

Socioeconomic characterization and analysis of resource-use patterns in community watersheds in semi-arid India

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Introduction

The semi-arid tropics is generally characterized by highly variable and low rainfall, soils with low productivity, high levels of risk, and deficient soft (e.g., education and health services) and hard (e.g., roads and communication facilities) development infrastructure. The fragile ecosystems in the dry areas are prone to degradation (loss of productivity) unless crop-livestock production activities are complemented by appropriate investments that maintain or improve the natural resource base. Much of the technological progress which transformed agriculture in the high-potential irrigated areas of India had little impact in the less-favored rainfed areas. Between 1972 and 1993, Fan and Hazell (1999) noticed a decline of 20% (from 37 to 30 million) in the absolute number of poor in the irrigated areas of India. However, the figure remained roughly constant in the rainfed areas (between 75 and 80 million). Pockets of rural poverty are often associated with low productivity of the resource base and scarcity of water. In marginal rainfed areas where the resource base has been subjected to degradation, integrated management of soil and water resources is imperative in order to enhance the productivity of agriculture and improve the well being of people. Watershed management is increasingly being recognized as a suitable unit of intervention for integrated natural resource management in rainfed systems.

A watershed is a catchment area from which all water drains into a common point, making it an attractive unit for technical efforts to manage water and soil resources. A large number of watershed projects are being implemented in India through various initiatives sponsored by the government, externally-aided projects, non-government organizations (NGOs), and local communities. In the mid-1990s, the total annual budget for watershed projects from various sources exceeded US\$ 500 million (Farrington et al. 1999; Kerr et al. 2000). Consistent with the general contemporary paradigm on soil and water conservation, much of the past work on watersheds focused on the technical aspects of technology development and the rehabilitation of degraded lands. Scant attention was paid to socioeconomic issues needed to sustain investments in water and soil conservation.

Much of the research focus of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in the early phases was on the technical efficiency of technologies in mitigating soil erosion and conserving water. Prior to the mid-1990s, the institute's work focused on developing technologies for improved soil, water, and crop management on-station at ICRISAT Center (Ryan et al. 1980; Pathak and Laryea 1992). In India, public funds were used to implement soil and water conservation measures on farmers' fields and communal lands. In fact, thousands of watershed programs provide subsidies reaching up to 90% of investment costs in order to foster sustainable development in rainfed areas. Increasing concern about the sustainability of watershed management interventions and the need to involve local resource users in technology design and development prompted ICRISAT to initiate integrated watershed management research in select communities in India, Vietnam, and Thailand. An innovative, multi-stakeholder consortium approach to community watershed research and development which relies on farmer and community participation, complemented by technical and minimal financial support, is being evaluated in the selected watersheds (Wani et al. 2002).

In view of this, some baseline socioeconomic farm household data was collected from three watersheds in India using a formal questionnaire¹. This study uses existing data from two Indian watersheds to characterize the study sites and document the socioeconomic conditions and resource-

1. The survey instrument was prepared by socioeconomists. However, biophysical scientists involved in the watershed research project collected the data in collaboration with some national program partners.

use patterns of the watershed farmers². The analysis aims at identifying gaps in the existing socioeconomic database and suggesting areas for further investigation as part of the ongoing research in the benchmark watersheds.

The paper deals with different socioeconomic issues and resource use-patterns; the general biophysical and socioeconomic characteristics of the watershed locations; the basic characteristics of the surveyed households with an emphasis on demographic features, labor force, and levels of education; land ownership and asset position (including livestock and other household assets) of surveyed households; and cropping patterns, input intensities, and average crop yields from farmers' fields. It also discusses crop utilization and the degree of commercialization of production in the areas; farmers' access to and utilization of credit from formal and informal sources; and the level of adoption and use of soil, water, and pest management technologies. The paper finally discusses the limitations of the baseline data and proposes some areas for future research.

2. Due to the quality of the data, the analysis focuses only on two watersheds (Adarsha and Lalatora). Due to limitations in data, household income from different sources and crop yields by land quality could not be estimated. The available data also precludes testing of hypotheses on farmer investment behavior, adoption of production and NRM technologies, and establishing cause-effect relationships.

General Description of Benchmark Watersheds

The three ICRISAT benchmark watersheds in India are located in the states of Andhra Pradesh and Madhya Pradesh (Map). In Andhra Pradesh, Adarsha watershed is located in Kothapally village in Ranga Reddy district, nearly 40 km south of ICRISAT Center at Patancheru. The watershed is inhabited by 270 farming households and covers 465 ha, of which 430 ha are cultivable and 35 ha wasteland. The annual average rainfall in the area is about 800 mm (85% of it occurs during Jun-Oct). The watershed is characterized by undulating topography (the slope of the land is about 3%) and predominantly black soils which range from shallow to medium deep black with a depth of 30 to 90 cm. Farmers diversify their cropping pattern across a number of crops grown during two seasons: rainy and post-rainy. The crops grown include sorghum, pigeonpea, black gram (*Phaseolus mungo*), maize (*Zea mays*), paddy (*Oryza sativa*), cotton (*Gossypium hirsutum*), sunflower (*Helianthus annuus*), and vegetable bean (*Dolichos lablab*), mostly under rainfed conditions. Paddy, sorghum, sunflower, and vegetables are grown in the post-rainy season using residual moisture and supplementary irrigation. There is also some area under turmeric (*Curcuma longa*), onion, and paddy grown which uses tubewell irrigation. Recently, ICRISAT introduced chickpea (new varieties) grown in the post-rainy season and the area under maize has substantially increased, often at the cost of cotton.

In terms of agroecological zonation, Ranga Reddy district is situated in the Northern Telangana plateau which is characterized by hot and moist semi-arid conditions. The length of the growing period in this zone extends from 120 to 150 days. The district covers an area of 753 000 ha. The land cover and land-use patterns in the district show that 35% is the net sown area, 9.7% is under forests, 8.6% is under fallow, 6.1% is under pasture and grazing lands, and 40.6% comprises nonagricultural land (barren, noncultivable, and settlements). In terms of area cultivated, the most important crops grown in the district are sorghum, paddy, pigeonpea, and cotton. Finger millets, maize, groundnut, and chickpea too are grown but they cover less than 9000 ha. About 24% of the cultivated area is under irrigation.

The literacy rate in Andhra Pradesh during 1997 was about 54%, which ranged from 43% among females to 64% among males. In terms of literacy, the state of Andhra Pradesh ranks 29th among the 32 States and Union Territories of India (DSO 2001). The level of literacy in Ranga Reddy district in the mid-1990s was about 40%. The 2001 projected population (based on the 1991 census) in the district is about 4.11 million, of which about 37% is found in the rural areas. This translates into a population density (persons per ha) of 5.72 in the district for net sown area. At 1993-94 constant prices, the per capita state domestic product in Andhra Pradesh increased by 10%, from Rs 7447 in 1993-94 to Rs 8214 in 1997-98 (GOAP 2001).

Coming to market access, Kothapally village is situated approximately 60 km from Hyderabad, the state capital of Andhra Pradesh. The other markets close by are in the towns of Chevella and Shankarpally, about 20 km away from the watershed village. Adarsha watershed has a total population of 1492, comprising about 270 cultivating and 4 noncultivating households. The average land holding per household (for cultivating households) is about 1.72 ha and the average cultivable land per household is 1.6 ha. The baseline data for Adarsha watershed is for the 1998 rainy season.

In Madhya Pradesh, Lalatora watershed is located about 140 km from Bhopal in the northeastern part of Vidisha district, at an altitude of 414 m above sea level (asl). The watershed is part of Milli watershed area (10 525 ha) and covers 725 ha. The average annual rainfall of 1200 mm here is higher than that in Adarsha watershed. The major crops grown are soybean, maize, and sorghum in the rainy season, and wheat, chickpea, paddy, and lentils during the post-rainy season. Some pulses, vegetables, and spices may also be grown in small quantities in both seasons. The baseline data for Lalatora watershed is for the 1999/2000 rainy and post-rainy seasons.

In terms of agroecological zonation, Vidisha district comes under the Malwa plateau which is characterized by hot, dry, and subhumid conditions. The length of the growing period in this zone extends from 150 to 180 days. The district covers about 730 000 ha, of which 72.3% is cultivated, 14.5% is under forests, about 5% under fallow and pastures, and 8.1% under nonagricultural use. Wheat is the most important crop grown in the district, followed by soybean and chickpea. Sorghum, maize, paddy, and pulses are also grown in smaller quantities. Only about 20% of the cultivated land in the district is under irrigation, unlike in Ranga Reddy district (24%). The total projected population of the district for 2001 is about 1.2 million, of which about 77% live in rural areas. The rural population density for cultivated land (projection for 2001) is about 1.75 persons ha⁻¹. This is much lower than in Ranga Reddy district and indicates the relative abundance of agricultural land in this district. The level of literacy in the district is 42%, comparable to that in Ranga Reddy district.

A look at some indicators of economic well being in the two districts will reveal that Ranga Reddy district stands out as the poorest in terms of educational opportunities, agricultural income, and endowment of agricultural lands. Female literacy in this district is only slightly more than half of that in Vidisha district. Per capita agricultural income in Vidisha is more than threefold the level in Ranga Reddy district (i.e., over 230% higher than that in Ranga Reddy district). The scarcity of agricultural land, proxied by rural population density per net area sown, indicates a serious shortage of land in Ranga Reddy district. The population density (projected for 2001) for Ranga Reddy district is about 2.8 times that in Vidisha district. Low and variable rainfall, coupled with scarcity of agricultural land in Ranga Reddy, *ceteris paribus*, can be expected to encourage more investments in land-augmenting and productivity-enhancing intensification strategies (e.g., soil and water management). A summary of the basic socioeconomic and biophysical characteristics of the districts and the watersheds, including land use and crop-livestock production activities is given in Appendices A and B.

Household and Demographic Characteristics

Adarsha Watershed

The baseline survey in Adarsha watershed was carried out in April 1999. A modified version of the questionnaire developed by ICRISAT's Socioeconomics and Policy Program as part of a technical manual for a training workshop (Wani et al. 1999) was administered to collect a wide range of socioeconomic data for the 1998 rainy season from a stratified sample of 54 households. Based on total land ownership, the 270 farmers in the watershed were stratified into 3 groups: small (less than 1 ha, 136 households), medium (1-2 ha, 60 households), and large (above 2 ha, 74 households) farmers. A certain number of households were randomly selected from each group to arrive at a sample size of 54 households. However, this stratification was based only on the simple concept of farm size per household, i.e., the normalization process using family size to arrive at land ownership per capita was not adopted. The stratification into different landholding classes would have been different if a methodology which accounts for household size had been used. Therefore, the classification was not very useful, and hence the 54 sample farmers were regarded as a random sample from all watershed households.

Table 1 shows the average characteristics of the households surveyed. The data shows that 22% of the surveyed households were women farmers. Family size exhibited a wide variation ranging between 2 and 25 persons. The average family size was 7.33 persons and the standard deviation 4.44. About two-thirds of the households had a family size less than the average. The remaining one-third

Table 1. Characteristics of the major households in Adarsha watershed, Kothapally, Ranga Reddy district, Andhra Pradesh.

Characteristics	Mean	Standard Deviation	Minimum	Maximum
Education of household head (yrs)	2.63	4.38	0.00	15.00
Average education in the family (yrs)	3.13	2.16	0.25	12.75
Age of household head	45.28	12.41	25.00	80.00
Persons below 5 yrs	1.19	1.20	0.00	4.00
Persons 6-10 yrs	1.06	1.09	0.00	4.00
Persons 11-15 yrs	0.59	0.88	0.00	3.00
Persons 16-55 yrs	4.09	2.47	2.00	13.00
Persons 56-65 yrs	0.31	0.54	0.00	2.00
Persons above 65 yrs	0.09	0.35	0.00	2.00
Family size	7.33	4.44	2.00	25.00
Total workforce (weighted) ¹	4.32	2.56	2.00	13.75
Dependents (nonworking) ²	3.01	2.38	0.00	11.25
Dependency ratio	0.78	0.53	0.00	2.11

Note: Sample size (n) = 54.

1. The total workforce was computed as $0.25 \times (\text{persons in the 11-15 age group}) + \text{persons in the 16-55 age group} + 0.25 \times (\text{persons in the 56-65 age group})$.

2. The dependency ratio was computed as the ratio of nonworking members to working family members.

had household sizes above the average. About half of the households also had a family size of less than five. The average number of males was 3.74 and females 3.59. The average weighted labor force per household was 4.32 persons, indicating a worker-consumer ratio of about 60%. The dependency ratio, i.e., the number of nonworking members per working family member was 0.78, indicating a high degree of dependency. This implies that every working member of the family supports on an average 0.78 dependents, which includes children and senior citizens. The caste composition of the surveyed households was as follow: Backward Caste (54%), Scheduled Caste (20%), Muslim (12%), and others (14%).

The average age of the household head was about 45 years. The average level of education of the head of a household was 2.63 years, which is generally very low. About 70% of the household heads were uneducated. The average level of education in the family was slightly higher at 3.13 years. The number of illiterate family members in every household averaged 2.95, indicating 40% illiteracy within the household. The average number of family members with preschool education was 0.67, elementary education 2.03, secondary education 1.33, and college education 0.33.

Though Kothapally has a good road link, the average distance to the nearest market-town (20 km away) implies major transportation costs for farmers. Agriculture was stated as the main source of income for all households, indicating the dire lack of other income-earning opportunities in the area. A majority of households (80%) indicated an acquaintance with the watershed approach through previous programs.

Lalatora Watershed

The baseline survey in Lalatora watershed was for the 1999/2000 rainy and postrainy season crops. The survey was carried out in February 2000. Like in Adarsha watershed, the questionnaire developed by the Socioeconomics and Policy Program as part of a technical manual for the training workshop

(Wani et al. 1999) was adapted to local conditions to collect a broad range of socioeconomic data. A total of 102 randomly selected farm households were included in the survey. The enumerators used the questionnaire translated into the local language (Hindi), making it time consuming and hard for nonspeakers to fully understand, crosscheck, and clean the data. Where data analysis has been completed, the final quality is considered to be reliable.

Table 2 shows the basic characteristics of the surveyed households in Lalatora watershed. Only 5% of the surveyed households were women farmers. Family size did not exhibit as much variation as in Adarsha watershed; the family size of the sample farmers ranged from 1 to 12 persons. The average family size was 6.08. About half the households had a family size less than the average. About 10% of the households were just around the average, while the remaining 40% had more than the average family size. Only 10% had family sizes of more than 8 persons. Information about the social background of the surveyed farmers was not included in the questionnaire. The average age of the household head was about 44 years. Nearly 51% of the household heads were unable to read or write compared to 70% in Adarsha watershed. This is consistent with the district-level data showing higher levels of illiteracy in the area. About 30% had studied up to the primary level, 12% up to the junior secondary level, while only 6% had secondary (high school) level of education. The average number of persons in the family with no education was 3.26, preschool 1.92, elementary school 0.5, secondary school 0.23, and college level 0.15.

Data from this watershed on the actual number of years of education of the family members was given as a categorical variable (e.g., elementary, secondary, etc.). In order to facilitate comparison, the average number of years of education under each category was used to convert the categories into corresponding completed years of education. The results showed that the average level of education of the household head was 2.32 years, while that of the family as a whole was 1.96 years. These values

Table 2. Major characteristics of households in Lalatora watershed, Vidisha district, Madhya Pradesh.

Characteristics	Mean	Standard Deviation	Minimum	Maximum
Education of household head (yrs)	2.32	2.92	0.00	12.00
Average education in the family (yrs)	1.96	1.45	0.00	7.00
Age of household head	43.95	12.19	18.00	70.00
Persons below 5 yrs	0.53	0.77	0.00	3.00
Persons 6-10 yrs	0.75	0.91	0.00	3.00
Persons 11-15 yrs	0.61	0.80	0.00	3.00
Persons 16-55 yrs	3.85	2.18	1.00	10.00
Persons 56-65 yrs	0.25	0.44	0.00	1.00
Persons above 65 yrs	0.08	0.34	0.00	2.00
Family size	6.08	2.57	1.00	12.00
Total workforce (weighted) ¹	4.07	2.20	1.00	10.50
Dependents (nonworking) ²	2.01	1.49	0.00	5.50
Dependency ratio	0.67	0.70	0.00	5.00

Note: Sample size (n) =102.

1. The total workforce was computed as $0.25 \times (\text{persons in the 11-15 age group}) + \text{persons in the 16-55 age group} + 0.25 \times (\text{persons in the 56-65 age group})$.

2. The dependency ratio was computed as the ratio of nonworking members to working family members.

were 12% (for the household head) and 38% (for the family as a whole) less than that in Adarsha watershed. The results on average education levels in the family are not fully consistent with district-level data that shows a slightly higher level of literacy in Vidisha district.

The average weighted labor force per household was 4.1 persons, indicating a worker-consumer ratio of about 67%. The dependency ratio, the number of nonworking members per working family member, was about 0.67. On an average, every working member supported about 0.67 nonworking ones. This reveals a relatively lower dependency ratio in Lalatora than in Adarsha watershed, mainly because of a relatively smaller family size. Like in Adarsha watershed, very few household members were above the age of 65, indicating a lower life expectancy in the area.

Land Ownership, Land Use, and Land Markets

Adarsha Watershed

As reported earlier, all the sample households in this watershed were primarily dependent on agriculture. The respondents were all cultivators, with an average land ownership of 1.432 ha per household, translating into a land-person ratio of about 0.195 ha. This is a very negligible size of land and requires serious intensification and multiple cropping to provide the required food security to the household. About 80% of the farmland was nonirrigated. The total owned cultivated land area was 1.295 ha, distributed into dryland (1.012 ha, 78%) and irrigable land (0.283 ha, 22%). All the respondents indicated that the soil type was black, with a depth ranging from 0.5-3.5 m (average depth of 2.19 m). If the data is reliable, this indicates that the farmers' estimates and perceptions of soil depth in the area were quite high. Farmers' responses showed that more than 90% of the farms had a soil depth of more than 1 m and more than half of them had a soil depth of more than 2 m. It appears that the question was not properly worded; it should have sought soil depth by plot and parcel rather than that of the farm as a whole.

In terms of access to irrigation, about 60% of the farmers revealed they had no source of irrigation. There was a slight discrepancy in the data on ownership of wetland, which shows that 63% of the households reported that they did not own irrigated land.³ Farmers used different types of water harvesting methods. A third of the respondents used tube wells while the rest used open wells and tanks as sources of irrigation. As community efforts towards investments in check dams and other structures to retain runoff water succeed, there are reports that the groundwater table as well as the water level in private wells is rising. There is an interesting contradiction between community ownership of water conservation investments (e.g., check dams) and private tapping of groundwater by drilling wells near check dams. If unregulated, this may increase the exploitation of groundwater, and has the potential to undo community benefits and enhanced ecological services of watershed investments, a result which resembles the tragedy of the commons. Unless correct incentive structures are quickly put in place, this could undermine the cooperation and collective action involved in community watershed management (Dyton-Johnson 2000). Table 3 shows average land ownership and related variables in Adarsha watershed. Figure 1 shows the distribution of agricultural land in the watershed. About 85% of the respondents had landholdings of less than 2 ha.

Seasonal land-use patterns indicate that the average operated area in the rainy season was 1.295 ha while the average for the post-rainy season was 0.275 ha. Very little of the operated area was under

3. The difference may indicate that some farmers who lacked their own irrigation infrastructure had access to water from markets or other informal arrangements.

Table 3. Land ownership (ha) pattern in Adarsha watershed¹.

Variable	Mean	Standard Deviation	Minimum	Maximum
Wet owned cultivated area	0.29	0.79	0.00	4.91
Dry owned cultivated area	1.01	1.40	0.00	6.94
Total owned cultivated (wet+dry) land	1.29	1.62	0.03	8.15
Current fallow	0.01	0.11	0.00	0.81
Permanent fallow	0.12	0.56	0.00	3.75
Total owned wet area	0.29	0.79	0.00	4.91
Total owned dry area	1.14	1.76	0.00	9.14
Total owned (wet+dry) area	1.43	1.97	0.03	9.37
Total owned cultivable land	1.31	1.62	0.03	8.15
Total owned land per capita	0.20	0.25	0.01	1.56
Total owned cultivated land per capita	0.18	0.22	0.01	1.36
Total owned cultivable land per capita	0.19	0.22	0.01	1.36

Note: Sample size (n)=54.

1. No land was reported as leased in, shared in, leased out, or shared out.

temporary or permanent fallow, indicating a high intensity of land use and rotation value for farmland. For some inexplicable reason based on the available data, it was found that none of the households participated in local land rental markets through fixed-rental leasing in/out or through share cropping. All the households were self-sufficient in land use, maybe due to a sampling bias or serious imperfections in village land markets. The small landholdings seemed to leave little in terms of surplus to rent out to other households. This seems so from the distribution of land, which indicates that only 16% of the respondents had landholdings above 2 ha, and about 55% had below 1 ha. The remaining 29% had landholdings between 1 and 2 ha.

Lalatora Watershed

The households surveyed in Lalatora watershed too primarily rely on agriculture for their livelihood. Nearly 97% of the households ranked agriculture as their primary occupation. A majority of the farmers did not have a secondary source of income, indicating imperfections in local markets and a general lack of opportunities in the area. Only 20% of the respondents were eager to earn income from off-farm and agriculture-related employment. One household among the respondents did not own agricultural land. Farmers' landholdings included wetlands (irrigated) and dryland (nonirrigated) distributed across different topographic locations in the watershed. Some of the respondents could not accurately identify their topographic location. Going by the correct responses, some 83% of the land is located in middle toposequence, while the remaining 17% is almost equally distributed between the bottom and top of a toposequence in the watershed. Results from 47% of the valid responses indicate that the soil depth ranged between 0.5 and 4 m on some lands. A few of the farms (about 11%) indicated soil depths of less than 1 m. Of the valid responses, 73% indicated an average soil depth ranging between 2 and 3 m. These figures, if reliable, only illustrate farmers' estimates and need to be interpreted carefully.

The average total farm size owned (including cultivated, fallow, leased out, and sharecropped land) in the area was 5.04 ha, amounting to 0.83 ha per capita. This is over four times the per capita

endowment of land in Adarsha watershed. As in Adarsha watershed, about 80% of the land was not irrigated. The average cultivated land owned was about 4.794 ha, of which the average irrigated cultivated land was 0.855 ha (18%) and the dryland 3.938 ha (82%), indicating a per capita ownership of 0.14 ha of the former and 0.64 ha of the latter. This indicates a higher level of land availability in Lalatora watershed compared to Adarsha watershed. Assuming a comparable level of land productivity, this also implies greater incentives for intensification of land use and adoption of land-augmenting technologies (like fertilizers, new varieties, multiple cropping, and soil and water conservation) in the Adarsha watershed. Responses to local land markets indicate that some farmers rented additional land through fixed-price leases or through sharecropping arrangements. The average area under fixed rentals amounted to 0.073 ha and that under sharecropping contracts 0.0122 ha. This raises the operating farm size to 5.13 ha. None of the farmers rented out or share cropped their land to others. This perhaps shows a relatively more efficient land market in the area. However, the scarcity of land in Adarsha watershed should have encouraged land rental markets. The relatively homogenous distribution of land among households in the area seems to preclude opportunities for trade. Only 17% of the households in Adarsha watershed owned more than 2 ha of land, while only very few owned more than 8 ha.

In terms of access to different sources of irrigation, 48% of the respondents in Lalatora watershed had no access, a relatively better situation than in Adarsha watershed, where 60% had no access. This also slightly departs from the earlier indication that 51% of the surveyed farmers did not have any irrigated owned land. In any case, the most common sources of irrigation among the users were river (42%) and ponds (38%). The rest used bore wells and a combination of methods.

The distribution of holdings indicates that about 25% of the households had a farm size exceeding 5 ha, about 50% had less than 2 ha, while the remainder owned between 2 and 5 ha. The large heterogeneity in land ownership pattern creates opportunities for the emergence of local land markets in order to balance the seasonal supply and demand for land in the local economy. Table 4 shows land ownership pattern and Figure 2 the frequency distribution of own cultivated land in Lalatora watershed.

Table 4. Land ownership (ha) pattern in Lalatora watershed¹.

Variable	Mean	Standard Deviation	Minimum	Maximum
Wet owned cultivated area	0.86	1.87	0	15.00
Dry owned cultivated area	3.94	4.98	0	25.00
Total owned cultivated (wet+dry) land	4.79	5.94	0	28.75
Leased in land	0.05	0.30	0	2.50
Shared in land	0.03	0.23	0	2.00
Current fallow	0.12	0.37	0	2.50
Permanent fallow	0.11	0.27	0	1.25
Total owned wet area	1.53	3.23	0	26.3
Total owned dry area	6.63	8.38	0	42.5
Total owned (wet+dry) land	5.02	6.24	0	30.00
Total owned cultivable land	4.91	6.13	0	30.00
Total owned land per capita	0.82	0.98	0	6.00
Total owned cultivated land per capita	0.78	0.89	0	5.00
Total owned cultivable land per capita	0.81	0.96	0	5.83

Note: Sample size (n)=102.

1.No land was reported as leased out or shared out.

Comparative Summary

A comparative analysis which takes into account equity issues in farm size involved the distribution of land per capita. Assuming that the quality of land remains the same, the larger the farm size per capita, the larger the relative availability of land in a given location. The cumulative probability distribution of landholdings per capita in the two watersheds is given in Figure 3. The results confirmed the findings that land is relatively more abundant in Lalatora watershed than in Adarsha watershed. About 95% of the households in Adarsha watershed had landholdings of less than 0.5 ha per capita, while only about 55% of the households had landholdings less than 0.5 ha in Lalatora watershed. The maximum own cultivated land per capita in Adarsha watershed was about 1.25 ha, while it was about 5 ha in Lalatora watershed. About 20% of the households in Lalatora watershed owned land areas more than the maximum per capita cultivated land in Adarsha watershed. About 25% of the households in Adarsha watershed operated land areas less than 0.1 ha per capita. The corresponding figure for Lalatora watershed was less than 5%. Without taking into account the quality of land, these results confirm the higher level of asset poverty and scarcity of land in Adarsha watershed. The implications of this for soil and water management need to further investigation.

Livestock and Other Assets

Adarsha Watershed

A majority of the farmers in the area are mixed crop-livestock producers. The major types of livestock included cattle, buffaloes, goats, sheep, and poultry (Table 5). Over two-thirds (72%) of the respondents owned some livestock in addition to indulging in crop-production activities. About 48% of the households also owned bullocks (including improved and local breeds). About 37% of the households owned a pair of bullocks needed for transportation and cultivation. About 6% owned more than a pair of bullocks while about the same percentage owned only one bullock. Very few households (11%) owned any milking cow, but about 35% owned she buffaloes. The average ownership of

Table 5. Livestock ownership (numbers) in Adarsha watershed.

Variable	Mean	Standard Deviation	Minimum	Maximum
Improved bullocks	0.19	1.06	0	6
Local bullocks	0.94	1.12	0	4
Cows	0.11	0.32	0	1
Young cattle	0.13	0.39	0	2
He buffaloes	0.00	0.00	0	0
She buffaloes	0.50	0.82	0	4
Young buffaloes	0.43	0.77	0	4
Goats	0.76	1.04	0	3
Sheep	0.83	4.53	0	30
Poultry	0.65	2.08	0	10

Note: Sample size (n)=54.

Table 6. Ownership of other farm assets (numbers) in Adarsha watershed.

Variable	Mean	Standard Deviation	Minimum	Maximum
Iron ploughs	0.06	0.30	0	2
Wooden ploughs	0.74	0.56	0	2
Blade harrows	0.81	0.62	0	2
Jumbo iron ploughs	0.44	0.50	0	1
Seed drill	2.15	10.80	0	80
Electric motors	0.41	0.53	0	2
Bullock carts	0.11	0.32	0	1
Crowbar	0.93	0.26	0	1
Spade	0.98	0.31	0	2
Khurpi	3.22	1.38	2	8
Sickle	3.13	1.43	1	8
Axe	1.24	0.43	1	2
Bicycle	0.35	0.52	0	2
Two wheeler	0.06	0.23	0	1
Sprayer	0.78	0.42	0	1
Tractor	0.02	0.14	0	1

Note: Sample size (n)=54.

different types of animals was 1.05 (bullocks), 0.11 (milking cow), 0.13 (young cattle), 0.5 (she buffaloes), 0.43 (young buffaloes), 0.76 (goats), 0.83 (sheep), and 0.65 (poultry). After bullocks that are needed for transporting goods and cultivation, goats are the most popular small stock kept on the farm. About 41% of the households engage in raising goats. Only a few households (4%) raise sheep on the farm. The average value of livestock wealth is Rs 12 869 per household. Figure 4 shows the distribution of livestock wealth in the watershed.

Apart from livestock, farmers also possessed other assets and implements (such as tractors, bicycles, plows, seed drills, and bullock carts) mainly used in crop and livestock production. The average farm equipment and related wealth of the sample households was Rs 15 374, of which 57% possessed assets worth less than Rs 10 000. Some 35% owned assets worth between Rs 10 000 and 25 000. Table 6 shows the average asset holdings of the surveyed farmers. Figure 5 shows the distribution of farm equipment and related assets in the watershed. In terms of important assets, nearly 98% of the households did not own any tractors. Hence the average tractor ownership was only 0.0185. On the other hand, more than 68% of the households owned a seed drill and 88% owned a sprayer.

Lalatora Watershed

Like in Adarsha watershed, a majority of the farmers in Lalatora watershed were mixed crop-livestock producers. The major types of livestock in the area included cattle, buffaloes, goats, sheep, and poultry (Table 7). About 86% of the respondents owned some livestock in addition to engaging in crop-production activities. The average ownership of different types of animals was 0.95 (bullocks), 0.83 (milking cow), 1.25 (young cattle), 0.10 (he buffaloes), 0.70 (she buffaloes), 0.57 (young buffaloes), 0.32 (goats), and 0.5 (poultry). Cows were the most popular stock kept by about 60% of the

Table 7. Livestock ownership (numbers) in Lalatora watershed.

Variable	Mean	Standard Deviation	Minimum	Maximum
Bullocks	0.95	1.07	0	4
Cows	0.83	0.86	0	3
Calves	1.25	1.22	0	4
She buffaloes	0.70	0.97	0	4
He buffaloes	0.10	0.33	0	2
Young buffaloes	0.57	0.91	0	4
Goats	0.32	1.62	0	10
Poultry	0.50	2.35	0	20

Note: Sample size (n)=102.

households, followed by bullocks (55%), and she buffaloes (43%). A number of farmers also kept calves and young buffaloes as replacement for aging cattle and buffalo stock. Unlike in Adarsha watershed, only about 5% of the households maintained goats while none raised sheep. The average value of livestock wealth (Rs 20 090.93 per household) in Lalatora watershed was much higher than in Adarsha watershed. Figure 6 shows the distribution of livestock wealth in Lalatora watershed.

Farmers in Lalatora watershed also possessed other assets and implements (like tractors, bicycles, plows, seed drills, and bullock carts) mainly used in crop and livestock production. The average farm equipment and related wealth of the sample households was Rs 49 873, much higher compared to Adarsha watershed. Of this, some 50% of the households possessed assets worth less than Rs 10 000 and 30% owned assets worth between Rs 10 000 and 30 000. Table 8 shows the average asset holdings of the surveyed farmers. Figure 7 shows the distribution of farm equipment and related assets in the

Table 8. Ownership of other farm assets (numbers) in Lalatora watershed.

Variable	Mean	Standard Deviation	Minimum	Maximum
Crowbar	0.03	0.17	0	1
Khurpi	2.07	1.29	0	5
Sickle	3.16	1.68	0	10
Electric motors	0.26	0.44	0	1
Spade	1.00	0.70	0	4
Wooden ploughs	0.07	0.25	0	1
Seed drill	0.65	0.59	0	2
Blade harrows	0.07	0.25	0	1
Axe	1.95	1.21	0	5
Soil container	1.35	1.22	0	6
Oil engine	0.11	0.31	0	1
Bullock carts	0.43	0.55	0	2
Bicycle	0.33	0.47	0	1
Tractor	0.16	0.39	0	2

Note: Sample size (n)=102.

watershed. The holding structure of important assets shows that 16% of the households owned a tractor and about 6% owned a thresher. On the other hand, more than 58% owned a seed drill, whereas less than 1% owned sprayers. Like in Adarsha watershed, a large number of farmers owned a wooden plow and bullock carts. These results reveal higher land ownership as well as livestock and nonlivestock wealth in Lalatora watershed than in Adarsha watershed.

Comparative Summary

A comparative analysis of the livestock and nonlivestock wealth in the two watersheds provides further evidence of the prevailing poverty in Adarsha watershed (Figures 8 and 9). Figure 8 shows that about 14% of the households in Lalatora watershed and 30% in Adarsha watershed had no livestock. However, in terms of livestock ownership, the cumulative distribution for Lalatora watershed was consistently higher than that in Adarsha watershed. As for land ownership, about 5-10% of the households possessed livestock wealth that departs significantly from the average. Overall, there seemed to be a more egalitarian ownership of land than livestock wealth. The distribution of nonlivestock assets (Figure 9) shows that about 55% of the households in both the watersheds did not possess significant nonlivestock wealth. Figures 5 and 7 already indicate that about 12% of the households in Adarsha watershed and about a quarter of those in Lalatora watershed had nonlivestock asset endowments of less than Rs 1000. Likewise, the ownership of farm equipment and other assets per capita was higher in Lalatora watershed. There were a few (about 5%) households who owned tractors and heavy machinery, thereby pushing the per capita wealth to higher than average in both locations. Better availability of moisture, higher endowment of land, and livestock and nonlivestock wealth per capita could be good indicators of higher levels of well being in Lalatora watershed than in Adarsha watershed.

Crop Production, Cropping Pattern, and Yields

The baseline survey included questions regarding crop production, cropping patterns, and input and output relationships. Data on cropping pattern indicates that some crops were grown as sole crops while others were grown as intercrops. In Adarsha watershed, crops grown as monocultures included cotton, paddy, vegetable bean, maize, sorghum, sunflower, and turmeric. Other crops mainly grown as intercrops on the same field included sorghum, black gram, and pigeonpea. In Lalatora watershed, crops grown as intercrops on the same field included wheat and chickpea during the post-rainy season and soybean and maize in the rainy season. Wheat and chickpea were also grown as sole crop. Paddy and lentils too were grown as sole crops to a small extent.

In Adarsha watershed, the most commonly grown crops during the rainy season were intercrops consisting of sorghum, black gram and pigeonpea. About 60% of the surveyed farmers in the area reported growing these crops as intercrops. Based on farmers' responses, the average share of land allocated to the different crops in the intercropping system was 80% for sorghum and 10% each for black gram, and pigeonpea. This shows that pulses actually occupy a small proportion of the land, which is mainly allocated to a cereal (sorghum). The results also show that relatively fewer households grew other crops (as single stands): cotton (30%), paddy (33%), vegetable bean (31%), sunflower (6%), tomato (7%), and turmeric (13%) (Table 9).

The average area cultivated to each of these crops reveals that the largest share of cropland was allocated to the sorghum-pigeonpea intercrop. Only a small proportion (less than 20%) of the land area under these crops was irrigated. The average level of fertilizer use was unreliable as data was perhaps

Table 9. Average area cultivated, inputs used, crop yields, and variability in yields in Adarsha watershed, rainy season.

Crops	Number of growers	Average area (ha)	Share irrigated (%)	Fertilizer DAP (kg ha ⁻¹)	Fertilizer Urea (kg ha ⁻¹)	Grain yield (kg ha ⁻¹)	CV (%)
Sorghum ¹	34	0.716	0.17	429	429	1097	120
Black gram ¹	34	0.716	0.17	429	429	110	126
Pigeonpea ¹	34	0.716	0.17	429	429	203	140
Paddy (rainy season)	18	0.330	95	392	354	5486	71
Paddy (postrainy season)	7	0.550	100	426	426	4477	65
Vegetable bean	17	0.402	0	231	231	2888	156
Sunflower	3	0.245	12	247	247	721	17
Cotton	16	0.629	0	100	100	1804	106
Turmeric	7	0.375	20	712	712	3379	89
Tomato	4	0.437	-	-	-	834	44

1. Grown as intercrops (sorghum-black gram-pigeonpea).

missing (due to empty fields) for a number of sample farmers. The average provided was based on recorded positive levels of use and on the assumption that empty fields meant nonuse. The results were on the higher side, indicating the substantial use of DAP and urea fertilizers per ha for all crops, except tomatoes. The average yield of sorghum was about 1100 kg ha⁻¹, black gram 110 kg ha⁻¹, and pigeonpea 203 kg ha⁻¹ in the intercropping system. The average yield of paddy grown mainly with supplementary irrigation during the rainy season was about 5486 kg ha⁻¹, while that grown during the postrainy season was about 4480 kg ha⁻¹. Vegetable bean, another important crop grown by a third of the farmers, gave average yields of about 2890 kg ha⁻¹. The share of farmers growing cotton was of a similar order of magnitude as that of paddy and vegetable bean, and the average yields were about 1800 kg ha⁻¹.

The variability and stability of yields were measured by the coefficient of variation (CV), the standard deviation as a percentage of mean yield. There was considerable variation in yield levels attained among different farmers, perhaps reflecting the effects of land quality and input intensities in growing these crops. The baseline data lacks such detail at the plot level and the relative contribution of variable and fixed factors in determining crop production in the area cannot be accounted for. One major factor associated with variability in crop yields is the level of irrigation used. The variability was greater in the case of nonirrigated crops and tended to decline with the share of land irrigated. Hence, the variability in yields was highest in vegetable bean and cotton as well as in the sorghum-pigeonpea intercrops grown under rainfed conditions. The variability in yield was less in paddy grown with irrigation.

Production data for a number of crops grown in both the rainy and postrainy seasons is available for Lalatora watershed. As in Adarsha watershed, all the households for which data on production and cultivated area for each crop are available were included. This will help in estimating the average area of each crop grown and the average yields obtained. Unfortunately, data on irrigated areas and input use by crop are incomplete, making it very difficult to determine the relative contribution of irrigation and input intensities (e.g., fertilizer use) for differences in the level and variability of crop yields. In the rainy season, farmers grow soybean (43% of respondents) while very few farmers grow maize and sorghum (less than 2% of the respondents). In the postrainy season, wheat is the most frequently occurring crop in the area, followed by chickpea. About 89% of the sample farmers reported growing wheat and 96% chickpea, mainly as sole crops in the postrainy season. The other relatively less

Table 10. Average area cultivated, inputs used, crop yields, and variability in yields in the Lalatora watershed¹.

Crops	Season	Number of growers	Average area (ha)	Share irrigated (%)	Fertilizer DAP (kg ha ⁻¹)	Fertilizer Urea (kg ha ⁻¹)	Fertilizer Grow-more (kg ha ⁻¹)	Grain yields (kg ha ⁻¹)	CV (%)
Chickpea	Postrainy	82	2.14	8.4	31.3	0.8	1.2	927	47.3
Wheat	Postrainy	85	2.50	8.4	40.8	12.7	15.1	1211	74.3
Wheat-chickpea	Postrainy	5	2.05	21.9	32.8	24.0	0.0	660	53
								567	122
Lentil	Postrainy	7	3.18	2.2	4.9	0.0	0.0	673	38.9
Paddy	Postrainy	10	1.52	4.9	0.0	0.0	0.0	607	50.8
Soybean	Rainy	44	1.80	36.7	9.0	4.1	0.0	758	61.2
Sorghum	Rainy	2	0.63	0.0	0.0	0.0	0.0	1167	20.2
Maize	Rainy	2	0.62	20.0	0.0	0.0	0.0	1050	128

1. The data for irrigated area and use of fertilizers is incomplete. The averages are based on the few farmers for which data was available. For many farmers, no data was recorded for irrigated areas and input use by crop. Therefore, these values should be taken with caution. For example, the average irrigated area for postrainy-season paddy given as 4.9% is simply unrealistic.

important crops were paddy, grown by about 10%, and lentil grown by about 7% of the farmers. All the postrainy season crops seemed to get some supplementary irrigation, while fertilizer was used on wheat, chickpea, and lentils. In the rainy season, soybean was also grown with supplementary irrigation (Table 10).

A look at the average yields will reveal that wheat and chickpea grown as sole crops had higher yields than the intercrops. As sole stands, postrainy-season wheat yields were about 1200 kg ha⁻¹, while chickpea yields were about 930 kg ha⁻¹. In the rainy season, the average soybean yield from farmers' fields was about 760 kg ha⁻¹, whereas paddy provided about 600 kg ha⁻¹. The results seem to show a relatively lower variability in yields among farmers in this area than in Adarsha watershed, perhaps due to the higher and more reliable rainfall pattern and better soils. For the most commonly grown crops, variability in grain yield seemed to be higher for crops grown in the postrainy season, perhaps indicating the importance of access to supplementary irrigation. Better data is needed to estimate the relative profitability of crops and cropping patterns, partial effects of improved input usage, the quality of soil, and the effect of irrigation on crop yields and variability of income.

Crop Utilization and Commercialization

Farmers use the total production of a given crop to meet various needs. Depending on crop type and the degree of commercialization, the output of a given crop may be consumed, sold, paid in kind to settle loans or for hiring labor, and used as seed or stored. The results (Table 11) show that some crops in Adarsha watershed were mainly grown for subsistence (domestic consumption) while others such as cash crops were grown mainly for sale. The first category comprised basal grains like paddy, sorghum, and pulses (black gram and pigeonpea). A maximum of 6% of the output of these crops was marketed. In terms of average domestic consumption among grains, paddy was the major item consumed (staple crop) followed by sorghum.

The major cash crops in the area are cotton and vegetable bean, grown almost entirely for sale. The other secondary crops targeted for markets and earning cash incomes include turmeric, tomato, chilli

Table 11. Crop utilization and commercialization of production in Adarsha watershed, rainy season¹.

Uses	Sorghum	Black gram	Pigeon-pea	Paddy	Cotton	Vegetable bean	Turmeric	Tomato
Sample	34	33	34	19	17	17	7	4
Mean production	310	40	41	1200	629	444	637	350
Consumed (%)	98	95	95	94	0	0	0	0
Marketed (%)	0	0	0	1.3	100	99	91	100
Other uses (%)	2	5	5	4.7	0	1	9	0
Stored (%)	0	0	0	0	0	0	0	0
Average prices (Rs kg ⁻¹)	-	-	-	-	12	9.38	10.57	8

1. Production figures are in kgs.

pepper, and beetroot. Vegetable crops grown mainly with irrigation are likely to increase in importance if watershed management interventions increase the availability of water and expand possibilities for irrigation. Due to the watershed's proximity to a major consumption center in the city of Hyderabad, market access does not seem to be a limiting factor for the expansion of cash crops. Middlemen and merchants now roam the village to procure marketable vegetables and milk, and bring the produce to the city.

It is important to note that in terms of immediate food security for the household, increasing the production of staple commodities (mainly paddy) would play a significant role. However, mere self-sufficiency in any of the staple commodities is not really important if alternative crops produced for markets bring in higher incomes that can in turn be spent to buy back the household's subsistence needs. Access to markets, export demand for local produce, and the stability of price of both staple and cash crops will determine the level of commercialization in future.

Crop utilization and commercialization varied in Lalatora and Adarsha watersheds. In Lalatora watershed, the major crop —both in terms of total production and consumption in the area — was wheat, which compared with paddy in Adarsha watershed. The average production of paddy was about 550 kg ha⁻¹, while that of wheat was about 2414 kg ha⁻¹ (Table 12). All the other crops seem to be

Table 12. Crop utilization and commercialization of production in Lalatora watershed¹.

Uses	Wheat		Paddy		Sorghum		Chickpea		Soybean		Lentil	
	P	%	P	%	R	%	P	%	R	%	P	%
Sample	96		14		3		93		49		7	
Mean production	2414		561		550		1494		1179		2079	
Consumed	843	35	7	1	0	0	99	7	51	4	96	5
Marketed	311	13	530	94	400	73	996	67	984	83	1300	63
Hiring labor	186	8	2	0.36	50	9	115	8	22	2	241	12
Other uses	60	2	11	2	0	0.00	20	1	12	1	21	1
Stored	1014	42	11	2	100	18	263	18	110	9	421	20
Average prices ³	6		17		11		11		8		13	

1. Grain quantities are given in kgs.

2. P = post-rainy and R = rainy.

3. Rs kg⁻¹.

grown mainly for sale. The most important crops in terms of commercialization are lentils, soybean, chickpea, and paddy. The preference for domestic consumption of sorghum also seems limited, as the average quantity consumed is nil. It is not clear what the household would do with significant quantities of stored grains. Whereas the reserved amounts of wheat seem to be targeted for consumptive use within the household, some other stored grains are perhaps temporarily held until market prices increase. Table 12 shows the utilization and commercialization of major crops grown in Lalatora watershed. Market participation in crop output seemed better here than in Adarsha watershed. Some percentage of all produced crops was marketed, although the degree of commercialization was much higher in the case of grain legumes (chickpea, soybean, and lentils) mainly intended for markets.

Although it is tempting to compute the per capita consumption levels for consumed grains and major nutrients, and compare levels of self-sufficiency in major grains, this was not done mainly because the data does not reflect the year-end consumption levels of households for different crops.

Access to Credit and its Utilization

Access to credit is an important constraint to farmers while making technology choices, adoption decisions, and for maintaining reasonable consumption levels in the face of risk and managing variability in income over time. For small farmers, the use of improved inputs like fertilizer and new varieties and investments in land and water management options highly depends on timely availability and cost of credit. Once credit is available, the cost of capital (rate of interest) influences its use. When the rate of return from the adoption of a new practice is higher than the cost of borrowing, the use of credit from a given source becomes economically attractive. Farmers also face special problems in accessing credit for consumption and medium-to-long-term investments, as many credit institutions prefer to extend credit for short-term productive activities. Spending on soil and water management may also be regarded as natural resource investments that do not provide immediate payoffs to small farmers. This makes it especially difficult to secure loans at market rates of interest.

Farmers gain access to capital credit from various sources, formal and informal (Table 13). The formal sources of credit in Adarsha watershed comprised mainly the cooperative bank. The informal sources were moneylenders, friends, and relatives. About 60% of the sample farmers obtained credit either from formal or informal sources. Of this, some 70% reported obtaining credit from cooperative banks. The remaining 30% borrowed from informal sources (village moneylenders, relatives, and friends). In terms of accessibility of credit, 40% of the sample farmers did not utilize the credit at all. It is not clear whether this was due to problems of access or the lack of demand for credit. Some 39% obtained credit only from cooperative banks; about 10% only from informal sources; and about 11% from both sources. The average size of loans obtained from cooperative banks was about double that obtained from informal sources. The rate of interest too was substantially lower in the formal sector than in the informal sector, lending support to the thesis of exploitative (usurious) rates of interest charged by village moneylenders. However, the difference that is not so huge, may also be explained by the higher risks of default in the informal sector, which necessitates higher rates of interest as a risk premium. The smaller size of informal loans and the higher rates of interest indicate that farmers use these local informal institutions for consumption-related purposes and to meet various social obligations for which they cannot obtain loans from banks.

In Lalatora watershed, farmers' responses indicated that only about 12% of the farmers did not use credit. The rest (88%) used credit from formal or informal sources. Of the total users of credit among the sample farmers, 24% obtained it from banks, 52% from cooperative societies, 10% from government agencies, 44% from moneylenders, and 49% from relatives and friends. These shares do

Table 13. Farmers' access and utilization of credit in Adarsha and Lalatora watersheds.

Village	Users	Mean	Standard deviation of loans	Interest rate (%)	Standard deviation of interest	Purpose of loan
Adarsha watershed						
Cooperative bank	27 (21 ¹)	18185	56941	9.4	5.6	Agriculture
Informal sources	11(5)	9545	4180	14.8	16.8	Agriculture and social functions
Lalatora watershed						
Bank	22 (8)	40686	66790	13.1	4.6	Tractor, electric motor, and inputs
Cooperative society	47 (12)	18287	41396	14.3	5.7	Seed and fertilizer
Government agencies	9 (4)	44833	96050	13.6	4.9	Seed and fertilizer
Moneylender	40 (8)	16000	19769	22.9	17.5	Agriculture and social functions
Other informal sources	45 (17)	12046	11439	21.6	15.1	Social functions, consumption, and inputs

1. Values in parentheses are the number of farmers who obtained credit from only that source.

not add up because many of the respondents reported using credit from more than one source (Table 13). The data also shows that 28% of the users of credit obtained loans only from the informal sector. Considering the high cost of credit from informal sources, these farmers were perhaps unable to access formal credit, and were therefore forced to take loans at high costs from village moneylenders. Average loan size seemed the largest for loans obtained from government agencies, followed by those from banks and cooperative societies. However, only a few farmers accessed credit from government agencies, and the standard deviation of the average loan size from this source is larger than that from banks, perhaps indicating that banks are the largest providers of short- and medium-term credit to farmers in the area. In terms of rate of interest, the scenario is similar to that prevailing in Adarsha watershed, where the formal sector provides loans at relatively lower rates of interest. While banks and government agencies provided loans at 13-14% interest per year, the village moneylenders charged between 20 and 23% interest. Here too, credit from informal sources seems to be channeled into consumptive use and social functions, whereas formal credit is used mainly to buy agricultural inputs and farm equipment. Some farmers reported using formal credit to purchase tractors and electrical motors to lift and pump water. However, none of the sample farmers reported taking credit for soil and water management investments like tree planting, and the construction of erosion and gully control structures.

Adoption of Improved Inputs and NRM Technologies

In order to understand the extent of use of improved and commercial inputs (fertilizer, pesticides, etc.), farmers were asked about their participation in previous watershed programs, the choice of production and resource management technologies, and the period of first adoption. The quality of the data does not allow the estimation of regression equations in order to understand the factors that affect or

determine the adoption and level of use of a given input or technology. This is particularly so in the case of soil and water management practices as many of the answers were not properly filled by the enumerators. The results reported are based on the limited number of valid responses that were available in the baseline data.

Soil Fertility Management

Farmers use improved inputs like chemical fertilizers in combination with organic farmyard manure (FYM) and crop rotation to improve soil fertility and counter the depletion of plant nutrients. In Adarsha watershed, all the surveyed farmers indicated that they had been regularly using chemical fertilizers since 1989. About 60% of them also indicated that they use FYM annually on croplands.

The use of inorganic fertilizers seems relatively less widespread in Lalatora watershed; only 75% reported using chemical fertilizers. Adoption of fertilizers seems to be spread over a long time, with a few farmers starting their use in the '80s and many more adopting them in the '90s. A few farmers also indicated the first use around the time of the survey (1999). Those who chose to use fertilizers seem to have continued their regular use. There is a need to investigate the major constraints that deter a quarter of the farmers in the area from using fertilizers. It would also be interesting to see how their use would change in the future with the widespread use of integrated watershed technologies and intensification of agriculture in the area. Despite the limited use of inorganic fertilizers, only 60% of the sample farmers indicated using FYM. None however indicated using other sources such as green manure and crop residues to replenish soil nutrients. This perhaps points to a high level of soil nutrient depletion in this watershed, as addition of external inputs to restore soil fertility and nutrients that are depleted with harvest and soil erosion seems to be limited. The average fertilizer used in the two watersheds by type of crop grown is shown in Tables 9 and 10.

Water Management

About 54% of the sample farmers in Lalatora watershed and 84% in Adarsha watershed reported having participated in earlier watershed management programs such as contour bunding in the areas. This shows that they are acquainted with integrated watershed management approaches. Moreover, about 60% of the farmers in Adarsha watershed and 50% in Lalatora watershed are not using surface and groundwater harvesting technologies for irrigation. Dug wells represent the most common type of irrigation in Adarsha watershed, while diverting water from rivers and ponds is the most common water harvesting method used in Lalatora watershed. However, a large proportion of farmers in the two watersheds still do not benefit from irrigation. The relatively higher level of rainfall and higher per capita land ownership in Lalatora area may not necessitate intensification of land use to increase yields per unit of land. Increase in population and availability of least-cost methods to harvest surface and groundwater can be expected to promote improved water management and a shift to irrigation.

Recent studies have shown that the groundwater level in selected wells in Adarsha watershed is increasing as groundwater recharge through check dams and other investments has improved. Improved availability of water has facilitated the intensification of agriculture and harvesting of two crops per year. Realising the benefits, a number of farmers have started digging new wells, especially close to check dams. About 10 to 15 wells are drilled every year. Access to irrigation is very expensive, as 25% of the produce has to be paid to those who own water wells, further putting pressure on farmers to own one themselves. If such a trend continues, it will result in the depletion of groundwater in the near future as withdrawals exceed the level of recharge. This in turn will snuff out the benefits of

watershed investments and the motivation for collective action (Dyton-Johnson 2000). In this light, future focus must be on designing incentive structures that encourage the regulated use of groundwater for irrigation, ensuring sustainable intensification of agriculture and the improved well being of the people in the watershed. In order to determine an optimal level of drill wells that approximate a sustainable trajectory of groundwater use, more work needs to be done on the groundwater recharging potential of check dams and other community investments.

Integrated Soil and Water Management

Respondents were also asked about the adoption of indigenous soil and water conservation practices. These indigenous technologies are widely used by farmers in different regions of India. The survey intended to quantify their level of use in the respective watersheds. The soil and water management technologies that were included without verifying their local suitability were:

- Water ways
- Farm ponds
- Land smoothing and field drains
- Dead furrows
- Deep furrows
- Deep tillage
- Keyline cultivation

These technologies are described in detail in Appendix C.

The intensity of use of these technologies was measured using a proxy variable which categorized farmers' responses into three groups: nonadoption, adoption of at least one field, and complete adoption. In case of partial adoption or nonadoption, farmers were also asked about the major constraints to full adoption. Farmers' responses are reported in Tables 14 and 15. In Adarsha watershed, valid and reliable responses were collected from all the 54 sample farmers. However, in Lalatora watershed, reliable data was collected from only 69 households. The results showed a very low level of adoption of indigenous soil and water conservation technologies in both the watersheds. In Adarsha watershed, the only technology that seemed to have been adopted in significant measure was land leveling and smoothing, with more than half the sample farmers fully adopting the method. About 7% partially adopted it on some of the cultivated plots. Some farmers also reported using the cultivation method. This indicates that before the intervention of participatory watershed development, many of the indigenous methods of soil and water conservation had not been adopted in the area. It would be instructive to see whether this situation has changed after the watershed project interventions.

In Lalatora watershed too, the level of adoption was quite low, ranging between 3 and 15%. While land leveling and smoothing did not find takers in this area, deep furrow and deep plowing seemed to be relatively more attractive, perhaps because of the more heavy and deep soils in the area. Respondents in both the watersheds felt that the limited adoption or nonadoption of indigenous methods was due to high costs (low profitability), poor suitability to local conditions, and lack of knowledge. This calls for extension, training, and education about the potential and suitability of these methods for different soil and cropping systems. The high costs and poor suitability of the technologies relate to shortage of farm labor, the labor-intensive nature of some of the technologies, and the location-specific nature of NRM technologies. These require attention in future research efforts in order to identify diverse options that are economically attractive to farmers under varying biophysical and socioeconomic conditions.

Table 14. Adoption of soil and water conservation and management practices in Adarsha watershed.

Practices	Level of adoption ¹	Number of farmers in group	Frequency of farmer response to non/partial adoption					Other risks
			Lack of knowledge	Technically unsuitable	Too costly	Not convenient	Failure to cooperate	
Dead furrows	0	53	41	8	0	7	0	0
	1	1						
	2	0						
Deep furrows	0	2	1					
	1	0						
	2	52		2		2		
Deep tillage	0	2	1					
	1	0						
	2	52		2		2		
Dugout ponds for water reuse	0	53	27	8		19		
	1	0						
	2	1						
Keyline cultivation	0	49	46	3				
	1	0						
	2	5						
Levelling and smoothing	0	22	17	1		4		
	1	4						
	2	28						
Water waste weirs	0	54	15	29		9		
	1	0						
	2	0						
Waterways	0	52	7	26		19		
	1	0						
	2	2						

Note: Sample size (n) = 54. It seems none of the farmers considered lack of collective action and other risks as important for any of the investments.

1. Level of adoption: 0 = no adoption; 1= adoption on at least one field; and 2 = complete adoption.

Table 15. Adoption of soil and water conservation and management practices in Lalatora watershed.

Practices	Level of adoption ¹	Number of farmers in group	Frequency of farmer response to non/partial adoption					Other risks
			Lack of knowledge	Technically unsuitable	Too costly	Not convenient	Failure to cooperate	
Dead furrows	0	61	30	6	28	13	24	
	1	8	5		3		2	
	2	0						
Deep furrows	0	60	26	9	29	15	15	17
	1	9	1			1		
	2	0						
Deep tillage	0	52	16	5	30	15	12	14
	1	13	3	1	7	1		1
	2	4						
Farm ponds	0	58	23	6	34	14	10	14
	1	7	2	1	6	1	3	3
	2	4	0					
Levelling and smoothing	0	67	28	4	44	11	13	19
	1	2	1		3		2	2
	2	0						
Waterways	0	65	24	20	28	13	16	15
	1	3	1	2	2			1
	2	1						

Note: Sample size (n)=69.

1. Level of adoption: 0 = no adoption; 1= adoption on at least one field; and 2 = complete adoption.

Plant Protection and Pest Management

Farmers traditionally use a variety of methods to control weeds, insects, birds, and rodent pests and diseases, ranging from mechanical weed control (manual weeding) to the use of herbicides, insecticides or treatment of seeds. Crop rotation, crop combinations (like in intercropping), and changing the date of planting may also provide plant protection benefits. When labor is relatively abundant and chemical inputs are relatively costly, farmers often opt for labor-intensive methods of plant protection. As market access improves and commercialization increases, higher returns from the use of chemical inputs provide incentives to use chemical plant protection methods. When pest attacks are severe and labor-intensive control methods are ineffective, farmers may turn to chemical inputs on low-value basic grains to ensure food security.

One of the shortcomings of the survey instrument was that it has not tried to identify the major pests and diseases for each crop grown in the area. Ideally, one should have asked for information on major pests, weeds, and diseases by crop type during pre- and post-harvest periods and how farmers control and manage them. However, the questions were designed only to understand farmers' use and local availability of pesticides (insecticides, herbicides or weedicides). Responses from Adarsha watershed indicate that all the sample farmers used pesticides of one type or the other. Adoption seems to have been facilitated after 1989. The fact that a significant number of farmers (88%) already own a sprayer seems to make spraying chemicals easier. In Lalatora watershed, the level of pesticide use was much lower (10%). Many of the respondents mentioned that pesticides were not readily available in the area throughout the year. These results are consistent with the low level of use of other commercial inputs like fertilizer in Lalatora watershed, perhaps also indicating low levels of intensification of land use and commercialization of production. An alternative explanation for the low demand for chemical pesticides could be low pest attacks. Future work should explore these hypotheses.

Summary

Soil and water degradation decrease the profitability from investments in new technologies, thereby making it unattractive for small farmers to adopt agricultural innovations. Farm-level resource deficiencies, including lack of reproducible productive inputs, prevent the realization of the maximum yield potential of new varieties and other agricultural technologies. This often explains the high disparity between returns to investments in new technologies attained on-station and on farmers' fields. This has led to the increasing realization of the crucial roles that improved soil fertility management and increased productivity of scarce water resources could play in the global effort to eradicate poverty. Alternative technology options suitable to variable local conditions (developed through participatory methods) as well as enabling policies and innovative institutional arrangements are urgently needed to create incentives for small farmers to invest in more sustainable and productive water and soil management practices. Several studies have demonstrated the enormous potential of small farmers in reversing degradation of natural resources, even under high population density when new technologies, policies, and access to markets and local institutions provide viable options and economic incentives (Tiffen et al. 1994; Heath and Binswanger 1996; Aylward and Gonzalez 1998; Templeton and Scherr 1999; Scherr 2000).

Since watersheds are often inhabited by heterogeneous group of households (belonging to different social, political, and administrative units) with fragmented land holdings and resource-use rights, optimal and sustainable management of water and soil resources in these areas requires integrated approaches and improved policy and institutional arrangements that encourage and

stimulate both private and collective efforts. In India and many developing countries, past watershed research and development efforts accorded primacy to promoting soil and water management options on private and communal lands through short-term project and program subsidies. The top-down and technocratic approach failed to consider farmers' constraints and priorities in the design and implementation of watershed programs. This has called into question the economic and environmental sustainability of many such interventions. Therefore, in recent times, second generation problems on sustaining the impact of watershed investments through minimum financial and technical support to the beneficiary communities have become an important policy issue. In order to address such issues together with technology design and development, ICRISAT along with NARS partners, recently initiated participatory, community-based watershed research in three locations in India and in one location each in Thailand and Vietnam. An innovative, multi-stakeholder consortium approach is now being tested for the development of appropriate technologies for integrated water, soil, nutrient, and crop management in the selected watersheds (Wani et al. 2002).

This study is part of the ongoing research on integrated management of watersheds and aims at the socioeconomic characterization of the baseline data collected at the two benchmark sites in India. The study analyzed the existing baseline data from Adarsha watershed and Lalatora watershed. The study focused on the socioeconomic characterization of the production systems and resource use and management patterns in the areas. As such, no conclusions can be given based on analysis of this data. Rather, the results are expected to serve as a reference on major socioeconomic conditions of agriculture and natural resource management in the watersheds, and provide a foundation for further research, including an assessment of the livelihood and environmental impacts of watershed management interventions in the area.

For this study to be useful for the future, we present the major limitations of the baseline data, identify research gaps, and outline some recommendations for further research to address issues related to monitoring impacts on poverty, the quality and productivity of the resource base, and understanding policy and institutional factors that promote more sustainable use of soil and water resources in the watersheds.

Suggestions for Future Research

Plot-level Input-output and Investment Data

The baseline socioeconomic survey conducted at the three benchmark watersheds in India attempted to collect primary data at the whole farm level with emphasis on household characteristics, landholdings, asset holdings, livestock wealth, cropping patterns, access to credit, and crop utilization. An attempt was also made to collect data on adoption of improved inputs and indigenous soil and water management methods, albeit at the whole farm level. The questionnaire also included a module for gathering data on production levels and the different kinds of inputs used by farmers at the plot level. This kind of information is very useful for estimating production functions, relative profitability of new technologies, and developing input-output coefficients needed in bioeconomic and farm household models. Unfortunately, the baseline data is weakest for this module. Moreover, the uncertainty and unreliability of the entire baseline data for one of the locations (Ringnodia) made it difficult to carry out a meaningful socioeconomic analysis at the site.

It should be emphasized here that production, input use, and technology choice decisions of smallholder farmers are often shaped by the existing biophysical conditions on each field and parcel. Farmers intentionally match crops, inputs, and soil and water management investments with the prevailing soil quality, moisture availability, and topographic conditions of specific agricultural lands.

This often explains the diversification of production and the partial and stepwise adoption of new technologies (Bellon and Taylor 1993; Reardon et al. 1992). The baseline survey failed to gather information on input-output relationships, and technology adoption and resource-improving investments at the plot level for all crops. A plot or parcel is characterized by relatively homogeneous land quality characteristics (e.g., soil type, soil depth, soil fertility, slope, irrigation) that farmers use as reference while choosing a crop and technology. Besides, common intercropping practices among Indian farmers make it necessary to record input and output relationships for each crop included in the intercropping system. Despite good efforts, the enumerators failed to distinguish between sole crops and intercrops, and the production and input use data, if at all recorded, was given only for the first crop in the intercropping system. In view of the poor quality of the plot-level crop-specific data, future surveys should rectify this lacunae by collecting detailed information on cropping patterns, crop-livestock production, input use, and investment at the most homogeneous level of land quality. Availability of such data could facilitate the effective monitoring of changes in the biophysical conditions of the watershed, improvements in productivity of soils, and potential impacts on the welfare of smallholders.

Sample Size and Seasons

As indicated earlier, the survey included 102 households from Lalatora watershed and only 54 households from Adarsha watershed. For a household survey, the sample size was very small (especially in Adarsha watershed) for undertaking a statistical analyses and to establish cause-effect relationships through econometric analysis. The survey also failed to include all the seasons and collect year-round data. Baseline data on Adarsha watershed only included the main rainy-season crops. Farmers, however, grow some crops in the postrainy season too using supplementary irrigation. Some farmers in the watershed also grow vegetables in the summer season using irrigation made possible by watershed management. Therefore, evaluating the full potential and impact of watershed interventions requires collecting year-round data on crops grown and incomes earned from various sources across seasons, from a sufficient number of sample households.

Diversification and Noncrop Income

The poor quality of household expenditure on factors of production and the lack of records on farmers' incomes from sources other than cropping has now made it difficult to estimate farmers' net incomes. In fact, the survey even failed to ask farmers about their earnings from livestock production; only livestock wealth at the beginning of the year was recorded. Often, computing gross returns from livestock requires data on changes in the stock of animals during a given year. Income from local farm and nonfarm employment, petty trade, migration (remittances), etc., was not compiled. As water availability in the watershed increases and land productivity goes up, the level of production risk faced by households may change. This may create new crop-livestock production patterns and increase possibilities for local employment. In view of the potential of watershed investments to create such employment and income-earning opportunities for landless households and smallholder farmers in the area, data on income from livestock and nonfarm sources need to be collected as part of future surveys. This implies that future surveys should not only increase the sample size but also include landless households. Monitoring changes in household income and livelihoods would be difficult without such a complete dataset.

Policy and Institutional Options

Investments in water and soil management practices (including cropping systems, cereal-legume rotations, agroforestry, soil conservation, water harvesting, etc.,) by a single landholder in watersheds often generate valuable economic and ecological goods and services that influence the flow of benefits and costs both on-site (for the resource owner) and off-site (for other members of the community). Off-site unintended spillover effects of private resource-use decisions that affect production (or consumption) activities of other farmers, which are not mediated through the market mechanism, are commonly referred to as externalities. Some of these externalities could be positive and others negative. The distribution of investment costs and benefits and the presence of unintended spillover effects determine farmers' technology choices, land-use patterns, and investment strategies in the watershed. Future research should look into improved policies and institutional incentives needed to internalize the watershed externalities. It should also explore alternative market and nonmarket institutional arrangements for water and soil management. Property rights to water need further clarification. Bioeconomic modeling will provide a means to explore the effect of alternative policy options. Ultimately, the lessons learned in sequencing of interventions, the methodologies developed for monitoring impacts and evaluating alternatives, the process of social organization and uptake of technologies, and the policy and institutional mechanisms used in mobilizing local resources and internalizing adverse externalities are perhaps the major outcomes that would be useful in scaling up the community watershed approach for a wider impact.

Integration of Village-Level and Watershed Studies

ICRISAT is well known for the unique historical socioeconomic data collected from Indian and African (Burkina Faso and Niger) SAT villages and households. The institute's Village-level Studies (VLS) in India include 10 rural communities in four states (Andhra Pradesh, Madhya Pradesh, Maharashtra, and Gujarat) carried out over a period covering 1975 to 1985, with some resurveys in 1989-90 and 2001. In the late 1990s, ICRISAT also initiated on-farm watershed management research. From the state of Andhra Pradesh (Mahabubnagar district) alone, there are two communities (Aurepalle and Dokur) included in the VLS database. These VLS locations served as on-farm laboratories for testing and evaluating ICRISAT's new varieties and germplasm. Unfortunately, the natural resource management research failed to use these VLS locations, where ICRISAT had accumulated a wealth of socioeconomic data, as on-farm technology testing sites. This has led to a lack of socioeconomic data in the benchmark watersheds where community-based participatory research is now underway. At this stage, ICRISAT is interested in revisiting at least some of the VLS locations in Andhra Pradesh and Maharashtra. Expanding the VLS work to include natural resource management problems and issues for some locations will provide a new dimension to improve the quality and relevance of the work. In the short term, extending VLS to watershed locations is the most optimal choice. The availability of holistic natural resource management and socioeconomic data provides a fertile ground for evaluating technologies and exploring alternative policy and institutional arrangements using bioeconomic modeling and other approaches. Therefore, future activities under VLS and watershed research should be integrated closely to exploit synergies. The diversity of issues and constraints to sustainable intensification of smallholder agriculture in the semi-arid tropics also call for an interdisciplinary and participatory approach to technology design and development.

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Figures, Map and Appendices

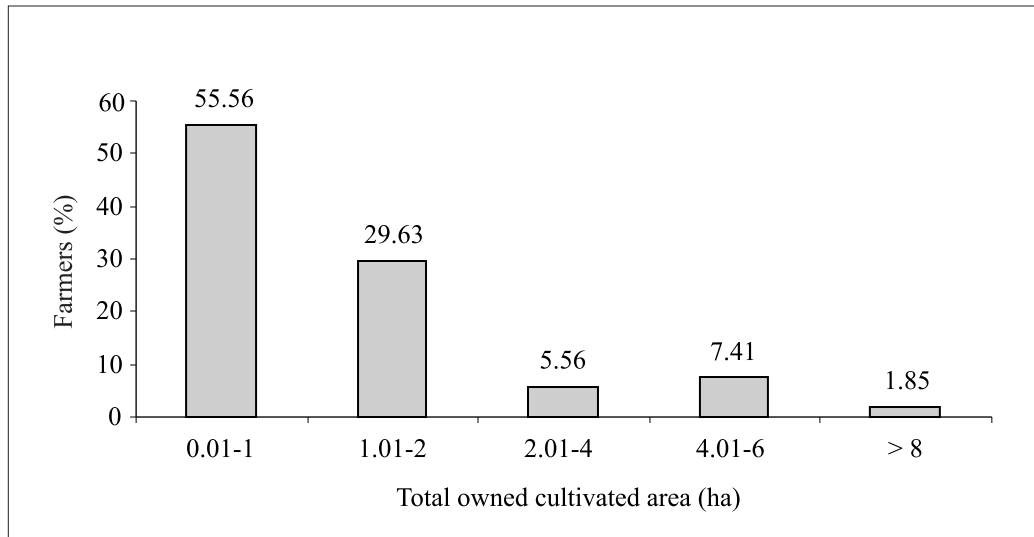


Figure 1. Distribution of own cultivated land by landholding classes in Adarsha watershed.

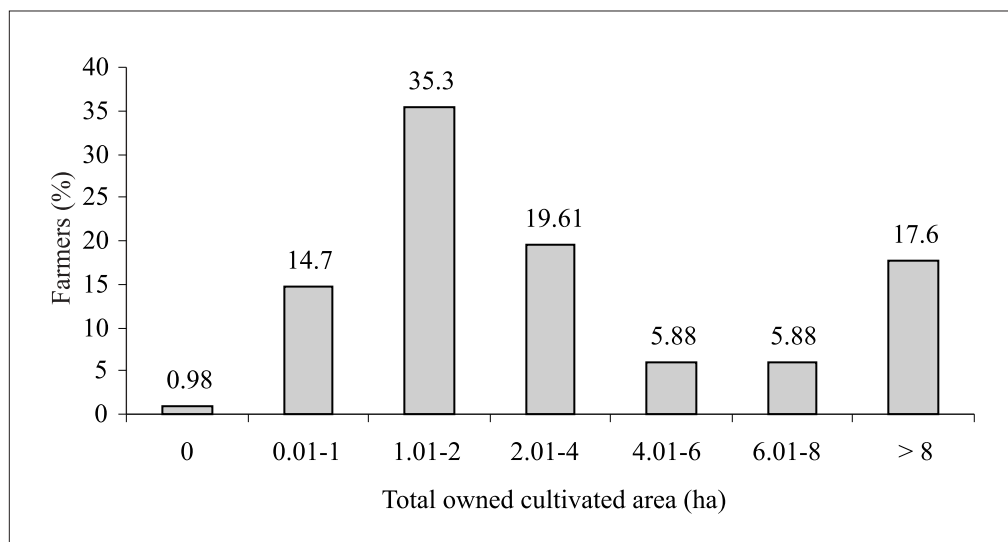


Figure 2. Distribution of own cultivated land by landholding classes in Lalatora watershed.

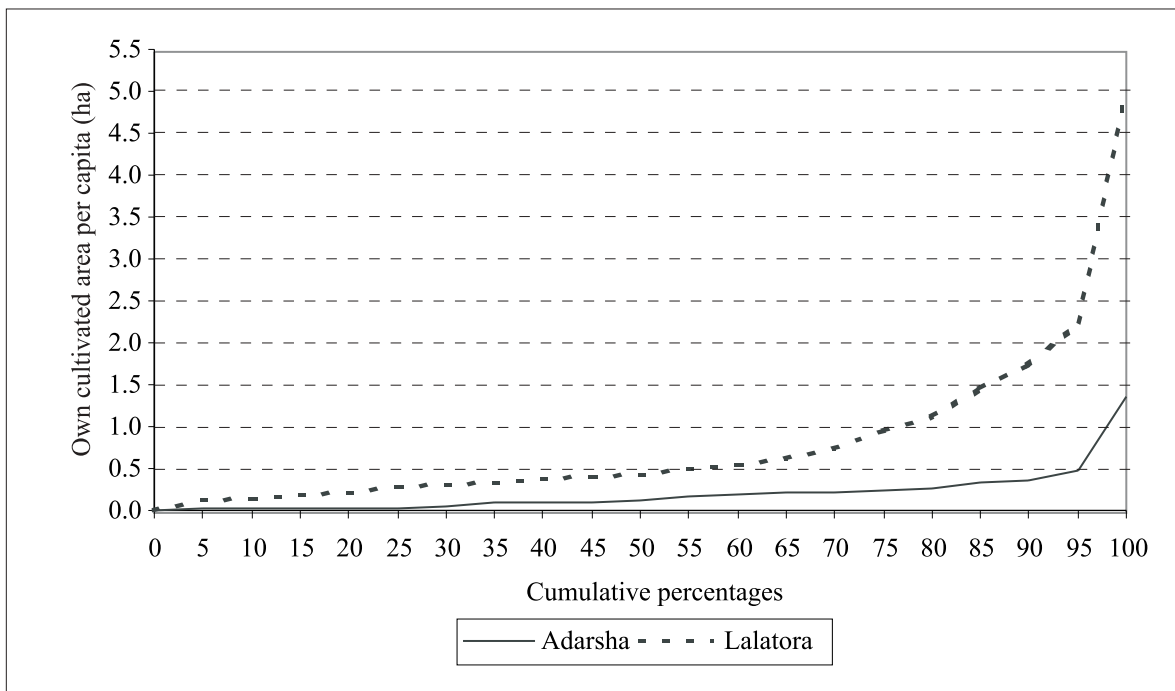


Figure 3. Cumulative probability distribution of own cultivated land per capita in Adarsha and Lalatora watersheds.

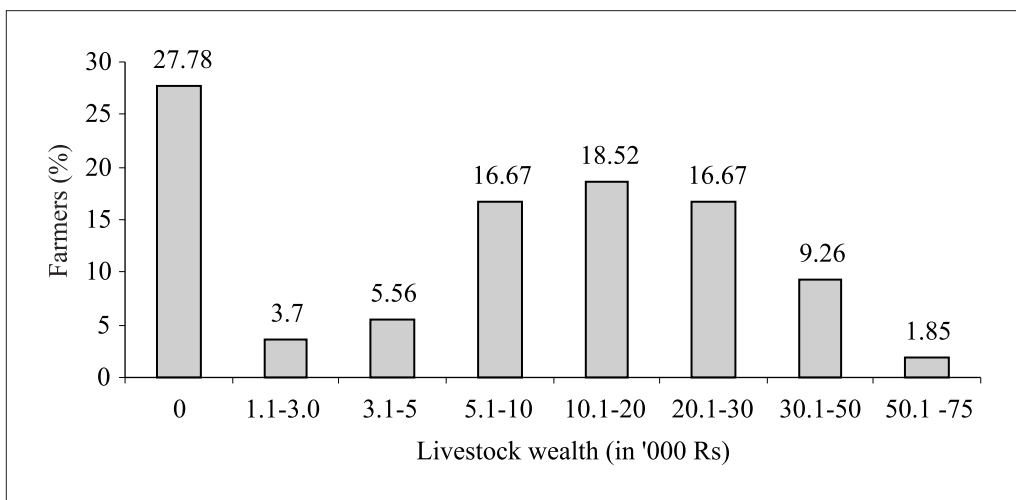


Figure 4. Distribution of livestock wealth in Adarsha watershed.

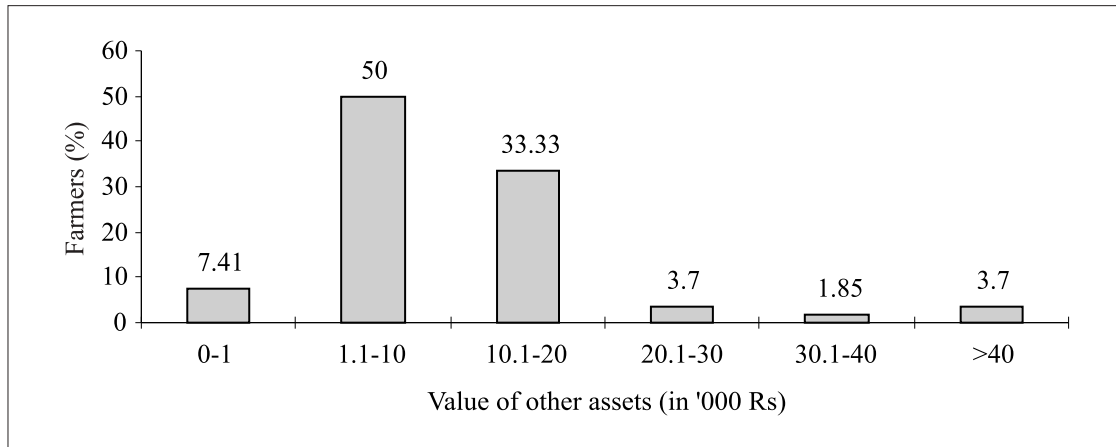


Figure 5. Distribution of nonlivestock wealth (farm equipment and related assets) in Adarsha watershed.

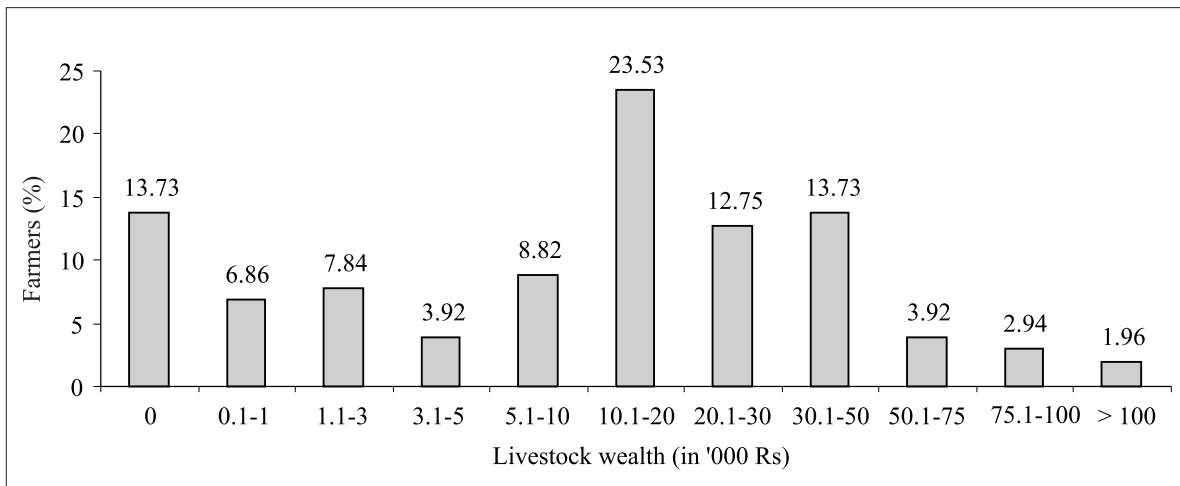


Figure 6. Distribution of livestock wealth in Lalatora watershed.

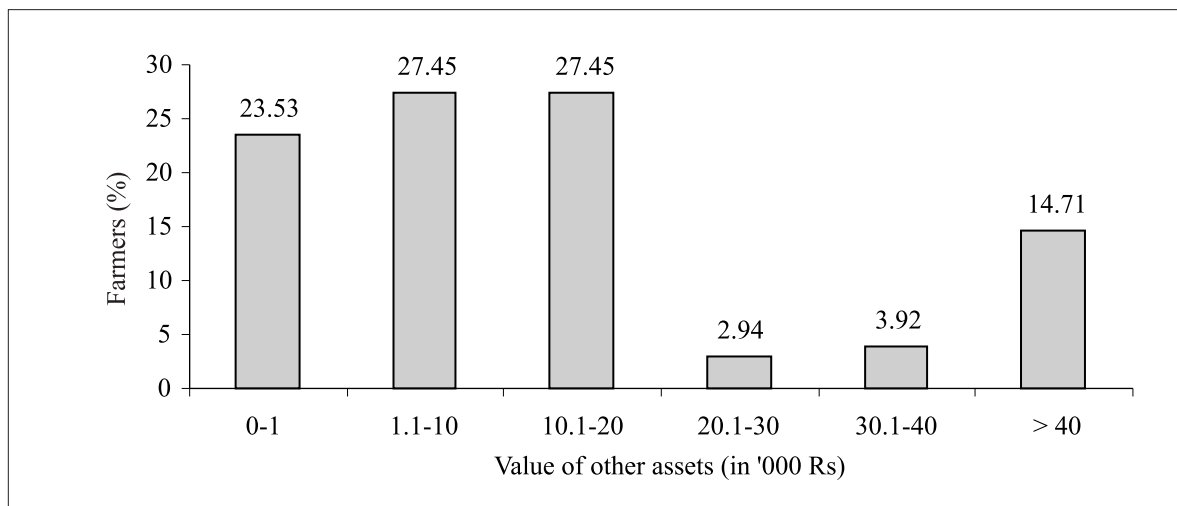


Figure 7. Distribution of nonlivestock wealth (farm equipment and related assets) in Lalatora watershed.

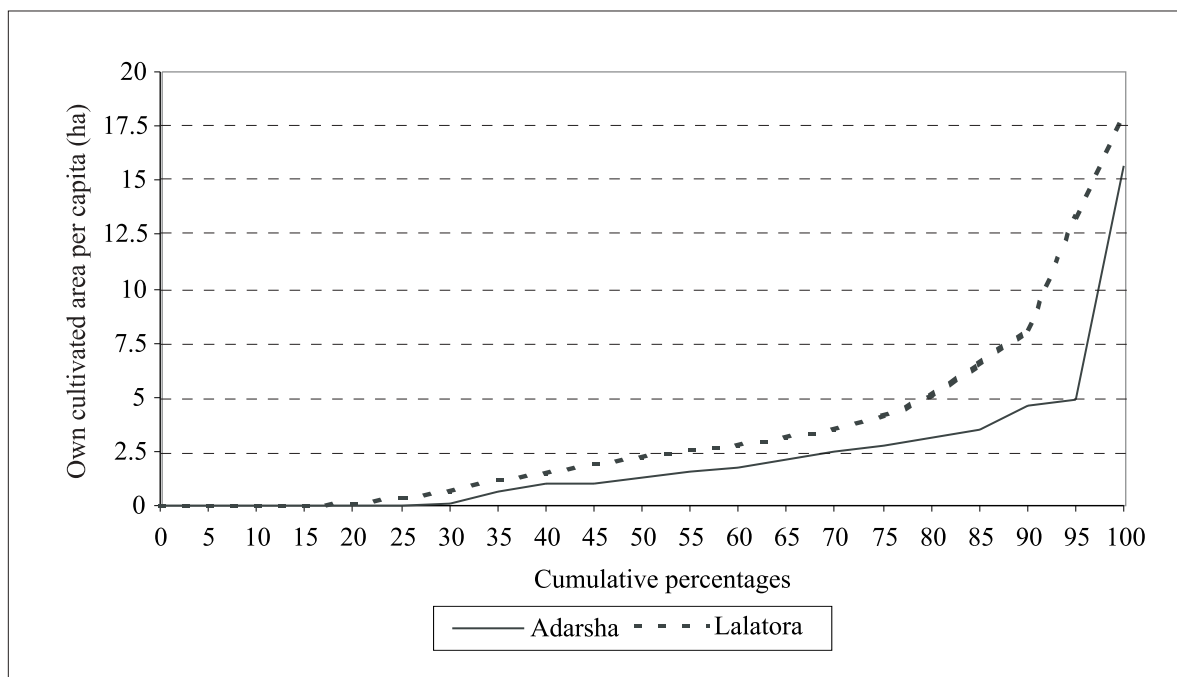


Figure 8. Cumulative probability distribution of livestock wealth per capita in Adarsha and Lalatora watersheds.

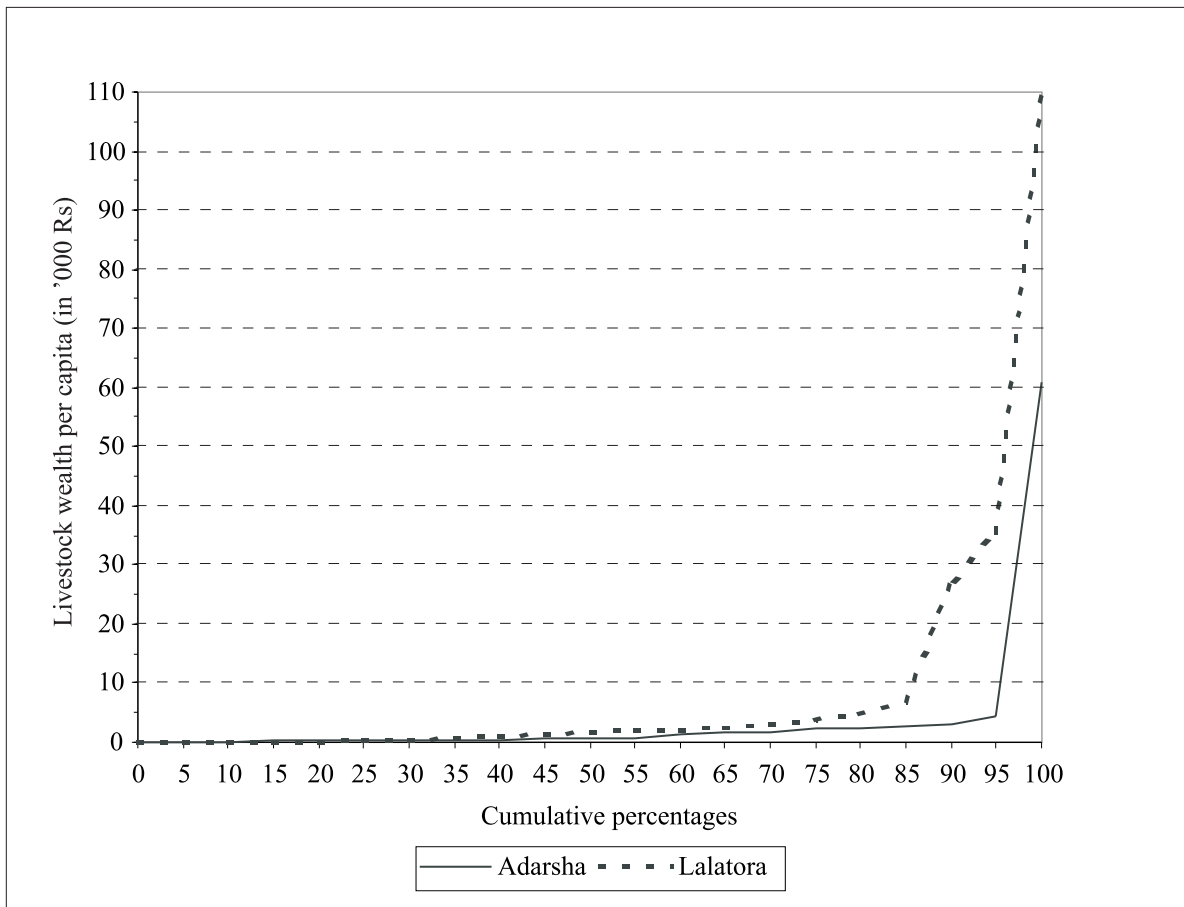
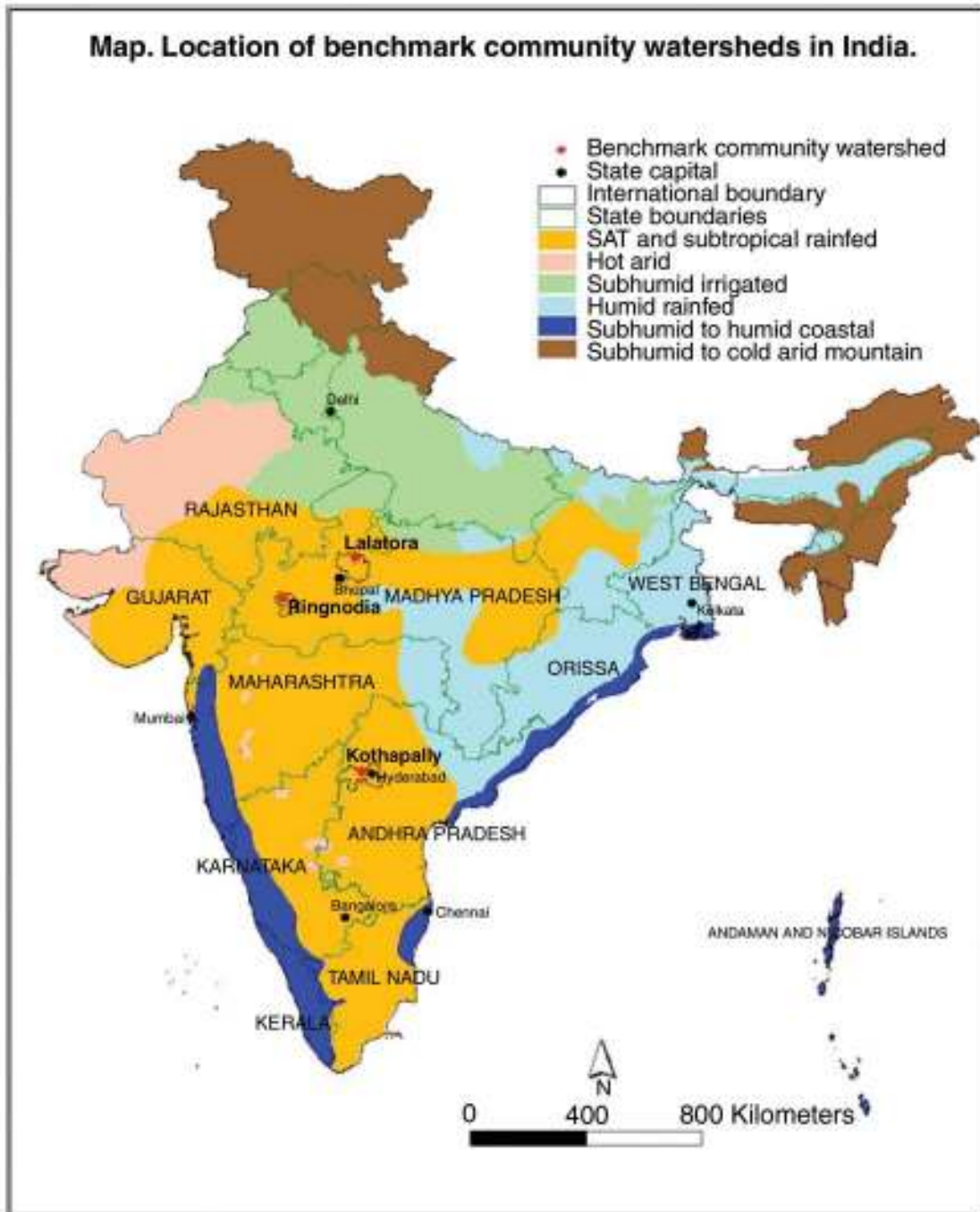


Figure 9. Cumulative probability distribution of nonlivestock assets per capita in Adarsha and Lalatora watersheds.



Appendices

Appendix A. Socioeconomic and biophysical characteristics of the watershed districts.

Characteristics	Ranga Reddy	Vidisha	Indore
State	Andhra Pradesh	Madhya Pradesh	Madhya Pradesh
Agroecological zone	Northern Telangana plateau, hot, moist, semi-arid, and length of growing period (LGP) of 120-150 days.	Malwa plateau, hot, dry, and subhumid, and LGP of 150-180 days.	Western Malwa plateau, and LGP of 120-150 days.
Geographic location	16° 30' to 18° 20' N and 77° 30' and 79° 30' E	23° 27' to 24° 24' N and 75° 49' and 76° 32' E	22° 28' to 23° 02' N and Major soil types
Vertic inceptisols and sandy alfisols	Vertisols and associated soils	Vertic inceptisols	
Rainfall (mm)	829	1331	1054
Land utilization (1997-98) in '000 ha			
- Geographical area	753	730.19	353.88
- Net sown area	309	527.82	257.58
- Forest	73	105.74	30
- Fallow lands	65	2.87	2.27
- Permanent pastures	46	34.26	32.48
- Nonagricultural uses	352	59.49	38.54
Irrigated area (% cultivated)	24.17	19.81	35.3
Temperature and relative humidity	9.1 to 42.4° C 48-69%	8.0 to 38.1° C —	3.3 to 42.5° C 39-60%
Total population in 1997 and 2001 (in thousands)	3400/4117	1104/1202	2151/2391
Rural population (%) in 1997 and 2001	42.4/36.6	78/76.9	28.7/27.5
Rural population density (persons per ha net sown area)	4.66/4.87	1.63/1.75	2.39/2.55
Literacy rate (%)	40.24	42.29	58.87
Rural female literacy (%)	14.59	23.87	24.78
Rural male literacy (%)	36.63	49.57	57.03
Per capita agricultural income (Rs)	588	1943	1212
Livestock (in thousands)	Cattle and buffaloes: 521.77; sheep: 241; goats: 235; and poultry: 10018.	Cattle and buffaloes: 486; sheep: 4; goats: 79.28; and poultry: 62.	Cattle and buffaloes: 399.48; sheep: 2; goats: 85.38; and poultry: 715.

Source: Compiled by authors from various sources.

Appendix B. Socioeconomic and biophysical characteristics of the benchmark watersheds.

Characteristics	Kothapally	Lalatora	Ringnodia
State	Andhra Pradesh	Madhya Pradesh	Madhya Pradesh
District	Ranga Reddy	Vidisha	Indore
Block, tehsil, mandal	Shankarpally	Lateri	Solsinda
Major soil types	Vertic inceptisols	Vertisols and associated soils	Vertic inceptisols
Location	50 km from Hyderabad, Shankarpally mandal	140 km from Bhopal	20 km from Indore
Altitude (m asl)	550	415	540
Rainfall (mm)	760	1200	1050
Total number of households	270	25	127
Major crops grown	Maize, pigeonpea, cotton, black gram, sorghum, paddy, sunflower, and vegetables	Soybean, wheat, chickpea, maize, sorghum, and pulses	Soybean, maize, fodder, wheat, potato, garlic, chickpea, and onion
Livestock types	Cattle, buffaloes, sheep, goats, and poultry	Cattle, buffaloes, sheep, and goats	Cattle, buffaloes, sheep, and goats
Partners in watershed research ¹	Farmers, ICRISAT, MVF (NGO), DPAP (State Government), and Central Government	Farmers, ICRISAT, CRIDA, BAIF, DRF (NGO), and RGWM	Farmers, ICRISAT, JNKVV, CRIDA, Watershed committee, NWDPPRA
Market access (nearest market point)	Shankarpally (20 km)	Anandapur (6 km) and Lateri (20 km)	Indore (15 km)
Nearest bank	20 km, Shankarpally	6 km, Anandapur	5 km, Dharmapuri
Watershed area (ha)	464	725	390
Water management (as of Dec 2001)	62 open and 52 tube wells and 6 check dams	2 ponds, 6 check dams, and 11 open and 14 tube wells	2 ponds, 14 open and 19 tube wells
Baseline survey (sample size) and seasons covered	574, rainy season, 1998	102, rainy and post-rainy seasons, 1999	49, rainy and post-rainy seasons, 1999-2000
Date of survey	April 1999	February 2000	October 2000
Baseline data quality	Good	Good	Insufficient

Source: Compiled by authors based on survey data and other sources.

1. MVF= M Venkata Rangayya Foundation; DPAP = Drought Prone Area Program (of the Government of Andhra Pradesh); CRIDA = Central Research Institute for Dryland Agriculture; BAIF = Bharatiya Agro-Industries Foundation; DRF = Development Research Foundation; RGWM = Rajiv Gandhi Watershed Mission; JNKVV = Jawaharlal Nehru Krishi Viswa Vidhyalaya; and NWDPPRA = National Watershed Development Project for Rainfed Areas.

Appendix C. Indigenous soil and water conservation methods.

The soil and water conservation practices mentioned in the baseline questionnaire are indigenous practices adopted by farmers in different regions of India. These are not recommended by ICRISAT. Following are the indigenous methods of integrated soil and water management.

- Waterways
- Farm ponds
- Land smoothing and field drains
- Dead furrows
- Deep furrows
- Deep tillage
- Keyline cultivation

The economic and technical suitability of these methods often varied depending on resource requirements for installation, local availability of construction material, and biophysical and agroclimatic conditions in a particular area. A brief description of these measures follows.

Waterways

Waterways are drainage channels either developed by shaping existing drainage ways or constructed separately to drain agricultural lands. They are aligned along the major slope to handle runoff discharge from contour/graded bunds, bench terraces, contour trenches, and contour furrows. Excess runoff diverted by graded bunds or conservation drains are required to pass through major waterways before merging with community drains. The objective is to provide drainage to agricultural fields by safely disposing excess rainwater, to convert gullies or unstable channels into stable channels by providing vegetal protection to the soil surface, and to channel and regulate runoff flows for water harvesting.

The cost estimate depends on the depth of the waterway, which may range from 0.15 to 0.5 m, the land gradient, and the materials used. The existing slope of the ground generally determines the gradient of the waterway. After the waterway is constructed, efforts are made to raise vegetation – a mixture of perennials and annuals (a combination of grasses and legumes) to protect against soil scouring.

Farm Ponds

Farm ponds are bodies of water made either by constructing an embankment across a watercourse or by excavating a pit or a combination of both. The objective may be to provide water storage for life-saving irrigation in a limited area; to provide drinking water for livestock and human beings in arid areas; to serve as water storage for providing critical irrigation to limited number of fruit plants for establishment; or to moderate the hydrology of small watersheds.

The size of a farm pond depends on soil type, moisture-holding capacity, and the total requirement of water for irrigation, livestock, and domestic use. The cost of construction is related to earthwork either in the form of filling as embankment or in digging, lining the pond, setting up inlets and outlets, and emergency spillways.

Land Smoothing and Field Drains

Leveling is the art of determining relative elevations of points or objects by using a leveling instrument. Depending upon the topography, land leveling requires moving a lot of soil, sometimes over large distances. After land leveling, the land surface requires further smoothing. Land smoothing (also known as land planning or land floating) involves removing minor irregularities. Land grading depends upon the topography of an area, soil type, soil depth, crops to be grown, source of water supply, and method of irrigation.

Dead Furrows

Dead furrows, also known as flat and furrow, involve ploughing between a depth of 15 and 20 cm, where the slope is less than 0.1% and essentially straight. It is best suited for row crops.

Deep Furrows

This involves ploughing to a depth of more than 20 cm.

Deep Tillage

One of the reasons for low yields in the semi-arid regions is the limited moisture available to crop roots. Available moisture increases if rooting depth is increased. It has been shown that deep tillage can help in some cases. Deep tillage is beneficial only to some crops and on some soils. It requires greater draught power, which is usually in short supply in semi-arid areas.

Keyline Cultivation

Keyline cultivation aims to spread the runoff water away from the centre of the valley to minimize the flow concentration in this area. By cultivating parallel to identified keylines, both above and below the line, a cultivation pattern is developed which spreads the runoff evenly across the valley and does not allow the water to follow its natural path and concentrate in the valleys. This aids in the stabilization of the valley and increases its ability to resist erosion and washouts. The key feature of keyline farming systems is to increase organic matter in the soil, which, in turn, will increase soil productivity. Keyline layouts of farm and grazing lands are designed to store runoff water on the farm itself to effectively spread the often irregular rainfall patterns.

The name keyline was given to the particular contour that runs through the point, in a headwater valley where the slope change occurs. The keyline pattern increases the time of contact between the rain and the earth, and turns storms into steady soaking rain.