Chapter 10
Soil Fertility Management in Semiarid Regions: The Sociocultural, Economic and Livelihood Dimensions of Farmers' Practices—*A Case of Andhra Pradesh*

B. Suresh Reddy

10.1 Introduction

India is predominantly an agrarian economy and more than 70 % of its population directly or indirectly depends on farming. Indian agriculture is often discussed in relation to the Green Revolution and its mixed record of successes and failures. Yet, what most Indian farmers (over 60 %) practise is rainfed agriculture, a farming system entirely different to that of irrigated areas. Green Revolution technology gains in agricultural productivity and food security were widely associated with irrigated lands, where the benefits of improved seeds and increased use of inorganic fertilisers could be realised. However, there are now widespread problems associated with the use of chemical fertilisers, mismanagement of surface water and overexploitation of groundwater, the most important source for irrigation (GoI, Economic survey 2008). The potential for expanding irrigated agriculture is decreasing as it becomes more expensive or risky to further exploit water resources. It has been fully realised that even if the full irrigation potential of the country were to become operative, 50 % of the net sown area would continue to be rainfed. Hence, its contribution is vital to the food security and livelihoods of the poorest farming families and communities who do not have access to irrigated land. Moreover, dryland agriculture holds the key for future food security in the light of Green Revolution reaching its saturation in enhancing land productivity. It is shown that returns on investments in rainfed agriculture are greater than those on investments in irrigated agriculture (Fan and Hazell 2000).

B. Suresh Reddy is an associate professor at the Division for Sustainable Development Studies (DSDS), Centre for Economic and Social Studies (CESS), Hyderabad. This chapter is based on my doctoral research work at CESS. An earlier version of this chapter has been published in *Economic and Political Weekly (EPW)*, dated 15 January 2011.

B. S. Reddy (✉)
Division for Sustainable Development Studies, Centre for Economic and Social Studies, N.O. Campus, Begumpet, Hyderabad 500016, India
e-mail: Srihithasuresh@yahoo.com

© Indian Society for Ecological Economics 2016

N. Ghosh et al. (eds.), *Nature, Economy and Society*,
DOI 10.1007/978-81-322-2404-4_10

In semiarid regions,[1] dryland farmers have developed cropping practices ranging from summer ploughing to crop rotations that are suited to the harsh agro-climatic constraints (Pionetti and Reddy 2002). These practices are derived from the farmers' deep understanding about the interactions between climate, soil, crops and insects, and enable the regeneration of soils and the optimal use of scarce moisture. As a major provider of organic manure, livestock are crucial to the stability of dryland agriculture and farmers also depend greatly on them for income (Reddy 2001; Sagari 2004, Reddy 2010a, Reddy 2010c). It is estimated that by 2025 India will use about 30 million t of plant nutrients per annum, 8.1 million t of which will come from organic manures. Soil fertility management (SFM) not only affects those who own or cultivate agricultural land, it is also important for the landless poor, especially women who often gather, process, transport and apply organic material to supplement their livelihoods. Cattle owners trade manure not only to be applied in fields, but also as a valuable source of fuel. Shepherds barter manure of their sheep and goats for the right to graze on particular plots of land (Adolph and Butterworth 2002). Through these multiple dimensions, SFM is a key to the sustainable livelihood of the rural people in semiarid tropics (SAT) in India. Based on the fieldwork done in Andhra Pradesh (AP), this study explores the local farmers' in-depth knowledge on SFM, and the cultural and socioeconomic web woven around these practices. It also looks at how policy interventions threaten this knowledge base and the sustainable practices it supports.

The objectives of this chapter are to identify and record the SFM strategies adopted across different size classes of farmers in dryland regions, to examine the ecological, economic, social and livelihood significance of SFM practices and contribute to the overall policy discourse on SFM in semiarid regions.

This chapter consists of seven sections including this Introduction. Section 10.2 describes the methodology followed for the study. The third section presents the findings of the study. The comparison of farmers' SFM practices with recommended practices has been done in the fourth section. Section 10.5 discusses the technical efficiency (TE) of major SFM methods. Section 10.6 presents the determinants of SFM, and the final sections make concluding observations with recommendations.

10.2 Study Area, Data Collection and Methodology

The state of AP was chosen for the study. Over 80 % of those involved in agriculture are small and marginal farmers and landless labourers who own a mere 35 % (3.5 million ha) of the total 10 million ha of cultivated land. AP has the distinction of much diversified livestock resources. In AP, agriculture has been undergoing many changes over the past two to three decades. The increasing intervention of the state in agriculture, and the Green and Yellow Revolutions, have prompted agricultural

---

[1] Semiarid refers to a climatic classification of typically dry areas with rainfall ranging from 500 to 950 mm and evaporative demand in excess of rainfall for a greater part of the year.

changes throughout the semiarid regions, especially in land ownership, cropping patterns, irrigation, credit and extension, agricultural productivity, prices and marketing. The use of fertilisers too was high in AP. In the period 2004–2005, as much as 11.57, 5.39 and 2.92 lakh t of nitrogen (N), phosphorus (P) and potassium (K) were used, respectively. In 2004–2005, the total NPK per hectare consumption was 158.80 kg (CMIE 2006) as against the India's 88.11 kg/ha (Fertiliser Association of India 2006). All the above-mentioned aspects have a huge bearing on the farmers' SFM practices, especially in the semiarid regions. It was in this context that AP was selected for the study on SFM focusing on the socioeconomic, ecological and livelihood dimensions of farmers' practices in semiarid regions.

The selected districts were Mahbubnagar, Anantapur and Prakasam from three different socioeconomic and ecological regions of AP, namely, Telangana, Rayalaseema and Coastal Andhra, respectively. Districts having the least percentage of net irrigated area in their respective regions with an annual average rainfall ranging between 500 and 900 mm falling under semiarid conditions were selected for the study. Two mandals from each district were selected. In each selected district, one mandal with the least percentage of net irrigated area falling under semiarid regions (those receiving rainfall between 500 and 900 mm) and another mandal with the highest net irrigated area falling under semiarid regions were selected. Though both mandals come under semiarid conditions, one mandal with high net irrigated area and another with the least net irrigated area was selected in order to observe the dynamics involved in the SFM under irrigated conditions and dryland conditions. A total of six mandals were selected from three different semiarid districts of Telangana, Rayalaseema and Coastal Andhra regions of AP. Similar criteria were followed even for the selection of villages from mandals. A total of six villages were selected from three different semiarid districts. In this way, a total of 60 farmers, 20 from each size class were selected from each village. A total of 360 farmers covering the three districts were interviewed for the research. The study used both qualitative and quantitative methods for understanding the farmers' SFM practices and the conditions under which they adopt such practices. Personal interviews were conducted with a structured interview schedule. The study used an ex post facto research design coupled with case studies, participatory rural appraisal (PRA) methods and focused group discussions (FGDs). Secondary data on rainfall, net irrigated area and demographic features of the district were collected from the Bureau of Economics and Statistics, CMIE reports, Fertiliser News and Economic Survey reports. Fertiliser recommendations were taken from the package of practices suggested by the Acharya NG Ranga Agricultural University of Andhra Pradesh.

The data analysis was basically done in two ways. One was comparing the various size classes of large, medium and small farmers; the other analysis was done comparing the irrigated and unirrigated (less irrigated) villages. The results of the study are discussed at two levels: one at the household (hh) level and the other at the plot level. The data gathered were analysed using different statistical tools. Averages, frequency and percentages were used to analyse the various information-related SFM. The model developed by Battese and Coelli (1988) for estimating stochastic frontier production was used for paddy, groundnut and sunflower crops.

Table 10.1 Study area in AP. (Source: Chief Planning Office of the selected districts)

District	Mandal	Village	No. of sample households
Telangana region			
Mahbubnagar	Peddakothapalli (3.16 % of net irrigated area and 625 mm rainfall)	Maredudinne (0.50 % of net irrigated area)	60
	Chinnachintakunta (91.57 % of net irrigated area and 565 mm of rainfall)	Dhupalle (89.20 % of net irrigated area)	60
Rayalaseema region			
Anantapur	Puttaparthi (0.36 % net irrigated area and 609 mm rainfall)	Brahmanpalle (10.16 % of net irrigated area)	60
	Tadipatri (39.30 net irrigated area and 667 mm rainfall)	Chinnapolamada (29 % of net irrigated area)	60
Coastal Andhra region			
Prakasam	Korisepadu (9.33 % net irrigated area and 865 mm rainfall)	Ravinuthala (0.48 % of net irrigated area)	60
	Darsi (75.12 % net irrigated area and 733 mm)	Darsi (82.06 % of net irrigated area)	60

Using the frontier production function approach, the average TE was calculated to find the TE of paddy, groundnut and sunflower with respect to size classes, fertility level of soils as perceived by farmers, number of SFM methods and types of soils. However, in this chapter we focus only on the TE of paddy and groundnut with respect to different SFM methods (Table 10.1).

10.3 Findings of the Study

10.3.1 Socioeconomics of Sample Households

In all the sample villages across all size classes, the percentage of backward classes (BCs) was the highest followed by other castes (OCs) in the sample hh. Among the total sample farmers, 38.61 % are illiterate and 61.39 % are literate to various educational levels. The illiterates depend on their neighbours and peers for useful knowledge on SFM. Due to self-help groups and occupational institutions, small farmers had higher social participation compared to other size classes. The highest average land-holding size with respect to large farmers (14.33 acres), medium farmers (6.90) and small farmers (3.35) was seen in Chinnapolamada, Maredudinne/Chinnapolamada and Dhupalle, respectively. Farmers from all farm size categories were keen on using organic practices, particularly Farm Yard Manure (FYM). The population of cows and bullocks is going down. Taking care of livestock is coming down slightly due to difficulties in accessing fodder, drinking water and easy labour. Livestock is taken care of by both men and women. Even today, on the whole, across all size classes more than 11.39 % of the children from the sample hh's take care of livestock.

The sample farmers depend on multiple livelihoods. Farming was found to be the main livelihood activity across all size classes, followed by dairy. For the majority of the small farmers, agricultural labour was an important source of livelihood. Dependence on small ruminants was high in unirrigated villages. Large farmers spent more on inputs which are external in nature, followed by medium and small farmers. Small and medium farmers depend on internal resources like human and bullock labour for timely agricultural operations. The average annual net income of the sample hh's was more for large farmers followed by medium and small farmers. This is attributed to bigger farm size with large farmers. The majority of the sample farmers (52.50 %) have indebtedness ranging between ₹ 1–20,000 followed by 35.83 % of them having ₹ 20,001–40,000. The majority of the sample farmers accessed loan from various sources at an annual interest rate of 12–24 %. Large farmers with better personal transport travelled greater distances for procuring agricultural inputs. Farmers' management of soil nutrients depended on a range of socioeconomic factors. Access to livestock, labour, credit and markets are of particular importance in explaining which farmers are able to maintain and improve the fertility of their soils. The hh remains central to the management of farm and the mobilization of resources, such as labour and capital. However, other social institutions are also of great value in enabling the farmers to negotiate access to obtain resources such as draught power, transport and credit.

10.3.2 Farmers' SFM Practices

Farmers actively manage soil fertility and other soil properties through a wide range of practices. These include the so-called "modern" methods like combining chemical and organic fertilisers and other practices based on long experience of farmers and a rich knowledge of the locally specific conditions; despite constraints, such practices are alive and vibrant. There are diverse SFM practices which are commonly used by farmers in AP (Butterworth et al. 2003, Reddy 2010a, b, c). Similarly, the practices adopted by sample farmers of the present study are explained in Table 10.2.

To get an idea of how various practices are being adopted and in what proportion, an attempt has been made to examine the SFM practices across size classes of the farmers. In total, there were 664 field plots distributed among 360 sample hh's covering all size classes in the six villages. Out of these 79 plots were lying fallow (current as well as permanent). Information from the remaining 585 plots is presented in the Table 10.3.

Table 10.2 Soil fertility management practices adopted by sample hh's. (Source: Field study)

Practice	Procedure	Cost and lasting effect
Farm yard manure	Gathering dung and other organic materials and dumping them in a heap. Materials are added regularly as and when available. Green leaves of pongamia, cassia tora, neem and dry leaves of various trees are added to enrich the compost. Decomposed compost is transported to field for spreading and incorporation into soil before ploughing	Ranges between ₹ 2000 and 4000/acre excluding transportation cost. The effect lasts for 3–4 years
Sheep penning	The pastoralists pen their flock in the field overnight. The faeces and urine of the flock are deposited on the farmer's field. This is rich manure and is incorporated into the soil by shallow ploughing	₹ 1000–1200/acre. Effect lasts for only one or two seasons
Legume cultivation	Growing of leguminous crop loosens soil, adds organic matter to soil through leaf fall and fixes nitrogen into the soil	Seed cost of crop. Generally ₹ 50–200/acre. In case of ground nut it is ₹ 1800–2500/acre. Effect lasts for one season
Oil cakes (neem and castor)	Neem and castor cakes are used for manuring crops. They give good colour and shine to fruits in the case of horticultural crops. They are also used to avoid certain soil-borne pests	₹ 250/50 kg bag. Cost varies depending on the crop and dosage applied. Effect lasts for one to twoseasons
Crop rotation	Crops which use different nutrients are grown alternately to keep the nutrient balance	Does not involve any cost except the decision to change the crop. Effect lasts for two seasons
Intercropping/mixed cropping	Growing a mixture of different crops in the same field. Small and marginal farmers often grow 5–6 crops in an acre	Cost varies depending upon the crops and their required quantities per acre
Tank silt application	Fine tank silt from the village tank is excavated and transported to the fields and applied to top soil	₹ 800–1000/acre. Effect lasts for 2 years
Chemical fertilisers (including micronutrients)	Chemical fertilisers are concentrated forms of nutrients that can be easily applied and are readily available to plants	Numerous brands are available in the market. Cost of most commonly used urea is approx. ₹ 250/50 kg bag and DAP is ₹ 550/50 kg bag. Effect lasts for 2–3 months only

It is important to note that multiple practices were followed in some plots. In a few plots, two to three practices were followed at a given time for a given crop. Hence, the percentages were calculated for each practice with respect to the area of the total number of sample plots in each size class and presented in Table 10.3. As

Table 10.3 Size class-wise adoption of soil fertility management practices in sample plots during the kharif 2005–2006 (in percent) ($N = 585$) (Source: Based on primary survey)

Soil fertility management practice	Large farmers ($N = 245$)	Medium farmers ($N = 183$)	Small farmers ($N = 157$)	Mean of all
Not followed any practice	1.63 (57)	4.37 (42)	10.19 (36.5)	5.40 (135.5)
FYM + chemical fertilisers	77.14 (1127.65)	63.93 (435)	57.96 (230)	66.34 (1792.65)
Only chemical fertilisers	15.51 (214)	24.84 (147.75)	17.83 (51)	19.39 (412.75)
Sheep penning	2.86 (44)	0.0	5.10 (22.5)	2.65 (66.5)
Sheep penning + chemical fertilisers	0.0	0.0	0.64 (2)	0.21 (2)
Tank silt	0.0	0.0	0.64 (3)	0.21 (3)
Neem cake	6.12 (95)	5.46 (43.5)	0.64 (0.5)	4.07 (139)
Castor cake	6.94 (99.5)	2.73 (22.5)	5.10 (15)	4.92 (137)
Legume cultivation	45.71 (606.75)	33.88 (228.5)	23.57 (92)	34.39 (927.25)
Intercropping/mixed cropping	40.41 (619.25)	38.80 (316)	40.13 (154.5)	39.78 (1089.75)
Others	00.0	00.0	1.27 (3)	0.42 (3)

Figures in the parentheses indicate the actual acres in which the practice was used. More than one practice is adopted in a given season in a given plot and the above table is based on multiple responses

more than one SFM practice was adopted in some sample plots, the total percentage exceeds 100.

Looking at the mean column in Table 10.3, it is evident that the practice of combination of FYM and chemical fertilisers (1792.65 acres) was predominant across all size class farmers followed by intercropping/mixed cropping (1089.75 acres) and legume cultivation with an area of 927.25 acres. A unique feature of farm yard manure is that it supplies humus (which can never be substituted by inorganic fertilisers). This humus is a major source of food for soil microorganisms and is essential for their wellbeing and development. The physical properties of the soil like soil porosity, water stable aggregates, water-holding capacity, infiltration rate and hydraulic conductivity are significantly increased with the conjunctive use of organic manures and inorganic fertilisers (Reddy 1999b). It was found that only chemical fertilisers were used in 412.75 acres, and no practice was followed at all in 135.5 acres. It is surprising to note that the practice of applying only FYM was not seen across any size class among all the study villages. This is due to lack of sufficient quantities of manure due to reduction in livestock population which has in turn been affected due to shortage of fodder and water crisis in summer. It was interesting to find that the practice of sheep penning still exists and is in great demand among farmers. Shepherds are the source of best quality FYM (Butterworth et al. 2003).

Organic fertilisers like neem cakes are being used for paddy to increase the efficiency of nitrogen uptake and to increase the resistance to pest attack. Similarly, another organic fertiliser, castor cake, is being used mostly for horticultural crops in Anantapur district along with neem cake. As revealed by farmers in FGDs and PRAs, organic cakes are more suitable for orchard crops than the chemical fertilisers as they serve several purposes such as adding to soil fertility, reducing pest incidence, increasing water-holding capacity of soil, giving good colour and shape to fruit and having longer shelf life which helps in transporting to distant places. It was surprising to note that vermicompost, which was becoming popular of late in some pockets of AP, was not used even in a single plot. This indicated that it is still in the early stages and is not widely spread. Efforts must be made to introduce the vermicompost technology and establish a good number of units, making it accessible to more small and marginal farmers. The empirical data of the present study clearly point out the fact that farmers attach immense significance to the practice of legume cultivation.

Contrary to the popular belief that farmers mostly use chemical fertilisers, the present study brings out the fact that across all size classes, farmers use several other methods of SFM including organic fertilisers. According to them, it is being done keeping in view the long-term sustainability of their soils. From Table 10.3 it is evident that FYM + chemical fertilisers is very predominant among the sample farmers across all size classes. This proves the fact that farmers clearly understand the prominent role of farm yard manure and other organic manures in the long-term sustainability of soil and crop yields. There is considerable diversity in farmers' conditions and SFM strategies and there is no blanket solution for improving soil fertility (Hilhorst and Muchena 2000 and Reddy 2010b).

10.3.3 Soil Type

The soils of the study area varied from deep black cotton soils to light sandy soils. The kind and depth of soils also influenced the soil fertility. Generally, it is seen that soils with greater depth will be more fertile than shallow soils. Similarly, black cotton soils and red sandy soils are more fertile compared to others. Table 10.4 indicates that the majority of the sampled plots were of depth ranging between 1.1 and 2 ft. The data show that more than 39 % of the soils belonging to large farmers have a depth of more than 2 ft and are likely to be fertile, whereas medium farmers had 12.92 % and small farmers had 13.84 % of their soils with depth greater than 2 ft. Similarly, small farmers had the highest percentage (33.05 %) of plots with a depth of less than 1 ft.

10.3.4 Agro-biodiversity

Farmers in semiarid regions developed diversified cropping systems to ensure that the most essential natural resources such as sunlight, wind, rainfall and soil are

Table 10.4 Size class-wise distribution of sample households according to their soil depth (in percent). (Source: Based on primary survey)

Soil depth	Large farmers	Medium farmers	Small farmers	Total
Up to 1 ft	17.10	31.88	33.05	23.19
1.1–2 ft	43.63	55.20	53.11	48.03
2.1–3 ft	27.94	7.78	8.47	19.91
3.1–4 ft	6.00	1.58	3.11	4.49
4.1 ft and above	5.33	3.56	2.26	4.38
Total	100.00	100.00	100.00	100.00

Table 10.5 Agro-biodiversity in study villages. (Source: Based on primary survey)

Kharif crops in 2005–2006	Rabi crops in 2005–2006
Unirrigated villages	
Groundnut, maize, red gram, green gram, black gram, cotton, chillies, chickpea, subabul, jowar, variga, bajra, sunflower, chillies, paddy, dry sown paddy, cow pea and field bean	Chickpea, groundnut, paddy
Irrigated villages	
Paddy, black gram, green gram, castor, fodder, jowar, pillipesara, red gram, maize, groundnut, sunflower, field bean, cowpea, orchards of ber, guava, lemon, mango and sapota	Paddy, groundnut, sunflower, rabi, jowar

optimally utilised throughout the year. Crops that were developed over centuries were specifically bred to suit local soils, nutritional needs of people, livestock needs and climatic conditions. A large number of farmers, especially women have been nurturing the agro-biodiversity and soil fertility without any sort of support from the government. The lands of the sample farmers of the study villages have hosted a wide range of crops (Table 10.5).

There was more crop diversity in the unirrigated villages than the irrigated villages during the kharif season. This is to insure themselves against the vagaries of nature and incidence of pests and diseases. It is noticed that millet crops like jowar, bajra and variga are still grown in unirrigated villages.

10.3.5 Crop Rotation

The growing of different crops on a piece of land in a preplanned succession is called crop rotation. The decision of rotating the crops has a huge bearing on SFM and hence it is being discussed in detail in this section. According to farmers, if we grow the same crop continuously on the same patch of land we do not get good yields. They have been advised by their elders that crops have to be rotated in order to preserve fertility of soils. Compared to monoculture cropping practices, multicrop

Table 10.6 Adoption of crop rotation by sample farmers during the last 2 years in their irrigated and dryland plots. (Source: Based on primary survey)

Village	Particulars	Irrigated plots			Dryland plots		
		Large farmers	Medium farmers	Small farmers	Large farmers	Medium farmers	Small farmers
Darsi	Total area in acres	249.5	116	60	6.5	2	2.5
	% of area under crop rotation	8.61	22.41	14.16	0	0	100
Ravinuthala	Total area in acres	–	–	–	267.5	128.5	48
	% of area under crop rotation	–	–	–	63.17	36.18	39.58
Chinnapo-lamada	Total area in acres	163.75	60.5	32.5	130.25	73.25	31
	% of area under crop rotation	27.78	38.01	6.16	31.86	39.59	59.67
Brahman-palle	Total area in acres	60.5	14.5	3.5	237.5	115	63
	% of area under crop rotation	57.02	62.06	28.57	19.36	13.04	0
Dhupalle	Total area in acres	212.9	121.5	54.5	28.5	11.5	9
	% of area under crop rotation	41.56	22.63	25.68	8.77	0	11.11
Maredudinne	Total area in acres	8	1	2.5	279	131	52.5
	% of area under crop rotation	0	0	0	32.97	30.53	32.38
Total	Total area in acres	694.65	313.5	153	949.25	461.25	206
	% of area under crop rotation	27.35	27.27	16.66	36.97	28.29	28.15

rotations with two or three crops in a year can result in increased soil organic carbon content (Purakayastha et al. 2008). This is because of the addition of large amount of biomass above the ground as well as underground. Such crop planning is practised in dryland regions. The complexity and diversity of such microenvironments created by the farmers are often undervalued (Chambers 1995). To get an idea of how crop rotation is being followed in the sample plots, data of crops grown in four crop seasons (i.e. kharif and rabi) in 2004–2005 and 05–06 were studied.

High crop rotation was seen in Chinnapolamada village across various size classes, but the area was less. Among the irrigated plots of the study villages, less crop rotation was seen in all size classes in Darsi of Prakasam district (Table 10.6).

Within the size classes, crop rotation was high (22.41 %) with medium farmers, followed by small farmers (14.16 %) and large farmers (8.61 %). Among the villages having larger area under irrigation, Dhupalle of Mahbubnagar had high crop rotation percentage when compared to Darsi (Praksam) and Chinnapolamada (Anatapur). In Dhupalle crop rotation was highest with large farmers (41.56 %) followed by small farmers (25.68 %) and medium farmers (22.63 %). There was no crop rotation in Maredudinne village in irrigated plots. However, the area under irrigation is negligible (10 acres) in this village. On the whole in the irrigated plots of sample farmers of six villages the crop rotation was significant among large farmers (27.35 %) followed by medium farmers (27.27 %) and small farmers (16.66 %). This is due to the importance of crop rotation in SFM. Crop rotation also controls weeds and diseases and helps a good variety of natural predators to survive on the farm.

Among the dryland villages, high crop rotation could be seen in Ravinuthala followed by Chinnapolamada and Maredudinne. In Brahmanpalle of Anantapur less crop rotation was seen as farmers were mostly cultivating groundnut continuously as they found it relatively more economical and suitable to their soils and climate. Among the size classes no crop rotation was seen in the case of small farmers. This might be due to small holdings coupled with dependence on other sources of income. Many farmers from this category find employment at the Satya Sai Trust, adjoining to their village.

The total area under crop rotation across all size classes was seen to be higher under dryland plots than in the irrigated plots (Table 10.6). Similarly, the overall percentage of crop rotation was high under rainfed conditions than under irrigated conditions. The probable reason could be lesser feasibility of crop rotation under irrigated conditions (canal irrigation) where water release is not under the control of farmers.

10.3.6 Farmers' Perception of Soil Fertility

The present research tried to assess the level of soil fertility of sample plots according to farmers' own perception. For this purpose, the sample plots were compared with the best fertile plot in the respective village (based on FGDs). The soils of the farmers were evaluated on a scale of continuum consisting of very bad, bad, average and good. More than 50 % of the sample plots were perceived to be less fertile. Soils with very bad fertility recorded were 5.02 % while 47.6 % had bad soil fertility status (Table 10.7). The low fertility status could be due to gradual decline in organic manure application and intensive cultivation. The bad fertility status of soils as perceived by the farmers could be the probable reason for the low yields in spite of higher NPK application than recommended quantities. Similarly, 37.13 % of the plots were perceived to be of average fertility status. Only 10.25 % had good soil fertility.

Among the size classes, the small farmers had more unfertile area. This could be due to more dependence on agricultural labour for their sustenance and also

Table 10.7 Size class-wise distribution of sample plots according to farmers' perception of level of soil fertility (percentage area) ($N = 585$). (Source: Based on primary survey)

Level of soil fertility	Large farmers	Medium farmers	Small farmers	Total
Very bad	4.17	4.86	9.07	5.02
Bad	50.61	41.86	46.17	47.6
Average	33.09	45.01	38.81	37.13
Good	12.13	8.27	5.95	10.25
	100.00	100.00	100.00	100.00

migration to distant places, leaving the soils unattended during certain years. Lack of resources for investing on inputs could also be one of the main reasons for the low fertility of the plots belonging to the small farmers. Another reason is that most of the lands distributed to SCs are far away from the village and are highly infertile and degraded. Medium farmers had more area under average soil fertility. Medium farmers have lesser amounts of very bad and bad soils and more of the soils with average soil fertility.

This makes it clear that unless the overall soil fertility status of soils is improved by way of applying good quantities of organic manures, adopting other tested traditional SFM practices, and controlling of soil erosion, the overall improvement in the yields may not be realised. The perception of farmers regarding their soil fertility also demands that the unirrigated villages be paid serious attention for improving the soil fertility in these villages which supports the livelihoods of millions of people.

10.3.7 Organic Versus Inorganic Inputs

An in-depth analysis was done to understand how the farmers are distributed with respect to the use of organic and inorganic inputs in the sampled plots (Table 10.8). For this purpose, the total amount spent by the sample farmers on organic manures and inorganic fertilisers, together in the period 2004–2005 and 2005–2006 was considered. Different ratios of both organic manures and inorganic fertilisers were considered for easier and better understanding of how money is being invested on organic and inorganic fertilisers and by what percentage of farmers. The analysis did not include cultural practices like crop rotation, intercropping/mixed cropping, as there is no separate investment for these practices, except the seed cost which the farmer has to invariably bear for raising the crop.

The distribution of sample farmers revealed that only 16.94 % used exclusively chemical fertilisers in their plots. There was no one exclusively using only organic practice. But, it was found that more than 32.50 % of the total sample farmers spend more than 50 % of their money on organic manures/practices, out of their total investment on soil fertility. This is a positive sign for the emerging organic market. This large group of farmers can be encouraged to become totally organic and

Table 10.8 Size class-wise distribution of sample hh's according to the ratio of use of amount in rupees for organic and inorganic fertilisers together in 2004–2005 and 2005–2006 (in percent). (Source: Based on primary survey)

Size class	OF:CF 0:100	OF:CF 10:90	OF:CF 20:80	OF:CF 30:70	OF:CF 40:60	OF:CF 50:50	OF:CF 60:40	OF:CF 70:30	OF:CF 80:20	OF:CF 90:10	Total
LF = Large farmer	5.83 (7)	15.83 (19)	23.34 (28)	17.50 (21)	18.33 (22)	5.0 (6)	7.5 (9)	6.67 (8)	0 (0.00)	0 (0.00)	100.0 (120)
MF = Medium farmer	20.0 (24)	5.83 (7)	12.5 (15)	20.83 (25)	9.17 (11)	10.0 (12)	9.17 (11)	5.0 (6)	3.33 (4)	4.17 (5)	100.0 (120)
SF = Small farmer	25.0 (30)	4.17 (5)	7.5 (9)	8.33 (10)	8.33 (10)	8.33 (10)	9.17 (11)	14.17 (17)	10.0 (12)	5.0 (6)	100.0 (120)
All	16.94 (61)	8.61 (31)	14.45 (52)	15.56 (56)	11.94 (43)	7.78 (28)	8.61 (31)	8.61 (31)	4.44 (16)	3.06 (11)	100.0 (360)

Figures in the parenthesis are the actual number of farmers
OF organic fertilisers, *CF* chemical fertilisers

take advantage of the growing organic market and better utilise the encouragement by the government towards organic agriculture. Among the size classes, 46.67 % of small farmers invest more than 50 % of their money on organic manures/practices.

10.4 Recommended Practices Versus Farmers' Practices

In the earlier sections, various SFM practices adopted by the total sample farmers were discussed, irrespective of the crops they were growing. In this section, an attempt is made to understand the farmers' practices with reference to agricultural university's recommendations regarding the SFM for the selected crops. Out of the total crops being cultivated by the sample farmers, only those crops which had good distribution (minimum sample of 30 farmers) were selected for analysis. Paddy, maize, sunflower, castor and groundnut (irrigated and rainfed) grown during kharif 2005–2006 were selected for comparing farmers' practices against the recommended practices. However, we are restricting our discussion to only paddy and groundnut in this chapter. It is a known fact that not only major nutrients like nitrogen (N), phosphorus (P) and potassium (K) but even micronutrients play a critical role in crop growth and yield. However, in this analysis and discussion, we are restricting ourselves to NPK and FYM.

10.4.1 SFM in Paddy

Acharya N. G. Ranga Agricultural University (ANGRAU) has divided the state of AP into nine agro-climatic zones based on physiography, soil types, crops and cropping pattern. It is interesting to note that the package of practices was given only for paddy crop based on the agro-climatic zones. Just like other package of practices, SFM recommendations were also made separately for each of the agro-climatic zone. Paddy has been one of the major food crops grown under irrigated conditions in AP. There is no specific recommendation made for the dosage of FYM in the "agricultural almanac" for paddy. But interestingly, FYM recommendations were made for other crops (viz., ground nut, sunflower and castor). The reason could be the assumption by scientists that farmers invariably use the available manure from their compost pits and hence it is not essential to mention it. But one cannot ignore the enormous importance of FYM in maintaining soil health and soil life. Hence, it is essential to make a specific mention of FYM dosages too for all the crops in the state.

Farmers across all size classes in Darsi of Prakasam district applied two and a half to thrice the recommended dosages of nitrogen and phosphorus supplying fertilisers per acre (Table 10.9). This is due to cultivation of three crops in a year due to which the soil has to be replenished either with FYM or inorganic fertilisers. The availability of FYM is comparatively less and hence excessive application of nitrogen and phosphorus fertilisers is seen when compared to recommended dosage. Coastal farmers are proactive in gaining information related to agriculture. Private companies are active in this region, and the farmers are motivated to use more of chemical fertilisers through company advertisements, which claim that they can give higher yields, whereas the applied potassium dosage is less than the recommended. This could be due to the good quantities of native potassium in the soil of Darsi Mandal (Table 10.11) and Prakasam district (Table 10.10) as a whole. Among the size classes, large farmers are seen to apply higher quantities of NPK nutrients followed by medium and small farmers. On the contrary, FYM is being applied in larger quantities per acre by small farmers (1919 kg) followed by medium farmers (1744 kg) and large farmers (980 kg). This is due to less land and more dependence of small and medium farmers on dairy, which eventually gives them some manure.

Excessive use of inorganic fertilisers over longer periods of time is a cause of concern, as it leads to gradual degradation of soils having access to assured irrigation. This is more so in cases where inorganics are not combined with good quantities of organic manures. Depletion of organic matter in the soil leads to deterioration in soil structure, reduced soil water and nutrient-holding capacity and reduced microbiological activity (Wommer et al. 1994; Reddy 1999a).

In Ravinuthala village there is no paddy crop at all. In Chinnapolamada of Anantapur district, the nitrogen dosages applied by the farmers are one third lesser and phosphorus and potassium are 50 % lesser than the recommended dosage, respectively. This is due to the lack of sufficient water, which reduces the dosages as it might have a negative effect on the crop yield under such moisture stress conditions. The fertility index in Tables 10.10 and 10.11 indicates that the soils in the study mandals and study districts have medium to high native nutrients of phosphorus and potassium. This could be one of the reasons for lesser use of phosphorus and potassium than recommended. Another reason is that the recommendations made by the scientists do not hold good for the conditions under which the sample farmers work. In this village, medium farmers were seen to apply the highest dose (21.5 kg)

Table 10.9 Soil fertility management inputs used per acre by sampled households in paddy crop during the kharif 2005–2006. (Source: based on primary survey)

Particulars	Large farmers	Medium farmers	Small farmers	Recommended nutrient dosage by Agricultural University of A.P(ANGRAU)	Recom-mended yield in kg/acre	Yield obtained by sample farmers in kg/acre
Darsi (Prakasam)						
Farm yard manure in kg	980.00	1744.53	1919.13	No specifications	2800	2031.16
Nitrogen in kg	84.91	81.68	75.86	24–32		
Phosphorus in kg	52.62	52.625	48.51	16		
Potassium in kg	9.34	9.43	8.93	12–16		
Chinnapolamada (Anantapur)						
Farm yard manure in kg	332.50	875.00	2705.00	No specifications	2500	1100
Nitrogen in kg	18.50	21.5	17.8	64		
Phosphorus in kg	17	15.00	12.60	32		
Potassium in kg	17	12.50	9.70	32		
Brahmanpalli (Anantapur)						
Farm yard manure in kg	879.90	1164.37	1531.25	No specifications	2500	1022.17
Nitrogen in kg	21.09	21.50	18.5	64		
Phosphorus in kg	18.36	18.50	16.75	32		
Potassium in kg	16.54	16.5	12.50	32		
Dhupalle (Mahbubnagar)						
Farm yard manure in kg	2061.94	1948.81	1184.33	No specifications	2500	1991.02
Nitrogen in kg	76.77	71.75	61.80	40–48		
Phosphorus in kg	42.27	37.50	27.26	24		
Potassium in kg	21.83	21.31	20.08	16		
Maredudinne (Mahbubnagar)						
Farm yard manure in kg	1075.00	0	541.66	No specifications	2500	1219.44
Nitrogen in kg	20	21	21.66	40–48		
Phosphorus in kg	16.4	16	17.33	24		
Potassium in kg	16.8	15	17.33	16		

No paddy was grown under irrigated conditions in Ravinuthala village of Prakasam

Table 10.10 Fertility index for macro nutrients (NPK) in the study districts during the year 2005–2006. (Source: Soil Testing Laboratories, Department of Agriculture, Govt. of Andhra Pradesh)

District	Fertility index		
	Nitrogen	Phosphorus	Potassium
Prakasam	1.10	1.88	2.75
Anantapur	1.18	2.78	2.81
Mahbubnagar	1.61	1.78	1.85

Fertility index rating: 0–1.66 = low, 1.67–2.33 = medium, > 2.33 = high

Table 10.11 Categorisation of soils in study mandals of selected districts based on the fertility index (2005–2006). (Source: Soil Testing Laboratories, Department of Agriculture, Govt. of Andhra Pradesh)

District	Name of mandal	Fertility index		
		Nitrogen	Phosphorus	Potassium
Prakasam	Darsi	1.08 (low)	1.89 (medium)	2.65 (high)
	Korisepadu	1.21 (low)	1.95 (medium)	2.50 (high)
Anantapur	Tadipatri	1.37 (low)	2.93 (high)	2.90 (high)
	Puttaparthi	1.07 (low)	2.46 (high)	2.84 (high)
Mahbubnagar	Chinnachinta kunta	1.81 (medium)	1.86 (medium)	186 (medium)
	Peddakothapalli	[a]	[a]	[a]

Fertility index rating: 0–1.66 = low, 1.67–2.33 = medium, > 2.33 = high
[a]Information is not available for this mandal

of nitrogen followed by large farmers (18.50 kg) and small farmers (17.8 kg). This can be attributed to the efforts of medium farmers to maximise the profits from the available land. The per acre FYM dosage being applied by small farmers in this village is the highest (2705 kg/acre) among all the study villages, whereas medium and large farmers are applying 875 and 332 kg per acre, respectively. This is quite low and the probable reason could be the lesser livestock maintained by these groups due to lack of fodder and water. However, small farmers still manage to keep the livestock as it helps them earn livelihood.

In the village of Brahmanpalle of Anantapur, the situation was found to be almost similar to that of Chinnapolamada but with slightly higher doses. FYM is applied in higher quantities by small farmers (1531.25 kg) followed by medium (1164.37 kg) and large farmers (879.90 kg). The reason is the higher livestock number with small farmers and also better maintenance by them.

In Dhupalle village of Mahbubnagar district, the NPK quantities being applied are one and a half to two times higher than the official recommendation. A significant observation made in this village was that the farmers across all size classes are applying higher doses of even potassium (it was lesser than recommended in other villages). The reason could be the medium fertility index of potassium in the villages of this mandal (see Table 10.11). Another reason is the extensive cultivation of paddy in this village in the past a couple of years due to new lift irrigation scheme and the cultivation of two crops per year. Application of complex fertilisers, which also contribute potassium, could be another reason for this. Moreover, the varieties being cultivated are long-duration BPT-5204, which require fertilisers for a longer period than short-duration varieties. Contrary to other villages, in Dhupalle, large farmers are seen to apply slightly higher quantities of FYM (2061.94 kg) per acre followed by medium farmers (1948.81 kg) and small farmers (1184.33 kg). The reason for this is the availability of FYM due to a good number of livestock and the capacity to purchase.

It can be observed from Table 10.9 that the actual yields obtained by the farmers is lesser than the recommended yield for that agro-climatic zone. Yields are lesser, both in case of those villages where nitrogen, phosphorus and potassium nutrients are being applied in excess, and also in those villages where they are applied in higher quantities than the recommended quantities. A possible reason could be that the recommendations might be based on the data obtained on research designs of 10–15 years back, which is not in line with the farmers' present condition. However, it indicates that excess quantities of chemical fertilisers are being applied in the coastal village Darsi, which may eventually lead to soil degradation. In case of the other villages, farmers are applying lesser nutrient dosages after their experience proved that it is the optimum they can apply in the given situation and higher amounts may not increase yields any more. On the other hand, it could only lead to soil degradation.

10.4.2 SFM for Rainfed Groundnut

The quantities of nitrogen and phosphorus being applied are higher than the recommended dosage (Table 10.12). Only 25 % of the recommended dosage of potassium is applied across all size classes. This is due to native potassium in the soil (Table 10.10), especially in Anantapur district where groundnut is predominantly grown under rainfed situations.

Gypsum is not at all being applied by small and medium farmers. Large farmers are applying only 12.14 kg per acre as against the recommended 200 kg/acre. This is due to difficulties in accessing the gypsum supplied by government on subsidy. The process of procuring gypsum on subsidy basis from the agricultural department is very complicated and is not within the reach of small and marginal farmers. All categories of farmers are applying very less FYM quantities for rainfed groundnut as compared to the recommended dosage. The reason attributed is the concentration of nutrients on irrigated plots to get better and assured income. Yields are quite lower than excepted. The reason is less FYM application, pest incidence and lack of gypsum application.

Table 10.12 Soil fertility management inputs used by sampled farmers per acre of groundnut crop under rainfed conditions during theperiod 2005–2006. (Source: Based on primary survey)

Particulars	Large farmers	Medium farmers	Small farmers	Recommended nutrient dosage by Agricultural University of AP (ANGRAU)	Recom-mended yield in kg/acre	Yield obtained by sampled farmers in kg/acre
Farm yard manure in kg	498.22	786.48	1053.65	4000–5000	480–600	387.24
Nitrogen in kg	18.05	15.68	10.57	12		
Phosphorus in kg	22.62	21.34	20.03	16		
Potassium in kg	5.72	5.41	4.46	20		
Gypsum in kg	12.14	0.00	0.00	200		

irrigated village, unirrigated village

10.5 SFM and TE

Production function is the average function. Each and every farmer's practice is much more important than the average production of all the farmers. Hence, it is essential to calculate the TE index of each farmer, which determines the farmers' yield, given the input bundle, and helps us find out whether the increase in TE index is because of SFM practices or some other practices adopted by these farmers. In this way, TE analysis enables us a more detailed analysis.

The frontier production function has the maximum feasible or potential output that can be produced by a farm with given level of inputs and technology.

Consider the frontier production function

$$Y_{it} = f(x_{it},\ \beta) + E_{it} \tag{10.1}$$

$$\text{and } E_{it} = V_{it} - U_i, \tag{10.2}$$

where Y_{it} denotes the appropriate function of the production for the ith sample firm ($i = 1,2,.\ N$) in the tth time period ($t = 1,2,.\ T$).

$\mathbf{x}_{it}$ is a (1 X k) vector of appropriate functions of the inputs associated with the ith sample firm in the tth period.

$\boldsymbol{\beta}$ is a (k X 1) vector of the coefficients for the associated independent variables in the production function.

V_{it} is a random variable assumed to be independent and identically distributed (*iid*) as N(0, σ_v^2) and independent of U_i random variable.

U_i is firm-specific TE-related variable and non-negative defined by the truncation (at zero) of $N(\mu, \sigma_u^2)$.

It is assumed that the random variables V_{it} and U_i are distributed independently of the input variables in the model. The density function for U_i is defined by

$$f u_i(u) = \frac{\exp\left[-\tfrac{1}{2}(u-\mu)^2/{\sigma_u}^2\right]}{\sqrt{2\Pi}\sigma_u\left[1-\phi(-\mu/\sigma_u)\right]}, \qquad u > 0.$$

By the convolution formula, the joint density function of e_i, i.e. (v_{it}—u_i) can be written as

$$f_y\,(y) = \frac{[1-\phi(Z)]\exp\left[\dfrac{-\sum(e_{it}+\mu)^2}{2(1-\mu)\sigma^2}\right]\exp\left[\dfrac{T^2\gamma(\ddot{e}_i+\mu)^2}{2(1-\gamma)\sigma^2(1+(T-1)\gamma)}\right]}{\{(2\pi)^T\sigma^2[1+(T-1)\,\gamma\,]\}^{1/2}\left[\,\sigma^2(1-\gamma)\,\right]^{T-1/2}\left[\,1-\phi(-\mu\sqrt{\gamma\sigma})\right]}$$

$$Z = \frac{{\sigma_u}^2 T\ddot{e}_i - {\sigma_v}^2\mu}{\sigma_u\sigma_v\sqrt{({\sigma_v}^2 + T{\sigma_u}^2)}}$$

$$\ddot{e}_i = \frac{1}{T}\sum_{t=1}^{T} e_{it}$$

$$M = \exp\,[\,-\,1/2\sum(e_{it}+\mu)^2/{\sigma_v}^2]$$

$$N = \exp\left[\frac{{\sigma_u}^2T^2(\ddot{e}_i+\mu)^2}{2{\sigma_v}^2({\sigma_v}^2+T{\sigma_u}^2)}\right]$$

and ϕ (.) denotes the distribution function of the standard normal random variable.

The density function of Y_i is written as follows:

$$f_y\,(y) = \frac{[1-\phi(Z)]\exp\left[\dfrac{-\sum(e_{it}+\mu)^2}{2(1-\mu)\sigma^2}\right]\exp\left[\dfrac{T^2\gamma(\ddot{e}_i+\mu)^2}{2(1-\gamma)\sigma^2(1+(T-1)\gamma)}\right]}{\{(2\pi)^T\sigma^2[1+(T-1)\,\gamma\,]\}^{1/2}\left[\,\sigma^2(1-\gamma)\,\right]^{T-1/2}\left[1-\phi(-\mu\sqrt{\gamma\sigma})\right]},$$

$$\text{where} \quad \sigma^2 = {\sigma_u}^2 + {\sigma_v}^2$$

$$\gamma\ = {\sigma_u}^2/\sigma^2.$$

The distribution of the non-negative firm effect *ui*, which is the generalization of the half-normal distribution in which $\mu\ = 0$. Log–likelihood function for the model is given by

$$\begin{aligned}\ln L_i = {} & (-NT/2)\ \ln(2\pi) - (N\,(T-1)\,/2)\ \ln[(1-\gamma)\sigma^2] \\ & - (N/2)\ \ln\{\sigma^2[1+(T-1)\,\gamma]\} - N\ln[1-\phi(-\mu/\sqrt{\gamma\sigma})] \\ & + \sum\nolimits^{N} \ln[1-\phi\,(Z)\,] - (2(1-\gamma)\sigma^2)^{-1}\sum\nolimits^{N}\sum\nolimits^{T}(e_{it}+\mu)^2 \\ & + T^2\mu\sum\nolimits^{N}(\ddot{e}_i+\mu)^2\{2(1-\gamma)[1+(T-1)\,\gamma]\sigma^2\}^{-1},\end{aligned}$$

$$\text{where} \quad Z = \frac{(T\ddot{e}_i+\mu)\gamma-\mu}{\sqrt{\{\gamma(1-\mu)[1+(T-1)\gamma]\}\sigma^2}}.$$

Further, a joint test on the significance of the random variable U_i in the frontier function is obtained from the generalised likelihood ratio. If the random variable is absent from the model (i.e. $\mu\ =\ \gamma^2 = 0$), then the ordinary least squares (OLS)

[2] γ is the ratio of individual variation to total variation in output, i.e. $\gamma = \sigma^2{}_u/\sigma^2{}_v + \sigma^2{}_u$.

Table 10.13 Frontier production function results for paddy

Independent variable	Yield in paddy	
	Frontier regression (half normal)	
Seed in kg	– 1.1173	a
	(0.2273)	
Farm yard manure in rupees	0.0196	a
	(0.0056)	
Total organic manures in rupees	0.0240	a
	(0.0065)	
Nitrogen (N) in kg	0.2226	a
	(0.0522)	
Phosphorus (P) in kg	0.2217	a
	(0.0460)	
Potassium (K) kg	0.0515	
	(0.0333)	
Other nutrients in rupees	0.0281	a
	(0.0076)	
Pesticide in rupees	– 0.0806	b
	(0.0329)	
Human labour in rupees	0.6479	a
	(0.0845)	
Bullock labour in rupees	0.1151	b
	(0.0540)	
R^2/sigma-squared	0.0199	a
	(0.0025)	
Gamma	0.9479	a
	(0.0228)	
log–likelihood function	202.8354	
LR test of the one-sided error	27.0134	
No. of observations	190	

Figures in the parentheses indicate standard errors
LR likelihood ratio
[a] 1 % level of significance
[b] 5 % level of significance

estimators of the remaining parameters of the production function are ML estimates. Thus, the negative of twice the logarithm of the generalised likelihood ratio has approximately Chi-Square (χ^2) distribution with parameter equal to the number of restrictions, i.e. if $\mu = 0$ then it follows the χ^2 distribution with parameter equal to one.

Table 10.13 presents the results of tests of significance conducted for paddy. In the frontier regression analysis it could be seen that the independent variables like FYM, total organic manures, nitrogen, phosphorus, other nutrients and human labour were positively significant at 1 % level, whereas bullock labour was positively significant at 5 % level of significance. This means that for every 1 rupee increase with respect to independent variables like FYM, organic manures, human labour and bullock labour, there was an increase in yield of 0.019, 0.024, 0.647 and 0.115 kg, respectively. Similarly, with every kg increase in independent variables like N, P and other nutrients, there is a yield increase of 0.222, 0.221 and 0.028 kg, respectively. The probable reason for the increase could be due to addition of more nutrients or synergetic effect which helped in higher yields, and the investments in human and bullock labour which might have helped to take up timely agricultural operation, leading to higher yields. Seed was negatively significant. With increase in every kg of seed, there will be a decrease of 1.11 kg of yield. This happens because as the seed rate increases and plant population per acre increases, competition for nutrients, moisture, sunlight and air also increases leading to lesser yields.

In the case of groundnut crop, the model showed neither positive nor negative significance for any independent variable. This means that there could be other variables such as rainfall and climate, which could have an impact on the yield, but could not be covered in this analysis.

TE After the regression analysis using frontier production function, the average TE was calculated for paddy and groundnut. TE was calculated using all inputs, which also included fertility-enhancing organic inputs.

TE is the ratio of the actual output represented in original units to the potential output measured in original units that is obtained when the firm is technically efficient ($U = 0$). Thus, the TE of the ith firm is defined by

$$TEi \quad = \frac{E(Y_{it}{}^{*}/U_i, x_{it}, t = 1{,}2\ldots)}{E(Y_{it}{}^{*}/U_i = 0, x_{it}, t = 1{,}2\ldots)},$$

where Y_{it}^{*} denotes the production in original units for the ith firm in the tth time period.

If the frontier production function (Eq. 10.1)–(Eq. 10.2) defined for the logarithm of the production, then the measures of individual firm specific technical efficiencies are calculated from the conditional distribution of U_i, given the joint distribution of E_{it}. The conditional distribution of U_i, given $\ddot{E}_{it}$

$$TE_i = \exp(-U_i/E_i) = \frac{1 - \phi[\sigma * -(M_i * / \sigma *)]}{1 - \phi(-M_i * / \sigma^2 *)} . \exp(-M * + {}^1\!/_2\, \sigma *),$$

where ϕ (.) is the standard normal distribution function

$$M_i{}^{*} = (-\sigma_u{}^2 \ddot{E}_i + T^{-1} \mu \sigma_v{}^2)(\sigma_u{}^2 + T^{-1} \sigma_v{}^2)^{-1}$$

$$\ddot{E}_i \quad = T^{-1} \sum_{t=1}^{T} E_{it}$$

$$\sigma^2 * \quad = \quad \sigma_u{}^2 \sigma_v{}^2 (\sigma_v{}^2 + T \sigma_u{}^2)^{-1}$$

Table 10.14 Average technical efficiency in different SFM practices. (Source: Based on primary survey)

SFM practices	Paddy	Groundnut
Chemical + FYM	0.90	0.88
Only chemical fertilisers	0.89	0.87
Sheep penning	0.92	[a]
Neem cake	0.92	0.79
Castor cake	0.85	0.87

[a]Practice was not used for this crop in 2005–2006

The details of the analysis results with respect to paddy and groundnut are discussed below.

SFM Methods and Average TE After assessing the crop-wise cost of cultivation and TE, an effort was made to see which methods were most effective for paddy and groundnut (Table 10.14). For this purpose, major SFM practices, excluding cultural practices like mixed cropping and legume crop cultivation were considered for analysis. The practices which are input-based were taken for analysis. For paddy, a combination of sheep penning and neem cake application realised the highest TE (0.92 %). This emphasises one argument that policy-makers and agricultural scientists should look at some of these traditional practices, and also practices which have been recently picking up like application of neem cake. There is a need to support such strong useful practices in various ways, so that farmers can enhance their soil fertility. It is also seen that a combination of FYM and chemical fertilisers had TE of 0.90 %; and chemical fertilisers ranked third with 0.89 %. Least TE was seen in the case of the practice of application of castor cake.

In the case of groundnut, the highest (0.88 %) average TE was seen with reference to the practice of combination of FYM plus chemical fertilisers. This is the practice being followed by a large number of sample farmers. Least TE was seen in the case of neem cake application (0.79 %). However, it must be noted that the number of farmers using this practice in groundnut crop is less.

10.6 Determinants of SFM

The SFM practices employed by farmers are determined by a wide variety of factors. An attempt was made to list out the determinants of SFM and their influence. Probit analysis was done to see what type of characters influence between the SFM adopting farmers and non-SFM adopting farmers. Regressional analysis was done to find out the variables which have influence on soil fertility. This regressional analysis was done with respect to paddy crop for which the TE was calculated earlier. The results are discussed below.

Table 10.15 Derivative probit analysis: Correlates of soil fertility management practices and paddy crop

(Dependent variable: Adoption of SFM = 1, Non-adoption = 0)			
Independent variables	Coeff.	Std. error	Sig.
Red sandy soil (= 1, Red loamy soil = 0)	0.1379	0.0873	
Black soil (= 1, Red loamy soil = 0)	– 0.0481	0.0907	
Gravel soil (= 1, Red loamy soil = 0)	– 0.1126	0.2389	
Average soil fertility level (= 1, bad soil fertility level = 0)	– 0.3119	0.2497	
Good soil fertility level (= 1, bad soil fertility level = 0)	– 0.3972	0.1971	a
Very good soil fertility (= 1, bad soil fertility level = 0)	– 0.4587	0.3592	
Rainfall in mm	0.0052	0.0015	b
Education: I–V (= 1, others = 0)	0.1366	0.0686	
Education: VI–VII (= 1, others = 0)	– 0.1374	0.1995	
Education: VIII–X (= 1, others = 0)	0.1681	0.0781	
Intermediate and above (= 1, others = 0)	0.1812	0.0753	b
Family size	– 0.0424	0.0165	a
Ratio of family labour to total labour used	0.0136	0.0061	a
Large ruminants	0.0241	0.0244	
Market distance	0.0082	0.0196	
Credit	– 0.0000005	0.0000012	
Medium farms (= 1, Big farms = 0)	– 0.2789	0.1724	
Small farms (= 1, Big farms = 0)	– 0.7660	0.1975	b
No. of observations	189.0000		
Pseudo *R*-square	0.6750		
Log-likelihood	– 41.6300		

[a] 5 % level of significance
[b] 1 % level of significance

10.6.1 Probit Analysis

Probit analysis is done to see what type of characters influence the SFM adopting farmers and non-SFM adopting farmers. This was done in the case of paddy. In the probit analysis, adoption of SFM practices by farmers (= 1) and non-adoption of SFM (= 0) was taken as dependent variable. It can be seen from Table 10.15 that the variables education level of intermediate and above and rainfall are positively significant at 1 % level, whereas the variable ratio to family labour is positively significant at 5 % level. This means that increase in education level, rainfall and ratio to family labour to the total labour used influences the adoptions of SFM practices positively, whereas the variable farm size is negatively significant at 1 % level. The variables' good soil fertility level and family size are negatively significant at 5 % level. With increasing rainfall, there is increase in adoption of SFM practices in paddy. This could be due to the use of only diverse practices like neem cake application, FYM, castor cake, sheep penning and chemical fertilisers due to assured moisture availability. These practices in turn help the farmer to achieve good crop yields. Similarly, with smaller farm size, the chances of adopting diverse practices is reduced, whereas farmers with bigger farm size have chances of adopting more number of SFM practices. Similarly, in soils with good fertility level, there is lesser need of adopting SFM practices as the fertility is excellent and can give good crop yields with the existing fertility level.

It is seen that the independent variables red sandy soil, black soil, gravel soil, shallow soils, medium depth soils, average soil fertility level, very good soil fertility, education: I–V, education: VI–VII, education: VIII–X, scheduled tribe, backward communities, OCs, large ruminants, market, credit and medium farms did not influence the adoption of SFM practices.

10.6.2 Regression Analysis

In this section, an attempt has been made to identify the hh, soil and climatic characteristics which influence the dependent variable percentage of organic manure value to total fertiliser values in paddy crop. For calculating the production function results of paddy crop, yield was taken as dependent variable. Hence, in this regressional analysis, the percentage of money spent on organic manures to the total amount spent on chemical fertilisers is taken as the dependent variable as soil health is directly influenced by organic manure application, which consequently gives better crop yields when crops are grown. Applied organic manure acts as a food source for soil life which in turn plays a key role in long-term sustainable soil health. Hence, the percentage of the amount spent on organic manures by farmers during the period 2004–2005 and 2005–2006 together with the total amount spent on chemical fertilisers during the same period was taken as the dependent variable.

The variables selected for the regression analysis are likely to influence the percentage of organic manure value to total fertiliser values and thereby soil fertility. The following lines describe the justification for selected variables in regression analysis and how these variables influence SFM. Generally, the soils with greater depth are more fertile and among soils black cotton soils are more fertile compared to the others. Based on farmers' perception, farmers' soils were evaluated on a scale of continuum consisting of very bad, bad, average and good. Soils with lesser fertility levels contain lesser organic matter content due to adoption of practices, which contributed lesser organic matter. Hence, the fertility level influences the ratio of organic manure used to total soil fertility inputs used per acre. Rainfall is another factor which influences soil fertility. Good amount of rainfall with proper distribution over the crop season influences higher use of chemical fertilisers. The long dry spells between two good rain showers discourages the use of fertilisers as there will be scorching effect on the crop. SFM practices which contribute good quantities of organic matter content are preferred by farmers as they hold more moisture and help to overcome the moisture stress periods. Literacy always helps farmers to get better information related to SFM from the print media. The variable family size influences the farmers' SFM through provision of family labour. Practices such as tank silt application, FYM transportation, green leaf manuring and mixed cropping require more manual labour inputs. Hence, those families with large family size contribute more labour helping easier adoption of labour-oriented SFM practices. The ratio of family labour to the total labour used in cultivation also influences SFM. Sample hh's with higher ratio of family labour to total labour used are likely to adopt more of organic practices. Caste largely determines the people's perceptions, values and knowledge, which in turn influence the adoption practices, which are either organic or inorganic in nature. Farmers from backward communities like "Gollas" own lots of sheep and hence adopt sheep penning practice in their agricultural fields. The variable "large ruminants" influences the ratio of organic manure value to total fertiliser value and thereby soil fertility by way of providing drought power for agricultural operations and supply of organic manure. Smaller market distance improves access to inorganic fertilisers and therefore, the percentage of organic manure value to total fertiliser values. Credit requirement of farmers is met from several sources. The credit provided by fertiliser dealers influences the use of inorganic fertilisers. Farmers with bigger farm sizes have lesser possibilities of applying organic manure in sufficient quantities as compared with those of small farm sizes.

In order to identify the factors that determine the percentage of organic manure value to total fertiliser values of the sample farms, a multiple linear regression model was used. The variables included in the function are given below.

$$Y = \text{Constant} + \sum\nolimits^{6}_{J=1} B_j X_j + \sum\nolimits^{17}_{j=1} C_j D_j + E_i,$$

where

Y is percentage of organic manure value to total fertiliser value

where

X_1	is rainfall in mm in the village
X_2	is family size
X_3	is family labour
X_4	is large ruminants
X_5	is market distance
X_6	is credit
$D_{1=1}$	if farmer cultivated in red sandy soil, otherwise 0
$D_{2=1}$	if farmer cultivated in black soil, otherwise 0
$D_{3=1}$	if farmer cultivated in gravel soil, otherwise 0
$D_{4=1}$	if farmer cultivated in shallow soil, otherwise 0
$D_{5=1}$	if farmer cultivated in medium soils, otherwise 0

$D_{6=1}$ if farmer cultivated in soils of average fertility level, otherwise 0
$D_{7=1}$ if farmer cultivated in soils of good fertility level, otherwise 0
$D_{8=1}$ if farmer cultivated in soils of very good fertility level, otherwise 0
$D_{9=1}$ if farmer has education level up to I–V, otherwise 0
$D_{10=1}$ if farmer has education level up to VI–VII, otherwise 0
$D_{11=1}$ if farmer has education level up to VIII–X, otherwise 0
$D_{12=1}$ if farmer has education level up to intermediate and above, otherwise 0
$D_{13=1}$ if the farmer belonged to scheduled tribe, otherwise 0
$D_{14=1}$ if the farmer belonged to backward caste, otherwise 0
$D_{15=1}$ if the farmer belonged to other caste, otherwise 0
$D_{16=1}$ if the farmer belonged to medium farm size, otherwise 0
$D_{17=1}$ if the farmer belonged to small farm size, otherwise 0

Dummy variables were used for soil types, soil depth, fertility level of soils, education, caste and farm size.

The results of the analysis in Table 10.16 reveal that in paddy crop, the variables rainfall, large ruminants and small farms are positively significant to the percentage of organic manure value to the total fertiliser value at 1 % level of significance, whereas the variable market distance was positively significant at the 5 % level. This means that with increase in rainfall and population of large ruminants the application of organic manures increases.

Similarly, the smaller the farm size, higher is the amount of organic manure used which helps in improving soil fertility. The nearer the market distance, higher is the use of organic manures. This indicates that organic manures/cakes have to be made easily accessible to farmers. The independent variables red sandy soil, black soil, gravel soil, shallow soils, medium depth soils, average soil fertility level, good soil fertility level, very good soil fertility, education: I–V, education: VI–VII, education: VIII–X, intermediate and above, family size, scheduled tribe, backward communities, OCs, ratio of family labour, credit and medium farms were not significant for paddy.

10.7 Conclusion

Soils are critical to agriculture, food security and livelihoods. With a large proportion of India's population being dependent upon small-scale, rainfed agriculture, sustainable management of soil is a high-priority issue. This chapter has brought out clearly that diverse SFM practices are being followed by farmers so as to effectively manage the health of their soils and to get good crop yields. It could be clearly seen that the contribution of organic matter by traditional SFM practices has been instrumental in maintaining soil fertility for generations. Probit analysis on paddy revealed that increase in education level, rainfall and ratio of family labour to total labour used, positively influenced the adoption of SFM practices. Without livestock,

Table 10.16 Correlation between percentage of organic manure value and total fertiliser value and household, soil, climatic characteristics in paddy

Independent Variables	Coeff.	Std. error	Sig.
Red sandy soil (= 1, red loamy soil = 0)	7.038	7.148	
Black soil (= 1, red loamy soil = 0)	5.674	3.702	
Gravel soil (= 1, red loamy soil = 0)	– 5.638	6.549	
Shallow soils (= 1, very shallow = 0)	– 6.729	3.934	
Medium depth soils (= 1, very shallow = 0)	– 7.298	5.394	
Average soil fertility level (= 1, bad soil fertility level = 0)	2.450	7.102	
Good soil fertility level (= 1, bad soil fertility level = 0)	– 4.776	7.094	
Very good soil fertility (= 1, bad soil fertility level = 0)	– 1.110	8.606	
Rainfall in mm	0.100	0.031	a
Education: 1–V (= 1, others = 0)	1.451	4.632	
Education: VI–VII (= 1, others = 0)	7.375	5.158	
Education: VIII–X (= 1, others = 0)	4.374	4.788	
Intermediate and above (= 1, others = 0)	0.098	5.879	
Family size	0.468	0.629	
Scheduled tribe (= 1, scheduled caste = 0)	– 22.593	11.773	
Backward communities (= 1, scheduled caste = 0)	– 7.187	10.887	
Other caste(= 1, scheduled caste = 0)	– 7.689	11.427	
Ratio of family labour to total labour	0.077	0.126	
Large ruminants	3.013	0.635	a
Market distance	1.068	0.431	b
Credit	0.000	0.000	
Medium farms (= 1, big farms = 0)	7.340	4.202	
Small farms (= 1, big farms = 0)	15.589	5.545	a
_cons	– 51.409	27.612	
No. of observations	186.000		
r-square	0.288		

[a] 5 % level of significance
[b] 1 % level of significance

farming in semiarid regions would not be possible. Results of the regression analysis revealed that the variable "large ruminants" was positively significant in paddy, indicating the importance of livestock for sustainable SFM.

We could see from this study how farmers' SFM options are being undermined by government policies that give more priority to chemical fertiliser-based strategies. These include promotion and credit for packages of practices that include chemical fertiliser-responsive seeds, lack of recognition to mixed cropping system, and subsidising chemical fertilisers rather than organic inputs. Policies that encourage fertiliser and irrigation subsidies may discourage soil conservation and encourage depletion of groundwater (Lutz et al. 1994; Reddy 2001). The empirical results of this study call for an argument to be made for an approach to supporting SFM by farmers which is more attuned to the range of circumstances which are found on the ground and best suits the long-term productivity of soils. Hence, the study makes the following recommendations:

- Subsidies and credit policies should allow farmers to purchase whichever form of fertilising input they want.
- Such policies are needed which encourage and support low external input and labour-intensive practices such as sheep penning, composting, vermicomposting, tank silt application, or incorporation of green manure crops.
- Development of appropriate credit programmes that enable farmers to obtain crop loans for diverse mixed farming systems, including organic inputs such as farm yard manure.
- Local animal breeds are important for livelihoods and sustainable agriculture should be conserved in situ by strengthening integrated farming and indigenous systems of land use in which livestock play a key role in nutrient cycles and the maintenance of soil fertility.
- Crops that take care of fodder needs of the livestock have to be provided with good market price.
- All agricultural development projects, especially those focusing on soils, should focus on increasing supplies of organic matter to the soils to nourish soil organisms.
- INM recommendations should take into account the integrated manner in which farmers combine SFM with other aspects of their farming system.
- A more participatory approach to SFM is essential, to take account of the diversity of management techniques. It generates energy and creativity both within the farming community and among researchers and extension workers.

Acknowledgements This chapter is based on my doctoral research work. I am grateful to my Ph.D. supervisor V. Ratna Reddy, Livelihoods and Natural Resources Management Institute (LNRMI), Hyderabad, for his insightful comments and great support. Thanks to C. S. Sambamurthy and Jyothis Sathyapalan of CESS for their valuable comments on the thesis draft. I am grateful to S. Galab, Director CESS, and M. Gopinath Reddy, CESS, for their strong support. I am indebted to the farmers of study villages who contributed a lot to my research.

References

Adolph B, Butterwoth, J (2002) Soil fertility management in semi-arid India: its role in agricultural systems and the livelihoods of poor people. Natural Resources Institute (NRI), United Kingdom

Battese GE, Coelli TJ (1988) Prediction of farm-level technical efficiencies with a generalised frontier production function and panel data. J Econom 38: 387–399

Butterworth J, Adolph B, Suresh RB (2003) How farmers manage soil fertility. A guide to support innovation and livelihood. Andhra Pradesh Rural Livelihoods Programme/Chattam: Natural Resources Institute, Hyderabad

Centre for Monitoring Indian Economy (2006) CMIE Energy, Bombay

Chambers R (1995) Paradigm shifts and the practice of participatory research and development. In: Nelson N, Wright S (eds) Power and participatory development. Intermediate Technology Publications, London, pp 30–42

Fan S, Hazell P (2000) Should developing countries invest more in less favoured areas? An empirical analysis of rural India. Economic and Political Weekly, April 22, pp 1455–1464

Fertiliser Association of India (2006) Annual report, Delhi

Government of India (2008) Economic survey 2007–2008, Ministry of Finance, Economic Division, New Delhi

Hilhorst T, Muchena FM (2000) Nutrients on the move—soil fertility dynamics in African farming systems. International Institute for Environment and Development, London

Lutz E, Pagiola S, Reiche C (1994) The cost and benefits of soil conservation: the farmers' view point. World Bank Res Obs 9(2):273–295

Poinetti C, Suresh RB (2002) "Farmers' perceptions of crop diversity in the Deccan Plateau", SEEDLING, Quarterly Newsletter of Genetic Resources Action International (GRAIN), Spain

Purakayastha TJ, Swarup A, Singh D (2008) Strategies to manage soil organic matter for carbon sequestration—Indian perspective. Indian J Fertili 4(3):11–16, 19–22

Reddy RV (1999a) Valuation of renewable natural resources: user perspective. Econ Polit Wkly XXXIV(23):1435–1437 5th June

Reddy UR (1999b) "Integrated nutrient management in tomato-onion cropping system", unpublished PhD thesis, Acharya N.G. Ranga Agricultural University, Andhra Pradesh

Reddy RV (2001) User valuation of renewable natural resources: the user perspective. Nova Science Publishers, Inc., New York

Reddy SB (2010a) "Assessment of economic and ecological returns from millet-based biodiverse organic farms vis-à-vis conventional farms", CESS Monograph series No. 8, Centre for Economic and Social Studies, Hyderabad

Reddy SB (2010b) "Soil fertility management in semi-arid regions: the socio-cultural, economic and livelihood dimensions of farmers' practices—a case of Andhra Pradesh", unpublished Ph.D. thesis, Centre for Economic and Social Studies, Dr. B. R. Amebedkar University, Hyderabad

Reddy SB (2010c) Organic farming: status, issues and prospects—a review, Journal of Agricultural Economics Research Review, Vol. 23, July–December, pp 197–208. New Delhi

Sagari (2004) Livelihoods and gender: equity in community resource management, overcoming gender barriers: local knowledge systems and animal health in Andhra Pradesh and Maharashtra. Earth Scan Publication Ltd., London

Woomer PL, Martin A, Albrecht A, Resck D, Scharpenseel H (1994) The importance and management of soil organic matter in the tropics In: Wommer, PL, Swift MJ (eds) The biological management of tropical soil fertility. Wiley-Sayce, Chichester