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Socio-economic and Environmental Perspectives of Sustainable Watershed Eco-System in Union Territory of Pondicherry

P. Nasurudeen[1] and N. Mahesh[2]

Abstract

The study conducted in the Karaikal region of the Union Territory of Pondicherry during 2004-05 has made a comparison of watershed and conventional systems. The crop diversification index has been found 0.28 in watershed and 0.32 in the conventional system. The study has revealed that nearly all the farmers in the watershed and only 40 per cent in the conventional system apply organic fertilizers. Moreover, farmers apply more fertilizers in the conventional (235 kg/ha) than watershed (210 kg/ha) system. The index of yield stability for all the crops has been found to be 0.98 in the watershed and 0.84 in the conventional system. The gross return has been found higher by 11.65 per cent, and net return by 32.18 per cent in the watershed than the conventional system. The input self-sufficiency ratio has been found to be 0.52 in the watershed and 0.47 in the conventional system. The analysis has indicated that if the agricultural income were considered, there has been no significant variation in food security in the two systems. The analysis has further revealed that there is a potential in promoting watershed system of farming for which it is necessary to devise policies that will provide incentives to watershed farmers both directly and indirectly. Until effective biological measures of soil fertilization are introduced, polices could be adopted to promote the application of biological and chemical fertilizers in a balanced way, so as to maintain soil structure and sustain or increase crop yields.

Introduction

Agriculture provides livelihoods to more than two-thirds of the rural population in the Union Territory of Pondicherry (UTP). In view of the scarcity of land, emphasis is being given to increasing food production by

[1]Professor and Head; [2]Assistant Professor,
Department of Agricultural Economics, PJN College of Agriculture and Research Institute, Karaikal-609 603,U. T. of Pondicherry

intensifying the use of land, chemical fertilizers, pesticides and irrigation sources. On the other hand, mono-cropping, along with imbalanced use of chemical fertilizers, pesticides and intensive use of land without application of organic fertilizers, has led to deterioration of both soil quality and fertility.

The increased use of chemical fertilizers, insecticides and pesticides has led to contamination of water resources, which has adversely affected the aquatic life, livestock and people's health. Likewise, the excessive use of groundwater is suspected to be the cause of seawater intrusion and development of alkalinity in the coastal areas of the Union Territory of Pondicherry. The declining soil fertility, depleting groundwater potential and increased and imbalanced use of chemical fertilizers and pesticides, have posed a serious challenge to the production of food on a sustainable basis for the growing population of UTP. In view of the problems arising from the conventional agriculture in UTP, the watershed system was introduced recently to promote alternative agriculture that emphasizes reduced use of external inputs, including agro-chemicals and increased use of local and on-farm resources in order to make the system both environmentally and economically sustainable. With this background, the present study has assessed the socio-economic and environmental perspectives of sustainable watershed eco-system in the Union Territory of Pondicherry.

Research Design

Study Area and Data Collection

To make a comparison of two agricultural systems at the micro level, two villages, one from conventional and the other from watershed system, were selected. Data were collected from both primary and secondary sources. Primary data were collected from farmers through an interview schedule, observation and discussions with farmer's groups, extension officials and progressive farmers in the tail end of Cauvery delta, Karaikal region in UTP. Altogether, 180 households were surveyed, 90 from the watershed and 90 from the conventional system in the agricultural year 2004-05. Sixty soil samples, 30 from each farming system, were collected from randomly selected farm plots and ten characteristics, viz. soil pH, electrical conductivity, organic carbon, nitrogen, phosphorus, potassium, zinc, copper, iron and manganese, were analyzed.

Sustainable Agriculture: Framework for Measuring Indicators

The three basic features of sustainable agriculture are: (i) maintenance of environmental quality, (ii) stable plant and animal productivity, and (iii) social acceptability. Consistent with this, Yunlong and Smith (1994) have suggested that agricultural sustainability should be assessed from the perspectives of ecological soundness, social acceptability and economic viability. 'Ecological soundness' refers to the preservation and improvement of the natural environment, 'economic viability' refers to maintenance of yields and productivity of crops and livestock, and 'social acceptability' refers to self-reliance, equality and improved quality of life.

Ecological Sustainability: It was assessed based on five indicators: land-use pattern, cropping pattern, soil-fertility management, pest and disease management and soil-fertility status. Land-use pattern was examined through proportion of land under agricultural crops, homestead and horticultural crops. Cropping pattern was analyzed using two criteria: cropping intensity and crop diversification, which was measured through a crop diversification index, using a formula developed by Bhatia (1965):

$$ICD = (P_a + P_b + P_c + \ldots + P_n) / N_c \qquad \ldots(1)$$

where, ICD is the index of crop diversification; P_a is the proportion of sown area under crop a; P_b is the proportion of sown area under crop b; P_c is the proportion of sown area under crop c; P_n is the proportion of sown area under crop n; N_c is the number of crops. The five major crops — paddy, black gram, green gram, sesame and groundnut — were taken into consideration. Soil-fertility management was evaluated based on the proportions of farmers using chemical and organic fertilizers, meaning farmyard manure and compost. The proportion of land area covered by each type of fertilizer and the amounts of chemical and organic fertilizers applied per unit of land were also considered. Management of pests and diseases was assessed based on the proportion of farmers using biological, mechanical and chemical methods. Soil fertility was examined through chemical analysis of soil samples collected from both conventional and watershed agricultural systems.

Economic Viability: Land productivity, yield stability and profitability from stable crops were considered to be the indicators of economic viability. Land productivity was measured through physical yield of crops. The stability of crop yield was examined by constructing an index based on farmers' subjective responses to a question related to yield trend. The index was constructed based on the following formula:

$$ITY = (fi*1 + fd*-1 + fc*0) / N \qquad \ldots(2)$$

where, ITY is the index of trend of yield; *fi* is the frequency of responses indicating increasing yield, *fd* is the frequency of responses indicating decreasing yield, *fc* is the frequency of responses indicating constant yield, and N is the total number of responses. Financial returns were analyzed through gross margin, benefit cost ratio and return per unit of labour. Value-addition per unit of land was calculated by deducting the value of intermediate goods, such as chemical fertilizers, pesticides, diesel, fuel and agricultural equipments from the gross revenue.

Social Acceptability : It was assessed in terms of input self-sufficiency, equity, food security and the risks and uncertainties involved in crop cultivation. Input self-sufficiency was determined on the basis of the ratio of local inputs cost to the total inputs cost. The higher the ratio of local inputs, the higher the input self-sufficiency. Family food-security was assessed in terms of adequacy of food grain produced as well as farm households' ability to purchase the food grain. Risks and uncertainties were examined based on cropping diversification and diversity of agricultural income. An index of risks and uncertainties was constructed using the formula:

$$Ir = \sum_{i=1}^{n} (x_i - \bar{x}) \qquad \ldots(3)$$

where, Ir is the index of risks and uncertainties, x_i is the amount of income from the ith source, $\bar{x}$ is the size of income at the minimum risk level and Σ is the summation of absolute deviation of ith income from the minimum risk level. The index value is zero when all agricultural enterprises contribute equally. The higher the degree of deviation, the higher the risk involved.

Results and Discussion

Ecological Sustainability

Land-use Pattern: The crop production was the dominant type of land-use in both the farming systems. Nearly 80 per cent of the agricultural land in both systems was being utilized for crop production. The remaining area was used for housing, industries and other infrastructure facilities. There was a slight shifting in land-use pattern towards horticultural farming in the watershed systems.

Cropping Pattern: The main crops cultivated in both the systems were paddy, black gram, green gram, sesame and groundnut. Paddy was the dominant crop in both the farming systems, occupying 80-85 per cent of the gross cropped area. Nearly 10-15 per cent of the area in the watershed system was occupied by pulses (black gram and green gram), and in the rest were grown oilseeds and other horticultural crops, including vegetables.

The indices of crop intensity and crop diversification revealed that there was no significant variation in the two farming systems. The cropping intensity in watershed system was 2.01, which was slightly higher than that of 1.78 in the conventional system. The crop diversification index was 0.28 in the watershed system and 0.32 in the conventional system. This may be attributed to practising of horticultural farming in the watershed system.

Soil-fertility Status: The declining soil fertility has been a major concern for agricultural sustainability in the Karaikal region. It is believed that declining land productivity, to a considerable extent, was due to the lack of adequate amounts of organic matter in the soil (Hossain and Kashem, 1997). Traditionally, farmers used to apply FYM and mulch crop residues to land to enhance soil fertility. This tradition has been abandoned gradually. The soil-fertility status of the two systems is presented in Table 1 indicated that nearly all the farmers in the watershed applied these fertilizers, while only 40 per cent of the conventional farmers applied organic fertilizers. The farmers applied about 15-20 t /ha of FYM in the watershed system while in conventional system, only 10-12 t/ha of FYM was applied for the cultivation of crops. All the available nutrients were higher in the watershed than conventional system. Organic matter in the soil contributes to improved soil structure and productivity (Pioncelot, 1986), as well as enhances the disease-resistant capacity of crops (Kotschi *et al.,* 1989).

Use of Chemical Fertilizers: Almost all the farmers in the conventional system and 85 per cent in the watershed system were applying chemical fertilizers to their farmlands, especially in the paddy cultivation. The farmers applied more fertilizers in the conventional system (235 kg/ha) than watershed system (210kg/ha). The farmers revealed that in the conventional system they have had to apply increasingly large amounts of chemical fertilizers over successive seasons to maintain yield because of gradual deterioration of soil quality by monoculture of paddy and over-use of chemical fertilizers (Hossain and Kashem, 1997; Rahman and Thapa, 1999).

Table 1. Soil-fertility status

Soil properties	Soil test value		Interpretation	
	Watershed system	Conventional system	Watershed system	Conventional system
pH	7.8	8.1	Slightly alkaline	Slightly alkaline
Organic matter (%)	0.29	0.18	Low	Low
Nitrogen (kg/ha)	142.4	134.6	Low	Low
Phosphorus (kg/ha)	3.64	2.74	Low	Low
Potassium (kg/ha)	138.4	129.8	Low	Low
Zinc (mg/kg)	0.43	0.36	Below critical	Below critical
Capper (mg/kg)	1.07	0.95	Below critical	Below critical
Iron (mg/kg)	3.35	2.04	Below critical	Below critical
Manganese (mg/kg)	1.42	1.10	Below critical	Below critical

The excessive application of fertilizers in the conventional system leads to gradual compaction of soil, resulting in constrained penetration of crop roots, reduced water infiltration and increased surface run-off (Steila, 1976). Since, this study area was located in the coastal agro-eco-system, substantial amounts of soil nutrients are washed away when surface run-off increases due to heavy rainfall. Besides, deterioration of soil and water quality, the ever increasing requirement of chemical fertilizers and pesticides would eventually make farming economically unviable in the conventional system by incurring increased costs and eroding farmers' profit margin.

Pests and Disease Management: There are significant variations between these two systems in the management of pests and diseases. Nearly 75 per cent of the farmers in the watershed system were controlling pests and diseases by weeding and cultivating crops in time and adopting other biological methods. While, about 80 per cent of conventional farmers were using chemical pesticides and fungicides and only 10 per cent of the farmers were using both chemical and biological methods for controlling pests and diseases. The accumulation of pesticides and other chemical residues in the soil was contaminating crops and adversely affecting the fertility of soil (Sattur and Mian, 1999). Earthworms were also reported to be dying because of the increasing concentrations of pesticides in water.

Economic Viability

Productivity: The average yields of major crops, presented in Table 2, reveal that the yield levels were higher in the watershed than conventional system. This could be attributed to the effective management practices in cultivation of these crops under watershed system. This is clearly an indication of a trend towards sustainability in the watershed system.

Stability of the Yield: The index of yield stability for all the crops was found to be 0.98 in the watershed system as 0.84 in the conventional system. The increase in yield was found more significant in the watershed than conventional system.

Profitability: The profitability was analyzed based on financial and economic returns and value-addition per unit of land to understand the performance of a system. The profitability of the paddy crop was worked out since it is the dominant crop in the study region and the results have been presented in Table 3. It has been found that performance of the watershed system was better than conventional system. The gross return was found 11.65 per cent more and the net return was 32.18 per cent higher in the watershed than conventional system. The total variable cost was found to be slightly lower

Table 2. Average yield of major crops in 2004-05

(kg/ha)

Crops	Watershed system	Conventional system	Change, %
Paddy	5625	5000	12.50
Black gram	1500	1450	3.45
Green gram	1400	1338	4.63
Sesame	1550	1488	4.17
Groundnut	3488	3150	10.73

Table 3. Profitability of paddy cultivation in Union Territory of Pondicherry

(Rs/ha)

Particulars	Watershed system	Conventional system	Change, %
A. Financial			
Gross return	28750	25750	11.65
Total variable cost	15913	16038	-0.78
Benefit cost ratio	1.81	1.61	-
B. Economic			
Net return	12837	9712	32.18
C. Value-addition			
Cost of chemical fertilizers	5500	5963	-7.76
Cost of pesticides	1000	1275	-21.57
Cost of fuel and charge of agricultural machinery use	1125	1300	-13.46
Cost of intermediate goods[a]	7625	8538	-10.69
Value-addition[b]	21125	17212	22.73

[a]Cost of chemical fertilizers, pesticides, fuel and agricultural machineries hire
[b]Value-addition = Gross return – Cost of intermediate goods

in the watershed system. The benefit cost ratio was 1.81 in the watershed system and 1.61 in the conventional system.

To determine the net contribution of agriculture to the economy, the value of chemical fertilizers, pesticides, fuels and other input services from outside the agriculture sector are to be deducted from the value of the agricultural output (APO, 1994). The results indicated that the value-addition was of Rs 21125/ ha in the watershed system, which was higher than in the conventional system, it being Rs 17212/ ha. If the indirect benefits of substituting local resources for external inputs were considered, the watershed system was economically superior to the conventional system, which depended heavily on these inputs.

Table 4. Input self-sufficiency in watershed and conventional systems

Particulars	Watershed system	Conventional system
Cost of all variable inputs (Rs/ha)	15913	16038
Cost of local inputs (Rs/ha)	8288	7500
Cost of external inputs (Rs/ha)	7625	8538
Input self-sufficiency ratio*	0.52	0.47

*Input self-sufficiency ratio= Cost of local inputs / Cost of all variable inputs

Social Acceptability

Input Self-sufficiency: The high dependency on external inputs, such as chemical fertilizers, pesticides, diesel and irrigation water increases farmers' vulnerability and reduces profit. The sustainable agriculture should seek to minimize dependency on external inputs (Altieri, 2000; Ikerd, 1993; Pretty, 1995). In the watershed system, there was a tendency to use more local inputs, such as labour draught power, seed, organic fertilizers and pesticides, which accounted for about 52 per cent of total variable costs on inputs. In the conventional system, the dependency on external inputs accounted for 53 per cent of the total costs on inputs (Table 4). The input self–sufficiency ratio was 0.52 in the watershed and 0.47 in the conventional system. Therefore, the watershed system was regarded as relatively more self-sufficient in terms of input dependency than the conventional system.

Equity: Any activity that creates employment opportunities will have a higher equity effect through the process of chain reactions across the rural economy. Thus, it was reasonable to consider labour requirements and labour cost per unit of output as indicators of the equity effect of any farming system. The labour requirement to produce one unit of paddy was found as 0.38 humandays in the watershed system and 0.36 humandays in the conventional system. The labour cost per unit of output was also higher (Rs 1.58) in the watershed than conventional (Rs 1.49) system.

Thus, the watershed system creates more employment opportunities than that by conventional system by either absorbing farmers' surplus labour or hiring of wage labourers. Moreover, watershed system uses relatively more local resources. This suggests that the watershed system may provide more equitable benefits to the local people.

Risks and Uncertainties: The over-dependency on monoculture of paddy makes the farmers vulnerable to the risk of severe economic difficulties. Crop diversification helps them to minimize risks arising from natural hazards. The relative income from different (Table 5) agricultural enterprises indicated that the watershed system was more diversified than the conventional system.

Table 5. Households' mean agricultural income

(Rs/ha)

Enterprises	Watershed system	Per cent contribution	Conventional system	Per cent contribution
Crop	17035	83.16	15625	84.03
Livestock	3450	16.64	2970	15.97
Total-income	20485	100.00	18595	100.00

The risk analysis revealed an index value of 0.64 for the watershed and 0.72 for the conventional system, implying that the conventional system was more vulnerable to the risk of economic losses.

Food Security: It has remained one of the most important concerns in the Karaikal region. The analysis has indicated that if the agricultural income was considered (Table 5), there was no significant variation in food security in two systems. Due to little diversification in the watershed system, the households were probably or comparatively consuming a more balanced diet.

Conclusions and Policy Implications

The study has indicated that the watershed system differs little from the conventional system, particularly in terms of cropping pattern, crop yields, equity, risk and uncertainties and food security. Paddy is cultivated in both the farming systems as the major crop. There is a significant variation in these agricultural systems in terms of use of chemical fertilizers and pesticides. Also, there is significant difference in crop yields and stability of yields and profitability benefits. These benefits are more in the watershed than conventional system due to high input self-sufficiency and dependability on available local resources. Besides, due to little diversification in the watershed system, the households are consuming a more balanced diet.

It has been found that there is a potential in promoting watershed system of farming for which, it is necessary to devise policies that will provide incentives to watershed farmers, both directly and indirectly. Other policy measures such as provision of effective extension service and credit facilities are also conducive to promoting watershed farming, provided they are implemented effectively. Until effective biological measures of soil fertilization are introduced, policies could be adopted to promote the application of biological and chemical fertilizers in a balanced way, so as to maintain soil structure and sustain or increase crop yields.

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