IRRIGATION POTENTIAL IN RAINFED WATERSHED FOR SUSTAINABLE RURAL LIVELIHOOD

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Abstract: *The continual unsatisfactory level of food security and agronomic sustainability of the rural communities living in the rainfed areas of India is predominantly confirmed. Families in these areas depend almost entirely on the income through cattle and goat rearing. No income from crop production is generated, although families have ownership to croplands. The main reason for this is that continuous crop failures are experienced with the conventional way of crop farming in an environment where water scarcity, poor soils and inappropriate management practices hamper successful crop production. This paper focuses mainly on the type of water harvesting technique suitably and successfully adapted in rainfed areas. The paper classifies various rainwater harvesting systems and also highlights the various biophysical and socio-economic factors suitable for selection of particular rainwater harvesting system. Also the paper describes the holistic way of managing water, integrating land, water and labour management. The comparison between water harvesting techniques and the construction of large or medium dams proves the feasibility of the rainwater harvesting systems in smallholder rainfed farming systems.*

Key words: *Water harvesting techniques, rainfed farming system.*

Introduction

The water scarcity in arid and semi-arid regions of India is the result of low and unevenly distributed rainfall throughout the season, which makes rainfed agriculture a unpredictable and risky investment. Several traditional water management techniques are prevalent in India since ancient times (Prinz *et. al.*, 1999) most of them being simple, sure to implement and of low capital investment. The conventional sources of irrigation water such as water supply from dams and wells are often at the verge degradation due to overuse and therefore unexplored sources of (irrigation) water have to be sought for increasing agricultural productivity and providing sustained income to farmers. Water harvesting for irrigating water constrained agriculture is a traditional water management technology to ease future water scarcity in many rainfed regions of India. The rainwater harvesting systems are site specific, therefore, the appropriate choice of technique depends on the amount of rainfall, its distribution, land topography, soil type and soil depth and local socio-economic factors. The water harvesting methods depend on local conditions and include such widely differing practices as bunding, pitting, micro-catchments water harvesting, flood water irrigation and ground water harvesting (Prinz, 1996).

Investigations of water harvesting technologies:

The various types of water harvesting techniques practiced in rainfed areas can be classified in three groups of water harvesting (Table 1):

1. Rainwater harvesting: Rainwater harvesting is defined as a method for inducing, collecting, storing and conserving local surface runoff for agriculture in arid and semi-arid regions. Three types of water harvesting are covered by rainwater harvesting.

a) Household Rain Water Harvesting System: Water collected from roof tops, courtyards and similar compacted or treated surfaces is used for domestic purpose or homestead garden crops (Fig.1)

b) Micro-catchment water harvesting: It is a method of collecting surface runoff from a small catchment area and storing it in the root zone of an adjacent infiltration basin. The basin is planted with a tree, a fruit garden or with annual staple crops.

c) Macro-catchment water harvesting: The runoff from hill-slope catchments is conveyed to the cropping area located at hill foot on flat terrain.

2. Flood water harvesting: It is defined as the collection and storage of runoff from rivulets and streams for the use of crop irrigation. Flood water harvesting is the large catchment water harvesting also known as 'Spate Irrigation', is classified further into two categories:

a) Floodwater harvesting within stream bed: In this type of water harvesting the water flow is dammed and as a result, inundates the valley bottom of the flood plain. The water is forced to infiltrate and the wetted area can be used for agriculture or pasture improvement.

b) Floodwater diversion: The water from rivulets, streams is diverted to leave its natural course and conveyed to nearby cropping fields or constructed ponds or small dams.

3. Groundwater harvesting: Groundwater dams like 'Sub-surface Dams' and 'Sand Storage Dams' are other fine examples of groundwater harvesting. They obstruct the flow of ephemeral streams in a river bed; the water is stored in the sediment below ground surface and can be used for aquifer recharge. Sand filled reservoirs have the following advantages:

(1) evaporation losses are reduced,
(2) no reduction in storage volume due to siltation,
(3) stored water is less susceptible to pollution, and
(4) health hazards due to mosquito breeding are avoided.

Type of Water Storage Systems

Above-ground water storage:

In most rain and floodwater harvesting schemes the water delivered by surface runoff and overland flow is stored only in the soil profile. This means, that its application is limited to the rainy season. To allow cropping outside the rainy season, a number of storage structures are constructed, ranging from ferro-cement tanks of 20 to 500 m^3 storage capacity (Fig 2) to large reservoirs, storing million cubic meters of water.

In India, more than 5,00,000 farm ponds are constructed to store rain-runoff water, sometimes supplemented by water from rivulets or small streams. Farm pond play several important roles e.g. as flood-controlling detention system and in preventing soil erosion and wastage of runoff during periods of heavy rainfall. Additionally, they recharge the groundwater in surrounding areas. The larger ones, 10 to 30 hectares in size, feed several thousand hectares of irrigated land. Some are equipped with sluices, which deliver water to an extensive canal system. Without this tank system, paddy cultivation in large parts of the India would be impossible (Agarwal & Narain, 1997). These rainwater reservoirs are not only used for irrigation in arid or semi-arid regions, but also in semi-humid areas (up to 1300 mm annual rainfall).

Underground Storage:

Several disadvantages are connected with surface storage of water such as large evaporation losses, loss of storage caused by siltation, pollution problems and loss of agricultural land. Therefore the underground storage of water may be the beneficial alternative (such as groundwater dams). This storage can be done in near surface aquifers (e.g. in *wadi* beds), calling for a conjunctive management of water resources. *Tankas* /Cisterns are practiced in Rajasthan which are man-made caves or underground constructions used to store water. The walls of these cisterns are plastered and water losses by deep percolation or by evaporation can be minimal. The construction of cisterns was already practiced several thousand years ago wherein chalky rocks were preferred. In the same region, '*Kunds*', were practiced which are the covered underground tanks with a plastered catchment, (Agarwal & Narain, 1997). Presently cisterns are constructed using concrete.

Factors considered in selection of rainwater harvesting system

The most important factors to be considered in identifying areas suitable for rain and floodwater harvesting are as follows:

a) Rainfall:

The knowledge of rainfall characteristics (intensity and distribution) for a given area is one of the pre-requisites for designing a water harvesting system. The availability of rainfall data and rainfall distribution is important for rainfall-runoff process and also for determination of available soil moisture. A threshold rainfall events (e.g. of 5 mm/event) are used in many rainfall runoff models as a start value for runoff to occur. The intensity of rainfall is a good indicator of which rainfall is likely to produce runoff. Useful rainfall factors for the design of a rain or floodwater harvesting system include:

(1) Number of days in which the rain exceeds the threshold rainfall of the catchment, on a weekly or monthly basis.
(2) Probability and occurrence (in years) for the mean monthly rainfall.
(3) Probability and reoccurrence for the minimum and maximum monthly rainfall.
(4) Frequency distribution of storms of different specific intensities.

b) Land use or vegetation cover:

Land use and vegetation is another important parameter that affects the surface runoff. The studies conducted in India and Syria (Prinz et. al., 1999) proved that an increase in the vegetation density results in a corresponding increase in interception losses, retention and infiltration rates which consequently decrease the volume of runoff.

c) Topography and terrain profile:

The land form along with slope gradient and relief intensity is other parameter to determine the type of water harvesting. The terrain analysis can be used for determination of the length of slope, a parameter regarded of very high importance for the suitability of an area for macro-catchment water harvesting. The runoff volume increases with the length of slope. The slope length can be used to determine the suitability for macro or micro or mixed water harvesting systems (Prinz et. al, 1998) (Table-2).

d) Soil type & soil depth:

The suitability of a certain area either as catchment or as cropping area in water harvesting system depend strongly on its soils characteristics viz.

(1) surface structure; which influence the rainfall-runoff process,
(2) the infiltration and percolation rate; which determine water movement into the soil and within the soil matrix, and
(3) the soil depth and soil texture; which determines the quantity of water which can be stored in the soil.

e) Hydrology and water resources:

The hydrological processes relevant to water harvesting practices are those involved in the runoff production, flow and storage of runoff from rainfall within a particular project area. The rain falling on a particular catchment area can be effective (as direct runoff) or ineffective (as evaporation, deep percolation). The quantity of rainfall which produces runoff is a good indicator of the suitability of the area for water harvesting.

f) Socio-economic and infrastructure conditions:

The socio-economic conditions of a region being considered for any water harvesting scheme are very important for planning, designing and implementation. The chances for success are much greater if resource users and community groups are involved from early planning stage onwards. The farming systems of the community, the financial capabilities of the average farmer, the cultural behavior of the people, attitude of farmers towards the introduction of new farming methods, the farmers knowledge about irrigated agriculture are crucial issues. The existing or planned infrastructures as well as regional development plans have to be duly taken into account when planning a water harvesting scheme.

g) Environmental and ecological impacts:

Semi-arid and dry ecosystems are generally fragile and have a limited capacity to adjust to change. If the use of natural resources (land and water), is suddenly changed by water harvesting, the environmental consequences are often far greater than foreseen. Consideration should be given to the possible effect on natural wetlands as on other water users, both in terms of water quality and quantity. New water harvesting systems may intercept runoff at the upstream part of the catchment, thus depriving potential downstream users of their share of the resources. Water harvesting technology should be seen as one component of a regional water management improvement project. Components of such integrated plans should be the improvement of agronomic practices, including the use of good crop varieties, plant protection measures and soil fertility management.

Conclusions:

Rainwater and floodwater harvesting have the potential to increase the productivity of rainfed land by increasing the yields and by reducing the risk of crop failure. They also facilitate afforestation, fruit tree planting or agro-forestry. With regard to agro-forestry establishment, rainwater and floodwater harvesting can contribute to the fight against desertification. Most of these techniques are relatively cheap and can therefore be a viable alternative where irrigation water from other sources is not readily available or too costly. Unlike pumping water, water harvesting saves energy and maintenance costs. Using harvested rainwater helps in decreasing the use of other valuable water sources like groundwater.

Remote sensing and Geographical Information Systems can help in the determination of areas suitable for water harvesting (Prinz et al. 1998). Rainwater harvesting should suit its purpose after accepted by local population and be sustainable in local environment. In dry areas without storage facilities, the field crops with deep rooting and drought resistant trees constitute the most promising application of in-situ rainwater harvesting.

The decision making process concerning the best method applicable in particular environmental and geo-physical conditions depends on kind of crop to be grown and prevalent socio-economic and cultural factors. Local availability of labour and material are the most important factors. The accessibility of the site has also to be considered for construction of water harvesting structures and distance from village. There are number of studies in India reporting that the rainwater harvesting can be economically profitable. *e.g.* In *Ralegaon Sindhi* village in Maharashtra wheat grown under micro-catchment water harvesting is more viable and profitable than any of the traditional methods (Agarwal & Narain 1997).

One of the crucial social aspects for the success is the participation of the beneficiaries. All beneficiaries have to get involved in planning, designing and implementation of water harvesting structure. A consensus is necessary for operation and maintenance of water harvesting structures.

Water management problems can only be tackled in a holistic way, integrating land, water and labour management. Finally a comparison between water harvesting techniques and the construction of large or medium dams shows that:

- Through the introduction of water harvesting, water resources in upstream watershed can be managed more efficiently.
- Water harvesting can supplement irrigation water supply during water scarcity or low water availability periods. Its proximity to cropping area can be an important point in improving water use efficiency and avoiding field losses.
- Water harvesting may be of small scale but certainly have edge over dams due to its suitability for immediate local environment, they are labour intensive (local employment generating), democratic and participatory in nature.
- With the small scale of water harvesting technology, low investment is needed.
- Some of the benefits of large dams like generating hydropower energy, supplying drinking water for big cities etc, can not be offered by water harvesting.
- Water harvesting to be successful requires local capacity building and agriculture extension

services, training and credit facilities for resources users, co-operation and extensive participation.

Recommendations

The possibility of transferring water harvesting methods to other areas shows that the transfer is possible in principle. A close examination of the other factors determining their success, such as socio-cultural environment, the possibility of adapting agricultural innovations, the development policy objective of the country are important for final consideration. This can be achieved by an agro-ecological, social-economic feasibility study covering the proposed area under consideration.

 National institutional arrangements should be made to co-ordinate the design and implementation of various water harvesting projects and to build a data base to record the experience. There is need to systematically collect and collate data on soil, natural vegetation and land use, cropping pattern, rainfall amount and distribution, water resources and crop water requirements as a national inventory of the potential of water harvesting.

The planning of water harvesting systems should be a part of an integrated land and water resource management plan, and should include the agronomic practices and farmers training.

Local resource users should be involved in all aspects of the planning, designing, implementation, and monitoring of water harvesting systems. As mentioned before, planning should explicitly be the effect on downstream water users of the hydrological changes brought out by implementation of water harvesting.

Opportunities for equal access to the benefits of the new technology should be provided; and the relation between land ownership, water rights and the introduced water harvesting technologies should be carefully considered.

Performance assessment of water harvesting system should be carried out to facilitate comparison between various systems. The database about water harvesting systems should include the suitability data and information on the size and type of water harvesting system, crops grown and yield levels, annual rainfall, amount of runoff collected per unit catchment area, socioeconomic impact and social acceptance.

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Table 1: Groups, types and subtypes of rainwater harvesting systems for agricultural production

WH Group	Rainwater Harvesting			Floodwater Harvesting		Groundwater Harvesting		
WH type	Courtyard WH	Micro catchment WH	Macro-catchment WH	FWH within stream bed	FW diversion	Percolation tanks	GW dams	Special wells
Technique	Paved/sealed surface	Inter-row WH	Hillside conduit system	Jessour type	Wild flooding	Percolation ponds	Sand storage dams	Horizontal wells
	Compact/treated surfaces	Negarin/Meka t type WH	Semicircular hoops	Dike type	Water dispersion		Sub-surface dams	Artesian Wells
		Pitting technique	Cultivated reservoirs	Percolation dams	Water distribution			
		Eye-brow terraces	Stone dams					
		Vallerani type WH	Liman terraces					
Kind of storage	Cisterns/Tanka	Soil profile		Soil profile				
	Ponds/farm ponds		Cistern/tanka	Reservoirs	Ponds			
	Jars		Ponds					
	Tanks		Reservoirs					
Aquifer recharge	none	Very limited	Limited	Strong	Very Strong	Limited	Medium	
								Source: Prinz et. al, 1999

Fig. 1 Rooftop rainwater harvesting system with interconnected ferrocement tanks

Fig. 2 Stream flow collection in interconnected ferrocement tanks