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Traditional Soil Fertility Management Practices in Semi-Arid Regions of India

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ABSTRACT

The over-dependence on chemical fertilizers for nutrient management in crop production for the last few decades has led to many problems impacting soil health, the environment and farmers themselves. Fieldwork of the study was done in semi-arid regions of A.P, Karnataka, M.P, U.P and Jharkhand. This paper highlights the contribution of organic matter by traditional soil fertility management practices in maintaining soil fertility. This study brings out that the farmers in semi-arid regions are actively managing the health of the soil and other soil properties adopting diverse practices that are based on local resources and knowledge. It also highlights the socio-economic web woven around these soil fertility management practices. This study highlights the contribution of organic matter by traditional soil fertility management practices in maintaining soil fertility. Livestock has a profound impact on the fertility of the soil through the supply of organic manure. Regressional analysis revealed that large ruminants are a key variable influencing soil fertility.

Empirical data of this study has revealed how farmers' fertility enhancement practices are not given importance by the agricultural policies of the government and instead are giving more priority to chemical fertiliser-based strategies. Based on the findings it is argued that there should be a "level playing field" for both organic and inorganic soil fertility management methods by promoting and supporting farmers in using organic methods. There is a need to provide credit to farmers for adopting their choice of soil fertility management methods which suit their socio-economic conditions and that best suit the long-term productivity of soils. The study suggests that the government policies related to soil fertility management must be farmer-friendly and within the resources and skills at his disposal. This will not only keep Indian soils in healthy condition but also support the livelihoods of millions of people, especially the small and marginal farmers.

Keywords: Soil fertility management; Traditional knowledge; Organic manures; Livestock and Livelihoods.

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INTRODUCTION

The Green Revolution has led to a steep increase in food production. It also led to many problems. Even today rainfed agriculture is predominant in India. Green Revolution technology gains in agricultural productivity and food security were widely associated with the irrigated lands, where the benefits of high-yielding varieties and increased use of inorganic fertilisers could be realised. However, there are now widespread problems associated with the use of inorganic fertilisers, improper management of surface water and groundwater exploitation(GoI,2022). The additional bill for fertiliser imports in 2021 and 2022 was at least US$4.8 billion for India. The potential for expanding irrigated agriculture is decreasing in India. Hence, rainfed agriculture remains a high priority for policymakers and is vital to the food security and livelihoods of people. It is shown that returns on investments in rainfed agriculture are greater than those on investments in irrigated agriculture (Fan and Hazell, 2000). Practices to be used for improving soil fertility have to address the overall health of soils. Sustainable Development Goals(SDG) aim to reach the goal of having 75% healthy soils by the year 2030 by way of achieving SDG goals 2 , 3, 13 and 15.

Cropping practices ranging from summer ploughing to crop rotations were developed by dryland farmers of semi-arid regions[1], and they withstand harsh agro-climatic constraints (Pionetti and Reddy, 2002). Livestock are crucial to the stability of dryland agriculture by way of providing manure to soils and income to farmers (Sagari, 2004; Reddy, 2011). Soil Fertility Management (SFM) affects landless, landed, shepherds and women. Through these multiple dimensions, SFM is a key to the sustainable livelihood of the rural people in Semi-Arid Tropics (SAT) in India.

Based on the empirical findings from field works in A.P, Karnataka, Uttar Pradesh, Madhya Pradesh and Jharkhand, this paper attempts to discuss the traditional SFM practices followed by various size class farmers that are based on local resources and knowledge and their contribution to livelihoods. In this study, probit analysis was done to see what type of characters influence those who adopted soil fertility management practices and those who did not. Regressional analysis was done to determine the variables influencing SFM with respect to paddy crops. It will also identify the factors influencing soil fertility management practices so that inputs for policymaking can be given.

This paper has been organized into five sections including this introduction. Section 2 is on the study area, data and methodology of the study. The findings of the study are discussed in section three. Determinants of SFM are presented in the fourth section. In the last section, some conclusions are made based on the empirical evidence.

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

STUDY AREA, DATA COLLECTION AND METHODOLOGY

This paper draws on the quantitative data from the States of Andhra Pradesh(AP), Uttar Pradesh(UP), Madhya Pradesh(MP), and Jharkhand(JHK) and qualitative data from the study done in Karnataka state. The study states majority are small and marginal farmers and also have the distinction of much-diversified livestock resources. Agriculture has been undergoing many changes over the past three decades. The increasing intervention of the state in agriculture, and the green and yellow revolutions, have prompted agricultural changes throughout the semi-arid regions, especially in land ownership, cropping patterns, irrigation, credit and extension, agricultural productivity, prices and marketing. The use of fertilisers too was high in states such as Uttar Pradesh. In 2019-20, the total NPK per hectare consumption in UP, MP and JHK was 170.1 kg, 90.3kg and 59.8 kg respectively (GoI, 2020) as against India's 133.1 kg/ha (Fertiliser Association of India, 2020). All the above-mentioned aspects have a huge bearing on the farmers' soil fertility management practices, especially in semi-arid regions. It was in this context that the states of A.P., Uttar Pradesh, Madhya Pradesh and Jharkhand were selected for the study on soil fertility management focusing on the socio-economic, ecological and livelihood dimensions of farmers' practices in semi-arid regions.

The selected districts were Anantapur, Mahbubnagar, Prakasham districts(AP) Lalitpur (UP), Sehore (MP), Hazaribagh (JHK) and Tumkur district(Karnataka). Districts having the least percentage of net irrigated area in their respective states with an annual average rainfall ranging between 500-900 mm falling under semi-arid conditions were selected for the study. Two blocks from each district were selected. In each selected district, one block with the least percentage of net irrigated area falling under semi-arid regions (those receiving rainfall between 500-900 mm) and another block with the highest net irrigated area falling under semi-arid regions were selected. Though both blocks come under semi-arid conditions, one block with a high net irrigated area and another with the least net irrigated area was selected to observe the dynamics involved in soil fertility management under irrigated conditions and dryland conditions. A total of 12 blocks were selected from different semi-arid districts of India (table 1).

Table 1: Research Locale in Semi-arid India

State	Districts	Village	No. of Sample Households
Uttar Pradesh	Lalitpur	Pawa, Gidwaha, Jhwar, Saurayi	360
Madhya Pradesh	Sehore	Uljawan, Belondia, Mogragram, Chainpura	360
Jharkhand	Hazaribagh	Allonjakurd, Barkakalan, Padma, Donaikalan	360
Andhra Pradesh	Mahubnagar, Prakasham and Anantapur	Maredudinne, Dhuppalle Ravinoothala, Darsi Brahmanapalle, Chinnapolamada	360
		Total Sample	1440

Source: Chief Planning Office of the selected districts, 2016.

Villages with the highest net irrigated area were selected from the blocks with the highest net irrigated area in the district. Villages with the least net irrigated area were considered as unirrigated. This helped to capture the holistic picture related to soil fertility management at the village level, both in irrigated and dryland conditions. A total of eighteen villages were selected from six different semi-arid districts. A total of 1080 farmers covering the six districts were interviewed for the research. The study used both qualitative and quantitative methods to understand the farmers' soil fertility management 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 Agricultural Universities of selected states.

The data analysis was basically done in two ways. One was comparing between the various size classes of large, medium and small farmers; and the other analysis was done comparing the irrigated and unirrigated (less irrigated) villages. The results of the study are discussed at the household level and also at the plot level. Averages, frequency and percentages were used to analyse the various information related soil fertility management. Probit analysis was done to understand what characters influence the farmers adopting SFM practices. Regressional analysis was done to find out the variables which have an influence on soil fertility.

FINDINGS OF THE STUDY

Empirical findings of the study revealed that farming, wage labour, cattle rearing, dairying and Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) work were predominant livelihoods of the sampled villages. Interestingly migration was a very important livelihood of the study villages and the people travelled to distant places such as Delhi, Surat and Bombay. Diverse soil types were present in the study villages hosting huge agro-biodiversity. Soil testing was not done by the majority of the sampled households. Those negligible number of farmers who have given their soil samples for testing did not receive the analysis results. In general livestock population has come down but in some villages. Soil Fertility Management related cultural festivals are celebrated by sampled households and these include *Maveshi pooja(worship of livestock)*, *Gram devatha pooja(village goddess worship), hariyali amavasya(no moon day festival), mohan parma, harvesting festival, navdurg pooja, diwali ka pooja(Festival of lights), Penta Pooja(worshipping of compost heap), Yendlagatte punnama(celebration of crop diversity), Shoonyam panduga (worshipping of mother earth) and vishwa karma jayanti.*

FARMERS' PRACTICES

Farmyard manure, chemical fertilizers, tank silt application, cultivation of legumes, inter/mixed cropping systems, crop rotation, incorporation of weeds in soils and sheep penning were predominant soil fertility management practices that were seen in all the six study states. In a few study villages, NADEP compost and vermicompost are being used by a few farmers. Hitherto important SFM practices such as green manuring, deep summer ploughing and green manuring These practices are based on their long experience and rich knowledge of locally specific conditions; despite constraints, such practices are alive and vibrant (Butter- worth et al 2003). were prevalent in the study villages. During the focused group discussions, farmers of all states felt that the prices have chemical fertilizers are skyrocketing and in the coming years, they would cut done its use and instead try to depend on local resources for enhancing soil fertility which is likely to contribute to sustainable soil health(table 2).

Table 2: Soil Fertility Management Practices Adopted by Farmers and Its Economics

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 the field for spreading and incorporation into the soil before ploughing.	Ranges between Rs.2000-4000/acre excluding transportation cost. The effect lasts for 3-4 years.
Sheep penning	Pastoralists penn 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	Rs.1000-1200/acre. The effect lasts for only one or two seasons.
Legume Cultivation	Growing leguminous crops loosens the soil, adds organic matter to soil through leaf fall and fixes nitrogen into soil.	Seed cost of crop. Generally Rs.50-200/acre. In the case of ground nut, it is Rs.1800-Rs.2500/acre. The 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 case of Horticultural crops. They are also used to avoid certain soil-borne pests.	Rs.1200/50 kg bag. Cost varies depending on the crop and dosage applied. The effect lasts for one to two seasons.

Crop Rotation	Crops which use different nutrients are grown alternatively to keep the nutrient balance.	Does not involve any cost except the decision to change the crop. The effect lasts for two seasons.
Intercropping/Mixed cropping	Growing a mixture of different crops in the field. Small and marginal farmers often grow 5-6 crops in an acre.	Cost varies depending on the crops and their required quantities.
Tank silt application	Fine tank silt from the village tank is excavated and transported to the fields and applied to topsoil.	Rs.800-1000/acre. The effect lasts for two years.
Chemical fertilisers(including micro-nutrients)	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. The cost of most commonly used urea is approximately Rs.250/50 kg bag and DAP is Rs.1350/50 kg bag. The effect lasts for 2-3 months only.

Source: Field survey and Focused group discussions

ORGANIC VS INORGANIC INPUTS

An analysis was done to understand how the sample farmers were distributed with regard to the use of organic and inorganic inputs (Table 3). For this, the total amounts spent by them on organic manures and inorganic fertilisers were considered. Different ratios of both were taken into account for an easier and better understanding of how money was being invested in organic and inorganic fertilisers and by what percentage of farmers. The analysis did not include cultural practices such as crop rotation and inter/mixed cropping as no separate investment is needed for these apart from the seed cost, which the farmer has to anyway bear for raising a crop.

The distribution of the sample farmers revealed that only 16.94% exclusively used chemical fertilisers in their plots. There was no one exclusively using only organic manures. However, more than 32.50% of the farmers spent more than 50% of their total investment on soil fertility on organic manures/practices. This is a positive sign for the emerging organic market. This large group of farmers can be encouraged to become totally organic and take advantage of the growing organic market and the facilities extended by the government to encourage organic agriculture. Among the size classes, 46.67% of small farmers invested more than 50% of their money on organic manures/ practices. They were followed by medium (31.67%) and large farmers (19.17%).

Table 3: Size-Class-wise Distribution of Farmers according to the Ratio of Amount Used for Organic and Inorganic Fertilisers (%)

Size-Class	OF:CF 0:100	OF:CF 10:90	OF:CF 20:80	OF:CF 30:70	OF:CF 40:60	OF:CF550:50	OF:CF 60:40	OF:CF 70:30	OF:CF 80:20	OF:CF 90:10	Total
LF	5.83	15.83	23.34	17.50	18.33	5.0	7.5	6.67	0	0	100.0
MF	20.0	5.83	12.5	20.83	9.17	10.0	9.17	5.0	3.33	4.17	100.0
SF	25.0	4.17	7.5	8.33	8.33	8.33	9.17	14.17	10.0	5.0	100.0
All	16.94	8.61	14.45	15.56	11.94	7.78	8.61	8.61	4.44	3.06	100.0

Note: OF = Organic Fertilisers; CF = Chemical Fertilisers; LF, MF, SF = Large, Medium, Small Farmers.
Source: Primary survey.

AGRO-BIODIVERSITY

Farmers of drylands have developed diversified cropping systems to ensure that the most essential natural elements such as sunlight, wind, rainfall and soil are optimally utilised throughout the year. Crops that were developed over centuries were specifically bred to suit the changes in the rainfall pattern from year to year (Pionetti, 2005). The short and long-duration varieties, water-tolerant and drought-resistant varieties, etc., that were developed were the result of this careful planning over centuries by farming communities. Intercropping, mixed cropping, relay cropping and multi-tiered cropping were the strategies adopted by the sample farmers and were highly relevant. By doing so, the farmers have balanced food and cash crops, along with the fodder needs of their animals and simultaneously managed the fertility of their marginal soils. Inter-temporal data on crop diversity was calculated for the past three decades. An effort was made to find out the minimum number of crops grown by farmers on a given piece of land at a given point in time in a given season, irrespective of the land area. Table 4 shows the diversity in cropping during the year 2020. A decrease in agro-biodiversity led to the disappearance or decrease in cultivation of certain crops in each study village.

Table 4: Size Class-Wise Distribution of Sample Farmers according to Crop Diversity in 2020(%)

Crop Diversity	Large Farmers	Medium Farmers	Small Farmers	Total
1-3 Crops	27.50	46.67	55.00	43.06
4-6 Crops	49.17	28.33	29.17	35.55
7-9 Crops	23.33	25.00	15.83	21.39
Total	100.0	100.0	100.0	100.0

Source: Primary survey

One of the reasons for this was to facilitate easy application of inorganic fertilisers, pesticides and weedicides. Another reason for the reduction in agro-biodiversity was the lack of easy access to labour during different times of the season, when these diverse crops get ready for harvest; and also market influence. Another reason cited by the farmers, which is a recent problem in some of the study villages, is wild pigs and monkeys that damage some of the food crops; hence, farmers prefer to grow crops which are not affected by these animals. However, it is very heartening to see that there is still huge agro-biodiversity in the farmers' fields across all size classes. The majority of the farmers across all size classes grow crops ranging between four and six in number. The reason revealed by the farmers in focused group discussions is the maintenance of soil fertility. A substantial number of sample farmers also grow between seven to nine crops. Contrary to popular perception it could be seen that a large number of sample farmers (23.33 per cent) are still growing 7-9 crops in a given piece of land. More land area might have enabled them to go for higher diversity in certain patches of the land. Recognizing the benefit of crop diversity with respect to soil fertility management and pest management, mainstream agricultural scientists are again advocating the mixed cropping system for long-term sustainable crop yields.

ADOPTION OF SFM PRACTICES

For a long time, farmers have been adopting a range of diverse soil fertility-enhancing practices for soil management and good crop yields (Acharya *et al* 2001; Adolph and Butterworth, 2002; Reddy, 2011). The present study looked at the adoption of these soil fertility management practices by sampled farmers. The total number of practices followed by each sample household in their total land area was taken as a base for calculating the adoption rate. It is clear from Table 5 that there used to be great diversity in the fertility-enhancing practices in the villages across all size classes. Hitherto, soil fertility management practices such as tank silt application, summer ploughing, green leaf manuring and green manure crop incorporation, used to be widely adopted by the sample farmers across all size classes. Now, the majority of farmers across all size classes are adopting less than four soil fertility-enhancing practices. The reason attributed to this is the easy access to chemical fertilisers, which are also easy to apply. Even, fertiliser dealers supply it on credit or tied up sale.

Table 5: Size Class-Wise Distribution of Sample Farmers according to Trends in Adoption of Soil Fertility Enhancing Practices in 2020 (%)

No. of Practices	Large Farmers	Medium Farmers	Small Farmers	Total
<2 Practices	55.0	70.83	71.67	65.83
3-4 Practices	44.17	26.67	28.33	33.06
5-6 Practices	0.83	2.5	00.0	1.11
7 & Above	00.0	00.0	00.0	00.0
Total	100.0	100.0	100.0	100.0

Source: Primary survey

On the other hand, lack of labour availability, lack of access to resources like green leaf manure and lesser availability of FYM have reduced the adoption of some of these practices from the year 2010. However, observing the negative impact of using only chemical fertilisers on their soils, many farmers express the need to get back to some of the traditional SFM practices and also seek strong support for some of these practices for the long-term sustainability of their soils. The poor and marginal farmers did not like to rely upon chemical fertilisers (Butterworth *et al*., 2003). Even today, farmers in the Deccan region of India adopt 22 diverse traditional soil fertility-enhancing practices (Satheesh *et al.*, 2001). It is essential to preserve these diverse practices which are based on the local resources and are good for soil fertility in the long run.

CHANGES IN SOIL FERTILITY LEVEL

In addition to the adoption of soil fertility-enhancing practices, the study also looked at how the sample farmers perceived the increase or decrease in the fertility level of their soils. Soil quality was one of the important factors that determine land productivity (Bekele *et al*., 2003). The perception was about the general fertility of all their soils rather than the individual plots owned by them. Their perception about the soil fertility level of their soils in 2010 was compared with the earlier decade of 2000 and similarly, 2020 was compared with 2010.

The data in Table 6 provides a very interesting scenario which tells us that the majority of the farmers across all size classes (73.33 per cent of large farmers, 65 per cent of medium farmers and 50 per cent of small farmers) perceived that their soil fertility increased in 2010 as compared with 2000. This could be due to better results in crop yields due to the use of inorganic fertilisers. Initially, chemical fertilisers could have fared well, as the soils had good organic matter, micro-nutrients and better texture due to the adoption of diverse soil fertility management practices until that period. However, the majority of sample farmers perceived that their soil fertility decreased by the year 2020 as compared with 2010 (45 per cent of large farmers, 43.33 per cent of medium farmers and 42.50 per cent of small farmers). This could be an interesting and important aspect of the present study which gives us an indication of what is in store in the future years. The negative effects of chemical fertilisers on their soils were seen by the farmers after a few years and more importantly, when they started depending more and more on chemical fertilisers alone, moving away from their traditional fertility-enhancing practices due to various reasons and constraints. This builds a case for the holistic approach to soil fertility management looking at the long-term sustainability of soil fertility. Hence, efforts must be made to provide a basket of soil fertility management options to farmers in the semi-arid regions rather than encouraging only inorganic fertilisers, or for that matter, any single practice.

Table 6: Size Class-Wise Distribution of Sample Farmers according to Changes in General Soil Fertility Level over Time as Perceived by Farmers (%)

Soil Fertility Level	Large Farmers		Medium Farmers		Small Farmers		Total	
	In 2010 compared to 2000	In 2020 compared to 2010	In 2010 compared to 2000	In 2020 compared to 2010	In 2010 compared to 2000	In 2020 compared to 2010	In 2010 compared to 2000	In 2020 compared to 2010
Decreased	14.17	45.00	19.17	43.33	34.17	42.50	22.50	43.61
Status quo	12.50	10.83	15.83	10.83	15.83	15.83	14.72	12.50
Increased	73.33	44.17	65.00	45.84	50.00	41.67	62.78	43.89
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Source: Primary survey

LIVESTOCK

Livestock forms an integral component of a rainfed ecosystem. There is great diversity in terms of the density of cattle, sheep and goats in different semi-arid regions. The livestock resources have considerable genetic diversity and have wide adaptability to withstand environment, nutrition and management stress. Table 7 indicates that there is a general decrease in the population of cows and more so with medium and small farmers. The population of cows is more or less the same with large farmers. This could be due to milk and manure needs. Small and medium farmers perceive that it is uneconomical to maintain cows these days. The reason as revealed in focused group discussions was water scarcity and the lack of sufficient fodder in these villages. However, large farmers who have better access to fodder are keeping these animals. The population of bullocks is reduced with the large farmers of study villages. Mechanisation through tractors has replaced bullocks. It is an alarming sign for future agriculture as the reduction in cow population leads to a reduction in bullock power, which will have an impact on timely land preparation and agricultural operations and lead to lesser manure availability. If no efforts are made to increase the population of cows, there could be a severe shortage of draught power[2] which will have a negative impact on farming in the semi-arid regions.

[2] *Draught power is the bullock power used for ploughing the land and carrying out inter-cultivation operations.*

Table 7: Size Class-Wise Distribution of Sample Farmers according to Changes in Livestock Population over Time (%)

Livestock Category	Large Farmers			Medium Farmers			Small Farmers			Total		
	2000	2010	2020	2000	2010	2020	2000	2010	2020	2000	2010	2020
a) Large Ruminants												
Cows	36.40	35.49	36.61	33.77	33.93	28.18	34.32	29.0	25.25	34.83	32.80	30.01
Buffaloes	34.42	37.12	38.28	36.77	37.50	40.87	37.77	40.95	44.18	36.32	38.52	41.11
Bullocks	29.18	27.39	25.11	29.46	28.57	30.95	27.91	30.05	30.57	28.85	28.68	28.88
Total	100	100	100	100	100	100	100	100	100	100	100	100
b) Small Ruminants												
Goats	35.71	27.10	24.20	32.93	28.75	70.55	72.67	61.88	85.38	62.10	51.53	53.61
Sheep	64.29	72.90	75.80	67.07	71.25	29.45	27.33	38.12	14.62	37.90	48.47	46.39
Total	100	100	100	100	100	100	100	100	100	100	100	100

Source: Primary survey

Among small ruminants, goats have been increasing over the past three decades with medium and small farmers; while on the other hand, sheep have been decreasing. A shift from cows to buffaloes and from sheep to goats has been seen in the last ten years (Ranjitha, 2004). As goats can withstand harsh environments and can eat all kinds of leaves, they are being reared by the farmers, especially the small and marginal farmers. Similarly, the goats are moving cash for the poor; furthermore, kidding is more in goats, resulting in a quick increase due to their quick multiplication. Poorer households carry the goats with them to the fields when they go out to work as agricultural labourers or to their own fields. In the case of sheep, they need grazing areas and sufficient drinking water for them to flourish.

DETERMINANTS OF SOIL FERTILITY MANAGEMENT

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

PROBIT ANALYSIS

Probit regressional 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 crops. In the probit analysis, SFM practices adoption by the farmer (=1) and non-adoption of SFM (=0) were taken as dependent variables. It can be seen from Table 8 that the variables education level of intermediate and above, and rainfall are positively significant at 1 per cent level, whereas the variable ratio to family labour is positively significant at 5 per cent level. This means that an 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 a 1 per cent level. The variables good soil fertility level and family size are negatively significant at 5 per cent level. With increasing rainfall, there is an increase in the adoption of SFM practices in paddy. This could be due to the use of only diverse practices like neem cake application, Farm yard manure, 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 sizes, the chances of adopting diverse practices are reduced, whereas farmers with bigger farm sizes have chances of adopting more SFM practices. Similarly, in soils with good fertility levels, there is less need to adopt 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: 1-V, Education: VI-VII, Education: VIII-X, Scheduled Tribe, Backward Communities, Other Caste, Large ruminants, Market, Credit and Medium farms did not influence the adoption of SFM practices.

Table 8: Factors Influencing Choice of SFM Practices: Probit Regression Analysis

Independent Variables (Adoption of SFM)	Coeff.	Std. Error
Good soil fertility level (=1, bad soil fertility level=0)	-0.3972**	0.1971
Rainfall in mm	0.0052***	0.0015
Education: 1-V (=1, others=0)	0.1366*	0.0686
Education: VIII-X (=1, others=0)	0.1681**	0.0781
Intermediate and above (=1, others=0)	0.1812***	0.0753
Family size	-0.0424**	0.0165
Ratio to family labour to total labour used	0.0136**	0.0061
Small farms (=1, Big farms=0)	-0.7660***	0.1975
No. of observations	189	
Pseudo R-Square	0.2750	
Log-likelihood	-41.6300	

REGRESSION ANALYSIS

In this section, an attempt has been made to identify the household, soil and climatic characteristics which influence the dependent variable percentage of organic manure value to total fertiliser values in paddy crops. For calculating the production function results of paddy crops, yield was taken as the 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 years 2018-19 and 2019-20 together with the total amount spent on chemical fertilisers during the same period was taken as the dependent variable.

The variables selected for the regressional 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 regressional analysis and how these variables influence soil fertility management. Generally, the soils with greater depth are more fertile and among soils; and black cotton soils are more fertile compared to the others. Based on farmers' perceptions, the soils of farmers 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 the use of organic manure to the total soil fertility inputs used per acre. Rainfall is another factor which influences soil fertility. A good amount of rainfall with proper distribution over the crop season influences the higher use of chemical fertilisers. The long dry spells between two good rain showers discourage the use of fertilisers as there will be a scorching effect on the crop. Soil fertility management practices which contribute good quantities of organic matter content are preferred by farmers as it hold more moisture and help to overcome the moisture stress periods. Literacy always helps farmers to get better information related to soil fertility management from print media. The variable family size influences the farmers' soil fertility management through the 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 sizes contribute more labour helping easier adoption of labour-oriented soil fertility management practices. The ratio of family labour to the total labour used in cultivation also influences soil fertility management. Sample households with a higher ratio of family labour to total labour used are likely to adopt more 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*' (shepherds) own a lot of sheep and hence adopt sheep penning practices 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. The 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 fewer 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. Dummy variables were used for soil types, soil depth, fertility level of soils, education, caste and farm size.

Table 9: Correlation between Percentage of Organic Manure Value and Total Fertiliser Value and Household, Soil, and Climatic Characteristics in Paddy Crop

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	**
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	**
Market distance	1.068	0.431	*
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	**
_cons	-51.409	27.612	-
No. of observations	186.000	-	-
r-Square	0.288	-	-

*** Indicates 1 per cent level of significance*
** Indicates 5 per cent level of significance*

The results of the analysis in Table 9 reveal that in paddy crops, the variables rainfall, large ruminants and small farms are positively significant to the percentage of organic manure value to total fertiliser value at a 1 per cent level of significance, whereas the variable market distance was positively significant at 5 per cent level. This means that with an increase in rainfall and the population of large ruminants the application of organic manures increases.

Similarly, the smaller the farm size, the higher the amount of organic manure used which helps in improving soil fertility. The nearer the market distance, the higher the use of organic manures. This indicates that organic manures/cakes have to be made easily accessible to farmers. The independent variables were 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: 1-V, Education: VI-VII, Education: VIII-X, Intermediate and above, Family size, Scheduled Tribe, Backward Communities, Other Caste, Ratio of family labour, Credit and Medium farms were not significant for paddy crop.

CONCLUSION

The number of soil fertility management practices has decreased from 2000 to 2020. Similarly, farmers have perceived that soil fertility has decreased in 2020 as compared to 2010. Having experienced the negative effects of chemical fertilisers on soils, many farmers realized the need to get back to some of the excellent traditional practices and demanded strong support for them. It can be seen that the contribution of organic matter by traditional soil fertility management practices has been instrumental in maintaining soil fertility for generations. Probit analysis on paddy revealed that an increase in education level, rainfall and the ratio of family labour to total labour used, positively influenced the adoption of SFM practices.

In this study, we could see how farmers' soil fertility management options are being undermined by government policies that give more priority to chemical fertiliser-based strategies. Policies have long focused on generating external solutions to farmers' needs (Pretty, 1995; Reddy, 2017). Without livestock, farming in semi-arid regions would not be possible. Results of the regressional analysis revealed that the variable large ruminants were positively significant in the paddy crop, indicating the importance of livestock for sustainable soil fertility management. In the mixed farming systems of the semi-arid regions, the soil, livestock and crops are inextricably intertwined. Cattle provide draught power for agricultural operations, organic manure for maintaining soil fertility and use green fodder. More importantly, livestock provide cash to many resource-poor farmers during critical times for meeting health and food needs. However, factors such as declining fodder and water resources combined with blanket animal breeding policies fuel a downward spiral of loss in livestock genetic diversity, draught power, natural fertilisers, livelihoods and assets. Reduction in cow population is resulting in declining populations of work bullocks which is leading to shortage in draught power during the critical agricultural season. Hence, special efforts have to be made to ensure that the decline in the cow population is reduced while simultaneously working for their improvement. Similarly, Crops that take care of the fodder needs of the livestock have to be provided with good market prices. Farmers' (both women and men) knowledge needs to be recognised and incorporated into soil fertility research. Farmers' concerns about the negative impact of chemical fertilisers on soils and ecosystems have to be thoroughly researched. The empirical results of this study call for an argument to be made for an approach to supporting soil fertility management 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.

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