

**Farmer-Participatory Integrated
Watershed Management:
Adarsha Watershed, Kothapally
India An Innovative and
Upscalable Approach**

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Background and rationale

The semi-arid tropics (SAT) are generally characterized by highly variable and low rainfall, low productivity soils and poor development infrastructure. It is these factors that are largely responsible for poverty in the rainfed areas of the SAT. Moreover, the fragile ecosystems of the dry areas are prone to degradation. Widespread poverty, hunger and malnutrition, with complex and diverse socioeconomic characteristics, make these areas challenging for researchers and development professionals.

Watershed management is increasingly being recognized as the ideal approach for integrated natural resources management in rainfed areas. About 51% of India's geographical area (329 million ha) is categorized as degraded, most of which occurs in rainfed agro-eco systems. About 70% of the population is dependent on agriculture, and two thirds of the cropped area is dependent on rainfall without any protective irrigation (Wani *et al.* 2001).

Problem

Rainfed arable lands are predominant (80%) worldwide and contribute 60% of the world's cereal output. In developing countries up to 70% of the population depends directly or indirectly on agriculture, and 560 million poor people live in the semi-arid tropics. Most of the rainfed areas in developing countries suffer from one or another form of land degradation. Currently the average productivity of rainfed areas in the SAT is around 800-1 000 kg ha⁻¹. Several studies have identified the main constraints for increased productivity in the tropics as low rainwater use efficiency for crop production (35-45%), inherent low soil fertility, inappropriate soil, water and nutrient management practices, low adoption of stress-tolerant cultivars of crops, insufficient pest management options and poverty (inability to invest for necessary inputs). Due to variations in seasonal rains during the crop growing period, crops may face drought and sometimes waterlogging due to torrential downpours causing runoff. In order to conserve rainwater, minimize land degradation, improve groundwater recharge, increase crop intensity and crop productivity a watershed management approach is adopted (Kerr *et al.* 2000; Samra 1997; Wani *et al.* 2002). The success of watershed management largely depends on the community's participation. In a recent review (Joshi *et al.* 2000; Kerr *et al.* 2000) on the watershed projects in India, it was observed that most watershed projects did not address the equity issues of benefits, community participation, scaling-up approaches, monitoring and evaluation. Moreover, most of these projects relied heavily on government investments and were structure-driven (rainwater harvesting and soil conservation structures), and failed to address the issue of the efficient use of natural resources (soil and water). This is mainly due to the lack of technical support to such projects implemented by NGOs (Wani *et al.* 2001).

Objectives

The overall objective of the project was to enhance and sustain productivity in soils of medium to high water holding capacity in the intermediate rainfall ecoregion with emphasis on arresting soil degradation.

The activities adopted to meet these objectives were (ICRISAT 2002):

- Characterization of the natural resource base, and identification of physical and socioeconomic constraints for sustainable production.
- application of integrated, cost-effective, soil-water-nutrient management (SWNM) practices appropriate to farmers' resources and the natural resources of the ecosystem.
- Rehabilitation of degraded soils, and studies on the effects of integrated SWNM strategies on system profitability and sustainability.
- Integration and evaluation of the techno-socioeconomic feasibility of promising strategies for crop intensification and reduction of soil degradation, and to learn lessons on the benefits of scaling-up and scaling-out of watershed-based integrated genetic and natural resource management (IGNRM) to other parts of the SAT.

Approach

The main components of the participatory consortium approach for community watersheds are:

- Involvement of government authorities in the consortium from the beginning.
- Formation of consortiums of local, regional, national and international research and development institutions for providing technical support to the NGOs and farmers.
- Refinement of technologies and on-farm strategic research experimentation by farmers with technical support from the consortium partners.

The process/approach is depicted in Figure 1.

Integrated watershed management: ICRISAT's innovative consortium model

A new farmer participatory consortium model for efficient management of natural resources emerged from the lessons learnt from long-term watershed-based research led by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and national partners. The important lessons learnt from earlier watershed-based research showed a lack of:

- equity in the benefits to small holders and landless;
- sustainability in the management of watersheds after cessation of the project;

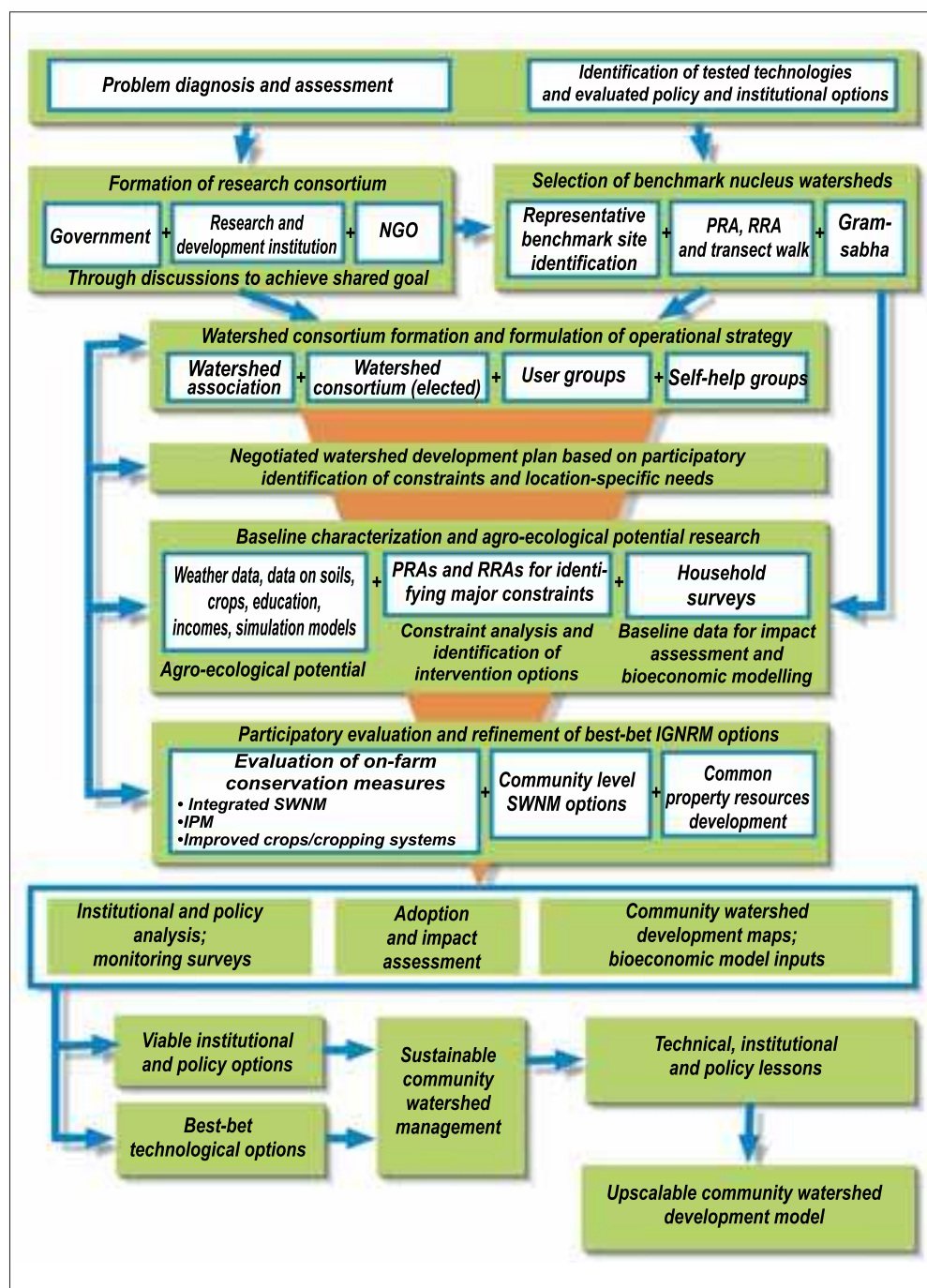


Figure 1. Process of participatory consortium approach through watersheds.

- community participation in watersheds;
- scaling-up methods and models;
- monitoring and evaluation of the impacts of watershed interventions;
- holistic approaches in the technical support to most development projects implemented by NGOs.

The important components of the new model, which are distinctly different from earlier models, (Wani *et al.* 2002) are:

1. Farmers in the watershed area collectively identify and prioritize the problems for possible technical interventions.
2. Participatory planning and implementation of watershed research and development involves all stakeholders. Farmers' groups selected the sites for rainwater harvesting structures, as well as cropping systems and varieties with technical support from the consortium partners.
3. New science and technology tools such as remote sensing, geographical information system, photogrammetry, digital terrain modelling and crop simulation models are applied.
4. Knowledge flow is facilitated by linking successful on-station watersheds and on-farm watersheds for strategic research.
5. A holistic systems approach for watershed management for livelihood improvement is adopted, instead of solely soil and water conservation.
6. A consortium of international, national, governmental and non-governmental organizations (NGOs) provide technical backstopping to community watershed programmes.
7. Increased individuals' participation is ensured by providing tangible economic benefits. The emphasis on *in situ* conservation of rainwater is translated into increased soil water availability, that is in turn translated into increased productivity through IGNRM.
8. The Islanding approach is used, in which a microwatershed is established within the watershed to serve as a site of learning.
9. For technical development and inputs on individual/private land, users pay (i.e., no subsidy), whereas for community-based interventions it is largely the government that pays, with only 10-30% contributions from beneficiaries.
10. Scaling up and technology dissemination is facilitated by using bench mark sites as training sites for partners and farmers, and for sensitizing policy makers.
11. Cost-effective and environmentally friendly soil, water, nutrient, crop and pest management practices are used for wider and quicker adoption, and to raise the carrying capacity of the system.
12. Traditional knowledge is combined with new knowledge for the efficient management of natural resources.
13. Capacity building of local farmers and NGOs is carried out to promote the effective dissemination of technologies.
14. Empowerment of communities, individuals and the strengthening of village institutions is achieved through concerted efforts to foment sustainable development.
15. Youth, women and landless people are involved in income-generating micro-enterprises within watershed projects.

16. Continuous monitoring and participatory evaluation by researchers and stakeholders is carried out to assess the overall performance of watershed management.

On-station SWNM research in a watershed at ICRISAT Centre, Patancheru, began in 1976 and has yielded impressive successes. The execution of technologies at ICRISAT and in farmers' fields was undertaken early on to demonstrate the potential benefits of these technologies in enhancing the productivity of rainfed farming systems. Based on the lessons learnt, a new IGCRM model was developed and evaluated from 1999 onwards. The new integrated watershed management model was developed by establishing five on-farm and three on-station watersheds covering various agro-ecological, socioeconomic and technological situations in India, Thailand and Vietnam, with technical backstopping by ICRISAT. One of the successful cases, the on-farm Adarsha watershed at Kothapally in Andhra Pradesh, India, is described hereunder.

Adarsha watershed, Kothapally

The watershed is located in Kothapally village (longitude 78° 5' to 78° 8'E and latitude 17° 20' to 17° 24'N) in Ranga Reddy district, Andhra Pradesh, nearly 40 km from ICRISAT Centre, Patancheru. It covers 465 ha of which 430 ha are cultivated and the rest are wasteland. The watershed is characterized by an undulating topography with an average slope of about 2.5%. Soils are predominantly Vertisols and associated soils (90%) (Figure 2). The soil depth ranges from 30 to 90 cm (Figure 3) and the soils have medium to low water holding capacities. The total population in Adarsha watershed is 1 492 belonging to about 270 cultivating and four non-cultivating families. The average landholding per household is 1.4 ha (Shiferaw *et al.* 2002).

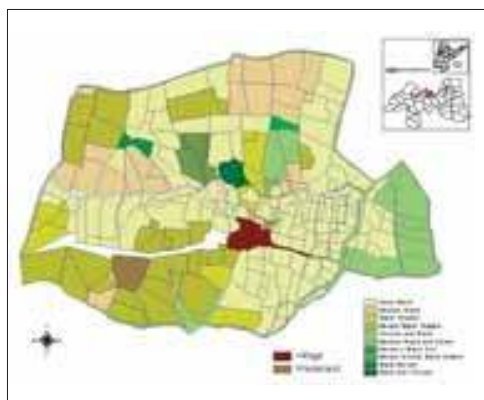


Figure 2. Soil types of Adarsha watershed, Kothapally.

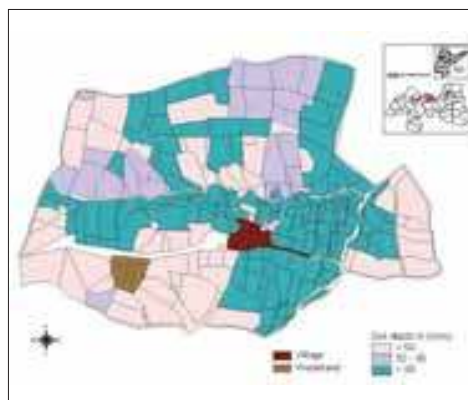


Figure 3. Soil depth map of Adarsha watershed, Kothapally.

Consortium approach

An innovative model with a consortium of institutions, as opposed to a single institution, was formed for project implementation and technical

backstopping. ICRISAT, M Venkatarangia Foundation (MVF) an NGO, Central Research Institute for Dryland Agriculture (CRIDA), National Remote Sensing Agency (NRSA), District Water Management Agency (DWMA), Ranga Reddy District of Government of Andhra Pradesh along with farmers formed the consortium (Figure 4) (Wani *et al.* 2001). All the partners were working, either individually or in partnership with another institution, to conserve rainwater and manage the watershed sustainably.



Figure 4. Farmer-participatory consortium approach for integrated watershed development.

Adarsha watershed was selected by ICRISAT, DWMA, and MVF in consultation with other stakeholders. The main criteria used in the selection were: existence of a large proportion of dryland farming, few water harvesting structures, and minimum interventions to conserve soil and water. Adarsha watershed was finally selected after a meeting with villagers in *Gram Sabha*, where villagers came forward to participate in the proposed watershed activities.

Promoting community participation

The participation of the local community i.e., farmers, is essential if watershed management is to have a successful impact. A successful partnership based on strong commitment by state and local agencies, community leaders and people is desirable. To promote community participation in the watershed for site selection, implementation and assessment of activities, various committees/groups were formed. It was

recognized that to shift the community participation from contractual to a consultative and collegiate mode it was necessary to provide tangible private economic benefits to individuals. Such benefits could come from *in situ* rainwater conservation leading to increased farm productivity through the application of the IGNRM approach. Most importantly, full participation is necessary from the initial stage of watershed selection through the selection of crops, systems, and varieties, to the monitoring and evaluation of watershed activities. No subsidies were given for investments on individuals' farms for technologies, inputs and conservation measures. The principle used was that "users pay". Once individuals were able to realize the benefits of soil and water conservation they came forward to participate in other community activities in the watershed by becoming members of various organized groups as follows:

- **Watershed Association:** All the 270 farmers are members of the watershed association. The association is registered under the Registration of Societies Act, and is a sovereign body that decides every activity in the watershed.
- **Watershed Committee:** This is an executive body of the association and is headed by a chairperson who is unanimously elected. A secretary, who maintains the records and eight members representing different sections of the community form the other members of the committee.
- **Self-help groups:** Self-help groups were formed to undertake specific watershed management activities.
- **User groups:** User groups were formed to manage (operate and maintain) water-harvesting structures.
- **Women self-help groups:** Women were empowered to form self-help groups to undertake village-level enterprises for income generation. Ten such groups with 15 members each took up vermicomposting as an enterprise in Kothapally village.

Baseline survey

A detailed baseline survey of the watershed was conducted to study major socioeconomic and biophysical constraints to sustainable crop production. The following information was collected:

1. socioeconomic status of the farmers and landless people (household and demographic characteristics, land ownership, land use, livestock and other assets), crop production, cropping patterns, yields, markets and livelihood opportunities;
2. soil characteristics, climate, cropping systems, their productivity and inputs (GIS maps were prepared for soil types, soil depth and crops grown in the village);
3. soil, water, nutrient and pest management practices followed by the villagers;
4. production constraints, yield gaps and opportunities for crop intensification.

The results of the survey indicated that in Kothapally village: (i) dryland areas were more extensive than irrigated land; (ii) literacy was low; (iii) labour was scarce; (iv) there was an inverse relationship between land size and fertilizer/pesticide use; (v) crop yields were low, (vi) there was not a single water harvesting structure in the village; and (vii) no income generating activities had been taken up by the villagers (Shiferaw *et al.* 2002).

Interventions to enhance productivity and income

Soil and water conservation measures

Using the baseline survey of the village and a detailed reconnaissance survey of the watershed, the watershed committee identified sites for soil and water conservation structures and other measures. ICRISAT provided technical support for cost-efficient water storage and soil conservation structures. The measures are categorized as community- and individual farmer-based.

Community-based interventions

These measures were implemented on common resources, viz. water courses, *nala* and wastelands. The committee members had identified 21 potential sites for water storage structures (small check dams), 270 sites for *gully* control structures, 11 *gabion* structures, 38 ha for field bunding, and a 500 m long diversion bund to avoid damage to crop lands. Fourteen water storage structures (one earthen and 13 masonry) with a capacity of 300 to 2 000 m³ water storage were constructed (Figure 5). Ninety seven *gully* control structures and 60 minipercolation pits, one *gabion* structure for increasing groundwater recharge, a 500 m long diversion bund and field bunding on 38 ha were completed.



Figure 5. Community-based masonry check dam.

Twenty-eight dry open wells, near *nala* (small streams), were recharged through runoff water flowing in the *nala* during runoff events. A users group was formed for each water storage structure, and the water collected in the storage structures was exclusively used for recharging the groundwater.

The total cost of all soil and water conservation structures was US\$20 023 which included 14 check dams (US\$16 586), 97 *gully* control structures of loose stones (US\$1 555), 60 mini-percolation tanks (US\$924), a 500 m division drain (US\$619) and runoff diversion pipe system to regenerate 28 abandoned dry wells.

Farmer-based interventions

Farmer-based soil and water conservation measures implemented in individual fields (Figures 6 and 7) (Wani *et al.* 2002) were broad-bed and furrow (BBF) landform and contour planting to conserve *in situ* soil and water; use of the tractors for planting, fertilizer application and weeding operations; field bunding (38 ha); and planting *Gliricidia* on field bunds to strengthen bunds, conserve rainwater and supply nitrogen-rich organic matter for *in situ* application to crops.



Figure 6. Broad-bed and furrow landform constructed with the tractor.



Figure 7. Gliricidia plantation on field bunds to produce N-rich organic matter and to conserve soil and water.

Several farmers evaluated BBF and flat landform treatments for shallow and medium-depth black soils using different treatment combinations. Farmers obtained 250 kg more pigeonpea and 50 kg more maize per hectare using BBF on medium-depth soils than from the flat landform treatment. Furthermore, even on the flat landform treatment farmers harvested 3.6 t maize and pigeonpea using improved management options compared to only 1.7 t maize and pigeonpea grain from their normal cultivation practices (Table 1). The farmers with shallow soils reported similar benefits from BBF landform and improved management options for other cropping systems. The rainfall during 1999 was 559 mm, 30% below normal and that received in 2000 was 958 mm, 31% above normal. Despite this variation in rainfall, the productivity of the crops marked a sustainable increase during 1999-2000 and 2000-01 (ICRISAT 2002).

Table 1. Productivity in on-farm trials at Adarsha watershed, 2001.

System	Soils	Landform	Yield (kg ha ⁻¹)		Total system productivity (1+2) (kg ha ⁻¹)
			(1)	(2)	
Maize ¹ /PP ²	Shallow	BBF	1 750	380	2 130
Maize/PP	Shallow	Flat	1 680	290	1 970
Maize/PP	Medium	BBF	2 830	1 070	3 900
Maize/PP	Medium	Flat	2 780	820	3 600
Maize	Medium	BBF	3 000	-	3 000
Maize	Shallow	BBF	2 030	-	2 030
Sorghum	Medium	BBF	3 000	-	3 000
Maize/PP (Local farmers practice)			1 400	230	1 710
Sorghum/PP (Local farmers practice)			470	115	585
Sorghum (Local farmers practice)			1 010	-	1 010

1. Main crop (maize/sorghum); 2. Component crop (pigeonpea -PP)
BBF - Broad-bed and furrow

Wasteland development and tree plantation

Common wasteland treatment involved by planting saplings of useful species along the roads, field bunds and *nalas*. Contour trenches at 10 m intervals with a 0.3 m height of bund were laid out. A custard apple plantation was undertaken by the farmers by planting on the bunds, and *Gliricidia* saplings were planted along the borders of the wasteland to serve as live fences. An avenue plantation was also adopted in the village as part of the village afforestation programme. Twenty five hundred fruit trees and teak plants were planted on field bunds (Figure 8).



Figure 8. Tree plantation on wasteland.

Integrated nutrient management

The integrated nutrient management approach was adopted to enable good crop growth from conserved soil and water. The project adopted the INM approach with on-farm evaluation by farmers of the Adarsha watershed.

Detailed soil characterization

Detailed characterization of the soils showed they are low in available P (1.4 to 2.2 mg kg⁻¹ soil), available N (11 mg kg⁻¹ soil), zinc (Zn), boron (B), and sulphur (S) in addition to low in organic carbon. Farmers in the watershed evaluated B and S amendments. Amendments with B, S and B+S treated plots resulted in 13 to 29% increases in sorghum grain yield and 20 to 39% increases in maize grain yield (Table 2) (ICRISAT 2002).

Table 2. Total productivity of sorghum and maize with boron and sulphur amendments at Adarsha watershed, Kothapally, 2001.

Treatment	Sorghum yield (kg ha ⁻¹)			Maize yield (kg ha ⁻¹)		
	Grain	Residues	Total productivity	Grain	Residues	Total productivity
Control	1 460	2 800	4 260	1 960	2 360	4 320
Boron (B)	1 650	3 030	4 680	2 360	2 640	5 000
Sulphur (S)	1 890	3 320	5 210	2 730	2 840	5 560
B+S	1 800	3 490	5 290	2 580	3 060	5 640

Nutrient budgeting

Nutrient budgets were studied using stratified random sampling by dividing the watershed into three toposesquences and farm holdings. This approach helped to calculate the nutrient budgets at a watershed level, and assisted in developing balanced nutrient management strategies. In Adarsha watershed, the balance for N, P and K were computed on 15 farmers' fields who were following improved soil, water and nutrient management options along with conventional practices.

The N, P and K nutrient uptake by maize/pigeonpea intercrop system and sole maize was greater in the improved BBF system compared to that on the flat landform, and was translated into higher crop yield on the BBF landform. The balances also showed that all systems were depleting N and K from soils, and that more P is applied than removed by crops (Table 3) (ICRISAT 2002).

Table 3. Nutrient budgeting studies in farmers' fields, Adarsha watershed, Kothapally, 1999-2000 (kg ha⁻¹ yr⁻¹).

Cropping system	Total input			Total output			Budget		
	N	P	K	N	P	K	N	P	K
Maize/pigeonpea									
BBF	28.3	16.4	17.1	84.5	10.6	57.6	-55	+6	-40
Flat	32.2	13.8	21.2	80.2	8.8	49.7	-48	+5	-29
Sole Maize									
BBF	20.5	10.0	0	74.8	14.1	70.6	-55	-4	-70
Flat	9.0	10.0	0	32.7	7.3	35.9	-24	+3	-35
Sole Sorghum									
Flat	18.3	9.0	11.0	41.8	9.7	64.3	-24	+0.2	-53

BBF - Broad-bed and furrow

In-situ generation of N-rich green manure

On-station watershed studies at ICRISAT have shown that *Gliricidia* loppings provided 31 kg N ha⁻¹ y⁻¹ without adversely affecting crop yield (ICRISAT 2002). Farmers have planted about 50 000 *Gliricidia* saplings on bunds for generating N-rich organic matter.

Worm farming to boost income

Training on vermicomposting was imparted to 10 women self-help groups (SHG). *Parthenium*, an obnoxious weed, agricultural wastes, earthworms, rock phosphate and cow dung slurry are the ingredients for vermicomposting. The SHGs have taken up vermicomposting as a microenterprise to generate income. Participatory evaluation of plots with applications of 3 and 5 t ha⁻¹ vermicompost resulted in increases of 4.8 and 5.8 t ha⁻¹ tomato yield when compared to plots to which 3.5 t ha⁻¹ of a conventional compost had been applied (Figure 9) (ICRISAT 2002).



Figure 9. Vermicomposting to promote micro-enterprises and generate income.

Village-level HNPV production

The project consortium identified and initiated the training, production, storage and usage of *Helicoverpa* nuclear polyhedrosis virus (HNPV) on different crops for minimizing pest damage. The farmers quickly adopted the technology, and produced 2 000 larval equivalent (LE) of HNPV, and used it on cotton, pigeonpea and chickpea. ICRISAT supplied an additional 11 650 LE of HNPV for use on these crops.

The project has given high priority to training village-level scouts to identify various pests and their natural enemies in different crops before the cropping season, and has assisted them in monitoring the pests during the cropping season. Farmers were also trained at ICRISAT on pest control techniques for cotton, chickpea and pigeonpea.

Monitoring

The following parameters were monitored to assess impacts, and to better understand the processes of integrated watershed management.

- An automatic weather station with a data logger was installed to collect data on rainfall, air and soil temperature, solar radiation and wind. Rainfall data was also collected at five other locations across the watershed to assess the spatial variability of rainfall.
- Changes in cropping pattern and cropping systems in farmers' fields along with productivity and incomes were monitored.
- Sixty-two open wells in the watershed were georeferenced, and periodic monitoring of water level and use was carried out.
- Water quality was monitored in all the wells and water storage structures in the watershed. Sediment samples were collected from the structures to help understand the runoff and erosion processes.
- Runoff and soil loss were monitored using automatic water level recorders and sediment samplers (Figure 10).

- Satellite monitoring was used for estimating vegetation cover.
- Periodic pest monitoring was carried out to assess pest infestation, and to take timely and cost-effective integrated pest management (IPM) measures.



Figure 10. Hydrograph monitoring of the entire Adarsha watershed.

Impact assessment

The normal annual rainfall at the watershed is about 890 mm received mainly in June-October (85%). The daily rainfall recorded during the past four years (1998-2002) is shown in Figure 11. There is a large variation in rainfall amount and distribution between years and within a season. The rainfall received in 1998 and 2000 was 36 and 47% more than normal, and in the other years the deficit ranged from 24% to 36%. High intensity and large rains were common at Kothapally as elsewhere in the SAT.

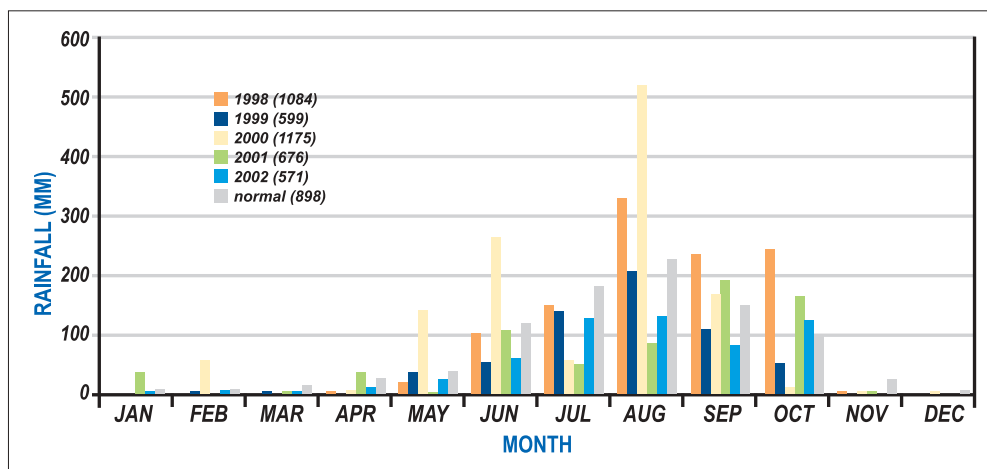


Figure 11. Monthly rainfall at Adarsha watershed (1998-2002).

Reduced runoff and soil loss

The soil and water management measures in the treated watershed included field bunding, *gully* plugging and check dams across the main water course, along with improved soil, water, nutrient and crop management technologies. Untreated areas represent farmers' practices without any technological intervention. There was a significant reduction in runoff from the treated watershed compared to the untreated watershed in 2000 and 2001 (Table 4). In the high rainfall year (2000) a significant reduction in runoff from the treated watershed (45% less than the untreated area) was observed. Even during a subnormal rainfall year (2001), a significant reduction in runoff volume (29% less than the treated area) was recorded. Daily runoff volumes and the effect of high intensity and large rains during 2000 on the treated and untreated watersheds are shown in Figure 12. The rainfall on 24 August alone accounted for about 70% of the total annual runoff (Pathak *et al.* 2002).

Table 4. Seasonal rainfall, runoff and peak runoff rates from the sub-watershed, Adarsha watershed, 1999-2001¹.

Year	Rainfall	Runoff (mm)		Soil loss (t ha ⁻¹)	
		Untreated	Treated	Untreated	Treated
1999	584	16	NR	*	*
2000	1161	118	65	1.04	*
2001	612	31	22	1.48	0.51

1. Untreated = control with no development work,

Treated = with improved soil water and crop management technologies, NR = not recorded

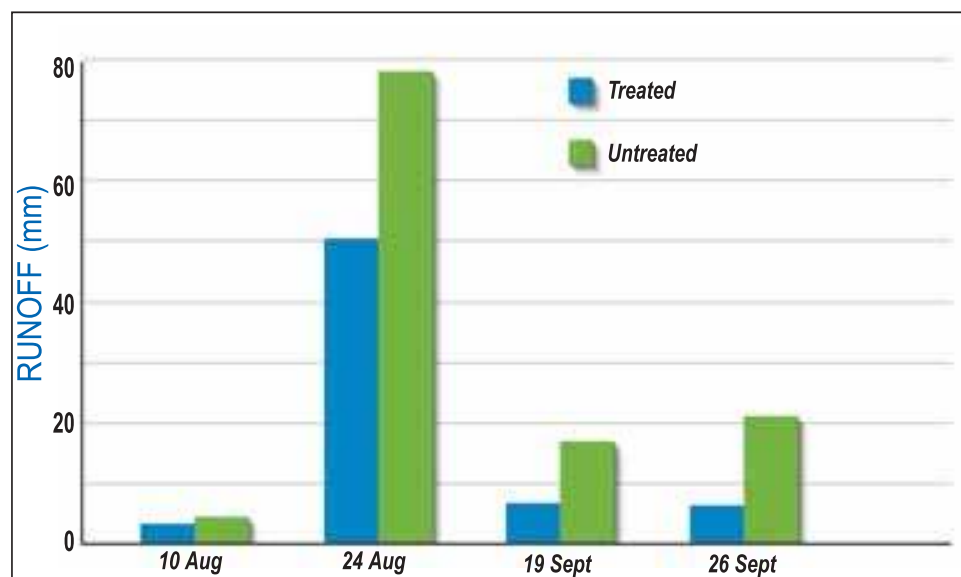


Figure 12. Daily runoff from the treated and untreated subwatersheds in Adarsha watershed, 2000.

Two years (1999 and 2001) out of three years were low rainfall years. In addition to low rainfall, most rainfall events were low intensity resulting in very low seasonal runoff during 1999 and 2001. In general, during low runoff years the differences between the treated and untreated watersheds are very small. During a good rainfall year, i.e., 2000, a significant difference in runoff was observed between treated and untreated watersheds (Table 4). Soil loss was measured from treated and untreated watersheds during 2001, and a significant reduction in soil loss (only 1/3) was found from treated compared to untreated watershed.

Improved groundwater levels

There are 62 open wells in the Adarsha watershed, most of which occur along the main watercourse. All the wells were georeferenced, and water levels were monitored continuously on a fortnightly basis. There were 15 bore wells before project initiation, and 55 new bore wells were dug during the project. There was a significant improvement in the yields of most wells, particularly those located near check dams (Figure 13). Due to additional groundwater recharge, a total of

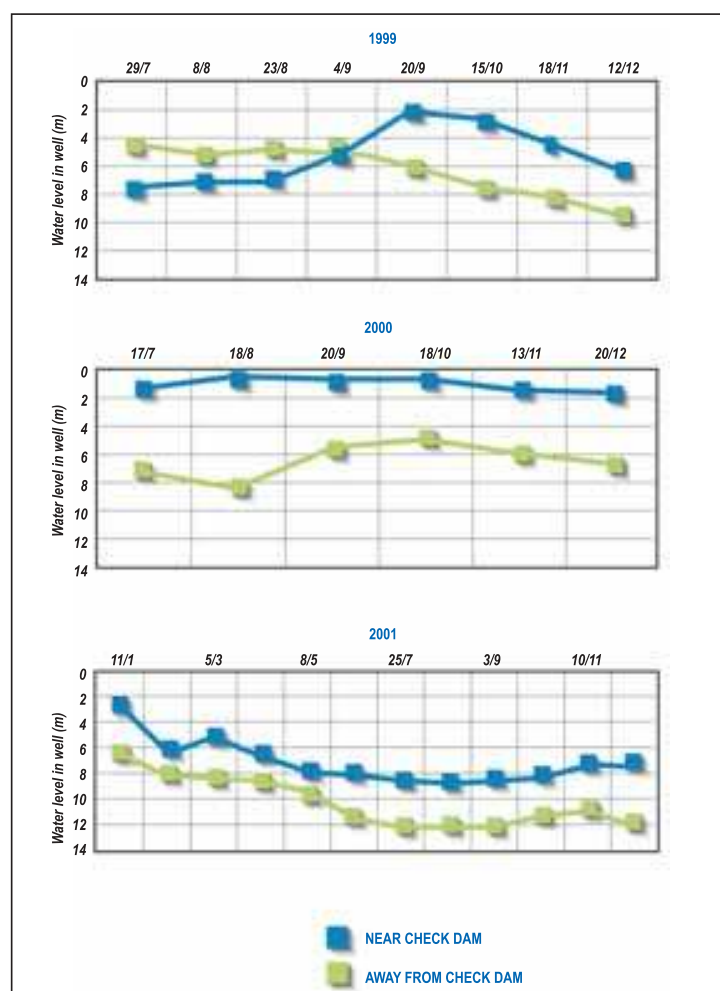


Figure 13. Groundwater levels in open wells at Adarsha watershed, 1999-2001.

200 ha were irrigated in post-kharif season and 100 ha in post-rabi season, mostly vegetables, during the 2002-2003 cropping season. Based on three years (1999-2001) of observations of groundwater levels in open wells, the estimated mean average rise of ground water was 415 cm. Thus the average contribution of the seasonal rainfall to groundwater in the watershed could be estimated at approximately 27% of the seasonal rainfall (assuming the specific yield of the aquifer material as 4.5%) (Pathak *et al.* 2002).

Integrated pest management

IPM was adopted to optimize crop productivity with integrated soil, water, crop and nutrient management in the watershed. The following IPM activities were implemented by the project.

- Crop surveys were carried out to determine the plant protection practices adopted within the village. The surveys indicated that farmers use chemical pesticides against insect pests and *Helicoverpa*, which is the key pest on a number of crops.
- *Helicoverpa*, a major pest on chickpea, pigeonpea and cotton, was monitored using pheromone traps (Figure 14).
- Effective indigenous methods like shaking pod borers from pigeonpea and using them for pest management were used (Figure 15).
- Pest tolerant varieties were used.
- Biological control measures using *Helicoverpa* nuclear polyhedrosis virus (HNPV) were adopted.
- Precise timing and application of pesticide treatments were ensured.
- Bird perches were installed in fields to encourage birds to alight on the perches and feed on *Spodoptera* and *Helicoverpa* larvae.



Figure 14. Chickpea grown on BBF and *Helicoverpa* monitoring with pheromone traps.



Figure 15. Shaking pigeonpea to control *Helicoverpa*.

Improved land cover (vegetation)

The land cover and vegetation density in Adarsha watershed was studied using satellite images to assess the impact of various interventions on these parameters. The IRS-IC and -ID LISS-III images in April 1996 and April 2000, and the NDVI images generated from these, are shown in Figure 16. Examination of the images from 1996 and 2000 revealed an increase in vegetation cover from 129 ha in 1996 to 200 ha in 2000 (Dwivedi *et al.* 2000).

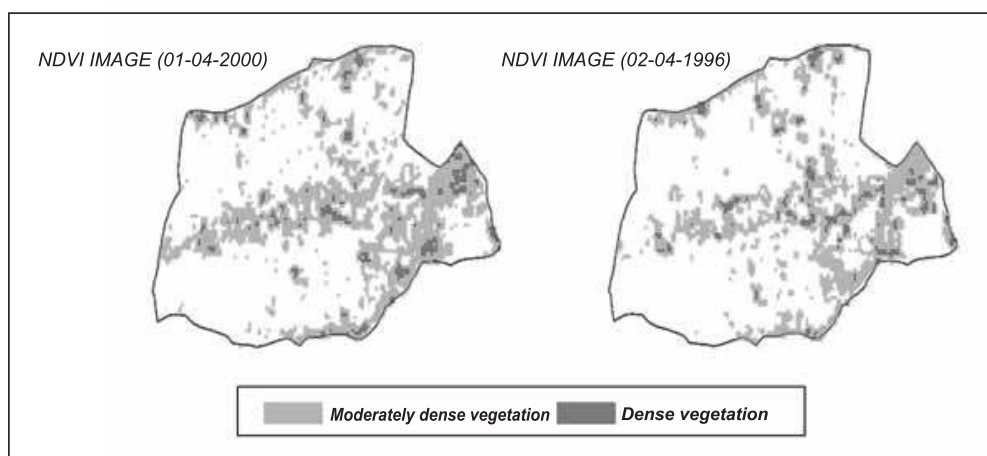


Figure 16. Satellite images of vegetation cover to study the impact of various technological interventions, Adarsha watershed, Kothapally.

Increased productivity

Farmers evaluated improved crop management practices (INM, IPM, soil and water management) together with researchers. With improved technologies farmers obtained high maize yield increase of 2.2 to 2.5 times the yield of sole maize (1.5 t ha^{-1}) in 1998 before improved practices were applied (Table 5). In the case of intercropped maize with

Table 5. Average yields with improved technologies in Adarsha watershed, 1999-2002.

Crop	Baseline yield (kg ha^{-1})	Yield (kg ha^{-1})			
	1998	1999	2000	2001	2002
Sole maize	1 500	3 250	3 750	3 300	3 480
Intercropped maize	-	2 700	2 790	2 800	3 083
Unimproved farmers' intercropped maize	-	700	1 600	1 600	1 800
Intercropped pigeonpea	190	640	940	800	720
Unimproved farmers' intercropped pigeonpea	-	200	180	-	-
Sole sorghum	1 070	3 050	3 170	2 600	2 425
Intercropped sorghum	-	1 770	1 940	2 200	-

pigeonpea, improved practices resulted in 1.7 to 3.8 times the yields obtained with farmers' traditional unimproved practices. For sole sorghum the improved practices increased yields by a factor of 2.3 to 3.0 compared to the 1998 baseline yield of 1 070 kg ha⁻¹. For intercropped pigeonpea the yield was increased five times in 2000 (ICRISAT 2002).

Of all the cropping systems studied in the Adarsha watershed, maize/pigeonpea and maize/chickpea proved to be most beneficial with benefit-cost ratio 2.67 (Table 6). Farmers could gain around Rs 16 500 and 19 500 from these two systems, respectively. Sole sorghum, sole chickpea and sorghum/pigeonpea intercrop also proved to be beneficial whereas sorghum, maize, and green gram traditional systems were significantly less beneficial to farmers. Cotton grown with traditional management practices resulted in a net loss (ICRISAT 2002).

Table 6. Total productivity, cost of cultivation and income for different crops at Adarsha watershed during 1999-2000.

Cropping system	Total productivity (kg ha ⁻¹)	Cost of production (Rs ha ⁻¹)	Total income (Rs ha ⁻¹)	Profit (Rs ha ⁻¹)	Benefit-Cost ratio
Maize/pigeonpea (improved)	3 351	6 203	22 709	16 506	2.67
Sorghum/pigeonpea (improved)	2 285	5 953	17 384	11 431	1.92
Cotton (traditional)	980	15 873	24 389	8 516	0.54
Sorghum/pigeonpea (traditional)	1 139	4 608	11 137	6 529	1.42
Maize/chickpea (improved)	4 319	7 317	26 774	19 457	2.66
Chickpea (improved)	840	4 886	17 292	12 406	2.54
Sole maize (improved)	3 150	4 578	13 532	8 954	1.96
Sorghum (traditional)	975	3 385	6 997	3 612	1.07
Sole sorghum (improved)	2 800	4 352	15 084	10 732	2.47
Maize (traditional)	1 600	3 599	7 281	3 682	1.02
Greengram (traditional)	600	4 700	9 000	4 300	0.91
Chickpea (traditional)	-	4 260	11 600	7 340	1.72
Sole pigeonpea (improved)	1 090	4 890	17 120	12 230	1.35

Impact on household incomes

The basic goal of watershed management in rainfed systems is to reduce rural poverty and improve livelihood security, while protecting or enhancing the sustainability of the environment and the agricultural resource base. In order to assess the impact of integrated watershed management interventions on poverty and the livelihoods of rural communities in Kothapally, ICRISAT collected cross-sectional panel data from a sample of randomly selected households from villages within and outside the watershed. A census of 825 households in the five neighbouring villages outside the watershed, and 308 households within the watershed preceded the detailed household survey. The villages located just outside the Kothapally catchment are used as a control group. Because of their

geographical proximity, the adjoining villages just outside the watershed have comparable socioeconomic and biophysical conditions, but with the major difference of not being involved in the watershed development project. A random sample of 60 households from each group was surveyed using a detailed survey procedure in 2002. Production, consumption and input-output data were collected from all plots operated by the sampled households (Table 7).

Table 7. Net income from crop production activities (Rs 1 000 ha⁻¹).

Crops	Within the watershed		Outside the watershed	
	With irrigation	Without irrigation	With irrigation	Without irrigation
Cereals	11.17	6.04	7.69	2.90
Pulses	8.86	3.81	4.08	1.92
Cotton	17.83	12.15	17.47	12.03
Vegetables	17.17	7.48	11.98	6.45
All crops	13.76	7.78	10.31	5.83

Analysis of this data shows that average net returns per hectare for dryland cereals and pulses are significantly higher within the watershed. For cereals, the returns to family labour and land (net income) are 45% higher even with irrigation, while the net returns on rainfed cereal crops have more than doubled. Similarly for pulse crops, per hectare net returns within the watershed are more than double with irrigation, and almost double without irrigation. This is mainly because the watershed development approach based on IGNRM includes improved cultivars of sorghum (cereals), chickpea and pigeonpea (pulses) developed by ICRISAT, along with improved management of water and soil fertility. Adoption of the improved varieties has not only increased crop yields, but also enhanced the economic profitability of other soil and water conservation investments, which might otherwise be economically unattractive to farmers.

In addition to the impacts on the net productivity of land, we also compared household incomes among the households within and outside the watershed. The results are striking. Average household income (in thousands of Rupees) from crop production activities within and outside the watershed is 15.4 and 12.7, respectively. The respective per capita income (in thousands of Rupees) is 3.4 and 1.9. This shows a significant impact of watershed intervention activities (initiated in 1999) towards poverty reduction in Kothapally watershed, through increased incomes for the poor from crop production activities. The average income (in thousands of Rupees) from agricultural wages and non-farm activities is 17.7 and 14.3 within and outside the watershed, respectively. The increased availability of water (and hence supplementary irrigation), and better employment opportunities in watershed development-related activities, have contributed to the diversification of income opportunities and reduced vulnerability to drought and other shocks.

Changes in cropping pattern

Analysis of prevalent cropping systems, their area and previous history before watershed management interventions, provides insight into the way the watershed management approach has benefited farmers. Kothapally was predominantly a cotton growing area prior to project implementation. The area under cotton was 200 ha in 1998, and maize, chickpea, sorghum, pigeonpea, vegetables and rice were also grown.

After 4 years of activities in Adarsha watershed, the area under cotton cultivation decreased from 200 ha to 80 ha (60% decline), with simultaneous increase in maize and pigeonpea areas. The area under maize and pigeonpea increased more than three-fold from 60 ha to 200 ha and 50 ha to 180 ha respectively, within four years, and the area under chickpea also increased two-fold during same period (Table 8) (ICRISAT 2002).

Table 8. Area (ha) under various crops in Adarsha watershed, Kothapally.

Crop	Before watershed management activities began (1998)	After 4 years of watershed management activities			
		1999	2000	2001	2002
Maize	60	80	150	180	200
Sorghum	30	40	55	65	70
Pigeonpea	50	60	120	180	180
Chickpea	45	50	60	60	100
Vegetables	40	45	60	60	100
Cotton	200	190	120	100	80
Rice	40	45	60	60	60

Capacity building of NARS

Key change agents like watershed committee members and agricultural and extension officials were trained on different aspects of integrated watershed management (IWM). Special emphasis was given to increasing awareness of new management options to women farmers, as they play a key role in the adoption of new technology. Women were trained on vermicomposting technology, and educated youth were trained in skilled activities like HNPV production and vermicomposting, which enabled them to generate income.

Hands-on training on various components of IWM was given to partner NARS scientists and technicians (Wani *et al.* 2002), and research scholars and apprentices from various universities conducted their research using the IWM approach. Other capacity-building activities were:

- About 700 farmers from all over India were trained on integrated watershed management at Adarsha watershed (Figure 17).
- One hundred and forty agricultural and government officials were trained in various aspects of integrated watershed management.



Figure 17. Farmers' awareness and training programme on integrated watershed management, Adarsha watershed, Kothapally.

- Fourteen research scholars and several apprentices were trained on different aspects of watershed management.
- About 1150 people visited Adarsha water-shed to become familiarized with IWM activities.
- Farmers' days were conducted in Adarsha watershed at Kothapally, and all farmers in the surrounding village were invited to become familiarized with IWM.
- Field days were conducted in Kothapally and were very successful in getting messages across to several provincial and district authorities, technology transfer departments, research managers, and policy makers.

Public awareness initiatives

An interactive computer-based tutorial on Integrated Watershed Development and Management was developed. Training material booklets and brochures on vermicomposting, and *Gliricidia* for *in situ* generation of organic matter, were prepared in English and Telugu. Several TV programmes for farmers covering IWM at Kothapally were shown at the regional and national levels. Several videos in Telugu on the use of the tropicultor, vermicomposting, improved cropping systems and IWM were prepared and broadcasted on TV programmes for farmers.



Information technology and watershed management

Details of this project are retained on the web site: (<http://www.icrisat.org/gt3/watersheds/ADBwsheds/wshedshome.htm>) to enable farmers, scientists, policy makers, extension agents and others to access information (Figure 18). This information, coupled with observations and measurements made by the watershed group, provides a means to characterize, assess, analyse and maintain the status and health of the benchmark watershed at Kothapally.

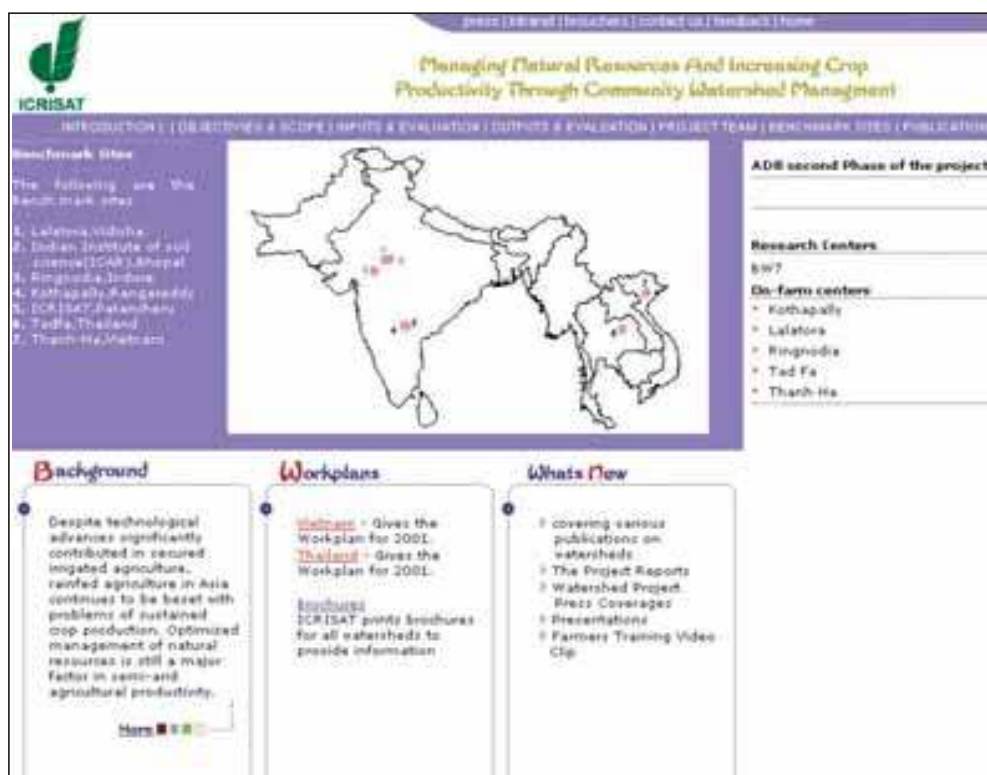


Figure 18. Information technology and watershed management web page, Adarsha watershed, Kothapally.

Flow of technology from Adarsha watershed to neighbouring villages

The adoption of improved technologies in Adarsha watershed was observed by farmers from the nearby watersheds of Nawabpet in Ranga Reddy District and Adilabad District. This led to farmers in these watersheds purchasing tropicultors for their field operations in order to construct BBF landforms. They were also keenly interested in other technologies, such as improved cropping systems, improved varieties, vermicomposting, HNPV production units, *Gliricidia* plantations and other soil and water management practices.

Scaling up

New scientific tools such as remote sensing, geographical information systems (GIS), digital terrain modelling for estimating runoff and soil loss, and crop simulation modelling for the analysis of long term potential productivity were used. These tools provide the capabilities for extrapolating and implementing technologies to other larger watersheds. To scale-up the benefits from the innovative farmer-participatory consortium model for managing watersheds at Kothapally, the following process shown in Figure 19 is being adopted.

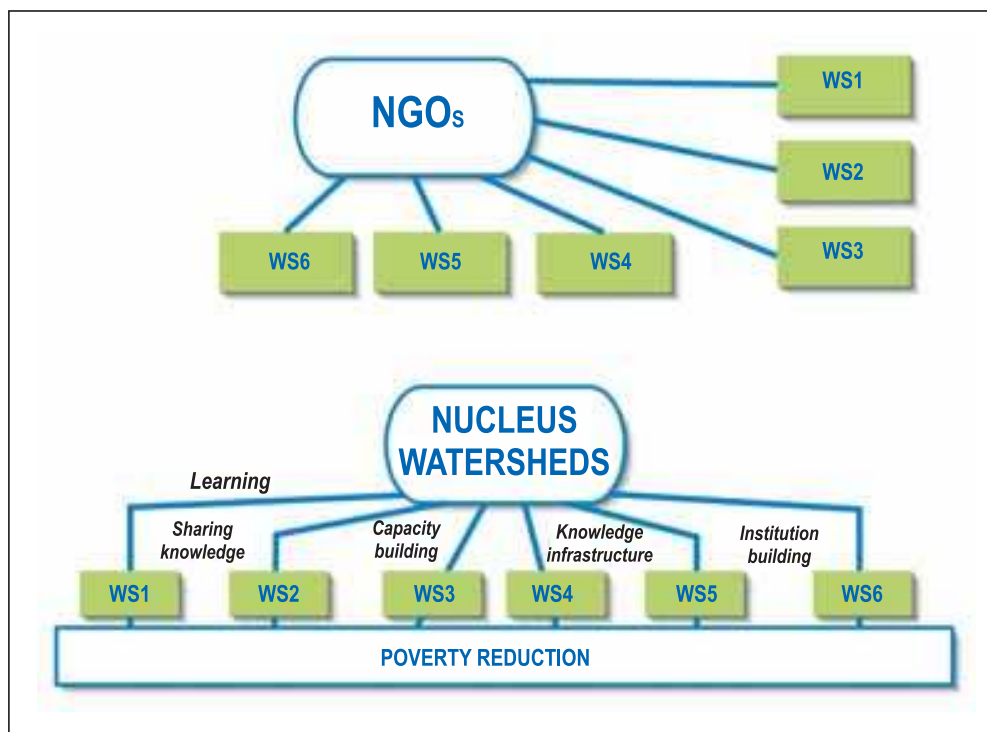


Figure 19. Scaling-up the benefits.

In the process of scaling-up it is envisaged that 3-4 nucleus watersheds are selected in each district. The process of selecting nucleus watersheds is a guided process as mentioned for Kothapally. An additional requirement is that the project-implementing NGOs should have the capacity and a good track record of implementing watershed projects in the district. The nucleus watershed-implementing NGO becomes the pilot trainer for other NGOs in the district. In addition, the pilot NGO transfers the lessons learnt from the nucleus watershed to other watershed projects implemented by their staff in the area, and so knowledge dispersion takes place. Each nucleus watershed has four satellite watersheds, and the farmers and SHG members from the nucleus watershed become the master trainers in the district for the satellite watersheds.

Emphasis in this project is on capacity building and empowerment of the NGOs, extension workers, farmers, and SHG members. In order to further

extend knowledge on the management of NRs through IGNRM, information and communication technology (ICT) is used. Currently, through the DFID-supported Andhra Pradesh Rural Livelihoods Programme (APRLP), this scaling-up approach has been extended to 50 watersheds (10 nucleus and 40 satellite) in three districts of Andhra Pradesh, and with support from Sir Dorabji Tata Trust it has been extended to two districts of Madhya Pradesh and one district in Rajasthan.

Adarsha watershed has served as a benchmark or nucleus watershed, and has already demonstrated the benefits of integrated watershed management. The technology has been adopted in watersheds of neighbouring villages and other areas by farmers with little technical support from the consortium. The satellite watersheds, which are similar in terms of soils, climate and socioeconomic patterns, can achieve broad impacts by adopting these technologies. The ICRISAT consortium focuses on training farmers, development agencies and NGOs through demonstrations of different technologies on benchmark watersheds, and acts as a mentor for technology backstopping. The farmers' community, through village institutions, takes responsibility for all activities of implementation and monitoring. Government and non-government agencies catalyse the process. The key factor while evaluating and scaling-up this approach is that the concerned line departments of the government need to be included in the consortium from the beginning, along with other partners.

Future issues

1. The consortium of national agricultural research systems, NGOs, government departments, extension agencies and farming communities should be multidisciplinary, and further strengthened to provide technical backstopping to optimize the sustainable use of natural resources for increased productivity.
2. Gradually, the watershed project management should reside in the community. Various aspects of watershed development and management could be handed over to community organizations over time when they have been adequately trained. This will sustain development.
3. There is a need to investigate the essential elements and mechanisms of village community participation in the development and management of natural resources.
4. Further research is needed to strengthen village-level institutions for watershed development and management.
5. Capacity building is a continuous process. The NARS scientists and staff of other organizations involved in the collaborative projects on watershed management need to be trained in the application of new scientific tools such as remote sensing, GIS and systems modelling.
6. Socioeconomic and policy issues to promote the equitable sharing of costs and benefits of improved natural resources management need to be researched.

7. There is a need to investigate and explore a range of opportunities through on-farm and off-farm activities to encourage and promote village level microenterprises, such as giving value addition to agricultural produce to help the landless, educated youth and women to ensure a more equitable sharing of the benefits of watershed management projects.
8. Watershed management projects need to become holistic livelihood projects, with soil and water conservation activities used as entry points. By adopting the IGNRM approach for all activities in the watersheds, these projects should become true livelihood programmes. That is the challenge to be tackled.

References

Dwivedi, R.S., Ramana, K.V., Wani, S.P. and Pathak, P. (2000). Use of satellite data for watershed management and impact assessment. Paper presented at ADB Review and Planning Meeting, 27-29 Nov 2000, ICRISAT, Patancheru, Andhra Pradesh, India.

ICRISAT (2002). Improving management of natural resources for sustainable rainfed agriculture. TA RETA 5812 Completion Report submitted to Asian Development Bank, The Philippines, September 2002. 94 pp. (Limited distribution.)

Joshi, P.K., Tewari, L., Jha, A.K. and Shiyani, R.L. (2000). Meta analysis to assess impact of watershed. In *Workshop on Institutions for Greater Impact of Technologies*. National Centre for Agricultural Economics and Policy Research, New Delhi, India.

Kerr, J., Pangare, G., Pangare, V.L. and George, P.J. (2000). An evaluation of dryland watershed development in India. EPTD Discussion Paper 68. International Food Policy Research Institute, Washington, DC, USA.

Pathak, P., Wani, S.P., Singh, P., Sudi, R. and Srinivas Rao, Ch. (2002). Hydrological characterization of benchmark agricultural watershed in India, Thailand, and Vietnam. Global Theme 3: Water, Soil and Agrobiodiversity Management for Ecosystem Health. Report No. 2. ICRISAT, Patancheru, Andhra Pradesh, India. 52 pp.

Samra, J.S. (1997). Status of research on watershed management. Central Soil and Water Conservation Research and Training Institute, Dehradun, India.

Shiferaw, B., Anupama, G.V., Nageswara Rao, G.D., and Wani, S.P. (2002). Socioeconomic characterization and analysis of resource-use patterns in community watersheds in semi-arid India. Working Paper Series No. 12. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 44 pp.

Wani, S.P., Pathak, P., Tan, H.M., Ramakrishna, A., Singh, P. and Sreedevi, T.K. (2001). Integrated watershed management for minimizing land degradation and sustaining productivity in Asia. Pages 207-230 in *Integrated*

Land Management Productivity in Asia, Zafar Adeel (ed). Proceedings of Joint UNU-CAS International Workshop, Beijing, China, 8-13 September 2001.

Wani, S.P., Rego, T.J. and Pathak, P. (eds). (2002). Improving management of natural resources for sustainable rainfed agriculture. *Proceedings of the training workshop on On-farm Participatory Research Methodology*, 26-31 July 2001, Khon Kaen, Bangkok, Thailand. ICRISAT, Patancheru, Andhra Pradesh, India. 68 pp.

Wani, S.P., Sreedevi, T.K., Pathak, P., Singh P. and Singh, H.P. (2001). Integrated watershed management through a consortium approach for sustaining productivity of rainfed areas: Adarsha watershed, Kothapally, India, Andhra Pradesh: A Case study. Paper presented at the *Brainstorming Workshop on Policy and Institutional Options for Sustainable Management of Watersheds*, 1-2 November 2001, ICRISAT, Patancheru, Andhra Pradesh, India.

Wani, S.P., Sreedevi, T.K., Singh, H.P. and Pathak, P. (2002). Farmer Participatory Integrated Watershed Management Model: Adarsha Watershed, Kothapally, India--A Success Story. ICRISAT, Patancheru, Andhra Pradesh, India. 22 pp.