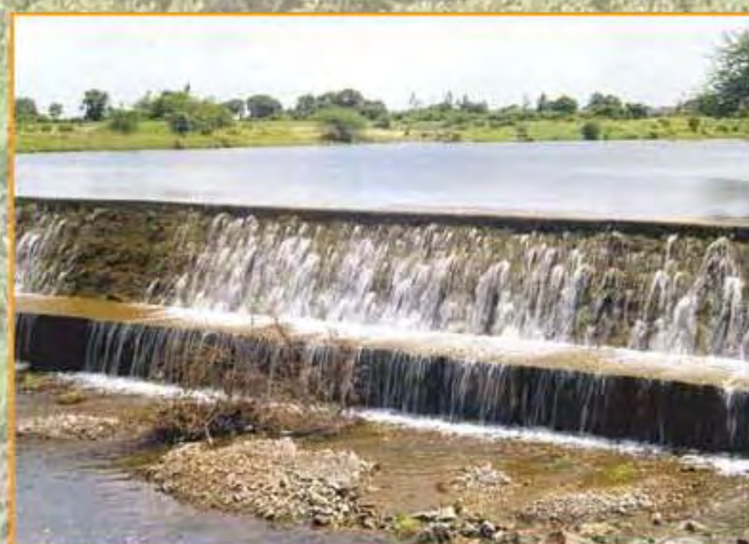
Global Theme on Agroecosystems

Report no. 20

On-site and Off-site Impact of Watershed Development: A Case Study of Rajasamadhiyala, Gujarat, India



International Crops Research Institute for the Semi-Arid Tropics

Comprehensive Assessment of Water Management in Agriculture

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Abstract

Detailed case study of Rajsamadhiyala watershed in the semi-arid tropical area of Gujarat in India revealed that rainwater harvesting through watershed management doubled the productivity of groundnut and other major crops, increased cropping intensity by 32% in eight years. With improved groundwater availability diversification with high-value crops like cumin, vegetables and fruits was observed. Food, fodder, fuel sufficiency substantially improved along with the increased incomes, literacy and social development. Substantial investment of 16.25 million rupees (US$ 0.36 million) in rainwater harvesting in one village created storage capacity to harvest 16% of mean annual rainfall of 503 mm which is equivalent to 100% of potential runoff during a normal year. Considering percolation seepage and evaporation losses 40% of annual mean rainfall could be harvested and stored. However, because of geological formation in the Deccan plateau where soils are formed over a layer of weathered trap laid on hard rock during normal rainfall years, these structures overflow 2–3 times in the rainy season. Downstream villages Aniyala and Katurba Dham benefited in terms of increased groundwater availability, reduced siltation and flooding through the base flow seepage water and excess runoff. Detailed studies in two downstream villages showed increased productivity, however, by 25–30%, improved groundwater availability by 25%, and reduced distressed migration. Dedicated leadership helped the villagers to chalkout the path to prosperity. Vast potential to increase productivity by 80–90% remains to be harnessed through adoption of increased water use efficiency measures, as most benefits are due to increased water availability only. However, looking at the trends of over-exploitation of groundwater by doubling the number of borewells and pumping hours call for urgent steps to develop suitable social/legal mechanisms for sustsainable use of water resources through integrated water resource management. Improved water availability through public investment triggered private/individual investment in agriculture in rainfed areas further hastening the process of development.

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Contents

Acronyms

BAIF	Bhartiya Agro-Industries Foundation
CGR	compound growth rate
DRDA	District Rural Development Agency
FAO	Food and Agriculture Organization
GOG	Government of Gujarat
GRISERV	Gujarat Rural Institute for Socio Economic Reconstruction Vadodara
GWSSB	Gujarat Water Supply and Sewage Board
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IRR	internal rate of return
ISRO	Indian Space Research Organization
IWMI	International Water Management Institute
PIA	project implementing agency
SGRY	Sampurna Gramin Rojgar Yojana
SGSY	Swarnajayanthi Gram Swarozgar Yojana
VDC	Village Development Committee
WHS	water harvesting structures
WDT	Watershed Development Team

Background

The world population is expected to touch 9.19 billion by 2050. Most of the population increase is expected in developing countries in Asia and Africa (5.33 and 1.66 billion respectively). Each year an additional 0.25 billion metric tons of grain must be produced to feed the increased population, which is 21% increase in food production each year (Lecture 40 - World Food Problems). Looming water scarcity over large parts of the world and increased withdrawal by agriculture from 2500 km^3 in 2000 to 3200 km^3 by 2025 (Shiklomanov, 1999) has attracted the attention of policy makers and researchers for achieving food and water security. It is estimated that by 2025, one third of the world's population (especially in the developing countries) would face severe water scarcity. (Secklar et al. 1998). To achieve food security, minimize the water conflicts and reduce poverty it has become essential to increase productivity of rainfed systems by harnessing the existing potential (Wani et al. 2003). Globally 80% of agriculture is rainfed and contributes 60% to world's food basket. Current productivity levels of rainfed agriculture are low (<1 t ha^{-1}). However, there are evidences to indicate that productivity of rainfed systems could be doubled in Asia (Wani et al. 2001 and 2004) or even quadrupled in Africa with adoption of appropriate soil, water and nutrient management (SWNM) options (Rockstrom et al. 2003).

The comprehensive assessment (CA) program has initiated an exhaustive study to assess the water needs for food production, which includes a multilevel assessment. The main objectives of the rainfed project are:

- To quantify potential of rainfed systems for achieving food security;
- To quantify constraints, alternative technological, policy, and institutional options for achieving the potential of rainfed systems; and
- To suggest intervention strategies including supplemental irrigation for increasing productivity through enhanced resource use efficiency.

In order to assess the achievable yields on farmers' field at micro-level we have adopted the approach of detailed case studies in different regions where improved technologies are applied for increasing productivity of rainfed systems. This case study is part of the larger study under the comprehensive assessment of rainfed systems in the semi-arid tropics (SAT) of India, where micro-level studies at watershed scale will be linked to meso and macro levels using simulation-modeling approach at eco-regional and global scales. Main expected outputs from studies at different scales are to assess the potential contribution of rainfed systems to global food basket, impact on livelihoods, environment, policy and institutional guidelines to meet the achievable yields on larger scale and identify the research and development needs to minimize the gap between potential and achievable yields of important crops in the rainfed systems.

In India watershed management is adopted on a large scale for conserving rainwater and soil and also for increasing production of rainfed systems (Wani et al. 2005). In India various watershed programs have spent more than US$ 2 billion till 2004 (Joshi et al. 2004).

Introduction

Erratic and low rainfall, low fertility soils, poor infrastructure development, along with high population pressure with low literacy levels are some of the main causes of poverty in the SAT. High demographic pressure of one billion people in India and additional 519 million people are expected to be added by 2050. Furthermore 33% of the world's population mostly from developing countries including India will be affected by water scarcity by 2025. Inherent low fertility soils in the tropics are prone to severe land degradation and 51% of India's geographical area (329 million ha) is categorized as degraded, most of which occurs in rainfed agro-eco systems (Wani et al. 2001). Water and soil resources are finite, non-renewable over the human life time frame, and prone to degradation through misuse and mismanagement (Lal 2000).

The Government of India (GOI) adopted watershed management as a strategy to address the sustainable agricultural productivity in the rainfed areas since the last three decades. Further GOI has adopted watershed management as a national policy since 2003 (Joshi et al. 2004). The case study region of Sourashtra is characterized by low, erratic and undependable rainfall with low productive soils. Scarcity of water for agricultural and domestic purpose remains a major problem in the region and has led to low crop productivity and environmental degradation. Decline in per capita agricultural production has seriously affected food security and livelihoods of people. Several studies have highlighted that appropriate rainwater management and utilization results in enhanced agricultural productivity (Samra 1997, Wani et al. 2003, Joshi et al. 2005). However, systematic assessment of on-site and off-site impact studies of watershed development are lacking (Wani et al. 2004). Through this study an attempt is made to study the on-site and off-site impact of considerable rainwater harvesting measures implemented at Rajasamadhiyala watershed, in Rajkot district of Gujarat since 1978, and the specific watershed development activities initiated from 1995 onwards.

A comprehensive assessment of Rajasamadhiyala watershed was taken up under the present study to assess the on-site impact of watershed development program as well as off-site impacts on two downstream watersheds. The overall goal of this case study is to get insights into watershed management programs as implemented and to identify the avenues for augmenting the progress and impact of it in India. The specific objectives of the study were to:

i) To assess the impact of watershed development on crop production, crop and fodder productivity, improved livelihoods, minimizing land degradation and groundwater availability in the micro-watershed
ii) To assess the off-site impact on the downstream villages in terms of groundwater availability and crop production, because of rainwater harvesting in the micro-watershed above on a toposequence
iii) To identify the gaps/constraints for increasing water productivity in the watershed for harnessing full potential of rainfed systems.

Description of Watershed

Physiographical properties

Location

Rajasamadhiyala micro-watershed at latitude 22° 8' 15"N to 22° 13' 15"N, and longitude 70° 54' 30"E to 70° 59' 15"E covering over an area of 1090 ha is situated 22 km from Rajkot in semi-arid Saurashtra region, on Rajkot-Bhavnagar state highway in Rajkot District of Gujarat (Fig. 1). The micro-watershed is surrounded by Lilisajadiyali, Lakhapur, Sardhar on upstream and Dhandhya, Kasturba Dham (Tramba) and Aniyala villages on downstream along the toposequence.

Rainfall

The annual rainfall at Rajasamadhiyala during 2002–04 was 419, 709 and 490 mm respectively with a mean annual rainfall of 539 mm (Fig. 2). Mean annual rainfall of Rajkot town located 20 km downstream West of the watershed village during 1985–04 is 503 mm. The lowest rainfall recorded during the past 20 years was 172 mm in 1987 and highest was 1016 mm in 1988. Rainfall received was below normal in 12 out of 20 years (Fig. 3).

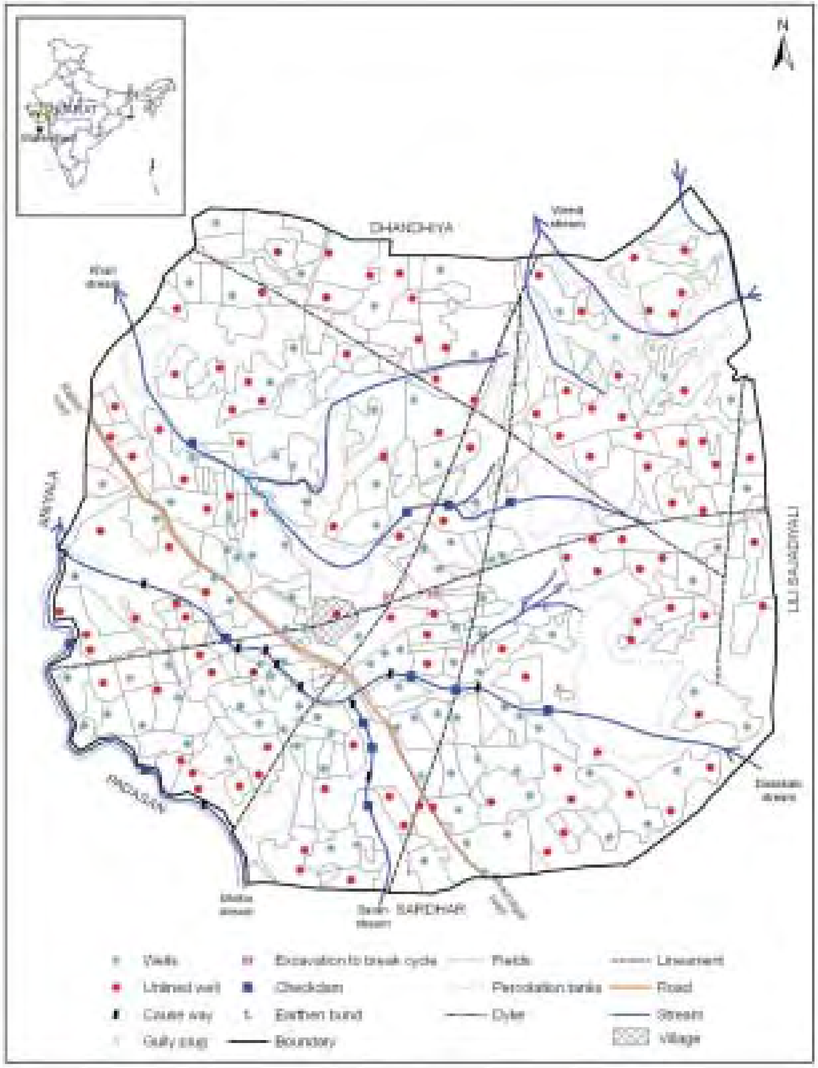

Figure 1. Physiographic map of Rajasamadhiyala micro-watershed.

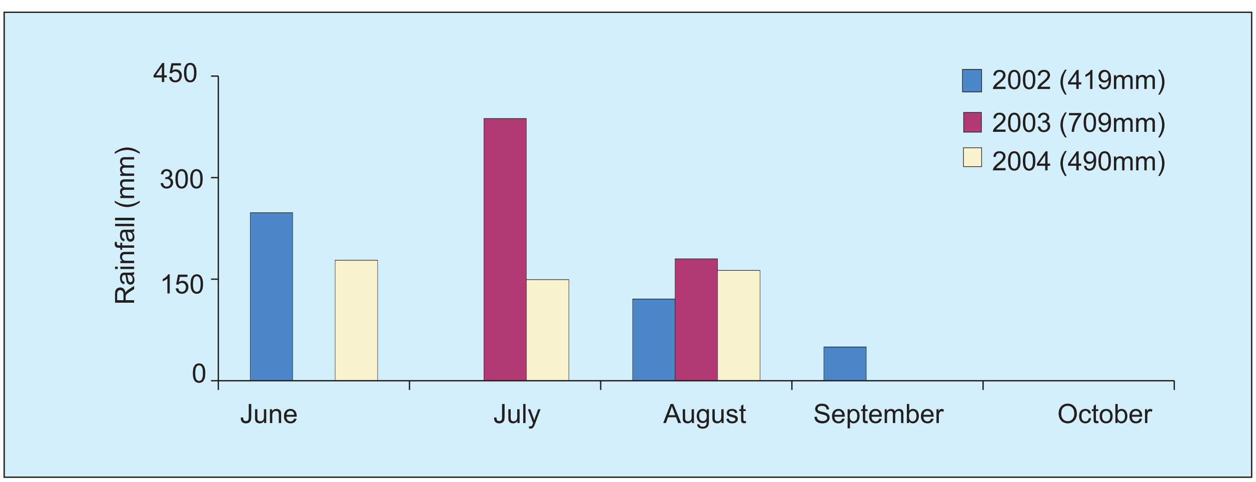

Figure 2. Monthly distribution of rainfall at Rajasamadhiyala, Gujarat (2002–2004).

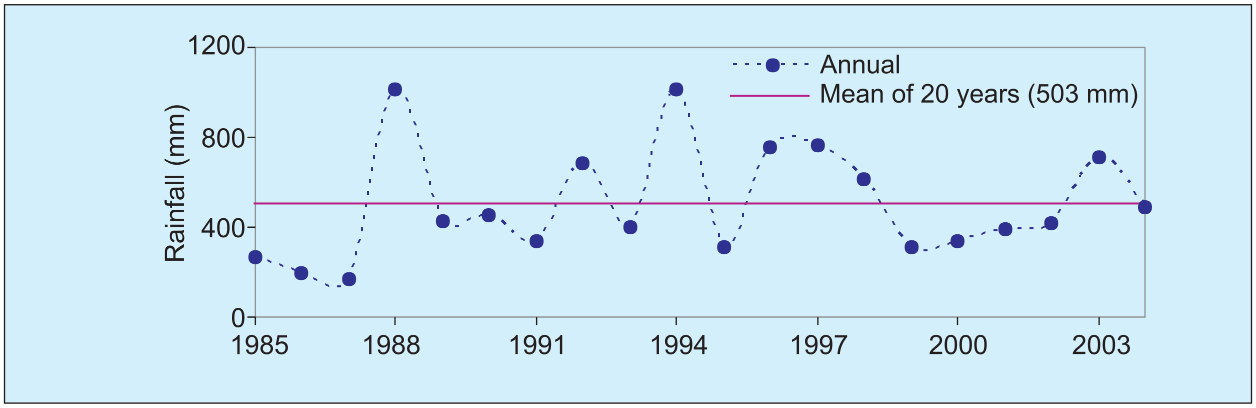

Figure 3. Annual rainfall of Rajkot, Gujarat (1985–2004).

Soils

Soils in the watershed are shallow to medium deep black soils (inceptisols) and are formed on hard rock bed. The soil depth ranges from 0.15 m to 1.25 m. Detailed analysis of surface soil samples collected from different locations in the watershed in 2004 revealed that these were clay loam to loamy soil. Moisture at field capacity (1/3 bar) ranged from 24.8 to 34.7% (mean 29.9%), and wilting point (15 bar) from 16.6 to 23.1% (mean 20.2%). Plant available moisture of soil ranged from 8.0 to 12%. These soils were severely deficient in boron, zinc and sulphur along with nitrogen and medium available phosphorus content (Table 1).

Table 1. Physical and chemical properties of surface (0–10 cm) soil samples from Rajasamadhiyala micro-watershed, 2004.

Physical properties		Chemical properties	
Texture		pH	8.24
Clay (%)	19.3	Organic C (%)	0.81
Silt (%)	27.5	Total N (mg kg^{-1} soil)	810
Sand (%)	53.2	Olsen P (mg kg^{-1} soil)	8.69
		Boron (mg kg^{-1} soil)	0.93
Moisture retention capacity		Sulphur (mg kg^{-1} soil)	9.21
At field capacity (%)	29.9	Zinc (mg kg^{-1} soil)	0.50
At wilting point (%)	20.2	EC (Ds/m)	0.36

Geology and geohydrology

The oldest formation found in Rajasamadhiyala watershed is 'Deccan Trap' of Cretaceous-Eocene age. Below the topsoil the weathered trap that is encountered has a thickness varying between 5 to 25 m. Below the weathered trap, hard trap with secondary fillings and occasional fractures are encountered with varying thickness. This is underlaid by a hard compact trap. The compactness of rock increases with depth resulting in poor groundwater recharge in general.

The Deccan basalt trap being a volcanic consolidated rock unit does not have a well-defined aquifer system due to lack of primary porosity. Groundwater is mainly confined to weathered zones within shallow depths as well as in the cracks, fissures, joints and fractures.

The fissures and other fracture filled channels cutting across the flows, occur as intrusive dykes. There are innumerable dykes running not only vertically but also to a very deep extent. These weak zones are the sources of recharging. Thickness of weathered zone varies widely giving rise to the highly heterogeneous groundwater conditions.

Physiography

The physiography of watershed is gentle to moderate sloping with an average slope of 1–2%. The land slope in upstream region is low (1.0%) and increases as it approaches downstream (2%). Farmers reported that soils are deeper (1.0–1.25m) between Saran and Morabo streams, and also in the upper portion where the slope is around 1% and lower region have very shallow to medium deep (0.15m to <1.0m) in the portion with comparatively higher slopes (about 2%).

Drainage

The Rajasamadhiyala micro-watershed drains the excess runoff water into four major streams – Saran *nadi*, Morabo *nadi*, Khari *nadi* and Dhadaklu *nadi*. These streams join the Aaji river at the downstream of Rajasamadhiyala towards Rajkot (Fig. 1). A reservoir on Aaji river constructed near Rajkot town, supplies water to the Rajkot town. Saran and Morabo streams emerge from Lakhapur and Sardhar villages, Khari stream surfaces from Lilisajadiyali and partly from Dhandhiya. The Saran stream in Rajasamadhiyala gets runoff water from Lakhapur watershed (about 50%) and Sardhar watershed (about 25%) as base flow/seepage water flow, hence still water flow exists in this stream. Three streams (Morabo, Khari and Dhadaklu) get less water compared to Saran. Due to good flow in Saran stream, farmers are able to store the runoff water in water harvesting structures that have helped in recharging of groundwater.

Crops

Groundnut and cotton are the predominant crops grown here. Some of the other crops are wheat, pearl millet, sorghum, vegetables, maize, pigeonpea, sugarcane, cumin and lucerne fodder crop.

Due to additional availability of water in wells, farmers are now able to grow vegetable crops during summer. Even after taking rainy season and postrainy season crops into consideration, they get a good price for vegetables in summer. Mostly farmers with large families prefer to grow vegetables, as the crops need timely availability of human labor to harvest and encash the market potential.

Demography

Rajasamadhiyala has a population of 1747 (male 872: 875 female) with 300 households and an average family size of 5.8 members Forty four percent among these households are marginal with <1 ha land holding, 38% are large with 74 ha land and 2% households are landless in Rajasamadhiyala (Table 2). Watershed project covered 80% marginal, 81% small and medium, 80% large and 100% landless households. Typically this village has mixed communities: *Patels* (50%), *Darbars* (10%), *Rajputs* (20%), schedule caste (10%) and others (10%). This village has drinking water supplied through pipeline, primary school, primary health centre, post office, telephone, electricity, cement concrete roads, street lights, drainage, and a *gram panchayat* run fair price food grain shop, well connected with road and an accessible market yard.

Table 2. Land holding households (HH) categories in Rajasamadhiyala.

Household categories	Number of HH	HH covered under project	HH under project (%)
Marginal (<1ha)	132	105	79.5
Small and medium (1–4 ha)	47	38	80.9
Large (>4 ha)	115	92	80.0
Landless	6	6	100.0
Total	300	241	80.3

Major constraints

Prior to rainwater harvesting, acute water scarcity was the major constraint for agriculture. As the watershed is in the semi-arid part of Sourasthra with low, erratic rainfall and for a short duration coupled with high intensity, it leads frequently to crop failure and drought. For domestic purposes the women of Rajasamadhiyala had to walk as much as 2.5 km previously to fetch water in summer. Poor soils with low-water holding capacity and inherent low fertility resulted in low crop yields. Migration of people to Rajkot in search of a livelihood used to be a very common feature.

Data Sources and Research Methodology

The present study is based on primary data collected through focused group discussions (FGDs) as well as through stratified detailed household surveys. For the purpose of collecting primary data sets of questionnaire was prepared by scientists of ICRISAT, IWMI and officials of BAIF. The team visited the watersheds, conducted meetings with farmers and had elaborate discussions followed by field visits to collect the primary information such as water conservation structures, groundwater, agricultural crop productivity, water conservation and socioeconomic data (Fig. 4).

Figure 4. Meeting with farmers and watershed committees.

The primary data was collected through investigation of farmers with pre-tested questionnaires and about 20% households/farmers were selected by stratified random sampling method in order to collect data in Rajasamadhiyala watershed for on-site impact assessment and two downstream villages to assess the off-site impact. The secondary data were collected from various sources like reports prepared by BAIF an NGO, project implementing agency (PIA) for the watershed program, Government of Gujarat. Data on expenditure incurred on various activities of watershed development were compiled from the published report (GRISERV-BAIF, 2003) and Government of Gujarat (2004). The storage capacity of water harvesting structures was quantified through detailed contour survey and measurements.

For the water filled structures, capacity was measured by recording the area under submergence up to outlet/crest level and depth of the water was measured at several places across the cross section to calculate the volume of water stored in the structures. To ascertain the extent of groundwater recharging due to water harvesting structures and natural recharging at Rajasamadhiyala the following method was adopted:

Scenario based on lean, normal and good rainfall years was generated. Rainfall data (1968–04) of Sardhar raingauge station (upstream of Rajasamadhiyala village) was used to generate scenario. The years identified for carrying out the study were grouped as follows:

Rainfall classification	Year	Rainfall (mm)
Good	1994	803
Average	1996	573
Lean	1995	233

The quantum of water harvested naturally and through watershed interventions was computed for different rainfall conditions. Based on the general values suggested for Saurashtra region and considering the terrain of Rajasamadhiyala the natural recharge is considered as 15% of total precipitation for all the three rainfall conditions. (Based on a study by PP Patel, Geologist, *Salinity Ingress Prevention Circle*, Rajkot, *in* Impact of Watershed Interventions on Groundwater in Rajasamadhiyala and Downstream Villages, prepared by Rishab Hemani, IWMI External Researcher, 2005). The net quantity of water, which additionally percolated through interventions, was computed by taking into account all the watershed interventions in Rajasamadhiyala. The duration of water, which remained in the structure, and area it covered, varied in different conditions of rainfall. Hence, appropriate assumptions were made for the duration (days) for which water was retained in water harvesting structures covering 100% area at full reservoir level (FRL) and decreased to 60% of area in later days. Three percolation rates of 20 mm day^{-1}, 15 mm day^{-1} and 10 mm day^{-1} were adopted for different periods of monsoon, to take into account the decreased percolation as substrata reaches saturation point.

Financial details were collected from PIA and Village Development Committee (VDC). The hypothesis testing was used to verify the sample data. The statistical techniques such as percentage, central tendency, and coefficient of variation, correlation, coefficient of determination were used to analyze the primary data. The post project impact assessment of investment on watershed activities in the village was carried out to examine the efficiency of economic returns, etc. In order to measure the crop diversification, Hirschman-Herfindahl diversification index model was used.

Results and Discussion

On-site impact of watershed development

Rajasamadhiyala watershed was taken for investigation for the on-site impact of various watershed activities such as water harvesting structures (causeways-cum-check dam, earthen bund, farm pond, gully plug and percolation tank), agriculture, afforestation and animal husbandry. These were implemented to support sustainable development of agricultural productivity, improving natural resources and environmental quality, and livelihood which would contribute to food security. Impact assessment is undertaken for the period since 1995 onwards only as baseline data were available from 1995 when watershed program was initiated although rainwater harvesting was undertaken since 1983. Large benefits through rainwater harvesting measures for 12 years prior to 1995 were missed out for calculating the impacts whereas the expenses since 1983 were used as costs. This has tremendously underestimated the impacts in terms of B:C ratio, cropping intensity, production and productivity gains, groundwater recharge, etc.

Biophysical indicators

Process of development: The process of development began in 1978, when Sri Hardevsinh Jadeja was elected as the *sarpanch* of the village. The Village Development Committee (VDC) was formed constituting leaders representing different sections and communities.

The committee had pledged to eradicate the evils of blind faith from the village and unanimously take decisions in all the matters of village development. The committee also guided and inspected the functioning of the village *panchayat*. The selflessness and strong commitment of the committee brought about the changes to transform the village from one of subsistence to one of prosperity. A set of rules at community level were formulated and strictly adhered to maintain discipline in the village (Government of Gujarat, 2004), which in turn played a key role in development process. The committee chalked out various developmental initiatives. Initially these included, widening of roads, renovation of Ram temple, getting rid of witch doctors, social ban on alcohol consumption and use of plastics and later followed by construction of rainwater harvesting and groundwater recharging structures, increase in cropping intensity or double cropping and crop diversification with help of organizations like Bhartiya Agro Industries Foundation (BAIF), Indian Space Research Organization (ISRO), and Government of Gujarat. The commitment and the fruits of their efforts received full support and cooperation from the villagers. Since then, this village has become a model for other neighboring villages (Fig. 5).

Figure 5. Well-built houses equipped with modern communication facilities.

Water harvesting and recharging structures

Construction of Rain Water Harvesting Structures (RWHS) was initiated in 1983. Initially, the VDC with the strong support of Mr Jadeja had to convince the farmers to build the first water harvesting structure. After realizing the benefits, it received full support and cooperation from the villagers. At present there are 46 structures comprising of check dams, causeways-cum-check dams, percolation tanks, and farm ponds (Fig. 6). These structures were constructed with the financial support from various organizations like District Rural Development Agency (DRDA), grants given by Government of Gujarat during drought years, Gujarat Water Supply and Sewage Board (GWSSB), Sampurna Gramin Rojgar Yojana (SGRY) and some social welfare trusts like Rajkot Lodhika Sahakar Sangh. Total investment of 16.25 million rupees in rainwater harvesting structures in Rajasamadhiyala is made since 1983. The Gujarat Rural Institute for Socio Economic Reconstruction (GRISERV-BAIF), Vadodara implemented the watershed project during 1995 to 2003 with grants from the Gujarat Government.

(a) (b) (c)

(d) (e) (f)

Figure 6. Various water harvesting structures at Rajasamdhiayala watershed (a and b) check dams (c and d) causeway check dams (e) percolation tank (f) farm pond.

Table 3. Details of water harvesting structures, storage capacities and average unit cost, 1995–2003.

Water harvesting structure	No. of structures	Storage capacity range (m^3)	Total storages capacity (m^3)	Average unit cost (Rs m^{-3})	Area benefited (ha)	Number of wells benefited	Number of farmers benefited
Check dam	13	1000–15000	64410	17	149	65	57
Causeway-cum-check dam	10	1266–11800	45855	28	132	63	55
Percolation tank	14	1100–132500	731811	20	461	149	101
Farm pond	6	800	4800	24	9	4	3
Earthen Bund	3	2550–4850	7385	7	4	2	2

The details of water harvesting structures are given in Table 3. The storage capacity of check dam/causeway cum check dams ranged from 1000–15000 m^3, and unit cost of construction varied from Rs 10–49 m^{-3} of water stored benefiting 128 open wells of 112 farmers with an area of 281 ha. Similarly percolation tanks with a larger storage capacity vary from 7600–132500 m^3 and the unit cost of construction worked out to be Rs 5–38 per m^3, has benefited 101 farmers with an area of 461 ha having 149 open wells. Farm ponds of 10 × 20 × 4 m were constructed with a unit cost of Rs 24 m^{-3} of stored water. The earthen bunds with natural outlets were constructed with considerably less cost of Rs 7 m^{-3}. Details of individual structures are given in Annexure 1. Details of watershed activities and the expenditure incurred are shown in Annexure 2. The various activities taken up during the watershed project were construction of water harvesting structures, agricultural activities, afforestation and animal husbandry. The total amount spent was Rs 1.8 million, in which Rs 0.12 million spent on entry point activities, Rs 1.55 million on water harvesting structures, Rs 0.042 million on agriculture, Rs 0.050 million on afforestion and Rs 0.041 million on animal husbandry.

Total storage capacity of all the water harvesting structures in the watershed is 855461 m^3 or 79 mm or about 16% of mean annual rainfall (mean of 20 years rainfall is 503 mm). This is equivalent to the potential

Box 1. Distress migration is a thing of past in Rajasamadhiyala.

Mr Devshibhai Kakadia *sarpanch* of the village proudly stated that the village prosperity was mainly due to the watershed interventions. "Not only do we have no problem for drinking water but also have sufficient water for irrigation purpose". Prior to implementation of watershed program, crops used to suffer during drought and therefore productivity and production would be low. As drought was a regular phenomenon, many male members would migrate to neighboring places or Rajkot in search of sustenance. This situation has changed tremendously during recent years with the availability of sufficient water for farming due to the introduction of watershed management. Now we have increased earnings and prosperity in the village. Also very few literates and skilled people are now leaving the village as there is so much work in the fields. We are now not only harvesting three crops a year but also using advanced machinery and tools".

runoff during a normal rainfall year in the watershed with an average unit cost of construction of Rs 19 per m^3. Considering the percolation/seepage and evaporation from the water harvesting structures, about 40% of mean annual rainfall can be harvested. Despite this fact, during normal rainfall years, 2–3 times overflow takes place from the structures. In addition, downstream watersheds get water through seepage/base flow from these structures; hence they are not affected by reduction in surface runoff to their watershed due to the construction of water harvesting structures in the upstream watersheds coming from upstream drains/streams. In addition to this, the downstream watersheds have also benefited by good groundwater recharge due to the water harvesting structures constructed in the upstream watersheds. This aspect of subsurface water flows and runoff benefiting the down stream villages in spite of huge rainwater harvesting in Rajasamadhiyala need to be considered along with geological formation in the region. Formation of soil on hard bed of basalt drastically affects ground water recharge but benefits through perched water table.

Box 2. Reduced drudgery for women

In the month of October 2004 the team visited Rajasamadhiyala and interacted with a group of women washing clothes on the wall of one of the several masonry check dams in the village. Mrs Radha Ben Timbedia a woman from the village washing clothes at one of the check dams in Rajasamadhiyala spoke with the team: "Earlier we used to walk a two km stretch to fetch water and almost the whole day we spent fetching water for household use. Now we have enough water in the village itself. It has relieved our drudgery of fetching water from long distances. Now we can devote much more of our time to either farming or to our children – thanks to watershed development. Now we are sure that our children will have a better life with education. Ours is a happy family. It was not so 10 years ago".

Indian Space Research Organization (ISRO), Vadodara, helped in identifying groundwater resource by using remote sensing technique in delineating the lineaments (water carriers) and dyke (water barriers) to open up the potential aquifers ISRO has inferred from the study that four lineaments and one dyke run through the watershed (Fig. 1). ISRO scientists advised the farmers to excavate pits at the spots where the lineaments and dyke intersected to open up the aquifers to recharge the groundwater (Fig. 7). It was found that this method increased the recharging potential by 125% (Government of Gujarat, 2004).

Table 4 shows the relation between the areas irrigated and production due to the water harvesting structures during 1995, 1999 and 2004. Total production includes cereals (wheat, pearl millet, sorghum and maize), pulses (mungbean, pigeonpea, blackgram, and chickpea), oil seeds (groundnut and til), vegetables (brinjal, cluster bean, chilly, coriander and tomato), cash crops (cotton, sugarcane and cumin), green fodder (lucerne and maize). During 1995, the production per unit storage capacity of WHS was 4.9 kg m^{-3} with an average production per unit area of 4443 kg ha^{-1}. During 1999, the production was 6.6 kg m^{-3} with an average yield of 5270 kg ha^{-1}. During 2004, a 7.7 kg m^{-3} production

Table 4. Water harvesting structures and its impact on area and production

Year	Rainfall (mm) (1)	WHS storage capacity (m³) (2)	Area irrigated (ha)	Yield (kg ha⁻¹)	Production (t) (3)	Production (kg m⁻³ of storage capacity)
1995	307	699510	769	4443	3417	4.9
1999	311	806058	1005	5270 (19)*	5296	6.6 (35)
2004	503	855461	1218	5434 (22)	6619	7.7 (59)
Mean	510	792389.3	1001.9	5106	5173.5	6.5 (33)
SD	185.4	51674.1	145.3	344.0	1042.4	0.91
C.V (%)	36.3	6.5	14.5	6.7	20.2	14.1

* Values in parentheses are the percentage increase over 1995; No. of observations = 10.

Figure 7. Pit excavated at the intersection point of lineament and dyke.

with an average yield of 5434 kg ha^{-1} was reported. The overall production of 6.5 kg m^{-3} of storage capacity with an average yield of 5124 kg ha^{-1} was observed, which is about 33% increase in production (kg) per unit storage capacity (m^3), while there was a 15% increase in yield (kg) per unit area irrigated (ha) in 2004 over 1995. This trend of increase in area irrigated and production due to increase in storage of water harvesting structures was consistent and is further supported by statistical analysis.

The standard deviation of storage capacity from 1995 to 2004 was computed 792389.3 m^3 and coefficient of variation was 6.5%. The standard deviation of irrigated area was 145.3 ha and coefficient of variation was 14.5%. The standard deviation of production was estimated 1042.3 t and coefficient of variation was 20.2%. The storage capacity of water harvesting structures over a period of time in comparison with area irrigated, production and the coefficient of variation, is quite consistent (Table 4).

Partial correlation between Rainfall (1), WHS (2) and Production (3)

$\mathbf{r}_{13.2}$ = –0.3796 Pro error = 0.314

$\mathbf{r}^2$ = 0.144

$\mathbf{r}_{23.1}$ = 0.9538 Pro error =0

$\mathbf{r}^2$ = 0.909

The higher degree of correlation amongst storage capacity of water harvesting structures, area irrigated and production was found. The coefficient of determination (r^2) between storage capacity of water harvesting structures and production was 0.95. This indicates the 95% change in the production was influenced due to the storage capacity of water harvesting structures and remaining 5% by other exogenous factors. The partial correlation between rainfall and production keeping water-harvesting structures constant are –0.3796 and r^2 is 0.144, which clearly indicate that there is no consistent relationship between rainfall and production. The analysis reveals that crop production had increased due to the water harvesting structures, which has nullified the effect of rainfall variability and increased resilience during low rainfall/drought years.

Groundwater recharge and availability

The total recharge taking place through natural and water harvesting interventions is greatly affected by the amount of rainfall, its intensity, duration of monsoon, ground and sub-surface characteristic (i.e., percolation rate and runoff coefficient). The total storage capacity of all the water harvesting structures is 0.855461 MCM or 79 mm. When all the structures are filled at FRL the area covered by water is 0.3379 million sq. m. The recharge by all the structures is computed by area of ground in contact with water, its duration of contact and percolation rate of upper soil strata. Considering the terrain of Rajasamadhiyala the natural recharge percentage has been considered as 15% of total precipitation for all the three rainfall conditions based on the values suggested for Saurashtra region (based on study by PP Patel, Geologist, *Salinity Ingress Prevention Circle*, Rajkot. *In* Impact of Watershed Interventions on Groundwater in Rajasamadhiyala and Downstream Villages, prepared by Rishab Hemani, IWMI External Researcher. 2005). A detailed computation of total water recharge and downstream runoff in Rajasamadhiyala village during good, average and lean rainfall year is presented in Table 5. Total groundwater recharge and downstream runoff from Rajasamadhiyala watershed during good, average and lean rainfall years estimated were 45% and 20%; 50% and 12%; 42% and 8% of rainfall, respectively.

Table 5. Groundwater recharging and downstream runoff in Rajasamadhiyala village.

Rainfall scenario	Rainfall (mm)	Recharge through CD & PT (mm)	Natural recharge (mm)	Total recharge (mm)	Total downstream runoff (mm)
Good Rainfall year (1994)	803	241 (30)*	123 (15)	364 (45)	163 (20)
Average Rainfall year (1996)	573	195 (34)	92 (16)	287 (50)	69 (12)
Lean Rainfall year (1995)	233	61 (26)	37 (16)	98 (42)	19 (8)

* Values in parentheses are the percent of rainfall

The total water requirement for crop irrigation in Rajasamadhiyala for good, average and lean rainfall year has been summarized in Table 6. It can be inferred from Table 6 that the total groundwater recharge has increased by three folds in different rainfall situations. Water requirement in Rajasamadhiyala has doubled after the watershed interventions due to increased cropping intensity and change in cropping pattern. This has had a direct impact on production, productivity and income, which have increased considerably.

Table 6. Pre- and Post-interventions scenario of total water requirement for crop irrigation and total groundwater recharge for good, average and lean rainfall years in Rajasamadhiyala.

	Pre-intervention groundwater (GW) scenario (mm)			Post-intervention groundwater (GW) scenario (mm)		
Rainfall scenario	Total GW recharge	Total water requirement for irrigation	Net ground water balance	Total GW recharge	Total water requirement for irrigation	Net ground water balance
Good	123	99	29	364	212	155
Average	92	79	13	287	165	122
Lean	37	39	-1	98	87	11

As many as 255 open wells existed in 1995, with very poor yield with an average water column of 5.9 m in 1995, but presently there are 308 wells with mean water column of 10.4 m (Fig. 8). The average depth of wells in the watershed is 18 m. The increase in water column during rainy season was 6.6 m, postrainy season was 5.3 m, and in summer was 1.3 m. Overall there has been an increase of 4.4 m of water column in 2004, as compared to that of 1995.

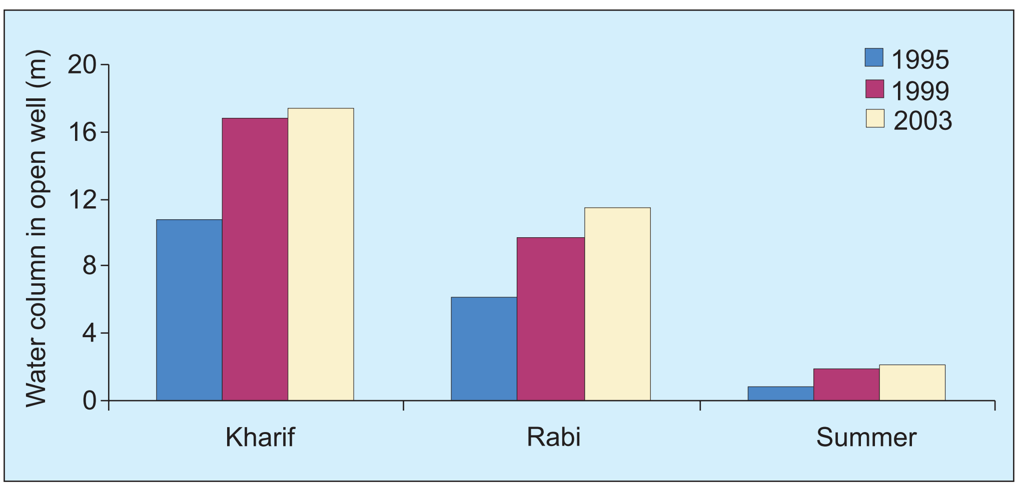

Figure 8. Average water column in open wells.

Not only an increase in water column is observed, but significant improvement in water yield in wells was also reported as evident by the duration of pumping hours per day for irrigation (Fig. 9 and 10). The average pumping duration of 5.25 hours per day in 1995 has increased to 10.4 hours per day in 2004. This reveals that there has been a net increase of 5.2 hours per day of pumping. The increase in pumping duration in rainy season was 9.5 h day^{-1}, postrainy season was 5.25 h day^{-1}, and in summer was 0.75 h day^{-1}.

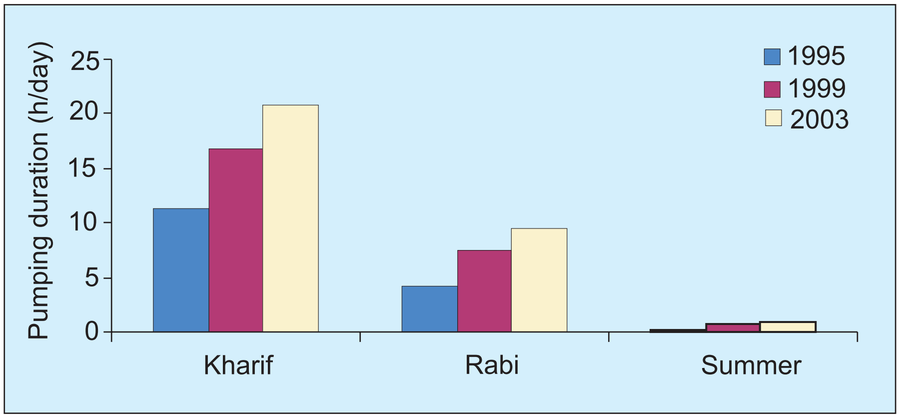

Figure 9. Average pumping duration of open wells.

Figure 10. Open well water level is up to the ground level recharged by water harvesting structure (WHS).

The increased availability of water in wells has tremendously increased the area under irrigation (Table 7). The increase in area under irrigation in 2003 over 1995 during rainy season, postrainy season and summer were 60, 55 and 118% respectively. The overall total area increased by 58% under irrigation.

Table 7. Area under irrigation (ha), 1995–2003

Cropping season	1995	1999	2003	% Increase in 2003 over 1995
Rainy season	402	518	643	60
Postrainy season	356	469	551	55
Summer	11	18	24	118
Total	769	1005	1218	58

Similarly 102 bore wells were present in 1995; most of them were defunct with very low groundwater level. At present 200 bore wells are in use. The density of open wells (number of wells per ha) in 1995, 1999 and 2003 was 0.23, 0.26, and 0.28 respectively, whereas bore wells was 0.09, 0.15, 0.18 respectively; and cumulative density of both open wells and bore wells was 0.38, 0.41, and 0.47 respectively over a period of time. The increase in number of wells and area irrigated has been due to the significant improvement in groundwater level and yield attributed to the water harvesting structures. This has significantly increased the irrigation facility and equipments procured by farmers (Fig. 11 and Table 8). Watershed development in Rajasamadhiyala has impacted positively in terms of increased groundwater availability, which farmers have harnessed through doubling the hours of pumping in 1999 as that of 1995 and also increased number of bore and open wells considerably. Area under irrigation has also increased from 769 ha in 1995 to 1002 ha in 1999. Doubling of the number of the bore wells in the watershed is a cause of concern as inspite of farmers' experience of defunct bore wells in 1995 and earlier, they have again drilled more bore wells than open wells. The marginal positive groundwater balance in lean and average rainfall years could tilt to negative side very soon if the farmers continued drilling bore wells and pumping at the rate they have done from 1995 to 1999. Although, villagers acted collectively for water harvesting there is no concern or awareness amongst the villagers for sustainable use of groundwater. There is an urgent need of community monitoring of groundwater and its allocation to individuals. Similarly suitable policy for restricting drilling of bore wells in developed watersheds is required to avoid the over-exploitation of groundwater by individuals or community. If such policies or community initiatives are not there, soon the benefits of well-developed watersheds would be undone and the villagers will be where they were prior to watershed development or in a worse situation.

(a) *(b)* *(c)*

Figure 11. Irrigation facilities developed in watershed (a) ÿood irrigation (b) drip irrigation in cotton crop (c) drip irrigation set.

The number of diesel engine pumps declined by 22% over the period (1995 to 2003), while there was considerable increase of 80% in the electric motor pumps. Such an increase in number of electric pump-sets in spite of erratic power supply is mainly due to the subsidized electricity supply to the farmers. The number of farmers who have procured pipeline for irrigation have increased by 156%, which helps in preventing the water loss through seepage and increases the irrigation efficiency (Table 8). There was also considerable increase in procurement of drip and sprinkler irrigation sets too.

Table 8. Change in irrigation facility and equipments available in watershed (1995–2003).

Irrigation facility/equipments	1995	1999	2003	Increase or decrease (%)
Diesel engine pumps	208	188	162	-22
Electric pump	205	281	368	80
No. of farmers procured pipeline	48	84	123	156
Drip irrigation set	16	22	38	138
Sprinkler irrigation set	1	2	4	300

Table 9 reveals that the total number of farmers having access to irrigation has increased by 188% from 1995 to 2003. There has been a sharp increase in the number of marginal and small farmers who have access to irrigation compared to large farmers (172%) increased by 292 and 317% respectively.

Table 9. Change in the number of farmers having access to irrigation.

Farmers category	1995	1999	2003	Increase in 2003 over 1995 (%)
Marginal	16	28	35	317
Small	25	82	98	292
Large	32	65	87	172
Total	73	175	220	188

Increased water availability due to various watershed development activities encouraged private investment from farmers on procurement of irrigation facilities and farm machineries. During the project period private investment of Rs 10.5 million (million US$ 0.24) for construction of open and tube wells, Rs 2.47 million (million US$ 0.06) on irrigation facilities and Rs 1.56 million (million US$ 0.04) on threshers and tractors was used for the watershed program. This is an excellent example of enhanced private investment in agriculture once the public investment through watershed development ensured groundwater availability.

Cropping pattern, area, production and productivity

After the implementation of water harvesting system, considerable area was brought under irrigation (Table 10) and 25 ha of wasteland were also brought under cultivation. Prior to the watershed development program in the village, one crop in a year was harvested and vegetables were not grown. After the implementation of watershed development program, there was considerable increase from 33 to 171 ha under double cropping (Table 11) owing to the availability of additional water (Fig. 12). At present several farmers harvest around three crops in a year including vegetable crops.

Table 10. The land use pattern of watershed area (ha).

Land use	1995	1999	2003
Agriculture (rainfed)	372	278	212
Agriculture (irrigated)	356	469	551
Pasture	64	56	54
Waste (uncultivated)	283	272	258
Village	14	14	14

Table 11. Change in cropping system area (ha year^{-1}).

Cropping system	1995	1999	2003
Single crop	403	348	386
Two crops	33	70	171
Long duration crops	323	396	377
Three crops	9	15	21
Agro-horticulture	3	5	7
Agro-forestry	7	11	15
Perennial crop	2	3	3
Pasture	64	56	54

Table 12 reveals the change in the area, productivity and yields of various crops grown during rainy, postrainy and summer seasons over a period of time. In rainy season, the area under maize crop increased sharply (55.56%) followed by vegetables (44.83%) and pearl millet (*bajri*) (37.5%) from 1995–96 to 2003–04. Although there was a considerable increase in the productivity of groundnut (119.4%), but the area decreased by 13% during the same period. In *rabi*, the percent change in the area of wheat cultivation was found highest (764%) followed by cumin (363%). The area under pulses crops decreased by 20% in 2003–04 compared to 1995–96. The percent of total cropped area in 1995, 1999 and 2003 is also provided in parenthesis in Table 12.

Figure 12. Good cotton crop in the Rajasamadhiayala watershed, 2004.

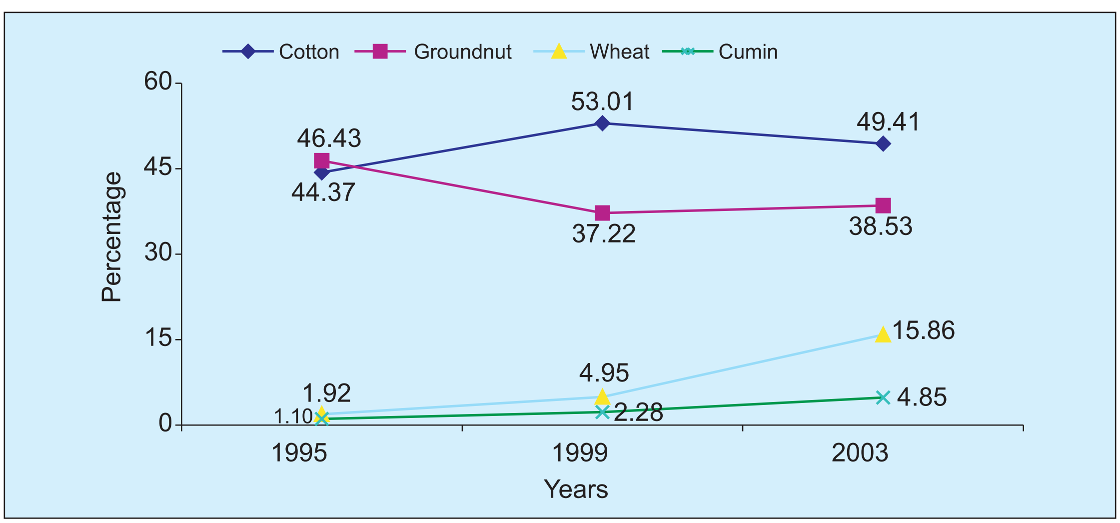

Figure 13. Change in cropped area over cultivable area in percentage.

Table 12. Area, productivity and production of various crops in Rajasamadhiyala watershed.

Crops	1995 Area (ha)	1995 Productivity (q ha^{-1})	1995 Production (q)	1999 Area (ha)	1999 Productivity (q ha^{-1})	1999 Production (q)	2003 Area (ha)	2003 Productivity (q ha^{-1})	2003 Production (q)
Rainy season									
Cotton	323 (44.5)	17.3	5594	396 (53.2)	24.8 (43)*	9833	377 (49.4)	26.6 (53)*	10021
Groundnut	338 (46.6)	7.1	2407	278 (37.3)	11.6 (63)	3219	294 (38.5)	15.6 (119)	4592
Jowar	7 (1.0)	14.3	100	5 (0.7)	16.7 (17)	84	9 (1.2)	18.1 (27)	163
Bajra	8 (1.1)	15.7	126	10 (1.3)	17.7 (12)	177	11 (1.4)	18.4 (17)	203
Maize	9 (1.2)	11.4	102	11 (1.5)	13.4 (18)	148	14 (1.8)	15.6 (37)	219
Vegetable	29 (4.0)	144.8	4200	33 (4.4)	162.5 (12)	5361	42 (5.5)	167.6 (16)	7039
Pulses	6 (0.8)	5.1	31	5 (0.7)	7.3 (42)	36	7 (0.9)	8.4 (65)	59
Other	6 (0.8)	4.1	25	7 (0.9)	4.9 (19)	34	9 (1.2)	5.3 (28)	47
Postrainy season									
Wheat	14 (42.4)	16.8	236	37 (59.9)	28.3 (68)	1048	121 (70.8)	32.9 (95)	3979
Cumin	8 (24.2)	7.2	57	17 (24.3)	9.2 (28)	156	37 (21.6)	10.7 (50)	3967
Pulses	5 (15.2)	6.2	31	3 (4.3)	7.3 (18)	22	4 (2.3)	7.8 (27)	31
Vegetable	3 (9.1)	132.2	397	8 (11.4)	158.9 (20)	1271	5 (2.9)	162.2 (23)	811
Fodder	3 (9.1)	692.9	2079	5 (7.1)	778.6 (13)	3893	4 (2.3)	793.9 (15)	3176
Summer									
Fodder	5 (13.5)	688.1	3441	8 (14.3)	762.8 (11)	6102	10 (13.2)	789.1 (15)	7891
Vegetable	4 (10.8)	128.1	513	7 (12.5)	152.7 (19)	1070	11 (14.5)	153.2 (20)	1685
Sugarcane	2 (5.4)	2042.8	4086	3 (5.4)	2188.3 (7)	6565	3 (3.9)	2218.5 (9)	6655
Maize+g.nut	19 (51.4)	382.9	7274	25 (44.6)	389.6 (2)	9739	34 (44.1)	397.5 (4)	13514
Pulses+g.nut	7 (18.9)	5.2	36	13 (23.2)	6.6 (28)	86	18 (23.7)	7.9 (53)	142

* Percentage change of yield over 1995.

During summer, the area of vegetable crops was found to substantially increase (175%) followed by pulses + groundnut (157.14%) and fodder (100%). Significant gains in crop productivity ranging from 15.72% in vegetables to 119% in groundnut crop were recorded in the watershed. The productivity of crops grown in rainy and postrainy seasons was increased along with the area under cultivation.

The cropping intensity in 1995 was 114% subsequently in 1999 and in 2003 it was 130% and 164% respectively (Table 11). Over a period of time, the cultivated area devoted to major crops viz., cotton, groundnut, wheat and cumin grew (Fig. 13 and Fig. 14). The cropping intensity increased in 1999 by

Figure 14. Crops diversification with sugarcane, cauliflower and ladies finger in Rajasamadhiyala.

16% over 1995 while in 2003 by 34% compared to 1995. As mentioned earlier, value for change in cropping intensity during 1995 to 2003 was lower by 50% as against 66% observed in other watershed programs in India (Joshi et al. 2005). This could be largely because the initial increase in cropping intensity during 1983 to 1995 period could not be captured due to lack of baseline data in 1983.

Crop Diversification

Crop diversification over a period of time is measured using the Hirschman-Herfindahl diversification index. The diversification index, calculated as DI = 1-H, where H is Hirschman-Herfindahl Index, measured by $—(P_{it}/— P_{it})^2$, P_{it} being the value of production at 2002–03 prices of the i-th crop in year t. The higher diversity index indicates greater crop diversity in production patterns (Fig. 15). Except pulse crops the indices of diversity for other remaining crops changed. The index of cotton declined in 1999–2000 but sharply increased in 2003–04 which indicates higher diversification rather than concentration in 1999–2000. The index of groundnut remains stable in 1999–00 the crop was diversified marginally but in 2003–04 it was concentrated. The index of both wheat and cumin crops declining continuously over a period, which indicates the concentration of crops during the same period of time. The Diversification Index (DI) in the output mix declining continuously from 1995–96 to 2003–04 which indicates higher concentration of mixed crops on production pattern rather than diversification. The results reveal that due to availability of water, crops like vegetables and fodder are grown instead of cereal crops – further diversifying the crops.

With a population of 1,747, the village is growing three crops, including an amazing 18–20 varieties of vegetables which garners Rs 5–6 crore annually (twice the income of neighboring villages) with its 300 families netting in between Rs 50,000 to Rs 12 lakh per year. The village is lush with 60,000 trees. The indices of diversification also indicate that traditional crops have concentrated rather than diversified during the period of interventions of watershed technologies in the village. The other commercial crops are diversified because of availability of water in the village (Fig. 16).

The DI for each crop examines their level of spread resulting in crop diversification and concentration (against diversification). The figure indicates that from 1995–96 to 1999–00 with the highest value of diversification index the pulse crop remained cultivated while there was high concentration in cotton in the village. However from 1993–94 to 2003–04 the scenario of cropping pattern changed sharply and the crop of cotton further diversified and groundnut dominated once again. It is interesting to note that the index of pulse crop remained constant indicating that there was neither diversification nor concentration over a period of time. This could be because of a stable market price of pulses as well as need for home consumption as a source of protein.

The gross output of each crop for different years is valued at constant (2003–04 farm harvest) prices and in order summed up to arrive at the aggregate value of crop production. The total value of output increased by more than two times between 1995–96 and 2003–04. The total value of output of all crops increased at a compound growth rate (CGR) of 11.39% during 1995–96 to 1999–00, but CGR declined sharply to 3.58% from 1999–00 to 2003–04. These results indicate that initial effects of irrigation resulted in higher CGR. However, to maintain similar CGR necessary intervention to bring in enhanced water use efficiency are needed. Overall from 1995–96 to 2003–04 the CGR of production of all crops increased by 18.92% (Table 13). In terms of value of production in constant prices in 1999–2003, Rajasamadhiyala recorded cotton receiving Rs 2750 per quintal, groundnut Rs 1625 per quintal, wheat Rs 800 per quintal, cumin Rs 6008 per quintal and pulses Rs 1500 per quintal.

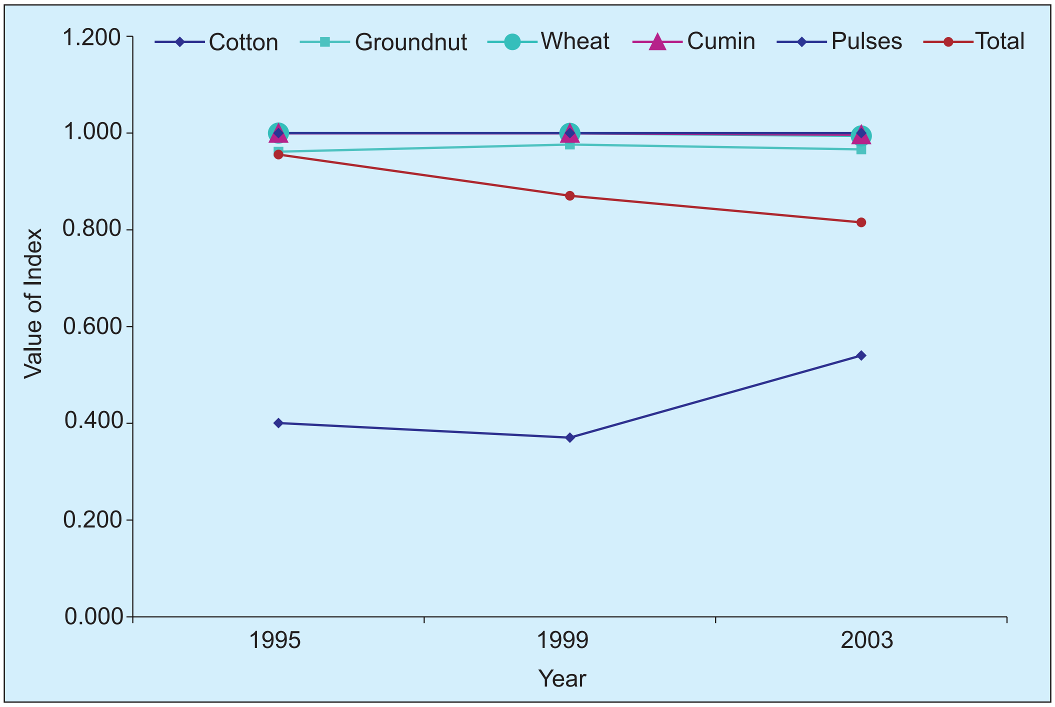

Figure 15. Diversification Index over a period of time.

Figure 16. Various crops like sugarcane, vegetable and fruit plants are grown.

Table 13. The value and growth of total production in Rajasamadhiyala watershed.

Year	Cotton (Rs)	Groundnut (Rs)	Wheat (Rs)	Cumin (Rs)	Pulses (Rs)	Total Production (Rs)	CGR
1995	15384490	3910660	188496	344160	45160	19872966	From
	(77.41)*	(19.68)	(0.95)	(1.73)	(0.23)	(21.00)	1995–99
	(0.401)**	(0.961)	(1.00)	(1.00)	(1.00)	(0.956)	11.39
1999	27039870	5231265	838272	937380	34944	34081731	From
	(79.34)	(15.35)	(2.46)	(2.75)	(0.10)	(36.00)	1999–03
	(0.371)	(0.976)	(0.999)	(0.999)	(1.00)	(0.871)	3.58
2003	27556815	7462455	3182784	2379840	52000	40633894	From
	(67.82)	(18.37)	(7.83)	(5.86)	(0.13)	(42.96)	1995–03
	(0.540)	(0.966)	(0.994)	(0.997)	(1.00)	(0.816)	18.92

* The figures in parentheses are the percentage of value of particular crops over total value of all crops
**The figures in parentheses are the values of diversification index

Socioeconomic indicators

The socioeconomic status of the people improved sharply because of watershed interventions within a short span of time in the village. Farmers are realizing the importance of watershed management which directly contributed in uplifting their standard of living.

Change in demographic status

The per capita income of population increased by 38.52% during project period. The village exhibits a fairly good sex ratio of 1003 female for every 1000 male, which is worth noting that the sex ratio in the village is above the average of the state and the nation. It indicates that the status of women have improved which is attributed to the standard of living as well as increased awareness of child care, nutrition intake and moral status. The literacy rates amongst male as well as female were found higher in 2004. There has been 100% enrollment in primary education and children below 5 years are going to *anganbadi*.

The literacy rate is about 41.5% for male and 56.2% for female. Generally boys are withdrawn from school to work on their farm by the 8th standard while girls continue with their study till the 12th standard. Total migration of unskilled labor has declined (2–3% of total population), as there is availability of work in the village itself. Although total migration has come down signiþcantly, the percentage of skilled labor was found to be on the higher side. The skilled labors move to nearby town Rajkot to start small business or þnd work in diamond cutting industry.

Food, fodder and fuel security

Food security is a state of assuring physical availability and economic accessibility of enough food (in an environmentally and socially sustainable manner) in terms of quantity (amount, distribution, calories), quality (safe, nutritious, balanced) and cultural acceptability for all people at all times for a healthy and active life. The parameters used to measure food security in the village based on the World Food Summit (1996) held in Rome, basically ensured availability, accessibility and acceptability. As per the norms of World Food Summit (1996), the availability of food requires adequate and reliable food for an active and healthy life at present and for future generation. While accessibility ensures distribution and access to food within and between societies, acceptability means culturally acceptable food and distribution systems, which respect human dignity, social and cultural norms. The various measures

Figure 17. Healthy animals indicate good availability of fodder in the watershed.

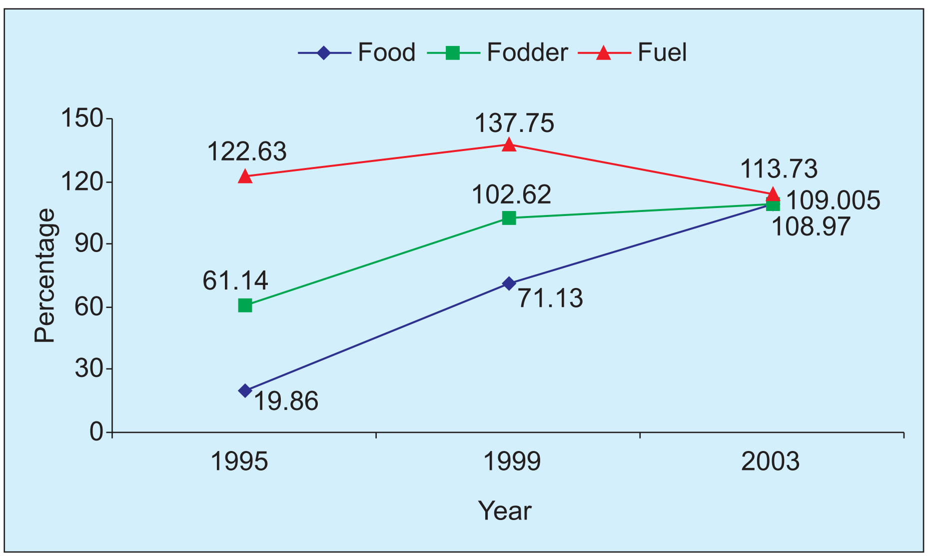

Figure 18. Change in food, fodder and fuel security over a period of time in Rajasamadhiyala.

implemented through watershed program have improved food, fodder and fuel security over a period time (Figs. 17 and 18).

Table 14 reveals the availability and requirement of food per capita per month in monitory value to measure the food gap as well as security. In 1995, per capita food secured was only 20% against requirement, while the food security increased significantly to 71% (59.5) in 1999. In 2003–04 total per capita food security attained was 109% (75.6). This was due to the overall development activities of watershed programs in general and in particular due to additional water availability through rainwater harvesting and groundwater recharging structures.

Table 14. Food security over a period of time

	Unit	1995	1999	2003
Total Population	No.	1631	1691	1747
Land Availability per capita	ha	0.446	0.442	0.437
Land value	Rs 100000/ha	0.558	1.336	1.747
Income from all sources				
Interest on land	Rs 100000	0.0335	0.0802	0.1048
Crops		18.75	169.69	306.57
Animal husbandry		11.41	11.26	11.6
Other Income (services/employment)		0.78	1.02	1.45
Total Income	–	30.97	182.05	319.72
Income per capita	Rs 100000 per month	0.019	0.108	0.183
Income Availability*	Rs per month	437.05	1564.91 (1300)**	2398.11(1662.40)**
Income Requirement	Rs per month	2200.00	2200.00	2200.00
Food Gap Rs (Required-Availability)*		-1762.95	-635.10 (-892)**	198.11 (-537.6)**
Food security per capita per month (%)		19.866	71.132 (59.5)**	109.005 (75.6)**

* Rs 70.97 per capita per day are calculated based on the definition of World Food Summit, 1996, Rome, to measure food security (availability, acceptability and utilization).
**Income availability is calculated by taking into account the All India Wholesale price index for comparing 1995 with 1999 and 2003.

In case of fodder security, only 61% was secured in 1995, while in 1999 it was fully secured (103%) within a short span of time (Table 15 and Fig 18). The fuel security also improved in 1999 (138%) compared to 1995 (Table 16 and Fig.18)

Over a period of time both per capita yield availability and cultivable area increased but there was a significant change in per capita yield recorded, compared to change in per capita cultivable land. The rate of marginal growth in case of yield is higher than cultivable land indicating that increased water availability resulted in extensification as well as intensification of agriculture in Rajasamadhiyala (Fig. 19).

Table 15. Fodder security over a period of time in Rajasamadhiyala.

	Unit	1995	1999	2003
Total animal	No.	1743	1526	1235
Total area	ha	1075	1075	1075
Area under fodder	ha	404	381	501
Area under fodder	%	37	35	46
Fodder productivity	kg ha^{-1}	5739	7979	7590
Fodder production	kg y^{-1}	2318556	3039999	3802840
Fodder from by-product	kg y^{-1}	1456805	1967169	2296282
Total fodder availability	kg y^{-1}	3775361	5007168	6099123
Fodder requirement (Village)	kg y^{-1}	6175251	4879453	5597122
Fodder insecurity (Village)	kg y^{-1}	-2399890	127715	502001
Fodder insecurity (Per animal)	kg y^{-1}	-1377	84	406.
Fodder security per animal per annum (%)		61	102	109

Table 16. Temporal change in fuel security in Rajasamadhiyala.				
	Unit	1995	1999	2003
Total Population	No.	1631	1691	1747
Total Area	ha	1075	1075	1075
Area under fuel	ha	335	411	395
Area under fuel	%	31	38	36
Production of cotton residue for fuel	kg y^{-1}	565251	720722	697453
Production of others fuel	kg y^{-1}	14822	15382	16123
Total Production	kg y^{-1}	580073	736104	713576
Fuel requirement	kg y^{-1}	473043	534364	627432
Fuel requirement (Per household)	kg y^{-1}	290	316	359
Insecurity of fuel (village)	kg y^{-1}	107030	201740	86144
Fuel security per capita/ year	%	123	138	113

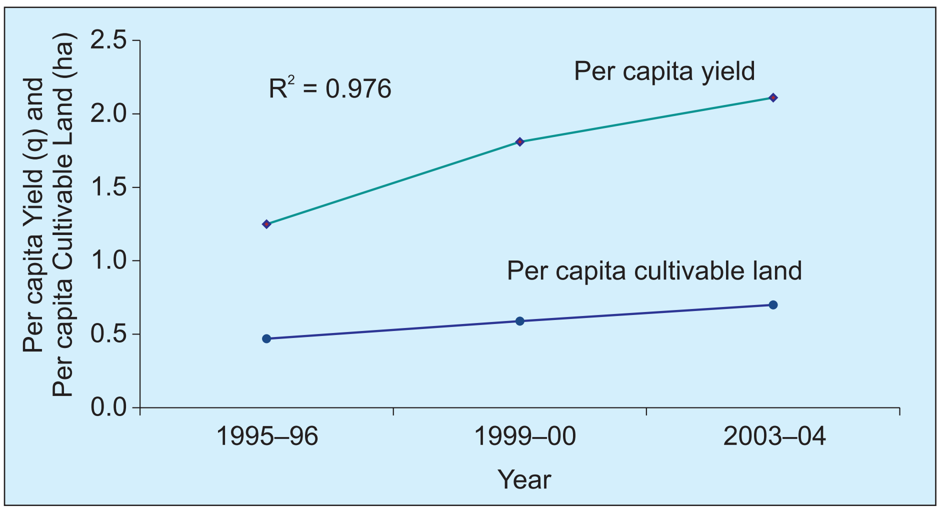

Figure 19. Per capita availability of yield and cultivable land in Rajasamadhiyala during 1995–2004.

Economics of cost of production

The cost of cultivation of five important crops i.e., cotton, groundnut, wheat, cumin and pulses which cover about 95% area of cultivated land were calculated from 1995–96 to 2003–04. In 1995–96 except cumin the gross returns from other crops were not covering even fixed cost for the farmers and therefore their profit volume and benefit cost ratio were negative ranging from –0.24 to 105.95. The profit volume ratio is the ratio of fixed cost and profit/loss to the gross returns. The highest negative profit volume ratio was observed in case of wheat while lowest in case of cotton. The benefit cost ratio of wheat was lowest, i.e., 0.40 while it was highest in cumin. The scenario of cost of cultivation slightly changed in 1999–00, the gross returns from all crops except pulses and wheat were higher than their variable and total cost. The profit volume ratio of two crops namely wheat and pulses were found negative while the benefit cost ratio was lowest in pulses, followed by wheat and groundnut. Cumin crop was highly remunerative providing highest benefit cost ratio i.e., 2.55 followed by cotton (Table 17).

Table 17. Cost of cultivation and economic returns from major crops, Rajasamadhiyala watershed.

Crops	Area (ha)	Area over cultivated area (%)	Fixed cost (Rs ha^{-1})	Variable cost (Rs ha^{-1})	Total cost Rs ha^{-1})	Gross returns (Rs ha^{-1})	Returns over FC (Rs ha^{-1})	Returns over VC (Rs ha^{-1})	Returns over TC (Rs ha^{-1})	Profit volume ratio	Profit/loss (Rs ha^{-1})	Benefit cost ratio
1995												
Cotton	323	44.37	8000	26120	34120	25980	17980	-140	-8140	-0.54	-8140	0.76
Groundnut	338	46.43	3000	12995	15995	9620	6620	-3375	-6375	-35.08	-6375	0.60
Wheat	14	1.92	4000	18360	22360	8915	4915	-9445	-13445	-105.95	-13445	0.40
Cumin	8	1.1	4000	12760	16760	32265	28265	19505	15505	60.45	15505	1.93
Pulses	11	1.51	4000	13020	17020	7903	3903	-5117	-9117	-64.75	-9117	0.46
1999												
Cotton	396	53.01	8000	27770	35770	49660	41660	21890	13890	44.08	13890	1.39
Groundnut	278	37.22	3000	14430	17430	16475	13475	2045	-955	12.41	-955	0.95
Wheat	37	4.95	4000	19350	23350	18908	14908	-442	-4442	-2.34	-4442	0.81
Cumin	17	2.28	4000	14010	18010	45950	41950	31940	27940	69.51	27940	2.55
Pulses	8	1.07	4000	14315	18315	10920	6920	-3395	-7395	-31.09	-7395	0.60
2003												
Cotton	377	49.41	8000	34108	42108	73095	65095	38987	30987	53.34	30987	1.74
Groundnut	294	38.53	3000	17469	20469	27782	24782	10313	7313	37.12	7313	1.36
Wheat	121	15.86	4000	20598	24598	26804	22804	6206	2206	23.15	2206	1.09
Cumin	37	4.85	4000	14910	18910	64320	60320	49410	45410	76.82	45410	3.40
Pulses	11	1.44	4000	15375	19375	13000	9000	-2375	-6375	-18.27	-6375	0.67

* Capital investment on land and irrigation facilities considered for fixed cost.

The results of cost of cultivation in 2003–04 sharply changed due to active intervention of watershed management technologies. Except in the case of pulses, most of the crops were highly remunerative and the returns were more than their variable as well as fixed cost. In spite of low returns, pulse area did not decline over the years pulses' yields are low (7.83 q ha^{-1}) and there was a need to include productivity enhancement interventions. Cumin was the highest profitable crop followed by cotton and groundnut crops during this year having higher profit volume and benefit:cost ratio. The overall results suggest that rainfed crops have more potential and economical benefit if they are managed properly through watershed interventions.

Impact assessment and evaluation of investment

Ex-post impact assessment of investment on watershed development activities estimate the accrued benefits from research and development and examine whether the economic returns are satisfactory and efficient in use of resources. It is desirable, even essential that research be properly evaluated to judge what impact it has on its target clientele (Bantilan 1993). In Rajasamadhiyala a single traditional water storage structure (percolation tank) existed way back in 1942; but from 1983 onwards funds were being invested on various watershed development activities through different agencies of government and non-government organizations.

The key interventions under watershed development programs and rainwater conservation measures were evaluated individually and in combination for their impact on productivity and resource conservation in the village. Accordingly, on-site and off-site impact assessment study was planned and undertaken by a multidisciplinary team of researchers The important details of the watershed activities at village level are mentioned earlier in the Annexure 1 and crop wise area is mentioned in Table 18.

Box 3. Prosperity at the doorsteps of villagers after watershed development program

Improved livelihoods of villagers: an example of Mr Narayan Bhai Ramani resident of Rajasamadhiyala village who is a typical farmer in the Rajasamadhiyala watershed. His family has 4 male and 2 female members. He holds 6.4 ha of land, and grows groundnut crop prior to watershed development use to harvest one tonne groundnut per ha. However with the improved water availability in his open well last year he harvested 1.7 tonnes per ha using Gujarat 20 variety. With the improved groundnut productivity and fodder availability, Narayan Bhai invested in 2 buffaloes and 2 cows (improved breeds). The two buffaloes yield 14 L milk and cross breed cow yields 16 L milk. Out of 30 L of milk 5 L is consumed in the family of 6 persons. In his family women participate in all types of field work including spraying pesticides and ploughing, etc. Two daughters studied up to 7th and 10th standard and then got married at the age of twenty. Family spent about 1.5 lakh rupee (US $ 3490) on each daughter's marriage. He possesses a TV, VCR, fridge and bullet motorcycle (seen in the picture) besides a house in Rajkot. He believes that prosperity came after construction of the check dams in the village. Mr Narayan Bhai Ramani is not an isolated case enjoying the fruits of prosperity due to improved water availability in the watershed but one amongst 300 households in the village.

Table 18. Area under major crops in the watershed in 2003–2004 and changes over 1995–1996

Village	Important crop	Area covered (2003–2004) (ha)
Rajasamadhiyala	Cotton	377 (16.72%)*
	Groundnut	294 (-13.02%)
	Wheat	121 (764.29%)
	Cumin	37 (362.50%)
	Pulses	11 (-20.00%)

* Figure in parentheses are percentage change in area for particular crop from 1995–96 to 2003–04.

Various watershed activities such as water harvesting structures (causeways-cum-check dam, check dam, earthen bund, farm pond, gully plug and percolation tank), agriculture, afforestation and animal husbandry were implemented to support sustainable development of agricultural and poverty alleviations (Annexure 2). Except for groundnut and pulses, the area under the five important crops viz., cotton, groundnut, wheat, cumin and pulses, covering around 95% of cultivable land increased sharply during 1995–96 to 2003–04.

Evaluation of economic impact

The evaluation of economic impact on investment of watershed activities carried out with the following technological and economic parameters necessary to estimate the approximate value.

- Period of analysis considered from 1995–96 to 2003-04 for calculating the benefits
- Cost of investment: Actual expenditure on WHS from 1983–84 to 2003–04 was used for calculating benefits.
- Returns rate: Calculated from 12 years after initiation of the watershed activities as rainwater harvesting started earlier than the watershed projects.
- Yield of all important crops increased from 43–119% over the period of time (1995–03)
- Change in cost of cultivation increase ranged between 10–28%, not considering the inflation rate of monitory value during 1995–03.
- Probability of success depends on actual achievement.
- Target areas are actual area falling under important crops.
- There is no adoption ceiling
- Depreciation on the value of technology in watershed activities is assumed to be constant over period of time.
- Compound rate: 8%
- Elasticity of supply and demand is assumed to be constant over period of time (1995–03).
- Only returns from cost of cultivation of important crops were taken into consideration for investment appraisal, while other impacts of watershed activities such as environmental and social benefits, environmental services, etc. were not valued in economic terms.

The additional expenditure and yield gained responding to each crop are summarized in Table 19. The cost of cultivation (Rs ha^{-1}) and yield (kg ha^{-1}) for all the crops increased over a period but highest economical benefit was recorded in case of wheat where the yield increased by 95.4% (CGR 7.72%) with only an additional increment in cost of cultivation by 10.01 per cent (CGR 1.07%). Groundnut was second economically viable crop with 119.4% increase in yield (CGR 9.12%) with an additional increment in cost of cultivation by 27.97% (CGR 2.78%). Other crops like cotton, cumin and pulses were also economical, as the percentage change in yield recorded higher compared to their percentage change in cost of cultivation.

Considering all assumptions and other components of the study, impact assessment on investment was done. The pay back period of investment was more because we calculated the benefits using available data during 1995–04 while investments were taken since 1983–84. Discussions with the community indicated that yields and area increased during 1983–95, however details were available for 1995–04 period only.

Considering the limitation as mentioned above we could not capture the large benefits during 1983 to 95 period due to unavailability of baseline data. The pay back period of investment is 8 years 5 months and 12 days while the net present value is Rs 8993895. The internal rate of return is 9.43% and benefit cost ratio is arrived at 1: 1. 24. These IRR and B:C ratio values are lower than the general watershed IRR and B: C ratios reported by Joshi et al. 2005 from 311 case studies in India mainly because of huge investments of 16.25 million Rs (9 folds more) in rainwater harvesting structures than the normal watershed programs. Secondly, large benefits during initial period of 1983–95 when rainwater harvesting structures were constructed could not be captured due to lack of baseline data (Table 19).

Landless households (HH) account for about 2% of total HH (6 landless HHs out of total 300) in Rajasamadhiyala watershed. The beneficiaries across different categories ranged from 71–88%. About 84% of landless and 88% of marginal households benefited from various watershed activities (Table 20).

Box 4. Empowerment and Discipline-oriented Development

Rajasamadhiyala village and its micro-watershed program is distinct when compared to its surrounding villages or to other districts of Gujarat. Its prosperity, development and improved livelihoods attract attention. It is the story of a charismatic leader leading his village Rajasamadhiyala on the road to success. Mr Hardevsinh Jadeja decided in 1978, to sacrifice his job and took up the challenge of developing his village. He was elected as a *sarpanch* in 1978. Rajasamadhiyala was like any other village where blind faiths prevailed, witch doctors ruled and common people were exploited Mr Jadeja was sure that without discipline and empowerment, his plan for a natural resource-based development program would not succeed. He devised social norms along with the respective community leaders in the VDC. Initially some members who were exploiting the blind faith of the illiterate villagers challenged his plans, but with the development of RWH structures the trigger for development was set in and community began appreciating his efforts. For the benefit of all members a nominal amount was paid to the *panchayat* and in due course it collected Rs 400000 net income with no outstanding dues. Echoing the community feelings of satisfaction Smt Bhawanaben who runs the *anganwadi* in the village remarked "we have seen the changes in the village and the services we enjoy from the tax we pay. We enjoy having a clean village and get enough water as long as power supply is there". Mr Jadeja remarked, "my methods of operation look radical but without discipline and adherence to rules mere investment in RWH or watershed development would not bring in the fruits of development. There is a need for adopting a holistic approach including human resources development".

Table 19. Impact of watershed development programs on the yield and profitability over a period of time.

	Years			Differences*	Percentage increase	Compound growth rate
	1995–1996	1999–2000	2003–2004	2003–1995	1995–2003	from 1995–2003**
Cost of cultivation (Rs ha^{-1})						
Cotton	34120	35770	42108	7988	23.41	2.36
Groundnut	15995	17430	20469	4474	27.97	2.78
Wheat	22360	23350	24598	2238	10.01	1.07
Cumin	16760	18010	18910	2150	12.83	1.35
Pulses	17020	18315	19375	2355	13.84	1.45
Total	106255	112875	125460	19205	88.05	1.86
Yield (kg ha^{-1})						
Cotton	1732	2483	2658	926	53.46	4.87
Groundnut	712	1158	1562	850	119.38	9.12
Wheat	1683	2832	3288	1605	95.37	7.72
Cumin	717	919	1072	355	49.51	4.57
Pulses	564	728	812	248	43.93	4.13
Total	5408	8120	9392	3984	361.65	6.32
Net Returns (Rs ha^{-1})						
Cotton	-8140	13890	30987	39127	580.68	21.59
Groundnut	-8875	-2955	4913	13788	255.36	10.98
Wheat	-13945	-4942	1706	15651	212.23	8.72
Cumin	15505	27940	45410	29905	192.87	16.42
Pulses	-9117	-7395	-6375	2742	-30.08	-3.90
Total	-24572	26538	76641	56069	911.06	16.22
Cost of Production (Rs kg^{-1})						
Cotton	19.70	14.41	15.84	-3.86	-19.58	-2.39
Groundnut	22.46	15.05	13.10	-9.36	-41.67	-5.81
Wheat	13.29	8.25	7.48	-5.81	-43.69	-6.18
Cumin	23.38	19.60	17.64	-5.74	-24.54	-3.08
Pulses	30.15	25.16	23.85	-6.30	-20.91	-2.57
Total	**108.98**	**82.46**	**77.91**	**-31.07**	**-150.39**	**-3.66**

* The differences are statistically significant at 5 per cent.
** Linear compound growth rate.

Table 20. Households benefited at Rajasamadhiyala watershed, 2003.

HH category	No. of HHs	No. of HHs under project	No. of HHs benefited	% of HHs benefited at the end of Project, 2003
Marginal	132	105	92	88
Small	47	38	32	84
Big	115	92	65	71
Landless	6	6	5	84
Total	300	241	194	81

GRISERV-BAIF, 2003.

Similarly the beneficiaries across all communities/castes (forward, scheduled and backward) varied from 56–84% of HHs with an average of 81% of total HHs. The landless were benefited through various watershed development activities in terms of labor employment for the construction of water harvesting structures, as farm labor due to crop intensification and diversification (3 crops a year), dairying, collection and selling of milk and some other micro enterprises under schemes like Swarnajayanthi Gram Swarozgar Yojana (SGSY), viz., small shops, vegetable vendors, bicycle repair shops, etc.

Institutional development

Catalytic to watershed development in Rajasamadhiyala a number of village level institutions were formed. The other institutions created in Rajasamadhiyala are – Village Development Committee (VDC), Watershed Association and Committee, Self-help and User groups. These institutions played an important role in bringing effective participation of people for successful implementation of the watershed program.

Village development committee

The VDC was formed consisting of 11 members representing each social caste/community in the village in the proportion of the population it represented. The committee is empowered to take decisions in all matters of village development in general and watershed development in particular. It has drawn sovereign authority from the villagers over the years. In the village the VDC and members of all wards appoint the *sarpanch* and deputy *sarpanch* unlike other villages. Elderly members of all communities represent the VDC. They ensure the implementation of VDC's decision in their community. In case of any conflict the VDC has greater power to resolve when compared to other local bodies of village panchayat.

Watershed association and committee

The village is also equipped with watershed association and committee consisting of members who directly or indirectly reside within the watershed area. The committee is registered under the Societies Registration Act as per guideline of watershed development. The watershed association nominates 12 members for watershed committee from different groups of User Groups (UGs), Self Help Groups (SHGs), *gram panchayat*, Watershed Development Team and women representatives along with member from minority communities in the village.

Self-help and user groups

The self-help and user groups constituted as per guideline of watershed development in the village consisting of 18–32 members. The SHG comprised of landless individuals with common or similar sources of income such as animal husbandry, goat rearing, poultry and agriculture labor, etc. The user groups consist of landowners who get benefits from watershed interventions such as water harvesting structures, farm ponds, farm bunds, etc. These groups also consist of the beneficiaries from interventions on common lands such as fodder development, plantation or protection of trees and vegetation.

Leadership oriented development committee

The whole development of the village under the charismatic leadership of the village *sarpanch* – Mr Hardevsinh Jadeja who built the institution of VDC in Rajasamadhiyala. Now though the *sarpanch* is

Mr Devashibhai Kakadia the VDC is headed by Mr Jadeja. He decides, prioritizes the work and decides where it has to be executed. Although it appears to be an autocratic way of functioning, all the sections of the village have benefited. The disciplinary rules and the VDC's decisions are adopted strictly and honestly without allowing any bias. Nobody is spared, if erred, including the village development committee members. The commitment and selfless nature of functioning of the committee and leadership is well accepted by the villagers in all the matters of development. The village members have developed confidence and faith in this kind of "guided democracy".

A very noticeable observation made during the study was – the involvement of women folk in decision making at community level. It was observed that women participate in livelihood activities but do not involve themselves in the community level initiatives. However women are revered in this village as a cultural legacy

Innovative and indigenous initiatives in the watershed

Some of the following innovative indigenous practices are noted:

- Tank silt application, is a very common practice in this village. The novelty here is that they mix the tank silt with farmyard manure (1:1 ratio) and apply it every year (Fig. 20). They even apply the silt about 15 cm deep on shallow uncultivable lands and then cultivate it.
- Farmers pump the bore well water into open wells to soften the bore water and use for irrigation (Fig. 21). Although farmers incur additional expense in pumping bore water into open wells, they still prefer to this method as they receive better quality of water for irrigation.

Figure. 20. Tank silt is collected and heaped.

Figure. 21. Bore water is pumped into open well and used for irrigation.

- Due to abundant water in wells most of the farmers prefer to use diesel and electric pump for pumping (Fig. 22). This practice has been adapted to overcome power shut down problem and to cover more area under irrigation.

Figure. 22. Electric and diesel pump is used in the same well.

- The villagers have used Remote Sensing Technology for identifying dykes and lineaments for recharging groundwater.
- Efficient irrigation systems like drip, sprinkler and water conveyance through pipelines are used.
- Planting fruit trees on field bunds
- Several gully plugs were constructed by farmers themselves
- The commitment of VDC to take up various developmental works such as cement roads and other amenities in the village and efficient utilization of funds from different governmental schemes.
- The cooperation and discipline of villagers to adhere to the disciplinary rules framed by the VDC and prompt payment of taxes to Panchayat
- Construction of a good cricket ground for children in the village and facility used by the surrounding villages for conducting tournaments (Fig. 23).

Figure 23. A well built cricket ground at Rajasamadhiyala village.

Upstream RWH benefited downstream villages

Aniyala watershed

Aniyala is a village located on the downstream of Rajasamadhiyala watershed on topo-sequence. The watershed area is 958 ha (about 80% cultivable and 20% waste lands) with a population of 1500 in 250 families. Soils are medium deep (~0.6 m) and shallow (0.15-0.5 m) black soils. There are 21 water harvesting structures of which eight structures were constructed during the last seven years. The check dams in this watershed were constructed after water harvesting structures were constructed in Rajasamadhiyala. Out of the 125 open wells, 50 wells are functioning and 60 bore wells exist in the watershed. Rainfall and crops grown here are similar to the Rajasamadhiyala. Runoff from the watershed drains into Aaji and Morabo streams.

Since most of the time water in the stream comes through base flow, sedimentation through soil loss is considerably reduced. Due to base flows water harvesting structures get water from Rajasamadhiayala structures and in addition catchment runoff in Aniyala is also harvested. Farmers in this watershed stated that the water harvesting structures constructed in Rajasamadhiyala has benefited them in terms of increased groundwater recharging by 25% over earlier years. In addition to this, after constructing water harvesting structures in their watershed, there has been a significant improvement in the groundwater source (about 50%) in a normal rainfall year. Water in the structures is available up to December and wells give a good yield upto January. The increase in the crop production is about 25 to 30%.

Increased water availability in downstream Aniyala village has changed the cropping pattern with high level of crop productivity. At present increased crop yields of cotton 2.19 t ha^{-1}; groundnut 1.21 t ha^{-1}; vegetables 10 t ha^{-1} and pigeonpea 0.55 t ha^{-1} are observed. The fodder productivity is 56.55 t ha^{-1}. The average crop productivity of important crops during rainy season is given in Figure 24.

Box 5. All round prosperity of the villagers in downstream village

Average land holding of Aniyala is 1.6 ha per household and 60% families have less than 2 ha and 4 ha are with 4–5 households and few have above 4 ha. The average family size is 4 to 5 members, boys study up to 8th standard while girls generally study up to 10th standard and at the age of 20 they get married. On an average Rs 50,000 is spent on a marriage. The village has five graduates (including one female). About 10% households are landless and they work as farm labor/professional labor. The village has 5 autorickshas and 20 tractors. Every house has electricity and 50 *goba*r gas plants in the village. Each family has 1–2 milking animals, of which 60% animals are buffaloes and 50% are improved breeds *(Jafarabadi*, *Murrah)*. Improved crossbred cows constitue 40% of milking animals. Buffaloes yield 13 L and cow 7 L per day. The men collect income from milk although it is the women who take care of the animals. Generally men are the decision makers in this village.

With improved water and food availability, the quality and number of livestock in the village have improved. Cross-bred cows per household are 0.6 out of which 0.4 (66.67%) are milching cows.

These cows produce on an average 7 litre milk per day. Similarly, per household, the number of milching buffaloes increased accounting to 0.6 (75%) out of 0.8 per household. The average milk of buffalo is 13 litre per day. The availability of bullocks in the village is low as 0.2 bullocks per household were found during the time of survey.

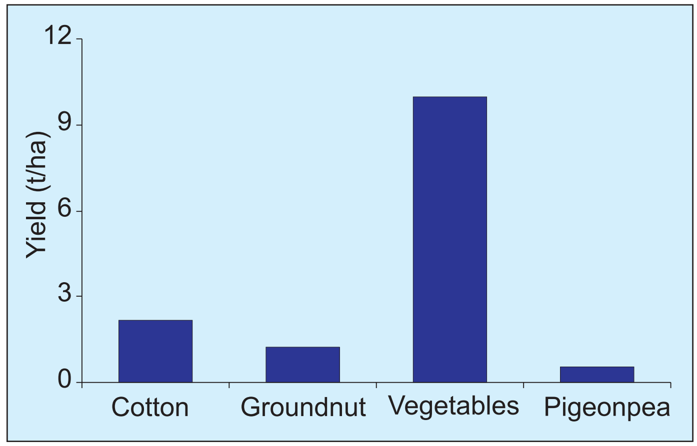

Figure 24. Average productivity of major crops in Aniyala downstream village.

Increased crop productivity enhanced the household income in the village as well as from diversified vegetables and fruits increased gradually parallel to Rajasamadhiyala micro-watershed. The initial increase in the income of farmers had a multiplier impact on different sources of income with an accelerator affect, coupled with the galloping increase in the non-agriculture income (about two times over the period) (Fig. 25).

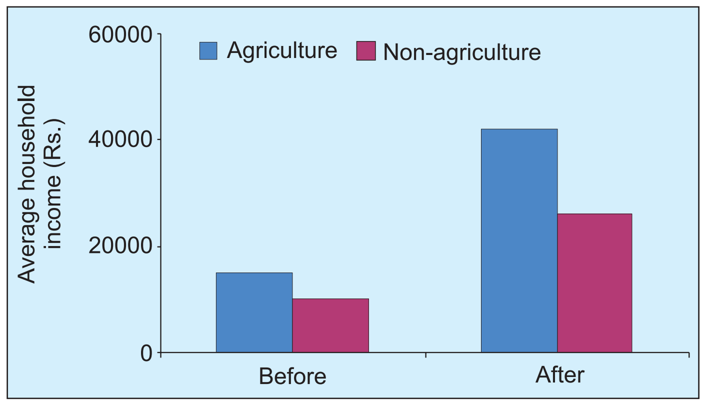

Figure 25. Average Income of households in the off-site village (Aniyala).

The higher level of water productivity has transformed the livelihood of farmers in the village and farmers are engaged in agriculture as well as other allied activities. These changes have led to declined migration of male labour force (there is no female labour migration). During the survey it was seen that only 12% of total population, of which 66% are skilled labor, migrated to nearby urban areas for better employment opportunities. Most of the farmers (72%) were happy to get opportunities for increasing their productivity and profitability due to improved watershed management in Rajasamadhiyala. Good number of farmers were of the view that the potential benefits from land have not been yet been totally harnessed and await for an integrated watershed management program to begin.

Kasturba Dham (K B Dham at Tramba)

KB Dham is a village situated further downstream to Rajasamadhiyala near the Rajkot watershed, where the Aaji lake is situated. KB Dham has an area of 1000 ha with a population of 4000, which is 15 km from Rajkot. Soils are medium deep (0.6–0.9 m) to shallow (0.15–0.5 m) black soil. There are three major streams converging here – Saran coming from Lakhapur, Sardhar, Rajasamadhiyala and Aniyala, Bhand coming from Dhandia, Morabo from Padasan Rajasamadhiyala and Aniyala. There are 21 water harvesting structures, out of which 15 are large ones. In most of the structures, water stays for about 5–6 days after 1st filling and with subsequent storms, water stays for 20–30 days. Normally 3–4 times overflows occur in a year from these structures. Check dams, which are constructed on Saran stream, retain water for longer duration than other check dams due to the continuous base flow in Saran stream. For example, during the field visit of team in the month of November 2004, 3 check dams in series were full of water on Saran stream upto a length of 1.25 km long with an average depth of water in structures of 1.8 m. The volume of water stored was about 90900 m^3.

There are around 200 open wells in the village with a depth ranging from 50–100 ft, out of which only 85 are functioning which are located near check dams. The remaining 115 are defunct. Fifty wells nearer to check dams on Saran stream have good water source, 25 wells on check dams on Bhand stream have moderate water source and 10 open wells in the vicinity of check dams on Morabo stream are deeper and comparatively have less water.

There are 525 bore wells in the village, dug before constructing the check dams. The farmers observed that there was good improvement in bore well water levels after constructing the check dams.

There was about 25% improvement in the groundwater source after the watershed program was implemented. Farmers observed that before the massive construction of check dams in upstream watershed Rajasamadhiyala and Aniyala, water used to flow into the Aaji river in a short span of time. Now after the check dams are full, water flows to downstream through base flow after increased groundwater rechargeability due to percolation. This way groundwater is recharged better and soil erosion is reduced. They also quoted an example of sedimentation in a 40-year old check dam, which used to get filled with silt every 2 years before the check dams construction in Rajasamadhiayala watershed. Now there is absolutely no siltation from upstream watersheds. Farmers are happy and not affected by the water harvesting structures in upstream watershed Rajasamadhiyala. In fact this watershed has benefited in terms of groundwater recharge through base flow from structures in the upstream watershed and reduced siltation in the village tanks. Farmers of KB Dham expressed that still 8–10 check dams can be constructed to prevent the excess runoff, which is draining into the Aaji lake. They also opinioned that bigger check dams (>20000 m^3 capacity) are more effective compared to smaller check dams in term of groundwater recharge based on their observation on open wells around these check dams. Water in structures normally stores upto December and is available for agriculture in open wells

Box 6. Watershed development revived open wells in Kasturba Dham

Kasturba dham being in the vicinity of Rajkot town villagers had good access to bore well technologies and farmers tried to cash on the market. Mavji bhai Trapasiya, a farmer from the village stated that the village had 200 open wells. Open wells dried up due to inappropriate land and water management practices and overexploitation of groundwater. Farmers started digging bore wells increasingly reaching upto 525 bore wells in a village of 769 households with 1000 ha area. Along with the number of bore wells, depth of bore wells also went on increasing. Most bore wells in Kasturba dham are 800 + feet deep. In spite of increased depth many bore wells had insufficient water of poor quality. Tea prepared with bore well water used to get spoilt due to splitting of milk. After observing the benefits gained by rainwater harvesting in Rajasamadhiyala the villagers with help of government officials constructed 21 rainwater harvesting structures on three streams. Impact of increased base flow from upstream rainwater harvesting structures was quick and visible.

Mr Mavji bhai Trapasiya is happy that now he has good quality water in his open well.

up to February-March. During summer well water is just sufficient for domestic and animal use. Only few farmers grow vegetables during summer in small area depending on water availability in their well.

Improved water availability resulted in cropping pattern shifting towards cash crops with short season crops like vegetables from perennial and long duration crops. The average productivity of cotton is 1.69 t ha^{-1}, groundnut 0.93 t ha^{-1}, vegetables 10.48 t ha^{-1} and pigeonpea 0.55 t ha^{-1} in the village (Fig. 26). Average fodder production recorded in the watershed is 62.8 t ha^{-1}.

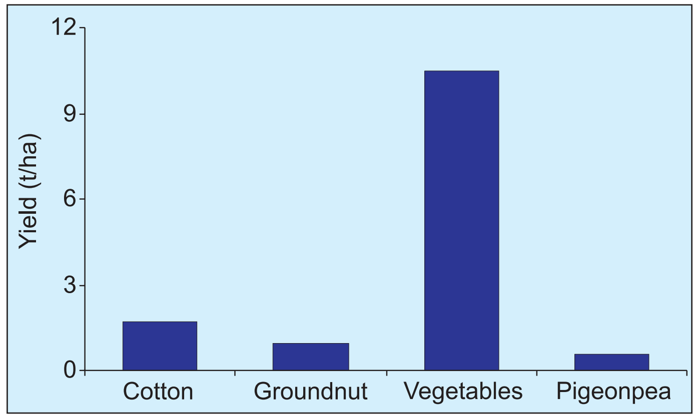

Figure 26. Crop productivity in off-site village Kasturba Dham.

Other composite impact of increased water availability was also realized on livestock production. Average availability of milching cow is 0.2 per household while the number of buffaloes is 1.2 per household. The availability of bullocks is higher i.e., 1.2 per household in the village as compared to Aniyala. Increased production and availability of fodder with better market facilities due to proximity of Rajkot city resulted in an increase in the numbers of buffaloes in the village.

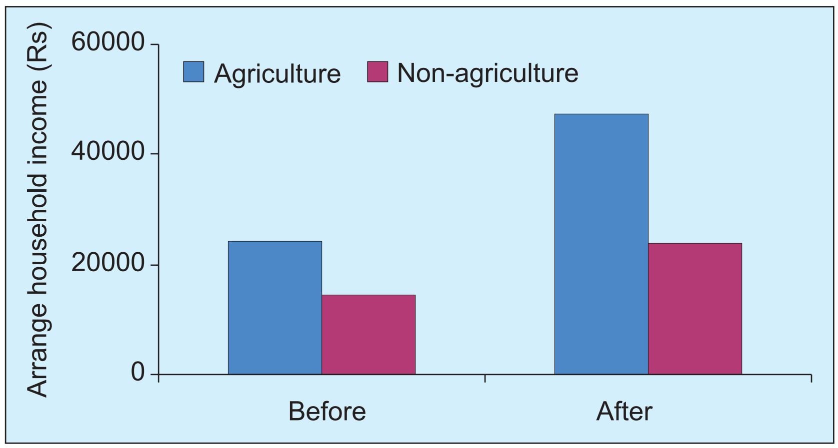

Figure 27. Average household income before and after watershed interventions Kasturba Dham.

The multi-dimensional impact of change in productivity has increased the income of households during the same period. The income of household increased from agriculture (from 24250 Rs to 47000 Rs y^{-1}) by 95.88% while the income from other non-agriculture sources (from 14300 to 24000 Rs y^{-1}) by 67.83% (Fig. 27).

Increased employment opportunities for people in the village resulted in reduced migration (8.2%) of which 64% were skilled people migrating for better livelihoods.

Movable and non-movable assets of farmers also increased, which led to better socioeconomic status of farmers. The perception of farmers about watershed technology is more inducive and they are keen on adopting the strategy of watershed technologies in the village itself.

Development in these two downstream villages is attributed to the enhancement of water availability due to watershed activities taken up in the upstream micro-watershed Rajasamadhiyala.

Conclusions

The study reveals that water scarcity and land degradation were the major constraints to agricultural productivity in the village Rajasamadhiyala before implementation of watershed development activities. Although the watershed interventions especially water harvesting structures were initiated in the village since 1983, substantial investment in watershed activities only started from 1987–88 onwards. Perceptible changes were observed in areas under irrigation, cropping pattern and intensity along with diversification of crops from traditional to commercial or cash crops. Over a period of time water storage capacity increased significantly, covering more area under irrigation and enhancing the cropping pattern, intensity and productivity of several crops. Both per capita cultivable land and yield increased but per capita availability of produce increased drastically in the village during the period of watershed development programs. Crop productivity in upstream watershed Rajasamadhiyala is higher than the two downstream villages. For example, in case of groundnut it is 29% higher than in Aniyala and 68% higher than in K B Dham. Similarly cotton productivity is 21% higher in Rajasamadhiyala than in Aniyala and 57% higher than in KB Dham. In Rajasamadhiyala watershed higher production is seen in some of the crops, such as vegetables, higher by 67% and 59%, pigeonpea 53% and fodder by 40 and 26% compared to Aniyala and KB Dham villages respectively.

A significant change was also observed in the cost of cultivation. Due to higher increment in returns of crops the benefit:cost ratio changed from negative to positive and at present except pulse crops other important crops have positive benefit cost ratio. Investments in watershed program showed good net present value and internal rate of returns. Interventions in watershed significantly improved the socioeconomic status of people, provided more employment opportunities while maintaining good environment and soil and water balance in the watershed. In the village food, fodder and fuel security improved sharply within a short span. Increased income from agriculture and other allied sectors such as livestock rearing, enabled farmers to maintain a higher consumption status and enhanced standard of living, this provided the farmers enough work opportunities in farming.

In conclusion huge investment of 16.25 million rupees in rainwater harvesting structures which is nine folds more than the normal watershed investments have currently benefited farmers in the watershed as well as the farmers from the downstream villages also. Agricultural crop productivity was increased by 119% in case of groundnut, 53% in cotton, 95% in wheat and by 50% in case of cumin. The internal rate of return was 9.4% with the cost benefit ratio of 1: 1.24 on such a large investment. Public investments through watershed programs in India improved water availability in rainfed areas and increased productivity and incomes which in turn triggered private investment in rainfed areas. However, over-exploitation of groundwater such as doubling the number of bore wells as well as pumping hours in Rajasamadhiyala will jeopardize the development unless suitable legal or social mechanisms for sustainable use of groundwater use are put in place by the community.

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Annexure 1

Details of water harvesting structures at Rajasamadhiyala watershed

Type of water harvesting structure	Storage capacity (m^3)	Unit cost (Rs m^{-3})	Year	Benefited area (ha)	No. of farmers benefited	No. of wells benefited	Catchments area (ha)
Causeway-cum-check dam	11765	10	1999	10	3	4	16
Causeway- cum-check dam	3456	49	1998	14	5	7	7
Causeway-cum-check dam	6292	11	1997	13	5	6	9
Causeway- cum-check dam	1350	15	1994	6	7	9	2
Causeway-cum-check dam	5344	15	1999	17	4	5	7
Causeway- cum-check dam	1725	38	1998	19	7	8	3
Causeway-cum-check dam	1266	41	1998	9	5	5	2
Causeway- cum-check dam	2229	33	1998	11	6	5	4
Causeway-cum-check dam	6428	31	2000	17	7	8	9
Causeway- cum-check dam	6000	42	2003	16	6	6	12
Check dam	5063	23	1998	11	8	10	7
Check dam	15306	9	1998	21	7	9	16
Check dam	11975	21	2000	12	3	4	23
Check dam	2100	17	1996	5	3	3	4
Check dam	1350	15	1998	4	5	5	2
Check dam	1040	28	1998	9	4	4	2
Check dam	6628	15	1997	18	5	6	9
Check dam	4046	5	1998	8	3	3	6
Check dam	3642	21	1998	14	5	6	5
Check dam	1806	6	1998	3	2	2	3
Check dam	8495	12	1999	29	5	5	12
Check dam	1411	28	1998	7	4	5	3
Check dam	1548	25	1998	8	3	3	3
Earthen bund (4 No.)	7385	7	1997	4	2	2	11
Farm pond (6 No.)	4800	13	1997	9	3	4	5
Gully plug (5 No.)	1200	5	1998	2	2	2	2
Percolation tank	61200	5	1992	32	11	16	109
Percolation tank	32231	31	1987	38	5	11	50
Percolation tank	112000	14	1983	53	9	19	142
Percolation tank	110700	5	1987	42	8	8	98
Percolation tank	59497	20	1987	42	7	11	75
Percolation tank	7595	4	1997	6	2	2	12
Percolation tank	70726	11	1992	32	9	9	90
Percolation tank	26980	4	1942	28	5	7	53
Percolation tank	13210	38	1986	25	6	8	19
Percolation tank	40000	13	1987	38	6	8	52
Percolation tank	39141	31	1987	31	7	9	35
Percolation tank	132475	15	1987	67	14	24	162
Percolation tank	1056	34	1999	6	4	6	2
Percolation tank	25000	20	2002	21	8	11	35
Total storage capacity (m^3)	855461	19.4*					

*Average unit cost of all structures.

Annexure 2

Various watershed development activities and their expenditure under watershed project

Details of works	Quantity	Expenditure (Rs)
Entry point activity	2	112101
Other expenditure	-	6880
I. Water harvesting structures		
Kutcha check dams	4	5000
Pucca check dams	3	87901
Percolation tanks	5	210902
Causeway-cum-check dam	7	624045
Composite structures	5	495811
Farm ponds	5	65500
Earthen bund	4	58020
II. Agriculture		
Farm bunding (R mts)	1050	21000
Demonstration plot	20	17728
Agro-horticulture plot	2	2512
Kitchen garden kit	20	920
III. Afforestation		
Afforestation (Gramvan area in ha.)	1	18916
Agro-forestry (No. of plants)	10000	5950
Fruit plants distribution (No.)	1500	25612
IV Animal Husbandry		
Pasture land improvement (ha)	10	11760
Deworming to cattle (No. of doses)	400	7760
Mineral powder distribution (kg)	75	3000
Fodder demonstration plot	7	1175
Chaff cutter	40	9400
FMD vaccination	400	3180
Infertility camp	3	4528
Total		1799601

Source: GRISERV-BAIF Report 2003

Annexure 3

Change in area, productivity and yield over 1995

Crops	Change in 1999 over 1995 (%)			Change in 2003 over 1995 (%)		
	Area	Productivity	Production	Area	Productivity	Production
Rainy season						
Cotton	22.60	43.36	75.76	16.72	53.46	79.12
Groundnut	-17.75	62.64	33.77	-13.02	119.38	90.82
Jowar	-28.57	17.25	-16.25	28.57	27.07	63.37
Bajri	25.00	12.47	40.59	37.50	17.24	61.20
Maize	22.22	17.93	44.13	55.56	37.43	113.79
Vegetable	13.79	12.18	27.65	44.83	15.72	67.60
Pulses	-16.67	42.47	18.72	16.67	64.77	92.24
Other	16.67	18.69	38.47	50.00	27.67	91.50
Postrainy season						
Wheat	164.29	68.27	344.72	764.29	95.37	1588.52
Cumin	112.50	28.17	172.37	362.50	49.51	591.49
Pulses	-40.00	17.80	-29.32	-20.00	26.70	1.36
Vegetable	166.67	20.18	220.47	66.67	22.67	104.46
Fodder	66.67	12.36	87.27	33.33	14.58	52.77
Summer						
Fodder	60.00	10.85	77.36	100.00	14.68	129.36
Vegetable	75.00	19.19	108.59	175.00	19.56	228.79
Sugarcane	50.00	7.12	60.68	50.00	8.60	62.90
Maize+g.nut	31.58	1.75	33.89	78.95	3.82	85.79
Pulses+g.nut	85.71	27.77	137.28	157.14	53.20	293.95

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The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is a nonproýt, 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 600 million poor people to overcome hunger, poverty and a degraded environment in the dry tropics through better agriculture. ICRISAT belongs to the Alliance of Future Harvest Centers of the Consultative Group on International Agricultural Research (CGIAR).

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