Rain water harvesting to manage the water scarcity and flood

ABSTRACT

The regions with massive floods in rainy season and even shortage of water in winter season need proper management of water resources. Some low-cost water-harvesting structures include dry stone masonry and upstream-wall cement masonry of heights 1, 2, and 2.5 m for catchments of less than 10, 10 to 20, and 20 to 30 ha, respectively using locally available materials are made. These structures are very cost-effective for the region with a benefit-cost ratio of 3.5:1. In some places of Assam, the *Garh* is built, where the both sides have big and long embankment and the middle side is left open to flow water. In the paddy field, the whole areas is divided into small pieces in square size, creating small embankment, called *Dara*, where rain water is stored for cultivation. In the entire region of Western Himalaya comprising Jammu, Himachal Pradesh and Northern Uttaranchal, *Guhl* is a standard water harvesting technique. The crop and livestock productivity and farm income increased significantly in Akola and Chittoor districts due to farm ponds. Supplemental irrigation resulted in an increase in productivity of different rainfed crops like pigeon pea, chickpea, groundnut, cotton and vegetables as well as mango and coconut plants which ranged from 5 to 72%. With the availability harvested rainwater for supplemental irrigation, the farmers planted additional fruit trees and it also resulted in productivity increase of existing fruit trees, mango (39%) in Chittoor district and coconut (51%) in Vellore district. Increasing the number of rain water harvesting structures would decrease runoff within the basin by 60%. Doha Models – percolation tanks dug along the length of lower order seasonal streams, in Jalna district of Maharashtra increase the cropping intensity from 129% to 132% and five out of seven crops exhibit relative higher percentage increase in yields. The productivity of harvested water is maximized when efficient application methods (e.g. micro irrigation) and high value crops are targeted.

Keywords: *Watershed management, flood protection, rain water harvesting, Supplemental irrigation, Doha Models.*

INTRODUCTION

Water is an important part of the ecosystem in which the reproduction of the bio diversity also depends. Scarcity of fresh water for agriculture, industry and household purpose is not only limited to the arid climatic regions, but also in areas having high rainfall. Water scarcity is caused by low water storage capacity, low infiltration rate, high evaporation demand and larger inter annual and annual fluctuations of precipitation. The term water harvesting was first time used by Geddes of the University of Sydney. He defined water harvesting as the collection and storage of any form of water either runoff or creek flow for irrigation purpose. Meyer's of USDA, USA has defined it as the practice of collecting rainfall water from an area treated to increase runoff from rainfall. Recently Currier from USA has defined it as the process of collecting natural precipitation from prepared watershed for beneficial use. Now a days water harvesting has become a general term for collecting and storing runoff water or creek flow resulting from rainfall in soil profile both over surface and under surface. Previously water harvesting was used in arid and semi-arid regions but recently their use has been extended to sub humid and humid regions too. In India water harvesting means utilization of the erratic monsoon rain water for raising good crops in dry tracks and conservation of the excess runoff water for drinking and for ground water recharging purpose.

When water harvesting technique are used for runoff farming, the storage reservoir will be soil itself but when the water is to be used for livestock, supplementary irrigation or human consumption, a storage facility of some kind will have to be produced. In countries where land is abundant, water harvesting involves: harvesting the entire rainwater, store it and utilize it for various purposes. In India, it is not possible to use the land area only to harvest rainwater and hence water harvesting means use the rainwater at the place where it falls to the maximum and the excess water is collected and reused in the same area. Therefore, the meaning of water harvesting is different in different areas and countries. The water harvesting methods are used for both agriculture purpose and to increase the ground water availability. The water harvesting for household purposes is also in existence for long years in the world. During rainy days, the people in the villages used to collect the rooftop water in the vessels and use this water for household purposes including drinking. In South East Asian countries, people used to collect the rooftop water by placing big earthen pots in the corners of their houses and they use this water for all household purposes. The main building of the Agricultural College at Coimbatore was constructed 100 years ago and they have collected all the rooftop water by pipes and stored in big underground storage tanks by the sides of the building. Hence rainwater harvesting system is as old as civilization and has being practiced continuously in different ways for different purposes though out the world. The only concern is that it has not been done systematically in all the places. Now need has come to harvest the rainwater to solve the water problems not only in the arid but also in the sub-humid and humid regions. Water harvesting was practiced more than 1000 years back in South India by construction of irrigation tank, temple tanks,farm ponds etc. In modern era the work is taken up at ICRISAT, Hyderabad, Central arid Zone Research Institute, Jodhpur, Central Research Institute for dryland Agriculture (CRIDA), Hyderabad, State Agricultural Universities and other dry land research centers throughout India.

The basic configuration and construction of rainwater collection systems is relatively simple consisting primarily of a catchment area, storage tank and interconnecting pipe work. Systems can be classified as either direct, indirect or gravity feed depending upon how the rainwater is stored and distributed within the installation. The materials from which the catchment area is constructed have a significant effect upon both the amount of run-off water and its physical, chemical and also biological quality. The first flush of rainwater from the catchment area is more heavily polluted than the subsequent run-off. For non-potable applications rainwater only requires treatment prior to entry into the storage tank using a cross flow or screen filter with a permeability of between 0.2 to 1.00 mm. Further treatment is also done within the storage tank via flotation and settlement. Below ground storage is preferable to minimize the entry of daylight and to maintain the collected water at low temperature, which reduces microbiological activities like algal growth. The capacity of the rainwater store is particularly important because it influences the system both economically and operationally.

MATERIAL AND METHODS

Causes of flooding

A flood is a water body that occupies ground that is ordinarily dry. Floods are widespread natural phenomena that can affect agriculture worldwide. Drinking water is also polluted by flooding and creates illnesses. Floods are mostly caused by flooding of rivers, lakes and seas. There are some factors which result in flooding:

i. **Heavy rainfall and thunderstorms:** This is one of the main causes of flooding. A colossal amount of water accumulates in the water bodies due to heavy rainfall. Thunderstorms with high-speed winds cause architectural damage and also increase the speed of the water flow.

ii. **Groundwater flooding:** Water collects beneath the ground surface clogging the pores of the soil. Heavy rain and melting of snow generally lead to this condition which causes flooding.

iii. **River overflow:** Due to heavy rainfall or melting of glaciers, water level rises at an exponential rate in the rivers lakes and seas which pass through the city or villages resulting flood.

iv. **Reduced area for infiltration:** With modernization and urbanization, surface area for the water to naturally recharge the groundwater has diminished at a drastic rate.

Rainwater harvesting system

Rainwater can be captured and stored by using rainwater harvesting system. Generally, rainwater harvesting refers to the direct collection of rainwater from roofs or other man made grounds; and the collection of sheet runoff from natural surface of catchment areas for domestic, industry, agriculture and environment use. Water harvesting systems can be classified as small, medium and large scale (Gould, 1999). Normally, the size of rainwater harvesting depends on the size of catchment area (Thamer *et al*., 2007). Rainwater harvesting system has been implemented and popularized in many developing countries like USA, Japan, China, India, Germany and Australia to support the increasing water demand for agriculture, industry and other sectors. There are six main elements in rainwater harvesting system. They are catchment area, gutter and downspout, filtration system, storage system, delivery system and treatment/ purification.

RESULTS AND DISCUSSION

Process for rainwater harvesting

A. Calculate water harvesting potential and match with the water demand:

Total volume of water = Area x runoff coefficient x rainfall

There is some loss of water due to evaporation or absorption by catchment surfaces and other kinds of losses. The runoff coefficient of a catchment gives you the proportion of the rainwater that can be harvested from the total rainfall.

B. Decide the type, capacity and location of structures:

There are two main techniques of rain water harvestings as given below.

i. Storage of rainwater on surface for future use

ii. Recharge to ground water.

Whether to store rainwater or use it for recharge?

The decision, whether to store for future use or recharge ground water depends on the rainfall pattern and the potential to do so, in a particular region. The sub-surface geology of the region also plays an important role in making the decision. Delhi, Gujarat and Rajasthan where the total annual rainfall occurs only during 3 or 4 months are the example of places where groundwater recharge is mostly practiced. In places like Tamilnadu, Kerala, Bangalore and Mizoram where rain falls throughout the year with a few dry periods, small sized thanks are used for storing rainwater and use it during the dry spells. For example in Ahmadabad, which has limited number of rainy days as that of Delhi, traditional rainwater storages known as 'tanks" are used to store rainwater even today in residential area, hotels and temples. In places where the groundwater is saline, the alternate system could be used for storing rainwater.

Traditional water harvesting techniques

Ponds / tanks: These are the most used methods to collect and store rain water. Most of the ponds have their own catchment areas which provide the requisite amount of water during the rainy season. Where the catchment area is too small to provide enough water, water from nearby stream is diverted through open channel to fill the pond. In some places water from irrigation canals is also used to fill ponds. Ponds are excavated in different shapes and sizes depending upon the nature of the soil, availability of land, water requirement of the village community etc. These ponds are known by different names in different regions (Table 1).

Ground water harvesting: In hilly areas of Uttaranchal, the people harvest ground water by making stonewall across ground water streams. These are called Naula or Hauzi. For various reasons, there has been a steady decline in the construction of these structures, the main reason may be due to drying up of underground streams due to large-scale deforestation and increased human activity in the hills. Similar practice is in parts of Kerela where the ground water is collected by excavating long deep trenches across a gentle slope. These are called Surangam. In Punjab, shallow wells dug near the streambeds to trap seepage water are called Jhalars. In Rajasthan these wells are called Beris which were built by kings in earlier times. In Gujarat shallow wells called Virdas are dug in depressions to tap ground water. In Tamil Nadu, Ooranis were built earlier.

Hill slope collection: In this system, in many hilly areas with good rainfall, lined channels are built across the hill slopes to intercept rain water. These channels supply water for irrigating terraced agricultural fields. The water is also stored in small ponds for domestic use. These practices are seen in Himachal

Pradesh, Uttarakhand, Meghalaya and Arunachal Pradesh.

Modern structures for water harvesting

Roof top harvesting: This system is useful mainly for drinking water purposes. In this system, rain water falling on roofs of houses and other buildings is collected through a system and is stored in tanks located on the ground or underground. The practice is in vogue at the individual household level in remote hilly areas with high rainfall and also in some semi-arid areas in the plains. This system can be seen in the northeastern states of Arunachal Pradesh, Assam, Meghalaya, Manipur and Nagaland. This is also in use in Bikaner, Jaisalmer and Jodhpur districts of Rajasthan. In recent years, at the initiative of the Central and State Governments, the practice has been increasingly adopted in many cities and towns in different parts of the country.

Check Dams: These are concrete or masonry structures built across small streams for surface storage and incidental benefit of ground water recharge. The design of these structures are done taking into consideration the volume of water that can be stored in the stream channel upstream, the surplus flood discharge that must be evacuated safely, stability of the structure against various forces and the likely ground water recharge. These are usually built by the State Government agencies like the departments of Irrigation/ Water Resources, Agriculture and Forests. These are the modified and improved versions of the traditional temporary or semi-permanent structures that people in the villages usually build across natural streams or drainage channels.

Percolation Tanks: These are built mainly to impound monsoon runoff over a large area to augment ground water recharge. Moderate to high porosity of soil and underlying rocky strata is the main criteria for the choice of percolation tanks. Ponding is done in such the same way as it is done in case of check dams except that the length of the bund is large but the height is low. The design aims at filling the pond as many times as possible during the rainy season in such a way that most of the water impounded during one spell of rain percolates into the ground before the next spell starts. In actual field conditions, however, this ideal operation is rarely achieved. These are also built by the government agencies since these require special skills in hydrogeology.

Sub-Surface Dykes: These are impermeable walls or barriers in masonry, concrete and/ or clay built below the bed level across natural streams to arrest sub-surface flow of water to improve the yield of existing wells and hand pumps in the upstream.

Besides these direct methods of water harvesting some indirect methods have also been developed.

These aim at augmenting soil moisture retention and preventing soil erosion and land degradation. These are:

(i) **Contour Bunding:** These are small earthen bunds built horizontally in parallel rows across the hill slope. These help in maintaining soil moisture and prevent erosion of topsoil.

(ii) **Gully Plugging:** These are soil and water retaining structures built across gullies in hilly areas. These are built with locally available materials like stone boulders, earth, brushwood etc.

Both contour bunding and gully plugging are the part of watershed improvement works. The other works in this category are:

- Bench Terracing
- Contour Cropping
- Contour Trenching

Some case studies of rain water harvesting

Makkowal project - A case study

Makkowal is situated in the state of Punjab (India) about 30 km from Hoshiarpur at the foothills of Shivaliks. The village has a habitation of 300 houses and an area of 243 ha. On Northern side of the village there is hilly area and western part of the village has leveled lands with moderate slope. Soils are sandy to sandy loam and are good for agriculture, but because of scarcity of irrigation water, the production of agriculture crops was very low. Although the average rainfall is about 1000 mm, its distribution is erratic and uneven. About 80% of the rainfall is received in three monsoon months. Heavy soil erosion due to flash floods and torrential rain and there are frequent crop failures due to drought are common. The problem of water scarcity can be judged from the fact that a 100 m deep open well was dug in the village long ago, could not provide enough water for drinking. The villagers had to traverse 2 to 3 km in the hilly terrain to fetch water from wells located along the side of streams, where perennial flow existed for most part of the year. A sketch layout map of drainage line treatment of Mokkowal watershed has been shown in Figure 1.

The project was launched in the year 1986 for seven years function for tapping of surface flow in the stream bed emanating from hill seepage from a point located at 3 km from village. Three existing shallow open wells on the bank of the stream were charged with seepage water connected with each other by cement concrete pipes. The village pond was deepened, widened and renovated to have a storage capacity of 2.4 ha-m. From the pond a network of underground pipeline of cement concrete was laid to convey water to the agricultural fields for irrigation. Just before the village pond, separate taps were also provided for drinking, bathing washing and for cattle. Surplus arrangement was made on the other side of the pond. The entire catchment area of choes was treated with different engineering and biological conservation measures. The cost of construction of earthen check dam and is effective life depend upon the location, proper design and proper maintenance. The earthen dams constructed in the area cost about Rs 2.5 to Rs 27.0 per m^3 of capacity. Prior to the implementation of the project, the farmers did not use fertilizer, high yielding varieties and weedicides etc. Only FYM was applied to the individual farmers. After the project, the farmers have started using seed of high yielding verities of maize and wheat. Use of chemical fertilizers, weedicides and pesticides has also been started after the project. The fertilizer use, yield of major crops viz. wheat, maize, gram, fodder and gross returns has been increased due to implementation of project (Figures 2-3).

Takarla project-A case study

The Takarla, surface flow harnessing project has been designed on the similar lines of Makkowal project but with slight modification. This project is located in foothills of Indian Shiwaliks at a distance of 13 km from Balachaur; district Nawashahar in the state of Punjab and the project was functioned for seven years. The area is sloppy and undulating. The soils are loamy sand to sandy loam in texture and at some places silt loam, sub angular to angular blocky in structure, very deep and erodible. The area is totally rainfed. The area is affected from torrential rain and the surface runoff flow is due to seepage from the side hills. The flow remains 3-4 month even after the rainy season and thereafter flow rate decrease but remains in the sub-surface sand bed of choe. In the channel a concrete toe wall was constructed at the stream bed. A weir of suitable section was made on the barrier wall and flow released over the structure close to the water pool. On one side of the stream, a stilling basin was constructed to create head of water. The inlet was connected to the stilling basin through a pipe. Above the weir, a filter of local stones and grits was provided in the choe bed to facilitate infiltration of water when surface flow diminishes during the lean period. An underground pipeline has been laid from the stilling basin to the agricultural fields located at lower level. Therefore, the system works on gravity flow. This system is providing supplemental irrigation to about 100 ha farm lands of the village. The major crops grown in the study area and their pre and post project yields and return have shown in Table 3 and Figure 4 & 5. The gross returns from major crops have shown increasing trends due to adoption of new water saving techniques. Similarly, studies of water resources in Shaheed Bhagat Singh Nagar- A Case Study was concluded by R. Agrawal *et al*. (2010).

CONCLUSION

The erratic and uneven distribution of rainfall both spatially and temporally, necessitates rainwater harvesting to increase and sustain the agricultural productivity. Excavated dug-out pond tanks are found most suitable for storing runoff in cultivated lands with inverted truncated pyramid shape having 1:1 side slopes with lining of polyethylene sheet of 200 micron buried at 20 cm soil depth and pitched with bricks. The earthen embankment for rainwater harvesting has cost benefit ratio of almost 1.38:1. The rainwater harvesting during monsoon and its use for irrigation during scarcity period was found to increase the crop yield by 25-35% during Rabi season and additional water for domestic use by 55% population of the area. There is urgent need for flood protection and irrigation on farm lands below the hills through control and utilization of runoff; and rehabilitation of upper watersheds through reduced run off and erosion from the hills through soil conservation measures. For successful implementation of traditional and new on farm rainwater harvesting techniques, strengthening of project implementing agency's capacity should be done for undertaking investigations and research of surface hydrology, groundwater and micro-watershed studies.

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Table 1: Local name of pond in in different states of India

State	Local name of pond
Nagaland	Zabo
Gujarat	Kunda, Jheel
Gujarat	Kunda, Jheel
Orissa	Katas, Mundas
Maharashtra	Bandharas
Karnataka	Volakere, Katte or Kunte
Andhra Pradesh	Tank
Kerela	Tank
Ladakh	Zing
Jammu	Chhapris
Sikkim	Khup

Table 2: Examples of traditional water harvesting systems in India

Regions	Water Harvesting Techniques
Trans-Himalayan Region	Zing: Tanks for collecting melted ice water in Ladakh.
Western Himalayas	Kul: Water channels to collect and store water in mountain areas of Jammu and Himachal Pradesh. Naula: Small ponds to collect rainwater in Uttaranchal.
Eastern Himalayas	Apatani system: Terraced plots connected by inlet and outlet channels in Arunachal Pradesh. Zabo: Impounding runoff water in Nagaland. Bamboo drip irrigation: In the hilly areas of Meghalaya, water from streams is brought to the plains via bamboo pipes for drip irrigation.
Brahmaputra Valley	Dongs: Ponds in Assam to collect and store rain water. Dungs or Jampois: Small irrigation channels linking rice fields to streams in the Jalpaiguri district of West Bengal.

Indo-Gangetic Plain	Dighis: Small square or circular reservoir fed by canals from rivers in Delhi. Baolis: A baoli is a reservoir in which rain water can be stored from which everyone could draw water for use.
Thar Desert	Baoris / Bers: Community wells in Rajasthan that capture and conserve rainwater. Tankas: Underground tank to store rain water in Rajasthan. Kund: A circular underground tank or small natural or artificial lake, having a saucer-shaped catchment area that gently slopes towards the center, where water that has fallen as rain is collected.
Central Highlands	Johads: Johads are small earthen check dams that capture and conserve rainwater, improving percolation and groundwater recharge, found in Alwar district of Rajasthan.

Table 3: Pre and post project average yields of major crops

Name of Crop	Pre-project yield (q ha^{-1})	Post-project yield (q ha^{-1})
Wheat	10.0	25.0
Maize	5.0	12.5
Gram	2.5	7.5
Fodder	40.0	100.0

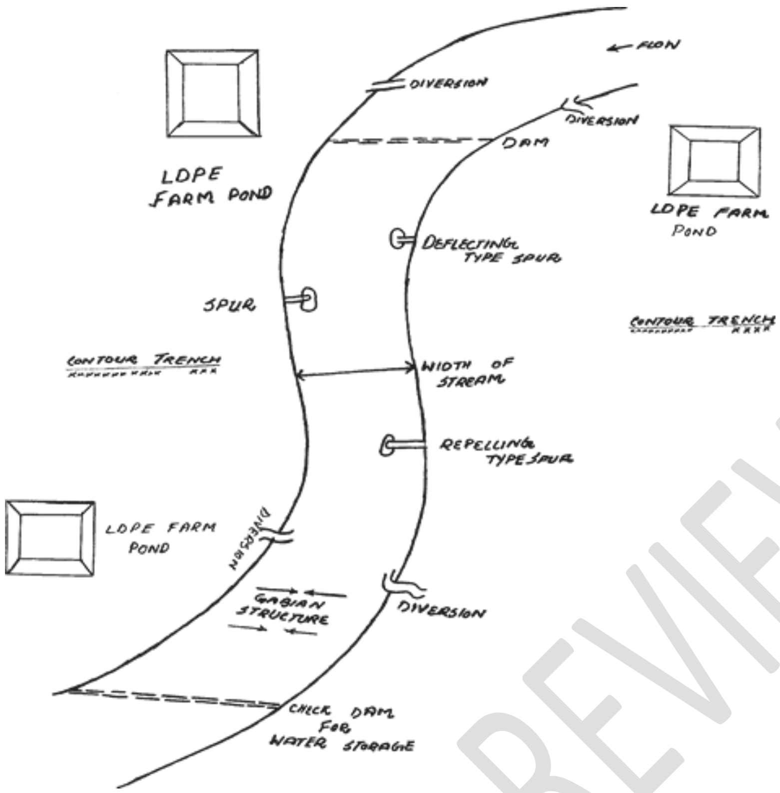

Fig. 1. Layout map of drainage line treatment of Mokkowal and Takaral Watersheds

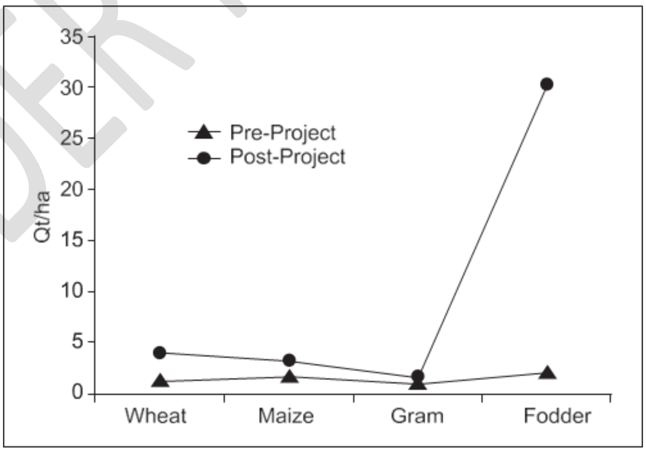

Fig. 2. Pre and post-project average yields (qt ha^{-1})

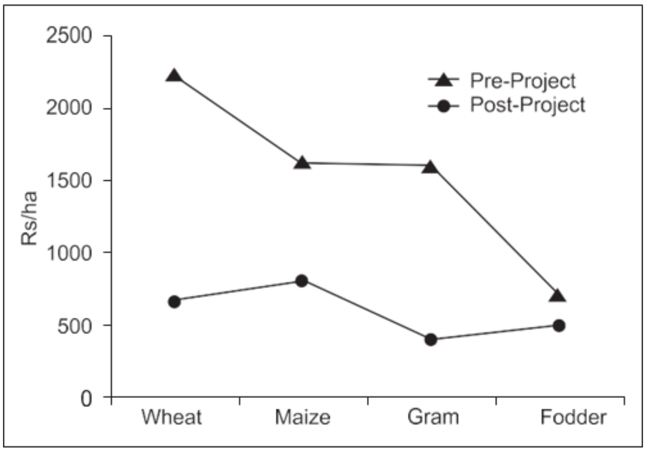

Fig. 3. Pre and post-project average returns (Rs. ha^{-1})

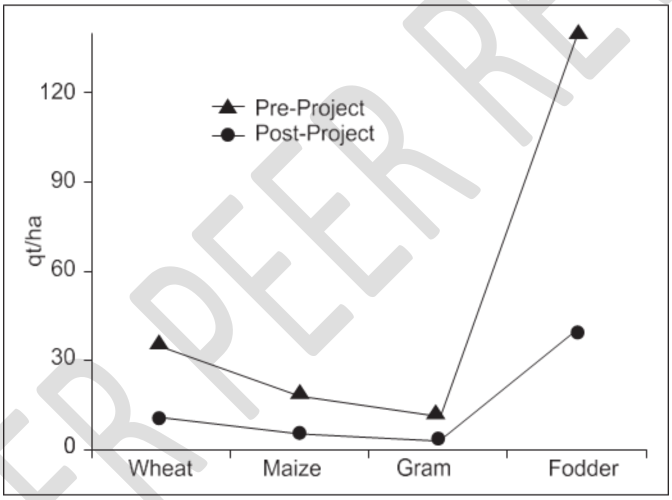

Fig. 4. Pre and post-project average yields (q ha^{-1}) of major crops

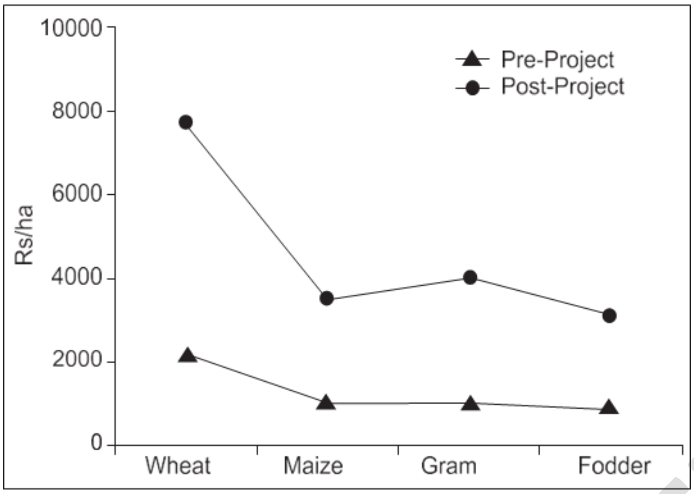

Fig. 5. Pre and post-project gross returns (Rs. ha^{-1}) of majorcrops