These materials are sensitive to temperature of weld and thus trained manpower is needed for the field sealing.
- The deformation of HDPE beyond yield point is through yielding as shown in Fig. 1. In case of uncontrolled deformation in actual field conditions, the thinning may not be uniform across the width of the sheet and may have areas of stress concentration leading to failure.
- Another factor of relevance is the effect of tangential stress combined with in planer stresses. For tangential stress, if the material deforms beyond yield then it continues to reduce in thickness till failure. This is a typical deformation in a puncture test. The useful deformation is thus limited to the yield point i.e. around 5%, although the elongation at break may be 500%. This is a significant limitation of these sheets. The yield point for other polyethylene based sheets like LLDPE extends to around 10%.

All these limitations of HDPE sheets lead to substantial costs and to the fact that a large number of lining projects are not taken up at all.

Poly Vinyl Chloride (PVC) geomembranes are increasingly being banned, especially in the critical applications of water conservation. This is demonstrated by a set of experiments. The commercial PVC geomembrane samples were field tested by placing them in a pond at Port Blair for around eight months. A very significant level of algae wais generated in a pond having these sheets, which could be related to leaching out of plasticizer. The question of release of plasticizers is vital for PVC as it containments water, and also changes its property. There are issues related to limited UV stability and thus life limited life to a few years.

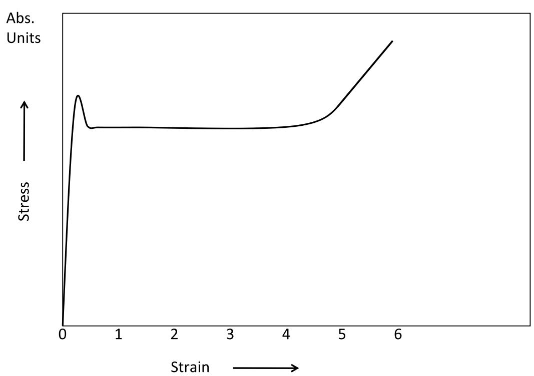


Figure 1. Typical Stress-strain curve of HDPE

IITD Sheet Materials as Geomembranes

We report development of a range of geomembranes sheet materials. These are poly (olefin) based sheets and are typically stabilised for UV radiations. These sheets have thickness in range of 0.6 mm and have puncture strength in the range of around 500N (ASTM4833). The extension to break is in the range of 40-80%. The yield strains are approximately 15%. The water permeability is limited to 10^{-6} cm/day. Advantages of these sheets are given below:

- As the thickness of these sheets is low, it is very ductile and has good conformability with soil. A comparison of bending rigidity of sheets of thickness of 1.5mm (say HDPE) to 0.6 mm will give a very high multiplier factor of approximately 6.25.
- Being very low thickness, these sheets could be suitably folded for transportation.
- Further, these sheets could be folded during the placement to take care of the contours in the sub grade and could be maintained in the fold shape indefinitely. This fact is particularly helpful in making a pond from a flat sheet. The situation is helped by the fact that these sheets have excellent stress crack resistance.
- These sheets could also be factory welded to fairly large dimensions (say 100x50 meters) thus reducing the field welding and with a consequence of superior performance. Additional requirements of field welding of these sheets could be met by standard heat wedge method. Further, this reduces the time for implantation of the project.
- The installation is possible even if there is some water on the bottom of the pond, as these sheets are not affected by the presence of water.
- The project implementation time is significantly reduced due to easy of handing the sheets.
- The sheets could simply be used on the water face to make a barrier using an earthen dam, which could be executed in a short duration. The stability of the structure is enhanced due to water seepage control.

- There may be a possibility of live installation in cases where dewatering is not practical.

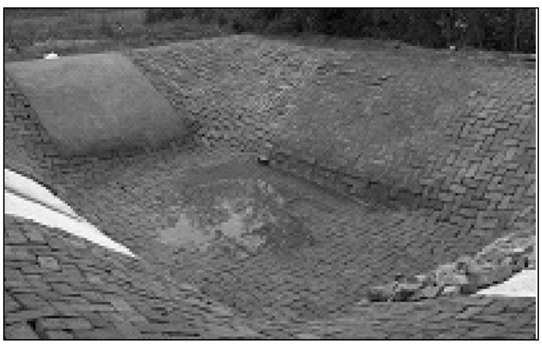
These sheets are installed at several locations including at IIT Delhi are shown in Figure.

References

1. Malcolm Steinberg, "Geomembranes and the Control of Expansive Soils", McGraw-Hill, 1998.
2. Peggs ID, Lawrence C and Thomas R. (2002) "The Oxidation and Mecha-

Karjat Maharashtra

IARI, New Delhi



IIT Delhi

CARI, Port Blair

nical Performance of HDPE Geomembranes: A More Practical Durability Parameter", Proceedings of Geosynthetics State of the Art Recent Developments, A.A. Balkema Publishers, Lisse, the Netherlands, pp 779-782.

3. Mengjia Li, "Evaluation of Oxidative Behaviour of Polyolefin Geosynthetics Utilizing Accelerated Aging Tests Based on Temperature and Pressure", Ph D thesis, Drexel University, April 2005.

Rainwater Harvesting: A Key to Survival in Hot Arid Zone of Rajasthan

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Abstract

The paper presents details of role played by water harvesting systems in arid zone of Rajasthan. Relationship on catchment area, amount of runoff generation and required water harvesting system capacity for different locations of the state are presented. Efforts made by CAZRI, Jodhpur towards renovation on traditional water harvesting systems suiting the changing times are also presented.

Introduction

"Water is life". Good quality potable water is a global issue, particularly in the developing world. With rapid growing population and improving living standards, the pressure on available water resources is increasing and per capita availability of water resources is reducing day by day. The per capita availability of water in India has dropped from 5300 m^3 in 1955 to 2200 m^3 in year 2000 compared to 7420 m^3 world and 3250 m^3 Asian average. The overall national availability of water may not pose a problem in the near future, but there would be a severe shortage of water in many regions of India particularly in the state like Rajasthan. Rajasthan is one of the largest state in Indian union but it is the driest state in term of availability of water resources. The annual per capita availability of water in the state is much below (857 m^3) the threshold value of 1700 m^3 considered for water stress conditions. The annual rainfall in the state varies significantly. There is a very rapid and marked decrease in rainfall in west of the Aravalli range, making Western Rajasthan, the most arid part of India. The average annual rainfall of the western arid region is 317 mm and that of rest of eastern Rajasthan is 680 mm with overall average rainfall of 554 mm for the state. The rainfall is highly variable at different places and it is most erratic in the western half with frequent spells of drought. The coefficient of variation (CV) of rainfall varies between 30 to 50%.

Surface water resources in arid part of Rajasthan are very poor and majority of the population depends on groundwater extraction to meet their essential water requirements. The source of drinking/municipal water supply in most parts of the arid Rajasthan is mostly groundwater or borehole based. With frequent droughts and chronic water shortages in many areas, most people pay an increasingly high price for water and for the lack of water. The poor, especially women and children, usually pay the highest price for small amounts of water. They also expend more in calories carrying water from distant sources, suffer more in impaired health from contaminated or insufficient water, and also lose more in diminished livelihoods.

In the absence of adequate surface and groundwater resources, rainwater plays an important role in the survival and livelihood in arid regions. If rainwater is appropriately harvested, it can be a reliable source of potable water for domestic purposes. Rainwater harvesting is an ancient practice and has been practiced for more than 4000 years in many parts of the world. Rainwater harvesting is collection and storage of rain from runoff areas such as roofs and other surfaces is has necessary in areas lacking any kind of conventional, centralized government supply system, and also in areas where good quality fresh surface water or groundwater is lacking. If collection and storage are designed carefully, it is possible for a family to live for a year in areas with rainfall as little as 100 mm per year. Central Arid Zone Research Institute, Jodhpur with over four decades of research, has perfected the technology of rainwater harvesting for different users and purposes.

Rainwater Harvesting

Rainfall is the principal source of water, which augments soil moisture, groundwater and surface flows. Agriculture and several of the other economic activities in the arid areas depend on rain. Rainfall in the arid areas is of convective nature and usually occurs at a very high intensity for shorter duration, generating high runoff in response of even with small event little rainfall. Runoff could be very high particularly in urban areas where buildings and roads haves high runoff coefficient. The runoff depends upon rainfall intensity and catchment characteristics particularly area, surface roughness, water absorbing capacity and slope, etc. Runoff can be estimated using equation 1.

$$R = P*C*A \quad (1)$$

Where R is runoff, P is rainfall, C is runoff coefficient which varies from minimum of 0 to maximum of 1 and A is the catchment area. By taking appropriate units of R, P and A and selecting suitable runoff coefficient 'C', runoff can be estimated.

A. Rainfall

The mean annual rainfall over the Indian arid region varies from more than 500 mm in the southeastern parts to less than 100 mm in the northwestern and western part of the arid region (Figure. 1). More than 85% of the total annual rainfall is received during the southwest monsoon season (July to September). The withdrawal phase of monsoon starts in the extreme western part by middle of September and retreats by the end of September. The rainy season varies from 50 days in the western part to 80 days in the eastern part of arid Rajasthan. A small quantum of rainfall of about 7-10 per cent of the annual is received during the winter season under the influence of western disturbances.

Rainfall is low and erratic and the coefficient of variation of annual rainfall varies from 42 per cent to more than 64 per cent. Long term statistical analysis of the rainfall

Figure 1.

data of the region indicates an asymmetric average storm intensity profile for storms of short duration, with the highest intensities falling in the first part of the storm. The statistical characteristics of high intensity and short duration are essentially independent of location within the region. A detailed statistical analysis of long- term rainfall data of all districts of western Rajasthan has been done to arrive at probable rainfall at three levels of probability i.e. 50, 60 and 70% and presented in (Table 1). As the probability (or the level of surety) increases, the rainfall decreases. Therefore, a balance between the probability and certainty of rainfall is must for planning any rainwater harvesting system (RWHS). Rainfall at 60% probability is generally considered safe for designing any RWHS.

B. Catchment

Catchment area is a place where raindrop first strikes. After striking the catchment the subsequent process is entirely dependent on the inherent physical and chemical characteristics of the catchment. Physical characteristics like surface roughness and slope determine the flow of runoff while its textural constituents i.e. proportion of sand, silt and clay determine the water absorbing holding and capacity of catchment. Certain chemical characteristics of catchment like presence of fertilizers, pesticides on natural surface determine the quality of runoff. The ratio of rainfall to runoff is denoted by the runoff coefficient (C) and is dependent on rainfall characteristics like intensity and& duration and physical and chemical characteristics of the catchment, as mentioned above. The shape of any given catchment area also has a considerable influence on runoff. Roof surfaces of building form the best catchment to generate runoff during rainy season. Studies conducted by CAZRI revealed that roof made of different materials can generate runoff ranging from 50 to 80% of the annual rainfall. Of the most, common roof types, the single pitch roof

Table 1. Rainfall at different probability for arid districts of Rajasthan

District	Probable rainfall equation	Correlation coefficient	Rainfall (mm) at probability of		
			50%	60%	70%
Barmer	R = -172.73 ln (P) + 892.57	0.9779	216.8	185.3	158.7
Bikaner	R = -139.88 ln (P) + 790.98	0.9552	243.7	218.2	196.7
Churu	R = -142.53 ln (P) + 878.18	0.9570	320.6	294.6	272.6
Ganganagar	R = -140.43 ln (P) + 754.77	0.9825	205.4	179.8	158.1
Jaisalmer	R = -124.54 ln (P) + 639.76	0.9765	206.5	183.8	164.6
Jalore	R = -205.26 ln (P) + 1128.7	0.9518	325.7	288.3	256.6
Jodhpur	R = -196.29 ln (P) + 1078.2	0.9682	310.3	274.5	244.3
Jhunhjunu	R = -148.61 ln (P) + 937.36	0.8954	356.0	328.9	306.0
Nagaur	R = -196.88 ln (P) + 1063.8	0.9649	293.6	257.7	227.3
Pali	R = -214.62 ln (P) + 1201.6	0.9586	362.0	322.9	289.8
Sikar	R = -207.82 ln (P) + 1207.2	0.9602	394.2	356.3	324.3

R= rainfall (mm) for probability (P) and ln is natural logarithm is the most appropriate for rainwater harvesting, since the entire roof area can be drained into a single gutter on the lower side and one or two down pipes can be provided depending on the area. Based on three levels of probable rainfall and three catchment characteristics represented by runoff coefficient (C), catchment area (A) needed for generation of 1000 liters (1 m^3) of runoff (R) is calculated for all districts of western Rajasthan (Table 2). For desired quantum of runoff and existing catchment characteristics, the required catchment area can be calculated or with known catchment, expected runoff can be calculated.

C. Runoff Coefficient

The runoff coefficient (C) as mentioned above is ratio of runoff to rainfall for a given catchment and is dependent on rainfall and catchment characteristics. Various studies have been conducted by CAZRI and others to estimate the runoff percentage. These studies shows that the average runoff generation from arid Rajasthan is between 1 and 15 per cent of rainfall, as much of the terrain is sandy. However, due to the spatial variations in rainfall and terrain type, deviations from this average value are expected. In the less than 200 mm rainfall zone, the dominantly interdune areas can generate 10 to 15 per cent of rainfall as runoff, if these are in undisturbed condition and have adequate vegetation cover. The rocky/gravelly surfaces, on the other hand, can generate between 20 and 25 per cent. In the 200 to 400 mm rainfall zone, the micro-catchments in the plains with sandy loam to loamy sand can generate as much as 30 to 40 per cent as runoff, although the larger catchments can generate between 15 and 20 per cent. The rocky/gravel1y surfaces in this zone can generate between 20 and 30 per cent of rainfall as runoff. In the more

Table 2. Catchment area required for 1 m^3 of runoff (m^2) at different rainfall probability for three catchment conditions.

District	Catchment area required for 1 m^3 of runoff (m^2)								
	Rainfall at 50% P			Rainfall at 60% P			Rainfall at 70% P		
	C- 0.2	C-0.3	C- 0.4	C- 0.2	C-0.3	C- 0.4	C- 0.2	C-0.3	C- 0.4
Barmer	23.10	15.40	11.50	27.00	18.00	13.50	31.50	21.00	15.80
Bikaner	20.50	13.70	10.30	22.90	15.30	11.50	25.40	16.90	12.70
Churu	15.60	10.40	7.80	17.00	11.30	8.50	18.30	12.20	9.20
Ganganagar	24.30	16.20	12.20	27.80	18.50	13.90	31.60	21.10	15.80
Jaisalmer	24.20	16.10	12.10	27.20	18.10	13.60	30.40	20.30	15.20
Jalore	15.40	10.20	7.70	17.30	11.60	8.70	19.50	13.00	9.70
Jodhpur	16.10	10.70	8.10	18.20	12.10	9.10	20.50	13.60	10.20
Jhunhjunu	14.00	9.40	7.00	15.20	10.10	7.60	16.30	10.90	8.20
Nagaur	17.00	11.40	8.50	19.40	12.90	9.70	22.00	14.70	11.00
Pali	13.80	9.20	6.90	15.50	10.30	7.70	17.30	11.50	8.60
Sikar	12.70	8.50	6.30	14.00	9.40	7.00	15.40	10.30	7.70

C= 0.2 for untreated natural catchment; C= 0.3 Compacted natural catchment C=0.4 Compacted artificially treated catchment than 400 mm rainfall zone, the hills and rocky uplands are able to generate 40 to 60 per cent as runoff, while the all1uvial and other sandy plains can generate between 20 and 30 per cent.

Techniques for Enhancing Runoff from Catchments

Catchment characteristics can be modified to a certain extent for higher runoff generation. The extent of modification depends on the investment available and the expected use of runoff water. Where no source of water exists and in area with inaccessibility of other water sources, higher initial investment is justified on long terms.

- Simple earth smoothing and compaction helps increasing runoff from the catchment areas. Success is generally greater on loam or clay loam soils. Care must be taken to reduce the slope and/or the length of the slope to lessen runoff velocity and thereby reducing runoff.
- Small amounts of sodium salts - particularly NaCl, $NaHCO_3$ applied to desert soils where vegetation has been removed- causes dispersion of the surface soil, reducing infiltration and increases runoff. However, this type of treatment requires a minimum amount of expanding clays in the soil.
- Removal of stones and boulders and unproductive vegetation from the catchment helps in uninterrupted flow, enhances runoff to collection site.
- Land shaping into roads and collection of water in channels.
- Sandy soils have low water holding capacity. Spreading of clay blanket ton the soil surface reduces the infiltration and consequently accelerates runoff.
- Chemical treatments like wax, asphalt, bitumen and bentonite prevent downward movement of water, which augments runoff.

Collection/Storage of Harvested Rainwater

Harvested rainwater can be stored in any structures on the surface or below the surface. Traditionally, people in the region have been are known to harvest rainwater and store it in efficient ways for crop production and drinking purposes. Based on the local wisdom, communities have designed effective and efficient methods for storing the rainwater. Some of the novel systems prevalent in the region are *baori* and *jhalara* (step wells), *nadi* (village pond), *tanka* (cistern), *khadin* (runoff farming system) and roof water harvesting system. *Baori and jhalara* are largely to benefit the urban and semi-urban population whereas *nadi, tanka* and *khadin* are well suited for the rural population. The demand for community- based water harvesting systems, which are the main sources of water for large population, became associated with progress in the rural areas. At present, the dependency of drinking water in villages in western Rajasthan is 42.4% on *nadi*, 34.7% on *tanka*, 15.0% on wells and tube wells and on 7.8% on other sources. This suggests that rainwater harvesting is the backbone of drinking water supply in rural areas.

Storage of rainwater in underground cistern, locally known as *Tanka* is a common practice in this region. Various types of *tanka* from rectangular to circular, in capacity from as small as 1000 liters to 500,000 liters are prevalent in this region. The construction of these *tanka* also varies from simple mud plaster to lime mortar, cement concrete, ferro-cement, fiberglass and PVC. The most common construction material for the storage tank in this region is lime mortar and cement concrete; however prefabricated PVC tanks are also used in some modern buildings in urban areas. Central Arid Zone Research Institute, Jodhpur has perfected the technology of *tanka* construction for various types of users.

Capacity of *Tanka*

Capacity of *tanka* is dependent on the need of individual family or community, intended use of harvested water and money available for investment. The designed capacity must match with the available runoff as estimated above using by the equation 1. For individual family water requirement can be worked out considering the family size, daily water requirement and time period using equation 2.

V = N x Q x T ....(2)

Where V is volume or Capacity of the *tanka*, N is number of persons dependent on *tanka*, Q is daily water requirement and T is number of days for which water is required. Daily minimum water requirement of a person varies from 7 liters to 10 liters depending upon the season and work stress. Additional requirement of water for other purposes like animals (about 40 liters per day) and raising small nursery, etc. can be worked out using equation 2 separately and total capacity can be worked out by adding all the individual water requirements. The total capacity should be multiplied by a factor 1.1 taking in to consideration of small evaporation and seepage losses, if any for arriving at the final capacity of *tanka*. A *tanka* of 21 m^3 capacity is sufficient to meet the drinking water requirement of a family of 6 persons for round the years. CAZRI has constructed many such *tankas* in different villages of arid Rajasthan for meeting drinking water requirement of individual families. A bigger *tanka* of 50 m^3 can be constructed for domestic and livestock requirement of 6-7 animals or a small nursery of 200 plants for round the years. A community *tanka* of 100 m^3 or 200 m^3 capacity can be constructed to cater the demand of a group of 5-6 families.

Design of *Tanka*

Once the capacity of *tanka* is decided, its shape and other dimensions can be worked out. Evaporation losses are higher in *tankas* with wider opening and shallow depth but are more stable and easy to construct. However, cost to cover the opening of such *tanka* is more. On other hand, narrow opening *tanka* with deeper depth causes less evaporation but needs extra strengths in terms of material in bottom for stability and cost of excavation is high for at deeper depth. Therefore, opening and depth of the *tanka* should be optimized for minimum evaporation loss and construction cost. For circular *tanka*, depth and diameter should be kept equal and can be calculated using equation 3.

$D = (1.27 \times V)^{0.33}$ ....(3)

Where D is diameter as well depth in meters and V is capacity in cubic meters. For designing of a rectangular *tanka*, two dimensions of either length, width or depth is first decided on the basis of local site conditions and third dimension is calculated using equation 4.

V = L X B X H.............................. (4)

Where L, B, H and V are length (m), Width (m), depth (m) and Volume (m^3) respectively. For known volume (V) and two pre-decided dimensions of length, width or depth, third unknown dimension can be worked out using equation 4.

Construction of *Tanka*

Tanka should be constructed at an appropriate site. If rainwater is to be collected from rooftop, its location should be constructed near to the place of intended use. If rainwater is to be collected from natural catchment then *tanka* should be constructed at one side of the depression area for maximum runoff and safe disposal of excess water. In arid area of western Rajasthan, a murrum layer is reported in the sub surface strata at many places. Special care is needed when *tanka* is to be constructed at these sites. Murrum has a tendency of swelling after getting some moisture and causes cracks especially in sidewalls. To avoid these cracks surrounding of whole *tanka* should have an envelope of 5 cm sand around sidewalls. In case of small little leakage from sidewall, sand envelope of 5 cm thickness of sand will absorb the pressure exerted by the swelling of murrum around sidewalls and will prevent the cracks developing in sidewalls. Circular *tanka* is more economical in comparison to rectangular *tanka* of same capacity in term of cost of materials. Further, the rectangular *tanka* has the tendency for development of cracks in four corners due to uneven distribution of pressure whereas in the circular *tanka* pressure distribution is even, thus less chance of cracks developing in sidewalls. Cement concrete is preferred over masonry construction due to cost and life span, especially for the larger *tanka* of capacity over 100000 liters. However, masonry construction is equally good for small capacity *tanka* and does not require trained workers for the construction as in case of the cement concrete.

Repair and Maintenance of *Tanka*

Repairing a *tanka* is easy and if the structure is finished and properly cured, then no leaks are likely to occur. Small leaks which create only a wet stain need not be attended to, since they will close after some time. Only leaks with water flowing out need have to be repaired. The major problem is not the repair work as such, but the fact that leaks usually cannot be identified until the *tanka* is filled. As mentioned, curing after the structure is finished as well as while it is still under construction, is just as important as the quality of craftsmanship and material. This will not only preserve the structure, but also furnish immediate evidence of any leaks. If there is no rainfall some days after the structure is finished, and the necessary amount of water is not available, a minimum filling of 100 mm is a must irrespective of whether it is of masonry or a cement concrete structure. This water serves as a long-term curing agent and will keep the plaster moist. In addition, especially in hot arid climates, the structure must be covered on all sides such a way that the moisture of the mortar cannot evaporate.

A properly constructed *tanka* serves for around 30 years if properly maintained. Its maintenance includes: keeping catchments clean and clear of moss, lichen, debris and leaves; cutting back trees and branches that overhang the roofs; cleaning of *tanka* inlets and screens every 3-4 months;, disinfecting the *tanka* if contamination is apparent, inspecting *tanka* annually and cleaning them out if necessary and ; testing the water periodically.

Rainwater Harvesting Experience of CAZRI

CAZRI, Jodhpur has perfected the designs of *tanka, nadi, khadin* and roof water harvesting system (RWHS) for efficient management and judicious use of rainwater. The improved designs of these structures have been replicated in large numbers in Western Rajasthan, which have remarkably improved water availability on a sustainable basis in the region. This is a clear testimony that water, food and fodder security may be obtained with large scale replication of the improved designs of rainwater harvesting structures developed by CAZRI at all potential locations in the region (Narain & Goyal, 2005). Looking to the financial implications, the work may be taken in a phased manner.

For rainwater management, the institute has designed underground *tanka* of 10 m^3 to 600 m^3 capacities for different rainfall and catchment conditions. These *tankas* were successfully constructed in Jhanwar, Sar, and Baorali-Bambore watersheds. Harvested water of these *tanka*s was used to provide life saving irrigation to plants. The Benefit cost ratio of *tanka* ranged from 1.25 to 1.40 under different uses (Goyal et al. 1995, Goyal & Sharma, 2000). The improved *tanka* designs developed and demonstrated by CAZRI have got wide acceptability in the region. The designs have been replicated in a large number by different developmental agencies. 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. Hauling water in the villages cost 75 paisa per liter, which is very expensive high compared to only 2 to 5 paisa per liter of water available from a *tanka* located near the settlement. Construction of *tanka*s for raising orchards at a few locations have significantly improved the economic condition of the farmers.

Under *ex-situ* rainwater management, CAZRI, has prepared a design package and guidelines for the construction of khadins (Khan, 1998). *Khadin* is a unique practice of water harvesting and moisture conservation in suitable deep soil plots surrounded by some sort of natural catchment (Fig.2). The system is very effective even in hyper arid region of Western Rajasthan where annual average rainfall is less than 150 mm. Recently, CAZRI under NATP has developed *Khadin* of 20 ha areas 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 the loss of valuable water. After construction of *Khadin*, farmer could take excellent *Kharif* and *Rabi* crops.

Large-scale development of *khadin* farms at suitable locations in western Rajasthan can enhance the land productivity to meet the food and fodder requirement of the local population.

Another common rainwater harvesting structure in this region is *nadi. Nadi* is a dugout pond used for storing runoff water available from adjoining natural catchment during the rainy season. Generally, *nadis* have the limitation of high evaporation losses due large exposed surface area, high seepage losses through porous sides and bottom, heavy sedimentation due to biotic degradation in the catchment and water contamination causing health hazards. To overcome these problems, CAZRI has developed improved design of *nadi*s with LDPE lining to provide safe drinking water to human and livestock population. In improved

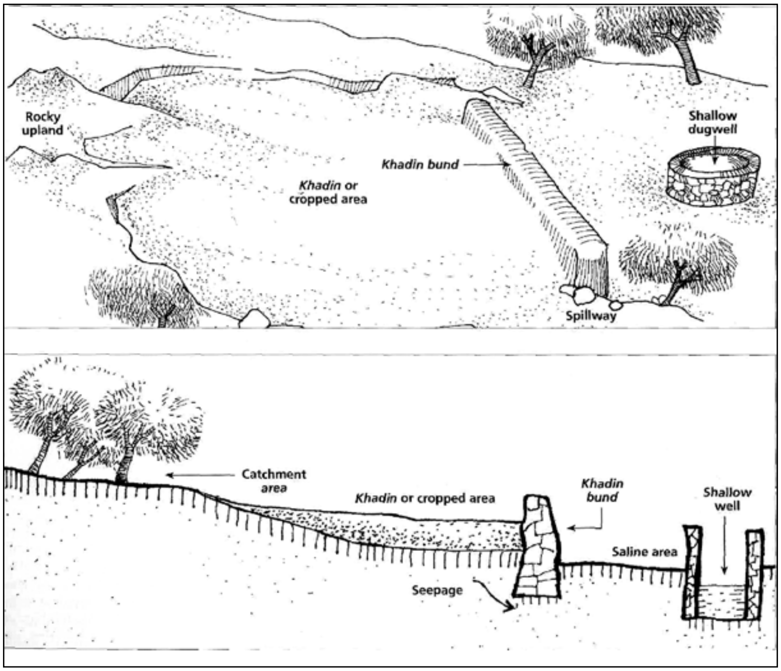

Figure 2. Khadin in Rajasthan

design, the surface to volume ratio had been kept 0.28. Provision of silt trap at inlet point has been made to prevent sediment load entering the *nadi* whereas provision of LDPE lining of sides and bottom is to control the seepage losses. Fencing of water point has been recommended for protecting the water from being contaminated. Renovation of *nadi* should be taken on large scale to improve the storage capacity and conservation of water for a longer duration.

For farm water management, a farm pond of 20,000 m^3 capacity was constructed at Kukma watershed at Bhuj in Gujarat. Construction of this farm pond resulted in assured availability of 20,000 m^3 water even in the region with as small as 150 mm rainfall region. The collected water was used to provide irrigation to date palm, ber, aonla and other fruits plants in the nearby area.

Harvesting of roof water is an age-old practice to obtain safe drinking water in arid Rajasthan. The possible water yield from a roof catchment system is directly proportional to the catchment surface area, its runoff efficiencies and the amount of rainfall. The highest runoff efficiency of 94% was achieved from when the surface was covered with plastic sheet, followed by roof made of corrugated GI sheet (85%), stone slab roof (81%), paved surface (68%), clay tile roof (56%) and metal road (52%). At institute level, the entire CAZRI building roof area (1500 m^2) has been used for roof water harvesting. The water outlet opening on the roof were connected with 100 mm conduit pipes to collect and divert roof water in a semi-circular open channel having 450 mm inner diameter and 525 mm depth and guided to a 300 m^3 *tanka*. The average annual water yield from the roof surface was 88%. As small as 225 mm rainfall is sufficient to fill this *tanka*, which is enough for a drinking water consumption of 30,000 person days at 10 liters per capita per day (lpcd).

Conclusions

Rainwater harvesting, recycling and its management is key to survival in hot arid zone of Rajasthan and elsewhere with similar climatic conditions. For the management of scarce water resources, multiple point strategies are needed. On one hand technologies of rainwater harvesting and conservation needs to be popularized and percolated at extreme down end and on the other hand, technological advancement is needed for the development of drought tolerant early maturing crops to use water efficiently. Traditional rainwater harvesting structures like *nadi, baori, talab,* etc., needs renovation on a continuous basis. Efforts should be made by the government for timely desilting of the traditional rainwater harvesting structures. Since rainfall in this region is convective in nature and occurs generally with high intensity for a shorter duration. The nature of this rainfall not only causes flash flood situations, but also leads to loss of huge quantity of runoff water, particularly in the urban areas. So special efforts are needed to harvest flash floodwater for the lean period and this can be done by construction of large storage structures at appropriate sites.

References

Goyal RK and Sharma AK. (2000) Farm Pond: A well of wealth for the dryland dwellers. Intensive Agriculture, Vol. XXXVIII (July- August 2000), No. 5-6 pp. 12-14 & 26.

Goyal RK, Ojasvi PR and Bhati TK. (1995) Economic Evaluation of Water Harvesting Pond under Arid conditions. Indian Journal of Soil Conservation 23(1): 74-76.

Khan and Venkateswarlu J. (1993) Rainwater harvesting for increasing water availability in arid Rajasthan. Journal of Institution of Engineers, 6: 18-26.

Khan MA. (1998) Design package and guide lines for Khadin constructions. Report submitted to Govt. of Rajasthan. 20p.

Narain P and Goyal RK. (2005) Rainwater Harvesting for Increasing Water Productivity in Arid zones. Journal of Water Management Vol.13 (2): 132-136.

Optimum Design of Watershed Based Tank System for Semiarid and Sub-humid Tropics

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Abstract

A software (SOFTANK) developed for analysis of water balance in watersheds is presented with a case study of Pimpalgaon Ujjaini Watershed in Maharashtra. The model can be used to evaluate the existing tank system. An optimum tank system can be suggested for new watershed projects with the help of optimization utility of the model. The model gave the detailed water balance of the watershed and showed that 42% runoff is harvested by the tanks and 58% went out of the watershed. The tanks were economical but over designed and therefore any treatment in the catchments of these tanks, which will reduce the inflow to the tanks, should be discouraged.

Introduction

It has been demonstrated in India that land and water resource development on a watershed basis offers sustainable approach to rainwater harvesting and resources conservation. Though watershed development programmes in the country started in the late 80's to develop semi-arid areas, it became the focal point for rural development by the late 90's with an annual budget of over $450 million (Kerr, 2002).

Due to the advent of watershed approach for the management of land and water resources, rainwater harvesting tanks i.e. nala bunds, check dams, percolation tanks, farm ponds are planned as an integral component of the watershed (Fig 1). Due to the different nature of watershed-based tank systems from stand-alone tank systems, the existing approaches of design of isolated tank systems (Palmer *et al* 1982, Panigrahi and Panda, 2003, Srivastava, 1996) can not be used for designing watershed-based tank system. At present, they are designed based on local experience and some empirical guidelines for different regions of India and can be found in Samra *et al* (2002). This often results in non-optimal rainwater harvesting through these structures. Therefore, a new

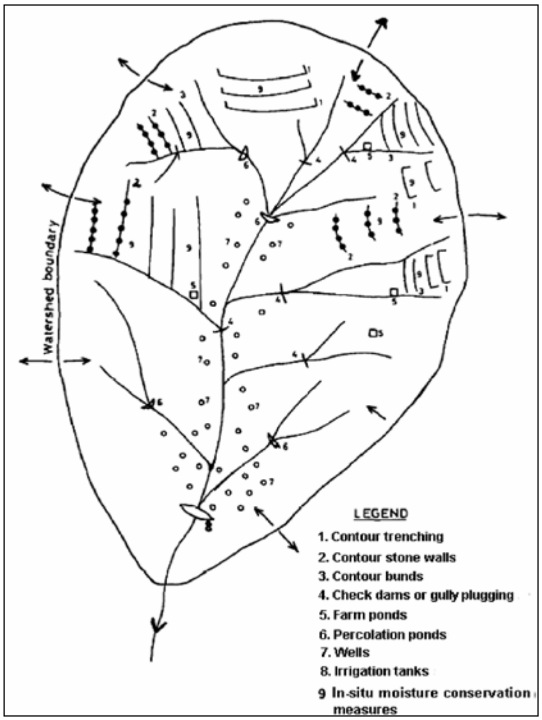

Figure 1. Integration of in-situ and ex-situ RWH systems int he watershed (Source: Sivanappan, 1995)

methodology is proposed for the design of watershed-based tank systems on the concept of Integrated Water Storage System (IWSS) in the watershed.

Methodology

A comprehensive methodology has been developed for the optimum design of tank system for the watershed. The methodology is based on three important water balances in the watershed i.e. field water balance, tank water balance and groundwater balance. The tank system for the watershed is optimized for maximum net benefits. First, fields are allocated to 'stream points'. Stream point is defined here as a point on the stream at which tank location is preferred. Tank strategies are generated based on the number of stream points. Tank strategy is a unique combination of number of tanks, their locations and tank type. Tank type is defined based on the orientation of the command area around the tank. Catchment and command field allocation is performed for each tank strategy. Initial tank capacity is determined with the design runoff depth (DRD). Simulation then starts from the first (or selected) tank strategy. A downstream release (DSR) criterion is given before the simulation. The DSR criterion in this research is the annual volume of water that passes the watershed outlet as per cent of annual volume of runoff generated in the watershed. For example, a DSR of 30% means tanks will harvest 70% of the runoff generated in the watershed and remaining 30% will go downstream out of the watershed. Tank system is designed for this DSR. In a simulation field, tank and groundwater balances are simulated simultaneously on a daily basis. At the end of simulation, output DSR is obtained. This DSR is compared with the input DSR ± deviation (e.g. 30 ± 10). Since the output DSR is the result of simulation and depends upon many factors like tank size, water use, climate etc., DSR may or may not match with the input DSR. If DSR criterion is not met, tank capacity is increased (or decreased) and simulation performed again. The procedure is repeated till the DSR criterion is met. When the DSR criterion is met, the project economics for the tank strategy is performed. In this way all tank management strategies are simulated. The conceptual flowchart of the methodology is shown in Fig 2.

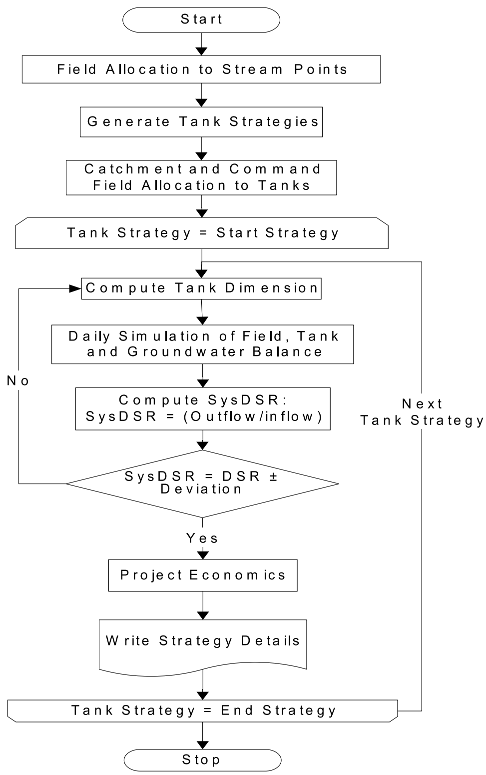

Figure 2. Conceptual flowchart of the methodology for finding optimum tank strategy

The SOFTANK Model

The comprehensive methodology for an optimum design of tank system is converted into computer code in C language, which resulted into computer model SOFTANK. This model provides an analytical tool for studying different aspects of tank system design in the watershed. The model can be operated in four different modes i.e. calibration, evaluation, simulation and optimization.

Results

The SOFTANK model was applied to the Pimpalgaon Ujjaini watershed in Ahmednagar district of Maharashtra state to evaluate the existing percolation tank system for water harvesting potential.

Pimpalgaon Ujjaini Watershed

Pimpalgaon Ujjaini watershed with an area of 1326 ha is located 15 km northeast from Ahmednagar (latitude 74º 05′ east and longitude 18° 15′ north). There are two percolation tanks on two streams in the watershed. Water is not used directly from the tanks for irrigation purpose. Common cereal, pulses and oilseed crops are grown in the command of the percolation tanks in the watershed with irrigation by groundwater. The location of the watershed is shown in Fig 3.

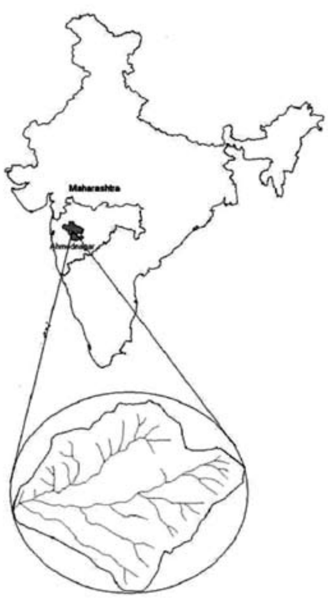

Figure 3. Location of Pimpalgaon Ujjaini watershed

The climate of the region is usually hot and the potential annual evaporation is about 1800 mm. The mean annual rainfall for the region is 642 mm, most of which falls in four months of monsoon i.e. from July to October. Rainfall starts in late June to early July.

Data

The daily values of climatic parameters available at Rahuri from 1975 to 2004 were used for the calibration and application of the SOFTANK model for Pimpalgaon Ujjaini watershed. Watershed data included data on stream points, fields, crops, soils, tanks, and groundwater. The watershed is comprised of 447 fields. These fields were allocated to different stream points based on their z-coordinates. The soils in the watershed ranged from very shallow to very deep and from sandy loam to clay in texture. Hydrologic soil groups in the watershed belonged to hydrologic soil group B, C and D. There are two percolation tanks one each on the two streams in the watershed. These tanks are used for recharging the groundwater only. Water is not used from storage of the tanks for irrigation. The details of the percolation tanks are given in Table 1. These tanks are of embankment type with irregular shape of the reservoir. This shape was approximated to the square prism shape in the analysis. Seepage rate for both the tanks was considered as 24 mm/day. There are number of wells in the watershed. Data on groundwater levels of nine wells were used for the calibration of the model for the watershed.

Table 1. Details of percolation tanks in Pimpalgaon Ujjaini watershed

t	Water spread area (ha)	Storage capacity (ha-m)	Catchment area (ha)
Tank I	20.5	69.6	297.41
Tank II	11.5	21.6	279.40

Evaluation of Existing Tank System

The detail water balance of the watershed has been analyzed for evaluating the existing tank system and discussed below.

Field Water Balance

There are 447 fields in Pimpalgaon Ujjaini watershed with an area of 1326 ha. Out of this 335 ha was under single cropping, 410 ha under double cropping, 491 ha was barren and 90 ha was occupied under two tanks. Field water balance involved computation of various inflows to and outflows from the field. (Fig 4). Annual rainfall was 541 mm. Runoff was 21.5% of rainfall. Evapotranspiration and deep percolation contributed 67.5% and 15.8% of the total outflow respectively. Deep percolation was 20.5% of the rainfall.

Tank System Water Balance

There are two percolation tanks on two streams in the watershed. Total storage capacity of two tanks is 91.2 ha-m. Tank system water balance components for 29 years are shown in Fig 5. Inflow ranged from 0.13 to 1.86 times the total storage capacity of tank system with an average (29 years) of 0.82. Major portion

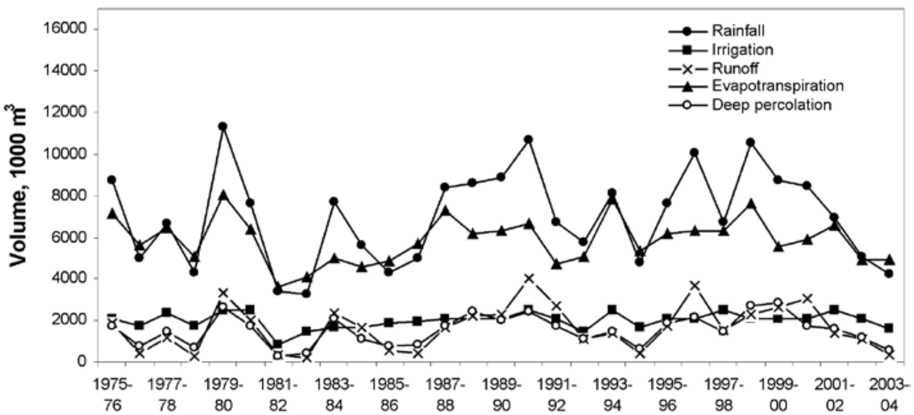

Figure 4. Components of field water balance for Pimpalgaon Ujjaini watershed

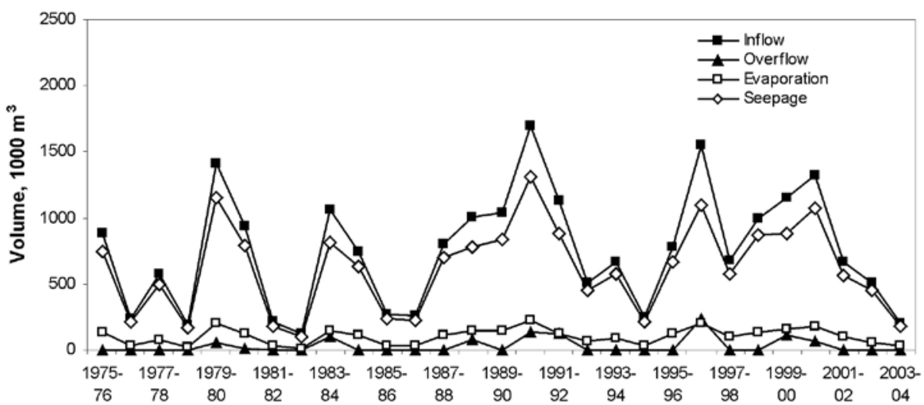

Figure 5. Tank system water balance components for Pimpalgaon Ujjaini watershed

of this inflow was lost as seepage, which accounted for 83.6% of the total outflow from the tank. Other loses were evaporation (13.6%) and overflow (2.6%). There was no carry over storage from the tanks. Though the overflow from the tanks was less, average DSR from the watershed was 58.5% since the tanks were at the middle of the watershed and area of watershed downstream of tanks contributed directly to the DSR. There was no irrigation from the tanks since tanks were used for groundwater recharge only.

Tank Water Balance

Tank water balance components of individual tanks are given in Table 2. Tank capacities were 69.60 and 21.70 ha-m. In Tank No. 1 annual inflow was less than the tank capacity whereas in Tank No. 2 annual inflow exceeded tank capacity. Of the total inflow, evaporation was about 15% in both the tanks whereas seepage was 85% in Tank No.1 and 74% in Tank No. 2. There was no overflow from Tank No.1.

Groundwater Balance

In estimating the groundwater balance, it was assumed that the underground storage volume is available below the watershed confined by bedrock at the lower boundary and ground surface as the upper boundary. Deep percolation from fields, seepage from tanks recharge this storage volume and water is withdrawn for irrigation and other use from the storage. In addition, water from adjoining area may join this storage volume and water may flow outside the storage volume as groundwater flow. In the PU watershed, irrigation was scheduled at 28 days in rainy season and 21 days in post rainy season with an irrigation application depth of 55 mm. Irrigation application efficiency was taken as 70%. Source of irrigation were open dug wells. There were 85 open dug wells in the watershed. Other use was estimated from the number of household units in the watershed. Field recharge and tank recharge were found to be 71% and 29%, respectively. Groundwater flow was 33.26% of the total groundwater outflow, whereas irrigation and other use contributed 65.53% and 1.21%, respectively. The contributions of groundwater recharge and withdrawal components are shown in Fig 6.

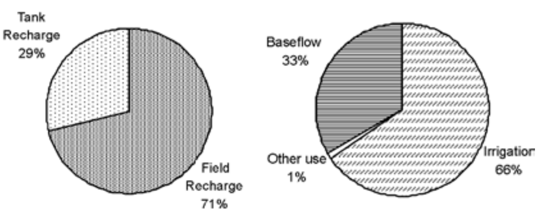

Figure 6. Contributions of groundwater recharge and withdrawal components for Pimpalgaon Ujjaini watershed

The water balance of watershed provided analysis of all the inflows to and outflows from the watershed. The two percolation tanks harvested 42% of the runoff and 58% went out of the watershed. Runoff was 21.5% of the rainfall and 20.5% of the rainfall contributed to the groundwater

Table 2. Individual tank water balance components for Pimpalgaon Ujjaini watershed (average of 29 years)

Tank No.	Capacity m^3	Inflow m^3	Overflow m^3	Evaporation m^3	Seepage m^3
1	695877	424172.2	0.00	60302.8	362280
2	216938	326924.9	33789.2	41983.9	250001

recharge. Major portion (83.6%) of the inflow to the tanks contributed to groundwater recharge, but major recharge to groundwater was through fields (71%) as compared to tanks (29%). Due to groundwater irrigation, groundwater withdrawal formed the major outflow (65.5%) from the groundwater storage. Though the investment in tanks was found economical (BC ratio 1.34), the tanks were over designed when the inflow/capacity ratio was 0.82. Hence any treatment (like CCTs) in the catchments of these tanks should be discouraged.

Soils in the watershed vary in depth, colour and other morphological characteristics. Common crops grown in the watershed are sorghum, pearl millet, wheat, gram and fodder. Fields are used for a single *kharif* or *rabi* cropping or double cropping. Most of the area downstream of the percolation tanks comes under double cropping system. The area in the catchment of the tanks is mostly under shrubs.

Lessons Learnt

The SOFTANK model offers a comprehensive analytical tool for studying the detail water balance of watershed-based water harvesting tanks. It incorporates many new features, which are unique to the watershed-based tank system. The model can be used to evaluate the existing tank system. The existing tank system can be improved by running alternate management scenarios with the help of simulation utility of the model. An optimum tank system can be suggested for new watershed projects with the help of optimization utility of the model. In this paper only the evaluation utility of the model is discussed. The model gave the detail water balance of the watershed and showed that 42% runoff is harvested by the tanks and 58% went out of the watershed. The tanks were economical but over designed and therefore any treatment in the catchments of these tanks, which will reduce the inflow to the tanks, should be discouraged.

Strategies for Upscaling

The SOFTANK model can be used for designing the water harvesting tanks for preparing plan for developing a watershed. There is thus scope for the use of the model for watershed projects. The model needs user friendly for that purpose.

References

Kerr JM. (2002) Watershed development, environmental services and poverty alleviation in India. *World Development*, 30(8), 1387-1400.

Palmer WL, Barfield BJ and Haan CT. (1982) Sizing farm reservoirs for supplemental irrigation of corn. Part I: Modeling reservoir size yield relationship. *Transactions of American Society of Agricultural Engineers:* 372-76.

Panigrahi B and Panda SN. (2003) Optimal sizing of on farm reservoir for supplemental irrigation. *Journal of Irrigation and Drainage Engineering,* 129(2): 117-128.

Samra JS, Sharda VN and Sikka AK. (2002) *Water Harvesting and Recycling, Indian Experiences*, Central Soil and Water Conservation Research and Training Institute, Dehradun, India.

Srivastava RC. (1996) Design of runoff recycling irrigation system for rice cultivation. *Journal of Irrigation and Drainage Engineering*, 122 (6): 331-335.

Evaluation of Watershed Development Programs in India using the Economic Surplus Method

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Abstract

Watershed programs in India are contributing to water resources development, agricultural production and ecological balance. Conventional methods using financial measures attempt to quantify the impacts in an isolated manner. In order to evaluate the impacts of watershed programs in a holistic manner, the Economic Surplus (ES) approach has been applied using the data from a cluster of 10 watersheds in Coimbatore district of Tamil Nadu, India. The ES method captures the impacts of watershed development activities in a holistic manner than the conventional methods. The distributional effects of watershed programs are also captured through the ES method. Hence the possibilities of using this methodology in the future watershed evaluation programs could be examined.

Introduction

Watershed development in India is not a new concept and has traveled a long way as a simple soil and water conservation programs to the recent integrated rural development program with more people participation. Both Central and State governments and international donors have been implementing watershed development program across the country in different modes. The over all objectives of these development programs, by and large, are three fold viz., promoting economic development of the rural area, employment generation and restoring ecological balance (Department of Land Resources, 2006). The watershed development program assumes importance in India where nearly two third of the cropped area is rainfed, characterized by the low productivity, degraded natural resources and widespread poverty particularly in rural areas. Under this situation, understanding the nature and extent of impact of these watershed development programs on various domains in the rural economy is crucial for development personnel/specialist, economists and policy makers. This is will guarantee more food, fodder, fuel, and livelihood security for those who are in the bottom of the rural income scale.

A watershed is a geographical area that drains to a common point, which makes it an attractive unit for technical efforts to conserve soil and maximize the utilization of surface and subsurface water for crop production (Kerr et al., 2000). Different Ministries like Ministry of Agriculture (MoA), Ministry of Rural Development (MoRD) and Ministry of Environment and Forest (MoEF) are involved in the implementation of watershed development in the country. Watershed development has been conceived basically as a strategy for protecting the livelihoods of the people inhabiting the fragile eco-systems experiencing soil erosion and moisture stress. Different types of treatment activities are carried out in a watershed. They include soil and moisture conservation measures in agricultural lands (contour/field bunding and summer ploughing), drainage line treatment measures (loose boulder check dam, minor check dam, major check dam, and retaining walls), water resource development/management (percolation pond, farm pond, and drip and sprinkler irrigation), crop demonstration, horticulture Plantation and afforestation (Palanisami and Suresh Kumar, 2006). Training in watershed technologies and related skills is also given periodically to farmers in watersheds. In addition, members are also taken to other successful watershed models and research institutes for exposure. These efforts appear to be contributing to groundwater recharge. The aim has been to ensure the availability of drinking water, fuel wood and fodder and raise income and employment for farmers and landless labourers through improvement in agricultural production and productivity (Rao, 2000). Today watershed development has become the main intervention for natural resource management. Watershed development programs not only protect and conserve the environment, but also contribute to livelihood security.

As an important development program, watershed development received much attention from both the Central and state governments. Up to Xth Five Year Plan (till March 2005), an area of 17.24 million hectares was treated with a total budget of Rs. 9368.03 crores under Ministry of Agriculture, 27.52 million hectares with an outlay of Rs. 6855.66 crores under Ministry of Rural Development and an area of 0.82 million hectares with an outlay of Rs. 813.73 crores under Ministry of Environment and Forest were spent. A total of 45.58 million hectares has been treated through various programs with an investment of Rs. 17,037 crores. Average expenditure per annum during the Xth Five Year Plan is around Rs. 2300 crores (Department of Land Resources, 2006). As millions of rupees have been spent on watershed development programs, it is essential that the programs become successful.

With the programs so large and varied, it is important to understand how well they function overall and which aspects should be promoted and which will be dropped. However, despite this importance, little work has been done to assess their impacts. This paper partially fills this gap by examining both social and environmental outcomes. In particular, it tries to answer the questions: (i) what impacts the watershed development activities bring to rural areas, (ii) how do watershed development activities impact on groundwater resources, soil and moisture conservation, agricultural production and socio-economic conditions?. This will help the policy makers in up-scaling and mainstreaming watershed development programs in the country.

Hence, it is important to apply relevant methodologies for the evaluation of the watershed programs so that future programs will be planned in an efficient manner. Most evaluators use conventional financial analysis to assess the impact of watershed development programs. However, the question is whether the conventional financial analysis captures the impacts in a holistic manner? Should we have a better methodology to assess the impacts of watershed program, as watershed development technologies not only benefit the participating farm households, they also benefit the not-participating farm and other rural households in the watershed village. Keeping these issues in view, this paper outlines the economic surplus method to study the impact of the watershed programs using data from sample watersheds in Coimbatore district, Tamil Nadu State, India.

Background

Watershed development and management has become big concern in India. As the Central and State governments diverting huge fund towards watershed development, proper assessment of the benefits accrued to the economy is essential. A program like watershed development, which involves a hierarchy of administration and communities at the grass roots level in highly varying agro-climatic and socio-economic conditions, invariably requires periodical assessment for achieving the developmental objectives. Typically, an implementing agency would see a greater value in spending an extra few millions of rupees for undertaking works in the field rather than spending this money for monitoring and evaluation.

In addition, the impact assessment contributes to improve the effectiveness of policies and programs by addressing the questions such as: (i) Does the program achieve the intended goal?, (ii) Can the changes in outcomes be explained by the program, or are they the result of some other factors occurring simultaneously?, (iii) Do program impacts vary across different groups of intended beneficiaries (males, females, indigenous people), regions, and over time?, (iv) Are there any unintended effects of the program, either positive or negative?, (v) How effective is the program in comparison with alternative interventions? and (vi) Is the program worth the resources it costs? (Palanisami and Suresh Kumar, 2006).

To successfully implement the watershed development activities, the Government of India has issued various guidelines. The GoI guidelines were first issued in 1995. In order to make the watershed development and management more people participatory, the GoI guidelines were further revised and issued in 2001. Subsequently, to involve Panchayat Raj Institutions more meaningfully in implementation of watershed development activities, the popular Haryali guidelines were introduced in 2003. In addition to all these guidelines, the guidelines for NWDPRA watershed development programs, CAPART, NABARD and NGO implemented watershed guidelines were implemented separately over the period. Though these guidelines were by and large successful in implementation of various watershed development activities, these are not exempted from lacuna particularly in the context of institutional issues, post project maintenance and sustainability and monitoring and evaluation of watershed development activities. Recently, the GoI has issued 2008 Common Guidelines for effective implementation of watershed development programs in the country.

In spite of the guidelines, the implementation aspects normally deviate due to local demand. Several studies had indicated that the watershed structures are not maintained after completion and benefits may decline over years (Palanisami and Sureshkumar, 2006). Also in order to push up the implementation of the watersheds in other locations, the evaluation of the existing watersheds has been conducted. But it is always mentioned that the benefits and costs are based on several assumptions. Impact Analysis of an area based program like watershed development has inherent difficulties. Apart from the benefits accrued from different technologies, the impact of watershed development should be looked into three major dimensions viz., scale (household level, farm level and watershed level) temporal and spatial. The dimensions of impact of watershed technologies further complicate the impact assessment.

Different studies have developed a variety of indicators for the impact assessment. The indicators of impact will cover watershed development activities covering soil erosion, groundwater recharge and water resources potential, agricultural production, socio-economic conditions and overall impact including the extent of green cover. These indicators were compared with before and after the watershed treatment activities, and also with that of the control village where watershed treatment activities is not taken up. The other methodologies such as Total Economic Valuation (Logesh, 2004) and bio-economic modeling were also employed by the researchers. However, still the researchers face challenges in quantifying the impacts of watershed development activities.

The problem of impact assessment of watershed development project lies on the following: (i) Developing a framework to identify what impacts to assess, where to look for these impacts and selecting appropriate indicators to assess the impacts, and (ii) Developing a framework to look at the indicators together and assessing the overall impact of the project. The nature of watershed technologies and its impact on different sectors pose challenges to Project Monitoring and Evaluating Agencies, economists, researchers and policy makers. More specifically, major challenges include (i) the choice of methodologies, (ii) selection of indicators, and (iii) choice of discount rate, (iv) quantifying benefits in upstream and downstream, (v) defining the zone of influence and (vi) extent of natural and artificial recharge (Palanisami and Suresh Kumar, 2006).

Methodology

Economic Surplus Approach (ES)

Economic Surplus (ES) is widely used for evaluating the impact of a technology on the economic welfare of households (Joseph and Quddus, 1998; Moore et al, 2000; Wander et al, 2004; Maredia et al, 2000; Swinton, 2002). The economic surplus method's goal is to measure the aggregated social benefits of a research project. With this method, it is possible to estimate the return of investments by calculating a variation of consumer and producer surplus through a technological change originated by research. Afterwards, the economic surplus is utilized together with the research costs to calculate the net present value (NPV), the internal rate of return (IRR), or the benefit-cost-ratio (BCR) (Maredia et al., 2000). The model can be applied to the small/large open/closed economy within the target domain of production environment. The term surplus is used in economics for several related quantities. The consumer surplus is the amount that consumers benefit by being able to purchase a product for a price that is less than they would be willing to pay. The producer surplus is the amount that producers benefit by selling at a market price mechanism that is higher than they would be willing to sell for. In the case of watershed programs, the producers are mainly the farm households who produce the goods using the benefits of the watershed interventions such as soil and moisture conservation, water table increase and livestock improvement activities and consumers are mainly the other stakeholders in the region viz., non-farm households representing the labourers, business people and people employed in non-agricultural activities.

Theoretical Framework

The model is based on the Marshallian theory of economic surplus that stems from shifts over time of the supply and demand curves. In Fig.1, the rightward shift (S_1) of the original supply curve (S_0) generates economic surplus for producers and consumers. Such a shift can stem from the changes in the production technology, in the present case watershed development intervention. Given that the demand function remains constant, the original market equilibrium a (P_0, Q_0) is transferred by the effect of technological change to b (P_1,Q_1).

Consumers gain because they are able to consume a greater amount (Q_1) at a lower price (P_1). The area P_0abP_1 represents this

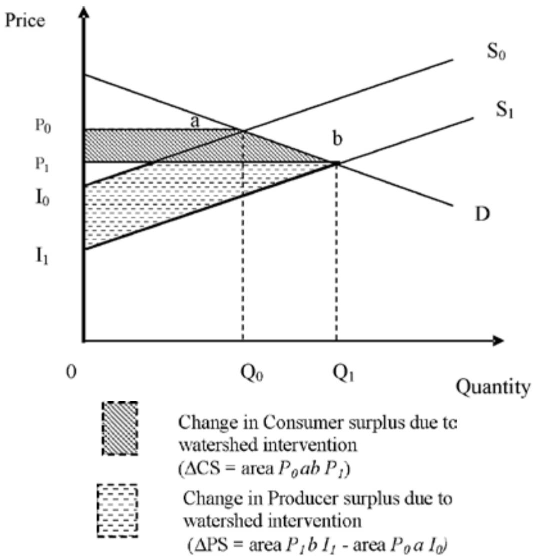

Figure 1. Graphical representation of Economic Surplus Method

consumer surplus. The watershed development intervention affects agricultural producers in two ways: (i) Lower marginal costs (according to the theory, the supply curve corresponds to the curve of marginal costs as of the minimum value of the curve of average variable costs), and (ii) Lower market price (P_0 reduced to P_1). Thus, the producers' surplus is defined as the area P_1bl_1-area P_0al_0.

The mathematical model used is based on the scheme proposed by Pachico et al. (1987), in which supply and demand functions are nonlinear with constant elasticity i.e. log-linear. The supply function for a product market is assumed that supply curves of the following functional form:

$$s_0 = c(P_0 - P_{lo})^d \quad \text{......................................(1)}$$

where: $\mathbf{s_0}$ = Initial supply before watershed intervention

c,d = Constants

P_0 = Price of product, and

P_{lo} = Minimum price that producers are willing to offer

Typically, the watershed development programs involving the entire community and natural resources influence different aspects such as agricultural production system, environment and socio-economic conditions of the watershed villages. By virtue of its nature, watershed is an area based technology cutting across villages comprising both private and public lands. Thus, the benefits from the watershed developmental activities are not only limited to the users/beneficiaries but also to the non-participating farmers. For instance, the watershed development technologies expected to have positive impacts on groundwater recharge, soil and water conservation, maintaining ecological balance, increased fodder availability, increased crop yield, etc. Similarly, the increased agricultural production favours the non-farming community like labourers, rural artisans and other rural households. Thus, the watershed development brings benefits not only to the producers (farmers) but also to the consumers (farmers, labour households and other households in the watershed village). In this context, the economic surplus approach captures the total benefits accrued due to watershed development intervention in the rural areas.

The advantage of the ES approach lies in the fact that the distribution of benefits to different segments of the society could be estimated. The watershed development could be treated as a 'public good' and covers both the private and public lands. Moreover, the benefits due to watershed developmental activities are not restricted to the producers alone. Increased supply and hence changes in the price of the agricultural products also benefit the consumers positively. In this context, the economic surplus approach captures the impact of watershed development activities in a holistic manner.

Application of Economic Surplus Method in Watershed Evaluation

Watershed programs play a dual role by safeguarding the interest of the producers as well as consumers, as the implementation of drought proofing aspects of the watershed programs are easily felt (Palanisami and Suresh Kumar, 2007). Producers can change the crop pattern due to increased water levels in their wells, moisture conservation in the soil, increase water use for the existing crops, increase the number of livestock and fodder production. There is also change in the cost of production of the commodities in the watershed. Over years, there is an increase in technology adoption due to watershed programs. In the case of consumers, the increased crop production in the watershed results in the availability of produce at comparatively lower prices. The consumption levels also increased among the consumers. The labour employment also increased due to increased land and crop production and processing activities in the watershed. Evidences show that the production levels increased as a result of watershed interventions and the consumers started enjoying the benefits of localized production in the regions. Hence, for the purpose of the analysis, it is assumed that, the output supply curve shifts gradually over time when the benefits from the watershed developmental activities started benefiting the agricultural sector through water resource enhancement. The supply shift factor due to technological change, in this case watershed intervention, is known as K. This factor varies in time depending on the dynamics of the rainfall, adoption, dissemination of soil and moisture conservation technologies and maintenance activities undertaken in the watershed. The supply shift factor (K) can be interpreted as a reduction of absolute costs for each production level, or as an increase in production for each price level (Libardo et al., 1999).

Micro economic theory defines consumer surplus (individual or aggregated) as the area under the (individual or aggregated) demand curve and above a horizontal line at the actual price (in the aggregated case: the equilibrium price). Following IEG, the demand curve is assumed to be log-linear with constant elasticity. Thus, the demand equation for this demand function can be written as:

$$P = gQ^{\eta} \quad \text{.......(2)}$$

Where η is the elasticity and g is the constant. Once, the parameters η and g are estimated, and then consumer surplus could be estimated by

$$CS = \int_{Q_0}^{Q_1} gQ^{\eta}\, dQ - (Q_1 - Q_0)P_1 \quad \text{.......(3)}$$

Combined, the consumer surplus and the producer surplus make up the total surplus.

Estimation of Benefits

Following the theory of demand and supply equilibrium, economic surplus (benefits) as a result of watershed development intervention is measured as follows:

$$B = K * P_0 * A_0 * Y_0 * (1 + 0.5\, Z * \varepsilon_d) \quad .(4)$$

Where, K = Supply shift due to watershed intervention. The supply shift due to watershed intervention can be mathematically represented as:

$$K = \forall * \rho * \psi * \Omega \quad \text{.......(5)}$$

K represents the vertical shift of supply due to intervention of watershed development technologies and expressed as a proportion of initial price. ∀ is net cost change, which is defined as the difference between reduction in marginal cost and reduction in unit cost. The reduction in marginal cost is defined as the ratio of relative change in yield to price elasticity of supply (ε_s). Reduction in unit cost is defined as the ratio of change in cost of inputs per hectare to (1+change in yield). ρ is the probability of success in watershed development implementation. ψ represents adoption rate of technologies and Ω is the depreciation rate of technologies.

Z represents the change in price due to watershed interventions. Mathematically, Z can be defined as:

$$Z = K * \frac{\varepsilon_s}{(\varepsilon_d + \varepsilon_s)} \quad \text{.......(6)}$$

P_0, A_0, and Y_0 represent prices of output, area and yield of different crops in the watershed before implementation of watershed development program. If we use the with and without approach, then these represent area, yield and price of crops in control village.

Cost of the Project

The analysis considered cost towards watershed development investment during the project period and maintenance expenditure incurred in the project. For watershed development projects with multiple technologies or crops, incremental benefits from each technology and crop were added to compile the total benefits. The worthiness of the watershed development projects was then evaluated at 10 per cent discount rate. Using above estimates of returns and costs, net present value (NPV), benefit cost ratio (BCR), and internal rate of return (IRR) were computed.

Study Area and Data

Our study was conducted in the Coimbatore district of Tamil Nadu, India. The predominant soil types are red soil, laterite, clay loam, sandy clay loam, and black cotton soil. Differences in soil type have differential impact on the water resources and agricultural production and productivity. The success of the watershed development programs critically depends upon the rainfall in the region. The major crops grown are sorghum, cotton, sugarcane, maize, coconut and vegetables. Of the total cropped area, the area irrigated accounts for 56.82 per cent. The chief source of irrigation in the district is through wells. Over the years, there has been a general decline in the water level in all of Coimbatore district, which is attributed to indiscriminate pumping of groundwater. Groundwater resource degradation has in turn resulted in changes in crop patterns, well deepening, and an increase in well investments, pumping costs, well failure, and abandonment and out migration of farmers (Palansami and Suresh Kumar, 2007). It is in this context that groundwater augmentation by artificial recharge through watershed development programs gained momentum.

Data

The major data were derived from the recently completed study on Comprehensive Assessment (CA) of Watersheds Programs in India implemented by the ICRISAT-lead consortium team (Wani et al. 2008). For the purpose of our research, the data were drawn from a cluster of 10 watersheds implemented in the Coimbatore district of Tamil Nadu, India. The details of all these watersheds with area treated are given in Table 1. A variety of indicators were developed and used for impact assessment. The indicators of the impact of watershed developmental activities covering soil erosion, groundwater recharge and water resources potential, agricultural production, socio-economic conditions and overall impact including the extent of green cover were developed. To make a comparative study, one control village where no watershed treatment activities were carried was selected for each watershed. The control villages were selected so as to have the similar agro-climatic conditions. The select indicators were compared with before

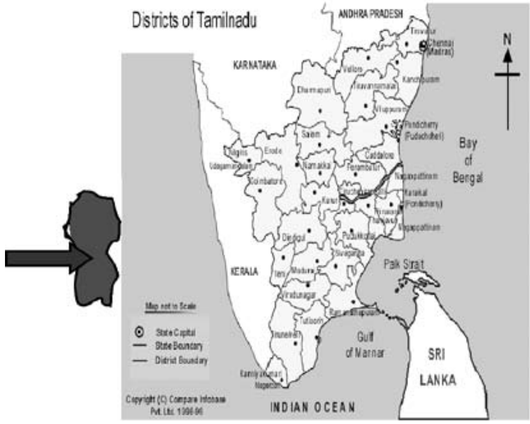

Figure 2. Map of the study area

and after the watershed treatment activities, and also with that of the control village where watershed treatment activities were not taken up. Thus, the data pertaining to 10 watershed villages and 10 control villages were gathered. The information on price elasticity of demand and supply of various farm products were obtained from published sources.

Results and Discussion

This section presents the key results and findings from the field experience of impact assessment of watershed programs implemented under Drought Prone Area Programme (DPAP) in the Coimbatore district of Tamil Nadu. The general characteristics of the sample farm households in the study watershed were analysed and are presented in Table 2. It could be seen that the average size of the holding is worked out to 1.28 ha and 1.75 ha, respectively for watershed and control villages. It is evident from the analysis that the average number of workers is 2.5 and 2.1 out of 4.07 and 4.2 for watershed and control villages.

The labour force participation rate thus comes out at 61.48 per cent and 50.79 per cent. The higher labour force participation is due to better scope for agricultural production, livestock activities and other off-farm and non-farm economic activities. It is evidenced from the analysis that the labour force participation rate among the farmers in the watershed villages is higher implying that the enhanced agricultural production is due to watershed treatment activities. Construction of new percolation ponds, major and minor check dams and rejuvenation of the existing ponds/tanks enhanced the available storage capacity in the watersheds to store runoff water for surface water use and groundwater recharge.

Construction of new percolation ponds, major and minor check dams and rejuvenation of existing ponds/tanks enhanced the available storage capacity in the watersheds to store runoff water for surface water use and groundwater recharge. The additional surface water storage capacity created in the watersheds ranged from 9299 M^3 to 12943 M^3. This additional storage capacity further helped in improving groundwater recharge and water availability for livestock and other non-domestic uses in the village as a result of watershed treatment activities. On the basis of the data collected from the sample farmers, it was found that the water level in the open dug wells has risen in the range of 0.5 to 1.0 meter in watershed villages. The depth of the water column in a few sample wells were collected both in watershed and control villages for comparison. The depth of the water column in the wells of the watershed villages was found to be higher than those in the control villages. For instance, the depth of the water column in the wells in Kattampatti watershed village was 3.53 meters compared to 2.16 meters in the control village with a difference of 63.43 per cent.

Information related to the duration of pumping hours before well goes dry (or water level depressed to a certain level) and time it takes to recuperate to the same level were collected for the sample farmers across villages. Due to watershed treatment activities such as construction of percolation ponds, checkdams etc., the groundwater recuperation in the near by wells increased. The increase in recuperation rate varied from 0.1 M^3 to 0.3 M^3/hour. It was also observed that the recharge to the wells decreased with the distance of wells away from the percolation ponds and check dams and the distance generally was 500 to 600 meters in the case of percolation ponds.

The impact of watershed treatment activities on area irrigated by groundwater revealed that the area irrigated in watershed villages registered a moderate increase after the watershed development activities in most of the watersheds. When compared to watershed villages, the area irrigated in the control village declined slightly over the period. It is evidenced that the irrigation intensity is higher in the watershed treated village than in the untreated village. This shows that the watershed developmental activities helped increase the water resource potential of a region through enhanced groundwater resources coupled with soil and moisture conservation activities. In the case of control villages, the water table in the wells declined due to continuous pumping with out making any interventions in recharging the aquifers. This is one of the reasons why farmers in most of the villages demand watershed programs in their villages.

The analysis of impact of watershed treatment activities on the increase in cropped area indicated that the increase in net cropped area, gross cropped area and thereby cropping intensity is realized in both the watersheds.

(Table.3.).

The cropping intensity indicates that it was relatively higher in the case of watershed treated villages and this appears to be a common phenomenon in all the watersheds. For example, the cropping intensity was worked out to 147 percent in the watershed village and it was little higher than the control where it is only 133 per cent. The CEI is used to compare the diversification across situation having different and a large number of activities since it gives due weight to the number of activities. The CEI has two components viz,. distribution and number of crops or diversity. The value of CDI increases with the decrease in concentration and increases with the number of crops/ activities. In general, the CDI was higher in the case of watershed treated villages than the control villages confirming watershed treatment activities help diversification in crop and farm activities.

The details regarding livestock per household and per hectare of arable land is furnished in Table.4. Livestock income has been a reliable source of income for the livelihood of the resource poor farmer households. Cattle, sheep and goats are maintained as important sources of manure and kept as liquid capital resources. It could be seen that nearly 46.67 per cent and 93.33 per cent of the households in watershed and control villages maintain cattle. Access to grazing land and fodder will make the farm households to maintain livestock in their farms to derive additional income. But the analysis revealed that relatively more number of households in control villages maintained livestock.

This is mainly due to the fact that inadequate grazing land and poor resource base for stall feeding persuade them to feed their livestock with green leaves and fodder obtained from crops and crop residues. Moreover, having poor resource base with little scope for improved crop production, the farm households in the control villages maintain mainly milch animals to derive additional income for their livelihood.

Application of Economic Surplus Method

The watershed developmental intervention is expected to impact first on the natural resources such as land and water. Increase in the water resources impacts agricultural production. Thus, various watershed treatment activities lead to increased agricultural production. The impact of watershed developmental activities on the yield of crops and the cost estimated are presented in Table 5.

The change in yield due to watershed intervention across crops varied from 31 per cent in maize to a maximum of 36 per cent in cotton. This is the maximum change in yield due to watershed intervention. Reduction in marginal cost due to the supply shift ranged from 33 per cent in vegetables to 64 per cent in sorghum. Net cost change due to watershed developmental activities varied from 32 per cent in vegetables to 60 per cent in the case of sorghum.

The change in total surplus due to watershed developmental activities were estimated (Table 6). The change in total surplus was higher in sorghum and maize compared to other crops like pulses and vegetables. Being the major rainfed crops, these two crops benefited more from the watershed interventions. The change in the total surplus due to watershed intervention is decomposed into change in consumer surplus and the change in producers' surplus.

It is evident that the producers' surplus was higher than the consumer surplus in all the crops. For instance, in sorghum, the producers' surplus if worked out to 61.2 per cent where as the consumers surplus was only 38.8 per cent. No doubt, the watershed developmental activities benefited more the agricultural producers. It is interesting to note that unlike in crop sector, the milk production had different impacts on the society. The decomposition analysis revealed that watershed development activities generate more consumers' surplus in milk production.

Efforts were made in the present study to assess the overall impact of different watershed treatment activities in terms of Benefit Cost ratio (BCR) and Internal Rate of Return (IRR). The NPV, BCR and IRR were worked out by economic surplus methodology assuming 10 per cent discount rate for a life period of 15 years.

The results of the economic surplus method indicated that the BCR worked out to more than one, implying that the returns to public investment such as watershed development activities are feasible. Similarly, the IRR is worked out to 25, which is higher than the long-term loan interest rate by commercial banks, indicating the worthiness of the government investment on watershed development. The Net Present Value worked out to Rs. 567912 for the entire watershed. The net present value per hectare worked out to Rs.4542 (where the total area treated is 500 hectares). This implies that the benefits from watershed development is higher than the cost of investment in the watershed development program of Rs.4000 ha[5].

Conclusion and Policy Recommendations

Experiences show that the watershed development programs produced desired results and there are differences in their impacts. Hence, the watershed impact assessment should be given due importance in the future planning and developmental programs. Comparing the results of economic surplus approach with conventional method of investment analysis, it is observed that there are significant differences between the economic surplus approach and the conventional approach. All the three indicators NPV, BCR and IRR worked out to be higher in the case of economic surplus approach compared to conventional methodology. It is hard to conclude whether conventional methodology underestimates the impacts or economic surplus method (ES) over estimates the impacts. However, as the economic surplus approach captures the distributional effects on different sectors of the economy in a holistic manner, this is possible to conclude that the conventional methodology underestimates the impacts of watershed development programs in the rural areas.

Regarding the policies, watershed developmental activities have significant impact on the groundwater recharge, access to groundwater and hence the expansion in irrigated area. Therefore, the policy focus must be for the construction of water harvesting structures particularly percolation ponds wherever feasible. In addition to these public investments, the private investments through construction of farm ponds may be encouraged as these structures help

[5] *However, recently the watersheds in India are allotted a budget of approximately Rs. 6000 per hectare. Thus, a watershed with a total area of 500 hectares receives Rs.30 lakhs for a five-year period. The bulk of this money (80 per cent) is meant for development/treatment and construction activities. According to the new Common guidelines 2008, the budget allotment is Rs.12000 per hectare.*

in a big way to harvest the available rainwater and hence groundwater recharge.

Watershed developmental activities altered crop pattern, increased in crop yields and crop diversification and thereby provided enhanced employment and farm income. Therefore, the alternative-farming system combining agricultural crops, trees and livestock components with comparable profit should be evolved and demonstrated to the farmers.

Once the groundwater is available, high water intensive crops are introduced. Hence, the appropriate water saving technologies like drip is introduced without affecting farmers' choice of crops. The creation and implementation of regulations in relation to the depth of wells and spacing between wells reduces the well failure, which could be possible through Watershed Association. The existing NABARD norms such as 150 meters spacing between two wells should be strictly followed upon.

People's participation, involvement of Panchayati Raj Institutions, local user groups and NGOs along side institutional support from different levels, viz. the Union Government, the State, the District and block levels should be ensured to make the program more participatory, interactive and cost effective.

References

Department of Land Resources. (2006). Report of the Technical Committee on Watershed programs in India, From Hariyali to Neeranchal, Department of Land Resources Ministry of Rural Development Government of India.

Joseph G and Quddus MA. (1998) National agricultural commodity research priorities for Pakistan, Agricultural Economics, 19 (3): 327-340.

Kerr John, Ganesh Pangare, Pangare VL and George PJ. (2000) "An Evaluation of Dryland Watershed Development Projects in India", EPTD Discussion Paper No.68, International Food Policy Research Institute, Washington.D.C.

Libardo Rivas R, James A García, Carlos Seré, Lovell S. Jarvis, Luis R. Sanint, and Douglas Pachico. (1999). Manual on Economic Surplus Analysis Model (MODEXC), International Centre for Tropical Agriculture, Colombia.

Logesh GB. (2004) Economic impact assessment of watershed development programs: A study of Kallambella watershed, Karnataka. *Ph.D. thesis,* Unpublished, University of Agricultural Sciences, Bangalore.

Maredia, Mywish, Byerlee, Derek, Anderson Jock. (2000). Ex Post Evaluation of Economic Impacts of Agricultural Research Programs: A Tour of Good Practice. Paper presented to the Workshop on "The Future of Impact Assessment in CGIAR: Needs, Constraints, and Options", Standing Panel on Impact Assessment (SPIA) of the Technical Advisory Committee, Rome, May, 3-5, 2000.

Moore, Michael R. Noel R. Gollehon and Daniel M. Hellerstein. (2000). Estimating Producer's Surplus with the Censored Regression Model: An Application to Producers Affected by Columbia River Basin Salmon Recovery, *Journal of Agricultural and Resource Economics* 25(2):325-346

Pachico D, Lynam JK and Jones PG. (1987). The distribution of benefits from technical change among classes of consumers and producers: an ex-ante analysis of beans in Brazil. Research Policy, 16:279-285.

Palanisami K and Suresh Kumar D. (2006). Challenges in Impact Assessment of Watershed Development in Impact Assessment of Watershed Development: Methodological Issues and Experiences (Ed.) K.Palanisami and D. Suresh Kumar, (New Delhi: Associated Publishing Company Ltd.,), 2006.

Palanisami K and Suresh Kumar D. (2007). Watershed Development and Augmentation of Groundwater Resources: Evidence from Southern India". Third International Groundwater Conference, February 7-10, 2007, Tamil Nadu Agricultural University, Coimbatore, India.

Rao CH. (2000). "Watershed Development in India: Recent Experiences and Emerging Issues", Economic and Political Weekly, 35 (45):3943-3947

Reddy RV. (2000). Land Degradation in India: Extent, Costs, Determinants and Trends, (Mimeo), Centre for Economic and Social Studies, Hyderabad.

Swinton SM. (2002). Integrating sustainability indicators into the economic surplus approach for NRM impact assessment. In (eds) Shiferaw, B., Freeman, H. A. Methods for assessing the impacts of natural resources management research. A summary of the proceedings of the ICRISAT-NCAP/ICAR International Workshop, ICRISAT, Patancheru, India, 6-7 December 2002

Wander, Alcido Elenor, Marilia Castelo Magalhaes, Graciela Luzia Vedovoto, Espedito Cezario Martins (2004). Using the Economic Surplus Method to Assess Economic Impacts of New Technologies—Case Studies of EMBRAPA, "Rural Poverty Reduction through Research for Development" Conference on International Agricultural Research for Development, Deutscher Tropentag, October 5-7, 2004, Berlin.

Wani SP, Joshi PK, Raju KV, Sreedevi TK, Wilson JM, Shah Amita, Diwakar PG, Palanisami K, Marimuthu S, Jha AK, Ramakrishna YS, Meenakshi Sundaram SS and D'Souza Marcella. (2008). Community Watershed as a Growth Engine for Development of Dryland Areas. A Comprehensive Assessment of Watershed Programs in India. Global Theme on Agroecosystems Report no. 47, Patancheru 502 324, Andhra Pradesh, India : International Crops Research Institute for the Semi-Arid Tropics. 36 pp.

Table 1. Details of Watersheds covered for the study in Coimbatore District

Name of the Block	Name of watershed	Area (ha)
Annur	Kattampatty I	460.00
	Kattampatty II	467.50
	Kuppepalayam	672.50
Avinashi	Naduvenchery	767.50
	Karumapalayam	752.50
	Chinneripalayam	524.85
Sulur	Arasur I	605.00
	Arasur II	590.00
	Rasipalayam	560.00
Palladam	Kodangipalayam I	455.00

Table 2. General characteristics of sample farm households		
Particulars	Watershed village	Control village
Farm size (ha)	1.28	1.75
Household Size	3.31	3.34
Land value (Rs./ha)	230657	153452
No.of wells owned	1.35	1.20
Average area irrigated by wells (ha.)	1.48	1.80
Value of household assets (Rs.)	261564*	184385
No.of persons in the household	4.07	4.2
Number of workers	2.5	2.1
Labour force participation (%)	61.48	50.79

*indicates values are significantly different at 1 %, level from the corresponding values of control village

Table 3. Cropped area, cropping intensity and crop diversification				
Particulars	Watershed villages		Control villages	
	Before	After	Before	After
Net area irrigated (ha)	1.08	1.10***	1.68	1.62
Gross area irrigated (ha)	1.25	1.35**	1.84	1.62
Irrigation intensity	115.74	122.73**	109.52	100.00
Net cropped area (ha.)	1.15	1.28**	1.78	1.62
Gross cropped area (ha.)	1.38	1.88**	2.43	2.16
Cropping intensity (%)	120.00	146.88	136.52	133.33
Crop Diversification Index (CDI)[6]	1.0	0.97		

*, ** and *** indicate values are significantly different at 1 %, 5 % and 10% levels from the corresponding values of control village

(Number)

Table 4. Livestock per household and per hectare of arable land		
Particulars	Watershed village	Control village
Per cent of households	46.67	93.33
Herd size (number)	2.57	2.64
Per hectare of gross cropped area (number)	2.01	1.63

[6] *Crop Diversification Index (CDI) was worked out by employing Composite Entropy Index (CEI) based on the proportion of different crops in the farm. The Composite Entropy Index for crop diversification was worked out as:*

$$C.E.I = -\left(\sum_{i=1}^{N} P_i.Log_N P_i\right) * \{1-(1/N)\}$$

Where,
CEI = Composite Entropy Index
Pi = Acreage proportion of ith crop in total cropped area
N = Total number of crops

Table 5. Impact of watershed development intervention on yield and cost				
Crops/ Enterprises	Change in yield (%)	Reduction in marginal cost (%)	Reduction in unit cost (%)	Net cost change
Sorghum	33	63.6	3.76	59.8
Maize	31	39.9	2.29	37.6
Pulses	36	41.0	1.47	39.6
Vegetables	32	32.8	0.76	31.9
Milk	28	27.3	7.81	19.5

NOTE: The reduction in marginal cost is the ratio of relative change in yield to price elasticity of supply (ε_s).
Reduction in unit cost is the ratio of change in cost of inputs per hectare to (1+change in yield). Ci is the input cost change per hectare. i.e., C_u = Ci/(1+Change in yield;. The net cost change (∀) is the difference between reduction in marginal cost and reduction in unit cost, i.e., ∀ = Cm-Cu.

Table 6. Impact of watershed development activities on the village economy			
Crops/enterprises	Total benefits due to watershed intervention (B)		
	Change in total surplus (ΔTS)	Change in consumer surplus (ΔCS)	Change in producer surplus (ΔPS)
Sorghum	293177.3 (100.00)	113636.3 (38.8)	179541.0 (61.2)
Maize	177774.2 (100.00)	85424.0 (48.1)	92350.2 (51.9)
Pulses	25777.5 (100.00)	12580.3 (48.8)	13197.2 (51.2)
Vegetables	29663.6 (100.00)	10627.5 (35.8)	19036.1 (64.2)
Milk	176878.5 (100.00)	105974.1 (59.9)	70904.4 (40.1)

NOTE: The Change in total surplus in the village economy due to watershed intervention is decomposed in to change in consumer surplus and change in producer surplus. The decomposition of total surplus is as follows:

$$\Delta TS = \Delta CS + \Delta PS = P_0 Q_0 K(1 + 0.5Z\eta)$$

$$\Delta CS = P_0 Q_0 Z(1 + 0.5Z\eta)$$

$$\Delta PS = P_0 Q_0 (K - Z)(1 + 0.5Z\eta)$$

Table 7. Results of Economic analysis employing Economic Surplus method		
Particulars	Economic surplus method	Conventional method
Benefit Cost Ratio	1.93	1.23
Internal rate of return (%)	25	14
Net Present Value (Rs.)	2271021	567912

Optimum Sizing of On-Farm Reservoir for Various Cropping Systems in Rainfed Uplands of Eastern India

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Abstract

The paper presents the concept of on-farm reservoir system to mitigate the ill effect of drought on agriculture. It is suggested that the cropping system should be based on hydrologic events considering water management and water harvesting potential of upland crop fields.

Introduction

Rainfed agriculture has occupied about 70% of the net sown area in eastern India, and it shares about 75% (5.2 Mha) of the total upland rice area in the country. Major constraints associated with production scenarios of rainfed agriculture in eastern India are its vast rainfed uplands, uncertainties in spatial and temporal variability of monsoon, barren land in non-monsoon seasons, adoption of unsuitable cropping pattern, and poor socio-economic status of the farmers. Yields under rainfed agriculture are low and quite unstable due to the uncertainty of monsoonal rainfall and variation in its onset and withdrawal pattern (Verma and Sarma 1990; Panigrahi *et al.*, 2002). The farmers harvest about hardly 1 t ha^{-1} of paddy from this topo-sequence. On the other hand, the low water holding capacity of the soil allows quick depletion of the residual soil moisture after the recession of the south-west monsoon, which leaves a question mark on the chance of growing a second crop (Agrawal *et al.,* 2004). The spatial heterogeneity and temporal variability of rainfall during monsoon season creates two extreme situations like drought or flood, leading to either stress or submergence, both responsible for the failure of crop.

In rainfed upland ecosystem, conserving rainwater in a small tank in the farm area, popularly known as the on-farm reservoir (OFR), and recycling the harvested water can mitigate the probable drought and submergence situations. However, the size of the OFR with respect to the farm area and its type (lined or unlined) plays a decisive role in the effective implementation of the technology at the field level. Because, an under- or over-sized structure in the crop field makes the system economically unacceptable. Hence, attempts have been made to arrive at an optimum size of the OFR (lined or unlined), with respect to various cropping systems at its upstream and downstream.

Methodology

Concept

The size of the OFR largely depends on the irrigation management strategies of the crops to be grown in the command area and the natural inflow and outflow components of the structure. The inflow components consist of direct rainfall and the runoff from the micro-catchments of the OFR, whereas the outflow components are the seepage and evaporation losses. Hence, a mass balance of the inflow and outflow components of the crop fields as well as the OFR including the irrigation demand of crops seems to be a correct approach, for making a decision on the size of the OFR for a particular period of rainfall events. Economic evaluation of the OFR system for a series of time-steps are required to arrive at an optimum size.

Cropping Pattern based on Hydrological Events

The onset and withdrawal of monsoon is the basic information to decide the time of sowing, selection of crop variety, and appropriate cropping pattern for the region. Analysis of the occurrence of such hydrological events along with dry spells during the rainy season is carried out using rainfall data of 22 years. Methods suggested by Verma and Sarma (1990) were used to analyze the onset and withdrawal of the monsoon. For the prediction of these events at certain probability of exceedance, selection of transformations and best-fit probability distribution functions is essential (Panigrahi *et al.*, 2002; and Panigrahi and Panda, 2001 b).

Water Management

Using the mass balance approach, daily root zone soil moisture balance of the crop field lying in the upland topo-sequence is carried out to assess the probable surplus and deficit moisture periods within the crop-growing season (Panigrahi *et al.*, 2001). The inflow components to the crop field are rainfall and supplemental irrigation and the outflow components are seepage, percolation, and actual evapotranspiration. This study will highlight the necessity of a water source for sustaining rice in the rainy non-rice in the post-monsoon seasons in rainfed uplands.

Two kinds of soil layers for the effective root zone depth have been used to compute daily inflow-outflow components during the growing season. They are i) single soil layer water balance approach; and ii) double soil layer water balance approach. In a single-layer system, the whole root zone has been considered as one-layer from the day of germination of the crop, whereas in double-layer system, the active layer extends from the soil surface to the position of the root on the day of prediction and it keeps on moving down, till the maximum root zone depth is attained. The degree of error in predicting the events by the later seems to be less as compared to the first one.

Water Harvesting Potential of the Upland Crop Fields

Water harvesting potential (WHP = SI/ Runoff) indicates the rainfall adequacy to meet the supplemental irrigation (SI) requirement of crops and also establishes the feasibility of the OFR system in the problem area. WHP less than one suggest the infeasibility of the OFR system in the area (Guerra et al., 1990; Oweis et al., 1999). When it is nearer to one or greater than one, a green signal is indicated to go for the OFR system. When it is nearer to 1, the deficiency can be met by the direct rainfall collected in the OFR.

The water balance model will be added with another two components such as surface runoff (SR) and SI to assess the amount of SR generated from the crop field, which will match with the amount of SI requirement of the crops. The time and quantity of SI requirement has to be decided earlier based on the type and sensitive stages of the crops grown in the command of the OFR. For many crops grown in the rainy season in the region, flowering to end of grain filling stage is assumed to be the most sensitive to moisture stress. So, it's been decided to apply SI during this period if soil moisture in the root zone depletes below management allowable depletion (MAD) level of the crop.

Size of the OFR

The size of the OFR largely depends on the irrigation management strategies of the crops to be grown in its command area and the natural inflow and outflow components of the structure. The inflow components consist of the rainfall and the runoff from the catchment of the OFR where as the outflow components are seepage, evaporation loss, and SI requirement of the crops. Since the components like rainfall and surface runoff are in depth units before coming to the OFR and it does not match with the depth of the truncated trapezium shaped OFRs, so they are converted to volume unit and volume balance of the inflow and outflow components of the OFR seems to be a correct approach that helps in deciding the accurate size of the OFR for a particular period of rainfall events or season.

The outflow components of the OFR play a decisive role in enhancing the production and productivity of the upland cropping system, increasing the cropping intensity of the existing mono-cropped rice intensive system, and also standardizing the degree of diversification possible with respect to high value non-rice crops in the post-monsoon seasons and pisciculture.

Seepage and percolation (SP) loss from the unlined OFRs constitutes 45 – 67% of the total outflow. Hence, an unlined OFR occupies a larger area than the lined OFRs. Reports reveal that SP can be controlled to a large extent even completely by using LDPE sheets of proper thickness (600μ). So, the lining of the OFR reduces the size of the structure on one hand and on the other, water during the post-monsoon period that can be used to irrigate a larger command or for growing a second and third crop in succession.

Evaporation loss from the OFR is estimated to be around 30% of its total outflow. Measures like shade net or LDPE cover over the water surface area are practiced to control the loss to a large extent. But the cost involvement in these practices is escalating the opportunity cost of the harvested water. Hence, some low cost measures like biological shading with the help of creeper have been used in the study to control evaporation loss from the OFR. It reduces evaporation loss to the tune of 50% as compared to an open OFR (Sahoo *et al*, 2009). In addition to mitigating evaporation loss, it embellished with some positive qualities like effective utilization of crop area diverted to the OFR construction.

Optimum Size of the OFR

Hydrological events like onset and withdrawal of monsoon, rainfall, runoff; ET, etc., are stochastic in nature, which also make the size of the OFR as stochastic. So, the water balance model of the OFR generates different sizes of the OFRs for different years. A very small sized OFR is expected in a high rainfall year and in contrast, a very large size in a scanty rainfall year. Of course, other factors like uniform distribution of rainfall also have some role to play in the size of OFR. Obviously, a small sized OFR will have less storage for the other enterprises like pisciculture, second and third crops in the system in contrast with a larger OFR size. On the other hand, the return from large OFR may be less as compared to the investment. So, an economic analysis is carried out to reach at a compromising size of the OFR, which will give highest return for all the years at certain probability of exceedances (Panigrahi and Panda, 2003). Based on the present worth analysis, the economic parameters like net profit (NP), benefit cost ratio (BCR), internal rate of return (IRR) and pay back period (PBP) are used in the study. The parameters are computed by using all the cost factors involved in the system such as initial investment, maintenance cost, land lease cost, irrigation cost, cost of production, and cost of return in excess of a rainfed system.

Summary and Conclusions

- At 50% probability of exceedance (PE), power transformation gives the onset and withdrawal of monsoon in the region as June 16 and October 3, respectively. Thus, the monsoon is effective in the region for 110 days. So, short duration rice of 100-110 days should be grown under rainfed farming system (Panigrahi and Panda, 2001b).
- At least two long dry spells, both are of 13 days duration, are likely to occur every year in the region during rainy season, out of which one comes on July, 18 and the other on August, 22 at 50% PE. Hence, the *biasi* operation in case of direct sown paddy and transplanting operation in case of transplanted rice are to be completed before July, 18 to achieve an effective physiological growth of rice. The second dry spell coincides with the critical growth stage of rice, which facilitate creation of water source to provide supplemental irrigation to rice for its sustenance in the rainfed uplands.
- Simulation of ponding depth and soil moisture status of rainfed uplands reveals that there is a need for drainage of ponded water during initial crop establishment and late season stage and supplemental irrigation during critical growth stage of rice. It was also found that the residual soil moisture at the time of sowing of light duty crop in the post-monsoon period is inadequate for germination of seeds in 45% of the years and thus, requires pre-sowing irrigation (Panigrahi and Panda, 2001a).
- When the rice crop is completely substituted by maize crop in the rainy season and soil moisture status is simulated, it is found that in none of the years during 1977 to 2006, the crop needs any supplemental irrigation. It indicates that a plenty of harvested water will be available to meet the irrigation demand of the winter crops as well as pre-sowing irrigation to a third crop in succession.
- Study on the water harvesting potential reveals that 85% of the supplemental irrigation requirement of the rainfed upland rice during the critical growth stage can be met from the surface runoff generated from the rice lands at 50% PE level. The rest can be met from the direct rainfall collected in the OFR (Panigrahi and Panda, 2003). The average seasonal surface runoff from the short duration rice field and irrigation requirement of rice crop was 133.1 mm and 144 mm, respectively (Panigrahi et al., 2001). So, the irrigation requirement can be supplemented by recycling the harvested runoff from the OFR and thus, there is a scope for rainwater harvesting in the OFR. Moreover, the rainwater harvested during maturity stage of rice and end of turn-in period was found adequate to meet the pre-sowing irrigation requirement of the winter (*rabi*) crop. Hence, the chance of double cropping is very much possible in rainfed uplands with the intervention of the OFR technology.
- On the other hand, the water harvesting

potential under partial crop substitution (non-rice: rice::1.5:1) is more than 3 times the irrigation demand of rainy season crops. It widens the scope of full irrigation practice during the critical growth stage of the rice as well as at least two irrigations to the second crop in the winter season.

- Economic analysis indicates that 12% of the farm area is optimum for the construction of lined OFR (Fig. 1) that can meet on an average 93 and 33 mm of supplemental irrigation to rice during critical growth stage in wet season and pre-sowing irrigation/SI demand to mustard in post-monsoon period. The average increase in yield of rice and mustard yield due to supplemental irrigation from the OFR is found to be 29.2 % and 22.3% more over the average yield of corresponding crops under rainfed condition (Panigrahi and Panda, 2003). The depth of the OFR and side slope is maintained at 2 m and 1:1, respectively, through out the simulation process.
- The unlined OFR is also equally capable to meet the SI requirement of the rice and pre-sowing irrigation to the mustard crop except with a few limitations like larger OFR size and quick depletion of the harvested water after recession of southwest monsoon as compared to the lined OFR. Second irrigation to the r*abi* crop is hardly possible in case of unlined OFR. The optimum size of the unlined OFR for crop-fish integration having 1:1 side slope was estimated to be 15% of the farm area for a return period of 5 year (Pandey et al., 2006) and the size of the OFR becomes larger with the increase in side slope.
- The BCR, IRR, and PBP of the optimum (12%) size of the OFR were found to be 1.22, 16.1% and 13 years, respectively (Panigrahi et al., 2005). BCR value of more than 1 indicates that the investment on the OFR irrigation system is justified.
- When fish is integrated with the OFR system (lined and unlined) in rainfed uplands along with rice-mustard cropping sequence, the net return to the beneficiary increased leading to a remarkable increase in benefit cost ratio

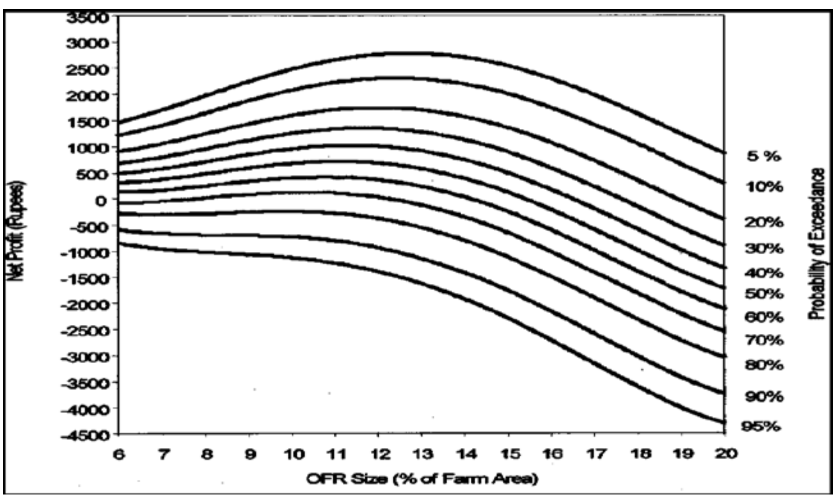

Figure 1. Variation of net Profit for different sizes of OFR at different PE

of the system (Pandey *et al.*, 2006; Sethi *et al.*, 2005; and Pandey *et al.*, 2005). The BCR value of lined and unlined OFRs occupying 10% of the farm area becomes 1.65 and 2.70, respectively (Sethi et al., 2005). Pay back period of unlined OFR is found to be 13 years where as that of lined OFR is 20 years. In both lined and unlined OFRs, the depth of water has been maintained at 2.4m.

- A user friendly software using Visual Basic 6.0 programme has been developed to find optimum sizing of the OFR in terms of percentage of the farm area in rainfed farming system (Roy et al., 2009). It is a menu driven system, flexible enough to simulate the OFR sizes for various combinations of OFR geometry, field sizes and cropping patterns. The user has to specify the crops to be grown, irrigation management practices, types of OFR (lined or unlined), side slope and depth of OFR and the farm area.

References

Agrawal MK, Panda SN and Panigrahi B. (2004) Modeling water balance parameters for rainfed rice. Jr. of Irrigation and Drainage Engineering, (ASCE), Vol. 130 (2):129-139.

Guerra LC, Watson PG and Bhuiyan SI. (1990) Hydrological analysis of farm reservoirs in rainfed areas. Agricultural Water Management, Vol. 17(4): 351-366.

Oweis T, Hachum A and Kijne J. (1999). Water harvesting and supplemental irrigation for improved water use efficiency in dry areas. SWIM paper No.7, International Water Management Institute, Colombo, Sri Lanka.

Pandey PK, Panda SN and Panigrahi B. (2006) Sizing on-farm reservoir for crop-fish integration in rainfed farming system in eastern India. Biosystems Engineering (Elsevier Science), Vol. 93(4): 475-489.

Pandey PK, Panda SN and Pholane LP. (2005) Economic evaluation of rainwater harvesting in on-farm reservoir for the integrated farming system - A sustainable approach to small farmers, Environment and Ecology, Vol. 23 (3): 671-675.

Panigrahi B and Panda SN and Agrawal A. (2005) Water balance simulation and economic analysis for optimal size of on-farm reservoir, Water Resources Management (Springer, The Netherlands) Vol.19 (3): 233-250.

Panigrahi B and Panda SN. (2003) Optimal sizing of on-farm reservoirs for supplemental irrigation. Jr. of Irrigation and Drainage Engineering (ASCE). Vol. 129 (2): 117-128.

Panigrahi B, and SN and Mull R. (2002) Prediction of hydrological events for planning rainfed rice. Hydrological Science Journal (IAHS, England), Vol. 47(3): 435-448.

Panigrahi B, Panda SN and Mull R. (2001) Simulation of water harvesting potential in rainfed rice lands using water balance models. Agricultural Systems**, (**Elsevier Science)**,** Vol. 69 (3): 165-182.

Panigrahi B, Panda SN. (2001a) Simulation of ponding and soil moisture status through water balance model for rainfed upland rice. International Agricultural Engineering Journal**,** (AAAE, Bangkok), Vol. 10 (1 & 2): 39-56.

Panigrahi B, Panda SN. (2001b) Analysis of weekly rainfall for crop planning in rainfed region. J. of Agricultural Engineering, (ISAE),Vol. 38 (4): 47-57.

Roy D, Panda SN, Panigrahi B. (2009). Water balance simulation model for optimal sizing of on-farm reservoir in rainfed cropping system: A user-friendly software. Computers and Electronics in Agriculture (Elsevier Science), Vol. 65 (1): 114-124.

Sahoo BC, Panda SN and Panigrahi B. (2009) Reduction of evaporation loss from the on-farm reservoir through biological shading. Proceedings of international conference titled "An International Perspective on Environmental and Water Resources" organized by EWRI of ASCE at AIT, Bangkok during 5-7 January, 2009, CTS#25, 1-18.

Sethi LN, Panda SN and Verma DP. (2005). Economic viability of rice-fish integration with the on-farm reservoir of rainfed ecosystem in eastern India. Journal of Food, Agriculture and Environment (WFL publisher, Finland) Vol. 3 (3 & 4): 194-199.

Verma HN and Sharma PBS. (1990). Design of storage tanks for water harvesting in rainfed areas. Agricultural Water Management, Vol. 18(3): 195-207.

Water Harvesting Potential Assessment in Rainfed Regions of India

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Abstract

The paper deals with the study on identification of crop-specific assessment of the surplus runoff water available for water harvesting in the country. A crop water balance analysis of 225 dominant rainfed districts provided information on the possible surplus runoff during cropping season. On a potential (excluding very arid and wet areas) rainfed cropped area of 28.5 million ha, a surplus rainfall of 114 billion m^3 (Bm^3) was available for harvesting. A part of this amount of water is adequate to provide one turn of supplementary irrigation of 100 mm depth to 20.65 Mha during drought years and 25.08 Mha during normal years indicating that water harvesting and supplemental irrigation are economically viable at the national level.

Introduction

Contribution of rainfed areas in India is relatively higher in the production of coarse cereals, rainfed upland/ lowland rice, pulses and oilseeds. Except for the last decade or so, the earlier efforts through the introduction of high yielding varieties, application of inorganic and bio-fertilizers and the implementation of variety of improved agronomic practices in rainfed agriculture did not produce the desired results for want of water availability at critical growth stages. However, the last decade has witnessed some dynamism in the rainfed areas because farmers/communities started limited adoption of water conservation and rainwater harvesting, purchase of groundwater from neighboring tube well/well owners, diversification of agriculture and improved access to knowledge and markets. Watershed management is perceived as an effective development paradigm with the potential of improving resources and productivity in the rainfed regions.

It is known that supplemental irrigation during flowering to grain filling stage significantly improves the crop's' productivity. A review of literature on the increase of productivity in various crops gave varying results on the effect of supplemental irrigation. The variability can be attributed to variation in soils, seasonal rainfall distribution, rainfall occurrence after supplemental irrigation and several other unmanageable variables.

Capturing rainfall, storing it for use when needed for partial or full irrigation, using it more efficiently and cutting the amount that evaporates unused are crucial to boost yields and incomes of the poor.

The available runoff can be harvested and utilized broadly for two purposes. One is to provide supplemental irrigation for the *kharif* crop after cessation of monsoon at critical stages in case of continuous dryspell and second to provide irrigation for a second crop for sowing the r*abi* crop.

In the present context, an assessment was made of the possibility of supplemental irrigation through water harvesting for *kharif (rainy season)* crop. The assessment involves estimation of available (surplus) rainfall runoff during second half of to September.

Methodology

includes

- ❖ Identification of dominant rainfed districts for different crops.
- ❖ Assessment of surplus/runoff for water harvesting and supplemental irrigation at a district level.

Identification of Dominant Rainfed Districts for Different Crops

For the present analysis, the dominant rainfed districts, which occupy a significant amount of area from national perspective, are identified for different crops since the proposed water harvesting mechanisms can be justified based on their potential utilization. Thus, we retain this definition i.e. districts in the descending order of area coverage limiting to cumulative 85% of total rainfed area for each crop in the country. With the adoption of this definition, it is possible to identify districts for various crops, which are predominantly rainfed covering a large area. Developmental activities related to a specific rainfed crop should be taken up first in these districts, which would significantly increase the total production.

Following process for the identification of a dominant rainfed crop district is adopted:

1. States covering semi-arid regions in full and margins from dry arid and sub-humid were identified. There are sixteen states (Andhra Pradesh, Tamilnadu, Karnataka, Orissa, Maharashtra, Madhya Pradesh, Jharkhand, Chattisgarh, Uttar Pradesh, Rajasthan, Haryana, Gujarat, Punjab, Bihar, West Bengal and Uttaranchal).
2. The area is limited to AESR 3-13 covering semi-arid region in full and marginal areas from arid and sub-humid regions within the states. The coastal, sub-mountain and cold arid regions were not included.
3. Districts in the descending order of area coverage limiting to cumulative 85% of total rainfed area for each crop is considered for the study purpose.
4. Crops covered are sunflower, soybean, rapeseed mustard, groundnut, castor, cotton, sorghum, pearl millet, maize, pigeon pea, rice in *kharif* and linseed and chickpea in *rabi*. Even though chickpea and linseed are *rabi* season crops, consideration was given as they follow mostly a fallow in *kharif*. The focus is primarily on the utilization of runoff from southwest monsoon in the present context.

Spatial distribution of selected rainfed crops across India

The five-year average of irrigated area, production and total cropped area were prepared on district basis. Based on the area under each crop, districts contributing to 85% of the area under the crop were identified. This was done to identify the major region in the crop as almost all the crops are grown in most of the districts except for a very few crops which have specific agro climatic requirements like soybeans and linseed.

Assessment of Surplus/Runoff for Water Harvesting and Supplemental Irrigation at District Level

In India, normal period of southwest mon-

Table 1. Details on dominant rainfed districts for various crops is given below

Crop	No. of districts		Districts covering cumulative 85% area
	Rainfed states	AESR 3-13	
Sunflower	224	179	11
Soybean	202	160	21
Rapeseed mustard	265	214	29
Groundnut	316	243	50
Castor	202	157	12
Cotton	296	237	30
Sorghum	346	261	71
Pearlmillet	346	261	43
Maize	346	261	67
Pigeonpea	266	215	83
Chickpea	346	261	85

soon is from June to September/October. About 70% of annual rainfall is received through southwest monsoon. Parts of south India covering Tamil Nadu, Andhra Pradesh and Karnataka are in the transient zones of both southwest and northeast monsoon (October to December). As total rainfall is spread over a few rainy days with high intensity, it results in surface runoff and erosion or causes temporary water stagnation on agricultural fields, resulting in higher evaporation. In either of these cases, rainfall is not available for plant growth to complete the plant cycle. In order to raise better crops, it is necessary to convert a part of the lost water (evaporation, excessive runoff) into a more productive use i.e. for supplemental irrigation during dry spells. Supplemental irrigation cuts the yield losses that result from dry spells, provides farmers the confidence to invest in other production inputs (fertilizers, improved varieties) and allows farmers to grow higher value crops and diversify the enterprise. Objective of this analysis is to assess the water availability for harvesting and thus making use of the same for supplemental irrigation during the crop-growing season.

For each of the districts both crop-wise and annual water balance analyses were done following the FAO procedure. The climatic water balance for the whole year provides information on the possible surplus and deficit period during the year. Proper management plans can be arrived at to augment the resources with in the year based on the surplus availability for meeting not only the needs of agriculture but also for other sectors. The water balance analysis was carried out for the entire year as well as for the cropping season for assessing the surplus and/or deficit during the year to estimate the changes in available water through rainfall and atmospheric requirements of through evaporation and changes in temporal availability of rainfall and plant water requirement, respectively. Actual rainfall, normal rainfall, and normal potential evapo-transpiration were taken from the available database.

Crop water balance based surplus/deficit assessment for on-farm water harvesting in different rainfed crops across dominant rainfed districts

Surplus runoff available from crop water balance analysis was considered for on-farm water harvesting. Total surplus from a district is obtained by multiplication of seasonal surplus with rainfed area under a crop. Total surplus available from a cropped region is obtained by adding the surplus from individual dominant districts identified for each crop.

Data under Table 2 presents a summary of total rainfed cropped area (covering 85% of the rainfed area in 16 states) under study for various crops and estimated surplus and deficit across rainfed region.

- An estimated amount of 11.5 M ha- m runoff is generated through 39 M ha of rainfed area covering major crops.
- Out of the surplus of 11.5 M ha- m, 4.1 M ha- m is generated by about 6.5 M ha of rainfed rice.
- Another 1.32 and 1.30 M ha of runoff is generated from soyabeans (2.8 M ha) and chickpea (3.35M ha), respectively.
- Total rainfed coarse cereals (10.7 M ha) generate about 2.1M ha-m of runoff.
- Spatial distribution of runoff on agro ecological sub region and river basin

Table 2. Available surplus runoff from the dominant rainfed districts/ regions for the important dryland crops of India (based on Crop Water Balance Analysis)

Crop group	Crop	Rainfed crop area ('000 ha)	Surplus (ha-m)	Deficit (ha-m)
Cereals	Rice	6442	4123673	0
Coarse cereals	Finger millet	607	158897	50
	Maize	2591	778397	0
	Pearl millet	3921	374664	11390
	Sorghum	3537	784167	1489
	Total (Coarse cereals)	**10656**	**2096125**	**12929**
Fiber	Cotton	4143	759143	111069
Oilseeds	Castor	351	19729	388
	Groundnut	4457	357602	121694
	Linseed	652	307276	1369
	Sesame	1354	421694	458
	Soya beans	2843	1329251	0
	Sunflower	902	13327	10891
	Total (Oilseeds)	**10559**	**2448879**	**134800**
Pulses	Chickpea	3344	1307276	13020
	Green gram	1279	91883	1330
	Pigeon pea	2615	671848	4766
	Total (Pulses)	**7238**	**2071007**	**19116**
	Grand total	**39038**	**11498827**	**277914**

Table 3. Potentially harvestable surplus runoff available for supplemental irrigation under different rainfed crops of India

Crop group	Crop	Rainfed crop area ('000 ha)	Surplus (ha-m)	Deficit (ha-m)
Cereals	Rice	6329	4121851	0
Coarse cereals	Finger millet	303	153852	0
	Maize	2443	771890	0
	Pearl millet	1818	359991	0
	Sorghum	2938	771660	0
	Total (Coarse cereals)	**7502**	**2057393**	**0**
Fiber	Cotton	3177	757575	8848
Oilseeds	Castor	28	14489	0
	Groundnut	1663	342673	1646
	Linseed	590	306360	0
	Sesame	1052	416638	0
	Soybeans	2843	1329251	0
	Sunflower	98	11811	0
	Total (oilseeds)	**6273**	**2421222**	**1646**
Pulses	Chickpea	3006	1304682	9166
	Green gram	458	80135	0
	Pigeon pea	1823	659328	238
	Total (pulses)	**5288**	**2044145**	**9404**
	Grand total	**28568**	**11402186**	**19898**

wise is shown in Fig 7a. Spatial distribution of surplus generation for all major rainfed districts and crops within a district and for rainfed rice, cotton, soybean, groundnut and maize growing districts is shown in Fig 8, 9.1 to 9.6.

- Based on practical field experiences it was assumed that harvestable runoff is practically available only with greater than 50 mm of runoff surplus or greater than 10% of seasonal rainfall as runoff which otherwise can be made use of through *in-situ* conservation methods (Annual report, 2001). Thus, surplus runoff generating districts were identified after deleting districts with runoff surplus of less than or equal to 50 mm and those districts with runoff less than 10% of seasonal rainfall. Following table (Table 3) gives summary of surplus and deficit for various crops after deletion of districts which generate either less than 50 mm of runoff or less than 10 % of seasonal rainfall.
- About 10.5 M ha of rainfed area generates runoff of less than 50 mm (10.25 M ha) and 10% of seasonal rainfall (0.25M ha) during the cropping period. Majority of 10.5 M ha is contributed by areas under groundnut, pearl mil-

let, sorghum, castor, and finger millet crops.

- Thus, the total estimated runoff surplus for various rainfed crops is about 11.4 million ha-m (114.02 billion cubic meters) from about 28.5 million ha which could be considered for water harvesting.
- Among individual crops, rainfed rice contributes higher surplus (4.12 M ha-m from an area of 6.33 M ha) followed by soybeans (1.30 M ha-m from 2.8 M ha). Deficit of rainfall for meeting crop water requirement is also visible for crops like groundnut, cotton, chickpea and pigeon pea.

Harvestable surplus during drought and normal seasons and its use for supplemental irrigation

In order to assess the assuredness of water availability, it is necessary to estimate surplus during drought seasons also along with normal and above normal seasons. If annual rainfall is less than 20% of normal rainfall, it is declared as drought year. Though there is good amount of surplus available as runoff in a season, all the runoff is not available at one time during the season.

Normally, farmers apply an irrigation depth of 20 to 50 mm as supplemental/ deficit irrigation in rainfed areas. In case of canal command areas, about 60 to 75 mm of water is applied per irrigation. In the present exercise, an amount of 10 cm was considered per irrigation including the conveyance losses. The quantity of irrigation may appear to be high in comparison with recommendations. This was only forced due to vast number of untrained water managers cutting across production systems with highly varying socio economic and educational background.

Based on this available surplus, irrigable area was estimated for single supplemental irrigation of 100 mm at reproductive stage of crop. This was estimated for both normal rainfall and drought years. Runoff during drought year is assumed to be 50% of runoff/ surplus during normal rainfall year (based on author's estimates for selected districts and rainfed crops in Andhra Pradesh). Based on the experience during drought years, more area can be brought under supplemental irrigation as farmers tend to apply water more economically on individual plant/ row basis. The estimated irrigable area for both scenarios is given below (Table 4).

The remaining available surplus after making provision for one supplemental irrigation of 100 mm at reproductive stage is given below (Table 5).

Conclusions

- Out of 114 billion cu m available as surplus about 28 billion cubic meters (19.4%) is needed for supplemental irrigation to irrigate an area of 25 million ha during normal monsoon year thus leaving about 86 M ham (81.6%) to meet river/environmental flow and other requirements.
- During drought years also about 31 billion cubic meters is still available even after making provision for irrigating 20.6 million ha.
- Thus it can be seen that water harvesting and supplemental irrigation do not jeopardize the available flows in rivers even during drought years or cause significant downstream effects in the study areas.
- By introduction of supplemental irrigation (with 'Business as Usual' scenario),

Table 4. Irrigable area ('000 ha) through supplemental irrigation (@100 mm irrigation) under different rainfed crops

Crop group	Crop	Rainfed crop area ('000 ha)	Irrigable area ('000 ha) during normal monsoon	Irrigable area ('000 ha) during drought season
Cereals	Rice	6329	6329	6215
Coarse cereals	Finger millet	303	266	224
	Maize	2443	2251	1684
	Pearl millet	1818	1370	837
	Sorghum	2938	2628	1856
	Total (Coarse cereals)	**7502**	**6515**	**4601**
Fiber	Cotton	3177	2656	1725
Oilseeds	Castor	28	25	22
	Groundnut	1663	1096	710
	Sesame	1052	919	741
	Soybeans	2843	2843	2667
	Sunflower	98	59	30
	Total (Oilseeds)	**5684**	**4942**	**4171**
Pulses	Chickpea	3006	2925	2560
	Pigeon pea	1823	1710	1374
	Total (Pulses)	**4829**	**4634**	**3934**
	Grand total	**27520**	**25076**	**20647**

Table 5. Summary of remaining runoff surplus available after provision of supplemental irrigation for different rainfed crops

Crop group	Crop	Rainfed crop area ('000 ha)	Surplus remaining after supplemental irrigation in normal season (M ha-m)	Surplus remaining after supplemental irrigation during drought season (M ha-m)
Cereals	Rice	6329	3489577	1428353
Coarse cereals	Finger millet	303	125195	50352
	Maize	2443	527494	160805
	Pearl millet	1818	188396	43056
	Sorghum	2938	478666	122937
	Total (Coarse cereals)	**7502**	**1319751**	**377150**
Fiber	Cotton	3177	446628	113242

Contd...

Crop group	Crop	Rainfed crop area ('000 ha)	Surplus remaining after supplemental irrigation in normal season (M ha-m)	Surplus remaining after supplemental irrigation during drought season (M ha-m)
Oilseeds	Castor	28	11647	4722
	Groundnut	1663	193860	61922
	Linseed	590	247440	95343
	Sesame	1052	313593	116441
	Soya beans	2843	1045003	380355
	Sunflower	98	2183	0
	Total (Oilseeds)	**6273**	**1813727**	**658783**
Pulses	Chickpea	3006	1005564	359956
	Green gram	458	39989	11695
	Pigeon pea	1823	478544	158771
	Total (Pulses)	**5288**	**1524096**	**530423**
	Grand total	**28568**	**8593778**	**3107950**

the crop production can be enhanced by a total of 28-36 M i. tonnes from an area of 20 -25 Mha during drought and normal monsoon periods which accounts for about 12 % increase over the present production.

- The benefits could be still higher if initiatives like improved cultivars, SRI cultivation in rice, crop and land use diversification, castor cultivation for silk worm, use of improved irrigation technologies like drip and micro-sprinkler (which further increase water use efficiency etc.) are taken up.
- In order to realize the above projected benefits, an amount of Rs 63.0 billion per annum for 20 years (a total of Rs 1260.0 billion ,.) is needed to develop 50 million ponds in rainfed areas spread across the country. The cost shall be much less with promotion of larger community based water harvesting structures which can also be used/ leased for commercial aquaculture besides meeting domestic and rural entrepreneur needs. This may also be dovetailed to rural development schemes like Rural Employee Guarantee Scheme.

The proposed expenditure is not only lower compared with cost of providing canal irrigation (i.e. Rs 25,000 for pond versus more than Rs.1,25,000 for canal irrigation ((4th Report of National Commission on Farmers,2006)) but also reduces the problems of water logging etc, and also makes available sufficient surplus available for different needs. Since water availability is not plenty, it would also not encourage farmers to go for water intensive crops.

Experiences of Water Harvesting through Farm Ponds in Vertisol Regions

Impact of Water Harvesting Structures on Water Availability - A Case Study of Kokarda Watershed, Nagpur District of Maharashtra

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Abstract

The paper presents in detail about a case study of water harvesting structures and their impact on water availability and their utilisation for rainfed crops through improved methods of irrigation. Notable finding is that water harvesting systems prevented farmers from deepening of their wells thus saving investments.

Introduction

Rainwater harvesting and recycling is an age-old practice in India, especially in the semi-arid regions. Unfortunately, modern techniques of groundwater utilization (tube wells) have over the years encouraged individualistic approach and the community participation in rainwater harvesting disappeared slowly. Increased population pressure and increasing demand from domestic and industrial sectors coupled with erratic monsoon has forced re-invention of old techniques. Water is becoming scarce in the rural livelihood.

Nagpur district of Maharashtra state agro-climatically belongs to "Eastern Maharashtra Plateau" experiencing the climate of a hot, dry, sub-humid *eco-region* (AESR-10.2) (Velayutham *et al.*, 1999). Rainfall varies from over 975 mm to less than 1100 mm per year. Rainfall is received mostly (about 90 %) from southwest monsoon during June to October in a year. Usually, July is the wettest month with an average 290 mm rainfall. *Vertisols* occupy 42 per cent of the total cultivated soils in the district. These soils encourage greater amount of runoff due to their inherently low infiltration rate. The crops grown in the *kharif* suffer from intermittent dry spells of monsoon, while the *rabi* crops entirely depends on residual moisture, which is inadequate. The research conducted by ICAR and SAUs indicated that the crop productivity can be increased substantially by providing one or two life saving irrigations during moisture stresses of crops in *kharif* as well as *rabi* seasons. Harvesting surplus water flowing out as run off during the monsoon months could facilitate irrigation. Therefore, an attempt was made to translate the techniques of water harvesting into practice, a study was made to determine effect of water harvesting on groundwater recharge of wells in Kokarda watershed with direct involvement of farmers through Technology Assessment and Refinement through Institute Village Linkage Programme (TAR-IVLP).

Methodology

In an effort to rekindle the interest of farmers in community approach for managing water resources, PRA was conducted in the village. Water scarcity, uneven and insufficient rainfall distribution is the major problems prioritized by the farmers in the watershed during Agro-Ecosystem Analysis through PRA (Conway, 1985). Transact walk was conducted to identify the points for construction of *nallah* bunds. Kokarda watershed (280 ha) is a typical agricultural watershed. In the watershed main stream (*nallah)* originates at top of hillock that runs (north-south) through middle of watershed. There are several small streams having width of 1-2 m originating from crop fields and joining the main 4th order stream. The width of the mainstream measured about 3-6 m with depth varying 2-3 m in the middle and lower reach while length of the stream was measured 1.5 km. After intensive discussions with farmers along with resource mapping, participatory plan was finalized to implement *nallah* bunding (Modified gabion structure), renovate the existing percolation tanks and construction of recharge pond near well. During 2001 summer months, construction of five modified gabions on the mainstream and the renovation of two percolation tanks was taken up through participatory mode in the watershed. Farmers (30 in number) around *nallah* and percolation tank participated in the programme. *Nallah* bunds were constructed by using low cost method that uses sand filled bags stacked into a covering of iron wire net. On the upstream and down stream sides of the embankment, boulders (locally available material) were used for protecting the structure. All the bunds were designed to impound water so as to facilitate increased percolation, as well as to reduce downstream flow velocity. A series of boulder bunds (16 numbers) without masonry were constructed across the *nallah* to check the gradient.

Heavy seepage through the embankments of the percolation tanks was arrested through low cost stone pitching. A small impervious wall of 50 cm depth, 20 cm top width and 1:4 upstream slope helped in reducing the seepage through the embankment base and increased the opportunity time for the vertical movement of water. In 2003, recharge pond dugout near a well to recharge the well through runoff water. The runoff water from a catchment measuring 5.6 ha was harvested in to a recharge pond measuring top length and breadth 6m and bottom length and breadth 4 m and height 1.5 m. The rainfall, water level in the wells, time taken to recuperation, period of water availability in the wells and area under irrigation before and after water conservation practices was monitored in 30 farmers' fields and also in another five farmers' fields without the conservation practices as control.

Location and Agro-climate of the Study Area

The watershed, where the impact of water conservation practices was evaluated is situated at 21^{0} 20′ N Latitude and 78^{0} 51′ E longitude on an altitude ranging from 340m to 360m above MSL (Fig 1). The soils are dominated by *Vertisols* (deep black soils) and associated soils (70%). Moderate deep-to-deep soils are found in the valley, while shallow to medium deep soils are on the escarpments. The shallow soils are severely degraded, while the deep soils have drainage problems. The dominant *kharif* (monsoon season) crops are sorghum, cotton and soybean. Chickpea is the main crop grown on residual soil moisture in the *rabi* (winter) season.

Results

Increased Water Levels in Wells

On the basis of the data collected from observation wells and perception of farmers, it was found that the water levels rose to the tune of 3 to 8 m in the vicinity of percolation tanks and 6 to 10 m in the vicinity of *nallah* bunds. Maximum rise in the water level of wells was observed near WHS 3 as compared to others. A total of 23 wells (50 %) were found to be partly or fully influenced by the water conservation measures in the watershed. The data presented in Table 1 clearly indicate that response was quick in showing its effect on recharge within 10-15 days rainfall.

The runoff collected for well recharge from an area of 5.6 ha catchment was 5423 m^3. Well-recharged water was used for giving protective irrigations to the cotton crop. The data presented in Table 2 indicate that the protective irrigation significantly influenced seed cotton yield over the control. Protective irrigation at the early boll development stage recorded significantly higher seed cotton yield compared to furrow irrigation at 0.6 or 0.8 IW/CPE but the yield on par with two protective irrigations at early flowering and boll development stage. WUE was the maximum in the treatment where only one protective irrigation was provided at the early boll development stage.

Increased Duration of Water Availability in Wells

The duration of water availability was taken as a measure to examine as to how the water conservation measures helped in improving the groundwater. Data on the duration of water availability in a number of wells *i.e.,* number of months in a year was collected before and after the interventions. Fig. 1 clearly illustrates that the duration of water availability in the wells was limited to 3-4 months earlier. After the water conservation interventions, it increased to 8-9 months. Due to increased period of water availability in the wells, the farmers could afford a greater number of irrigations to crops, especially to the orange crop (Table 3) than control fields.

Table 1. Rainfall and well water levels (mean of 3 years)

Period	Rainfall (mm)	Effect of percolation tank	Effect of *nallah* bunding
June-Sept. (Rainy)	442.0	7.2 m	9.9 m
Oct.-Jan. (Post Rainy)	38.7	8.0 m	9.2 m
Feb- May (Summer)	56.5	3.4 m	7.4 m

Table 2. Yield of cotton as influenced by reuse of water harvested through recharge pond.

Treatments	Seed cotton yield (q/ha)	Irrigation water applied (mm)	WUE (kg mm^{-1})
Rainfed (90 x 90 cm) (Control)	13.8		
Paired row (180 x 60 x 90 cm) planting and irrigation at early boll development stage with harvested water	20.3	50	406
Paired row planting and irrigation at early flowering and boll development stage with harvested water	18.7	100	187
Furrow irrigation at 0.6 IW/CPE	18.4	100	184
Furrow irrigation at 0.8 IW/CPE	18.5	100	185
C.D at 5%	1.70	-	-

Table 3. Effect of *nallah* bunding and percolation tank on water resources of watershed

No. of Irrigations	2002-03			2003-04	
	757 mm			928 mm	
	Crops	18.1.1 Area (acre)	No. of Irrigations	Area (acre)	No. of Irrigations
Near *nallah* bunding	Citrus	4.5	16-20	4.5	20
	Wheat	2.0	4	2.0	4
	Gram	1.0	2-3	1.0	-
Near percolation tank	Citrus	2.0	18-20	2.0	20
	Wheat	2.0	4	2.0	4
	Gram	0.5	2-3	0.5	3
Control (Rs. 10,000/- spent on deepening of wells)	Citrus	2.0	10	2.0	16
	Wheat	2.0	2	2.0	3
	Gram	0.5	-	0.5	-
Average net profit (Rs/ha) due to increased water resources		8,000		10,000	

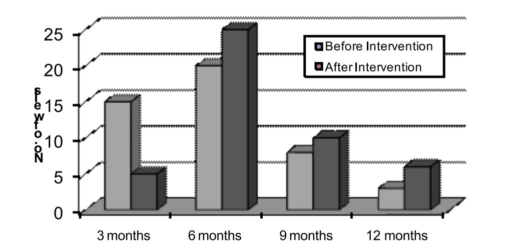


Fig. 1: Water availability duration in wells

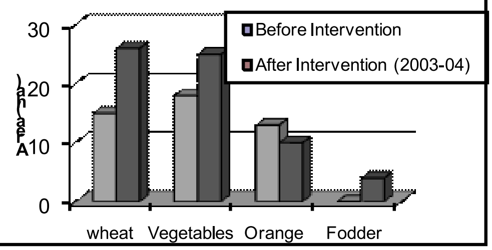
Increased Well Yield/Recuperation

Data with regard to duration of pumping hours before well goes dry and time it takes to recuperate to the same level were collected from sample wells. Water yield/recuperation rate before and after interventions for different wells indicate that recharge rate increased by 15-20 per cent. Before intervention, the wells went dry after 1 to 1.5 hrs pumping and got recuperated in 24-36 hours. After implementation of interventions, pumping could be done for 1-2 hours before well went dry and it took 18-24 hours to recuperate. This may be attributed to enhanced groundwater augmentation as a result of water conservation measures.

Increased Irrigation Area and Crop Diversification

Sample survey of the selected farmers in the zone of percolation tank and *nallah* bunds in Kokarda watershed showed increased irrigated area (41%) and crop diversification (Fig. 2). Before the intervention, there was no forage crop grown under irrigated condition but now 10 farmers (large and medium farmers) grow fodder maize (3 ha), lucerne (1ha) and berseem (1ha) throughout the year because of an increased water availability. Similarly, the number of vegetable crops grown rose from 2 to 5.

Fig. 2: Area under irrigation and crop diversification



Lessons Learnt

- The effects of the structures was seen in the 2002 and 2003 as the farmers reported satisfactory water levels in the wells.
- The increased area in the *rabi* also indicates the effect of these structures despite a drought year (2003) (65 % normal rainfall).
- Another advantage reported by the downstream farmers was that the structures have diminished the flooding of their fields during heavy spells of rainfall. These farmers reported higher production.
- One of the important benefits of the structures was that the farmers stopped deepening of their wells. Before intervention, at least one farmer would spend around Rs.10,000 on deepening of the well every year. This amount was saved.
- The expenditure incurred was returned in the very first year.
- In the last four years, no expenditure has been incurred on deepening of the wells.
- Farmers voluntarily look after the maintenance and contribute physical labour.

References

Convway GR. (1985) Agro-ecosystem Analysis. *Agricultural Administration*. 20 (1):31.

Velayutham M, Mandal DK, Mandal C and Sehgal J. (1999) *Agro-Ecological Sub regions of India for Planning and Development*. NBSS& LUP, Nagpur, 452p.

Water Harvesting and Recycling Technology for Sustainable Agriculture in Vertisols with high Rainfall

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Abstract

Case study on water harvesting and it's reuse is presented for Central India. The economic analysis of pond as the source of irrigation water for the *kharif* paddy crop (30 ha) and *rabi* wheat (24 ha) and chickpea (16 ha) cropping sequence was worked out The cost of pond including associated structures and irrigation grid system including pump house has been considered for the calculation of benefit cost ratio. The benefit cost ratio works out to be 2.03, considering the total benefit and cost under irrigated condition. From the foregoing discussions, it can be concluded that the technology of water harvesting pond is feasible and economically viable in black soil areas with high rainfall for stabilizing the agricultural production

Introduction

Nearly a billion people in the world do not have access to clean drinking water. If we do not care, then the number of those who would be badly in need of potable water could swell to a mind- boggling 2.5 billion in just 25 years and more shockingly, the majority of these people would be in India. The center and states alone cannot be expected to tackle the problem, which calls for peoples' participation in tackling water scarcity. India receives about 4000 billion cubic meters (bcm) of rainfall every year of which 1869 bcm flows off as average annual runoff in the various rivers of the country. Due to geographical limitations only about 890 bcm of surface water can be utilized in addition to 423 bcm of replenishable groundwater.

Madhya Pradesh in spite of all its sources remains a state of developmental paradoxes. Of a gross cropped area of 26.126 (1998-99) million ha of agricultural land, only 4.918 million ha have some kind of assured irrigation and out of a net cropped area of 19.954 (1998-99) million ha only 6.172 (1998-99) million ha are actually double cropped. Yet, the state remains the source for all the major river systems of central India receiving an average rainfall of 1150 mm annually. With most agriculture falling in the rainfed category, the incidence of drought has become a more or less perpetual feature. During the last two decades, droughts have occurred almost every year in one part or the other in India, of them widespread were during 1965-66, 1972-73, 1979-80, 1985-86 and 2000-01. As many as 14 districts of the state are classified as semi-arid and another 21 as dry sub-humid, while almost 80 per sent of total cropped area is classifiable as belonging to the rainfed category. Added to this is the relentless and rapid depletion of the natural resource base in the form of groundwater, soil and vegetative cover as the pressure on them mounts.

Need for Improved Technology

Unplanned plundering, thoughtless pillage, ravenous devastating destruction and ruinous selfish exploitation of natural resources degraded the lands, dwindled the availability of water resources and erased the greenery. The gloomy status coupled with drought conditions, have their interactive, negative influence on the environment. The crisis in India is more due to the misuse of natural resources like soil, water and forests, than due to industrialization. Present pace in progress, especially in growing greenery with watershed concept is insufficient to yield enough corrective results as the annual area brought under greening is less than the area eroded. It is definitely high time to stall the impending famine with determination.

Immediate hastening of the efforts is warranted for preserving the meager dense greens, maintaining good lands, improving bad conditions and restoring green foliage through scientific, integrated management. Watershed management concept, implemented on war footing, should help the country in not only reversing the trends, but also reviving the good environment through modern but simple, technical, appropriate, economical and feasible measures.

A major part of the Indian agriculture mainly depends upon rainfall, which is both inadequate and uncertain. The agro-climatic regions and crop zones in Madhya Pradesh including Chhatisgarh (Table-1) indicate that the rainfall varies from 800 to1600mm per annum and there is very good potential for rainwater harvesting and recycling for stable agricultural production. However, the total food grain production is 1097kg ha^{-1} as compared to all India production of 1620 kg ha^{-1} (1999-2000). Madhya Pradesh being blessed with very good land and water resources, has potential for increasing the productivity of land through water harvesting and recycling. The state is having shallow and medium black soils on 3.06 m.ha (6.91%), deep medium black soils on 16.21 m.ha (36.53%) and mixed red and black soils area 8.11 m.ha (18.30%).The water harvesting technology developed at CIAE, Bhopal is suitable for deep medium black soils of Madhya Pradesh. However soil and water conservation technology is highly location specific and a guideline based on detailed needs to be carried out region-wise in the state.

Soils

The blackish clayed soils of CIAE farm are dark coloured Vertisols silty clay to clay in texture with depth greater than one m. Three soil series namely, Nabi Bagh - 1 (49.1 ha) Nabi Bagh-2 (4.4 ha) and Lambakheda (10.5 ha) have been identified and physico-chemical properties of these soils have been studied.

As per the textural analysis, soils have 7% gravel, 15% sand, 2% coarse, 13% fine, 31% silt and 55% clay. The structural class of the soils is sub angular blocky. Bulk density is 1.84g/cc and bearing capacity of soil is 11 t/m^2. Soil depth is 2.4 m. Field capacity is 30.86% and wilting point 19.22%. The available water is 21 cm/100 cm of soil depth. Average infiltration rate on prolonged wetting is 10 mm/h. The hydraulic conductivity of soil is 23 cm/day at 0 to 40 cm depth and its value is 1.27 cm/day at 0 to 180 cm depth. Drainable porosity is 7%. The peculiar trend of hydraulic conductivity and low value of drainable porosity poses drainage problems in these soils. The pH of soil is 8.0 (slightly alkaline). Organic carbon is 0.48%. Exchangeable cations of Ca, Mg, Na, and K are 31.23, 8.39, 0.864 and 0.511 Meq/100 gm of soil respectively and cation exchange capacity of soil is 49 meq/100 gm.

Rainfall Analysis

The area receives an average annual rainfall of 1200 mm (at Bhopal), 90 per cent of which is received during June through September as torrential monsoon showers. There is late onset of monsoon, which recedes early, and the *rabi* crops are not sown in time. During winter the probability (at 75% chance) of getting rain is 33mm only, which is meager. Analysis of the 50 years data shows that there is probability of drought occurrence is one in every 5 or 6 years.

The conclusions drawn based on analysis of 50 years of rainfall are: the probability of getting average annual rainfall (1210 mm) is 40 per cent. Table 2 shows probability of rainfall for the log normal distribution. The onset and withdrawal of monsoon is on 25th and 37th weeks, respectively. The 24th and 25th weeks can safely be utilized for dry sowing and 25th and 26th weeks for normal sowing after the onset of monsoon. First inter-culture operation can be performed during 29th, 30th and 31st week and second during 33rd week. Waterlogging may occur during 32nd and 35th weeks. There is some risk in taking *rabi* crop after the *kharif* harvest under rained condition. *Rabi* crops can be established in time with supplemental irrigation (recycling runoff water) if the winter rains are delayed. The little rainfall received during January and February helps in the survival of the *rabi* crops. Rainfall harvesting and recycling is of utmost importance during *kharif* for timely transplanting of rice and irrigating rice and soybean in the latter stage of crops in case of early withdrawal of monsoon and pre-sowing irrigation and at least two irrigation one at crown root initiation and flowering stage one needed to stabilize wheat productivity.

Runoff Estimation

Binnie's percentage of rainfall as runoff based on the results from two river basins in Madhya Pradesh is given in Table 3. Runoff was reported to be 63 per cent (943mm) of monsoon rainfall (1488mm) or 57 per cent of annual rainfall (1653mm) and same percentage was adopted here (as shown in SI. No. 12). This is based on the report of Betwa Command Area (CGWB, 1981).

The average annual rainfall data of 50 years at Bairagarh/CIAE, Bhopal, was classified into 14 groups and the runoff was estimated (as shown in Table 3). The probability of occurrence of annual runoff was calculated using Weibulls equation for different period and plotted in Fig. 1, which shows that probability of occurrence of 350 to 400mm runoff is 80 to 75 per cent, respectively. The runoff event mostly occurs during July and August. On an average, seven to eight rain storms occur during normal years, which can produce runoff.

The Design and Construction of Farm Pond

Two dugout farm ponds of 2.54 ha-m and 12 ha-m capacity were constructed at CIAE farm. The area of farm is 93 ha. The design of farm pond can be divided into: (i) design of pond capacity based on the total loss and gain basis (ii) estimating the volume of an excavated pond, (iii) spillway design and inlet design. The relationship given as followed by Krimgold between the various hydrological factors and the dimensions obtained was used in the design of farm pond.

$$\frac{RA}{a} + P - \left(E + \frac{U}{a} + S\right) = d + \frac{W}{a}$$

where

A= the size of watershed area draining into pond, one to six ha.

R= total runoff from the contributing drainage area per ha during the period under consideration (July to Sept.) 0.3 ha-m (Fig.1)

P= Precipitation falling on the reservoir during the period irrespective of whether or not it produces surface runoff from the drainage area, 0.92m (calculated from 10 years data of rainfall at 50% probability level for the period under consideration).

U= amount of water used during the period under consideration, 0.2 ha-m per ha for rice crop (two irrigations or assumed to be nil)

S= seepage during July to September, 0.3 m (based on observations at CIAE, Bhopal)

E= evaporation from pond water surface (July to September) 0.29m(estimated from pan evaporation data at CIAE, Bhopal)

d= depth of water in the pond, assumed 2,3 and 4 m.

W= amount of water in excess of the capacity of the reservoir which is wasted over the spillway, ha-m. This factor was assumed to be nil, since pond is being designed for 75 to 80 per cent expected runoff.

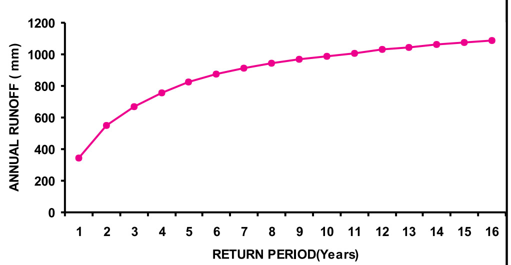

Fig.1. Annual runoff curve for black soil of Bhopal

$a = Lb + (bz + Lz) d^2 + (2z^2) d^2 X 10^{-4}$

where

a = mean surface area of pond, ha

L = length at the bottom of pond, m

b = breadth at the bottom of pond, m

z = side slope of bund (u/s)

Recycling of Stored Water in *kharif* and *rabi* Season

When to Irrigate

The monthly water deficits and surpluses were determined for a better understanding of irrigation water requirement of crop. It was found that only three months in a year July, August and September- are with surplus water and rest of the months are with deficit and irrigation water has to be supplied to meet the crop water demand during these months.

How much to Irrigate

The studies on soil moisture regime indicates that the top layer (0-15cm) was below wilting point during the critical growing period of the *rabi* crop after harvest of the *kharif* crop. The moisture is available below 30cm soil depth and there is no such equipment available to sow the crop in the moist zone. The only solution for timely establishment of the *rabi* crops is to have a pre-sowing irrigation. About 100 mm per month irrigation is required. Table-4 gives water requirement of crops and their irrigation needs.

Water Utilization Studies

The maximum storage capacity of pond was 2.54 ha-m with water submergence area of 1.3 ha. The maximum head of water was 3.0 m at full capacity of pond. The irrigation was given to *kharif* crop (rice) and *rabi* crop (wheat and chickpea) in the vicinity of pond. The loss through evaporation and seepage varied from 38 to 68 per cent of stored water depending on storage time of 3.5 to 6.5 months. Water which was utilized in *kharif* for transplanting of rice was refilled (36.16 to 8.4 per cent of stored water) depending on rains. Water utilized was 69 per cent of the stored water. About 1.5 ha was irrigated during *kharif* and 6 to 7 ha during *rabi* from the pond (2.54 ha m). Based on this study, the area of submergence as affected by watershed area and pond depth is given in Fig. 2 and command area of pond is given in Fig 3.

The Results of the Studies on Water Recycling

The results of the studies on recycling of the runoff water for the *kharif* and *rabi* (Table 5) showed that one and two irrigations at transplanting and grain filling stages to rainfed rice increased the grain yield by 44 and 90 per cent, respectively over no irrigation. For soybean, one life saving irrigation at grain filling stage in the years of early withdrawal of the monsoon could raise the yield by 45 per cent, and for wheat the yield was raised by 43, 78 and 100 per cent when irrigated once at CRI, twice at pre-sowing + CRI and thrice at per-sowing + CRI+ flowering stage. Similarly, grain yields of chickpea, linseed and safflower were increased by 90, 56 and 51 per cent with two irrigations at pre-sowing start, which is most essential to *rabi* crops in the event of early withdrawal of monsoon and insufficient storage of residual moisture in the soil after the harvest of *kharif* crops and delayed winter rains.

It was further observed that the application of nitrogen fertilizer along with the life saving irrigation to crops like chickpea, linseed and safflower (Table 6 & 7) gave a good boost to crop productivity in this area. The mean increment in grain yield of the irrigated chickpea with 10 and 20kg.N/ha was 5.0 and 6.6 q/ha over no N. In linseed the response to N in the presence of irrigation at 40 and 80 kg. N/ha over control was 2.0 and 3.0 q/ha. For same N levels, the response for safflower was 2.6, 4.4 and 6.4 q/ha with 30, 60 and 90 kg N/ha, respectively over control. This showed that for harvesting maximum benefit from the limited irrigation potential, the N fertilization should be increased at matching rate in order to meet the increased nutritional demand of the crop.

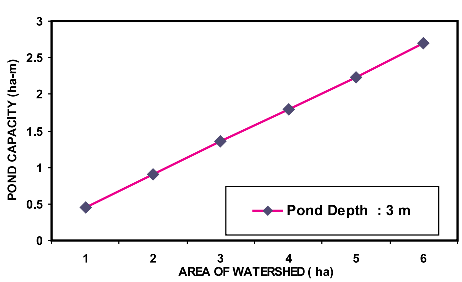

FIG. 2 CAPACITY OF POND (ha-m)

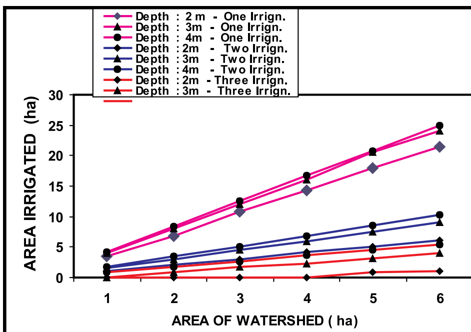

FIG. 3 COMMAND AREA AT DIFFERENT LEVELS OF IRRIGATION (ha)

Economics of Water Harvesting Pond

The economic analysis of pond as the source of irrigation water for the *kharif* paddy crop (30 ha) and *rabi* wheat (24 ha) and chick-pea (16 ha) cropping sequence was worked out. It is not possible to cultivate 30 ha of paddy in present situation, however, for general recommendation the growing of paddy under irrigated condition has been suggested under *kharif* season. The cost of pond including associated structures and irrigation grid system including pump house has been considered for the calculation of benefit cost ratio. Considering additional benefit obtained through irrigation net benefit ratio works out to be 1.13. The benefit cost ratio works out to be 2.03, considering the total benefit and cost under irrigated condition. From the foregoing discussions, it can be concluded that the technology of water harvesting pond is feasible and economically viable in black soil areas with high rainfall for stabilizing the agricultural production.

Conclusions & Recommendations

- Water harvesting pond should be constructed in 10-12 per cent of the watershed area with 3m depth.
- The minimum runoff received is about 300 mm to fill up the pond every year.
- About 60 to 70% of the stored water can be utilised for irrigating crops.
- Entire *kharif* and 50% of the *rabi* crop (of the watershed area) can be irrigated twice with two fold increase in yield.
- Groundwater recharge through pond is 0.8 to 1.2 ha –m/ ha
- Water harvesting is technically feasible and economically viable (Benefit cost 1.3 – 2.0) and socially acceptable.

Table 1. Agro-Climatic Region & Crop Zones in M.P. including Chhattisgarh

Zone / Crop	Agro-climatic Regions	Soil Type	Rainfall Range, mm	Districts Covered	Partly Covered Districts
1. Rice	Chhattisgarh plains including Balaghat	Red & Yellow (Medium)	1200 to 1600	Raipur, Durg, Rajnandgaon, Bilaspur	Raigarh: Raigarh, Kharsia, Gharghoda, Leloonga & Sarangar Tehsils Kanker: Kanker & Narharpur Tehsisls
-do-	Baster Plateau	-do-	1400 to 1600	Entire Bastar District Except Kanker & Narharpur Tehsils.	
-do-	Northern Hill Region of Chhattis garh	Red & Yellow Medium black & skeltal Medium/ light)	1200 to 1600	Surguja, Shahdol, Mandla, Jashpurnagar	Raigarh: Dharamjaigarh Tehsil. Sidhi:Singroli Tehsil (Bedhan),
2. Wheat - Rice	Kymore Plateau & Satpura Hills	Mixed red and black soils (Medium)	1000 to 1400	Rewa, Satna, Seoni, Sidhi (except Singroli tehsil of Jabalpur)	Panna, Katni Tehsil, Katni (except Katni Tehsil)

Zone / Crop	Agro-climatic Regions	Soil Type	Rainfall Range, mm	Districts Covered	Partly Covered Districts
3. Wheat	Central Narmada Valley	Deep black (deep)	1200 to 1600	Narsinghpur, Hoshangabad	Sehore: Budni Tehsil. Raisen:Bareli Tehsil.
-do-	Vindhya Plateau	Medium black deep black (Medium/ Heavy)	1200 to 1400	Bhopal, Sagar, Damoh, Vidisha, Raisen (except Bareli), Sehore Ashoknagar	Guna: Chanchoda, Raghogarh & Aron Tehsils
4. Wheat-Jowar	Gird Region	Alluvial (Light)	800 to 1000	Gwalior, Bhind, Morena, Sheopur-Kala, Shivpuri, (except Pirchore. Karera, Narwar, Khaniadana,) Guna (except Aron. Raghogarh, Chachoda Tehsil)	
Wheat -Jowar	Bundelkhand	Mixed red and black (Medium)	800 to 1400	Chhattarpur, Datia, Tikamgarh, Betul & Chhindwara	Shivpuri:Karera Pichhore, Narwar & Khaniadhana Tehsils, Panna
-do-	Satpura Plateau	Shallow black (Medium)	1000 to 1200	Betul & Chhindwara	
5 Cotton Jowar	Malwa Plateau	Medium black (Medium)	800 to 1200	Mandsaur, Ratlam, Ujjain, Dewas, Indore, Shajapur, Rajgarh	Dhar : Dhar, Badnawar & Sardarpur Tehsils. Jhabua:Petlawad Tehsil.
-do-	Nimar Plains	Medium black (Medium)	800 to 1100	Khandwa, Khargone	Dhar: Matlawar, Dhampuri & Gandhawani Tehsils
-do-	Jhabua Hills	Medium black skeletal (Light / Medium)	800-1000	Jhabua District. (except Petlawad Tehsil)	Dhar : Only Kukshi Tehsil.

Table 2. Probability of rainfall (mm) for log normal distributions

Recurrence interval (years)	Per cent chance	Rainfall (mm)
1.25	80	738
2.00	50	1075
2.5	40	1210
5.00	20	1600

Table 3. Annual rainfall and runoff at Bairagarh + CIAE Bhopal based on Binnie's percentage

S.No.	Rainfall class value	Frequency in 50 years	Runoff Per cent	Runoff mm	Weighted runoff mm
1	550	2	18	198	99
2	650	2	23	299	149
3	750	1	27	202	202
4	850	4	31	1054	263
5	950	4	36	1368	342
6	1050	7	39	2866	409
7	1150	5	42	2415	483
8	1250	4	45	2250	562
9	1350	7	48	4536	648
10	1450	5	51	3697	739
11	1550	3	54	2511	837
12	1650*	2	57	1881	940
13	1750	3	60	3150	1050
14	1850	1	63	1165	1165
15	Total	50		27594	551

Table 4. Water utilization studies of pond

Sl.No	Particulars	Year of Study	
		First	Second
1	Maximum storage capacity, m^3	20125	23345
2	Dead storage, m^3	20	412
3	Maximum storage depth m	2.8	3.0
4	I. Water lost, m^3 II As percentage of total storage	13596 67.62	8540 37.25
5	I Water pumped, cum II As percentage of total storage	13781 68.54	15905 69.35
6	Water refilled during *kharif* (As percentage of total storage)	36.16	8.4
7	Water storage Duration month	6.5	3.5
8	Water applied (a) *kharif*, ha-m (b) *rabi*, ha-m	 32.8 105.0	 62.25 96.80
9	Area irrigated (a) *kharif*, ha, Rice (b) *rabi*, ha , Wheat & chick pea	 1.6 (twice) 6.5 (twice)	 1.5 (four times) 7.0 (Once)

Table 5. Effect of supplementary irrigation on grain yield (t ha^{-1}) of rice, soybean and wheat			
Stage of Irrigation	**Rice**	**Soybean**	**Wheat**
No Irrigation	1.8	1.6	1.6
Transplanting (T)	2.5	-	-
Grain filling	2.3	2.3	-
T + Grain filling	33.5	-	-
Pre-sowing (PS)	-	-	22.1
CRI	-	-	22.6
PS+CRI	-	-	28.2
CRI + Flowering (F)	-	-	26.5
PS+CRI+F	-	-	31.4
C.D. (5%)	2.9	2.22	3.12

Table 6. Effect of supplementary irrigation on grain yield (t ha^{-1}) of Chickpea, linseed and safflower			
Stage of Irrigation	**Chickpea**	**Linseed**	**Safflower**
No Irrigation	1.3	0.9	1.2
Pre-sowing (PS)	2.1	1.0	1.5
PS+Flowering (F)	2.4	1.3	1.7
PS+Pod filling	2.5	1.4	1.7
PS+F+Pod filling	2.7	1.5	1.9
C.D. (5%)	0.13	0.04	0.12

Table 7. Effect of supplementary irrigation and nitrogen on grain yield (t ha^{-1})										
Irrigation	**Chickpea**			**Linseed**			**Safflower**			
N (kg/ha	0	10	20	0	40	80	0	30	60	90
No Irrigation (control)	1.0	1.2	1.4	0.7	0.8	0.9	0.9	1.0	1.2	1.3
Pre-sowing irrigation only	1.6	1.9	2.0	0.8	0.9	1.1	1.2	1.4	1.6	1.8
Pre-sowing + Flowering	1.9	2.2	2.4	1.0	1.2	1.2	1.4	1.7	1.8	2.1
Pre-sowing +Pod filling	2.0	2.3	2.5	1.1	1.3	1.3	1.4	1.6	1.7	1.9
Pre-sowing + Flowering + pod filling	2.1	2.6	2.8	1.1	1.4	1.6	1.5	1.8	2.1	2.3
Mean for Irrigation	1.7	2.2	2.4	1.0	1.2	1.3	1.4	1.6	1.8	2.0
C.D. (5%)irrigation		0.13		0.07				0.12		
C.D. (5%)Nitrogen		0.14		0.03				0.05		
Irrigation X N		0.23		0.04				0.07		

Use of Water Harvesting Tanks in Black Soils of Malwa Region– A Case Study

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Abstract

Though construction of tanks has been advocated by the various workers for storing runoff water at suitable places in farmers' fields, not much information is available on the economic aspect of tank construction. In the present study, various tanks of different shapes and sizes have been constructed in the farmers' fields using various heavy earth moving machineries. It was observed that the initial cost of construction in the case of excavated cum embankment type of tank with suitable gabion outlet remain is always lower than the excavated tanks. Even with backhoe loader machines (JCB), circular shaped tanks can be constructed which having geometrical advantage over tanks of other shapes.

Introduction

In the Malwa region, crop productivity suffers mainly on account of moisture stress during prolonged dry spells after the sowing of the *kharif* crops especially during the termination of the monsoon rains. Thus even during monsoon, crops need life saving irrigation. In this region, the runoff potential is very high and if this excess water is suitability harvested, it could be used for irrigating the *kharif* and *rabi* crops (Ranade *et al.* 1996). Similarly, various research workers advocated water harvesting and recycling for dryland crops (Narayan *et al.*1988 and Mishra *et al.*1998). In the Malwa region, the topography is such that two types of the tanks can be constructed in the farmers fields (i) excavated tanks suited for flat topography and (ii) excavated cum embankment type tanks particularly in degraded or gullied portion. In the first case, the provision of inlet in structural form is not required as flow enters through entire width of the tank. Even for the outlet, the provision of the spillway in the form of temporary mechanical structure is sufficient, as excess water drains off safely and not exerts much pressure on the structure. However, in the second case, the construction of water harvesting structure (tanks) requires provision of inlet and particularly outlet in the absence of which the stored water may not be retained as flowing water develops gullies (Singh, 1983). Thus in the second condition, it is presumed that the initial cost of the tank would be higher. However no information particularly for the black clay soil region is available on economic aspects of these tanks. Keeping this point in view, the present study has been carried out during 2005-06 in various villages of Indore district of the Malwa region.

Material and Methods

Preliminary Studies

Before the start of the actual work, a study was carried out to find the suitable material for the construction of outlet of the tank so that the tanks constructed in the gullied portions work satisfactorily without any structural or mechanical failure particularly at the outlet. For this purpose, various observations were made on the performance of various structures constructed under various schemes in the region.

It was observed that the gabions serving as outlet (in the tanks constructed in the village Hingonia and Pipliyatapha during 1990-91 constructed under Operational Research Project on Dry Land Agriculture, College of Agriculture, Indore) are working quite satisfactorily. The outlets are retaining water on upstream side and draining only excess water from the crest portion even after fifteen years. Similarly the gabion outlet of water harvesting tank constructed at College of Agriculture, Indore campus during the year 2000, has been observed to be working satisfactorily without any structural/ hydraulic failure. On the other hand, it has been observed that at many a places, the concrete structures left the positions and allowed the water to run down in the other direction. In most of the cases, structural and mechanical failures in these concrete structures have been observed.

Results and Discussions

This shows that rather than concrete structures gabion can withstand the swelling and shrinkage of black clay soil. Therefore, sufficient evidences are available through which it can be recommended that in black soil region gabion structure can be provided in the form of outlet in water harvesting tank. Thus gabions are cheaper and very effective structure, which can be adopted in this region.

From the above studies, it is emerged that

1. Rather than concrete structures, gabion can withstand the swelling and shrinkage nature of black clay soils.
2. Gabion structures should be constructed in a fairly reasonable uniform section of gully instead of narrow section.
3. In the black soil region, the gabion structure can be provided in the form of outlet in water harvesting tank very safely.
4. Thus gabions are cheaper and very effective structure, which can be adopted in this region.

Thus, in the present study, the use of masonary structure was discouraged and a suitable flexible, cheaper and effective alternative gabion structure was constructed by the farmers themselves under the technical guidance of project team.

Site Selections for the Construction of Various Tanks under the Scheme

Before the start of actual project work in 2005, a few probable sites particularly in the farmers cultivated fields for the construction of excavated water harvesting tanks, were selected after assessing various hydro-geo-morphological characteristics of the each micro-watershed. Reconnaissance survey and transect walk of the watersheds was carried out for this purpose. Based on the survey and the observations made, a few suitable sites were identified keeping in view the probable size, shape, catchment area, command area and provision of inlet/outlet.

Similarly, one extra suitable site for the construction of excavated cum embankment type water harvesting tank with suitable outlet was also selected. The following points were considered while selecting the gullies for the studies:

- No abrupt change in the bed slope;

- Less rocky outcrop;
- Less spur and molds, maundering;
- Less scour holes in the gully;
- Easy accessibility to the site to increase its demonstrative value;
- Depth of the gully; and
- Catchment with cultivated fields, which are affected due to deepening and widening of the gullies; and
- Sufficient run off gully that can accommodate structures within it.

Soil Profile Survey

After the selection of sites from hydrological point of view, detailed depth wise soil analysis of the probable sites was carried out in order to select suitable sites where the runoff water can be collected for longer time without any appreciable loss of the stored water due to percolation.

The soils at the sites are clayey in nature. Since it is a heavy deep clayey soil with very low permeability, there are chances that water would retain in the tanks for longer time, which would be made available for irrigating the crops in the adjoining fields.

After the site selection, the construction work of all the proposed tanks was taken up one by one during the first week of April 2005 by engaging heavy earth moving machineries viz. crawler tractor (bulldozer) back-hoe–loader machines (JCB) for excavation and dumpers, tractor trolleys for transporting and spreading the excavated soils.

Construction of Excavated Type Water Harvesting Tanks

Based on the requirement of the technical program and the objectives of the project, two suitable sites were finalized for the construction of excavated water harvesting tanks in the farmer's fields itself. The sites were selected in the natural drainage lines existing in the farmers' fields in such a way that these receive maximum runoff from the farmer's field and other adjoining areas. Before the actual digging of the tank area, the contour map of the proposed site was prepared. Based on contour map, the estimation for the total earthworks involved was calculated and dimensions of the tank were decided.

Construction of Excavated cum Embankment Type Water Harvesting Tanks

In this case, a gullied wasteland portion in the farmer's field was selected with a view to create water harvesting tank for storing runoff water in the tank and for providing irrigation to adjoining cultivated fields. The detailed topographical survey was carried out and estimation for the earthwork was made. While construction of this type of tanks, generally tank boundaries are fixed first and then deepening of tank area is carried out.

Similarly, an earthen embankment is also required to create of the earthen dam to plug the gully and to store the runoff water at the upstream site. Since the area receives a huge amount of runoff, the provision of outlet was also very essential to drain out excess water through the spillway without causing any damage to the earthen embankment and adjoining fields. For this purpose, the construction of outlet and excavation of tank area was carried out simultaneously.

Construction of Various Tanks under the Scheme

As already mentioned, during the study period (2005-2006), the following types of tanks have been constructed under the scheme:

- Construction of seven excavated type of water harvesting tanks.
- Construction of one excavated cum embankment type of water harvesting tank.

The details of these tanks are given in Tables 1 and 2.

Table 1. Particulars of various tanks constructed in the year 2005

Particular	Tanks			
	Manohar	Abhyankar	Prasanna	Sandeep
Type of tank	Excavated cum embankment	Excavated	Excavated	Excavated
Length (m)	206	84	56	50
Width (m)	35	49	48	40
Maximum depth (m)	3.3	2.1	3.0	3.0
Storage capacity (cu.m.)	7458	2723	2938	3055
Shape of the Tank	Rectangular	Rectangular	Rectangular	Rectangular
Land use	Waste/gully portion	Cultivated	Cultivated	Cultivated
Outlet	Gabion	Natural	Natural	Natural
Cost of construction (Rs)	263000	200000	161820	161100
Year of construction	2005	2005	2005	2005
Cost of creating 1 ha cm of storage capacity (Rs)	3526	7345	5507	5273
Heavy machines used	JCB, Bulldozer	JCB, Bulldozer	JCB	JCB

Table 2. Particulars of various tanks constructed in the year 2006

Particular	Tanks			
	Devendra	Chain Singh	Dharmendra	Gajendra
Type of tank	Excavated	Excavated	Excavated	Excavated
Length (m)	--	59.3	--	48
Width (m)	--	22.5	--	48
Radius (m)	26.8	--	27.2	--
Maximum depth (m)	3.0	1.897	2.0	2.0
Storage capacity (m^3)	7338	2396	4623	4886
Shape of the Tank	Circular	Rectangular	Circular	Square
Land use	Cultivated	Cultivated	Cultivated	Cultivated
Outlet	Gabion	Natural	Natural	Natural
Cost of construction (Rs)	306830	151875	161805	181010
Year of construction	2006	2006	2006	2006
Cost of creating 1 ha cm of storage capacity (Rs)	4181	6338	3500	3704
Heavy machines used	JCB	JCB	JCB	JCB

It is clear from the data Tables 1 and 2 that during 2005-06, eight tanks of varying sizes and shapes have been constructed. For the construction of tanks waste portion as well as cultivated portion/land have been utilized. It is very clear that farmers are not only convinced with the technology for water conservation but also they are sharing even their cultivated portions of the land. This is certainly an evidence of change in their mindset and attitude otherwise earlier they (villagers) were ready to provide only community land /government land for the creation of water bodies.

Before construction of Abhyankar tank

Use of JCB Machine

Use of Bulldozer

During rainy season

Before construction of Manohar tank

Use of Bulldozer

Use of JCB

During rainy season

Gabion outlet

Overflow from Gabion outlet

Out of these eight tanks, one was constructed in a gullied portion using bulldozers and JCB machines. Bulldozer was engaged to make the tank boundary, shaping of tank area, construction of earthen /embankment tanks. JCB machines are taking for the tank area. At the same time a huge gabion structure in form of outlet was constructed at the foot of these gully where it runs on to stable gradient. However, no separate outlets were made in the remaining seven tanks, as these tanks are excavated tanks constructed on natural drainage lines, thus providing safe disposal of the excess runoff. The cost of creating 1 ha-cm of storage capacity for each tank has also been worked out. It is evident that the cost of construction of excavated cum embankment type tank is lower than that of the excavated tanks. Thus the cost of 1 cum of water worked out to be Rs. 35/- in case of excavated cum embankment type tank. On the other hand the cost of 1 cum water varies from Rs. 35/- to 73/- depending upon the soil type and location of the excavated type tanks. It is also observed that the highest cost involvement was in the Abhayankar tank. This is mainly due to involvement of bulldozer machine for deciding the boundary in this tank area. However in this type of tanks, bulldozers are not required as only JCB machines can create storage area. Thus, it is recommended that for the construction of water harvesting tanks in the Malwa region, priority should be given to the gullied portion where tanks can be created with suitable gabion outlet as the initial cost of the tank remains lower than the excavated tank. Similarly, for the excavated tanks, back-hoe-loader machine (JCB) should be utilized instead of bull-dozer machine. However, one advantage of excavated tanks over the excavated cum embankment tanks is that much more soil is available for spreading over the undulating fields making them suitable for cultivation.

Similarly, with the JCB Machine, square, rectangular and even circular tanks can be constructed without any difficulty, which is otherwise very difficult to construct a curved shaped tank. It is also to be noted that the circular tanks have geometrical advantage as they have the highest storage capacity and least circumferential length for a given surface area and side slopes. Therefore, it is concluded that despite the provision of outlet in the tanks constructed in the gullied portion, the cost involvement is always lower than the excavated tank.

Acknowledgement

The authors are very much thankful to the ICAR for sanctioning adhoc scheme on "Rainwater management through economically feasible water harvesting tanks in Malwa region" and for providing the opportunity to work on these very important aspects of soil and water conservation in Malwa region.

References

Mishra PK, Rama Rao CA and Shiv Prasad S. (1998) Economic evaluation of farm pond in a micro watershed in semi arid alfisol Deccan Plateau. Indian Journal of Soil Conservation 26 (1): 59-60.

Narayan HC, Itnal CJ, Gopalakrishnan, Hebber B and Patil VS. (1988) An evaluation of supplemental irrigation through farm pond on drylands. Indian Journal of Soil Conservation 15 (1): 1-6.

Ranade DH, Gupta Ram K and Patel AN. (1996) Predicting runoff from Vertisols of Malwa region. Crop Research 11 (1): 9-16.

Singh RP. (1983) Farm ponds. Project Bulletin No. 6, All India Coordinated Research Project for Dryland Agriculture, Hyderabad, Andhra Pradesh.

Productivity Enhancement and Livelihood Enhancement through Rain Water Harvesting in Vertisols of Adilabad District: A Case Study

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Extended Abstract

Adilabad district in Andhra Pradesh is known for the highest cover under forest (50%) and high rainfall. The district has an average annual rainfall of 1050 mm received mostly through south west monsoon (80%). The area has undulating topography and mostly inhabited by *Gond* tribe. There is a high potential for rainwater harvesting and recycling. Small dugouts created as farm ponds earlier in the watershed and National Rural Employment Guarantee (NREGS) scheme didn't enthuse the farming community as the water was retained for a very short period and was found to be of little use. An attempt was made to undertake the participatory situation analysis by convincing the farming community to go for a large structure with higher depth. A farm pond of 900m^3 capacity having a dimension of 17m x 17 m top, 13 m x 13 m bottom and 4.5 m depth, was dug out during the mid-July 2008 under NAIP on a pilot basis. The pilot farm belongs to Mr. Nam Dev. The farm pond got filled during the first week of August and the water was retained even after use till the end of February 2009. The project met the cost of digging, while the farmer with ITK ventured to go for the diesel pump set for lifting of water and pipeline for irrigating tomato on a half-acre plot as his contribution.

The total cost of cultivation of tomatoes in 0.5 acre land was worked out to be Rs. 23,600/-. The picking of tomatoes occupied a lion's share of total cost of cultivation, which accounted for (34%) followed by watch and ward (25%), transportation (11%), irrigation (10%) and transplantation (8%). The gross returns accrued from the production of 4460 kg tomatoes from 27 pickings in 0.5 acre land was found to be Rs. 1,30,450/-. The price ranged from as high as Rs. 40/- per kg to as low as Rs. 15/kg from September to December, 2008. The benefit-cost ratios (BCRs) based on the total cost of cultivation of tomatoes and based on total cost of cultivation of tomatoes including cost of pond were calculated as 5.53 and 2.23, respectively (Table 1).

This indicates that on every rupee investment made on cultivating tomatoes in 0.5 acre land paid a rich dividend of rupees 5.53 on the one side and Rs. 2.23 by covering the cost of the pond in one season, on the other side revealing a higher impact of the farm pond. The case study has come out with conclusive evidence of livelihood improvement in terms of five capital formation namely natural, social, human, financial and physical of the farmer, Mr. Namdev, belonging to the village Garkampet, Seethagondi Gram Panchayat in Gudihatnoor mandal of Adilabad district in Andhra Pradesh.

The response of tribal population who were earlier reluctant is now overwhelm-

Table 1. Impact of farm pond on net returns accrued from production of tomatoes (in 0.5 acre land) during 2008

S. No.	Particulars	Amount (Rs.)
1	Gross returns	1,30,450
2	Total cost of cultivation of crop (a)	23,600
	Cost of digging of pond (b)	35000
3	Net returns accrued from production of tomatoes (1-2a)	107,350
	Net returns accrued after recovering cost of farm pond [1-2 (a+b)]	72,350
4	BCR based on total cost of cultivation of crop	5.53
	BCR based on total cost of cultivation including cost of pond	2.23t

ing and the technology has been up-scaled to 30 more farmers through participatory demand-driven approach and convergence with NREG within the *Gram Panchayat* and also it is being up-scaled by the line department in the district.

Dugout Farm pond - A Potential Source of Water Harvesting in Deep Black Soils in Deccan Plateau Region

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Abstract

The black soils possess great production potential, but general crop productivity of these soils is poor and unstable due to low and uncertain rainfall and inefficient crop management. To improve crop productivity and reduce risk uncertainties, rain water harvesting through dugout ponds is devised as an efficient tool and a detailed discussion in this regard has been carried out in this article. The harvested water can be effectively used to provide life saving irrigation to tide over moisture stress during critical stages of crop growth as well as growing of multiple crops around the harvesting structure. This technology proves to help in stabilizing and supporting a large proportion of agriculture in the semi arid tropics.

Introduction

Water harvesting refers to the collection and storage of rainwater and also other activities aimed at harvesting surface and groundwater, prevention of losses through evaporation and seepage and all other hydrological studies and engineering interventions, aimed at the conservation and efficient utilization of the limited water endowment of a physiographic unit such as watershed. In general, water harvesting is the activity of direct collection of rainwater. The rainwater collected can be stored for direct use or can be recharged into groundwater.

Benefits of Rainwater Harvesting

The Major benefits are:

- To meet water demand for domestic, animal and recreational use.
- To provide life saving / supplemental irrigation to crops and plantation
- To augment groundwater recharge
- To improve moisture status of the soil profile
- To reduce soil erosion
- To help in peak flood retardation
- To spray insecticides /pesticides in crop management.

Technology Developed and Scope

Black soils, which constitute 23.1 per cent of rainfed lands in India, possess great production potential. These soils are generally put under cultivation in the winter (post-rainy season) mostly on stored moisture. The annual precipitation in the *rabi* tracts varies from 500 to 700 mm. Crop yields are very poor and unstable due to low and uncertain rainfall and inefficient crop management. Hence, the major task in the region is to improve production per unit area and reduce the risks of uncertainty. This can be achieved by an effective utilization of the natural rainfall, as water deficit is the major constraint in production. To mitigate this problem, water harvesting through dug-out farm ponds in every 10 ha catchment is required to stabilize crop production as recommended by CSWCRTI, Research Centre, Bellary (Karnataka) (Chittaranjan *et al*. 1980). The water harvesting through dug out farm pond is a major water harvesting structure in the semi-arid black soil region. Therefore, this structure has been discussed here in detail.

Types of Farm Pond

As per the method of construction and their suitability to different topographic conditions, there are three types of farm ponds. They are:

1. Excavated farm ponds for flat topography;
2. Excavated cum-embankment ponds in mild sloping topography ; and
3. Embankment farm ponds for hilly and rugged terrain.

In the black soil regions with flat to mild sloping topography, generally excavated type ponds are more suitable.

Methodology

Selection of Site

The selection of a site in a participatory mode depends on:

- Availability of suitable site for pond location;
- Farmers' willingness to part with a portion of the land for pond construction and to share harvested water with neighbors.
- Optimum catchment size for considerable storage for relatively long period.
- Well-protected (treated) catchment for arresting rapid siltation.
- While deciding the capacity, the conservation measures such as agronomic and mechanical measures are considered. The command area near the pond should be free of salinity /alkalinity and the site should require little or no land shaping around the pond.

Criteria for the Location of Pond

i. Purpose

- For drinking water, it should be near to village, utmost care is taken to avoid pollution
- For supplemental irrigation, the pond should be located on a site such that it benefits maximum number of farmers.

ii. Location

Pond should be located on one side of the watercourse to avoid rapid siltation.

iii. Sequence of Soils

When soils of different permeabilities occur in a succession like red and black soils or shallow and deep black soils, the pond should be located in the deep black soils to avoid pond lining for arresting seepage.

iv. Nature of Sub-soil Strata

Ponds in shales, basalt or on shattered rocks are likely to lose more water. It is therefore advantageous to know about the nature of the substrata.

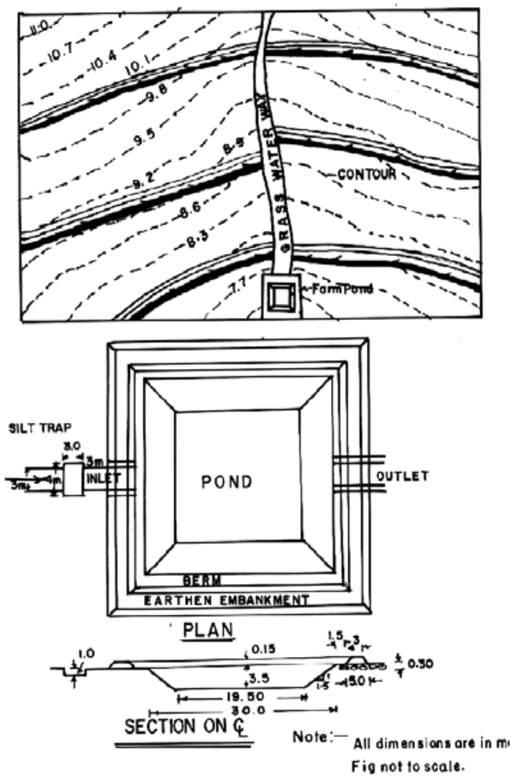


Figure 1. Line diagram of a typical farm pond showing the location in a field with contour lines and graded bunds

Design Criteria of Dugout Farm Pond

The design of a dug out pond envisages the determination of the design specifications for

a. Storage capacity
b. Shape
c. Dimensions (Depth, Top and bottom widths, side slopes)
d. Inlet
e. Outlet.

a. Storage Capacity

The capacity of the pond depends on

- Purpose for which the pond is created
- Annual water yield
- Storage losses and
- Area considering the volume of silt anticipated

The pond should be of sufficient capacity to fully meet the purpose for which it is created. For water supply, it should meet the drinking water requirements of the village community, cattle, poultry etc. round the year. In drought prone areas, it should be able to tide over the successive years of drought. In case one pond is not sufficient, required capacity is met by creating more ponds. If the pond is for supplemental irrigation, the extent of the area to be irrigated, the estimated deficiency of soil moisture, which is required to be replenished for optimum crop yields, the storage losses in the pond, the efficiency of conveyance and application systems. The corrections required for advection effect have to be considered.

The capacity of the pond created depends upon the catchment size and factors affecting its water yield. Water yield from the catchment is a product of the interaction of effects of the rainfall factors and the physiographic features of the catchment. While rainfall amount, intensity and antecedent precipitation are the climatic factors to be considered;

Soil, topography, land use and surface detention measures such as bunding intensity etc. are the physiographic features which influence the water yield. Sometimes, the information on annual runoff (percent available from a representative research stations) (Table 1) can be used to estimate the water yield. In this context, the following information obtained at some research stations for black soils may be useful.

Table 1. Runoff per cent from different region of black soils		
Research station	**Soil type**	**Runoff per cent**
Central Soil and Water Conservation Research and Training Institute, Research Center, Bellary (Karnataka)	Deep black soils	10
Agricultural research station, Hagari (Karnataka)	Deep black soils	20
International Crop Research Institute for semi-arid Tropics, Hyderabad (A.P.)	Medium deep	10
Dry land main center, Solapur (Maharastra)	Medium deep	15 to 20

b. Shape

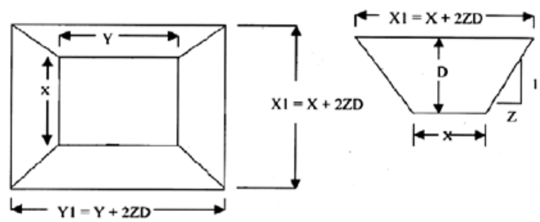
Excavated farm ponds are of two types viz. square and rectangular. However, the square pond is most commonly adopted having less evaporation and seepage area compared to a rectangular pond and this is easy to construct.

c. Dimensions

Side slopes: The side slopes are decided by the angle repose for the sub-soil. Where the soils are very deep (more than 90 cm), the angle of repose for the deep black soils may also have to be considered. The constant action of standing water may require relatively flatter side slopes to avoid slippage due to saturation. Generally, the side slopes of 1.5:1 would be sufficient for the murrum obtained under the deep black soils in this tract.

The design detail, construction procedures are as follows.

Pond design



Dugout Farm Pond

NB: For square section X = Y

Table 2. Dimensions of best section (square) of dugout farm ponds for different design capacities (V) and depths (D) in black soil with a recommended side slope (Z) of 1.5:1				
Design Capacity (V) cum	**For 2.0 m depth**		**For 2.5 m depth**	
	Bottom side of square section (X), m	**Top side of square section (X1), m**	**Bottom side of square section (X), m**	**Top side of square section (X1), m**
500	12.5	18.5	9.9	17.4
750	16.1	22.1	13.2	20.7
1000	19.2	25.2	15.9	23.4
1250	21.8	27.8	18.3	25.8
1500	24.2	30.2	20.5	28.0
1750	26.4	32.4	22.4	29.9
2000	28.5	34.5	24.3	31.8
2250	30.4	36.4	26.0	33.5
2500	32.2	38.2	27.6	35.1

Design Capacity (V) cum	For 2.0 m depth		For 2.5 m depth	
	Bottom side of square section (X), m	Top side of square section (X1), m	Bottom side of square section (X), m	Top side of square section (X1), m
2750	34.0	40.0	29.2	36.7
3000	35.6	41.6	30.7	38.2
3250	37.2	43.2	32.1	39.6
3500	38.7	44.7	33.5	41.0
3750	40.2	46.2	34.8	42.3
4000	41.6	47.6	36.1	43.6
4250	43.0	49.0	37.3	44.8
4500	44.3	50.3	38.5	46.0
4750	45.6	51.6	39.7	47.2
5000	46.9	52.9	40.8	48.3
Design Capacity (V) cum	For 3.0 m depth		For 3.5 m depth	
	Bottom side of square section (X), m	Top side of square section (X1), m	Bottom side of square section (X), m	Top side of square section (X1), m
500	7.6	16.6	5.5	16.0
750	10.7	19.7	8.4	18.9
1000	13.2	22.2	10.8	21.3
1250	15.4	24.4	12.9	23.4
1500	17.4	26.4	14.8	25.3
1750	19.2	28.2	16.5	27.0
2000	20.9	29.9	18.1	28.6
2250	22.5	31.5	19.6	30.1
2500	24.0	33.0	21.0	31.5
2750	25.4	34.4	22.3	32.8
3000	26.8	35.8	23.6	34.1
3250	28.1	37.1	24.8	35.3
3500	29.4	38.4	25.9	36.4
3750	30.6	39.6	27.1	37.6
4000	31.7	40.7	28.1	38.6
4250	32.9	41.9	29.2	39.7
4500	34.0	43.0	30.2	40.7
4750	35.0	44.0	31.2	41.7
5000	36.1	45.1	32.2	42.7

Design Capacity (V) cum	For 4.0 m depth	
	Bottom side of square section (X), m	Top side of square section (X1), m
500	3.4	15.4
750	6.3	18.3
1000	8.6	22.6
1250	10.6	22.6
1500	12.4	24.4
1750	14.0	26.0
2000	15.5	27.5
2250	16.9	28.9
2500	18.3	30.3
2750	19.5	31.5
3000	20.7	32.7
3250	21.9	33.9
3500	23.0	35.0
3750	24.0	36.0
4000	25.0	37.0
4250	26.0	38.0
4500	27.0	39.0
4750	27.9	39.9
5000	28.8	40.8

Farm pond – Grassed waterway leading to farm pond (inlet, gauging scale seen)

d. Inlet

The inlet is designed as a chute spillway for diverting the runoff into the pond in a controlled manner. The entry section can be designed as a rectangular broad crested weir. The peak discharge rate for deep black soils from a 10 years recurrence interval can be taken as 0.15 cum/sec/ha. Accordingly, the design the width and height of the crest and provide an allowance of 20 per cent extra height for free board.

e. Outlet

It is economical and advantageous to go in for an inlet-outlet structure where possible. When it becomes necessary to separate the two, the outlet is constructed as a rectangular or square channel, this outlet position will be a little lower than the elevation of the inlet to avoid backwater effect. The discharge capacity of the outlet can be assumed to be half that of the inlet capacity at peak rate of runoff.

Construction of Farm Pond

Construction of an Excavated Farm Pond involves the Following Works:

i) *Site clearing*: The area, where the pond is to be finally dug out should be cleared to an extent of about 20 m from all sides after demarcation. All bushes, shrubs, stumps, thorns and other unwanted materials like roots; etc. should be removed.

ii) *Leveling:* As there will be depressions and undulation, it may be necessary to plough the area and harrow it to get a more or less even topography. This will facilitate easy calculation of earthwork quantities. If more precise data on earthwork is required and if there are many big humps/ mules and depressions which can not be eliminated by ploughing and harrowing them levels at 5 m or 10 m grids may be taken to find cut the actual lay of the area where the pond is to be constructed.

iii) *Demarcating pond area*: The farm pond site is demarcated by driving pegs to indicate the four corners and if necessary the sides can be extended beyond the actual site of the pond.

iv) *Establishing reference level*: Spot level at the corners and at the mid point is taken with reference to a nearby temporary B.M. The average of these levels is transferred on to a permanent/semi permanent object at an approximate distance of about 15 to 20 m from the pond site.

v) *Stepping method of constructions:* Since it will not be possible to have the cutting exactly to the trapezoidal shape, a segment wise construction known as stepping method is adopted during the time of actual excavation. These steps like formation can be subsequently cased out to get the required shape and designed side slopes. By doing so calculation of earthwork and payment of wages for the day's work becomes easy. While using earthmovers care should be taken to maintain the side slope.

Formation of Spoil Bank

Since considerable quantity of spoil would be obtained from such dug out ponds, the disposal of the same should be done systematically and in a proper manner. Though it was estimated that 40% of the cost of construction could be obtained by disposing murrum obtained from such dug out ponds (for the utilization of forming rural roads) this proposition is not gaining popularity with different agencies. Hence it is desirable to spread murrum in a proper way to keep the loss of area to a minimum and to avoid the wastage of the layout on spreading it. Hence, the existing bunds and internal farm roads can be strengthened using the excavated murrum. The excess soil can be placed on the field after making a bund around the pond.

Farm pond at Joladarasi watershed showing inlet, outlet and spoil bank

Shoulder Bund and Toe Drain

The rainwater falling on the spoil bank and the berm is likely to enter the pond, which creates rills around. To prevent such riling the shoulder bund with a small toe drain, which should run along with soil bank, may be provided; allow the water thus collected into the pond or take it out through earthenware pipes.

Silt Trap

A silt trap of suitable dimension is created in the watercourse just near the entrance of the inlet to check the bed load entering the pond. The length of such silt trap can be slightly greater than the width of the watercourse and the depth may be about 0.75 to 1 m with side slopes of 1:1.

Cost: The average cost of construction of storage works out to Rs.90=00/cum and this includes formation of spoil bank, inlet, out let and silt trap as per the present rates.

Maintenance of Farm Ponds

i) *Desiltation:* The farm ponds constructed in deep black soils get silted up @ 5 to 6 t/ha per year. Hence, periodic desilting to restore the original storage capacity is required. In the case of drinking water ponds, desilting may be necessary once in 2 years, where as in the case of ponds meant for supplemental irrigation, desilting may be done once in 5 to 10 years, depending upon the volume of silt accumulation and decrease in the storage capacity.

ii) *Maintenance of inlet and outlet:* Construction of any structure in the black soil requires specific attention and care, owing to the excessive swelling and shrinkage properties that develop and ultimately the structure collapses. A firm murrum base may be provided before the actual construction of any such structures like inlet and outlet in black soils.

iii) *Maintenance of shoulder bunds*: toe drains and spoil bank: Breaches and rill formations in the spoil bank and shoulder bunds should be attended to and plugged promptly. Toe drains should be free of earthen boulder or humps to permit easy passage of water flowing through the toe drain.

iv) *Clearing silt trap:* The silt accumulated in the silt trap should be removed periodically, and preferably as and when it gets filled up after a few runoff events.

v) *Fencing of the farm pond:* Barbed wire fencing of 4 to 5 strands barbed wire may be provided around the farm pond to prevent human beings and animals from slipping or falling into the pond. Provide wicket gate with bamboo/ wooden sticks wherever required. Bio-fencing with local materials is another alternative.

vi) *Maintenance of depth gauges*: In order to know the depth of water and thereby volume of water stored in the pond, depth gauges are installed. Repainting and rewriting the scales should be done periodically to maintain them.

vii) *Control of water pollution*: Drinking water ponds should be chlorinated periodically to prevent waterborne communicable diseases. The water should be periodically tested for quality.

viii) *Control of aquatic weed growth*: With the deposition of silt/sediment from the runoff some aquatic weeds like reeds and other obnoxious weeds do come up and thrive well under such conditions.

ix) Efforts should be made to remove them, or else these weeds/plants not only transpire large quantities of water but also induce decaying, thereby affecting quality of water in the pond.

Brief Results

Recycling of Pond Water

Rabi crops are, in general, grown on residual moisture conditions, as there is practically little or no rainfall after sowings. The success or failure of early sown *rabi* crops depend on October rains. Experience shows that crops suffer from moisture stress right from 30^{th} day of crop growth. The potential of stored water as a source of supplemental irrigation to save the crops was, therefore, studied since 1972 and its economics evaluated. The results show that providing protective irrigation to sorghum in small quantities of 5 cm over large areas at the start of mild stress is more paying than at higher levels of irrigation. The cost benefit ratio varied between 2.5 to 3.4 for sorghum crop in this region. This means, harvested water should be given as a life saving practice to tide over moisture stress during critical stages namely, at or between grand growth period and boot leaf in case of sorghum.

Lessons Learnt

The areas around the farm pond could also be developed for growing horticultural and vegetable crops, which would further make the system more viable. Thus, water harvesting and runoff recycling helps to stabilize and support a large proportion of agriculture in the semi arid tropics. It further brings awareness in the farmers on the benefit of conserving the twin natural resources soil and rainwater.

Strategies for Up-scaling

Water is the most attractive part for dryland agriculture. Farmers are accepting this water harvesting technology. However, the Implementation of farm pond on watershed basis must be done through farmers watershed committee/watershed societies. Because it involves huge cost, it must be financed by state, central agencies NGOs, etc. Poor farmers of the dryland areas cannot afford the cost of construction. Once implementation is made in one watershed successfully then this technology may be adopted swiftly in other watersheds.

References

Chittaranjan S, Ram Mohan Rao MS and Selvarajan S. (1980). Runoff Harvesting and Recycling on Black Soils for Increasing Crop Production. *Bellary Extension Bulletin No.3 CS&WCR&TI, RC, Bellary. (Karnataka).*

On-farm Testing of Lining Materials in Small Experimental Tanks for Supplemental Irrigation

CR Subudhi

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Abstract

Four tanks with full storage capacity of 11.31 cubic meters were excavated at Sudreju village of Kandhamal district of Orissa near Dryland Research Station, Phulbani during 2003-2005. Out of four, three tanks were lined by soil-cement mortar (6:1) of 6 cm & 8 cm thickness, concrete plaster (8:4:1) of 4 cm thickness and the fourth was kept unlined. Observations on seepage loss were recorded in all the tanks. The unlined tank had recorded a seepage loss of 936 lit day^{-1}. Observations from three other lined tanks indicated that the seepage loss was 78.15 lit/day in soil-cement (6:1) mortar with 6 cm thickness, 12.26 lit/day in soil-cement (6:1) mortar of 8 cm thickness & 39.48 lit/day in concrete plaster (8:4:1) of 4 cm thickness. The cost of construction of the soil-cement (6cm) lined tank (Rs.1950/-) was nearly 21 per cent cheaper than that of soil-cement (8cm) lined tank (Rs.2362/-). The economic loss due to seepage was lowest (2.03Rs/day) in soil-cement (6:1) mortar of 8 cm thickness. Thus soil-cement (6:1) mortar of 8 cm thickness is economical in all respects and is the only means of storing water in the laterite regions of Orissa.

Introduction

Orissa comes under high rainfall region of the country. It receives annually an average rainfall of 1500 mm. Nearly 40 per cent of it is lost through deep percolation and is never available to crops. Porous soil accelerates the movement of underground water. The district of Kandhamal is on a centrally located plateau and mostly comprises of red laterite soil whose water retentive capacity is very poor and seepage loss is very high. The district has the irrigation potential of only 10 per cent of the total cropped area. It receives an average annual rainfall of 1393 mm. The farmers grow a single crop in a year due to lack of irrigation water. The water table is very deep. Most of the lands are undulating. Nearly 80 per cent of the cropped area belongs to high lands. Under such situation, tank irrigation is an imperative means for water resource development. The major limiting factor to such water resource development is the seepage loss.

Methodology

This experiment was conducted from 1998-99 to 2000-2001 (3 years) in the Dryland Agriculture Research farm, OUAT, Phulbani, Orissa with an objective to study the performance and economics of selected lining materials for tank irrigation. Three tanks were excavated with following dimensions:

Top width: 3.8 m x 3.8 m; bottom width: 0.8 m x 0.8 m; side slope: 1:1; depth of the pond: 1.5 m; wetted area: 20.144 m^2; capacity of the pond was 11.31 m^3

The type of soil in all the cases was sandy-loam. The treatments were T_1- lined by soil-cement mortar (6:1) of 6 cm thickness, T_2- soil-cement mortar (6:1) of 8 cm thickness,

T_3-concrete plaster (8:4:1) of 4 cm thickness and T_4- with no lining. The seepage loss was measured immediately after a heavy rainfall. The method adapted for measuring the seepage loss was, volume of water lost daily from the pond.

Results

The results showed that the unlined tank had a very high seepage loss of 936 litre day^{-1} (Table 1). Panda and Bhattacharya (1983) have reported the seepage loss in the unlined irrigation channel of 420 m^3 week^{-1}. It is established that the soil had very low water retentive capacity and thus tanks need lining for water storage for irrigation. Observations from the three other lined tanks indicated that the seepage loss was 78.15 lit/day in soil-cement (6:1) mortar of 6 cm thickness, 12.26 lit/day in soil cement (6:1) mortar 8 cm thickness and seepage loss was 39.48 lit/day in concrete plaster (8:4:1) of 4 cm thickness. The cost of construction of the soil-cement (6cm) lined tank (Rs. 1950/-) was nearly 21 per cent cheaper than that of soil-cement (8cm) lined tank (Rs. 2362/-). The economic loss due to seepage was the lowest (Rs. 2.03 /day) in soil cement (6:1) mortar of 8 cm thickness.

Thus soil-cement lined tanks are economical in all respects and are the only means of storing water for irrigation purposes in the lateritic region of Orissa.

Acknowledgements

The authors wish to acknowledge the help of Dean Research, OUAT, Bhubaneswar for his guidance and PI, NATP, RRPS-7 for his guidance & financial help to conduct this trial.

References

Panda RK, Bhattacharya RK. (1983). Lining of small irrigation channels. *J. Irrigation and Power*: 83: 385-391.

Table 1. Seepage loss in different treatments

Treatments	Seepage loss from the tank (lit day^{-1})	Cost of storage (Rs. m^{-3})	Cost of lining (Rs. m^{-2})	Cost of pond with lining (Rs. m^{-2})	Total cost of the tank (Rs.)	Economic loss due to seepage loss (Rs. day^{-1})
T_1- lined by soil cement mortar (6:1) of 6 cm	78.15	196.4	92.13	107	1950	15.35
T_2- soil cement mortar (6:1) of 8 cm thickness	12.26	165.82	114.8	130	2362	2.03
T_3-concrete plaster (8:4:1) of 4 cm thickness	39.48	164.13	75.08	90	1640	6.48
T_4-No lining	936	27.53	0	15	275	25.77

Factors affecting the adoption of farm ponds in drought prone areas of Gujarat: Sharing Experiences of AKRSP (I)

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Abstract

The experience gained on adoption of farm ponds among the farmers in the drought prone areas of Gujarat are discussed in the present paper. A case study of Surendra Nagar district of Saurastra region of Gujarat on farm ponds construction and management were carried out. The selected area had the issue of less rainfall, soil erosion due to deforestation and grazing, uncontrolled ground water exploitation and rainfed agriculture to name a few. The AKRSP working in the area adopted the drought coping measures namely soil and water conservation, water resource development and alternate livelihood development through SHGs. A total of 416 farm ponds, 105 boribunds, 132 check dams, 18 tanks and 6 water recharge system were constructed spread over 46 villages. Significant improvement on livelihood were observed in the area under study.

Introduction

Drought is a normal, recurrent feature of climate. It occurs almost everywhere, although its features vary from region to region. Drought should not be viewed as merely a physical phenomenon or natural event. Its impact on society results from the interplay between a natural event (less precipitation than expected resulting from natural climatic variability) and the demand people place on water supply. However, some areas are particularly drought-prone with relatively high frequency of its occurrence. Human responses can exacerbate the impact of drought. Recent droughts in both developing and developed countries and the resulting economic and environmental impacts and personal hardships have underscored the vulnerability of all societies to this hazard.

Issues of the Region

- Surendranagar district, located in the Saurastra region of Gujarat, is the most drought-prone area in the state. Average annual rainfall is about 450 mm.
- Uncontrolled water use exceeds groundwater recharge.
- This hilly, semi-arid area has no perennial rivers and streams. The problem of thin, rocky soil is compounded by soil erosion due to deforestation and overgrazing.
- About 25% of the population is comprised of Rabari and Bharwad communities that are engaged in animal rearing, whose interest often conflict with those of farmers. Their migratory nature has made them difficult communities to work with.
- Scarce water as well as poor soil conditions have led to low agricultural productivity.
- Only 10% of the region is irrigated.
- Acute scarcity of drinking water has

affected livelihood security.

- The scheduled castes constitute 11 per cent of the total population against 7.4 per cent for the state average. The feudal social structure with rigid caste and occupational divisions makes it difficult to work with village institutions.
- The social structure imposes many restrictions on women.

The Programme Area

Surendranagar district, located in the Saurastra region of Gujarat, is the most drought-prone area in the state.

The population is primarily dependent on rainfed agriculture with only 10% of the region being irrigated. Rain fed agricultural crops includes cotton, millet, sesame seed, pulses and some vegetables.

Drought Coping Measures adopted by AKRSP (I) under SCALE (2002-2012)

Under the Drought coping theme, we are working in 2 districts: Surendranagar and Rajkot covering 204 villages of 7 *taluka*'s and provided benefit to over 22300 households.

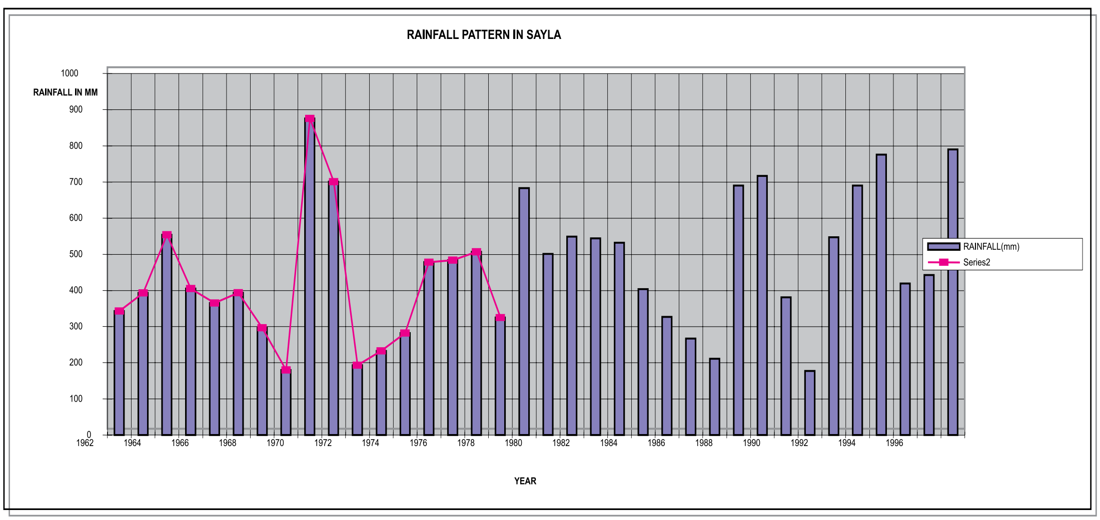
Under Sustainable community based Approaches for Livelihood enhancement (SCALE) we are using multi pronged strategy to address the issues of the region. The focus areas are:

1. Drought coping

- Soil and water Conservation activities.
- Water Resource Management
- Agriculture Extension & irrigation facilities.
- Special Wadi Package Programme for small farmers.
- Training centre as Rain Centre with focus on Drought coping.

2. Drinking water facilities

- Facilitating communities to plan, construct, operate & maintain their own drinking water facilities.
- Providing support in constructing Individual & community-based RWHS.



- Water Quality Testing Laboratory to support the stress on drinking water quality & providing remedial /preventive measures for the same.
- Focus on safe drinking water & environmental sanitation issues.

3. Alternate livelihood development

- Understand the needs of the landless, poor and women & help them to help themselves through SHG. Sub village, village & Supra village level structures help in the same cause.
- Increase the involvement of poor women in the development of income-generating activities by providing loans and linking them with banks for various activities.
- Enabling the development of robust methods for developing successful micro enterprises, tool kit library, cheese plant, brass bead, etc.

Besides this, AKRSP is also running Computer Training & Learning Centers (CTLC) that provide education, information, networking and linkages to the outside world.

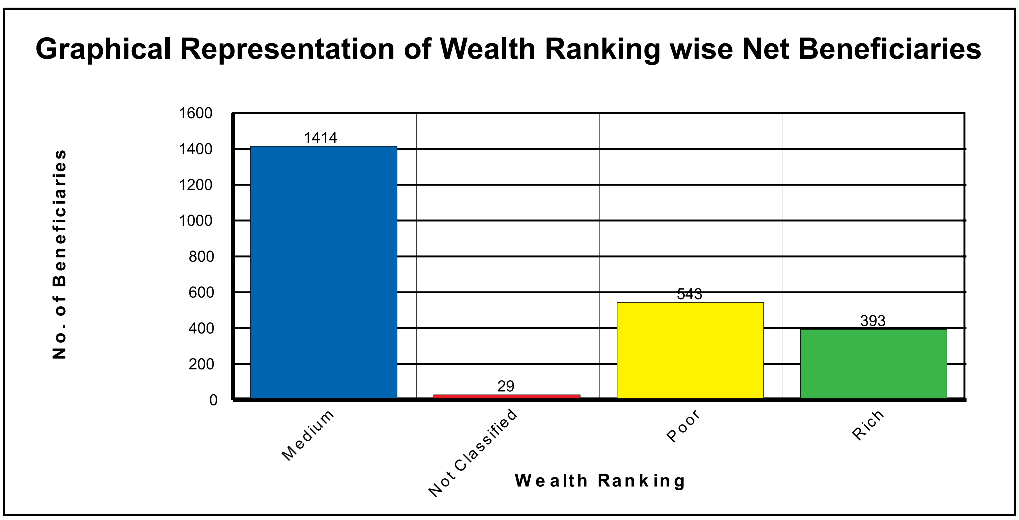
Activities under WRM in Surendranagar Area

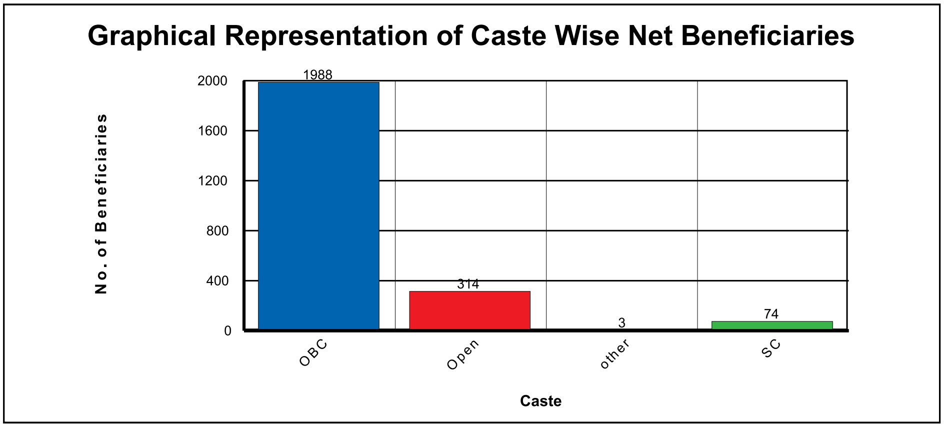
The successful production of rainfed crops largely depends on how efficiently soil moisture is conserved in situ or the surplus runoff is harvested, stored and recycled for supplemental irrigation. AKRSP (I) has promoted simple and low-cost water harvesting structures, evolved water-sharing methods, community regulation of water use, which helped in up-scaling the models to a certain extent. On-farm water harvesting through farm ponds on individual holdings was emphasized and cost benefit data generated on use of harvested water.

Since 2002, 677 WRD interventions have been undertaken in 70 villages of Sayla project area. The details are as follows:–

416	Farm ponds.
105	Boribands.
132	check dams & UCGD
18	Tanks
6	Well recharge.

Potential Irrigation Area of these structures is 1312.07 ha





Potential Storage Capacity is 140.40 MCFT, providing direct recharge to 440 wells.

A total of 3047 households and net 2379 households have been benefited by the interventions.

Focusing on Farm Ponds

The demand for farm ponds has been increasing as it has emerged as a low cost viable option to harvest rainwater in the drought-prone areas. Along with increased recharge, it also provides support irrigation. After excess rain, it also copes with the problem of excessive waterlogging in the fields. It is more so beneficial in this area because even if the first spell of the rainfall is decent, then the water storage is sufficient to irrigate crops and can cope with the late second spell of the rainfall. The late and lower second spell of rainfall is normally the trend in Surendranagar. Hence, farm ponds act as source of support irrigation for crops, thus assuring for farmers of a decent livelihood.

416 structures have been constructed in the programme area benefiting 416 household & farmers in 46 villages. Of these, 101 structures have been constructed in one particular village.

Farm pond is generally constructed at the tapering end of the field to reduce soil erosion and conserve water for recharge or irrigation purpose.

Dimension of the structure

The average size of the structure is 20 m x 20m x 1.5 m. However, it may vary based on the landholding and farmer's capacity to invest.

Cost of the structure

In 2003, the cost was Rs 15000 and increased to Rs 20,000 in 2009.

Subsidy

AKRSP (I) provides 45% subsidy and now reduced it to 35 % grant to better off farmers and reduced from 90% to 70 % for the poor farmers. This classification is based on a village PRA exercise. The definition of the term vary from village to village based on the local conditions.

Factors Augmenting the Cause

a. Shift from Community based Intervention to Individual based Intervention

To address the scarcity Issue of water, especially for agriculture, the geographical condition of the area, most of the times does not provide better options for big structures. This opens the option of individual based structures in the villages. Navagam Bavadiaya was a classic case.

In village Navagam Bavadiya, big structures were not feasible on public land hence the VDC members (100% women) decided to focus on the individual basis. Hence farm ponds on individual lands were planned and constructed. Now 101 farm ponds have been completed in the village. The demand is for more such structures because of the benefits.

1. The farmers whose crops were affected during harvesting time due to lack of water now get good production. The farmers who had not taken any winter crop during his entire life now have started taking crops in the winter.
2. 50% of the soil excavated from the pond is used in the bund and the remaining is spread in the fields. Hence due to good soil there was increase in production.
3. The damage to the crop due to the problem of waterlogging has been tackled.

b. Sharing the Impact of the Farm pond

Impact of the benefits when shared and analyzed by the beneficiary himself has a greater impact on others. Here is one such case study. It's also known as "the spread effect".

A Case Study: Deva bhai ghusa bhai Jamphadia is a resident of Khintla village in Sayla taluka of Surendranagar district. He has a land holding of 17.5 bighas and owned a well to irrigate the land. But due to irregular monsoons and drought every third year he could not take a very good yield from his land. As the monsoon arrived he had to wait for at least 20 days for recharging of his well after one of the ponds in the village was filled.

Season after season this continued for him and then in year 2005 AKRSPI staff discussed with the villager about the construction of farm pond (a pond constructed in the direction of slope were all the rainwater from that catchment area gets collected, and directly results in quick recharge of the well). Following this discussion, around 25 people were taken on an exposure visit to another programme village to see the farm pond and talk to farmers. After the exposure visit, farmer constructed the farm pond on his land and from there on there is no looking back for him.

The intervention has brought many fold changes for Deva bhai, i.e.

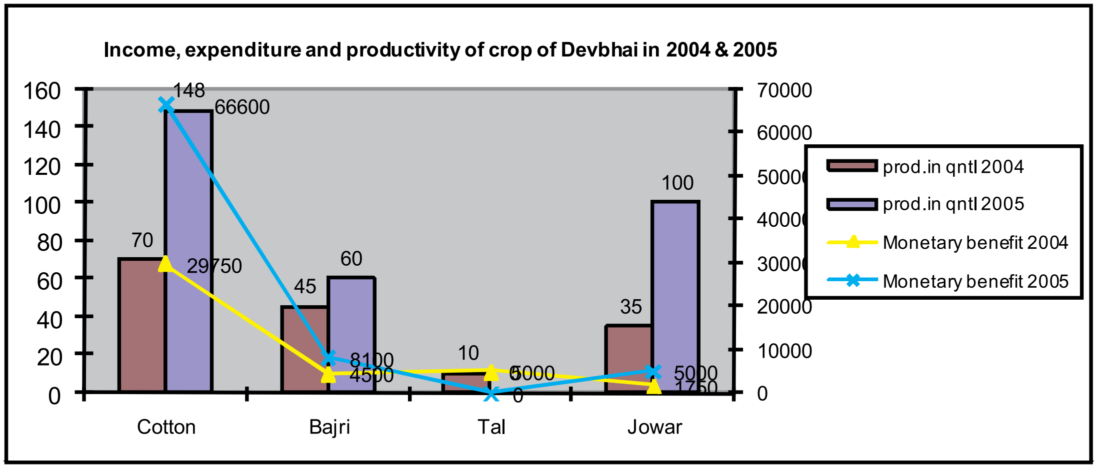
- The command area of the well has increased from 2 acres to 7 acres, as water level has gone up by 20 feet
- The timely availability of irrigation facility has increased the productivity and the cultivation of cotton in majority of land
- The fertile soil which used to runoff is deposited in the farm pond will be used as fertilizer in the coming years.

These three changes had a positive impact in the net income of Deva bhai as shown in the table containing comparative analysis of income and expenditure in the context of agriculture before and after the intervention.

The net profit in 2004 was Rs. 8450 (41000-32550) and in 2005, it was Rs. 33510 (79700-46190). Thus, there was a four fold increase in the net profit in one year due to availability of water to irrigate the land.

S.No	Activity	Expenditure in 2004	Expenditure in 2005
1	Pesticides	8000	5700
2	Fertilizers	6400	13000
3	Seeds	2380	4200
4	Land preparation	2900	3750
5	Weeding	3300	3400
6	Irrigation	6000	9000
7	Harvesting	3570	7140
	Total	**32550**	**46190**

S.No	Crop	Qnt.*market price	2004	Qnt.*market price	2005
1	Cotton	70*425	29750	148*450	66600
2	Bajari	45*100	4500	60*135	8100
3	Tal	10*500	5000	-	-
4	jowar	35*50	1750	100*50	5000
	Total		**41000**		**79700**



This increase in the net profit has given confidence to Deva bhai to further invest in the agricultural infrastructure, which will increase the efficiency and reduce the cost. He has already invested his first year's profit in the maintenance of his well. As he says "Ghar banavva ma paisa nakhva thi koi aavak thavani nahi ghar to be varah pachhi pan bani sake aatyare kheti ma paisa nakhis to aavak vadhse aane pacchi aa paisa ma thi vichari ne baddhu karsu." (Investing the money in construction of house can wait for year or so as it is unproductive expenditure, right now investing in agriculture will be productive and increase the income. I will think what can be done with the income in the coming years.)

c. Special focus on Training and capacity building of the villagers and village leaders

This was undertaken through various types of project training, institutional training, mass awareness programmes, internal & external exposure

In this particular village, the following activities were undertaken:

- Project training was provided to 40 members
- Institutional Training was provided to members,
- Mass awareness programmes were undertaken.
- Internal exposure was provided to 48 members
- External exposure was provided to 54 members
- Total villagers trained was 182, of these net household covered were 111, of these 34 are poor, 76 medium and 1 rich.

D. Special Focus on Poor

In all the development programmes despite subsidy, the real poor or the needy are always left out. The condition becomes even more serious when the member is from the lower segment of the society (SC, ST, and OBC). Special subsidy amount was paid for the poor who are identified based on a village wealth ranking PRA exercise. The definition of the terms varies from village to village based on the local conditions.

Secondly, the time spent in motivating the poorest especially from the weaker section is four times greater than the normal beneficiaries. According to the field staff *"If we construct 50 farm ponds a year in the general category, with same resources, we can construct 12 to 15 ponds from the poor category , as they require more follow-up and more support / confidence in undertaking the particular activity. "*

E. Role of community Institutions

In every village there is a Village Development Committee (VDC), which looks into the developmental activities in the village. The farmers were interested in undertaking a farm pond, and put their demand to their VDC. The VDC approved the demand and sent it to AKRSP (I) for implementation through the E.V. (Extension Volunteer). A strong VDC can plan and bring in programmes from various agencies.

F. Focusing / promoting Gender

In all the Village Development Committee (VDC), there are women members. It's mandatory to have 1/3rd female members. The point worth noting is that the VDC of the village Navagam Bavadiya was not able to resolve the problem of drinking water in the village. After rounds of debates and discussions the women of the villages decided to take the responsibility of village development in their hands. Today the Village Development Committee (VDC) comprises of all female members.

Secondly, priority for the construction of farm ponds or other WRD structures or SWC activities are given to those women who are owners of agricultural land / farm over male beneficiaries. 32% of all the farm pond beneficiaries across the programme area are women.

Thirdly, the payment in case of all WRM & SWC activities are made in the name of women members of the family to emphasize that along with the labour work she does on the farm, she also has a say in its planning and future development.

G. Specific benefits perceived by the people based on the local conditions particular to the area

"The rain pattern in Sayla area is very peculiar, the gap between the first spell and second spell of rain are often more. The second spell is low and spread over in few days. So we lose. But with the construction of this farm pond I have been able to manage the situation and saved my crop from being a failure. I have 3 acres of land and could take only cotton crop as the water in my 60 feet well would dry up. Earlier, the water in the well would come at the end of the monsoon and would last only 2 months. Now with the construction of the farm pond, the water in the well comes within a week of the rains and last for more than 4 months. The production is almost doubled. Further, I could grow wheat for first time. This year I have taken an additional 4 acres of land on lease for agriculture."

- **Devabhai Laxman bhai, village - Pipaliya** ***taluka*** **- Kamlapur.**

Excessive waterlogging**:** Excessive water causes waterlogging in the farms, which causes extensive damage to the crop. With the construction of the farm pond, water diverted to the pond.

Late and Low second spe**ll:** Seeds of cotton are costly and farmers sow them after the first spell of rain. If the second spell of rain is delayed, the young crop dries up. With the construction of farm ponds, water can provide the life- saving dose.

Use of 50 % excavated soil in field: People use 50% of the excavated earth on the bund and the remaining 50% are spread out in the field. This new layer of soil in their field has helped in increasing the productivity of the land.

Increase in the rate of percolation in the well**:** With the construction of the well, the percolation of the recharged water in the well is fast. The water is available within a week, which earlier took nearly a month.

Increase in the water holding capacity of the well: The duration of water availability in the well has also increased. People who had never taken a second crop have started getting a second crop.

Despite the success in the construction of individual farm ponds in village Navagam Bavadiya, we have not had the same success in other villages (> 50%) even with focused efforts in training & support. The reasons for this are –

- Non availability of proper geographical conditions likes –
  - Availability of hard rock in excavation. Ex. Gadh, Kotada, Dhandhalpur, Vatavachh, etc.
  - Non availability of recharge strata.
  - Availability of saline soil, which increases the salinity of the water, stored in the farm pond and even seeps into the well. Example villages, Dhamarasara, Mota Sukhpar, Sukhda etc.
- Small Land holding: Farmers having small land holding are skeptical of giving away 400sq mts of their land. It's really tough convincing people that "something is better than nothing". People are moving towards it. but the process is slow.

Conclusion

For scaling–up the adoption of the farm pond we need to be flexible and have a supportive programme with a degree of commitment from the implementers. Focus on capacity building, exposure and gender.

Harvesting and effective utilization of rainwater in diked rice fields of medium lands in eastern region – A case study

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Abstract

The present study deals with the intervention to enhance the land and water productivity and cropping intensity through multiple-use management of the harvested rainwater. The research was focused on the conservation of rainwater and adoption of integrated rice-based farming systems at five farmers' fields, located in the medium lands at Sadeiberini village of Dhenkanal district, Orissa (Lat. 20°58′ N and Long. 83°51′ E) for three consecutive years (2001-02 to 2003-04). Each plot was provided with broad-crested rectangular weir as partition dike between farm pond and rice field to allow excess rainwater to spill from rice field to farm pond. The method attributed to significant improvement in rice yield with BC ration of 2.65 to 2.70.

Introduction

Rainwater harvesting is an age-old technique practiced by our ancestors since ages. This practice of rainwater harvesting can be felt from the existence of farm ponds in every villages of our country. The requirement is to properly design and manage these ponds in a scientific manner. The importance of rainwater harvesting has increased very much with ever increasing demand for water from different competing sectors like agriculture, domestic and industry. Further, the importance of rainwater harvesting is gaining importance as in certain pockets there is depletion of groundwater level due to its overexploitation. Significant amount of rainfall is lost as surface runoff during the monsoon, causing substantial loss of soil. Due to this, the sedimentation of reservoirs is taking place at a faster rate. Rainwater harvesting not only reduces runoff and soil loss, but also facilitates groundwater recharge. It also prevents early sedimentation of the reservoirs. The rainwater harvesting and groundwater recharge enables farmers to provide supplementary irrigation to the *kharif* crops and also to go for the second crop during the dry season. Therefore, it is desirable to harvest as much of rainwater to avoid water scarcity.

The eastern region of the country is blessed with a plenty of rainfall. Bulk of this rain (about 80%) occurs during monsoon. During this period, about 50% of the annual rainfall comes from a few intense storms (Pisharoty, 1990). Water received from such intense storms is subjected to high runoff losses (Pal *et al.,* 1994). Added to this, is the erratic nature of the onset, distribution and the withdrawal of rains, which increases the probability of water stress at various crop growth stages of rice (Bhuiyan and Goonasekera, 1988). Therefore, the rainfed rice ecosystems (upland, mid land and low lands) have common characteristics of uncertain moisture supply. Field may have too much water, too little water or both within the same cropping season. This is one of the major reasons for which the average productivity of rice crop of eastern region is much less than the country's average rice productivity (Mishra *et al.,* 1998). Further, this region is prone to frequent occurrences of natural calamities such as flood, drought and cyclone, which repeatedly weaken the financial backbone of the farming community. Therefore, to ensure continuous flow of income throughout the year and minimize the risks associated with natural calamities affecting mono-cropping system, rice-based farming system through multiple/cascading use of water seems to be promising and viable technological option. Rice-based integrated farming systems are less risky due to their efficiency, derived from synergism among other components, their diversity of produce and environmental soundness. Although various combinations of integrated farming systems have been introduced worldwide, integrated rice-fish system has shown greater potential, feasibility and efficiency to improve the use of agricultural resources (Mishra and Mohanty, 2004).

In the backdrop of this, the research effort focused here on the conservation of rainwater and adoption of integrated rice-based farming systems in the mid lands. The objective of the intervention was to enhance the land and water productivity and cropping intensity through multiple use management of the harvested rainwater. The rainwater immediately falling over the rice field is conserved through strengthening of bund height around the rice field and providing a surplus weir at the down stream bund of the rice field at an optimal height. The excess rainwater spilling over the weir is further harvested through the provision of a small farm pond constructed in the rice field at its downstream portion. The harvested water in the farm pond is utilized for providing supplemental irrigation in dry spells to the *kharif* rice, rearing of a short duration fish culture of about four to six months, cultivation of light duty crops in the *rabi* and growing of horticultural crops on the embankment of the farm pond.

Methodology

The study was carried out in five farmers' fields, located in the medium lands at Sadeiberini village of Dhenkanal district, Orissa (Lat. $20^{o}58^{/}$ N and Long. $83^{o}51^{/}$ E) for three consecutive years (2001-02 to 2003-04). In the mid lands, each rice plot was provided with a brick masonry broad-crested rectangular weir at the partition dike between the farm pond and the rice field. The length of the weir was kept at about 1 to 1.5 m. Three weir heights of 15 cm; 20 cm and 25 cm were considered as treatments with two replications each (total six plots) for *in-situ* conservation of rainwater in the rice fields. In this process, a portion of rainwater was conserved in the rice field up to the weir crest level (weir height). The excess rainwater above the crest level, was allowed to spill over the weir for further conservation in the farm pond. Though the design area of the farm pond was kept at 10% area of the rice field, farmers initially did not spare that much area for farm pond. Therefore, at the downstream end of each plot, a farm pond was constructed, approximately occupying 5-8% of the individual plot size to harvest the excess rainwater during heavy downpour. The average depth of the farm pond was kept at 1.75 m with a side slope of 1:1. The top width of the embankment of the farm pond was kept 1 m. The excess water from the farm pond was drained out through a hume pipe (fixed at weir crest level) with fine-meshed net to prevent escape of fish (Mishra *et al.,* 2003). Schematic diagram of the farm pond with rice field and surplus weir is shown in Fig. 1.

During the rainy season, 'Saruchinamali' (farmer's choice, a traditional local variety),

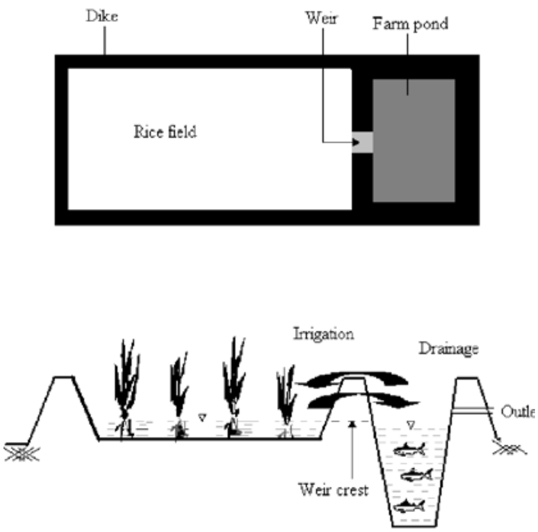

Figure 1. Schematic diagram of water harvesting through farm pond and optimum dike height in rice fields of rainfed medium lands.

'Jagannath' and 'Moti' (high yielding) cultivars of rice were grown. Transplanting of the rice was carried out during 3rd to 4th week of July with a spacing of 20 x 10 cm. Chemical fertilizer at 80:40:40 (N: P: K) kg/ha was applied in three split doses along with bio-fertilizer (*Azosprillum*). On the embankment of the farm pond, horticultural crops such as Banana, Papaya, drum stick, French bean etc. were grown. During the *rabi* season, farmers grew winter crops such as *rabi* rice ('Lalat' and 'MW-10'), ladies finger (*Hibiscus esculentus* L.), greengram (*Phaseolus radiatus* L.), blackgram (*P. mungo* L) and watermelon, etc., using the harvested rainwater from farm ponds. Fish and prawn were reared in the farm ponds seven days after first manuring and fertilization. Early fingerlings (<1.5 gm size) of *Catla, Labeo rohita, Cirrhinus mrigala* and *Cyprinus carpio* were stocked with a species composition of 30:30:20:20, respectively. Stocking density of 20,000 fingerlings/ha was maintained in all the treatments and rearing continued for about 180 days (3rd week of August – 3rd week of February).

Results and Discussion

Rainwater Conservation and Management

In 2001, rainfall of 1535 mm and 1420 mm were received during the entire year and rainy season, respectively. In this year, an unusual rainfall during July amounting to 719 mm (2.2 times than that of 20 years average value) had occurred. In spite of heavy rainfall during July and subsequent scanty rainfall during August and September, water levels in the farm ponds were observed to be sufficiently high till the end of February 2002 (Table 1). In the year 2002, rainfall of 728 mm and 543 mm was received during the entire year and rainy season, respectively. Similarly, in 2003, rainfall of 1572.5 mm and 1451.5 mm was received during the entire year and rainy season, respectively. Twenty years average annual rainfall and rainy season's rainfall are 1415 and 1226 mm, respectively. Thus, the first and third years' experiments were excess rainfall years and the second year was a drought year. Amongst these two excess rainfall years, the monsoon rain was well distributed in 2003 and was poorly distributed in 2001. However, in all these extreme cases, the water levels in the farm ponds were observed to be sufficient enough (>1 m most of the period) till the end of February. This enabled the farmers to successfully rear the fish for a period of about six months. After the harvest of fish in February, on an average 1 m depth availability of water in the farm pond (farm ponds occupying 5 to 8% area of each field) provided about 7 cm depth of irrigation water to rest of the area for the *rabi* crops. Out of the three experimental years, 2002-03 being a drought

Table 1. Average depth of standing water (m) in the farm ponds in different years								
Weir height, cm	Year	August	Sept	Oct	Nov	Dec	Jan	Feb
15	2001-02	1.70	1.70	1.71	1.69	1.66	1.62	1.63
	2002-03	1.10	1.08	1.07	1.05	1.02	1.03	1.02
	2003-04	1.21	1.20	1.20	1.19	1.16	1.17	1.15
	Average	1.34	1.33	1.33	1.31	1.28	1.27	1.27
20	2001-02	1.58	1.43	1.45	1.31	1.24	1.17	1.18
	2002-03	1.28	1.24	1.09	0.89	0.79	0.74	0.65
	2003-04	1.62	1.57	1.54	1.53	1.43	1.40	1.36
	Average	1.49	1.41	1.36	1.24	1.15	1.10	1.06
25	2001-02	1.62	1.61	1.59	1.54	1.47	1.39	1.38
	2002-03	1.22	1.16	1.05	0.93	0.87	0.81	0.74
	2003-04	1.60	1.59	1.58	1.56	1.48	1.40	1.38
	Average	1.48	1.45	1.41	1.34	1.27	1.20	1.17

year, the farmers could grow paddy during the monsoon using the stored water from the farm ponds as life saving irrigations. They could also successfully carryout fish culture in the farm ponds. In this drought year, the stored water depths in all the farm ponds and pond were lower in comparison to other two experimental years.

Kharif crop Growth and Yield

Table 2 presents the treatment wise and variety wise average yields and yield attributes of the rainy season's rice crop. Highest grain yield of 5.3 t/ha was obtained in 20 cm weir height plots. Highest panicle/m^2 was observed in 15 cm weir height plots, followed by 20 cm weir height. Similarly,

Table 2. Average yield attributes and yield of *kharif* rice (2001-02 to 2003-04)			
Weir height (treatment)	Panicles/ m^2	No of filled grains/ panicle	Grain yield (t/ha)
15 cm	272.1	140.8	4.59
20 cm	267.6	143.9	5.30
25 cm	257.9	150.3	4.83
CD (0.05)	NS	NS	0.556
Rice variety			
Saruchinamali	238.4	131.2	4.12
Moti	272.3	147.4	4.7
Jagannath	286.8	156.4	5.91
CD (0.05)	NS	NS	0.382

the highest-filled grains per panicle were obtained in 25 cm weir height, followed by 20 cm weir height. The variation of both the yield attributes at different weir heights were found to be statistically non significant. Perusal of individual years' yield data infers that due to sufficient rainfall in first and third years of experimentation, maximum yield of rice was recorded in the 20 cm weir height plot. However, in the second year (drought year) the highest yield was recorded in the 25 cm weir height plot. This clearly indicates the effect of *in-situ* conservation of rainwater as a function of weir height on crop growth and yield. Among varieties, Jagannath recorded the highest grain yield (5.91 t/ha), followed by Moti (4.7 t/ha) and Saruchinamali (4.12 t/ha). This was primarily due to the highest number panicles/m^2 and filled grains/panicle. Thus, from highest grain yield point of view, 20 cm weir height may be considered as the optimum height for the study site to have two-stage rainwater conservation.

Rabi Crop

In the first year (2001-02 *rabi*), two rice varieties i.e. MW-10 and Lalat were grown and they recorded yield of 2.34 t/ha and 2.70 t/ha, respectively. Ladies finger was also grown in the same year, which resulted in a productivity of 1.85 t/ha. In the second year, the rice variety MW-10 recorded 3.5 t/ha grain yield. In this year, rationing was practiced in Savitri and Durga varieties of rice. Savitri resulted in good productivity (2.73 t/ha). Pulses such as black gram and green gram were cultivated in the second year, which registered pod yield of 0.34 t/ha and 0.45 t/ha, respectively. In the third year, rice varieties MW-10 and Lalat yielded 1.23 t/ha and 1.3 t/ha, respectively. Black gram and green gram were also grown in the third year, which resulted in better yield compared to that in the previous year.

Horticulture on the Embankment

On the embankment of the farm ponds, dwarf variety of papaya, banana and drum stick were grown at a spacing of 1 to 1.5 m. Irrigation to these plants was given using the harvested rainwater from the farm ponds. Among these three horticultural plants, banana performed the best in terms of yield and survival. These plants (specifically drum stick) were subjected to severe damage by cattle grazing in the *rabi* and summer because of adjacent fallow fields of other farmers in that locality. The yield of banana and papaya was 1600 kg/ha and 200 bunch/ha, respectively.

Cropping Intensity

Before the intervention, the *kharif* rice was the only crop grown in the study site. The harvested rainwater from the farm pond was utilized for growing a second crop which has resulted in increasing the cropping intensity of the site from 100% to 131%, 176% and 200% in the 1st, 2nd and 3rd year of the experiment, respectively. In the very first year of experiment, the farmers were not much interested to go for a second crop. Motivation and benefit from the second crop, gradually developed interest among the farmers to bring more area under cultivation during the *rabi*. That is how in the third year of the experiment, the entire area was brought under double cropping.

Growth Performance and Yield of Fish

Irrespective of stocking density, faster growth rate was recorded for *C. carpio* followed by *Catla* and *C. mrigala* during 180 days of culture. Average daily growth rate decreased with increase in weir height that reduces water availability in the farm pond. Overall survival rate (inclusive of all species) was high in the farm pond with 15 cm weir height, while species-wise, no such trend was observed among the treatments. Fish yield in terms of production (kg ha^{-1} 180 $days^{-1}$) in 15 cm weir height farm pond (1693.6) was however, significantly higher ($p<0.05$) than the yield in the 20 cm and 25 cm weir height farm ponds. However, there was no significant difference between yields of farm ponds of 20 cm (1265.3) and 25 cm weir height (1279.4) (Table 3).

Rice Equivalent Yield

Considering the sale price of rice as Rs. 4.00/kg and fish as Rs. 40.00/kg, the rice equivalent yield (REY) for all three treatments in medium land was calculated (Table 4). The highest rice equivalent yield was recorded in 20 cm weir height plots (5.74 t/ha), followed by 25 cm weir height plots (5.44 t/ha). The bench mark survey of the study site revealed that before the interventions, the average yield of rice was 1.8 t/ha. Thus, there is a 3.2 fold increase in the land productivity due to efficient and multiple use of the conserved rainwater and scientific crop management practices.

Water Productivity

The total water utilized per ha (average of three treatments) was estimated at 8204.5 m^3. Considering the selling price of rice, fish, banana, papaya, black/green gram and ladies finger at Rs. 4, 40, 50/bunch, 4, 15 and 7/kg, respectively (in the base year 2004), the net returns from mono-crop rice, rice + fish, rice + fish + embankment horticulture and rice + fish + embankment horticulture + *rabi* crop were calculated. The economic index of gross water productivity was computed as 2.76, 2.94, 4.94 and 5.87 Rs/m^3 for mono-crop rice, rice + fish, rice + fish + embankment horticulture, rice + fish + embankment horticulture + *rabi* crops, respectively. Similarly, the economic index of net water productivity for different farming systems were computed as 2.06, 2.17, 3.07, and 3.76 Rs/m^3 for mono-crop rice, rice + fish, rice + fish + embankment horticulture, rice + fish + embankment horticulture + *rabi* crops, respectively. The percentage increase in net water productivity for rice + fish, rice + fish + embankment horticulture and rice + fish + embankment horticulture + *rabi* crop over mono-cropped rice was 5.34%,

Table 3. Fish yield (kg/ha) from farm ponds in different years

Weir height	1st year	2nd year	3rd year	Pooled
15 cm	1232.40	1988.80	1859.60	1693.60
20 cm	1004.8	1553.00	1238.10	1265.30
25 cm	1109.90	1478.35	1250.00	1279.40

Table 4. Rice equivalent yield

Weir height	Rice area (m^2)	Farm pond area (m^2)	Total area (m^2)	Rice yield (t/ha)	Fish yield (kg/ha)	REY, (t/ha)
15 cm	3202.4	171	3373.4	4.6	1694	5.23
20 cm	4595.2	294	4889.2	5.3	1265	5.74
25 cm	2217.2	184	2401.2	4.83	1279	5.44

49.03% and 82.52%, respectively. Thus, the highest water productivity in rice + fish + embankment horticulture + *rabi* crop combination indicates the most efficient and multiple use of conserved rainwater, which has almost doubled the water productivity over mono-cropped rice.

Economics

The highest gross returns of Rs. 46,238 and net returns of Rs. 29,617 were recorded with 20 cm weir height, followed by 25 cm weir height (Table 5). The highest benefit cost ratio of 2.78 was obtained with 20 cm weir height, followed by a ratio of 2.70 with 25 cm weir height. The cost difference between different weir heights was not significant; hence it was not taken into consideration. The gross returns were calculated by adding the returns generated from *kharif* rice, fish and *rabi* crops. The returns from banana and papaya were also included. The above cost benefit was calculated for the base year of 2004.

Lessons Learnt

In the rainfed medium land, *in-situ* and *ex-situ* conservation of rainwater through provision of optimum dike height and farm pond, respectively observed to be a viable solution in harvesting the rainwater in diked rice fields. Individual farmers can make this intervention (construction) in their own field with a little training. This is suitable for small and marginal farmers. Efficient and multiple use management of harvested water have been successfully demonstrated in the farmers' fields. Supplemental irrigation to the *kharif* rice during dry spells, short-duration pisciculture in the farm ponds, horticulture on the farm pond embankment and cultivation of light duty *rabi* crops have been successfully tried in the farmers' field. This has resulted in significant increase in the crop yield, cropping intensity and net return. The dual production system (rice and fish) in the *kharif*, perennial horticulture and light duty *rabi* crops generate additional income, employment opportunity and nutritional security. In addition, this also minimizes the risks due to natural calamities. The system is eco-friendly and promotes synergism between different components.

This technology can be successfully implemented in large areas. Selection of the appropriate area (medium and shallow low land) for its implementation is extremely important. Sporadic application of this technology will lead to problems like cattle grazing in the *rabi* season and poaching of fish from farm ponds. Hence, it is recommended to adopt this technology in relatively large patches to avoid these problems. Further, if high duty crops are to be grown in the *rabi*, then more area needs to be put under farm pond.

Strategies for up scaling

Individual farmers can implement this technique of rainwater harvesting in their

Table 5. Benefit cost ratio of the farming system (three year's average)

Weir height	Gross returns (Rs./ha)	Cost of cultivation (Rs./ha)	Net returns (Rs./ ha)	B:C ratio
15 cm	43,990	16,620	27,370	2.65
20 cm	46,240	16,620	29,620	2.78
25 cm	44,830	16,620	28,210	2.70

own field. In the state of Orissa, this technology has been given to the Watershed Mission, Government of Orissa which is implementing it in large scale through various watershed development schemes. This has become one of the very popular water conservation measures in the watershed development schemes. Other states having similar areas can implement it through various watershed development schemes.

References

Bhuiyan SI and Goonasekera K. (1988) "Rainwater management for increasing production of rice and upland crops." Paper presented at the International Rice Research Conference, IRRI, Los Banos, Philippines.

Mishra A, Ghorai AK and Singh SR (1998) "Rainwater, soil and nutrient conservation in rainfed rice lands in Eastern India." *Agricultural Water Management.* 38: 45-57.

Mishra A and Mohanty RK. (2004) "Productivity enhancement through rice-fish farming using a two-stage rainwater conservation technique". *Agricultural Water Management*, 67:119-131.

Mishra A, Mohanty RK, Kannan K, James BK and Nanda P. (2003) "Rainwater conservation and management for integrated rice (*Oryza sativa*)-fish farming in the rainfed medium and low land ecosystems". *Indian Journal of Agricultural Sciences* (ICAR), 73(11): 605-608.

Pal AR, Rathore AL and Pandey VK. (1994) "On-farm rainwater storage systems for improving riceland productivity in eastern India: opportunities and challenges". In: On-farm Reservoir Systems for Rainfed Ricelands (S.I. Bhuiyan eds.), IRRI, Los Banos, Philippines, 105-125.

Pisharoty PR. (1990) "Indian rainfall and water conservation. Proc. of the All India seminar on modern techniques of rainwater harvesting, water conservation and artificial recharge for drinking water, aforestation, horticulture and agriculture". Directorate of Groundwater Surveys and Development Agency. Rural Development Department, Govt. of Maharashtra, India, 55-53.

Rainwater harvesting through farm ponds & shallow dug wells and reuse through paddle operated low lift pump in Bastar region of Chhattisgarh

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Abstract

The tribal-dominated Bastar region of Chhattisgarh, has only 2.5 % double-cropped area whereas the rainfall is quite high (1200-1400 mm) with excellent potential of water harvesting (550-650 mm surplus). The harvesting of water is attempted through several government schemes (DPAP, IWDP, NREGP) with limited success. Site selection for pond construction is one of the major issues for the limited success of this technology. It is important to have a series of ponds in proper places, so that soil the moisture and water availability in relatively large areas (25-50 ha) can be enhanced and the effect sustained. Further, the utilization of harvested water remains a critical issue as most of it is not being used for cultivation. Major issues are lifting of water, adoption of suitable irrigation methods and selection of crops/ cropping systems, as the quantity of water is limited in ponds. We established a model, of series of ponds to harvest runoff in considerably large area (50 ha). Dug wells were made in between these ponds and are used for trapping the seepage water and using it for irrigation / storage in ponds. Peddle operated low lift pumps were provided to farmers for lifting the water from ponds and plastic pipes for water distribution. The financial support of NREGP was provided to farmers through *zilla panchayat* of Bastar for construction of six ponds. The model helped in bringing 1.5 to 2.0 acres of land with each pond under vegetable cultivation in the *rabi* season, which was previously left fallow besides stabilizing rice yield in *kharif* season (12-15 % yield increase). Most of the farmers have shown interest in intensifying the work of water harvesting and reuse in the future. The quantity of water harvested became a limiting factor. Linking pond-low lift pump model with low-pressure drip system can be very effective in this regard.

Target Domain

The work is carried out in the Bastar region of Chhattisgarh. The state of Chhattisgarh occupies 13.77 Mha with a gross cropped area of 5.8 Mha. It is divided into 16 administrative districts and three agro-climatic zones namely Bastar plateau, Chhattisgarh plains and northern hills. Bastar, where the work is carried out is located in the southern part of Chhattisgarh, occupying 39.06 thousand sq. km area and divided in to five districts.

The area is situated between $17^0 46'$ to $20^0 34'$ North latitude and $80^0 15'$ to $82^0 15'$ East longitude with altitude ranging from 550-760m above mean sea level (MSL). The zone is surrounded by Koraput district of Orissa state on Eastern side, Warangal and Khammam districts of Andhra Pradesh on southern

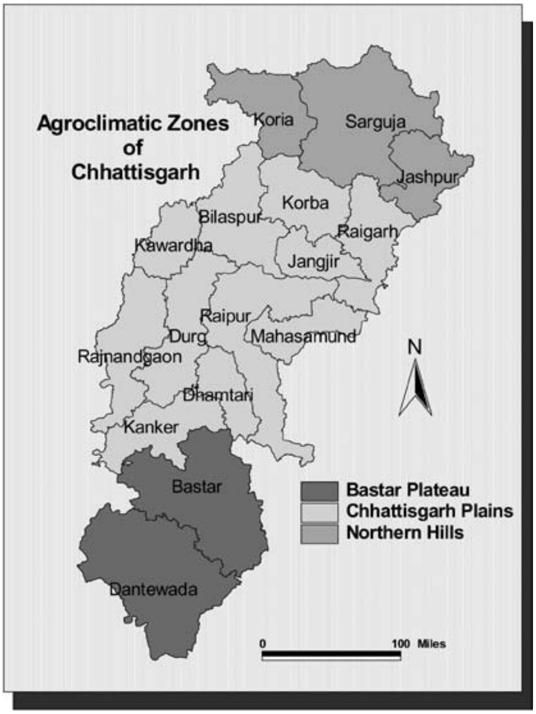

Figure 1. Location Map of Bastar Plateau

side, Chandrapur district of Maharashtra state on western side, Rajanandgaon, Durg and Raipur districts of Chhattisgarh state at Northern boundary of the zone.

About 97 percent-cultivated area of Bastar plateau is rainfed. The cropping intensity of the region is 104 per cent. Its elevation ranges from 300 to 600 above MSL. It receives rainfall mainly through southwest monsoon. The rainfall varies from 1200-1600 mm. The zone is dominated with tribal population, which accounts about 67% of the total population. The economic condition of the tribal farmers is very poor, in general and most of them are small farmers with fragmented land holdings. Rice is the major crop of the region. Other important crops are minor millets, maize, horse gram, niger, toria, vegetables and fruit crops. Farmers adopt traditional methods of cultivation with no or a little use of fertilizers and plant protection measures. Irrigation facilities are negligible (about 3% of the cultivated area) hence mono cropping "rice-fallow" is in prevalence.

Climate and Rainfall

The climate is sub-humid type with an average rainfall of about 1400 mm. The rainfall in Bastar is the highest with stability (Table 1). There is a considerable spatial variability in the distribution of coefficient of variation in different districts. The highest coefficient of variation (%) of annual rainfall is in Kanker.

Climate Water Balance

The actual evapotranspiration shows spatial variability in different districts. The surplus water is highest in Bastar. This variability of surplus water is due to soil and rainfall variability. The period of surplus water begins in mid July. This gives a general idea about the time and amount of rainwater that can be harvested in different cropped area to alleviate the drought conditions. The water deficit conditions start from the mid October.

Water Availability Periods

The water availability periods are the periods where the rainfall is balanced against the evaporative demand of the atmosphere, which is called "potential evapotranspiration". When rainfall is more than potential evapotranspiration, it is called humid period. When rainfall is less than potential evapotranspiration but it is more than half of PET is called moist period. The moist period occurs twice in a year, that is, prior to and immediately after the humid period. The highest LGP is observed in the Bastar district.

Table 1. The district wise annual rainfall, seasonal rainfall, annual rainy days and seasonal rainy days in Bastar

Station name	Annual rainfall (mm)	CV (%)	Seasonal rainfall (mm)	Annual rainy days	Seasonal rainy days	CV (%)
Kanker	1371	28.6	1061	68	53	12.6
Bastar	1570	20.4	1218	83	63	13.8
Dantewara	1412	23.5	1172	76	62	17.8

Table 2. Dates of beginning of water surplus, water deficit period and annual amount of AET, surplus and deficit in Bastar region

District	Rainfall (mm)	AET (mm)	Water surplus		Water deficit	
			Amount	Starting period	Amount	Starting period
Kanker	1371.0	739.4	586.7	17 July	733.2	15 Oct.
Bastar	1570.4	823.6	652.3	21 July	649.0	20 Oct.
Dantewara	1412.2	754.1	577.0	19 July	718.5	12 Oct.

Table 3. Water availability period for different stations in Chhattisgarh

Station name	Moist-I	Humid	Moist-II	L.G. P.
Kanker	10-25 June (16)	26 June-24 Oct (121)	25 Oct-10 Nov (17)	154
Bastar	6-18 June (13)	19 June-28 Oct (132)	29 Oct-20 Nov (23)	168
Dantewara	18-30 June (13)	1 July-26 Oct (118)	21 Oct-5 Nov (16)	147

On Farm Site

The site is located in Village Tahakapal in Tokapal block of Bastar district. It represents the typical undulating topography of the region (Fig 2). Bastar plateau Zone has peculiar land topography. On the basis of land topography, soil types and its physio-chemical properties, five major farming situations are identified. On top is upper upland (*Marhan*), followed by lower uplands (*Tikra*), midland (*Mal)* and lowland (*Gabhar) at the valley bottom*. When upper upland is protected, it is called homestead garden (*Badi*). The forest is on the upper side. The uplands consist of 55% area, followed by 25% mid and 20% lowlands. Due to lack of *in-situ* moisture conservation measures like deep ploughing, contour cultivation, inclusion of cover crops, use of organic manures, etc., most of the precipitation is not conserved properly. Approximately 70 to 75% precipitation is being flown through drainage lines in the form of runoff. This results in severe erosion in the uplands. This excess flowing water is to be trapped by formulating such technologies by which the water can be reused through sustainable approach.

Table 4. Farming situations of Bastar region of Chhatisgarh			
Sl. No	**Farming situation**	**Area (% of Cultivated)**	**Characteristics**
1.	Homestead garden (Badi)	5	Protected, situated on the top of landscape close to homestead. Have light and well-drained soils, rich in organic matter. Early maize-mustard (toria) is the most common crop sequence; tuber crops. Sulphi-palm, vegetables are also grown.
2.	Upper upland (*Marhan*)	28	Situated down the slope next to Badi. Have coarse textured, shallow and infertile soils. Extra early varieties of paddy, small millets like kodo, kutki, sama and mid season crops like niger and horse gram are grown.
3.	Lower upland (*Tikra)*	26	Situated next to Marhan down the slope. Have relatively better and moisture retentive soils. Upland paddy, small millets, horse gram and niger are grown.
4.	Midland (*Mal)*	21	This occurs below Tikra lands. Suitable for rice (generally bunded).
5.	Lowland (*Gabhar)*	20	Occurs on valley part of topo sequence. Fields are bunded and have fertile soils. Rice is the main crop.

Figure 2. Farming Situations in Bastar Plateau Zone

Technology

A series of eight farm ponds were constructed in lowland situation so that the runoff water can be trapped and stored in different points following the natural drain line of the area with the aim to conserve surplus flowing water (Fig 3). The size of the farm ponds varied from small to large depending upon the runoff contributing area and area spared by the farmer. In the region like Bastar where rainfall and surplus water is high it is not possible to determine the pond size only on the basis of water availability. Series of 8 ponds were constructed following the natural drain line and covering a command area of 50.0 ha. The total cost of excavation was Rs 6.317 lakh with the support from National Rural Employment Guarantee Act (NREGA) during the financial year 2007-08. Shallow dug wells were also constructed to harvest the seepage water from the ponds and thus trying to conserve and utilize the maximum amount of rainwater in the harvested form. The average depth of shallow dug wells was kept 15 feet. The total volume of water stored in 7 ponds of 30X35X3 M^3 size and one pond of 65X60X3 M^3 with total water harvesting capacity of 33750 cum. The ponds were scientifically constructed with proper designing of inlet opening for tapping the surplus water and outlet for discharging of excess water. The embankments of the excavated farm ponds were maintained at 1:4 side slopes and were neatly dressed.

The dug wells were used in between and near the ponds so as to tap the seepage water from the excavated farm ponds (Fig 4). The farmers were given paddle operated low lift pumps for use in ponds and dug wells. This tool is very economic and can be afforded by most of the farmers. The cost of low lift pump is Rs 1929/- only with appropriate subsidy from the government under different schemes. The water harvesting techniques are adopted by various developmental agencies through watershed and other panchayat activities but without the proper implementation of reuse technologies of this harvested water, it is treated as waste of precious land. So for encouraging double cropping system

Figure 3. Series of ponds and Dug wells for Water Harvesting

Figure 4. Shallow dug wells and Farm ponds following the natural drain line

by promoting low cost irrigation system in the rainfed areas like Bastar, paddle-operated low lift pump was distributed among the farmers. After decline in the water level of pond an innovative idea of two-stage lifting was also tested. The farmer lifted water from dug well to pond in first and in second stage the water is lifted from pond for irrigating vegetable crop.

Results and Discussion

Runoff from cropped and fallow lands is harvested in small farm ponds in the low lands of a marginal farmer, Sh. Sampat of village Tahkapal, Post- Chhaparbhanpuri, Tehsil-Tokapal, District-Bastar (C.G.). A pond of 30 X 30 X 3 m size was dug in the field of Sh. Sampat with water storing capacity of About 3150 m^3 in one season from the runoff collected from the upper side of the farmland followed by a existing shallow dug well near to the pond for tapping the seepage lose from the farm pond. Paddle operated low lift pump was provided to him for encouraging to take up second crop cultivation by reusing the stored water from the farm pond (Fig 5). The paddle operated low lift pump is a low cost, maintenance free, manually operated pump with a discharge capacity of about 3000-4000 liters/hr from a suction depth of 10-12 ft. The pump is very lightweight and easy to install and operate. One woman or even a child of above 14 yrs of age can operate this pump for more than 2 ½ hrs/day, leading to a supply of about 0.7 acre-cm of water per day for eight hours of working.

Figure 5. Irrigation from Pond-Low lift pump

With farm pond and low lift pump, the farmer is able to grow crops in the *rabi* season, which was otherwise left fallow. He could cultivate 1.5 acre of land to grow cauliflower, tomato (Pusa ruby), onion (Royal Selection), radish, coriander (Selection-81), spinach *palaksag* and lalbhaji) in the *rabi* season after the crop of paddy. A yield of 22274 Kg/ha of cauliflower, 12302 kg/ha of tomato, 12129 kg/ha of onion, 6738.5 kg/ha of radish, 1752 kg/ha of spinach *palaksag*, 1617 kg/ha of lalbhaji and 1887 kg/ha of coriander were obtained. Growing of vegetables in the *rabi* season could give returns of Rs 65765/- from 1.5 ac of land by efficiently utilizing harvested water through paddle operated low lift pump. A 12.5% increase in the yield of paddy (2.25 q/ha) is also experienced due to better moisture availability. The net returns obtained by adoption of this technology are 10.44 times higher.

Lessons Learnt

The technologies used in this case like farm ponds, dug wells, low lift pumps and vegetable cultivation are already available and are not new. However, it is important how these technologies are linked in an area into a successful model. Further, water harvesting structures require initial capital investment and hence farmers are reluctant to adopt. The government has started several schemes but most of the farmers do not

Table 5. Yield data of different crops at the project site (0.55 ha cultivated area)

Crop	Yield (kg) Without farm pond-Low lift pump	Yield (kg) With farm pond-Low lift pump Technique	Income (Rs)	
			Before using low lift pump	After using low lift pump
Paddy (*Kharif*)	964	1102	8194	9367
Cauliflower	--	5230	--	41840
Tomato	--	155	--	775
Onion	--	1800	--	23400
Radish	--	250	--	2000
Spinach	---	70	---	1750
Lalbhaji	--	65	--	520
Coriander	--	60	--	480
Total Output	--		8194	80132
Cost of Cultivation*	--		1000	5000
Net income	--		7194	75132
Additional income generated	--			**67938**

* Excluding labor cost since family labor is involved.

know about these schemes. It is observed that the financial institutions (*zilla panchayat*) have funds but do not have technical expertise for program planning. Similarly, the extension departments are not able to mobilize communities for large-scale adoption of technologies as an area action plan. Establishment of synergy between financial institution, extension agencies and research organization is very essential.

Strategies for upscaling

The technology can be adopted / upscaled in Bastar, Narayanpur, Dantewada, Bijapur and Kanker districts of this region where the landscape is undulating plateau with high rainfall in the *kharif* season. This technology can be used in midland and lowland farming situations. Existing practice in this area is mono cropping of rice, millets and maize, the *Rabi* season being fallow. There are perennial streams and good soil moisture availability in lowlands. The lowlands have great potential of water harvesting and utilization. However, due to lack of suitable technology and awareness farmers are not able to take advantage.

The financial support from NREGA was used with the help from *zilla panchayat,* Bastar, for digging the ponds. It was ensured that human resource from the village itself is employed. This helped in mobilizing the village community towards adoption of water harvesting structures. The low lift pumps are available on subsidy from the department of agriculture. If these funds are properly tapped and social communities are made aware of such facilities, water harvesting and reuse can be given considerable boost.

This technology is suitable for lowland, which is 20% (182800 ha) of cultivated area in Bastar region. If this technology is up-scaled even to 5% area, it is likely to have a large impact on net income of tribal farmers.

References

Bhuiyen SI and Ziegler RS. (1994) On-farm rainwater storage and conservation system for drought alleviation: issues and challenges, in S.I. Bhuiyan (ed), *On-farm Reservoir Systems for Rainfed Ricelands*, IRRI, Los Banos.

Garrity DP. (1992) On-Farm research methods in the uplands: selecting an experimental approach in *Rice Farming Systems Technical Exchange* 2(3), Asian Rice Farming Systems Network (IRRI) and Farming Systems and Soil Resources Institute (UPLB).

Experiences of Water Harvesting through Farm Ponds in Alfisol and Other Related Soil Regions

Farm ponds for a Viable and Profitable Dry Land Agriculture – Experiences in Alfisols of Karnataka

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Abstract

The arable lands in the micro-watersheds in *Alfisols* are more prone to runoff and nutrient losses leads to the degradation of resources and land becoming barren in a few years. Harvesting and recycling of rainwater in dry lands is important in order to improve water use efficiency. Restoration and maintenance of resources in the long-run in micro-watershed requires holistic and continuous management strategies. Dry land Research Center, University of Agricultural Sciences, Bangalore evaluated the alternate use of harvested rainwater for soil and moisture conservation, crop production, and fish farming in predominant *Alfisols* of dry lands. The technology has great influence on the local farmers leading to swift adoption by many of them.

Introduction

Soil and water are the two important critical inputs in dry land agriculture. Land is fixed in supply, which can not multiply but can be managed properly for optimum utilization. Water is another scarce input owing to erratic and poor distribution of rainfall, which limits the production of crops. In this direction, there is a need to emphasize the conservation of these limited resources with appropriate practices. Harvesting and recycling of rainwater in dry lands is important in order to improve water use efficiency (Shankar and Shivakumar, 2005). Farm ponds are small storage structures used for collecting and storing runoff water. The research cum demonstration plots were maintained at Dry land Research Center, University of Agricultural Sciences, Bangalore to evaluate the

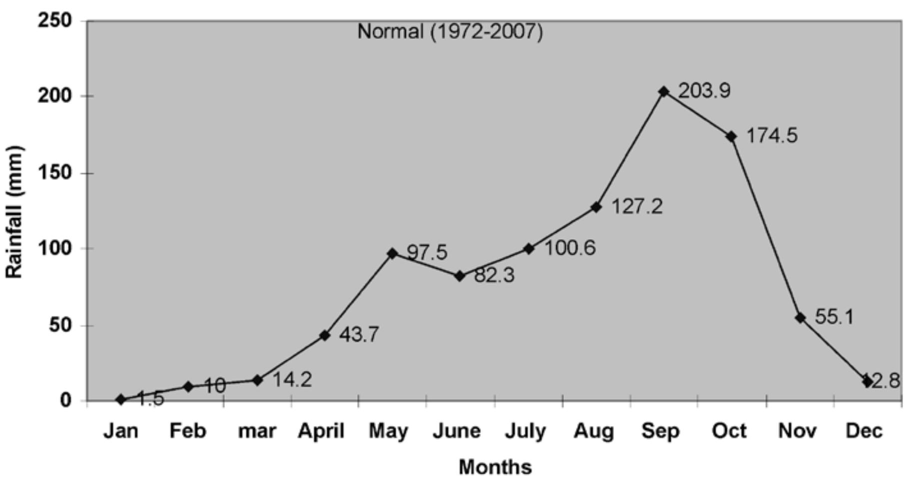

Figure 1. Normal rainfall (1972-2007) received in different months at GKVK, Bangalore

alternate use of harvested rainwater for soil and moisture conservation, crop production, and fish farming.

Restoration and maintenance of resources in the long-run in micro-watershed requires holistic and continuous management strategies. In watershed areas, natural resources were conserved through soil and water conservation methods, compatible crops and cropping systems, inter-terrace management practices and agro-forestry etc. The arable lands in the micro-watersheds in *Alfisols* are more prone to runoff and nutrient losses leads to the degradation of resources and land becoming barren in a few years. Keeping these facts in view, a long-term research cum demonstration experiment was planned at the Land Center, GKVK, Bangalore

Methodology

The soil and water conservation experiment was laid out in non-replicated permanent blocks with varying plot size (2640- 5610 m^2). Horse gram was sown during early *Kharif* and it was incorporated *in situ* as a green manuring crop, followed by a short duration finger millet (100-105 days). In addition to other biometric observations, horse gram biomass yield, finger millet grain yield were recorded at the upper and lower sides of the each block. Each block is separated by about ten years old well established Khus (*Vetivera zizinoides*) and Nase grass (*Pennisetum hoenickeri*) live barriers along contour bunds compared with no live barrier (control). The number of runoff events and soil loss were recorded in each block.

Results

The average annual rainfall (1972-2007) received at dry land agriculture project was 927 mm of which 18.1 per cent (166.7 mm), 55.6 per cent (513.1 mm) and 24.9 per cent (229mm) was received during pre rainy (March- May), rainy (June- September) and post rainy seasons (October-December), respectively. The rainfall was fairly well distributed from March to October with two peaks one in May (97.5 mm) and another in September (203.9 mm). The average number of rainy days is about 62 days in a year.

The experimental results (mean of eight years) indicated that the biomass yield of horse gram was higher in the lower reach as compared to the upper reach in both the live barrier blocks. However, Nase grass proved as effective live barrier in reducing runoff and soil loss than compared to Khus grass (Table 1).

The grain yield of finger millet was influenced by inter-terrace management practices in *Alfisols* of Dryland centre, GKVK, Bangalore. Relatively higher grain and straw yield of finger millet was recorded in lower reaches in both the live barriers as compared to upper reaches. While, Nase grass live barrier is found to be effective in reducing soil loss and improving grain yield of finger millet. The maximum soil moisture retention was observed in Nase live barrier and Khus live barriers as compared to the untreated block. The decrease in grain yield of finger millet in untreated block was up to 35 and 43 per cent over Khus and Nase grass live barrier, respectively during eight years (Table 2). The long-term experimental data indicated that Nase grass, as live barrier is effective to reduce runoff and soil loss. *In-situ* incorporation of early *Kharif* sown horse gram followed by short duration finger millet is considered as sustainable practice for improving soil and crop productivity in drylands.

Results indicated that the soil + cement (8:1) lining with 5 cm thickness was found to be better in reducing seepage loss even though initial cost was higher (Somashekara *et al.,* 2003). Further, the combined seepage and evaporation losses were of the order of 28.5-26.2 mm/day for 0-1 m head of water, 63.6 mm/day in 1.0 to 2.0 m head of water (Table 3).

Table 1. Horse gram Biomass as influenced by inter-terrace management practices

Treatments	Horse gram biomass yield (kg/ha)					
	2004-05	**2005-06**	**2006-07**	**2007-08**	**2008-09**	**Mean**
Khus grass live barrier						
Upper	7000	8000	17330	12590	11100	11210
Lower	7800	9930	22470	14430	12800	13480
Mean	7400	8970	19900	13510	11950	12340
Nase grass live barrier						
Upper	7000	6630	20600	13870	11300	11880
Lower	8200	9970	20330	16450	13600	13710
Mean	7900	8300	20470	15160	12450	12860
Control	5600	6000	15530	8690	9600	9080

Table 2. Grain and straw yield of finger millet as influenced by inter-terrace management practices (1999-2008)

Treatments	**Grain (kg/ha)**	**Straw (kg/ha)**
Khus grass live barrier		
Upper	2530	4700
Lower	2720	6370
Mean	2630	5540
Nase grass live barrier		
Upper	2530	4450
Lower	2980	6060
Mean	2770	5250
Control	1930	2570

Table 3. Seepage losses in field size farm ponds

Head (m)	**Combined seepage and evaporation losses in lined farm Pond (mm/day)**
0.0-1.0	28.5
1.0-2.0	63.6
2.0-3.0	96.0
Small catchment (Cultivated area)	
0.0-0.05	
0.5-1.0	26.23
1.0-1.5	36.56
1.5-2.0	47.87
2.0-2.5	91.33

Double Cropping System with Protective Irrigation

Alfisols in the dry lands of Karnataka are 'thirsty and hungry' for natural resources and suffer from intermittent drought. The rainfall received in two peaks is maximum during south-west monsoon (Aug-Sept) with an average annual rainfall of 927 mm distributed in 62 rainy days. The number of rainfall events, which cause runoff, varied from 25-30, depending upon the intensity and duration of continuous rainy days. The runoff water collected in farm pond could be utilized for protective irrigation during the dry spells. We found that early sowing of the fodder crops, followed by chilli with protective irrigation during the dry spells improved the system productivity under rainfed eco-system.

A field experiment to study enhanced cropping intensity was conducted from 2000 to 2007 during *Kharif* at Dry Land Center, GKVK, Eastern Dry Zone of Karnataka. The experiment was laid out in split plot design involving three forage crops and two chilli varieties at two fertility levels. The results showed a high palatability of sweet sorghum as compared to other fodder species. Chilli crop was transplanted soon after the harvest of forage crops (65-70 days old) during last week of July or first week of August. Two protective irrigations

Table 4. Double cropping of forage crops followed by transplanted chilli under *Kharif* rainfed situation with protective irrigation during dry spells utilizing farm pond water (Mean of 8 years)

Treatments	Green forage yield (t/ha)	Mean fruit yield (g/plant)	Mean fruit No. per plant	Fruit length (cm)	Dry chilli yield (kg/ha)
Main plot (Forage cropping) A					
S.A. Maize (M_1)	21.6	24.8	14.3	7.1	920
Sweet Sorghum (M_2)	13.4	21.6	13.1	7.5	830
Giant bajra (M_3)	28.2	27.8	15.7	7.9	760
S.Em.±	0.56	5.82	0.83	0.55	30
C.D. (p=0.05)	1.55	NS	2.30	NS	90
Sub plot (Chilli varieties) B					
Samrudhi (V_1)		26.3	13.6	7.7	960
Guntur-4 (V_2)		23.2	15.1	7.3	720
S.Em.±		2.67	1.21	0.40	40
C.D. (p=0.05)		NS	NS	NS	90
Sub-Sub plots (Fertilizer Dose) C					
Rec. Fert. Dose (F_1)		26.0	15.1	7.2	900
75% Rec. Fert. Dose (F_2)		23.5	13.6	7.8	780
S.Em.±		2.16	0.71	0.41	25
C.D. (p=0.05)		NS	1.56	NS	55
CV %		16.3	14.9	16.5	9

Figure 2. Giant Bajra

Figure 3. Chilli cv. Samrudhi

(approximately 5 cm depth) were provided during the dry spells in August and September using water from farm ponds.

The results (means of eight years) indicated that excess runoff water collected in farm ponds was utilized to take up double cropping system under dry land conditions. Significantly higher forage yield was recorded in Giant Bajra (28.2 t/ha) as compared to sweet sorghum and South African maize. The quality parameters of forage crops viz., neutral detergent fiber (77%), acid detergent fiber (57.4%) and silica content (9.83 %) were higher in giant bajra whereas, crude protein content (15.64%) was higher in sweet sorghum. Significantly higher dry fruit yields, fruit number per plant and fruit length were recorded in chilli cv. 'Samrudhi' as compared to Guntur-4. Application of the recommended dose of fertilizers out yielded both in forage crops and chilli varieties as compared to 75 per cent of recommended dose of fertilizers. The technology has been accepted for inclusion in the package of practice book of UAS, Bangalore. The technology could be adopted by the dryland farmers wherever there is a facility of storage structures to collect runoff water.

Fish Production

The success of rainfed agriculture depends on the efficient utilization of rainwater with a prime objective "better crop for every rain drop". The *Alfisols* of the region are more prone to all types of erosion, resulting in loss of soil and nutrients accumulated in the water storage structures. Thus, the nutrient rich runoff water could be utilized for production of crops, rearing of fish and livestock under dry land condition. Keeping these facts in view, a study was initiated in 2007-08 to determine the profitability of fish production in farm ponds along with crop production activity. The composite fish culture scientific technology for getting maximum fish production from unit area through stocking of compatible species of fish for rational utilization of natural fish food resources and farm management techniques (Senthivelu *et al*., 2008).

Fish production in ponds was studied with different breeds of fishes viz., Common Carp, Catla, Rohu and Grass Carp fish fingerlings were released in 4:3:2:1 proportion, respectively to big (3200 m^3) and small ponds (180 m^3) (Table 5). It is possible to collect about 32 and 1.8 lakh litres water in big and small farm ponds respectively and could be stored up to four-five months. Water samples were analyzed for sesquioxide and mineral content before and after the fish production. The catchment area for farm

Table 5. Different sized Farm ponds and lining material		
Particulars/Pond dimensions	**Big Farm pond**	**Small Farm pond (Micro-watershed)**
Top dimensions (m)	Length – 35 m Width – 33 m	Length – 10.5 m Width – 10.5 m
Bottom dimensions	L x W – 27 m x 26 m	L x W– 6 m x 6 m
Pond depth	3.5 m	3 m
Farm pond capacity	3200 Cubic mt	180 Cubic mt
Water storage capacity	32 lakh litres	1.8 lakh litres
Lining	Kadapa slab	Soil + Cement (8:1)
Height of lining material	1.2 m	3.0 m
Area of lining	Bottom - 901 Sq. m 4 Sides - 155 Sq. m (34.2 x 2 sides= 68.4 Sq. m & 43.2 x 2 sides= 86.4 Sq. m)	Bottom - 36 Sq. m 4 Sides - 138 Sq. m (34.26 x 4 sides)
Total area lining	1056 Sq. m	175 Sq. m

ponds is from both arable and non arable land. The different lining material tried in small farm ponds are stone slabs, bricks, cement + soil (1:8) and frame work.

Application of lime, organic and inorganic fertilizers is essential to improve the soil condition and supplement the nutrients in the soil and water to ensure adequate and continued supply of fish food organisms. Rate of lime application depends on the soil status. For normal soils lime was applied at 40 kg in 2-3 days before fingerlings released for both the ponds. Initial dose of 120 kg cow dung, 5 kg of super phosphate and 5 kg of urea were applied about 8-10 days before stocking the fingerlings. Thereafter, 10 kg of cow dung, one kg of single super phosphate and one kg of urea were applied every month to maintain good growth of plankton. Every day, ground nut cake and rice bran were applied at the rate of 4 % of the body weight of fishes (Basavaraju, 2002). For crop production activity, corn was grown with two protective irrigations from harvested farm pond water during the dry spells. Observations on fish length and width, fish weight were recorded at different intervals.

A successful fish rearing is possible up to three months in the big farm ponds (35 m x 33 m). Further, the runoff water use efficiency is possible to enhance by adopting drip irrigation and other improved irrigation methods to add value to the harvested water. Results indicated that the growth and development of all types of fishes was normal and each weighed 40-110g during 2007-08 but was harvested before attaining physiological maturity due to recession in water level in the pond (Table 6). By adopting scientific method of fish production, about 50-60 kg in small farm pond (180 m^3) and whereas, 400 kg in big farm pond (3200 m^3) fully matured fishes (6-8 months) depending upon the maintenance of pond water could be harvested. So that, on an average Rs. 2400/- would be the additional income from the activity (Table 7).

During 2007-08, as the water level in the pond depleted earlier, fishes were harvested before attaining maturity. (Seenappa and Khadar Khan, 2008)

Table 6. Mean weight of different breeds of fishes reared in farm pond.			
Fish Breed	**Feeding zone**	**Weight range (g)**	**Mean weight (g)**
Common carp	Bottom	76.8 to 153.4	113.0
Catla	Surface	20.4 to 67.4	40.2
Rohu	Middle	30.6 to 60.4	44.8
Mrigal	Top (grass)	9.6 to 27.3	17.3

Table 7. Economics of fish production: (225 sq. m. area)	
Particulars	**Rs.**
Farm pond preparation (lime and cow dung)	100
Fish fingerlings	150
Fish feed 940 kg@ Rs.7.5/kg)	300
Cow dung 300 kg (Rs. 500/ tonne)	150
Maintenance	200
Total	900
Fish yield 60 kg (Rs.40 /kg)	2400
Net profit (Rs.)	1500

Figure 4. Fish production in farm ponds

Lessons Learnt

Rainwater harvesting is a technology of runoff farming, which is most feasible in dry land areas. The technology of rain-water harvesting is highly location specific. In very low rainfall areas, there is a need to induce runoff by treating the uncultivated catchments with the objectives of its collection in the cropped micro watershed. Nase grass as a live barrier was helpful in reducing runoff and soil loss in the micro watershed. Runoff harvesting in reservoirs and its subsequent recycling for crop production is an essential component of dry land agriculture. The profitable fodder crops and chilli-based double cropping system is possible with protective irrigation with water from the farm ponds. The results are well accepted by farmers at the Operation Research Project sites. The fish culture in dry land areas is technically viable and economically feasible and could be adopted by marginal and small farmers. All the fish breeds performed better in growth and development. Effectiveness of Pisciculture depends on the period of water availability in farm ponds. Normally an area receiving rainfall more than 650 mm annum would be sufficient for fish production.

Strategies for Up-scaling

Realizing the importance of farm ponds, the Karnataka state government in its golden jubilee celebrations has announced a scheme popularly known as “Suvarna Krishi Honda” to motivate farmers by giving 50 per cent subsidy.

Farm ponds are the effective water storage structure to collect the excess runoff water, in the areas receiving 650 mm or more rainfall and pisciculture could be successfully taken up so that farmers were benefited by additional income of at least Rs. 2,000/- to 2,500/-.

Scarcity of fodder could be overcome by growing fodder crops in the early *kharif* and chilli/vegetable crops could be raised by giving 2-3 protective irrigations using water stored in the farm pond.

Different lining materials for farm pond construction could be used from the locally available resources in order to reduce the cost of construction.

References

Basavaraju Y. (2002) Potential for fish culture in water harvesting structures in watersheds, *in:* workshop on watershed development programmes in Karnataka, April, 30, 2002 pp: 74-81

Shankar MA and Shivakumar HR. (2005). Sustainable cropping systems for the Deccan Plateau, Symposium on sustainable agriculture for dry land on the Deccan plateau, knowledge for application Bangalore. 214-222.

Seenappa D and Khadhar khan H (2008). *Jalaanayana Krishi Hondagalli Meenu Saakane* (Kannada), technical leaf let, Directorate of Extension, UAS, Bangalore.

Senthivelu M, Surya Prabha AC and Srikanth M. (2008). Farm ponds: A boon for sustainable dry land agriculture, *Rashtriya Krishi Technical Magazine*, **3**(20): 55-57.

Somashekara K, Murukannapaa and Panduranga. (2003) Rainwater management, *In:* Three decades of dry land agricultural research for *Alfisols* of South Karnataka (1971-2000). Pub: Chief Scientist. Dry Land Agriculture Project, Editors: Shankar, M.A., Manjunath, A., G.N. Gajanan, Pandurangaiah, K., Lingappa, B.S., Mariraju, H. and Indrakumar, N., Pp: 33-63.

Talaparige: A unique traditional Water bodies

Shree Padre and Mallikarjuna Hosapalya

Tumkur

Abstract

Talaparige, a unique traditional water body was once very popular and found predominantly in Tumkur region of Karnataka. Water from talaparige was widely used for drinking as well as irrigation purposes. By virtue of constructional and locational uniqueness, talaparige can provide water after the normal tanks dry off. As such, it comes in very handy and useful during summer when entire village experiences acute water shortage. In this chapter the near extinct talaparige has been thoroughly discussed with an essence of its historical background and efforts made to rejuvenate it.

Introduction

Talapariges, the small traditional water bodies of Karnataka that saved many lives during drought years barely quarter century ago are today by and large forgotten. When mention is made about the traditional water bodies of the state, talaparige rarely finds a place. Unfortunately, no printed documents are available on the life-saving tanks.

Though talaparige looks like a small tank, it is neither a tank nor a well. For a casual onlooker hurried look, it looks like a small pond. Not deep or wide as an open well. It is a unique structure. It is the only source of irrigation for summer crop. Water is taken through a channel and by gravity – without using a motor.

Mat– sized Water Body that Irrigates Acres of Land

Consider a water body of the size of a mat irrigating 5 to 100 acres of land. Recalls Dr. Nagaraj of Akkirampura. "Talaparige used to provide water that would equal the output of a ten HP motor." This water body situated near the cremation grounds of Akkirampura catered water up to 8 kilometres distance, up to the fields of Rayavara village.

Though concentration of talaparige is high in Pavagada, Madhugiri, Shira and Koratagere taluks of Tumkur, it is prevalent in adjacent districts like Chitradurga, Koodligi taluk of Bellary and Kolar districts. In some parts of Kolar, it is known as *Ootekunte*. According to some sources, similar structures are found in Ananthapur and Kadapa districts of Andhra Pradesh.

According to the geology textbook of 6th standard of fifties, "In Pavagada *taluk* of Tumkur district, farming was done by using water from talaparige." Recalls Chaluvaraj, elderly historian of Pavagada: "In fifties and sixties, at many points of Pavagada town like the shandy street, bus stand etc. had water springs that oozed out clean water. Nallamudda's spring that was in the heart of the town provided drinking water to all the population. The spring near the foothills of Pavagada hills is century old."

Ask Doddanna, 82, of Chikkasamjeevegowdanapalya about presence of the massive talaparige in the nearby Soolekere tank, recalls he, has kept all the villagers alive during severe droughts of early part of the last century. Fresh in his memory is the drought of the seventies, which saw 6 to 7 successive scarce rain years. Even now it provides water for irrigation. "At one time, when our villagers tried to dry the talaparige for cleaning, it required 6-7 kerosene engines to pump out the water", he recalls. The Karnataka Irrigation Act, 1957 has reference to talapariges that were providing water for less than hundred acres. K.M.Shankarappa (80), a farmer from Siddapura was growing paddy in hundreds of acres by using water from talaparige.

The Foothill Spring

Talapariges are situation specific and found in the areas of shallow topsoil beneath which there is a rocky stratum. The rainwater that falls on the land and the nearby hills slowly gets percolated in the topsoil. The rocky stratum doesn't allow water to go very deep. As such, it finds out a lateral route. This low-pressure flow of water comes up in some points where soil is pretty sandy.

Our wise elders used to identify such marshy spots and develop it into a water body. To avoid the surrounding soil collapsing into the pond, stonewall was built. The pond with round-shaped retaining wall is called *gerandi bavi* and the ones with square walls as *chowka bavi.* Protection wall serves another purpose too. It prevents the 'eye of water' getting buried when the tank is filled with water.

The retaining wall served two purposes – one is protecting the spring. Secondly, it provided clean water as the cattle and other livestock didn't have access to water. The oozing water was taken in a channel to the lands below for irrigation.

Talapariges are considered as holy places too. People don't walk in that area with chappals on, nor do they spit or throw wastage in the vicinity. Ancestors who have developed these water bodies have made strict rules as to who can use this water and what is their collective responsibility towards that. Each talaparige has a *gamkaara* (water distributor) who decides and keeps track of the water allowed to individual properties.

At Hosapalya, *Marammana jathra* is conducted once in every three years. During the festival, Maramma, the goddess is taken in procession for a ritual called 'going to jaladhi.' The procession goes to the local talaparige and elaborate pooja is conducted there. Devotees take this *theerth* before returning from the holy water body.

Three Types of Locations

Depending upon the location where talaparige is found, it can be classified into three types. The first one is situated in the floor of the tank. In the Tumkur district, considerable number of tanks has talapariges. Second category is in the command area of a tank. Third type is found on the banks of large streams or rivers.

For the talapariges located in the tank floor, rain percolated in tank's catchments and the nearby hill is the main source. For those in the command areas of the tanks, tank itself is the source. For the third category, nearby river or stream is the feeder.

In a few cases, talapariges are dug in the riverbed itself. For example, a big stream flows in Roppa village of Pavagada. About three decades ago, farmers used to dig three talapariges in a gap of five kilometers. Recalls Maruthi Prakash of Roppa. "They used to identify points where water still oozed in the stream in summer. From this water body, they used to take water to the lower fields through a long channel. After a certain distance, another talaparige was dug."

According to G.P. Choudhury who hails from Pavagada, "except for the talaparíges situated in the floor of tanks, a lot of plant diversity also co-exists. Since sufficient moisture is available in talapariges and on both sides of its water channel, a good number of various trees like tamarind, pongamia, jamun, etc., can be found there. As grass grows in their vicinity, sheep and cattle come there for grazing. That area also attracts birds and wildlife".

These water bodies were maintained under community ownership. Maintenance, regular desilting of channels, etc., was carried out by the local beneficiaries. Very rarely talapariges are kept under individual ownership.

Most interesting aspect of talapariges is that they can provide water after the normal tanks dry off. As such, it comes in very handy and useful during summer when whole village experiences water shortage. This is why, it can be termed as a 'back-up tank' or 'reserve bank for water.' Nature plays a very contrasting role in the case of talapariges located in the tank floors. As and when the tanks get filled with water, it heaps upon silt on the tummy of talaparige. If and only when this silt is cleared off, the 'tank-in-tank' provides clean water for the rest of the year!

Total 'Death'

Unfortunately, most of the talapariges are in a pathetic state today. Only a few are in good condition. Reasons for the decline are many. Introduction of bore-well technology, successive droughts, encroachments, diminishing community spirit – all have contributed in their own way. Near Koratagere town, a talaparige has been encroached by an influential person who has had a bore-well dug there. Madhugiri town also has a similar example.

Sand plays an important role in the functioning of this water body. Rampant sand mining that is going unabated from the rivers, tanks and even fields of late is also posing big threat. Latest addition to the list of threats is granite and blue metal–*jally*-mining. Mining activities are systematically damaging the hills which are the main water feeders for talapariges. The recent crisis in farming front seems to be the proverbial last straw on the camel's back.

Slow Realization

A ray of hope is the slow realization of importance of talapariges is creeping in the mind of communities. Pavagada and Madhugirui taluks in Tumkur have very high rate of fluoride in bore-well water that goes around thousand feet deep. Quite in contrast, the talaparige water is sweet and safe without high fluoride content.

Recently, there was an interesting development in Basavanahalli village of Madhugiri taluk. *Jalasamvardhana Yojana Sangha* (JSYS) drew a master-plan for the rejuvenation of the local tank. Though the womenfolk had demanded repair of talaparige too along with the tank, it was not included in the draft plan. Women weren't ready to leave the matter there. They tried to convince the District Collector as to how important this water body is to them. An impressed DC endorsed their views. Finally, two talapariges that were buried under the tank got a new lease of life. The channels were also desilted. This summer, the villagers took this water to their fields and protected their sixteen hectare paddy crop.

Till date, JSYS has rejuvenated more than 19 talapariges. Community demand at Karekyathanahalli, Tumakunte, Koththooru, Devalakere, Magadalabetta, and Byalya have resulted in the rejuvenation of their talapariges.

Madurai based NGO, *DHAN Foundation* has rejuvenated 8 talapariges in Tumkur district and one in Kolar in the last five years, according to their Project Executive Mahanthesh H.K. "We realized the importance of these structures during the drought periods, amidst the PRA sessions, the villagers took us and narrated the importance of talapariges", he reveals. Following their own realization and rejuvenation programmes, DHAN Foundation had included talaparige in their awareness agenda.

Mahanthesh has an interesting experience to narrate. At Kannamedi in Pavagada, a farmer maintained a talaparige and used the water by lift irrigation. When DHAN Foundation went to the village, he was happy and offered that he too would contribute, if they are taking up the rejuvenation work. He paid Rs. 5,000 as his contribution out of Rs. 67,000 total expenses.

Instead of going on digging bore wells, why can't Karnataka government rejuvenate selected talapariges wherever there is water scarcity? Notable is the fact that talapariges give safe water that doesn't have harmful fluoride levels. If only the nearby villagers can be inspired to rejuvenate their talapariges with the provision of some cash incentives, it might work. Compared to the tank desilting work that's massive, talaparige desilting is easy and within the local communities reach. If JCB – is used, it might cost around Rs. 25,000.

Mahanthesh recalls a very interesting happening at CK Pura three years ago. As there was severe water shortage elsewhere, people started using talaparige water. Many of them were surprised to realize that the leg and joint pains have subsided after they had shifted to this water. This was because the bore-well water they were using earlier had high fluoride content and this water was safe. Water shortage in the summer is acute and a pot of sweet water sells for two rupees. If not for any other purpose, to provided safe cooking & drinking water in the heavy fluoride areas, talapariges can be maintained and water distribution can be entrusted to local committees.

People's Initiative towards Rejuvenation

Dhanya, a Tumkur-based NGO has now taken interest in sensitizing the communities about the need for rejuvenating talapariges. Latest issue of *Jalasiri,* the NGO's water newsletter has carried features with regard to this. As a first step towards this objective, they did a one day workshop, '*Come, Let us save talapariges'* at Madhugiri on August 10th 2008. For the first time, a 130-page book containing articles from grass-roots writers were released on that day. Resource persons from different areas shared their experiences and observations.

Farm pond for Income and Livelihood security : A case study from Anantapur district of AP

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Abstract

Harvesting every drop of rainwater *in-situ* is very crucial for promoting sustainable agriculture in the semi arid regions (GNS Reddy *et al.*, 1999). The traditional concept of locating dug out structures (locally known as KALYANI) at strategic locations was revived and promoted as farm ponds. This was introduced for rainwater harvesting in the soil and water conservation measures taken up under the DFID-NRSP Project R8192, implemented by BAIF in collaboration with CRIDA, ANGRAU, UAS (B) and ICRISAT in 3 districts namely Anantapur & Mahabubnagar districts in Andhra Pradesh and Tumkur district in Karnataka during 2002-05. This case study deals with the success story of two farm ponds executed under the project at Pampanur Thanda in Anantapur district of Andhra Pradesh.

Target Domain

The climate of the area is semi-arid. The mean annual rainfall is 520 mm with LGP 90-120 days. The summers are hot and winters are mild. The area receives rainfall from both southwest and northeast monsoon. Out of the total rainfall, only 10-15% water is utilized for agriculture, while the remaining is wasted as runoff. There was not enough water harvesting structures in this area. Groundwater level is alarmingly depleting (below 200 ft depth) and there was acute scarcity of drinking water, fuel and fodder. The soil depth is approximately 30-50 cms and the slope of the land is 2-6%. The soil is mainly red sandy loam with patches of black soil with moderate nutrients content. The total area selected for the project was 361 ha of which fallows and wastelands constitutes 51 ha and the net cultivated area was 304 ha. The major crops grown during the *kharif* were groundnut, pigeon pea, sorghum, castor, pulses, papaya and sweet lime, while paddy, groundnut, horsegram and vegetables were grown in the *Rabi*. The irrigation sources in this area consists of tanks-2 Nos. (55 ha), dug and borewells – 25 &100, check dam – 1 No (50 ha). There were no percolation tanks or farm ponds existing in this area prior to the project.

Identified Issues

- Low rainfall with uneven distribution,
- Poor crop yields due to moisture stress,
- Non-availability of water harvesting structures,
- Mono cropping of groundnut and lack of alternative choices and
- Inadequate fodder supply to milch animals.

The project site typically represents the semi arid areas and is characterized by frequent droughts due to failure of monsoon. The rainfall distribution is primarily uni-modal and results in heavy rains in a short period, causing high runoff and soil loss. Prolonged dry spells between two rains during the monsoon occurs often, resulting in drying of the sown crops. The soils are also poor and degraded. Farmers report that groundwater is over exploited, resulting in the drying of open wells (PRA Findings, DFID-NRSP (U.K) Project R8192). Crop cultivation is restricted to a single season. This situation called for strategies for harvesting and storage of rainwater for later use as well as *in situ* conservation of the rainfall and moisture.

The major crop in this area is groundnut and the productivity of groundnut is as low as 400 kg/ha under rainfed condition due to frequent dry spells during the critical growth stages. Often, the economic yields are not realized. It has been reported that increase in yield to the tune of 33% could be achieved with 1 supplemental sprinkler irrigation of 10 mm at pod development stage (AICRPDA, 2003). Critical irrigation can be given to crops by harvesting and storage of runoff water in dug out ponds and trench cum bunds at suitable locations.

Methodology

The intervention choices for cluster villages to address water scarcity in agriculture were construction of trench cum bunds, farm ponds, water diversion structures, mini percolation tanks, check dams and gully plugs. During this project, a number of farm ponds were excavated in the selected locations of the farmers' field with 10% contribution by farmers as labour or cash. The number of ponds excavated in Pampanur was 7 +1 (lined) and 19+1 (lined) in Kothapalli.

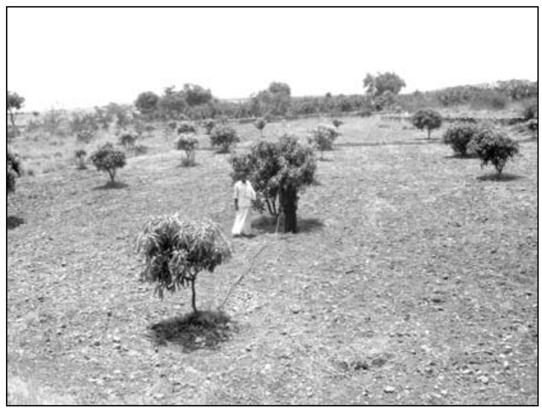
Although there was reluctance in the beginning, many farmers adopted farm ponds during the course of the project and used them successfully for supplemental irrigation. Two types of farm ponds were advocated and adopted by the farmers for harvesting the runoff in the farmers' field viz., farm ponds with lining and farm ponds without lining. The unlined ponds are dual purpose, serving both as percolation ponds for groundwater recharge and as an irrigation source. This case study pertains to the success story of Mr. Govindu Naik of Pampanur Thanda in whose field 2 farm ponds were excavated during this project in 2003. By observing this success, the interest of farmers in construction of farm ponds has increased.

Case Study

1. Name of the farmer : Mr. P. Govindu S/O. Meetya Naik
2. Total land holding : 8 acres (3.24 ha)
3. No of farm ponds : 2 (1 with lining + 1 without lining)
4. Dimensions : 10m x 10m x 3m
5. Type of lining: Gravel based with cement and sand lining
6. Cost of pond:
   a. Pond without lining : Rs. 8000
   b. Pond with lining : Rs. 12000
7. Water storage capacity: 300 m^3

The ponds were excavated in a participatory cost sharing basis where in the farmer contributed 10% of the total cost. The ponds filled up by rainfall of 90 mm in 2 consecutive days. The unlined farm pond dried up in 4-10 days due to the porous nature of the soil, indicating that the potential for recharging the groundwater is good, but the water holding capacity is poor. This was clearly indicated by the increasing groundwater table. The groundwater depth prior to the excavation of farm pond was 90-150 feet. The water level measuring device was used in a participatory way to sensitize the farmers about groundwater table. After the farm ponds were excavated (total 6 farm ponds in and around area), the groundwater level has reached an average depth of 35 feet. The unlined pond was not much useful for supplementary irrigation during the dry spells, but it helped in recharging the groundwater (Currently at 28 feet). The farm pond with lining retained water from June to January.

The farmer has made use of the stored water for life saving irrigation of mango plants and has established a 2-acre mango plantation by pot watering with water from the lined farm pond. This way, farmer has managed to plant 150/200 mango saplings. The water from the lined farm pond is being exclusively used for mango cultivation using drip irrigation.



The well, which was earlier defunct in the farmers' field, has now become recharged and the water was used by the farmer for irrigating the remaining 6 acres of his land.

Before executing the farm ponds, the farmer had been cultivating groundnut only in the *Kharif* and horse gram in the *Rabi* and the productivity was as low as 4 q/ha. After farm ponds were executed and water table improved, he was able to cultivate groundnut in 2 seasons. The groundnut productivity was also enhanced to 7.9 q/ha because the farm ponds provided water for irrigation during dry spells and his income from groundnut was almost doubled. The recharging of the existing defunct well has enabled him to cultivate groundnut in the *Rabi*, producing 10 q/ha.

Seeing the rise in the groundwater table, (current level of groundwater at 28 ft.), the farmer has drilled a bore-well in his field during 2006. Now he has started cultivating bananas, sweet orange, vegetable (tomato) and paddy in addition to groundnut from 2007 onwards. Mango plantation started yielding fruits from 2007. In 2007-08, the farmer earned Rs. 1000/- from the sale of mango and in 2008-09 he is expecting an income of Rs. 8000-10000 through selling of mango. Income from the other crops namely banana, sweet orange, groundnut, vegetable, paddy during 2007-08 is given below:

Lessons Learnt

1. Farmers can be sensitized about the need and importance of rainwater harvesting using farm ponds through participatory learning approach by monitoring groundwater level in the presence of/with the involvement of the farmers.
2. Sensitization makes the farmer more willing to adopt the farm ponds and other groundwater conservation methods.
3. Water for critical irrigation can be made available by excavating farm ponds to harvest the rainwater.
4. Productivity can be enhanced by adopting farm ponds for soil and water conservation
5. Crop diversification and cultivation of perennial crops – promoting agro forestry can be effectively done by introducing farm ponds with lining.
6. Nutritional needs of the rural poor can be addressed by enabling them to cultivate vegetables through irrigation from farm ponds.
7. Farm ponds are means to achieve increased income by farmers with low investment.

A need for upscaling the success of farm ponds is very essential, to bring about sustainable rural development. The strategies needed to be adopted for upscaling the success of farm ponds are:

S.No	Crop	Area (Acre)	Earnings (Rs)
1.	Banana	1.0	1,00,000
2	Groundnut	2.0	30,000
3	Vegetables (Tomato)	1.0	30,000
4	Paddy	0.5	10,000
5	Mango	2.0	1,000
6	Sweet Orange	1.5	-
		8.0	**1,71,000**

1. Exposure visits,
2. Regional workshops,
3. Policy briefs and
4. Convergence with NREGS for implementing farm ponds.

References

All India Coordinated Research Project for Dryland Agriculture (AICRPDA)**.** (2003) Annual REPORT 2002-03, Hyderabad, India: Central Research Institute for Dryland Agriculture.

DFID-NRSP (U.K) Project R8192, Final Technical Report. (2002-05) CRIDA, Hyderabad, India

Reddy GNS, Doreswamy C, Raghunath K and Basanth Kumar S. (1999) "Networking of Farm Ponds – A Novel Method for Rainwater Harvesting and Management". Paper presented at National Workshop on Watershed Management held at Trivandrum from August 15-16, 1999.

Farm Pond - A Means for Poverty Reduction-Experiences from Chittoor district of AP

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Abstract

Chittoor district, located at the Southern end of Andhra Pradesh very often faces drought due to failure or late onset of the monsoon. Low and irregular rainfall combined with poor soils have been identified as major challenging issues in this region as far as earning livelihood from agriculture is concerned. Tank-based watershed program is being implemented in the Punganur *manda*l of this district since April 1998 by DHAN Foundation, a NGO. In this chapter, a case study has been presented, where farm ponds have been effectively used to alleviate poverty level of a poor farmer and gradual improvement of his socioeconomic level.

Introduction

Chittoor is, one among the districts, located in the Southern end of Andhra Pradesh covering 15,152 Sq. kms. and very often faces drought due to failure or late onset of the monsoon. It is situated between 12^0 37" of Northern latitude and 78^0 55" of the Eastern longitude and an altitude of 2386 feet (MSL).

Low and irregular rainfall combined with soil fatigue have proven the immediate need to address this issue. As a part of that tank-based watershed program is being implemented in the Punganur *manda*l since April 1998 by DHAN Foundation.

Tank-based Watershed Development Programme

The watershed approach has been accepted as a means to increase agricultural production. It can arrest the ecological degradation in rainfed and resource poor areas. It would at the same time, improve the level of living of the poor by providing more sustainable employment. The main thrust of the programme relates to soil conservation, water resources conservation, pasture development and vegetative bunding. These activities would be undertaken on both private and government lands available in the watershed area. In Watershed Development Programmes, the Government and many NGOs ignore the existing traditional small-scale water resources (tanks) because these structures are considered by them as irrigation sources. But in tank-based watershed programme, tanks are also considered and treated on a cascade basis. For each work, the beneficiaries contributed 25 per cent of the expenditure as cash or labour or kind.

About the Village

Penchupalle is a small hamlet with 42 households in the Kummaranatham micro watershed. The watershed was sanctioned by district watershed development agency (DWMA), Chittoor, during 2001-02. Except 10 families, all are landholders. Only eight households are fully engaged in agriculture and all others work as wage labourers. Though one tank exists, bore wells act as the major source of irrigation in the hamlet. Majority of the population belong to SC community.

Environment

Red loamy, red sandy and white sandy soils coexist in the village. Just before the intervention, groundnut, *ragi* and *samulu* were the major crops grown in the drylands. Dry paddy and sugarcane were grown under the tank ayacuts. Due to severe drought for the past four years, most of the bore wells and open wells dried up (Table 1). Agriculture was fully dependent upon the monsoons, which often fail. The farmers with borewell mostly used to grow paddy and sugarcane. Migration was predominant among the landless, marginal and small farmers. Though land is available, it was kept fallow due to the fear of loss of investment on agriculture. Hence, the marginal and small farmers also leave their lands fallow and join the labour force.

Rainfall

During the last five years, annual rainfall was significantly higher only in 2001 as compared to the average rainfall during last 10 years (Table 2). But late arrival of monsoon in August, instead of June-July, was of little use to farming community. Either late arrival of monsoon or long dry spells during the cropping season made agriculture more vulnerable in the *mandal* for the last five years, where cropping season starts in June-July and ends in November- December.

Farm Pond: A Means of Poverty Reduction

Farm pond is a small scale water harvesting structure constructed across the slope of the land to hold rainwater for livestock, groundwater recharge through infiltration and life saving irrigation of the crops or protective irrigation in times of delayed monsoons in a small area. Here is a case study of Mr. Ramaiah, who belongs to Penchupalle, a small village in Punganur mandal of Chittoor district in Andhra Pradesh. He excavated a small farm pond as a part of tank based watershed development program implemented by DHAN Foundation during 2001–02. This project was funded by DWMA (Erstwhile DPAP), Rural Development Department, and Government of Andhra Pradesh. After excavating the pond and subsequent developments changed his lifestyle drastically and he has got good recognition in the society. The cropping pattern on agriculture land underwent suitable changes and he is happy with the crops growing in his farm.

History and Family Background

Ramaiah (51 years old) is a native of a small hamlet called Penchupalle in Kummaranatham *panchayat* of Punganur *mandal* in Chittoor district, Andhra Pradesh. He belongs to scheduled caste community and is a marginal farmer with a land holding of 5.06 acres without any water source. He is living with his wife and two children. 30 years back, former Prime Minister, late Smt. Indira Gandhi declared that those who belong to scheduled castes could take hold of the land, which they are cultivating or willing to cultivate. At that time, Ramaiah cleared some wasteland near his village, which was around 9.5 acres. At the same time, he also got a colony house. After taking hold on that land he has struggled for more than twenty years to get the registration. He had given four acres of land to his brother. It is a rainfed land with a slopy topography (2-6% slope).

During the year 2000, he approached DHAN Foundation, Punganur, a voluntary Developmental Organisation working towards bringing significant changes among poor farming communities in Chittoor district of Andhra Pradesh to excavate a farm pond in that field through tank based watershed development programme and showed his field. The staff visited the site and advised him to excavate the existing pond and increase the pondage. The Penchupalle Dryland Farmers Association (D.F.A.), a user group promoted by DHAN Foundation for the benefit of the villagers asked him to deposit the Rs.1,000/- as contribution for an estimated cost of Rs. 4,000/- but when he couldn't pay that amount, it was reduced to Rs. 500/- as cash and remaining through kind.

Only Ramaiah and his wife used to work on the land because of fewer returns while his other family members were engaged as daily wage labourers in neighbouring villages. To cultivate the lands, he brought Rs. 5,000/- credit from private money lenders and purchased a pair of cows. Some amount of money was engaged in silkworm rearing and he got some income from there too. With this money he completed registration of his lands, but he had to stop silkworm rearing as mulberry trees dried up because of lack of rains. And it was the reason that he came forward to excavate the farm pond in the existing small dugout pond.

Implementation (Land Treatment)

The pond was excavated with manual labour and the sectioning work was done. In no time quarter of the pond was filled up with seepage water and it became the turning point of his destiny. He did bunding work for his entire field under 'Food For Work Programme' to harvest the maximum water with in his fields and received 280 kgs. of rice and Rs. 1,560/- cash.

Then, he came forward to excavate a small farm pond on upstream side of the existing pond under 'Food For Work Programme' at an estimated cost of Rs. 5,000/- and got 662 kgs. of rice and Rs. 1,247/- as cash. He also realized that the harvested rain water, could be used to cultivate mulberry or paddy.

Agriculture Pattern Before the Farm Pond

Before excavation of the farm pond, he used to cultivate the land once in a year on his own without engagement of any labourers. Ramaiah used to grow Byrodlu (local traditional variety of paddy) by broadcasting method.

I Phase - Agriculture Pattern After Farm Pond (during 2001-02)

Just after excavation of the farm pond, it got filled leading to many positive changes in his agricultural ventures and even in his life.

First crop

Crop	Area under cultivation (ac)	Expenditure (Rs.)	Yield in kgs.	Returns (Rs.)
Groundnut	2.50	4000.00	2000	5000.00
Paddy IR-64	0.50	1000.00	900	4050.00
Paddy-Byrodlu	0.25	-	400	2000.00
Horse gram	1.00	500.00	200	2000.00

II phase - Observations of Family of M. Ramaiah on Farm Pond (during 2002-03)

The stages of economic development of a poor farmer, Mr. Ramaiah, were very conspicuous and convincing. A small water harvesting structure called "Farm Pond", which worked excellently as means of poverty reduction.

Different crops were grown in patches all over his land around the farm pond are as follows. He used common sense to grow multiple crops making good use of land and also water available in that farm pond.

Name of the crop	Extent (Per cent)	Investment (Rs.)	Output (Quantity)	Out put (Rs.)	Profit (Rs.)
Paddy	25	750.00	7 qtl	3,150.00	2,400.00
Tomato	75	1,280.00	---	4,100.00	2,820.00
Tomato	25	400.00	---	7,700.00	7,300.00
Coriander	10	1,040.00	---	3,000.00	1,960.00
Coriander	10	600.00	---	1,500.00	900.00
Tomato	30	500.00	---	8,000.00	7,500.00
Paddy	13	700.00	3.5 qtl	1,700.00	1,000.00
Total		**5,270.00**		**28,950.00**	**23,880.00**

(Note: The investment made for labour, ploughing and intercultural operations were met by him.)

Expenses made from the income/output

- Rs. 4,100.00 – Rs. 2,000.00 – household expenses
  Rs. 2,100.00 – clothes for the family members
- Rs. 7,500.00 – utilized for paying the debts and got back his pair of cows which were taken away by money lenders.
- After getting back his cows, he sold them and purchased a diesel engine to irrigate his lands from the farm pond.

- Immediately he began cultivating tomato without hiring labourer. He also decided to utilize the water more effectively.
- For Rs. 8000/-, he purchased a pair of milch animals (cows)
- He got 10 liters of milk per day, which he sold and earned about Rs. 70/- to 80/- per day. So far he earned Rs. 4,500.00/- from selling milk alone after deducting the investment made for labour and fodder.
- He purchased a house near by for Rs.1,500.00/-.
- He gives the diesel engine for rent and earned additional Rs. 10,000/- (apart from his own use)

Inference

Farm pond is really a means of poverty reduction, because by investing just Rs. 5,270/- the farmer earned a profit of around five times more than the investment. The important factors that contributed to the said changes are –

- Hard work
- Common sense
- Dedication
- Memories of the problems he suffered in the past
- Above all the "farm pond"

III phase of Farm Pond - M. Ramaiah (2003 - 2004)

- Sold out a pair of cows (because now he has pair of bullock) for Rs. 7000/- in Oct - 2003 and purchased 9 sheep worth of Rs. 12000/-.
- Began cultivation of mango in 6 acres of land.

Crop	Extent (ac)	Investment	Out put	Value of out put	Month of sowing
Paddy - Byrodlu	0.50	1450.00	5 qtl	2250.00	Aug - 03
Paddy - Tella hamsa	0.50	1000.00	8 qtl	4800.00	Sep - 03
Ragi	0.50	500.00	2 qtl	950.00	Sep - 03

IV phase of Farm Pond - M. Ramaiah (2004 - 2005)

Details of cultivation in his lands near the pond						
Crop	Extent (ac)	Cropping	Investment (Rs.)	Out put (kgs.)	Value of out put (Rs.)	Month of sowing
Paddy (Byrodlu)	0.25	Rainfed	630.00	70	1,330.00	June - 04
Paddy (Sonamasuri)	1.00	Irrigated by pond	2,000.00	900	7,400.00	July - 04
Tomato	0.25	Irrigated by pond	1,000.00	1,000	4,000.00	June - 04
Field bean	0.25	As inter crop in Tomato	360.00	800	6,000.00	June - 04
Groundnut	5.00	Rainfed	4,650.00	1,200	4,100.00	June - 04

Details of cultivation in the land taken for lease						
Paddy	1.00	Irrigated	2,500.00	400	3,300.00	July - 04
Ragi	0.75	Irrigated	1,420.00	300	1,050.00	June - 04
Tomato	0.50	Irrigated	2,050.00	1,750	3,500.00	June - 04

Other Activities

- Taken Rs. 7,000/- loan from a micro finance group for all the above mentioned agricultural activities.
- Purchased 16 sheep.
- He took 2.25 acres of land (having borewell as water source) on lease from a large farmer of the same village.
- Provided wage employment to many labourers of the same village through agricultural activities.
- He planned to go for a holy visit to Shabarimalai in Kerala and visited twice.

Success of the Programme

- Stakeholdership on assets created: Contribution from the user (25% of the total estimated cost paid as contribution)
- Direct stake holders participation in works execution
- Need-based trainings and exposure visits to the suitable locations to the stake holders
- Need-based works implementation
- Other civic activities intervention
- Creation of endowment fund for the sustaining the farmers associations
- Availability of credit through micro finance to the farming communities for agriculture and allied activities
- Technical support through Agriculture Development Centres

Impact of Farm Ponds

Farm pond is a small water harvesting body made by either construction of embankment or excavating pit/dug out in the lowest point of the field where water tends to accumulate. The ideal location for a farm pond is the lowest point of the private field in middle and lower reaches so that any excess water from the field can be stored. It facilitates recharge of the groundwater through infiltration and provides protective irrigation in times of delayed monsoons.

Tomato and mulberry are the most preferred crops by the farmers with farm ponds. Seepage caused by the presence of pond increased the moisture level in the field and prompted farmers to go for moisture loving crops. In this village, horticulture was extensively promoted under the farm ponds. They take the water from the pond and use it for the irrigation of the crops. Thus, 14 acres of mango plantations were established through the farm pond water.

Details of Groundwater Recharge

In the Penchupalle village, groundwater recharge was observed at a nearby farm pond. In an open well, belonging to a farmer named C. Krishnappa, the water level increased to six feet and the area under irrigation increased by 0.5 acre and able to support their mulberry crop. These ponds also have considerable impact on the migration pattern.

Strategies for Up-scaling this Initiative

The stakeholders need to involve in the activity from the planning stage itself. In order to make the farmers/beneficiaries understand, we need to make them aware about the activity through capacity building events or by organizing exposure visits. The respective farmer needs to contribute at least a part of the total cost in the total amount of work without fail in order to get the stake. In addition, the farmers needs to get the financial assistance through some mechanism (in this case, it was facilitated through micro finance group formed for the purpose) for agricultural activities. The technical support regarding agriculture and its allied activities also need to support through the agri clinics.

Innovations in Financing

The farmers can be provided incubation fund with interest free loan / with minimum interest to those who are interested to take up the activity with more technological inputs for the farm ponds purpose. The existing projects under NABARD, CAPART, Rural Development projects can be fine tuned towards this end and new projects in the relevant departments like National Rainfed Areas Authority (NRAA), etc., can be developed towards fulfilling the requirement of the farmers in rainfed and drought-prone areas. In the existing programmes like National Rural Employment Guarantee Scheme (NREGS), farmers can plan where to take up the activity and involve in the activity throughout the implementation period. The will help in the asset creation in the farmer's field. But, we need to ensure the involvement by the respective farmer.

Conclusion

In the field of Mr. Ramaiah, after excavating the pond, it changed his lifestyle drastically and he got good recognition in the society. The cropping pattern on his agriculture land changed. All in all, he is a happy man with the crops grown in his farm.

Rainwater Harvesting and Supplemental Irrigation through Farm-ponds and Evaluation of Lining Materials

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Abstract

Water harvesting and supplemental irrigation through dug out farm ponds with different lining materials were studied at Agricultural Research Station, Anantapur during 2003-2007. The treatments included lining material, sodic soil; cement + sodic soil (1: 10); cement + soil (1: 8); cement + murrum (1: 6); cement + soil + murrum (1: 3: 5); cement + cement bricks; cement + sand + bricks and Kadapa slabs. Greater amount of runoff water was retained by cement + murrum as the lining material of the pond. The length of cracks developed in the cement + murrum lined farm pond was minimum as compared with other treatments. Four runoff events were recorded during the crop season and crop yields were increased by 120 per cent by giving two supplemental irrigation of 10 mm each for breaking the dry spell of 43 and 37 days during vegetative and pod development stages, respectively. The haulm yield increased by 50 per cent.

Introduction

Groundnut is cultivated on 14 million ha area during the *kharif* under rainfed condition. Anantapur district is the largest groundnut growing district in India with an area of 0.65 to 0.85 million ha in different divisions with rainfall as low as 250 mm. The length of the dry spells in the district ranged from 15 to 55 days. Rainfall is the most limiting factor in groundnut production (Reddy *et al*., 2003). However, the rainfall occurs in high intensity and induces runoff. Chittarangan *et al* (1996) reported that runoff events mostly occur in July, September and October in the semi-arid tropics of South India and could be harvested into dug out ponds. The adverse effect of drought can be overcome by application of stored water during dry spell.

Materials and methods

A field experiment was conducted at the Acharya N. G. Ranga Agricultural University, Agricultural Research Station, Anantapur, Andhra Pradesh, India during 2003 to 2007. The experiment consisted of two major components. Lining of farm ponds and supplemental irrigation,

1) The treatments for lining farm ponds were:
   T1: Sodic soil
   T2: Cement + sodic soil (1: 10)
   T3: Cement + soil (1:8)
   T4: Cement + murrum (1: 6)
   T5: Cement + soil + murrum (1:3:5)
   T6: Control

2) The treatments under supplemental irrigation were:
   T1: Control
   T2: Supplemental irrigation with 10 mm of water with sprinkler whenever the dry-spell was more than 10 days and water was available in the farm ponds

Climate of the region is classified as arid tropics with decennial rainfall of 550 mm, mainly received from June to October. The mean annual open pan evaporation is 2050 mm. The soils are shallow in depth (20 cm), low in available N, medium in available phosphorus (32 kg/ha) and available potassium (20 kg/ha) and have a pH of 6.5.

Small farm ponds of size 1.0x1.0x1.0 m (trapezoidal shape) were dug and lined with different types of material. Each farm pond was filled with 1000 liters of water. Evaporation and seepage losses were measured regularly until end of the experiment.

A farm pond of size 11 m x 11 m x 2.5 m was constructed and lined with Cuddapah slabs (locally available slabs with a size of 1 m x 1 m with thickness of 5 cm). The fields were provided with graded bunds and runoff water was collected in the farm pond. The

Farm pond lined with Kadapa slabs

Farm pond lined with cement bricks

Farm pond lined with bricks


Farm pond lined with cement + soil (1:8)


Farm pond lined with cement + murrum (1:6)

Farm pond lined with sodic soil

catchment area for the farm pond was 5 ha, which was being cultivated with groundnut during the rainy season (*kharif*).

The crop was sown on 20.5.2004 with rainfall received on 17.5.2004 and harvested on 7.9.2004. The widely grown variety of groundnut TMV 2 was used as the test variety.

Results and Discussion

Lining of Farm Ponds

The results clearly indicated that the farm pond lined with cement + murrum produced better results compared to other lining materials. The length of cracks (2 mm size) developed in the cement + murrum lined farm pond was minimum as compared with cement +soil, cement + soil+ murrum, sodic soil + cement and sodic lined farm ponds. In the sodic soil, farm pond lined material continuously depleted and settle down at bottom. Seepage losses were more due to the dissolution of lined material from sides of the pond.

Farm pond lined with cement + sodic soil recorded low seepage losses and cracks compared to sodic soil lined material. The farm ponds were filled up thrice on 29-09-03 (43 mm), 20-10-03 (42.4 mm), and 24-10-03 (18 mm) and runoff collected during rainfall events are presented in the Table 2.

Only two farm ponds at field No. 4 and 33 were lined with Kadapa slab and the rest ponds were left unlined. During 2004, four farm ponds at the station were lined with different materials like sodic soil, cement bricks, cement + soil (1:8) and brick material. These farm ponds were filled with runoff water four times on 17-05-04 (43.4 mm), 25-05-04 (53 mm), 13-07-04 (41 mm) and 04-09-04 (42 mm) during the *kharif*, 2004. The quantity of runoff water filled in the farm pond in each rainfall event is presented in the Table 3.

Table1. Length of cracks and evaporation losses in farm pond (1m x 1m x 1m) lined with different types of materials.

Treat-ments	Lined material	Length of crack size 2 mm, (cm)				Evaporation losses (cm/ day)				
T1	Cement + murrum	115	460	396	12.5	6.0	5.0	3.5	3.2	3.0
T2	Cement + soil	332	592	520	5.5	5.0	4.0	4.5	4.0	3.5
T3	Cement + soil + murrum	200	502	212	4.3	5.5	6.0	5.0	4.7	4.5
T4	Sodic soil	571	638	550	35.4	36.0	----			
T5	Sodic soil+ cement	487	442	429	8.5	11.0	10.5	8.5	6.8	5.7
T6	Control	NA	NA	NA	56.0	----				

Table 2. Farm pond capacity, lining material and quantity of runoff water collected during *kharif* 2003.

S. No	Location	Shape of the farm pond	Lining material	Storage capacity (lit)	No. of times farm pond filled	Amount of runoff collected at each rainfall (lit)
1	Field No.4	Trapezoidal	Kadapa slabs	1,75,000	2	i) 50400 ii)29000 iii)1489 iv)6827
2	Field No.12	Trapezoidal	--------	244163	1	i)not dug ii)154000 iii)----- iv)------
3	Field No.16	Square	--------	1,50,000	2	i) 150000 ii)4217 iii)---- iv)682
4	Field No.18	Trapezoidal	--------	429333	1	i)not dug ii)25200 iii)----- iv)------
5	Field No.33	Trapezoidal	Kadapa slabs	6,50,000	1	i) no source ii)13663 iii)------- iv)26848

Table 3. Farm pond capacity, lining material and quantity of runoff water collected during *kharif 2004*.

S. No	Location	Shape of the farm pond	Lining material	Storage capacity (lit)	No. of times farm pond filled	Amount of runoff collected at each rainfall (lit)
1	Field No.4	Trapezoidal	Kadapa slabs	1,75,000	4	i) 1,75000 ii) 1,75000 iii) 39928 iv) 1,75000
2	Field No.12	Trapezoidal	Sodic soil	244163	2	i) ------- ii) 162753 iii) ------- iv) 244163
3	Field No.16	Square	Cement bricks	1,50,000	2	i) ------- ii) 1,50,000 iii) ------- iv) 1,50,000
4	Field No.17	Trapezoidal	Unlined	123050	1	i) Not dug ii) 85211 iii) ------- iv) --------
5	Field No.18	Trapezoidal	Unlined	429333	2	i)------- ii) 247000 iii)------- iv)85000
6	Field No.19	Square	Cement +Soil	2,25,500	2	i) Not dug ii) Under construction iii) 2,25,500 iv) 2,25,500
7	Field No.21	Trapezoidal	Bricks	4,13,300		i) ------- ii) ------- iii) ------- iv) -------
8	Field No.33	Trapezoidal	Kadapa slabs	6,50,000	3	i) 228708 ii) 6,50,000 iii)------ iv) 17257

During the year 2005, some farm ponds were lined with different types of materials i.e. sodic soil; cement + sodic soil (1: 10); cement + soil (1: 8); cement + murrum (1: 6); cement + soil + murrum (1: 3: 5); cement + cement bricks; cement + sand + bricks and Kadapa slabs.

During 2006, three farm ponds were constructed at the station and another three farm ponds were constructed at on-farm sites in the villages namely Pathacheruvu, Siva Puram and West Narasapuram. All the above farm ponds were lined with cement + murrum (1:6). Four mild runoff events were recorded during the crop season. Farm ponds were not sufficiently filled due to low intensity and less amount of rainfall. Because of this, supplemental irrigation was not given to the crop during *kharif* 2006 at the station.

Supplemental Irrigation

The experiment was conducted on large sized plots of one hectare each treatment. The two treatments tested were rainfed and irrigated. Supplemental irrigation was given with sprinklers to a depth of 10 mm whenever water was available in the farm pond and when the dry spell was more than 25 days during the vegetative stage and more than 8 days during the pod development stage. The supplemental irrigation was given on 21.6.2004 and 20.7.2004. Data was collected on water levels in farm ponds, plant height, number of flowers, number of pegs, number of pods, pod and haulm yield.

Table 4. Farm pond capacity, lining material and quantity of runoff water collected during *kharif* 2005.					
S. No	Location	No. of times farm pond filled	Date	Quantity of water at time of filling (lts), lakh	Quantity of water at time irrigation (lts), lakh
1	Field No.4	3	30-05-2005 16-07-2005 30-08-2005	i) 1.50 ii) 2.40 iii) 2.40	-------------
2	Field No.12	2	16-07-2005 30-08-2005	i) 8.40 ii) 8.40	1.95 (24-08-05) 1.25 (29-09-05)
3	Field No.13	2	16-07-2005 30-08-2005	i) 2.44163 ii) 2.44163	Drip Irrigation given to tamarind (22-08-05)
4	Field No.16	2	16-07-2005 30-08-2005	i) 1.50 ii) 1.50	--------------
5	Field No.17	2	16-07-2005 30-08-2005	i) 2.23050 ii) 2.23050	1.82 (22-08-05) 1.40 (30-09-05)
6	Field No.19	2	16-07-2005 30-08-2005	i) 2.25500 ii) 2.25500	1.50 (21-08-05) 1.65 (04-10-05)
7	Field No.21	1	30-08-2005	1.42000	--------------
8	Field No.33	1	30-08-2005	6,50,000	--------------

The total amount of rainfall received during the crop season was 348.6 mm in 2004. There were four rainfall events of more than 40 mm, which resulted in runoff and filling of farm pond took place during those events. There were two prolonged dry spells of 43 and 37 days duration during the vegetative and pod development stages respectively and one mild dry spell of 11 days during pod initiation stage. The soil moisture just before the first supplemental irrigation was 2.67% in 0-15 cm of soil depth, which is less than that at the permanent wilting point of the soil.

Four runoff events were recorded during the 2005 crop season and crop yields were increased by 33 per cent with two supplemental irrigation of 10 mm each for breaking the dry spell of 38 and 34 days during vegetative and pod development stages, respectively. Similarly, the haulm yield was increased by 36 per cent. The cost of the construction of cement + murrum farm pond was reduced to 60 per cent as compared to cement + cement bricks; cement + sand + bricks and Kadapa slabs.

In Sivapuram and Venkatapuram villages, two supplemental irrigations of 10 mm each were given to groundnut crop using stored water in farm pond during 2006. The yield increase was 35 % in both of the villages as compared to no supplemental irrigation. The groundnut yields recorded are 722 kg/ha and 756 kg/ha, respectively.

During *kharif* 2007, one supplemental

Table 5. Farm pond capacity, lining material and depth of water collected during *kharif* 2006

Field No.andlining material	Depth of water in farm pond (cm)			
	Date 16-9-06	Date 27-9-06	Date 4-11-06	Date 16-11-06
	Rain fall 29.4 mm	Rain fall 32.6 mm	Rainfall 43.6 mm	Rain fall 13.4 mm
1 (Cement + Murrum 1:6)	0	0	17.5	0
4 (Kadapa slabs)	0	45	10.0	0
12 (A) Sodic	0	57.67	0	0
12 (B) Sodic	0	28	0	0
12(C) Cement + Murrum	24.89	43.43	37.35	35.6
21 (Brickes)	0	0	0	0
19 (A) Cement + Murrum	23.67	90.0	55.0	34.5
19 (B) Cement + Murrum	10	63.6	15.0	10.0
18 (Cement + Murrum	61.3	92.25	53.5	50.0
17 (Cement + Murrum	45	0	65.0	50.5
30 (Unlined)	0	0	0	0
27 (A) Cement + Murrum	10.0	16.0	3.0	7.5
27 (B) Unlined	0	0	0	0

Table 6. Farm pond capacity, lining material and depth of water collected during *Kharif* 2007

Field No. and lining material	Depth of water in farm pond (m)			
	Date 7-6-07	Date 16-06-07	Date 21-07-07	Date 25-08-07
	Rain fall 50.8 mm	Rain fall 20.0mm	Rainfall 28.6 mm	Rain fall 110mm
1 (Cement + Murrum 1:6)	1.10	0.90	1.50	0.90
4 (Kadapa slabs)	2.50	2.00	1.45	2.50
12 (A) Sodic	1.40	0.82	0.10	2.50
12 (B) Sodic	2.50	1.18	0.10	2.50
12(C) Cement + Murrum	2.50	1.15	0.43	2.50
21 (Brickes)	0.30	0.00	0.04	2.50
19 (A) Cement + Murrum	2.50	1.65	2.50	2.50
19 (B) Cement + Murrum	2.50	1.15	1.08	2.50
18 (Cement + Murrum	2.50	1.20	1.83	2.50
17 (Cement + Murrum	2.50	1.00	2.5	2.50
30 (Unlined)	0.80	0.25	0.03	2.50
27 (A) Cement + Murrum	0.32	0.18	0.05	0.17
27 (B) Cement + Murrum	0.70	0.30	0.03	0.64

Table 7. Yield attributes and yields of groundnut as influenced by supplemental irrigation

Parameters	Rainfed	Irrigated
Filled pod/m^2	50	153
Hundred pod weight, g	43	45
Shelling percentage	68	69
Pod yield, kg/ha	315	698
Haulm yield, kg/ha	1250	1843

Table 8. Yield and yield attributes of groundnut as influenced by supplemental irrigation during *kharif* 2005

S. No.	Location	Parameters	Rainfed (kg/ha)	Irrigated (kg/ha)	Per cent increase
1	Field no. 17	Pod yield	515	773	33.37
		Halum yield	727	840	13.45
		Shelling percentage	59.515	66.25	10.16
2	Field No.19	Pod yield	437	655	33.28
		Halum yield	526	832	36.77
		Shelling percentage	61.5	65.45	11.14

irrigation of 10 mm was given to groundnut crop using stored water in farm pond at field no 3 of ARS, Anantapur. The yield increase was 18.4 % as compared to no supplemental irrigation. The increase in haulm yield and shelling percent were 17.8 and 10.1, respectively.

There was marginal increase in hundred-pod weight and shelling percentage with supplemental irrigation. Pod yield of rainfed crop was 315 kg/ha compared to 698 kg/ha with supplemental irrigation. Similarly, the haulm yield was higher (1843 kg/ha) with supplemental irrigation than rainfed crop

Table 9. Yield and yield attributes of groundnut as influenced by supplemental irrigation from farm ponds at 2 villages during *Kharif* 2006.

S. No.	Location	Parameters	Rainfed kg/ha	Irrigated kg/ha	Per cent increase
1.	Sivapuram	Pod yield	535	722	34.9
		Halum yield	740	860	16.2
		Shelling percentage	55	62	12.7
2.	Venkatapuram	Pod yield	560	756	35
		Halum yield	720	810	12.5
		Shelling percentage	62	69	11.2

Table 10. Yield and yield attributes of groundnut as influenced by supplemental irrigation from farm pond in field No. 3 during kharif 2007					
S. No.	Location	Parameters	Rainfed, kg/ha	Irrigated, kg/ha	Per cent increase
1	Field no .3 ARS, Anantapur	Pod yield	1055	1250	18.4
		Haulm yield	1650	1945	17.8
		Shelling percentage	59	65	10.1

Water harvesting (farm pond) and supplemental irrigation through sprinkler system

(1250 kg/ha). The higher growth and yield of the crop with supplemental irrigation was due to availability of more soil moisture for plant growth and development. Plants with irrigation had longer leaflets exposed to sunlight, resulting in longer period of photosynthesis. In the present study, the increase in yield with 2 supplemental irrigations was 121 % with 10 mm of irrigation water during each irrigation.

From these results, it can be concluded that water can be harvested and supplemental irrigation could be given even in the arid regions. Pod yield of groundnut can be substantially increased in drought-prone areas with dugout ponds and supplemental irrigation.

References

Reddy TY, Reddy VR and Anbumozhi V. (2003) Physiological responses of groundnut (*Arachis hypogaea* L.) to drought stress and its amelioration: a review. Acta Agronomica Hungarica, 51 (2) pp 205 – 227.

Farm Pond Technology for Semi-Arid Alfisol Region of Telengana in Andhra Pradesh

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Abstract

The effect of combined land uses on the behaviour of water yield for designing the storage structure and utilizing the water for small scale supplemental irrigation has been carried our at semi-arid *Alfisol* of Telangana region of A. P. The experience at farm level has shown enough potential of brick lined farm pond technology in growing vegetables in the off-season by satisfying water requirement at 50% of weekly evaporation. This technology may be more viable and economical in *vertisols* where lining is not essential.

Farm pond – A Case Study at CRIDA

A micro-watershed (4 ha) on Alfisols was developed at CRIDA (Hayathnagar Research Farm) to study the effect of combined land uses on the behaviour of water yield for designing the storage structure and utilizing the water for small scale supplemental irrigation.

Watershed Site and Land Uses

The watershed is located in Hayathnagar at $17^0 2' 02''$ North latitude and $78^0 35' \ 08''$ E longitude in the Ranga Reddy district of Andhra Pradesh. The site represents the Alfisols of sandy loam textural class (sand: 79.1%, silt: 7.6% and clay: 13.3%). A loose rock layer or murrum exists at 30-45 cm depth in the horizon; weathered rocks at 60-75 cm depth and hard rocks are found beyond 75 cm. The slope varies between 1 to and 5% with an average of 3%, depending on the slope, soil depth, graveliness and erosion inventory. The broad land use pattern in the watershed is given in Table 1. The land capability classes vary from class II to class VIII.

Table 1. Land uses in the watershed

S. No.	Land Use	Area (ha)
1.	Crop land	1.47
2.	Vegetables	0.13
3.	Horticulture	1.43
4.	Natural vegetation (Pasture)	0.92
5.	Fallow(road)	0.05
	Total	4.00

Conservation Measures

The main conservation measure taken up in this micro-watershed was graded bunding ($0.375 m^2$) at a vertical intervals of 1.0m. Two waterways were provided for channelizing the water to the runoff gauging site (outlet point). Stone checks were made at 1 m interval in the water courses to cut down the velocity of running water. The bunds were strengthened by growing natural vegetation and *Glyricidia* plantation all along. Micro-catchment basins were constructed around each plant. At the outlet point, a farm pond of 500 m^3 was made and lined with brick masonry for seepage proofing.

Hydrology

The 4 ha catchment was equipped with a 60 cm H-flume and water level recorder assembly for gauging the runoff in time scale. Coshocton wheel with sediment collection tank was provided to collect the runoff water for estimating the soil loss from the catchment.

The data on different hydrologic parameters over a period of five years (1990-1994) are presented in Table 2. The study reveals that in such red soils, about 60% of the annual rainfall cause runoff events with an average of 12 major rainstorms over a period of 5 to 7 months (Table 2) in a year. The conservation measures (bunding) are very much effective in reducing the runoff to about 2% of the total rainfall. The average soil loss was 0.7 t/ha. This justifies the adoption of conservation measures for resource augmentation. The analysis of runoff showed that a minimum of 500 m^3 of rainwater can be harvested in a year. By the end of the rainy season, the pond would be full to its capacity. It was further noticed that the runoff events came in two major spells - one in the beginning of the monsoon, and the other towards the end, making it possible to fill the pond twice (provided one filling is used in the dry spells during the rainy season) and increasing the effective storage to 1000 m^3. However, to be more conservative and to be sure of the quantity of water, construction of a 500 m^3 pond, as mentioned earlier, was justified.

Development of Generic Equation for Pond Design

In order to minimize the seepage area as well as the evaporation losses, a dugout farm pond (Figure) can be best designed for a given storage volume (V), depth (D) and side slope Z: 1 (Z horizontal to 1 vertical) using the following equations (Mishra and Sharma 1994)

Table 2. Analysis of hydrologic data of a 4.0 ha micro-watershed at CRIDA research farm, Hyderabad over a period of 5years (1990-94)

S. No.	Description	1990	1991	1992	1993	1994	Mean
1.	Total rainfall. mm	778.8	913.1	766.1	755.2	851.3	813
2.	Rainfall events	81	57	58	70	75	68
3.	Rainy days(>2.5mm)	54	41	41	48	54	48
4.	Runoff causing rainfall, mm	429.7	628.6	504.3	360.8	534.4	492
5.	Runoff events	11	12	11	10	14	12
6.	Runoff causing rainfall (% of total rain)	55	69	66	48	63	60
7.	Runoff, mm	19.2	32.5	13.9	12.1	17.3	19
8.	Runoff, m^3	768	1300	557	485	692	760
9.	Runoff (% of runoff causing rainfall)	4.47	5.17	2.76	3.36	3.24	4
10.	Runoff (% total rain)	2.46	3.6	2.0	1.95	2.03	2
11.	Soil loss (t ha^{-1})	0.95	1.5	0.18	0.34	0.71	0.7

$$X = (0.5/C)\ [\ \sqrt{\{DZ\ (1+C)\ \}^2 - 4C\ \{2D^2Z^2 - (V/D)\}} - DZ\ (1+C)]\ \ldots\ldots \qquad \text{(Eq. 1)}$$

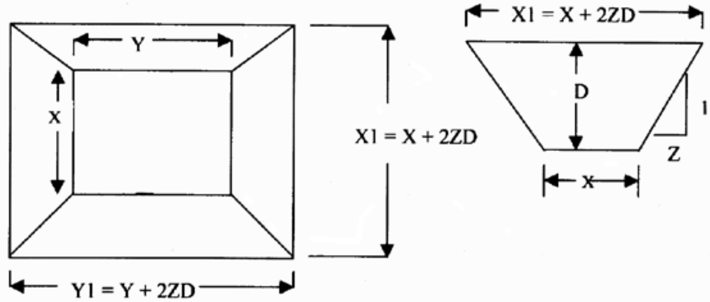
Where, X, Y = Two sides of the dug out pond (rectangular) at the bottom and C = Y/X

For a square section (C=1, i.e. X=Y) the above equation is simplified as follows:

$$X = \sqrt{[\ (V/D) - D^2Z^2]} - DZ \ldots\ldots\ldots\ldots\ldots\ldots \qquad \ldots\ldots\ldots\ldots\ldots\ \text{(Eq. 2)}$$

For a square bottom section having side slope 1:1 (Z=1) the Eq.2 can be further simplified as:

$$X = \sqrt{[\ (V/D) - D^2]} - D\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ \text{(Eq. 3)}$$



Dugout Farm Pond

Considering the actual runoff from 4 ha micro-watershed as discussed earlier, a trapezoidal farm pond of 540 m^3 (Top: 17mx17m, bottom: 12mx12m, depth: 2.5m, side slope: 1:1) capacity was constructed at the outlet point. The pond was lined with brick masonry. By accounting for the annual silt load, the effective storage capacity of the pond was taken as 500 m^3 for the analysis.

Pond Lining

Loss of water due to seepage from water harvesting structures on Alfisols of the semi-arid tracts is a major problem. The evaluation study by Mishra *et al.* (1994) shows that the HDPE (black containment liner, 150 micron) lined pond though initially effective, proved to be ineffective in the fourth year of laying and permitted heavy seepage. Other materials like soil-cement and asphalt lining were worse: they suffered much more from the seepage problem as time passed. Only the brick lined pond with cement plaster withstood well in the field situation and proved to be most cost effective in storing water for reuse. Hence brick lining is recommended for Telengana region of Andhra Pradesh

Use of pond water and economics

The pond water was utilized for growing vegetable crops during the post rainy and summer season. Mishra *et al.* (1993) observed that with stored water from 500m^3 pond vegetable crops of 4 months duration (November- February) can be grown on 0.1 ha by irrigating at 50 per cent evaporative demand (open pan evaporation) for achieving the maximum water use efficiency. The typical water budgeting of farm pond (in research farm) in Telengana area of Andhra Pradesh (Table 3) is as follows (Mishra *et al.*, 1993).

The experience at farm level has shown enough potential of farm pond (brick lined) technology in growing vegetables in the off-season by satisfying water requirement at 50% of weekly evaporation. Economic analysis was carried out by cultivating tomato in 0.1 ha during post rainy season (Mishra *et al*. 1998). It is unlikely that the pond would get filled every year before and during the season. Hence, supplemental irrigation to cereal crop for additional returns from the use of pond water may not be always feasible during the rainy season. But, the results of the experiment show that the pond was always full by the end of the rainy season. Hence, in arriving at the regular benefit flow, the assured net returns only from 0.1 ha of vegetable crops was considered in the post rainy season. Both the costs and output prices were assumed to increase from the original cost by 10 per cent every year for 20 years, the expected life of pond. Thus, a cost and benefit flow for 20 years was generated for economic analysis. The conventional measures of project evaluation on Pay Back Period (PBP), Benefit-Cost Ratio (BCR) and Internal Rate of Return (IRR) were worked out to assess the economic viability of the pond. The figures on the profitability measures are presented in Table 4.

An economic analysis of the above pond with tomato as test crop shows a pay back period of 10 years with BCR 1.5 and IRR 19%. This technology will be more viable and economical in *vertisols* where lining is not essential. The BCR will certainly be higher if intangible benefits are quantified and the use of water during the season (if any) is also considered.

Constraint and up-scaling

The poor farmers find it difficult to go for high initial investment to adopt this technology for which institutional subsidized credit support is needed. This program can be linked to watershed project and NREAGA. The banks can come forward for providing loan to the interested farmers for adopting this technology. The policy of the Government should also be favorable for making a

Table 3. Budgeting of farm pond water

Capacity of farm pond (Full capacity by October end)	500 m^3
Catchment area	4 ha
Water loss by evaporation and seepage (From November to February)	95 m^3
Water available for irrigation	405 m^3
Water requirement of vegetable crop (@ 50% open pan evaporation)	349 mm
Area irrigated by farm pond for growing vegetables	0.1 ha

Table 4. Cost benefit analysis of the farm pond

Particulars	Measures
Pond size, m^3	500
Pay Back Period (PBP), years	10
Internal rate of return (IRR), %	19
Benefit cost ratio (BCR)	1.6

bankable scheme with liberal subsidy component for up scaling of the technology.

Conclusions

In a watershed, series of ponds may be constructed along the water courses/drainage channels to intercept runoff, reduce peak flow, control erosion and store water for supplemental irrigation/groundwater recharge. This case study generates the following issues on water harvesting and use. This case study generates the following issues on water harvesting and uses in drylands for their generic solution in future R&D efforts.

- Runoff yield potential of the catchment should be carefully studied for designing small-scale water harvesting structures and for determining catchment- command ratio, ponds may be made lined in light soils.
- Prioritization of crops and cropping systems that can efficiently utilize the limited water to improve the water productivity.
- Modern methods of irrigation for utilization of harvested water.
- Government intervention for popularization of small-scale water harvesting structures and for supporting mechanical measures.

References

Mishra PK, Manjunath BL, Rao JV and Subba Reddy G. (1993). Farm pond- A potential source for vegetable production. Indian J. Dryland Agric. Res. & Dev., 8(2): 171- 72.

Mishra PK and Sharma S. (1994). Theoretical considerations in design of farm ponds for minimising evaporation and seepage losses Indian J. Dryland Agric. Res. & Dev., 9(2): 114 –120.

Mishra PK, Padmanabhan MV and Sivaprasad S. (1994). Effectiveness of different lining materials in farm pond J. Water Management, 2(1&2): 55 – 58.

Mishra PK, Rama Rao CA and Sivaprasad S. (1998). Economic evaluation of farm pond in a micro-watershed in semiarid alfisol deccan plateau Indian J. Soil Cons., 26 (1): 59 – 60.

Rainwater Harvest and its reuse for Groundwater Recharge – A Case Study

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Abstract

Present study was undertaken to improve ground water through artificial recharge and it's economic viability. The constraints in realizing the ground water development project and lessons learned are also discussed.

As per the Indian Rainwater Budget, an amount of 400 Mha-m of water through precipitation is received every year with an average rainfall of 1194 mm on 328 Mha area.

With all this, 'Monsoon' is a blessing to Indian agriculture, providing enough water to harvest two good crops, at present. However, uncertain rainfall having uneven distribution and varied intensity with respect to time and space always cause floods, droughts and waterlogging at one or the other place.

Various technologies, for improving the efficiency of rainwater and runoff management and their use on-farm, are developed to suit different agro-climatic situations, with particular reference to dryland crop cultivation, considering rainfall, cropping pattern, soil type, topography (Verma, 2005b). Such research technologies mainly included terrace level practices like contour bunds, graded bunds, zingg terraces, border strips; inter terrace level practices like compartment bunding, scooping, tied ridges/furrows and runoff storage technologies/practices like nala bunding, check dams, gully plugs, farm ponds, they are being practiced with good impact on crop production. However, with all this technological advancement, the scarcity of water in the form of soil moisture still exists in almost all dry farming situations of the country.

On the other hand, cultivable area is getting reduced with time due to urbanization, colonization, industrialization, etc. With reduction in cultivable area available for food grain production and the loss of rainwater (29 per cent) eroding enormous quantity of fertile top soil (on an average 42 t/ha/yr), the targeted food/crop production in the limited available area, which is mandatory, is difficult to achieve. Hence, the pressure on demand for water for this and to meet the domestic, industrial and other requirements is greatly increased. This is resulting in extensive, continuous and indiscriminate overexploitation of groundwater resource through increased number and depth of bore wells. Easiness in bore well digging, due to advanced bore well engineering technology, has made an indirect impact on fast depletion of groundwater resource availability and alarmingly dropping the water table depth from surface (Verma, 2005a). It is very evident from the number of failing bore wells/open wells and it is unsustainable to pump out water from wells without recharging the same from the rainwater. To reverse the trend or to reduce the effect of over exploitation, the groundwater recharge is essential at large scale at agricultural, residential and institutional premises. But the efforts made towards the replenishment or augmentation of groundwater resource, are very meager (Anon. 2006).

Target Domain

On account of frequent / continuous drought situations, acute shortage of water for both agricultural and domestic/industrial purpose is being experienced. Faulty soil and water management practices including excess use of irrigation water, crop production practices of high water requirement like use of HYV's inorganics, etc., in agriculture, man-made disturbances such as encroachments in natural pockets of runoff storage structures like tanks, non availability of open soil surface due to pavement in 80-100 per cent unbuilt compound area, road metalling, drilling of large number of new bore wells without maintaining statutory minimum distance of 240 m between two successive points, etc., particularly, in urban localities due to increase in area under housing and buildings are some of the reasons for over exploitation of groundwater by increasing population.

The groundwater availability is declining very fast. Survey of 3 lakh wells in 72 *taluks* (17 districts) of Karnataka from 1982 – 2001, indicated that more than 50% of the wells were dried and in the rest, water table had declined by 5 m to 8m due to 20 – 59 per cent less rainfall, accompanied by high temperature up to 43^0 C during the period. Average depth to GW level of the wells/bore wells at various locations in Bangalore city was 15.59 m in May 2003 as against 10.88m observed in May 2001. Similarly, in Hubli-Dharwar city, out of 17000 bore wells, the average depth to groundwater level increased from 3.42 m (2000) to more than 45 m (2004). Such situations are creating socio-economic problems to public, government and other institutions like corporations and municipalities (Report of CGWB and PHE Dept.2005). At the same time, in some sites of the command area like UKP, M & G, TBP etc., the cultivable area is waterlogged with very shallow water table due to inefficient irrigation management (CADA, 2008). Hence, it is imperative on the part of researchers, extension workers, farming community, in particular and public at large, to harvest efficiently rainwater for *in situ* conservation and store it under ground effectively by employing suitable technologies for the future sustainable water availability. Hence it is high time now, for suitable scientific interventions to recharge underground reservoirs through bore wells / open wells, by artificial methods, at economic cost using the surplus runoff for storage of groundwater. The sub-surface geological formations may be considered as "warehouse" for storing water that come from sources located on the land surface and the sub-surface reservoirs. They are very attractive and technically feasible alternatives for storing surplus monsoon run off. These reservoirs can store substantial quantity of water. The deeper water levels in many parts of the country may be substantially raised, resulting in reduction in the lifting costs and energy saving (CGWB 2000).

It is, therefore, inevitable at the present to enhance the natural phenomenon of rainwater infiltration into the aquifers through techno economical artificial techniques. Surface runoff and roof top water are important and amply available water sources for groundwater recharge. With such points in view, efforts were made to adopt the project with the following objectives:

Objectives

- To improve groundwater resources by artificial recharge.
- To know the technical feasibility and impact of recharge system/unit.
- To know the economic aspects of recharge techniques.

To address these objectives, an attempt was made at the University of Agricultural Sciences, Dharwad, to design and develop a technology for enhancing intake rate of runoff with Inverted Filter system/unit by harvesting rainwater available in the form of surplus runoff and its reuse for groundwater recharge through bore wells/open wells. Such case studies were conducted to determine the impact by recharging bore wells/ open wells existing on UAS farms at the Main Campus Dharwad and sub campuses at Bailhongal and Hebballi and farmers' fields at Tadkod village in Dharwad *taluk*, using rainwater surface runoff.

Methodology

The basic design and development this innovative technology was the result of deliberations of scientific knowledge, expertise and experience of scientists from research, development and extension of agricultural engineering, crop production and several other related aspects. It was then recommended for field adoption on adhoc basis depending upon the field situations and techno-economic feasibility (CGWB, 2000). The basis for the design and development of this technology was the result of discussions on various concepts/assumptions, approaches, advantages and practical field situations pertaining to sub-surface storage and the artificial recharge structure required for this process. The salient outcomes are:

- The underground storage of water has beneficial influence on the existing groundwater regime and the system recharges the sub-surface storage either below the well under treatment or in other places.
- The structures required for artificial recharge of the groundwater through bore wells / open wells by inverted filter system / unit are, generally, of small size unlike other methods viz., check dams, percolation tanks, surface spreading basins, subsurface dykes, etc.
- No gigantic and separate surface structures are required to store surface runoff.
- The structures and methods for artificial recharge of groundwater are cost effective and may work as economically viable proposition.
- The sub-surface storages, when located in technically feasible and hydro geologically suitable situations, are environment friendly.
- The sub-surface storages are free from the adverse effects like inundation of a large surface area, loss of cultivable land, disturbance to normal living, substantial evaporation loss, etc.
- Results in reduction of water lifting costs and energy saving and on the cost on water conveyance system compared to storing elsewhere on land surface.
- Results in substantial improvement of natural groundwater quality in brackish and saline areas due to conjunction of rainwater.

This innovative technology basically included the following major design details/ specifications with due flexibility for suitable modification of types/models/ components of techniques to suit to the location-specific situations during the process of implementation. (Fig. 1 and 2.)

A. Source of rainwater for recharge:

- Surface runoff harvest
- Roof top water harvest

B. Recharge technique:

- Point recharge filter unit surrounding bore well and perforations on casing pipe
- Point recharge filtering unit away from bore well and connected by underground conveyance pipe

C. Type/Model of filter unit of about 3 m x 3 m x 3 m standard size:

- Inverted vertical type
- Horizontal type

D. Shape of filter unit of about 9 cubic metres capacity:

- Cube shape
- Circular shape
- Semi circular shape

E. Civil Materials for refilling filter unit in inverted fashion (top to bottom):

- Rubbles/ boulders
- Pebbles/ jelly
- Charcoal
- Aqua / metal mesh
- Rough sand
- Cement bricks/stones for coping wall

Results

The impact of technology was surprisingly predominant and quite visible. It resulted in enhanced infiltration within a span 14 hours after a rainfall of 55 mm during the previous night, runoff collected near filter unit that flowed to groundwater resource through it. But the runoff collected near bunds on upper reaches of the filter unit was still ponding even after a lapse of time duration (as depicted in photos).

An amount of 118.56 and 102.96 cubic metres of runoff was found ponding/stagnant in two plots on the upper reaches of the Groundwater Recharge Filter Unit as against no collection at the bund near the system (Table 1). An amount of Rs. 15020/- and Rs. 16235/- was to be invested towards expenditure on installation of groundwater recharge filter units around bore well and away from bore well, respectively (Table 2). This excludes the cost on the diversion of runoff to concentrate at the filtering unit. Considering the proposed cost on extension of farm pond/percolation tank for surface storage and to recharge groundwater (Table-3) using surplus runoff, it was noticed that the cost on this proposal was too high as compared to that involved the installation of filter units for subsurface storage.

Constraints

Constraint includes the availability of suitable material like rubbles, pebbles, coarse sand at the farm itself to make the project economical/cheap. The cubical structure of 3 m3 (cube) pit, when opened freshly, appeared very small and hence it was enlarged on all sides for which the quantity of civil materials required were considerably large.

This was important in terms of agriculture as the water from selected bore well or surrounding bore wells was used for agricultural / crop production purpose.

Lessons Learnt

The venture appeared successful and was also adopted by one farmer on his farm voluntarily.

Strategies for up scaling

The quality of recharged water (physical and chemical quality) should be monitored for its use for domestic or drinking purposes. Govt. subsidy should be provided to the pilot demonstrations conducted at rural and urban sites.

References

Anonymous, 1999, Report of National Commission for Integrated Water Resource Development Plan.

Anonymous, 2006, "Amruthavarshini - A guide for Rainwater Harvesting" published by Karnataka State Council for Science and Technology, Bangalore.

CADA, 2008. Report on achievements of M& G and TBPCommand Area Development Authorities,

CGWB, 2000, Guide on Artificial Recharge, Central Groundwater Board, Ministry of Water Resources Report, New Delhi, May.

Report of CGWB and PHE Dept. 2005, Report on to Groundwater in Hubli-Dharwad cities for planning Water Supply.

Verma, H.N. 2005 a, Multiple and conjunctive use of Rain, Surface and groundwaters for sustained agricultural production. (Training Lecture Notes), CSSRI, Karnal.

Verma, H.N. 2005 b, Watershed Development and rainwater harvesting techniques for enhancing groundwater recharge (Training Lecture Notes), CSSRI, Karnal.

Table 1. Volume of runoff at and on upper reaches of Groundwater Recharge Filter Unit

Sl.No	Particulars	Runoff Volume collected		
		Near Bund at Filter Unit	Near Bunds on upper reaches	
			Plot-1	Plot-2
1	Rainfall amount	55 mm	55 mm	55 mm
2	Size of Runoff collection	nil	18.0m x 22m x 0.26m	22.8m x 20x 0.26m
3	Runoff volume collected	nil	102.96 cub- m	118.56 cub- m

Table 2. Approx. Quantities and Cost of important items of different G.W. Recharge Units

S. No.	Particulars	L(m)	B(m)	H(m)	Qntily M3	Rate	Amount for Filter Unit	
							Around bore well	Away fom bore well
A	Construction of thefiltering system forGW R							
1	Excavation of Recharge pit Depth3.0 m	3.00	3.00	3.00	27.00	267.90	1469.34	1469.34
2	Refilling/construclion of Recharge pit by rovg following m aterials							
	a) Boulder layer (15-25 cm))	3.0	3.0	1.0	9.00	364.00	3276.00	3276.00
	b) Jelly layer Graded jelly/ metal(45-63 mm)	3.0	3.0	1.35	12.15	212.00	2575.80	2575.80
	c) Sand layer: coarse sand	3.0	3.0	1.00	9.00	69.98	629.82	629.82
	d) Charcoal layer (Good quality at market rate)	3.0	3.0	0.15	1.35	LS	1200.00	1200.00
3	Construction of stone wall around recharge Biter uiit(3 m x 3m) wrUi stones of about 30 cm size andpointing with 1:5 cement : sand mixture	12.0	0.30	0.75	2.70	691.00	1865.70	1865.70
B	Drilling of holesto casing pipe at suit able depth for inserting conveyance pipe as per directions.	-	-	-	-	LS	2500.00	2500.00
C	Layout of PVC pipes: Providing/laying PVC pipes specification of approved make &withnece ssary specials/phigs wherever nece ssary as per requirem ents. (forAv.20M)	10 10	-	-	10 10	55.65 66.15	-	556.50 661.50
D	Other charges/expenditure (Nylon mesh/iron mesh, completion' petty items etc.,)					LS	1500.00	1500.00
						Total Rs.	15016.66	16234.66
						R/.O .Rs.	**15020.00**	**16235.00**

Table 3. Quantities and cost Estimates (in Rs.) for Groundwater Recharge though Extension of farm / percolation ponds

II. Proposed Extension of pond at UAS Campus, Dharwad.		
1)	Proposed top dimension	40 m
	Existing top dimension	15 m
	Extension top dimension	25 m
	Proposed bottom dimension	15 m
	Existing bottom dimension	15 m
	Extension top size	25m x 15 m
	Extension bottom size	20m x 10.m
	Av. dimension	22.5 mx12.5 m
	Depth	2.5 m
	Side slope	1:1
	Av. Area / Av. Capacity/volume	218.25 Sq.m /703.12 Cub m
2)	Volume of earthwork excavation: (Average) Rate of excavation for varying depth from 0-30 m	Rs. 53.23/Cub.m
3)	Cost of earth work (703.12 x 53.23)	Rs. 37427.08
4)	Cost on Inlet-outlet silt trap & other charges	Rs. 8000-00
5)	Total Cost	Rs. 45427-08
	R/O	**Rs.45430/-**

Farm Pond Initiative in Rainfed Areas in Rajasthan

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Abstract

Present paper discuss the farm pond intervention in order to mitigate the water crisis in Rajasthan. The standard 10′X10′X2′ pond was constructed which increase the soil moisture condition of the field, increase the water table in the adjacent wells and provided opportunity for agro-forestry and orchards and scope of sprinkler irrigation.

Background Information about the State of Rajasthan

Rajasthan is one of the largest states of India, covering nearly 10.4 percent of India's geographical area. The state is divided into 33 administrative districts and 10 agro-climatic regions. Over 65% of the cultivated area is rainfed and nearly 60% of the area falls under a desert environment. Nearly, two thirds of the population of about 6 crores depend for their livelihood on agriculture and animal husbandry, agro-forestry and agri-business. The average annual rainfall is 557 mm and there is a considerable degree of variation between seasons and regions within the state. Groundwater is getting both depleted and polluted. The economic well being of a vast majority of the population depends heavily on the progress in agriculture.

Climate of the state is mostly arid to semi-arid with high annual evaporation rate. The rainfall is highly variable, irregular & erratic in nature. The monsoon season is between July to September. Maximum summer temperature ranges between 48°C to 17°C and minimum winter temperature ranges 32°C to 4°C.

Groundwater Availability: Total no. of blocks in Rajasthan in 2004 was 237, out of which 140 are in the Overexploited category and 50 critical, 14 semi-critical and only 32 can be considered safe. Groundwater is the major source of water in the state, meeting 91% of the drinking and 65% of the irrigation needs of the state. The groundwater resources have been gradually getting depleted over years. There has been a marked deterioration of groundwater quality over the past 15 years.

Water Table: Water table ranges from 2 to 130 meters. In majority of western Rajasthan, it ranges from 40 to 80 meters, southern & eastern parts 10 to 30 meters, eastern alluvial parts 20 to 50 meters and > 80 meters in parts of Jaisalmer, Barmer, Bikaner, Churu and Jodhpur districts

Drought condition is one of the phenomenal characteristic of the state where rainfall is highly variable, irregular and erratic in nature. State faces drought, which occurs every 2 to 3 years. In the past, out of 30 years 26 years have been drought years. 31 of 32 districts faced drought. These are the challenges the farmers have to face in sustaining their livelihoods, which is dependent on agriculture and animal husbandry as the major sources.

Drought: Famine and scarcities are the most familiar word of the state, which had affected 3.2 million people & 40 million cattle. 70 % of the population are deprived of drinking water. Groundwater level has dropped down by 15-20 meters.

Water crisis in Rajasthan: The state has limited water resources 1.15 of the country. Surface water resource is very meager. Groundwater resource is highly depleted and the state has 50% of fluoride-affected villages in the country are in Rajasthan. Groundwater is saline to highly saline in most western districts.

In the state, the average annual rainfall is 557 mm and with a total area of 342239 sq. km, with valuable source of water. Rains are the main source of fresh water but generally stored runoff water and groundwater are considered as major sources of water for agriculture.

There has been a number of initiatives undertaken by the state government as well as NGOs in the rainwater conservation and management in the state.

This case on the initiative of farm pond in Rainfed area is being put forward for the District of Ajmer:

Under drought relief operation in the year 2006, there were major initiatives being taken which are as follows:

- A successful attempt has been made to ensure life saving irrigations for rainfed crops.
- The activity were chosen and executed on individual farm fields on a pilot basis to reduce the risk of crop failure, especially for the small and marginal farmers.

The persistent drought condition indicates the fragile nature of the rural economy. The financial implications of each year of drought are enormous. The small and the marginal farmers are the most affected segment. These segments of farmers also don't have the potential of having life saving irrigation facilities. For them, the initiative of farm ponds has been a boon.

Farm ponds have been found to be the best way of coping with the distress condition in the region. Farm ponds are not only cost effective for small and marginal farmers, but have also provided the support of life saving irrigation. Farm ponds though look like a very simple structure, the intrinsic value of farm pond is multifaceted.

Farm Ponds: Farm ponds are rainwater storing structures made by constructing a dam or an embankment or by excavating a pit or dugout. Generally, the size of the farm ponds constructed is of 10X10X2 m^3. The soil extracted from farm pond during the digging process is used to strengthen the embankment of the farm field. The water stored in the farm pond is used as critical life saving irrigation. Due to farm ponds, the moisture content in the field also gets enhanced. The water table in the near by wells also increases due to farm ponds. This also ensures the availability of drinking water for animals.

Process Facilitation

One of ARAVALI partner organization, *Gramin evam Samajik vikas Sansthan*, (GSVS) Ajmer, initiated the process of dialogue with District Agriculture Department where in there was a scheme for constructing 10 farm ponds in a village *panchayat*. GSVS mobilized the community to participate in the scheme. Wherever construction of farm ponds was taken up with individual farmers, two members of the farmer's family and 6 additional labour were deployed for work. Total cost of the farm ponds was 8000 /- Rs which was given as labour cost. This also helped in providing employment opportunity.

Objectives of constructing Farm ponds were as follows: -

- To harvest rainwater.
- Recharging of wells.
- Increase moisture content in the field.
- Ensuring the availability of drinking water for Livestock.

The primary objectives of farm pond constructions were to ensure life-saving irrigation. In the absence of monsoon rain, water from the farm pond could be used to save the crop. Farm ponds also maintain micro humid conditions during the dry spells, replenishes groundwater and most importantly availability of water for human consumption as well as for livestock. Farm ponds also provide opportunity for undertaking orchards & agro-forestry and the sprinkler system can be easily run with farm pond water.

Terminal drought is defined as the inadequacy of the rainfall when required i.e. during flowering, pollination and seed formation stages of the crop. Terminal drought reduces production of food grains by 80% and fodder by 20 to 25 %. Farm ponds provide critical irrigation facility to the crops during the terminal drought phase.

There has been increased demand by farmers for the construction of farm ponds in the region and our partner organization, GSVS is working in many of the villages.

The impact of farm ponds have yielded several benefits such as:

- Crop production even under terminal drought,
- Checks soil erosion and retains silt,
- Increased moisture content in the field,
- Prevents excess runoff from the field,
- Availability of drinking water for the livestock.

Major conclusions can be drawn from the initiative of farm ponds are as follows:

- Reintroduction of traditional farm ponds should be included in the regular government schemes
- Farm ponds construction should be incorporated and converged with Swarn-

Supplemental irrigation with harvested water

Critical irrigation with water from the farm pond during the terminal drought					
Crops	Water Requirement (mm)	Actual Rainfall (mm)	Shortfall (mm)	Water available in Farm Pond (mm)	Additionally Available water in Farm Pond for Drinking / Plantation (mm)
Maize	550	350	200	200	0
Jowar	450	350	100	200	100
Bajra	350	350	0	200	200

jayanti Gram Swarojgar Yojana, National Rural Employment Guarantee Scheme and Rashtriya Krishi Vikas Yojana programmes for large scale up scaling.

- With the construction of farm ponds, the small and marginal farmers have benefited the most.
- Innovative methods such as the use of plastic lining sheet, pitching to control soil erosion could be incorporated.

References

Development of Agriculture and Animal Husbandry in Rajasthan, Report of the TASK FORCE constituted under the Guidance of Prof. M.S.Swaminathan, Agriculture Department, Government of Rajasthan.

Presentation on Farm Pond by the CEO, Ajmer.

Pahal logon ki, Issues: 40, January 2008, ARAVALI, Jaipur.

Experiences of Water Harvesting through Farm Ponds in High Rainfall Hill and Mountain Regions

Water Harvesting in Hilly Areas of Uttarakhand: Opportunities and Challenges

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Abstract

About 70% population living in mountainous regions of Uttarakhand State mostly depend on agriculture for their livelihood. But various climatic, geographical and socio-economic constraints have led to a dismal low agricultural productivity in the region. Agriculture is largely (about 90 %) rainfed, and farmers generally face severe soil-moisture stress at germination stage and long dry-spells during the subsequent growing of winter (*rabi*) and pre-monsoon crops due to erratic distribution of rainfall amount and distribution. Though the average annual rainfall in Uttarakhand is about 1000 mm, the agricultural productivity is adversely affected by non-availability of sufficient water at critical stages of crop growth. Therefore, the only option is to collect and store water resources available in three forms namely, direct surface runoff, runoff through roof-tops of houses, and the discharge from natural water springs. The spring water in low quantity goes waste, but its collection in the storage tanks can be developed into a large water resource to solve the problem of drinking water and irrigation in the region. The field studies conducted in Garhwal region about 2000 m above mean sea level, revealed that construction of a brick-lined cement tank to store spring-water for drinking purpose, in combination with a dugout farm pond lined with 0.25 mm thick low density polyethylene (LDPE) sheet to collect the overflow from this tank and the surface runoff, is a technically feasible and economically viable option to develop water resources and to enhance the irrigation potential in the region. This integrated approach must be spread to far-off places in the mid and high hills, which is a challenge for the developmental agencies in the undulating, rugged and inaccessible terrain.

Introduction

About 30% of the total geographical area of India is drought prone, primarily, due to erratic pattern of rainfall distribution. Out of about 142 million ha total cultivable land, about 60% is categorized as rainfed or drought prone. It is evident from Table 1 that a wide scope to beneficially utilize the available rainwater in the zone of 1000-2500 mm rainfall exists. The mid and high hills of Uttarakhand fall under this category. Water is the single most important element for sustaining mountain agro-ecosystems. Mountains are the major sources of all the natural resources including forest, land, water, animal, minerals, etc. and they are called life giver to the biotic means not only to the inhabitants residing in this region but also to the inhabitants downstream. The Himalayas have given birth to many perennial rivers and streams for the survival of living beings in the downstream regions of most of the northern states of India, but the inhabitants of the mid- and upper-reaches in Himalayan region keep struggling for their own survival for want of adequate water resources at their disposal, food security and sustainable livelihood due to various topographical and socio-economical constraints.

Since generations, the inhabitants of Himalayan region have been depending on the natural water springs and streams to meet their daily water needs for drinking and domestic uses, irrigation, animal consumption, etc. During recent times, most of the perennial springs and streams have become seasonal or have dried-up for want of adequate recharge due to various natural and man-made hazards. Women have to walk several kilometers daily to fetch a head-load of water for drinking and domestic uses. Though about 90% of population in the hilly areas of Uttarakhand earns their livelihood from agriculture and animal husbandry, they are still in the subsistence class, characterized by extremely limited capital resources and consistent use of traditional means of crop production. Various climatic, geographical and socio-economical constraints have led to a dismal low agricultural productivity from unconsolidated, small and scattered land holdings in the region. About 90%of agricultural lands, mostly in mid and high hills, are rainfed and vulnerable to severe soil erosion and degradation due to erratic rainfall, cloud-bursts and large dry spells during the crop growth period. Ever increasing population of humans and cattle has resulted into inappropriate cultivation practices on the marginal lands and intense use of water resources, which cause considerable surface runoff and soil erosion on one hand, and reduce the infiltration and discharge of natural water springs on the other.

Though most areas receive good annual rainfall, its intensity and distribution is quite erratic and causes severe drought spells to hamper the growth of timely sown winter crops, and subsequent planting of spring crops due to the lack of soil moisture. This situation forces the farmers to risk their winter (rabi) crops at the germination and ripening stages of growth. Frequent and long dry spells retard the growth, size and yield of important fruit crops like apple, plum, peach, apricot, etc. If proper irrigation facilities are assured, vegetable crop production has a great potential to raise the economic standard of the hill farmers. Off-season vegetables (pea, potato, cauliflower, cabbage, etc.,) can be produced on a large scale and can be sold at high prices in the plain areas. Assured irrigation can also promise cultivation of pea and potato crops twice a year.

Considering all these points, there remains no option but to appropriately harvest the available water resources at suitable locations. In the hilly areas, water is available in three forms namely, direct surface runoff, runoff through roof-tops of houses, and the discharge from natural water-springs. Several authors have emphasized runoff harvesting to eliminate the ill-effects of droughts and low productivity in the arid semi- arid and foothill areas in the country (Chitranjan and Rao, 1986; Grewal *et al.*1989 and Oswal, 1994). The studies conducted by Kumar (1992) suggested the feasibility of cost-effective low density poly ethylene (LDPE) lined dugout small ponds for irrigation purpose in mid-Himalayan region. In order to minimize the adverse effects of water stress, particularly at the productive stages of crop growth, the conservation of rainfall in soil profiles and providing irrigation through runoff/spring flow harvesting in ponds or tanks at suitable locations, are the only ways out to solve the drinking water problems as well as to enhance productivity of rainfed agriculture on high and medium hills in Uttarakhand. This study also analyses socio-economic aspects of water resources planning and management in terms of resource sharing and maintenance of storage structures.

Study Area

The study was conducted at the Hill Campus of G. B. Pant University of Agriculture & Technology, Ranichauri located at the longitude of 78^0 2′ E and latitude 30^0 15′ N with an altitude of about 1900 m above the mean sea level. The mean annual rainfall of this region is about 1176 mm, of which about 75% is received during the monsoon months, from June to September. The soil of the region is generally sandy-loam type. The surface runoff tends to be high due to high slopes and low water holding capacity of the soils. Coarse soil texture and high seepage losses through the soil do not permit sufficient moisture retention in the surface soil and upper horizons of the sub-soil. Because of this phenomenon, the crops suffer badly due to moisture stresses at different critical stages of crop growth during pre- and post-monsoon periods and long dry spells during the rainy season.

Hydrologic Analysis

The surface runoff, which can be estimated using various methods on the basis of past rainfall data and land use, is mostly suitable for irrigation. Runoff through roof-tops can be estimated using a reasonable value of runoff coefficient for different type of roofs, and this water can be utilized for domestic uses after proper filtration. The flows from water-springs can also be estimated using past records and this water can be used for drinking purpose. The optimum size of a lined pond depends on the amount of runoff expected, crops to be irrigated and benefit-cost ratio for the harvesting system. The probability analysis of rainfall data reveals that at 80% probability (assured level), the expected rainfall during pre- and post-monsoon periods is almost negligible for the germination of *rabi* (winter) crops creating large moisture stress at the germination and reproductive stages of *rabi* crops and timely sowing of summer crops. Under these circumstances, rainfall and/or runoff harvesting during rainy season along with spring-water harvesting at suitable locations seems to be the only way out.

Though water requirements of the farmers are greater, the size of storage structures has to be restricted according to water availability and topography of the location. The capacity of the storage structures depends mainly on the availability of relatively flatter land on which these structures could be made, and the runoff passing through that point. The small and scattered land holdings on different terrains permit the construction of small water storage tanks at the upstream end of a cluster of fields to facilitate irrigation through gravity flow. The experiments were conducted at the research station and nearby areas to evaluate the technical feasibility and economic viability of lining materials. Out of the existing options viz. cement-concrete, brick/stone masonry, and LDPE sheet, for lining the dugout pond, the LDPE lining has proved to be technically feasible and economically viable for the hill farmers. This technique is the most appropriate for poor farmers, as it can be implemented and maintained by the farmers themselves using their own labour and locally available resources.

Design of the Pond

The construction of dugout pond includes digging of a truncated reverse-pyramid shaped pit with 1:1 side slopes. The depth of the pond was restricted to 1 to 1.5 m only to avoid upward movement of the bottom soil due to buoyant force of water. At the locations where stones are available near the site, the depth of pond may be increased to 2 m by doing the stone pitching all around the surface of the pond. As shown in Fig. 1, a single piece LDPE sheet (0.25 mm thick) of required size is placed with properly folded corners and buried ends on all sides. Before placing the sheet, the inner surfaces of the pond were plastered with 5 cm thick mud plaster so that the sheet is properly stuck to the surfaces. Another 10 cm layer of mud mixture of soil and wheat straw or chopped dry pine-needles (4:1) is placed on the sides, and a 15 cm thick layer is placed at the bottom. In case of harvesting the surface runoff, a small silt retention trench of 1x 0.5 x 0.5 m size is dug at the entry point to the main pond so that debris and suspended particles along with overland runoff could settle down and relatively clean runoff water may enter the main pond. The silt retention trench is not required while harvesting the runoff through roof-tops or water-springs. Evaporation losses from the pond can be minimized by spreading a small quantity of burnt engine oil or by broadcasting polyethylene granules of about 3 mm size on water surface. Being relatively free from dust or foreign materials, the runoff from roof-tops and the flows from water-springs can be stored in closed brick-cemented tanks for drinking, domestic uses and cattle feeding after proper treatment or filtration.

The cost analysis of the pond is shown in Appendix 1. The construction cost of this pond comes out to be Rs. 150 per cubic meter storage of water, which is much less than the brick-masonry cement plastered tanks of the same capacity costing more than Rs. 1000 per cubic meter. Another advantage of LDPE lined pond is that this system can be constructed, repaired and maintained by the farmers themselves at a reasonably low cost, as the only material to be purchased is the LDPE sheet, which may be available from local markets. As a precautionary measure, the LDPE sheet should not be exposed to the sun light for longer duration as sun's ultra-violet rays can damage the sheet. The useful life of such ponds is normally 20 years, which can be further extended if special care and maintenance is ensured. Water from these tanks is taken by siphoning through rubber pipes to irrigate the crops at lower elevations through gravity.

As an integrated approach, all the available water resources can be combined in such a way that a cemented tank is used to store spring-water and runoff from roof-tops for drinking and domestic uses, while the over flow of this tank and overland surface runoff may be stored in the LDPE-lined dugout ponds at lower elevations (Fig. 2). In this way, the water resources are utilized to the maximum extent and all the needs of the farming communities are also met simultaneously.

Utilization of Water

The harvested water must be judiciously and efficiently used for irrigating the high value cash crops in the region. It has been found that the off-season vegetable production is one such option where farmers can fetch high returns for their investments. Important vegetables like potato, pea, cabbage, capsicum, etc. along with ginger, garlic etc. have shown significant increase in their productivity with the application of life saving irrigation at the right and the earliest opportunity. This water has also been successfully and beneficially used in raising other crops such as medicinal and aromatic plants, orchards, and forest nurseries, which are the major sources of income for hill farmers. Efforts have also been made to use this water through more advanced and efficient methods of irrigation such as drip and sprinkler in the orchards and other cash crops.

Experiments were conducted to utilize the stored water for supplemental irrigation of wheat crop at the critical stages (pre-sowing, crown-root-initiation, and flowering) and their combinations. The results indicate that a supplemental irrigation of 2 cm at CRI stage alone increased the wheat yield by 44%; whereas, two irrigations at pre-sowing and CRI stages increased the yield by 53% as compared to the control. Therefore, it is very clear that proper planning and management of available water resources can solve the problem of drinking water shortage and greatly enhance the crop productivity of large rainfed areas of the Uttarakhand.

Summary and Conclusions

The farmers of Uttarakhand, being mostly dependent on rainfed agriculture for their livelihood, face a great difficulty due to lack of water availability for drinking and domestic uses and for irrigation at crucial times of crop growth. Though the region receives good rainfall, the farmer's still face serious problem of moisture stress during pre- and post-monsoon periods. As the farm holdings are small and scattered on different terrains, the storage of runoff from land surface and roof-tops, and flows from natural water-springs in the cemented and/or LDPE-lined dugout ponds is a viable and feasible option to stabilize the rainfed farming in the hilly areas. Such ponds can be constructed and maintained by the farmers themselves at affordable costs. The stored water has to be judiciously utilized for the cultivation of high value off-seasonal vegetables, medicinal and aromatic plants, forest nurseries and orchards using the most efficient methods of irrigation like drip and sprinkler irrigation. Dissemination of this technological approach to the far-off places is being carried out through government agencies and the NGOs. Since the number of available resources (natural water-springs and streams) is limited, sharing and maintenance of these resources/schemes by local communities pose some difficulties. As drinking water is the most vital requirement of all the people of an area, development, conservation and management of spring water gets the top priority, followed by water needs for house hold activities, which can be met by roof water harvesting. The irrigation requirements can be met by surface water harvesting as per the needs and availability of runoff at a location. Since the farmers of the area are poor, some incentives from the government in terms of supply of raw materials (LDPE sheet, tin sheet, etc.,) at subsidized rates will ensure quick acceptance of the technology. Also, the overall water resource planning on small watershed basis has to be done by the scientists, planners and managers together with the beneficiaries and governmental/non-governmental organizations.

References

Chittaranjan S and Rama Mohan Rao MS. (1986) Runoff Harvesting and Recycling on Vertisols for Increasing Crop Production. In Soil Conservation in India. R.K. Gupta and M.L.Khybri (eds.). Jugal Kishore and Co. Dehradun, pp. 188-191.

Grewal SS, Mittal SP, Agnihotri Y and Dubey LN. (1989). Rainwater Harvesting for Management of Agricultural Droughts in the foothills of Northern India. Agril. Water Mangt. 16 (4), 309-322.

Kumar Anil. (1992). Development and Conservation of Water Resources in Garhwal Himalaya. J. Soil and Water Conservation (USA), 47(2): 249-250.

Oswal MD. (1994). Water conservation and dryland crop production in arid and semi-arid regions. Annals of Arid Zone, 33 (2). 95 -104.

Table 1. Distribution of area and rainwater availability in the country

Rainfall zone (mm)	Geographical area (M ha)	Rainwater available (M ha-m)	Net sown area (M ha)	Volume of rainwater received	
				(M ha-m)	(%)
100 - 500	52.07	15.62	29	8.70	55.7
500 - 750	40.26	25.16	22	13.75	54.6
750 - 1000	65.86	57.63	24	29.75	51.6
1000 - 2500	137.24	205.86	44	66.00	32.1
> 2500	82.57	95.73	14	41.15	43.0

Table 2. Observed mean and expected lowest assured rainfall at various probability levels

Probability levels	Observed mean	Probability levels	
		80 %	50 %
Jan	58.2	7	59.8
Feb	83.3	28.7	80.9
Mar	77.9	33.9	66.5
Apr	52	14.3	39.5
May	83	33.8	77.2
Jun	114	89.1	129.2
Jul	274	163.9	289.3
Aug	263.1	200.1	284.6
Sep	136.9	60.2	133.5
Oct	33.3	-	5
Nov	21.4	-	4.3
Dec	58.5	-	51.9
Spring (Feb-May)	296.4	177.3	296.2
Summer (Jun-Sep)	788	659.6	759.8
Winter (Oct-Jan)	171.4	82.8	135.9
Annual	1255.6	1019.5	1299.8

Appendix 1

Cost of construction of LDPE lined pond at Hill Campus (G. B .Pant University), Ranichauri, Tehri Garhwal (Uttaranchal) in the year 1996.

A. Excavation of pit

Total earth work	= 20 .30 m^3
Rate of excavation	= Rs. 25 per m^3
Cost of digging	= Rs. 507.50

B. Weight of LDPE sheet (0.25 mm)	= 13.15 Kg
Rate of sheet	= Rs. 55 /Kg
Cost of sheet	= Rs. 723.25

C. Plastering the pond

Weight of wheat straw	= 80 Kg
Rate of straw	= Rs. 1.50 /Kg
Cost of straw	= Rs. 120

Labour involved in mixing the soil with straw /pine needle and plastering below and above the sheet were 4 man-days @ Rs. 35 per day

Labour cost	= Rs. 140.00
Total cost involved in A, B and C above	= Rs. 1490.00
Storage capacity of the pond	= 15 m^3

Cost of pond per cubic meter of water stored = Rs. 99.38, say **Rs. 100.00**

Assuming a price hike by 50% for 2008, the cost = **Rs. 150 per m^3 water stored**

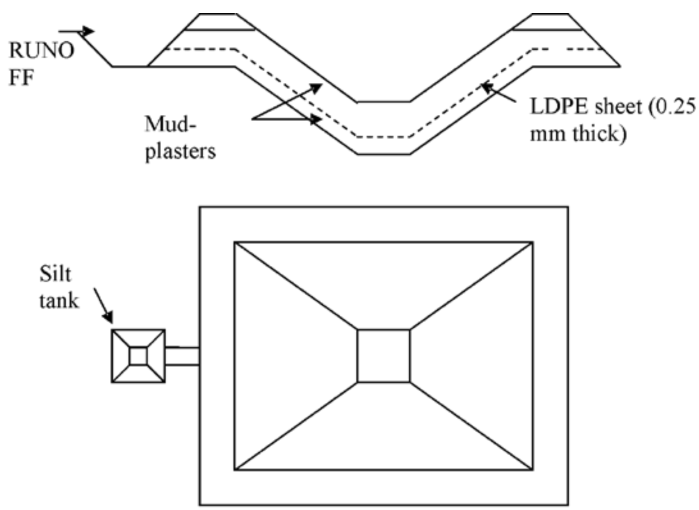

Figure 1. Details of LDPE lined tank suitable for hilly areas.

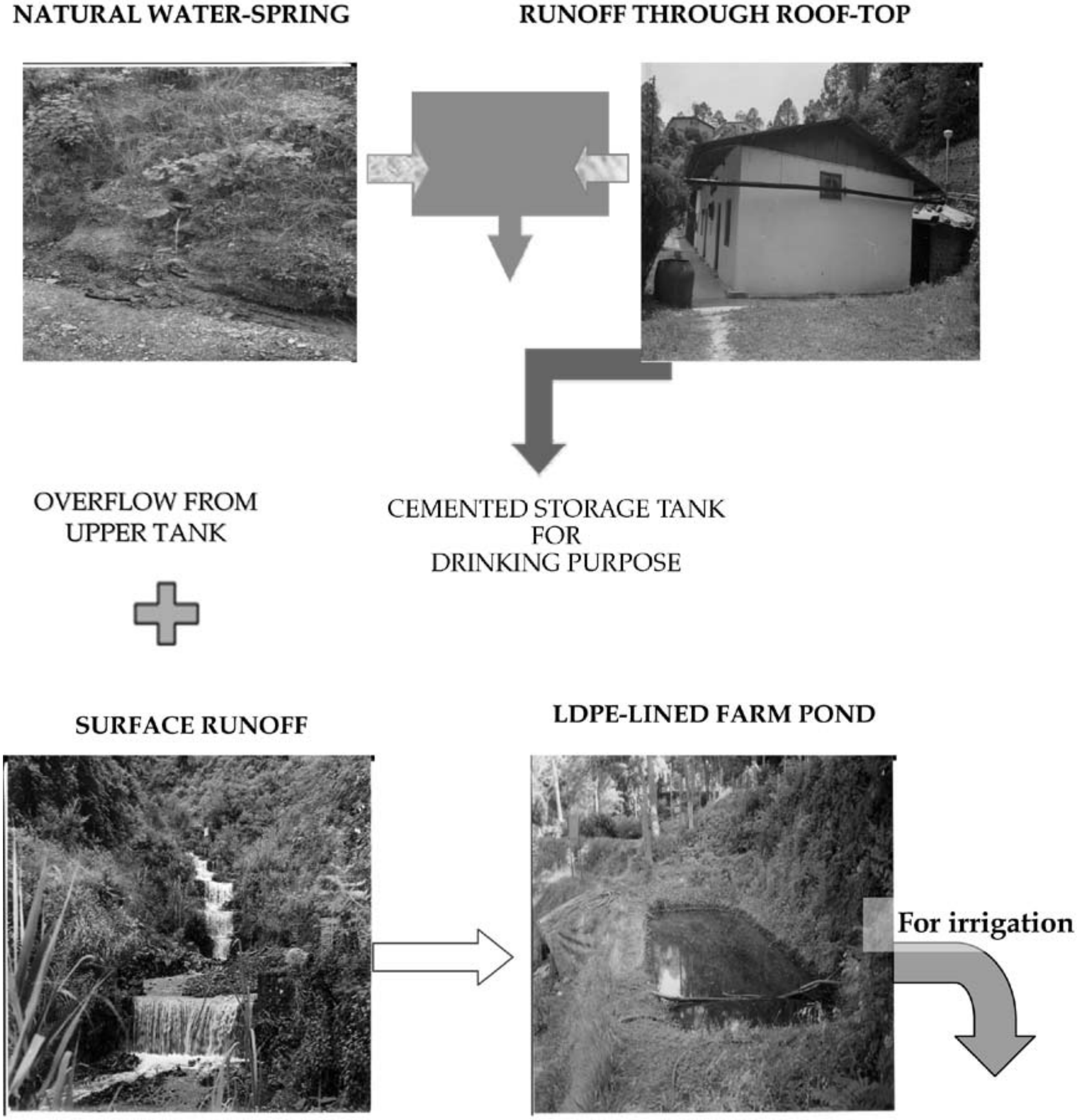

Figure 2. Appropriate Water Harvesting Model for Hilly Areas

Farm Ponds for Supplementary Irrigation to Plantation Crops in Goa

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Abstract

Goa falls in a high rainfall zone of the country. The agriculture in Goa consists of both irrigated and rainfed components. As the possibility of launching new major irrigation projects in the state is minimum due to lack of vast continuous stretches of agricultural land in an undulating topography. Hence, water harvesting and recycling through construction of farm ponds bear the scope to mitigate the problems of drought and may enhance the agricultural productivity in the region. Both small and large farm ponds can be constructed, depending on the localized factors. Harvested water can be utilized for irrigation of plantation crops like coconut, cashewnut and mango using micro irrigation systems to bring in higher water use efficiency.

Introduction

Goa state covers 3702 Sq. km of geographical area of the country and receives annual rainfall averaging from 2800 mm in the coastal belt to 3800 mm in the high ranges of Western Ghats along the eastern border of Goa. Nearly 95% of rainfall, which is spread over four months from June to September, is received in 122 rainfall events. The water resources of Goa have been assessed at 8570 million cubic metres. Of this, the utilizable water resource is only 1465 million cubic metres. At the time of its liberation from the Portuguese rule on 19th December 1961, Goa had about 7860 ha of land under irrigation. Then, there were tanks, ponds, diversion structures, *bhandharas* and wells. Except for a few diversion structures, which were constructed and maintained by the Government, the community of villages called the 'Communidade' managed all other irrigation structures. The irrigated area increased from 9860 to 13,273 ha by 1980 and 23,230 ha at present. The total cultivable area in the state is 1,96,618 ha. There is a scope to bring an additional area of 29,332 ha under irrigation by developing new irrigation projects. At the same time, the possibility of launching new major irrigation projects in the state is minimum due to the undulating topography of Goa, which does not have vast continuous stretches of agricultural land to permit gravity flow for irrigation. Though, the Goa state receives higher rainfall, still many places experience severe water scarcity during the summer months as the maximum amount of rainfall is received during monsoon period (June to September). The resultant moisture stress and drought adversely affects the productivity of horticultural crops like cashew, mango, arecanut, coconut, etc. Hence, water harvesting and recycling techniques bear the scope to mitigate the problems of drought and may enhance the agricultural productivity in the region. The term water harvesting is defined as the collection and storage of any form of water; either runoff or creek flows for irrigation use. In many parts of world, the collected rainwater from the natural precipitation is the only source of water supply and it is considered as an economical and useful method. In most of the places in Goa, the soil type is laterite in nature with high infiltration rate and low water holding capacity. Hence, it is suggested to construct small to large size farm ponds, depending on the situation, with plastic lining, which can serve the purpose of irrigation during the summer months for plantation crops.

Smaller Farm Ponds

Smaller farm ponds are designed to harvest the rainwater from the self-catchments area of pond during the rainy season. The harvested water can be used to irrigate the mango, cashew and any other similar type of plants for their initial establishment. Smaller size ponds having the dimension of 2m (L) x 2m (W) x 1m (D) or 4m (L) x 1m (W) x 1m (D) can be excavated in the center of the area having about 8 to 10 plants at the field. The dimensions can be decided based on the soil depth. If the soil is deep and enables to excavate up to 2m deep, the ponds dimensions having 2m X 2m X 1m may be adopted. If the soil is shallow and the soil above one-meter depth is too hard, it is better to go for 4m X 2m X 1m size pond.

Method of Construction

After deciding the site and dimension of the pond, the pit has to be excavated in proper shape. Any sharp corners of the pit should be removed and surface of the sides should be smoothened. The excavated soils should be distributed uniformly around the pit and to make bund having the width of 0.3 m for a height of 0.3 m to avoid any surface flow and silting. Then dig 20 cm width and 20 cm deep pit around the bund to hold the plastic sheet so that it will not get damaged. After completing the earth work, the sides of the pit has to be lined with paddy straw or any other grass materials to offer cushioning effect to avoid possible physical damages to the plastic sheets. To place and fixation of the cushion materials, wooden nails and threads can be used. Termite control powder should also be applied over the paddy straw or cushion materials to avoid damages caused by termites to the plastic sheets. Over the cushioning materials the plastic silpaulin sheets should be laid from one end to the other end. One should make sure that it does not have any folds left with. The excess portion of the plastic sheet should be buried in to the trench excavated along the border. Various thicknesses of silpaulin sheets were evaluated and the results revealed that Silpaulin 200 GSM thick plastic material was the best lining material to store rainwater. Hence, 200 GSM Silpaulin poly film is recommended for lining the smaller farm ponds and these sheets are available in Goa itself. These smaller farm ponds store water about 4 cu. m or 4000 liters per season and can be used to irrigate 8 to 10 horticultural plants. The number of ponds to be dug can be decided based on the number of plants in the field.

Cost of the Farm Pond

The total cost for construction of each pond varies from Rs. 1,923/- to Rs. 2,924/- and depends on the dimensions and type of the soil. The construction cost under various types of soil and different dimensions is furnished in Table 1. Item-wise expenditure to construct a pond in ordinary soil with the dimension of 4m X 1m X 1m, is given below:

1. Cost for earthwork
   excavation for 4 Cu. M
   @ Rs. 48.75/- per Cu. M - Rs. 195/-

2. Cost of 200 GSM, 7 m X 4 m size silpaulin films - Rs.1608/-
3. Cost of Paddy straw, termite control powder, nails and threads – Rs. 60/-
4. Installation charges - Rs. 60/-
5. Total Cost per pond - Rs.1923/-

Table 1. Cost of the construction of a smaller farm pond in various soil types

Soil type	Cost / pond (Rs.)	
	4m x 1m x1m	2m x 1m x 2m
Ordinary soil	1,923	2,479
Hard soil	1,975	2,531
Laterite rock	2,368	2,924

Water Management

Harvested water can be used to irrigate 8 to 10 cashew or mango plants during the summer months, arbitrarily @ 10 liter per week per plant. The pond has to be covered with suitable vegetation or lids and neem oil can be applied to avoid evaporation losses. The study conducted at the ICAR Research Complex for Goa, Old Goa, indicated that the utilizable harvested rainwater varies from 3.0 to 3.2 Cu. M per pond. The capacity and dimensions of the ponds, and the amount of utilizable rainwater are furnished in Table 2.

The irrigation should be done along with mulching. For efficient utilization of harvested water, irrigation should be done through mud pots or bamboo poles.

Larger Farm Ponds

Larger farm ponds are designed to harvest the rainwater from the catchments area of pond during the rainy season and to irrigate plantation crops in one ha area during summer. Larger farm pond in

Table 2. Utilizable rainwater from different sizes of smaller farm ponds

Dimensions of the pond L X W X D (m)	Designed capacity (Cu. m)	Amount of water to be harvested (Cu. m)	Utilizable rainwater (Cu. m)
4 X 1 X 1	4.00	4.00	3.2
2 X 1 X 2	4.00	4.00	3.0

Application of termite control powder before placing the cushion material

Paddy straw is used as cushion material

Lining of a smaller farm pond with 200 GSM Silpaulin poly film

Direct rainwater harvesting in smaller farm ponds

designed dimensions has to be excavated in trapezoidal manner with steps on all four sides. After the spray of herbicide, fine sand has to be applied to a depth of 10 cm on bottom of the pond. Plastic silpaulin sheets should be laid from one end to the other end. The poly film has to be fitted with cooks systematically. In the steps, the poly film has to be laid under applied weight by placing sand or smooth boulders pockets.

Specifications of Farm Pond

Length	: 40 m
Width of farm pond	: 22 m
Depth	: 3.0 m
Side slope	: 1.5: 1
Capacity	: 3500 cum
FTL	: 2.8 m
Free Board	: 0.2 m
Losses	: 0.8 m
Available water for recycling	: 2750 cu. m
Cost of farm pond	: 3.02 Lakhs

Lining material : 250 GSM Silpaulin poly film

Half-life period of poly films : 6 years

Water Management

Harvested water can be utilized for plantation crops like coconut and mango in one ha area (approximately 156 plants) for six months period. It is advisable to irrigate using micro irrigation systems for efficient utilization of the harvested water.

Acceptance of Technology

Smaller as well as larger farm ponds lined with silpaulin poly films were accepted by farmers and it has been adopted under watershed development project.

Constraints

In case of larger farm pond, the cost of silpaulin poly films varies from Rs. 1.10 lakhs to 1.30 lakhs and small farmers are not able to adopt due to lack of finance.

Strategies for up-scaling

Seventy five percent subsidies can be given on the cost of poly films for larger farm ponds to farmers by the State or General Governments. With further rise in subsidy rate, the farmers may adopt this technology at a larger scale.

View of a larger farm pond lined with 300 GSM silpaulin poly films

Rainwater Harvesting through Cost-effective Water Storage Structures in Mid Hills of Himachal Pradesh: A Success Story

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Abstract

The farmers of hilly region of Himachal Pradesh face the problem of acute water shortages during non-rainy period though the region receives adequate rainfall. To overcome the problem of water for agriculture, low cost water harvesting structure using LDPE film lined ponds were demonstrated at various locations and compared with the existing alternative of ferro-cement tanks. The storage cost of these ponds was Rs. 0.8 to 1.0 per litre as compared to Rs. 3.5 to 4.5 per litre.

Introduction and Background

Himachal Pradesh, receives an average rainfall of 1200 mm in a year, still problem of water scarcity becomes more acute due to the erratic behavior of monsoon/ winter rains *i.e.,* early and late onset and the closure of rains. This erratic behavior of rainfall badly affects the sowing of crops and other associated agronomical practices. The state of Himachal Pradesh of North-west Himalayan region, lies between 32° 29′ N and 75° 10′ E .

Figure 1 : Location map of Himachal Pradesh

The region receives precipitation mainly through rains. However, the districts of Shimla, Kinnaur and Lahaul & Spiti receives greater proportion of precipitation through snowfall. The 80% of the rains are monsoon based and confined from July to August months and rest of the rainfall is received during winter months *i.e.* December to February. Hence, there is always a scarcity of water for meeting domestic, agricultural and livestock requirements despite receiving rainfall more than the national average. This erratic behavior of rainfall in both the seasons results into various problems related to the agriculture of the region. To address these problems, work on the rainwater harvesting and its efficient utilization that has been taken as a policy in the state were initialized and is being demonstrated as low cost technology for adoption by farmers.

Approach

The water harvesting in the state has been undertaken from two main natural resources *i.e.,* rainfall and low discharge water springs and rivulets (discharge as low as 1-30L/mt). About 60% of the total rainfall, is lost as surface runoff. Water harvesting from these resource were realized using linear low-density polyethylene lined (LLDPE) farm ponds (Figure 1 and 2).

A number of other treatments to minimize surface infiltration including treatment of surface soil by sodium salts, bentonite & kaolinite clay minerals were also tried during R&D approach. For harvesting water using LDPE sheet at the Departmental Research Farm of Soil Science & Water Management, a series of trapezoidal shaped water harvesting farm ponds were constructed in the year 1995-96 using 250 micron (0.25mm thick) black colour LDPE sheet along with loose brick lining that has water storage capacity of 4 lacs and 1.3 lacs liters.

The water storage cost ranges from Rs. 0.75 to Rs.1.0 per litre. The harvested water fulfilled the water requirement of different selected crop under research trials during the water scarcity period, which commonly occur after the receding of the monsoons (Sept-December) & after winter rains,(March to June). In order to use the water efficiently, water were applied through micro irrigation system under gravity head. Realizing the benefits of water storage, two more water harvesting ponds having storage capacity of 6 lac liters were constructed in the year

Figure 1 and 2. LDPE sheet water storage pond at UHF Nauni, Solan.

Figure 3. Construction procedure of LDPE lined farm pond

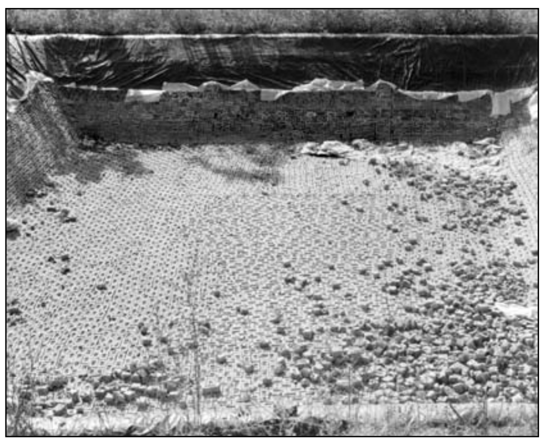

Figure 4. Laying of polysheet and lining of pond with bricks

2007 for fulfilling the water requirement of additional research trials conducted by the Precision Farming Development Centre (PFDC) of this department.

This technology was demonstrated at KVK's and Regional Research Stations of the university. These water harvesting structure sites are visited by the progressive farmers/officers of the state as well as by visitors from other parts of the country and foreign delegates. The farmers who got the inspiration from the university scientists adopted this low cost technology in their fields. The farmers realized the benefits of water harvesting in the LDPE storage ponds as they were able to save their crops by using life saving irrigation during the water scarcity period and increased production of fruits and vegetables, etc. This technology has been replicated in 560 ha of land by increasing storage capacity 40 times at the farm of the university.

Keeping in view the success story of the LDPE lined farm ponds at Dr. Y.S. Parmar University of Horticulture & Forestry, Solan, the Ministry of Water Resources, Government of India, has sanctioned a project entitled "Farmers Participatory Action Research Programme" demonstration of efficient techniques under rainfed condition in Himachal Pradesh, which also aims at the demonstration of same technology all over the state at 100 different sites covering subtropical to dry temperate climate having average rainfall between 900 mm to 2650 mm, including some sites where the precipitation through snow is only 250mm.

The same technology is being adopted by different developmental departments as a part of their programs. Encouraged the demonstrations of ponds, the farmers have started thinking of replicating the technology with their own efforts and money. A visit of farmers interested in learning more about plasticulture applications and adopting the technology, on water harvesting and its improvement was arranged by the Precision Farming Development Centre with financial support of National Committee on Plasticulture Applications in Horticulture, New Delhi during 1.2.09 to 6.2.09 to

Figure 5. LDPE lined farm pond at farmer's fields

Vivekananda Parvatiya Krishi Anusandhan Sansthan (VPKAS) Almora (Uttarakhand), a Research Institute of Indian Council of Agricultural Research, New Delhi. The Director of institute, Dr. Hari Shankar Gupt during his inaugural address exhorted participants for the adoption of the technology and emphasized that it is suitable for the slopy land as well as valley areas of the hill state. Thereafter, the farmers were apprised with low cost water harvesting technology being adopted at the Research Farm and demonstrated the construction of different types of farm ponds. The VPKAS Almora has adopted village namely Bhagartola, 40 km away from Research Station where the plasticulture technology is being adopted by the villagers with the concept that for protective cultivation, there must be assured irrigation, which can be supplemented by the use of this technology.

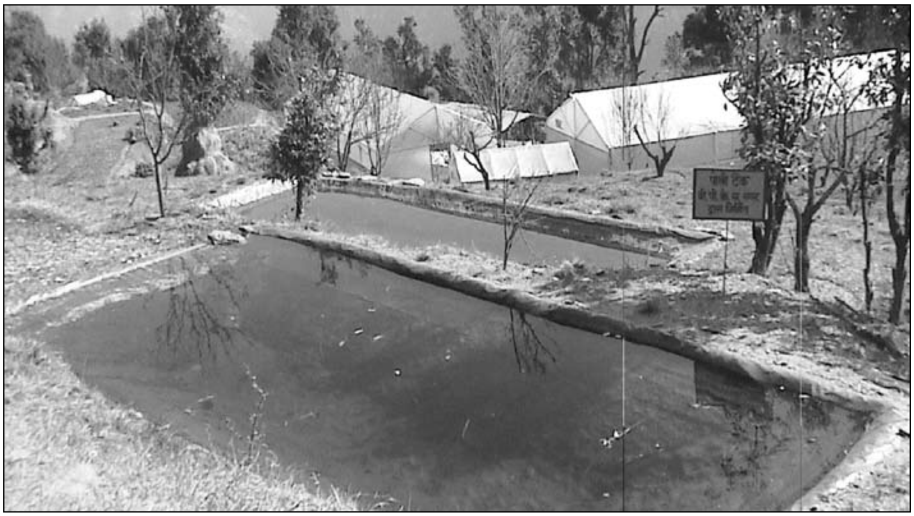

Figure 6. LDPE lined water storage demonstration by VPKAS, Almora

Figure 7. Rooftop rainwater harvesting at VPKAS, Almora

On similar lines, rooftop rainwater harvesting in low cost ferro-cement tanks and concrete block tanks are also becoming popular in the farming community as these are constructed by various non-governmental organizations with the financial support of the Council for Advancement of People's Action & Rural Technology (CAPART), under the aegis of Ministry of Rural Development, Government of India and beneficiaries' contribution in terms of cash and kind. The technology of concrete blocks and ferro cement tank with 3000 and 5000 liters capacity are most popular with their life span of about 20 years.

The water stored in these tanks is being used for kitchen gardening *viz.* growing garlic, coriander, etc., besides providing life saving irrigation to plants, washing of clothes and drinking water for livestock. This has resulted in saving a lot of time being wasted earlier in bringing water from the far away places, in addition to providing better opportunity of livelihood to the artisans involved in constructing these tanks, the storage cost of water in concrete block and ferro-cement tanks varies from Rs. 3.5 to 4.5 per liter depending on the distance from road and condition of the locality. Encouraged by the success of ferro-cement technology, more and more Volunteer Organizations are coming forward for replicating the technology. Farmers are ready to adopt the technology at large scale. It is estimated that about 5000 concrete block and ferro-cement tanks are functioning satisfactorily, providing life saving irrigation to the crops in 200 ha of land, in addition to supplementing the domestic needs of water (Figure 8).

Conclusion

The studies include technology development of cost effective water storage through LDPE lined farm ponds, concrete block & ferro-cement storage structure to harvest rainwater and its effective utilization for irrigation and domestic purpose. The LDPE lined farm pond with storage capacity of 3-4 Lakh litres @ at Rs.0.8/litre in valley areas and 0.5 lakh litre in slopy land site with cost @ at Rs. 1 was found more feasible and are being demonstrated throughout the state for adoption by farmers. To harvest roof rainwater, concrete block & ferro cement technology with storage capacity of 3000-5000 litres @ at Rs.3.5 – 4.5 per litre has been found a success story.

Figure 8. .Rooftop rainwater harvesting ferro-cement tanks/ concrete block in different villages

Water Harvesting for Supplemental Irrigation - A Case study from in Shivalik Hill Region

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Abstract

Rennovation of water harvesting pond at Mandhala village in Solan Distirct of Himachal Pradesh were studied. The pond had the storage capacity of 2.0 ha-m which can provide supplemental irrigation to 10 ha area. The pond water was applied to the field using gravity (4.0 ha) and lift irrigation (6.0 ha). The pond after construction was handed over to water user society which in turn took the responsibility of water distribution. The pond helped in increasing the productivity of wheat by 3-5 folds providing maximum net return of Rs. 9321/ha which has change the situation of rainfed farming in the region that gave negative net returns. 95% of farmers approved the usefulness of such ponds. It is the recommended that without community involvement and creation of self sustaining local level institution, the aims of self sufficiency and enhanced productivity in the rainfed areas through water harvesting and water management programme cannot be achieved

Introduction

The Shivalik region spread over an area of about 3 m ha represents one of the eight most degraded eco-systems in India. The Shivaliks are characterized with low hills, undulating topography, steep slopes and easily erodible soils. The region is dissected by numerous seasonal streams. Like other sub-humid region, it has vast water, soil and biological resources. Vast resources of Shivaliks have its share of constraints also. Water scarcity for irrigation is one of the critical issues of this region. It receives an average annual rainfall of 1122 mm (Av. of 1958-2005) (Agnihotri *et al.* 2005). About 80 per cent of this rainfed is received during monsoon, i.e. June-September, which produces runoff in the range of 30-50 per cent in untreated watersheds. Vast volume of runoff inundates low-lying fields and causes temporary water excess. Analysis of 42 years rainfall data (1958-94) at Panchkula (Haryana) reveals that during this period, the region experiences 8 large and 5 severe droughts. Thus, one out of every three years had severe rainfall deficit even in the *kharif* crops. In the absence of good winter rains and irrigation facilities, the *rabi* crops fail completely twice in every five years. Only 18 per cent of the cultivated area in the Shivaliks is irrigated and rest all is rainfed (Verma, 2000).

The rainfed areas of the Shivaliks have no possibilities of providing irrigation through conventional methods. Due to multidirectional slopes and fragile geology, the region lacks canals and availability of groundwater in the hilly tracts of the Shivaliks, which is at a depth > 150 feet below ground level. Groundwater depletion is noticed in some patches of the lower Shivaliks, particularly in Punjab and Haryana due to over exploitation of the groundwater for irrigation and industrial purposes. In Punjab and Haryana, almost all districts have been experiencing a decline in the groundwater level by 20 cm per year for the past 10 years during1995-2004.

The participatory process of watershed management was initiated by Central Soil and Water Conservation Research and Training Institute at village Sukhomajri (Haryana) in 1974 through the Regional Centre at Chandigarh. The immense success of the Sukhomajri model led to its implementation at 102, 72 and 30 locations in the states of Haryana, Punjab and Himachal Pradesh, respectively. The analysis and overall experiences of the project implementation in the Shivalik region revealed that the integrated watershed management project, where the component of rainwater harvesting and recycling was successful, resulted in increased agricultural production. The water resource developed under these programmes became a common binding factor and the source of income generation. And ensuring people participation from the project implementation stage to execution stage is the key factor for sustainability of the projects. But unfortunately, it was found that many of the water harvesting structures failed in these northern states, immediately after implementation due to unscientific planning and they could not assure a sustainable water resource. It was thought over to scientifically plan the water harvesting structures; refine the water harvesting technique to have a sustainable availability of water.

Case Study of the Renovation of Water Harvesting Pond at Village Mandhala

The project scheme was taken up at village Mandhala, in Solan district of Himachal Pradesh in collaboration with and participation by farmers/ beneficiaries of the village.

Development of Pond

A pond having submergence area of 0.4 ha was renovated in the village. It was an old pond silted up over a period of time. Desiltation of the pond and increasing the height of the embankment increased its capacity from 0.7 ha-m to 2.0 ha-m. The old embankment of the pond had the problem of leakage, which was intruding in the house of a farmer on the down streamside. The centre of the embankment was dug up to a depth of 3-3.5 m and a core wall of clayey soil was packed for a length of 60 m with a width of 1 m. This could check the seepage from the old embankment. Also, the plastic sheet was provided at more vulnerable points to check the seepage completely. After desilting the pond the good soil was dug up at the beginning was spread at the base of the pond to reduce the seepage losses, which generally increases after the desilting work. And now this pond is being effectively utilized for supplementary irrigation of about 10 ha of land, which was under rainfed farming in the past. Different features of the farm pond are listed below:

Harvesting Surface Water in the Pond at Mandhala

Catchment area	-	4.32 ha
Capacity of pond	-	2.0 ha-m
Command area	-	10.0 ha (under sup plementary irrigation)
Gravity irrigation	-	4.0 ha
Lift irrigation	-	6.0 ha

The pond is well equipped with inlet chute structure, draining the catchment through 60 cm dia RCC pipe. Outlet structure has been given a rectangular drop structure with facility of gauging the runoff through automatic stage level recorder.

Embankment Type Storage

The torrential flow during the monsoon in the small choe also provides a good opportunity of water harvesting. One of the structures with a height of 4.5 m has been installed in the upper Mandhala watershed. The check dam has been constructed as a multipurpose structure to check erosion and retain surface and sub-surface water. The catchment of the structure is 8 ha. This can easily supplement or divert the rainwater to main pond in the case of drought or low rainfall. The water from this structure has been channelized through a pacca channel to make the main pond sustainable all the time to come. A valve at the check dam controls the supply as per requirement to fill up the main pond.

Recycling of Harvested Rainwater

Gravity irrigation

An inlet box at 96.0 m elevation connects the water through 150 mm GI pipe initially and further transmits the water through underground PVC pipeline of 110 mm diameter running into 400m length in agricultural fields. The available water between the elevations of 98.5 to 96.0 m (contour) at the pond can be used through gravity system.

Lift irrigation

The irrigation water is being lifted through 8 hp diesel pump to the water tank, which provides the water to agricultural fields through a complete underground network system of PVC pipes over 6 ha of land. Thirteen sluice valves have been provided at suitable locations to provide irrigation water to terraced agricultural fields which delivers the water at a discharge rate of 10-12 litres/sec. This system has also reduced the seepage and evaporation losses, thus providing additional irrigation water to agricultural fields.

Water management

About 5 cm of water is being taken up for single irrigation to wheat crop in the area being irrigated by pond. And the crop yield has gone up by 3-5 times the past yield of the crop, depicting a high range of water use efficiency. Supplying the water through under ground pipelines has increased the overall efficiency of the gravity and lift irrigation by preventing losses through the seepage. Availability of water for irrigation has motivated the farmers for leveling their own fields, which further helped in better water management.

Water users society

After completing all the aspects of water resource development for upper Mandhala (viz. pond, pump, overhead tank, pipelines, outlets) the scheme was handed over to the water user society, which was formed at the inception of the work. And presently, the society is handling the complete responsibility of operation of the diesel pump set and the distribution of water. The water users society has been quite effective in sharing the water between the beneficiaries.

Rainfall-runoff Relationship at Water Harvesting Structure (WHS)

Total rainfall, rainy season rainfall and runoff to WHS were measured in Mandhala to study the rainfall-runoff relationships. Storms were categorized in six classes (like, 0-12.5, 12.6-25.0, 25.1-50.0, 50.1-75.0, 75.1-100.0 and >100 mm). It has been found that runoff was initiated only when rainfall event exceeded 25.0 mm.

It was measured that maximum runoff occurred during 2003, (>2 ha-m) as compared to 2004, 2005 and 2006. Maximum 19

Multi purpose check dam for harvesting surface and sub-surface water and diverting to main pond

rainfall events (>25 mm) occurred during 2003, which caused maximum runoff. Even overflow through spillway was noticed during 2003. Number of rainfall events greater than 25 mm was 14 in case of 2005 and 2006. Whereas, in 2004 only 10 events caused runoff to WHS. It could be stated that the threshold limit of rainfall event that caused runoff in Mandhala was 25 mm and the number of high rainfall events was found to be more important as compared to that of the total amount of rainfall causing runoff. This is reflected in the years 2004 and 2005. In these years, the total amount of rainfall was almost the same, but the year 2005 yielded more runoff as it received 14 rainfall events (>25 mm) as compared to 10 in 2004.

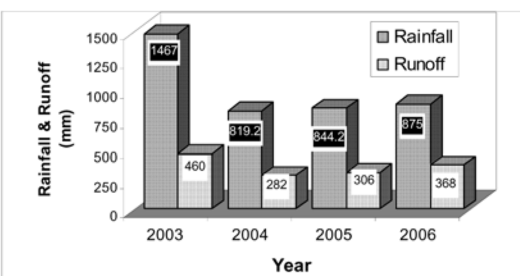

Figure 1. Rainfall and runoff in monsoon for different years at Mandhala

Rainy season rainfall and runoff in different years of Mandhala are also depicted in Figure 1. It is clearly observed that maximum runoff occurred during 2003 followed by 2006, 2005 and 2004. In 2003, the overflow occurred through spillway during September.

Significant Findings

The project resulted in an increase in cropped area to the tune of 27.4 percent during the *kharif* and 46.8 % during the *rabi* season. The wheat crop which was taken under rainfed condition earlier, got supplementary irrigation after the project from the harvested rainwater in the renovated pond. Yield of wheat and maize shot up to 29.8 q/ha and 30.0 q/ha, respectively as compared to the earlier level of 8.8 q/ha and 9.5 q/ha, respectively.

Economics of growing wheat crop was worked out under the four situations. It is seen that farmers got the maximum net returns from the pond-irrigated crop (Rs. 9231/ha). Next in sequence were the crop irrigated through government. tubewell (Rs 8714/ha) and the that irrigated by private tubewell (Rs. 8471/ha) respectively. Rainfed wheat was found to have negative net returns (- Rs. 837/ha). Since the major component (55.2%) in the input cost was that of family labour and the entrepreneur does not have to pay for the same in cash, rainfed farming is done at the subsistence level.

Farmer's evaluation about appropriateness of the project interventions was undertaken. About 95 percent of the farmers of the village felt that the pond was very much appropriate, while 86.8 percent termed the irrigation system as the most appropriate. Majority of the farmers were satisfied with the availability of water, production aspects, increased income, working of the water user's society, redressal of the gender issues and soil conservation measures. Thus the research project was highly favoured by the stakeholders in the village.

The project demonstrates the techniques of water harvesting in this region for surface and sub-surface flow and increasing water yield through diversion from other adjacent catchments. The water management in the crop fields from WHS had been quite effective as no water is wasted and also only 4-5 cm of each irrigation is given in the *rabi* season for wheat corp. Crop yields have gone up by 3-5 times of the original yield, and people have been benefited by the project. Only 60% of water was used for irrigation rest was left for fisheries and animal and unavoidable losses. The project has been highly acclaimed by the media.

Recommendations Arising Out of the Project Work

The project presents a proper design for water harvesting and further refinements in water harvesting techniques for the region. Effective utilization of the stored water for increasing productivity is the only answer to combat the low economy of the rainfed areas of the Shivaliks region. Following recommendations arise from the study for the rainfed areas of Shivaliks.

1. Project is to be taken up in participatory mode to get the desired impacts of development of water harvesting structures and effective water management.
2. Old ponds in the region should be renovated in the following manner.
   i. Desilting of old pond.
   ii. Retaining upper layer of the pond by desilting and spreading at the bottom after completion of the work.
   iii. Channelization of the rainwater to the pond.
3. Refinement in water harvesting technique by:
   i. Runoff inducement through diversion from other potential catchments.
   ii. Channelization to increase the existing catchment area to have a sustained water yield.
4. Water market governance by the society has to be effective to force the beneficiaries to utilize the water judiciously.
5. Increase in water conveyance efficiency by underground pipelines and suitable valves and improved irrigation technology is required for proper water management.
6. Treatment of the catchment area of the WHS with appropriate soil conservation measures should ideally start before their construction, in order to reduce erosion from the degraded hilly areas.
7. Villagers should be the actors to manage the water harvesting systems and the government, department should be only facilitators. Thus, a village level society is a prerequisite for the effective utilization of harvested water resources, proper maintenance and operation of the system including catchment protection and common area development.
8. Research investigations are needed for developing design procedures/specification for surface and sub-surface water harvesting structures in such areas.
9. Efforts should be made to generate social funds to the maximum by introduction of fishery etc, sale of harvested water and by adopting alternative use systems in common land/Panchayat land.

It is the recommended that without community involvement and creation of self sustaining local level institution, the aims of self sufficiency and enhanced productivity in the rainfed areas through water harvesting and water management programme cannot be achieved.

References

Agnihotri Y, Bhattacharya P, Sharda VN and Tiwari AK. (2006) Weather trends at Chandigarh Bulletin No. **T-52/C-12**. CSWCRTI, Research Centre, Chandigarh. India. pp.8-9.

Tiwari AK, Singh P, Aggarwal RK, Agnihotri Y, Sharma Pawan, Ram Prasad and Bhattacharya P. (2005) Integrated land and water management for sustainable production in Shivalik foothills in Mandhala village, Distt. Solan, H.P. Annual Report, CSWCRTI, Dehradun.

Verma HN (2000) Rainwater harvesting and its recycling for crops and fish production in Shivaliks. *In*: Fifty years of Research on Sustainable Resource Management in Shivaliks (Eds. S.P.Mittal, R.K.Aggarwal, and J.S.Samra). CSWCRTI, Research Centre, Chandigarh pp. 327 – 334.

Rainwater Harvesting and Recycling for Sustainable Agricultural Production in North Eastern Hill Region

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Abstract

Present paper describes various methods adopted in North-eastern region of India in water harvesting and utilization. The utilization methods namely furrow irrigation in bench terrace, zabo system, and bamboo drip irrigation is discussed in detail. These discussions are substantiated with the case study of water management practice at apatani valley.

Introduction

The North Eastern region of India is unique in its physiographic land characterstics varying agro-climatic condition, land tenure systems and cultivation practices, distinct from the rest of the country. Water is one of the key resources of the country and North Eastern region accounts for about 40% of the total water resources in the country. The region experiences excessive rainfall and high floods during the monsoon months and also suffers from acute shortage of even drinking water in many areas due to lack of water management. Irrigation is one of the weakest link in the region, only meager 7.75 per cent of the net cropped area is irrigated. Some of the important aspects of rainwater management in the terrain can be envisaged as; management of runoff on the slopping land use and *in-situ* retention of rainfall by the adoption of appropriate soil conservation measures and land use practices; ensuring safe disposal of surplus water from higher to lower level; increased utilization of stream flow through diversion works at feasible locations; storing surplus water at appropriate locations by constructing small reservoirs and recycling it in the same area. Stream flow lift irrigation; conjunctive use of surface and groundwater on rotational basis; adoption of scientific on farm water use and management technology (Thansanga and Saxena, 2000). The importance of water harvesting structures, mainly comprising of earthen embankments with spillways for conservation of water resources for multiple use including drinking water supply, irrigation or aquaculture, is well recognized. Rolling topography of hills and gorges in the North Eastern Hill region facilitate the construction of such embankment type ponds with high storage- earth work ratio. Some experiences related to rainwater harvesting in hilly regions are discussed.

Indigenous Water Harvesting Practices

The traditional method of irrigation in hills consists of harnessing the hill streams during monsoon by constructing temporary check dams on streambed for diversion and conveyance of water through earthen channel. Boulder, timber and earthen dams are built across the stream to raise the level of water for diversion. There is a tradition of such irrigation works being done by village/community as a whole in carrying water from streams over large distances. A variety of typical water management techniques based on local skill and resources are prevalent in the region. Based on long experience under existing soil and climatic conditions as well as the availability of large number of hill streams, farmers in certain areas have developed typical systems of water management, which are very effective under the existing condition of topography and terrain. Some of these practices, mostly confined to the places of their origin are:

Continuous Flow Irrigation in Bench Terraces

In this system the hill streams are tapped at or near the source of emergence and the water is channalised to irrigate a series of terraces in such a manner that water continuously flows from the upper terraces to the lower ones without soil erosion and maintaining a desired level of water in the terraces. In some pockets of Nagaland such irrigated bench terraces are seen even on a very poor land having hardly 10 to 15 cm of soil depth, 5 to 8 cm of water is continuously maintained in the sources.

Zabo System

Zabo system of farming is practiced by Chakhachang tribe of Mikruma village in the Phek district of Nagaland. The system is a combination of agriculture, forestry and animal husbandry with well-founded conservation base for soil control, water resource development and water management as well as for the protection of environment. The rainwater is collected from the catchment of protected hilltops of above 100% slopes in a pond with seepage control. Silt retention tanks are constructed at several points before the runoff water enters into the pond (Fig 1). The cultivation fully depends on the amount of water stored in the pond. (Sonowal *et al.,* 1989).

Bamboo Drip Irrigation

This system is practiced by the farmers in Jaintia hill district of Meghalaya to irrigate arecanut and betelvine grown on steep hill slopes with rocky soils. In this system small hill streams from upper reaches are diverted into bamboo fitted about 1 to 2 m above the ground surface with the support of bamboo stands (Fig. 2). The water brought to the field by these channels gravitationally and distributed through secondary, tertiary or more branches of pipe line with a typical water diversion system at the joint of each branch, ultimately drips to the individual plants enabling the system to deliver 15 to

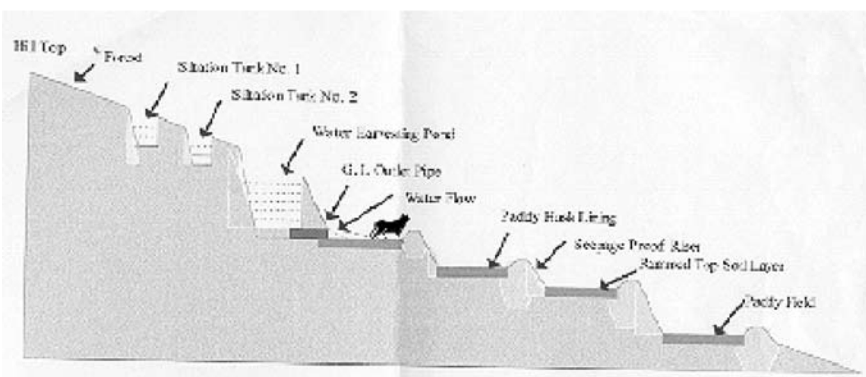

Figure 1. Zabo System of Farming in Phek district of Nagaland

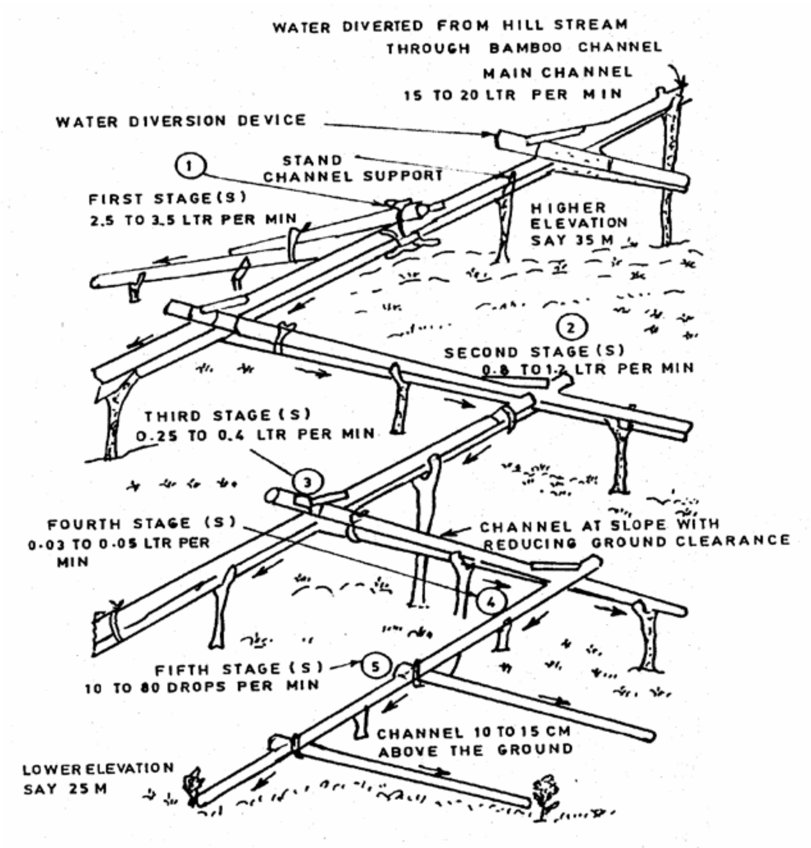

Figure 2. Bamboo drip irrigation system of Meghalaya

25 lit/min at the terminal of these branches (Singh 1989).

Water Management Practices of Apatani Valley

This is unique land use and water management technique is adopted by Apatani tribe in the Subansiri district of Arunachal Pradesh to irrigate gently sloping lands at the foothills by diverting hill streams from upper reaches. Earth, boulder, brushwood dams are used for the diversion work. The stream water brought through the micro watershed channel is diverted to a network of sub channels to serve as irrigation cum drainage channels. The lay out of fields and channels are made in such a way that entire plateau functions as a watercourse. Bamboo and wooden log pipes of various size used are as pre-fabricated water management structures for use as conduit for water inlets and outlets, waste weirs and energy dissipaters (Sharma, 1991).

Alternative Land Use Model

The multi-disciplinary research programme of ICAR aimed at developing alternative land management practices has identified several viable land use models for the region following their evaluation in terms of their long term runoff, production potentials, soil and nutrient losses, yield behaviour, biotic and abiotic changes and so on. Watershed based farming system, appropriate soil conservation measures, mixed land use of agri-horti-silvipastoral system, subsidiary source of income through livestock rearing, creation of water harvesting and silt retention structure at low reaches-these are the important distinguishing features of the suggested agricultural strategy on this hill slopes (Singh *et al* ., 1996 and Satapathy, 2003). The model developed is based on the following distinct approaches:

- The watershed, a natural drainage unit, should form the basis for planning various land uses to optimise the use of soil and water resources for sustained production. This watershed-based farming system coupled with mechanical soil conservation measure contour bunds, bench terrace, half moon terrace; grassed waterway, etc., at appropriate locations can retain maximum rainfall within the slope, safely disposing off the excess runoff from the slopes to foot hills with non erosive velocity.
- Application of Improved production technology and Increase of cropping intensity by growing atleast two high yielding crops have the possibility to Increase the productivity of rainfed bench terraces 3 to 5 times more than that of sloppy land with no detrimental effect on natural resources. The trials conducted by ICAR have demonstrated that with intensive crop production, one hectare of terraced land can sustain a family of five, with 60-70 percent of yield meeting the food requirements and marketing the remaining for other needs. Introduction of remunerative horticultural crops can instill in the Jhumias' long term interest in the land to tie them down to settled agriculture.
- Subsidiary income from rearing of livestock by feeding on the by-products of crops and cultivated fodders, trees raised on the terrace risers, bund surface and very steep slopes unfit for cultivation.
- Construction of small earthen dams for water storage and slit retention at lower reaches of the watershed by utilizing local resources-earth, stones and human labour to utilize the stored water for fish production or to recycle back for life saving irrigation.
- By these technologies the crop production has increased 3 times and monitory returns has increased 9 times. The analysis of the hydrological data indicated that the runoff production and silt yield has reduced substantially from the watersheds

In-situ Retention of Rainfall

Land uses practiced in micro watersheds with appropriate soil and water conservation measures were found effective in retention of rainfall. Mixed land use systems with appropriate soil conservation measures namely bench terraces; contour trenches etc. were most effective in checking erosion and retaining 80-100% annual rainfall in situ and simulate the effects of the natural forest. From the observations on annual runoff and, soil it is apparent that use of conservation measures developed from local resources (soil, vegetation, manpower) as reinforcement to the desired land use is capable to perform functions as that of forest (or natural vegetation). The water retained in slopes within the watersheds was thus made available for use by the crops/ plants and recharge of streams, springs and groundwater. The contributions to stream flow in the watersheds with substantial area under natural forest is primarily by subsurface flow (base flow). Subsurface flow from the upper slopes often was a significant proportion of total flow from the catchments. Pipe networks are formed at various depths below the surface due to biological activities. Rainwater infiltrating into the soil is carried laterally by these pipes and delivered into the stream. Where pipes are close to the surface they lead to saturation of soil and overland flow occurs. Land uses namely forest, agro-forestry and pine afforestation during their first 6 years of establishment yielded 72 to 93%, 76 to 92% of total water yield as base flow respectively. Annual water yield through base flow works out to be 0.27, 0.28 and 1.76 m ha respectively against the annual rainfall of 2.58 m. There was consistent reduction in peak discharge. In another experiment, water yield potential of hill slopes was found to vary between 0.21 and 0.73 ha.m of catchments for agricultural and agri-horticultural watershed (Satapathy, 1996; Rao and Satapathy, 2005 a, b, 2008). Besides rainfall management, the approach proved highly effective in conserving soil as the loss were negligible in almost all the watersheds, particularly at Barapani, which received high rainfall.

Harnessing Hill Springs

The rugged hilly terrain supports a large number of springs, perennial as well ephemeral with yields varying from a few litres to tens of cubic meters per hour, giving rise to numerous stream and rivulets, the discharge being the highest during monsoons that gets reduced during autumn and reaches at their lowest in summer (Fig. 4). These natural springs continue to be the main source of water supply to bulk of the tribal population living in the hills for meeting their domestic and irrigation needs. Springs water can be used through several techniques such as diversion into channels, storage in tanks or even through the development of artificial spring by excavating, long sub-terranean galleries. However in spite of difficult terrains and rugged soil conditions, there are a number of indigenous technologies prevalent for the conveyance and management of such water. Six such springs having water yield potential of 0.99 to 7.72 ha m /yr. (Table 1) are being currently pooled for water supply at ICAR Complex at Barapani. Construction of suitably lined storage tanks of adequate size with protection measure for possible pollution by humans and animal is essential for effective utilization of these water resources.

Dugout-Cum Embankment Type Pond

Small earth dams can be used in large scale for water storage in the North Eastern Hills

Table 1. Water Yield Characteristics of Natural Springs in Barapani

Spring source	Discharge lit/sec		Coefficient of variation %	Av. Annual water yield (ha.m)
	minimum	maximum		
1	0.18	0.66	40.60	1.10
2	0.10	0.70	54.43	0.99
3	1.51	3.75	24.26	7.72
4	0.12	1.25	49.84	0.99
5	0.07	1.28	65.07	2.10
6	0.16	2.31	56.27	2.07

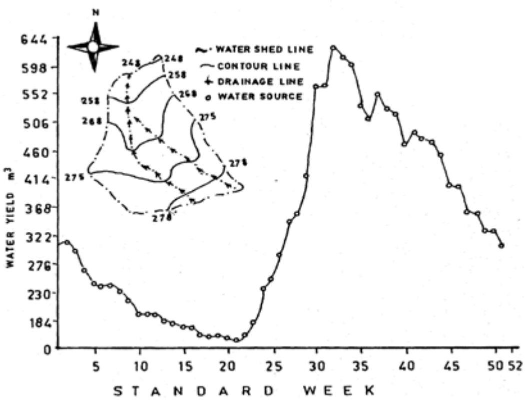

Figure 4. Water yield behaviour of a hill spring at KVK Tura

Region. Construction of these structures involves chiefly manual labour input and use of locally available materials- earth stones etc. Experiences on water harvesting in dugout – cum- embankment type of pond in the hilly region of North East India clearly indicate the feasibility of harvesting runoff from hilly watersheds for beneficial use (Fig 5 & 6). The soil in the area has extremely low water holding capacity and the seepage losses are very high. Thus water storage may be seasonal or perennial depending on the site condition. Partial emptying of the farm pond is possible to irrigate crops during the dry spells. Stored water however, has more scope for fish production. Limited water available for irrigating winter crops should be used at the earliest opportunity to reduce seepage and evaporation losses. Relatively expensive, such structures however defy standardisation and are normally built on the basis of past experiences as well as similar constructions in the area. However, some of the general features are:

- Adequate storage capacity with least amount of earth fill; availability of fill material near the site; adequate scope for outlet for safe disposal of surplus water; relatively impermeable strata under the dam and the water surface; at least 2.5 to 3.0 meter water depth over 15-20% of submergence area at normal level- these are the most important considerations for suitability of sites.
- In general the dams up to 50 ft high with average soil the up stream slope of 3:1 and the down stream slope of 2:1 would be satisfactory. The up stream slope should be protected by a cover of hand placed rip rap of suitable stones. The down stream slope may be sodded with thick layer of grass to protect it from erosion.
- To effectively seal all percolations in the under earth dam, an impervious cutoff

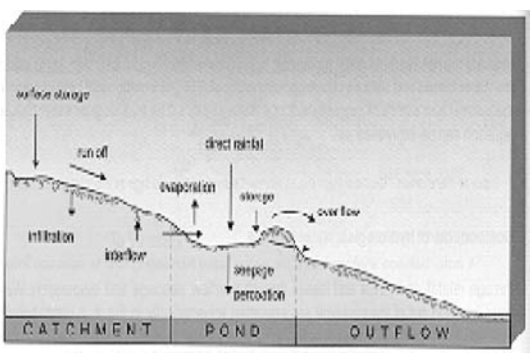

Figure 5. Schematic representation of pond inflows and outflows

Figure 6. A water harvesting structure in hilly region

wall (cement concrete 1:3;6) extending from the surface to the impervious (rock) layer is essential along the central axis of the dam. The stone masonery core-wall, built on the cutoff wall, provides a perfect barrier to the seepage water passing from the upstream side to the downstream of the dam.

- Removing loose and potentially unstable materials from the foundation, thorough compaction of all embankment zones, impervious core and cut of walls adequate drainage provisions- all the measures would check the seepage from the water harvesting structures effectively.
- As per the experience, generous allowance of 10% of the designed height is essential to be added to the dam top of the fill to neutralize the settlement. To prevent sagging of the dam top, maximum fill should be on the natural water course with crown sloping at either end.

Sizing of Farm Pond

Experiences on water harvesting in dug-out – cum – embankment type of pond in hilly region of North East India clearly indicate the feasibility of harvesting runoff from watersheds to an extent of 38.44% of monsoon rainfall. Contribution of subsurface flow from upper slopes accounts for 82-90% of the annual inflow into the water harvesting pond located in the lower reaches and only 10 – 18% comes from direct interception of rainfall and collection of surface runoff. The soil in the area has extremely low water holding capacity and the seepage losses are very high. Thus water storage may be seasonal or perennial depending on the site condition. The study indicated a decline of seepage rate with the age of the pond and stabilizes in a period of 7-8 years. Water harvesting structures can be designed on the basis of inter flow. It is possible to estimate the inter flow into the pond on the basis of a certain probability level of annual rainfall. For any desired probability, runoff volume can be obtained as the product of runoff depth and catchments size. In general, the capacity of the tanks increases as the probability of assured inter flow decreases. Further, the volume of available water per unit tank capacity increases as this probability level increase for various sizes of tank (Satapathy, 1996). Fig. 7 presents a monogram, which gives a direct relationship between catchments size and runoff volume. This graphical form could be used to estimate the availability of runoff for water harvesting projects in small hilly watersheds, if annual rainfall records are available.

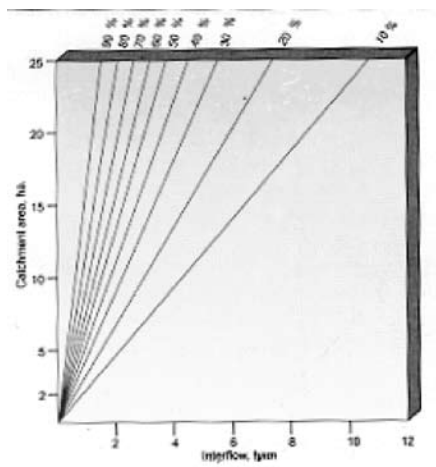

Figure 7. Catchment area and interflow at different probabilities

Plastic Lining of Ponds

Construction of small water harvesting structures in the lower reaches of micro-watersheds to store runoff and intercepted base flow for utilizing the stored water for pisciculture or to recycle back for life saving irrigation provides ample scope for water resources development in the NE Hills at a relatively low cost. This type of ponds generally have a high rate of seepage and percolation and cannot hold water during the crucial dry season. Two small ponds with storage capacity of 0.3 ham (AE pond) and 1.0 ham (FSRP pond) were created in the ICAR Research Farm at Barapani (Meghalaya). The pond were subsequently lined with LDPE Agri Film of 250 micron and covered with 30 cm soil on the bed as well as sides. The effect of lining and hydrological behaviour of ponds was studied. The maximum percolation rate through the AE pond under unlined condition was to be tune of 0.040 m^3/m^2 wetted perimeter/ day. The percolation rate was remarkably reduced to 0.0029 m^3/m^2 wetted perimeter/ day after lining pf the pond with Agri Film, showing average reduction of about 93% in the seepage loss (Rao and Satapathy 2005). Storage hydrographs of the pond after and before lining clearly show an increase in the water saving efficiency of the pond after lining in terms of both quantity and duration of storage

Some Important Issues

Some of the important aspects of rainwater management and the major scope for enhancing Irrigation facilities in the terrain can be envisaged as follows:

- Management of runoff on slopping land use and *in situ* retention of rainfall by adoption of appropriate soil conservation measures and land use practices.
- Ensuring safe disposal of surplus water from higher to lower level.
- Increased utilization of stream flow through diversion works in suitable sites.
- Storing surplus water at appropriate locations by constructing small reservoirs and recycling it in the same area.
- Stream flow lift irrigation.
- Conjunctive use of surface and groundwater on a rotational basis.
- Adoption of scientific on-farm water use and management technology.
- Drainage of areas with high water table.
- Tackling flood and irrigation in an integrated manner.

References

Rao BK, Satapathy KK. (2005a) Hill slope runoff estimation by using Curve Number method Indian Journal of Hill Farming, Vol. 19. No. (1 & 2).

Rao BK, Satapathy KK. (2005b) The effect of plastic lining on preventing seepage losses in water harvesting ponds Proceedings of International Conference of Plasticulture & Precision Farming.

Satapathy KK. (1996) Hill slope runoff under conservation practices. Research bulletin. No. 40, ICAR Research Complex for NEH Region, Barapani.

Satapathy KK. (1996) Hydrological aspects of water harvesting tanks in hills. Research Bulletin. ICAR Research Complex for NEH Region, Barapani4 (2, 3 &4): 171 –179.

Satapathy KK. (2000) Development and management of watershed: Concept and approach. Journal of North Eastern Council 20 (2): 1-8.

Satapathy KK. (2003) Land use planning for sustainable development in North Eastern Hills Region. Processing regional workshop on policy framework for efficient management of water and land resources for poverty alleviation for NE Region. June 2-3, 2003. Tejpur. Pp. 67–78.

Singh KA, Yadav BPS and Goswami SN. (1996) Farming systems alternative to shifting cultivation. Journal of soil conservation 3: 136 –145

Sharma BR. (1991) Conservation and efficient utilization of water resources for development of Himalayan Agriculture. Journal of Water Resources Society 2(4) :2-5.

Singh, A. (1989). Bamboo drip irrigation system. Research Bulletin, ICAR Research Complex for NEH Region, Umiam

Sonowal DK, Tripathy AK and Kirekha V. (1989) Zabo – An indigenous farming system of Nagaland. Indian J. Hill farming 2(1) : 1-8.

Thansanga R and Saxena RS. (2000) Water resource availability and Management In the North Eastern Region of India, International conference on Managing natural resources for sustainable agricultural production in the 21st century, February 14 -18, 2000 New Delhi, pp 457 - 459.

Networking of Farm Ponds A Novel Method for Rainwater Harvesting and Management in Dryland Farming

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Abstract

It is very crucial to harvest every drop of rainwater *in-situ* for the promotion of sustainable agriculture in dry lands. In various watershed programmes, it is a normal practice to go for construction of water harvesting structures such as check dams in the drainage line. These structures, in addition to being costly, require community participation for maintenance. Moreover, they will not y help the farmers in the up stream from where water has flowed down carrying silt. The concept of dug out structures such as farm ponds is well known but it is seldom practiced in watershed programmes effectively. The traditional concept of locating dug out structures (locally know as KALYANI) at strategic locations is not normally employed in the watershed programmes.

This paper deals with the experience and result of reviving the traditional water harvesting technology. The experiment involved excavation of 340 ponds in a watershed of 700 ha in Hassan district of Karnataka. The area receives an annual rainfall of 550 to 700-mm. The soils are shallow sandy and highly porous. Coconut cultivation is the main commercial crop in the area in addition to finger millet as a staple food crop. The watershed area covers 350 families spread in three villages and three hamlets.

To encourage *in-situ* harvesting of rainwater for the promotion of sustainable dryland farming system, the following activities are undertaken.

- Formation of trench cum bund across the slope. The trench cum bund formed helps to retain silt and water *in-site*.
- The trench in the bund is used for the plantation of different forestry plants up to 1000 per ha.
- The fields are planted with dryland fruit species such as tamarind, cashew, mango and alma.
- For every two ha of catchment one farm pond measuring 30 X 30 X 10 feet is excavated.
- Series of farm ponds are located on contour lines.
- These ponds are located in such a way that the field trench cum bund acts as conducting channels for the flow of water in a horizontal line.
- Once a pond is filled with rainwater, the excess water flows to the next pond through the conducting channels. The last pond in the chain discharges to a check dam in the drainage line. In a line normally there can be 5 to 15 ponds.
- If the water is allowed to flow vertically down, because of the velocity gained, the gushing water carries away maximum silt down the valley. Hence the ponds are not connected vertically.

- The ponds are not lined with any impervious material. Instead the ponds are regularly desilted for encouraging maximum percolation.

Perceptible Impact

- It is estimated that in one rainy season up to 15 crore liters of water percolate from all the ponds put together.
- Good quantity of water also gets evaporated. The effect of evaporation from 340 water bodies in an area of 700 ha creates very congenial microclimate and helps to reduce the aridity in the area.
- The horizontal connection of ponds helps to retain water for maximum time in the upper reaches of the watershed.
- The water seeping in to the soil helps to maintain good moisture regime in the soil, which feeds the crops, and other vegetation in the watershed for longer periods even after the rainy season is over.
- The area is characterized by coconut plantations in the valleys. The effect of percolation of substantial quantity of water in the upper reaches of the watershed results in very good moisture regimen in the valleys due to seepage and subsoil flow. Hence the need for irrigating the coconut orchards is reduced.
- The farmers are already reporting longer duration of flow of water in the drainage line even after the rains have subsided.
- The mound formed around the ponds due to the excavated soil is also very fruitfully utilized for the plantation of medicinal plants such as Aloe vera and Witania somnifera, which give a return of up to Rs. 2000/- per year per pond. Many vegetable and fruit species are also planted on the mound, which help to harvest substantial quantities of fruits and vegetables to meet the family requirements.
- Some of the ponds that retain water for more than six months, are also used for rearing fish. Each pond can hold up to 100 fingerlings of Common Carp variety. Average fish yield could be around 50 kg per pond per year.

General

The watershed development programmes being implemented in vast tracts of the country can to some extent help to augment the groundwater level with scientific planning and execution.

However, it is noticed that for various reasons the meaning of watershed treatment gets narrowed down to mean only the construction of a few structures here and there. Systematic treatment of catchment is as crucial as the drainage line treatment. This paper discusses such an attempt in one of the watersheds and the results obtained.

Location

The project is located in Arsikere taluk of Hassan district in southern Karnataka The area is characterized by an annual rainfall of 550 to 700mm/ The rainfall is received in two peaks. The soils are red, shallow and sandy with high porosity.

Crops

Coconut is cultivated traditionally in the valleys as a cash crop. *Ragi* (finger millet) is staple food crop. In addition, pulses such as redgram, horse gram and dolichos are also cultivated to some extent. Sorghum is a major fodder crop. Sesame and green gram are cultivated in the pre-monsoon period.

The project Interventions

A watershed project was initiated in an area of 700 ha in January 1997. The area is spread in 3 villages and 3 hamlets and covers 350 families. The project activities include the following:

Preparatory Activities

- Family level micro planning was done to involve each and every family in the project planning process.
- PRA exercises were carried out to understand the community perceptions and to plan community based activities such as water harvesting structures.
- Participant families were involved in carrying out the activities with their own lands. Project actively discouraged hiring the labour through contractors. Individual families were encouraged to hire labour wherever required.
- Each and every family was trained in all aspects of watershed management. In addition to village-level training and classroom training, major thrust was given to the exposure visits to successful projects with in and outside the state.

Field Activities

- Field bunds were created across the slope. Bunds were formed by creating a trench across the slope instead of traditional pit method by excavating the soil. This trench cum bund helps to retain maximum soil and water *in-situ*.
- The bund size was restricted to 0.3 sq.m sections. Horizontal interval between bunds was kept around 25 Mts.
- Forestry plantation of mixed species was taken up on the bunds. Important forestry species planted included – teak, casurina, eucalyptus, glyricidia, cassia siamia, pongamia, neem, sapindus, etc.

Rainfall Data

FROM: 1995 - 2008													
Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1995	-	-	-	21.30	105.80	14.00	78.60	140.90	109.60	107.60	91.40	-	669.20
1996	-	-	-	127.80	56.80	81.90	42.00	119.60	176.80	100.40	-	15.80	721.10
1997	-	-	37.50	12.00	177.00	70.00	53.40	76.30	60.70	218.00	126.00	6.80	837.70
1998	-	-	3.00	100.50	74.50	52.00	189.00	270.30	156.30	89.30	28.30	3.50	966.70
1999	-	23.00	14.00	56.70	109.00	24.00	75.50	17.00	129.50	389.00	34.50	2.00	874.20
2000	-	16.00		36.50	45.00	23.00	48.00	180.00	283.00	227.00	4.00	2.00	864.50
2001	-	-	-	92.00	45.80	31.00	95.20	48.50	292.00	51.30	57.80	11.00	724.60
2002	-	40.5	11	9.2	67.9	116.7	48.4	26	83.2	191.7	41.5	-	636.1
2003	-	-	35	55.5	-	44.6	15.8	62.1	13.9	241.9	4.2	-	473.0
2004	-	-	11.7	99	234	17.1	145	33.8	110.1	93.2	31	-	774.9
2005	43	11	-	69	148.7	49.6	115.5	71	73.3	184.9	21	-	787.0
2006	-	-	35	49.5	111.5	112	8.8	35	25.5	44.5	91	-	512.8
2007	-	-	-	19.5	158	46.0	23.5	156.5	120.5	259.5	3	10	796.5
2008	-	130	143	36	70.5	27	101	201	30.5	153.5	65	-	957.5

- Horticultural species such as mango, cashew and tamarind were planted in the fields at a spacing of 30 X 30. Assistance for horticulture was restricted to 1 ha per family.
- Regular traditional food crops are cultivated in between horticulture plantation.

Water Harvesting

A series of farm ponds were excavated and they were located on contour lines.

- For every 2 ha of catchment there was one pond.
- The capacity of these ponds varied depending on the location. Minimum size of the pond was 25 X 25 X 10 ft. i.e. 6250 cft, with a capacity to hold 175000 liters of water at a time. Average cost of a pond was Rs 5000/-. This works out Rs 0.30 per liter capacity of the pond. These ponds are not lined with any impervious material to facilitate percolation.
- The ponds occupy approx. 0.5% of the land area.
- 340 ponds have been excavated. Each pond with a capacity of 1.75 lakh liters, can harvest approximately 5 crore liters of water with one filling. Most of this water gets percolated down. In a normal rain fall year, we can expect these ponds to over flow at least three times during the rain season.
- These ponds help in harvesting run off during a stray rains in the summer. With the first peak of monsoon in June – July, all the ponds overflow. With subsequent rains the ponds get topped up. With the second peak of rains in Aug-Sept, when maximum rainfall is received in the area, the ponds overflow more than once.
- The ponds are shaped either as step-well type ponds or as deep cut ponds. Step-well type ponds are of lower capacity.
- Each pond is provided with a silt trap just before the inlet. This silt trap is normally a pit measuring 4 X 4 X 3 ft.
- The inlets and outlets of the ponds are lined with stone pitching.
- 10 to 15 ponds located on a contour are linked in a chain. The field trench cum bunds act as conducting channels for carrying water from one pond to another. The last pond discharges in to a check dam through horizontal flow of water from one pond to another. The vertical flow of water from the ridge to the valley, with erosive velocity, is avoided.
- Check dams are constructed in the nala where the farm pond chains on either side can discharge. Thus, the water coming into the check dam will be almost devoid of any silt. Silt gets arrested at the farm pond level itself. Thus, the life of the check dams can be enhanced by several times.
- As enormous amount of water gets percolated in the upper reaches of the watershed, regular seepage occurs in the valley portion. This seepage is seen for extended periods even after the farm ponds dry out water continues to accumulate in the check dams.
- The number of check dams can also be minimized to a bare minimum expenditure as most of the water gets arrested in the upper catchment.
- In addition to the traditional masonry check dams, which are not very cost effective, earthen check dams with ferro – cement core wall were experimented. These can be executed at approximately 1/3rd of the cost of the masonry structures.

Rationale of this Novel Approach

Distribution of Water

The water harvested in the structures in the *nal*a such as check dams is normally not very democratically distributed. The people in the upper reaches of the catchment, where water is more required, almost get share in this water harvested. Very few people located close to the structure derive benefits.

The series of ponds located in the upper reach of the catchment help to maintain good soil moisture levels throughout the watershed. This also encourages good water percolation for groundwater recharging. The check dam is fed even during the dry period with the seepage water in the valleys. This seepage rends increase year after year as most of the subsoil strata get saturated with water during the first or second year of execution of these percolation structures. During subsequent years, most of the percolated water tends to seep out. This is very much determined by the nature of the soils and the under ground strata.

There is very little individual initiative from farmers for the maintenance of community structures such as check dams. The individ-

A comparison of the traditional water harvesting structure with the farm ponds is as follows.

Comparison between farm pond and other structures

Sl. No.	Farm pond	Other structure (check dam, earthen bunding etc.)
1.	Occupies less area & less submergence of land, small exposed water surface	Occupies less area, more submergence of land, more exposed water surfaces
2.	Deep-water column, less evaporation and greater percolation into surrounding areas.	Water column is less exposed area is more & more evaporation and less recharge
3.	Sub surface flow is more	Sub surface flow is less
4.	Generates more employment for the families of watershed area	Less employment opportunities, since it requires skilled labour
5.	Major portion of money goes to local people	Major portion goes to materials, which is not available to the local people.
6.	Easily manageable by local people	Requires skilled labour & heavy investment
7.	It protects & increases the rest of the structures of the drainage line because of *in-situ* conservation of soil	Without ponds at the upper reaches danger of breaching & siltation of structures
8	Benefits more people especially poor and marginal	Benefits less number of peoples and merely rich people
9	Equity in water distribution	Unequal water distribution in the watershed
10	Very effective microclimate management	Little effect on the microclimate
11	energy efficient structure	Loss of energy, requires additional energy to bring back water to upper reaches

ual farmers maintain the ponds located on individual farmer's lands, though treated as community assets. The silt trap is regularly desilted after each rain. The silt accumulated in the pond also provides a valuable silt for bund application, which does not require much effort for transportation.

Energy Issues

Water from the catchment normally flows down to the valley with considerable speed carrying silt. If this water is to be lifted for watering plants/crops in the upper reaches, either manually, using bullock power, or by pumping, the energy required to be spent will be enormous. This gravitational energy can very well be utilized to make water percolate in the upper reaches itself. By providing a very slight gradient in locating the ponds in the same contour we can conduct the water across the watershed horizontally. This can ensure that water stays in the upper reaches for a longer time.

Ecological issues

Maintenance of good subsoil moisture for longer time can stimulate and promote living organisms in the soil. The mound of soils formed around the pond is planted with diverse plants to meet the farmer's day-to-day requirements. The mound formed is utilized for plantation of medicinal herbs such as Aloe vera and witania somnifer, which can give a return of upto Rs 2000/- per year. Vegetables and fruit plants are planted on the mounds, which helps to harvest substantial quantity of fruits and vegetables for the family requirements. The water available within a farmer's land brings about a change in the behavioral aspects of the farmer. He tends to stay longer time in his fields with his livestock doing some thing or the other. This binding of man to his land will result in an improved farming system, taking shape slowly but surely.

The ponds attract birds of diverse mature. This further stimulates the on set of a series of developments, which collectively can be termed as pond ecology. Ponds located relatively on the lower reaches of the catchment tend to retain water for a longer time (say beyond six months). These ponds can very effectively be used for small-scale fisheries.

The effect of 340 farm ponds in an area of about 700 ha can itself bring about a relative change in the humidity levels, reducing the intensity of aridity in the microclimate.

Critical Observations

The effect of farm ponds is regularly monitored using three important indicators.

- Water level in the open well on a monthly basis
- Water level in selected ponds on a daily basis.
- Yield of coconuts in the valley portion in 20 selected gardens – done as and when the coconuts are harvested.

- The farmers have started reporting better performance of their coconut gardens since the last summer. The need for irrigating these gardens has been reduced. The effect of percolation of substantial quantity of water in the upper reaches of the watershed helps to maintain good moisture regime in the valleys. However, it is too early to conclude on the actual coconut yields as the data collection is to be continued at least a couple of years more.
- The farmers are reporting longer duration of flow of water in the drainage line even after the rains have subsided. This seepage continues to feed the check

Table. Economic of fisheries in farm ponds		
1.	Size of the pond	8m x8m x3m = 192 cmt. (50% of this is taken as effective capacity)
2.	Area required per fish	1 cmt
3.	Total nos of fish per pond	Approx 80 nos
4.	Consider 15% mortality (Each fish catch weigh approx 2 kg after 6 to 8 months (common crap variety)	Approx 65 will survive
5.	Total fish catch	120 kgs (Approx)
6.	Market rate	Rs. 25 per kg
7.	Total value	Rs 3000/-
8.	Expenditure (Approx) (Feed, labour, finger lings etc)	Rs 1000/-
9.	Net Profit	Rs 2000/-

dam in the valley with clean water with out seepage.

- The farm pond technology can be utilized very fruitfully in all watersheds with suitable modifications depending on the soil types and slopes. The check dams where water is stored against a head are costly, cost ranging between Rs. 50000/- and Rs 200000/-. A combination of check dams and farm ponds can be designed for maximum efficiency. This will reduce the number of check dams required in a catchment.
- The water stored in big check dams is normally used by a few rich farmers in the valleys and hence is not a democratic way of water distribution.
- The cost of lifting water to the upper reaches of watershed from the check dams is high and hence is not feasible.
- The farm pond network with approximately one pond for every 2 ha is grossly under designed. Hence during peak downpour (2 or 3 times in a year), a large amount of water overflows of all the ponds.
- Though 0.5 to 1 % of the land area is not available for cultivation, the benefits accumulated over a period of time will far out weigh the loss. In fact, the increased direct benefits can be perceived from the very second year.

Scope for Further Research

- Cost benefit analysis of investments over a longer period of time.
- Ecological impact of *in-situ* soil moisture conservation with the run off reaching the valleys.
- Issues related with the riparian rights of farmers in the down stream and the related social issues.
- Cost sharing mechanisms between various stakeholder groups. It is noticed at least in this particular case study the farmers in the down stream with coconut gardens tend to get maximum benefit in spite of the runoff reaching the valley through seepage.

- Long-term impact in terms of water logging in the low– lying areas.
- Pond designs for different soil types, (ponds in black soils tend to cave in). Several methods of stabilizing the ponds can be thought off.

Conclusions

The farm pond technology can be used very fruitfully in all watershed areas. This is very good low cost supplement to check dams. Each farm pond costs around Rs. 5000 for excavation. Check dams cost anywhere between Rs. 50000 and Rs. 200000. The cost of water storing against a head in check dams is substantially higher compared to dug out ponds. The water stored in big check dams is normally used only by the down stream farmers and hence is not a democratic way of water distribution. Lifting water from the check dams to upper reaches of the catchment will also be very costly and will not be energy efficient. The number of check dams in a watershed can be reduced and supplemented with farm ponds. Decentralized farm ponds are scattered all over the catchment and hence water is made available to maximum area with least cost. The life of a pond is also longer and is maintained by the farmer in whose land the pond is located. The silt harvested regularly from the ponds can be a good addition to the fields for improving fertility.

Understanding a dryland agro-eco-system in all its entirety is very crucial for making any meaningful intervention for achieving sustainable development in the vast tracts of the country. Depleting forest cover, irregular rainfall and increased exploitation of groundwater have aggravated the situation of groundwater table. There are no systematic efforts to regulate the groundwater exploitation or any such meaningful regulatory system can be thought off in the near future.

Proceedings of the National Workshop cum Brain Storming on Rainwater harvesting and reuse through farm ponds: Experiences, issues and strategies held during April 21-22, 2009 at CRIDA, Hyderabad

This brain storming was held with the following objectives:

- Sharing of experiences on water harvesting and reuse through farm ponds and related issues, among scientific institutions, Govt. Departments, NGOs, civil society organizations and progressive farmers.
- Understand the biophysical, technological and social constraints in adoption and upscaling of farm pond technology
- Identify critical research gaps and policy initiatives for wider adoption of farm pond technology in the country.

The brain storming was attended by about 80 participants representing various ICAR research institutes (CRIDA, CAZRI, NBSS-LUP, CSWCRTI, CICR etc), Agricultural Universities (ANGRAU, UAS Bangalore, UAS, Dharwad, GBPUAT, YS Parmar University etc), NGOs (WASSAN, AKRSP, Aravali, Foundation for Ecological Security etc), officials from central (Ministry of Agriculture) and state government ministries of Agriculture (AP, Karnataka, Tamilnadu, Gujarat, Madhya Pradesh (MPRLP)) and Rural development and NABARD. The list of participants is given in Annexure I. Instead of regular academic seminar, it was organized mainly to share experiences, lessons learnt and identify critical issues needing future attention.

The brain storming was inaugurated by Dr.S.M.Ilyas, Director, NAARM who emphasized that farm pond technology is the one which empowers the farmer in water management in rainfed areas. He stressed the need for looking at the issue as a package from the point of harvesting, lifting and making proper reuse for suitable crop and profitability rather than water harvesting alone, which is more prevalent now. Further, it has been mentioned that the program should be demand driven with contribution and effective participation from farmers in the whole process. In his opening remarks Director, CRIDA informed that though the farm pond technology is in existence for many years, adoption of the same by the developmental agencies is not to the desired level. He also pointed out that water harvesting systems are taken up vigorously in many watershed programmes but the utilization of harvested water is not tied up in many cases (in terms of area that can be covered with critical irrigation, timing of irrigation etc). He stated that in order to make the farm pond technology viable for small and marginal farmers, the technology need to be developed as package with proper measures for seepage control in farm ponds, suitable lifting devices and identification of appropriate locations with in farmer fields. He further emphasized that rainfed crops to be provided with one critical/supplemental irrigation with harvested water so as to increase the productivity and income from these areas. The inaugural session was followed by four technical sessions.

A total of 30 papers were presented in the four sessions. The program is given as Annexure-II.

The papers presented in session I covered generic issues like perspectives of farm pond technology in the livelihood programmes, design methodologies, implications of water harvesting at different scales of operation (up stream –downstream), opportunity of water harvesting and technologies for water harvesting in arid regions, improved sheet material for control of seepage losses. In session II, case studies from vertisol regions were presented covering aspects like design methodologies, identification of suitable sites, successful utilization of harvested water for enhancing the income, involvement of local institutions for up scaling farm ponds through training and capacity building programme. Similarly in session III and IV, case studies related to Alfisols and related regions and high rainfall hill and mountain regions were presented. These papers discussed issues related to technical aspects of farm ponds for making them a success with location specific technologies, research studies being carried out at various institutions, upscaling the technologies through convergence with rural development programmes.

Following the presentations, the recommendations were finalized based on group discussions. The following three groups were constituted to discuss various issues in the light of the presentations made and identify specific research gaps. The issues listed are as follows:

1. Determination of the harvestable runoff potential in various agro ecological zones
2. Optimization of the size of the farm ponds for different agroecological zones
3. Identification of the cost effective lining material and efficient water lifting device
4. Choice of crops and method of irrigation for increasing water productivity
5. Policy support to individual farmers for adopting the farm pond technology
6. Strategies for integration of farm pond technology into the existing watershed/ NREGA programs.

The three groups are as follows:

Name of the Group	Group leader	No. of participants in the group
Design aspects of farm pond, lining materials, storage and harvestable runoff, etc.	Dr.R.N.Athavale	30
Lifting, conveyance, efficient use, water productivity and choice of crops, etc.	Dr.Mohd.Osman	20
Policy, institutional and support systems for upscaling	Dr.A.K.Tiwari	15

The recommendations of the three groups are given below.

Group 1: Design aspects of farm pond, lining materials, storage and harvestable runoff, etc.

1. Size optimization of farm ponds need to be done for various rainfall zones i.e, <500, 500-1100 and more than 1100 mm rainfall zone with a view to provide one supplemental irrigation of 5-7.5 cm at critical stage of crop.
2. Purpose for which water harvesting ponds are to be dug need to be clearly defined first (for storage and reuse or for recharge of groundwater) before the design and storage capacity are optimized.
3. Harvestable runoff per ha be assessed in different crop/cropping systems across different climatic zones.
4. The farmers who donate the land for ponds to be given preference for use of stored water than the down stream users.
5. Lining material should be durable with more life span, puncture and tear resistant, environment friendly, cost effective, non toxic and adaptable to any shape.
6. Shape of the pond depends on the individual. Ideally it should be circular but it should left to farmer's choice. In case of community water harvesting structures, which are larger in size, L-shaped or horse-shoe shaped structures may be adopted.
7. Innovative evaporation control mechanisms are to be inbuilt in the farm pond design.

Research Issues:

1. Standardization of catchment- storage-command relationship for every Agro-ecological zone.
2. Development of decision support system for farm ponds covering different agro-ecological zones. The system should be user friendly and include various aspects of materials, farmer's choice, intended use of water, shape, size etc.
3. Adaptive research through field trials for various lining materials including locally available ones and possible recommendations across agro ecological zones.
4. Standardization of inlet and outlet for different agro-ecological zones.

Recommendations of Group 2 include

Group 2: Lifting, conveyance, efficient use water productivity and choice of crops etc.

- ❖ Ideal lifting devices to be identified from among choices like diesel engine/tractor/power tiller operated pump set, solar pump set, pedal operated pump set, electric pump set etc. for lifting water from farm pond.
- ❖ The lifting devices be promoted through Custom hiring mechanism.
- ❖ Better water use be achieved through use of pipes for conveyance instead of conventional furrow irrigation.
- ❖ Improved irrigation methods like sprinkler/drip be promoted for irrigation with harvested water
- ❖ Sharing mechanism be developed to promote equity in case of community-owned ponds

- In order to compensate the loss of land due to digging of farm pond (specially unlined ponds), the embankment be used for horticulture. pasture/ bio diesel/ medicinal/ forestry plants.
- Pendal system be promoted over pond for raising creepers, vines belonging to cucurbitaceae family for utilizing the space with gaps for light penetration for fish rearing. .
- With in the pond, fisheries and prawn culture and duckery be promoted wherever feasible.
- Horticulture crops followed by oilseeds (groundnut, soyabean), cotton, pulses, FCV tobacco etc in that order be preferred for supplemental irrigation where returns
- Farm ponds be promoted as an integral component of farming system across rainfall zones

Researchable issues

Developing a low head, energy efficient lifting device along with delivery mechanism

Recommendations of Group 3 include

Group 3: Policy, institutional and support systems for upscaling

- Priority should be given for water resource development in different governmental schemes and a specific budget should be earmarked for promotion of farm ponds.
- Adequate incentives should be given with a flexible approach to extend the technology among farmers as being done us the state of Gujarat.
- For rapid expansion of the programme, machines may also be allowed for digging of ponds wherever labour is not available. Provisons may be made in the guidelines for passing a resolution to this effect by the panchayat.
- Renovation of old ponds which are national assets should be taken up in the ongoing government schemes on priority for water resource development and ground water recharge.
- Large/medium farmers should be encouraged through incentives like capital subsidy or differential interest rates to construct farm pond in his land as being done in case of roof top water harvesting for big buildings.
- 5% budget of the department of land resources should be allocated for research on water harvesting, improving water productivity and sharing mechanisms.
- Scientific planning of farm pond in the participatory mode (involving village level institutions) be promoted to avoid conflicts among up stream and down stream users.
- Operational maintenance, capacity building and other relevant issues to be given due attention in the programme.
- Technical literature and success stories should be published for extension education programmes.
- Cost benefit analysis should be worked out and widely made known to stake holders to remove the apprehensions on loss of land.
- Saturation approach be promoted on a pilot basis in selected districts

Annexure-1

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Annexure-II

National Workshop cum Brainstorming on Rainwater Harvesting and Reuse through Farm Ponds: Experiences, Issues and Strategies

Jointly Organized by
CRIDA, NAIP & ICRISAT, Hyderabad
21-22 April, 2009

Day 1 (21-04-2009)

10.00 – 10.45 hrs.	**Inaugural Session**	
	Welcome	Dr.B.Venkateswarlu, Director, CRIDA
	Importance of the theme in NAIP Comp.3	Dr.A.P.Srivastava, NC, Comp-3, NAIP
	Water harvesting as key priority in NRM research	Dr. P.D. Sharma, ADG (Soils)
	Importance of water harvesting in Watershed Programmes	Dr S.P. Wani, ICRISAT
	Remarks by Chief Guest	Dr.S. M. Ilyas, Director, NAARM
	Vote of thanks	Dr.P.K.Mishra, PC, AICRPDA
10.45 – 11.00 hrs.	**Tea**	
11.00 – 13.30 hrs.	**Technical Session I : Rainwater harvesting and recycling: current status and issues**	
	Chair : Dr.S.M. Virmani, Co-Chair : Dr.A.P.Srivastava,	
	Rapporteur: Dr D. H. Ranade	
	1. Rain Water Harvesting through Farm Ponds and Well Recharging Structures- Experiences from MP	Sandeep Khanwalkar, State Co-ordinator MPRLP, Indore.
	2. Water Harvesting Structures in Naturally Water Scarce Regions: Hydrological Assessment and Economic Viability	Dinesh Kumar, Institute for Resource Analysis and Policy, Hyderabad
	3. Seepage Control through a New Class of Sheet Material	B L Deopura, IIT Delhi
	4. Rainwater Harvesting: A Key To Survival in Hot Arid Zone of Rajasthan	R K Goyal, CAZRI , Jodhpur
	5. Optimum Design of Watershed based Tank System for Semiarid and Sub Humid Tropics	Mukund Shinde, MPKVV, Rahuri
	6. Evaluation of Watershed Development Programmes in India using The Economic Surplus Method.	K.Palanisami, IWMI Tata Program, Patancheruvu
	7. Optimizing On-Farm Reservoir size for various Cropping Systems in Rainfed Uplands of Eastern India	S.N.Panda, IIT, Kharagpur
13.30 – 14.15 hrs.	**Lunch**	

14.15 – 16.30 hrs.	**Technical Session II : Experiences of water harvesting through farm ponds in Vertisol regions**	
	Chair: Dr.R.N. Athavale, Co-Chair: Dr. A.K. Tiwari,	
	Rapporteur: Dr. R.K. Goyal	
	1. Impact of Water Harvesting Structures on Water Availability-A Case Study of Kokarda Watershed in Nagpur District of Maharashtra	V.Ramamurthy, NBSSLUP, Nagpur
	2. Water Harvesting and Recycling Technology for Sustainable Agriculture in Vertisols with High Rainfall	D.M.Bhandarkar, CIAE, Bhopal
	3. Harvesting and effective utilization of rainwater in diked rice fields of medium lands in eastern region – A case study	Atmaram Mishra , WTCER, Bhubhaneshwar
	4. Use of Water Harvesting Tanks in Black Soil of Malwa Region – A Case Study	D.H.Ranade, AICRPDA, Indore
	5. Productivity Enhancement and Livelihood Security through Rain Water Harvesting in Vertisols of Adilabad District	Mohd. Osman, CRIDA, Hyderabad
	6. Dugout Farm Pond – A Potential Source of Water Harvesting in Deep Black Soils in Deccan Plateau Region	R.N.Adhikari, CSWCRTI, Bellary
	7. On-farm Testing of Lining Materials in Small Experimental Tanks for Supplemental Irrigation	C.R. Subudhi, AICRPDA, OUAT, Phulbani
	8. Factors affecting the adoption of farm ponds in Drought prone areas of Gujarat : Sharing Experiences of AKRSP(I).	Vitthal Kakaniya & Shailja Kishore, AKRSP,Gujarat
16.30 – 18.30 hrs.	**Technical Session III : Experiences of water harvesting through farm ponds in Alfisols and other related soil regions**	
	Chair : Dr.S.P. Wani, Co-Chair : Dr. Y.S. Ramakrishna,	
	Rapporteur: Dr K. S. Reddy	
	1. Farm Ponds for A Viable and Profitable Dry Land Agriculture – Experiences in *Alfisols* of Karnataka	G.N. Dhanapal, AICRPDA, UAS, Bangalore
	2. Talaparige: A Unique Traditional Water Harvesting System in Karnataka	Mallikarjuna Hosapalya, Dhanya, Tumkur
	3. Farm Pond for Income and Livelihood Security- A Case Study from Anantpur District of AP	B.Shivarudrappa,BIRD- AP, Hyderabad
	4. Farm Pond- A Means for Poverty Reduction: Experiences from Chittoor Dist,AP	B. Sada siva, Dhan Foundation, Hyderabad
	5. Productivity Enhancement through Rain Water Harvesting in Alfisols of Prakasam District in A.P.	R.Srinivasulu, CTRI Res.Sation, Kandukur,AP
	6. Rain Water Harvesting - A Case Study in Changeri Watershed Area of Udaipur, (Rajasthan)	A.K. Singh, NBSSLUP, Udaipur
	7. Rainwater Harvesting and Supplemental Irrigation through Farm-Ponds & Evaluation Lining Materials	John Wesley, AICRPDA, ANGRAU, Anantapur
	8. Farm Pond Technology for semi arid alfisol region of Telengana in Andhra Pradesh	P.K.Mishra, CRIDA, Hyderabad

	9. Farm Pond Initiative in Rainfed Areas in Rajasthan	Ambuj Kishore, Aravali, Jaipur
	10. Rain Water Harvest and its reuse for Ground Water Recharge – A Case Study in Karnataka	Dilip Mudkavi, UAS, Dharwad
18.30 hrs.	**Cultural Programme**	
20.30 hrs.	**Dinner (Sponsored by ICRISAT)**	

Day 2 (22.04.2009)

09.30 – 11.00 hrs.	**Technical Session IV : Experiences of water harvesting through farm ponds in high rainfall hill, and mountain and tribal regions**	
	Chair : Dr.K.Palanisami, Co-Chair : Dr.P.K.Mishra,	
	Rapporteur: Dr. Sidhpuria	
	1. Water Harvesting in Hilly Areas of Uttarakhand: Opportunities and Challenges	Anil Kumar, GBPUAT, Pant Nagar
	2. Farm Ponds for Supplementary Irrigation to Plantation Crops in Goa	S.Manivannan, ICAR Complex, Goa
	3. Rainwater Harvesting through Cost Effective Water Storage Structures in Mid Hills of Himachal Pradesh-A Success Story	I.P.Sharma, Dr YSPUHF, Solan, Himachal Pradesh.
	4. Water Harvesting for Supplemental Irrigation- Case Study from Shivalik Hill Region	A.K. Tiwari , CSWCRTI, Chandigarh
	5. Rain Water Harvesting and Recycling for Sustainable Agricultural Production in North Eastern Hill Region	B.Krishna Rao, CTRI, Rajahmundry
	6. Integration of farm ponds into the dryland farming systems – A Case Study from A.P.	Venkatraj Dedya, Foundation for Ecological Security
	7. Rainwater harvesting through farm ponds & shallow dug wells; reuse through peddle operated low lift pump in Bastar Region of Chattisgarh	D.S.Thakur, AICRPDA, Bastar
	8. Water Harvesting Potential Assessment in Rainfed Regions of India	KV Rao, CRIDA,Hyd
11.00 – 11.30 hrs.	**Technical Session V : Issues, Strategies and research gaps: Brainstorming**	
	Chair: Dr. P.D. Sharma, ADG (soils)	
	Co-Chair: Dr. G.R. Korwar	
	• Key issues and research gaps – Dr.P.K.Mishra	
	• Moderators : Dr. K.V.Rao and Dr. Sreenath Dixit	
11.30 – 13.15 hrs.	**Group activity**	
13.15 – 14.00 hrs.	**Lunch**	
14.00 – 16.00 hrs.	**Plenary Session, open discussion and wrap-up**	
	Chair : Dr.B.Venkateswarlu, Co-Chair : Dr.P.K.Mishra,	
	Rapporteur: Dr Ch. Srinivasa Rao	
16.30 hrs.	**Close**	

About CRIDA

The Central Research Institute for Dryland Agriculture (CRIDA), a part of Natural Resource Management (NRM) Division of Indian Council of Agricultural Research (ICAR), is a national level research institute with a mandate to carry out basic and strategic research in the field of rainfed agriculture. The current research thrusts include resource characterization, rainwater management, crops and cropping systems, integrated nutrient management, alternate land use systems etc. CRIDA was responsible for implementation of 30 Model Watershed Programmes in the country during 1980s and their success lead to formulation of national level watershed programme. CRIDA is leading the consortium on Sustainable Rural Livelihoods Program in selected districts of AP with NGOs as partners under National Agricultural Innovation Project.

www.crida.ernet.in

About ICRISAT

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is a non-profit, non-political organization that does innovative agricultural research and capacity building for sustainable development with a wide array of partners across the globe. ICRISAT's mission is to help empower 644 million poor people to overcome hunger,poverty and a degraded environment in the dry tropics through better agriculture. ICRISAT belongs to the Alliance of Centers of the Consultative Group on International Agricultural Research (CGIAR).

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