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Countering vulnerability and enhancing resilience: coastal agriculture in West Bengal, India

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Abstract We analyse the economics of 14 farming systems in the Sundarban region of West Bengal, India. Most of the farmers in our sample (84.53%) were smallholders who practised a cereals-based farming system limited to monocropping kharif paddy (18.89%). We suggest two farm plans that require farmers to reallocate their resources to vegetable farming, fishery, poultry farming, and rearing dairy animals. One plan, at the existing level of resources, can increase net income by more than 25% over the existing plan. The other plan, at an enhanced level of resources, could increase net income by more than 45%.

Keywords Coastal agriculture, farming systems, linear programming, normative farm plan, soil salinity

JEL Codes O13, Q12, C61

The average farm size in India has declined to 1.15 hectare (ha), and of the 138.35 million operational holdings around 92.83 million are smaller than 1.0 ha—challenging the sustainability and profitability of farming (Agriculture Census Division 2014). Small and marginal farmers constitute more than 80% of the farming community, but they cultivate only 32.5% of the total operational area. Specializing farming may not be viable or sustainable in the long run (Mahapatra and Bapat 1992), therefore, and it is imperative to develop strategies and agricultural technologies that facilitate the generation of adequate employment and income (Behera and Sharma 2007).

West Bengal has 3% of the country's cultivable land and it produces more than 8% of its food. More than 55% of the state's population depends on agriculture, directly and indirectly, for their livelihood. Agriculture contributed more than 18% of the net state domestic product in 2010–11. In the agriculture sector of West Bengal, too, smallholders predominate; more than 90% of the farmers operate 68% of the cultivated area; the average landholding has dwindled to 0.77 ha; the productivity growth of major crops has stagnated; and farming is no longer profitable, especially in monocropped areas. Thus, farm diversification, and enhancing the income from existing resources, has become imperative (Singh 1994; Jayanthi et al. 1994).

Agriculture in the coastal Sundarban region is complex, diverse, and prone to numerous biotic and abiotic stresses, shocks, and disturbances. The cropping pattern is predominantly monocropped. Crop production in the kharif season (rainy season, July to November) is vulnerable to frequent cyclonic storms, heavy and intensive rain, and floods, resulting in periodic inundation by high tides; because the surface and subsurface drainage is poor, the fields are waterlogged. Traditional rice, planted in almost 98% of the area, underperforms in the kharif season.

In the coastal districts, the net sown area makes up nearly 73% of the land in East Medinipur, 67% in North 24 Parganas, and 39% of South 24 Parganas. And the cultivable land is fragmented—more than 85% of the

operational holdings are marginal (<1 ha) and nearly 10% of the holdings are small (1–2 ha). Most of the cultivable land (80–90%) lies fallow after the kharif season, due primarily to the high soil and water salinity, lack of good quality irrigation water, improper drainage, and congestion.

The overall productivity of rice is 2.2–2.6 tonnes/ha. Paddy is grown in three seasons: boro (summer, rabi, December to April), aman (winter), and aus (autumn). Productivity is higher in boro (3 tonnes/ha) than in aman (2 tonnes/ha) or aus (2.2–2.6 tonnes/ha). Most of the rice is grown as aman (80% in South 24 Parganas and 62% in East Medinipur and North 24 Parganas). Fresh water is scarce in the rabi season (after the rains), and the salinity of the soil is higher; therefore, the scope for cultivating rice is severely restricted.

Adopting suitable soil–water–crop management practices under the present rice monoculture in coastal areas can facilitate crop diversification towards high-value fruits and vegetable crops (Mandal et al. 2011). In determining the relevance, practicability, and potential success of any innovation, however, it is crucial to understand the production process and decision behaviour in traditional agriculture (Anandajayasekeram 1985). Few studies have been conducted on optimizing net farm income in rice-based monocropped farming systems in the coastal regions of India. This study analyses the farming system in the Sundarban and the farmer income levels, and it attempts to identify a farming system that optimizes farm income based on the present resource base.

Methodology

Most of the salinity-affected cultivable land in West Bengal (around 86%) lies in the South 24 Parganas district. Thus, this district is purposively chosen for the study.

Data

The data for this study was obtained from a survey conducted in 2013–2014 as part of the doctoral dissertation of the first author. The Sundarban region of West Bengal, India was selected as the study area. The primary data was collected from farmers using the personal interview method and a pre-tested structured schedule. The region is agrarian, based on traditional farming methods on problematic degraded coastal soil.

Information was collected on the socio-economic conditions of the sample farmers, such as age, education, family size, number of dependants, cropping pattern, size of operational holdings, and the existing farming system. Information was collected also on the cost of cultivation, inputs used, crop yield, price of output, expenses, income from different enterprises, and non-farm sources of income.

Sampling technique

We used a multi-stage sampling technique, the simple random sampling without replacement technique, to select the study area and sample respondents.

South 24 Parganas district has 29 development blocks. In the first stage, we chose 2 development blocks where various types of farming systems are practised, along with other enterprises, to the largest extent. In the second stage, we randomly selected 3 villages from each block, totalling 6 villages. In the third stage, we randomly selected 30 farmers from each village. Thus, we formed a sample of 180 farmers.

Analytical tools and techniques

This study is concerned primarily with identifying farming systems, not cropping systems. We combined the compatible crops to form a group. Then, we estimated the costs and returns structure of all the production activities of the sample respondents and computed the net earnings of each group/enterprise. And we considered only those enterprises that contributed at least 10% of the concerned farmer's total agricultural income.

Linear programming formulation

To work out the maximum returns attainable by optimally allocating the resources available, we employed the deterministic linear programming technique—a linear function of variables to be maximized subject to constraints in the form of linear equalities and inequalities.

We can express the one-year (two seasons) linear programming model in mathematical form:

Objective function

$$\text{Maximize } Z = \sum_{j=1}^{n} C_j X_j$$

Subject to the constraints,

$$1.\ \sum_{j=1}^{n} a_{ij}X_j \geq b_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (j = 1 \text{ to } k)$$

$$2.\ X_j \geq 0$$

where,

Z = net returns from all crop and allied activities included in the model,

C_j = net returns from j^{th} activity measured in rupees per acre of land,

X_j= level of j^{th} activity in acre (for crop/horticulture activity) and in unit (for allied activities),

a_{ij} = the quantity of i^{th} input required per unit of j^{th} activity, and

b_i = total quantity available of the i^{th} resource.

Activities used in the model

We classify the activities (Xjs) used in the model as real, disposal, and fixed activities.

The real activities, also known as production activities, constitute the principal alternatives of the farming system. We consider the individual crop–livestock rotation in a particular zone an activity. In each block, farmers in groups of different sizes follow rotations of crops, livestock, poultry, goats, and pigs; each rotation constitutes an activity in the model.

We derived the disposal activities to convert the inequalities in the model into equalities to solve the problem. In the WinQSB programming model, the computer automatically generated these activities.

Resource levels and constraints

One of the most important components of the linear programming model was the identification of resource constraints on the farms in each farming system. Farms experienced constraints on several types of resource (bj): land, labour, and capital.

Land constraint The farmer's operational holding is taken as the maximum area cultivable.

Labour constraint The number of man-days employed on a farm in each production season is used to estimate the availability of both hired and owned human labour. Women's labour is converted into the equivalent of men's labour by multiplying with 0.8; this conversion factor is based on the ratio of women's wages to men's wages. In Optimum Model-I (M-I), we impose the restrictions on human and machine labour in all the phases of production, and we relax these restrictions in the alternative, Optimum Model-II (M-II).

Capital constraint Farmers require capital to meet the day-to-day farm expenses and to purchase seeds, fertilizers, manure, pesticides, concentrates, and animal fodder, but they may not have enough. And the constraints around the availability of cash, credit supply, and debt management may limit the scope for the adoption of improved production practices.

The constraint on the availability of capital in a specific phase of production is set at the cost incurred on variable items for a particular activity depending upon the returns from previous crops. Model-II considers restrictions on land, labour, and capital; the capital constraint is relaxed.

Land restrictions

b_1 = kharif land (acre)

b_2 = rabi land (acre)

b_3 = minimum area under kharif paddy (acre)

The agroecological conditions of the study area do not favour the cultivation of any crop other than kharif paddy. Productivity is low, and cultivation uneconomical, but farmers in this region grow kharif paddy over a large area. Paddy is the staple food of the region; it dominates all the cereal crops grown.

The model imposes a minimum area restriction.

Labour restrictions

b_4 = labour availability during kharif (man-days)

b_5 = labour availability during rabi (man-days)

Capital restrictions

b_6 = capital available (INR)

These restrictions are common for all systems in both blocks. Some restrictions differ by region and system (Table 1).

The information related to input-output of farm production activities is important for constructing the

Table 1 Restrictions that differ by region and system

FS-I	Minimum restriction	b_7: kharif paddy area (0.83 acre)
	Maximum restrictions	b_8: boro paddy area (0.80 acre)
		b_9: vegetables area (0.80 acre)
FS-II	Minimum restriction	b_{10}: kharif paddy area (0.75 acre)
	Maximum restrictions	b_{11}: boro paddy area (1.00 acre)
		b_{12}: fish area (1.00 acre)
FS-III	Minimum restriction	b_{13}: kharif paddy area (0.67 acre)
	Maximum restrictions	b_{14}: boro paddy area (0.85 acre)
		b_{15}: fish area (0.85 acre)
FS-IV	Minimum restriction	b_{16}: kharif paddy area (0.75 acre)
	Maximum restrictions	b_{17}: boro paddy area (1.00 acre)
		b_{18}: vegetable area (1.00 acre)
FS-V	Minimum restriction	b_{19}: kharif paddy area (0.83 acre)
	Maximum restrictions	b_{20}: boro paddy area (1.10 acre)
		b_{21}: vegetable area (1.10 acre)
		b_{22}: fish area (1.10 acre)
FS-VI	Minimum Restriction	b_{23}: Kharif paddy area (2.00 acre)
	Maximum Restrictions	b_{24}: Boro paddy area (1.75 acre)
		b_{25}: Maize area (1.75 acre)
		b_{26}: Vegetable area (1.75 acre)
		b_{27}: Fish area (1.75 acre)
FS-VII	Minimum Restriction	b_{28}: Fish area (0.10 acre)
	Maximum restriction	b_{29}: vegetable area (0.25 acre)
FS-VIII	Minimum restriction	b_{30}: kharif paddy area (0.33 acre)
FS-IX	Minimum restriction	b_{34}: kharif paddy area (1.00 acre)
	Maximum restriction	b_{35}: boro paddy area (1.5 acre)
FS-X	Minimum restriction	b_{36}: kharif paddy area (1.00 acre)
	Maximum restriction	b_{37}: boro paddy area (1.00 acre)
FS-XI	Minimum restriction	b_{38}: kharif paddy area (1.67 acre)
	Maximum restriction	b_{39}: boro paddy area (0.33 acre)
FS-XII	Minimum restriction	b_{40}: kharif paddy area (1.33 acre)
	Maximum restriction	b_{41}: boro paddy area (1.33 acre)
		b_{42}: fish area (1.33 acre)
FS-XIII	Minimum restriction	b_{43}: kharif paddy area (1.00 acre)
	Maximum restriction	b_{44}: boro paddy area (0.67 acre)
FS-XIV	Minimum restriction	b_{47}: kharif paddy area (1.67 acre)
	Maximum restrictions	b_{48}: boro paddy area (1.83 acre)
		b_{49}: fish area (1.83 acre)

technological matrix for the linear programming model. The input coefficients are land, labour, and capital. Land is classified into kharif and rabi land. Labour includes both family labour and hired labour.

Capital refers to funds required to meet the cost of seeds, fertilizers, farm yard manure, plant protection chemicals, irrigation charges, dry fodder, green folder, concentrates, veterinary expenses, insurance charges, marketing expenses, and wages of hired human, bullock, and machinery labour.

The input-output prices are the average prices paid and received by the sample farmers. The input-output

coefficients in the model are calculated per acre in the case of crops; per animal in the case of dairy, pigs, and goats; or per thousand birds in the case of poultry.

Optimum Plans

We employed the linear programming technique to develop optimum farming systems under different situations; to accomplish the study objectives, we developed alternative plans by incorporating a few variations in the basic models.

Existing plan The models in the existing plan describe the existing crop alternatives and cultivation practices and the resources available to the farmers.

Model-I We use the linear programming technique to reallocate the resources in the existing plan; otherwise, these models are similar to the existing plan.

Model-II The restrictions on capital, and on the availability of labour, are relaxed; otherwise, these models are similar to M-I. These models are designed to assess how optimum farm plans maximize net farm income by examining the effect of increasing the availability of capital and labour.

Model-II was worked out by relaxing capital and labour at 25%, 50%, 75%, and 100% level. We observed the increase in net farm income. The difference between M-II at 50%, and at 75% or 100%, is little; and so we chose M-II at 50%.

Each of these models is designed for all the major farming systems; thus, 75 models are simulated for 15 major farming system, and 30 models are presented in the study.

We use M-I to find the optimum farming system at the existing level of resources and M-II to find the optimum farming system at the enhanced level of resources.

Results and discussion

We categorized the farmers of the study area using the classification of Reddy et al. (2004).

Categorizing farmers

We categorized the respondents by their operational holding into marginal farmers (those with landholdings ≤1.25 acres), small farmers (1.25–2.5 acres), and semi-medium farmers (≥2.50 acres) (Table 2). Marginal farmers made up most of the sample (43.89%); small farmers 40.55%; and semi-medium farmers 15.56%.

Table 2 Sample farmers by landholding size

Type of farmers	Size of land holdings	Number of farmers
Marginal farmers	≤ 1.25 acre	79 (43.89)
Small farmers	1.25 to 2.5 acres	73 (40.55)
Semi-medium farmers	2.5 acres to 5.0 acres	28 (15.56)
Total		180 (100.00)

Note Figures in parentheses indicate percentage to total

Identifying the major farming systems

The enterprise combination of the sample respondents depends on a host of micro- and macro-level factors: type of land, location, topography, soil fertility status, access to irrigation facility, availability of family and hired labour, preferences of the farm families, finance, other resources availability within and outside the farm, and the relative prices of farm inputs and outputs.

The study is concerned primarily with farming systems, not cropping systems. Therefore, we grouped the compatible crops; for example, kharif paddy and boro paddy form the cereals group, and tomato, ridge gourd, bitter gourd, chilli, cabbage, cauliflower, etc. form the vegetables group.

The farmers had a wide range of cropping systems and enterprise combinations; it was difficult to include every crop and present the existing farming system. Therefore, we worked out the costs and returns structure of the respondents' production activities. We computed the net earnings of each group/enterprise and retained only those enterprises that contributed at least 10% of the total agricultural income.

Due to soil salinity and other agroecological conditions, coastal agriculture is mostly monocropped, but farmers supplement their farm income with an allied enterprise.

The sample farmers follow a diversified and mixed farming system and three types of farming practice: a mixed farming system, or an allied enterprise, along with a crop production unit (72.22%); a specialized farming system (18.89%); or a diversified farming system (8.89%), with two types of crop enterprise, such as cereals and vegetables, in combination (Table 3).

Table 3 Existing farming systems by farmer category

(farmers in number, net returns in INR per acre)

Farming type	Marginal farmers	Small farmers	Semi-medium farmers	Overall	Net returns
Specialized	7	17	10	34	8,612.25
	(30.43)	(34.00)	(58.82)	(18.89)	
Diversified	9	7	0	16	15,550.58
	(0.00)	(0.00)	(0.00)	(8.89)	
Mixed	63	49	18	130	27,295.38
	(69.57)	(66.00)	(41.18)	(72.22)	
Total	79	73	28	180.00	24,739.29
	(43.89)	(40.55)	(15.56)	(100.00)	

Note Figures in parentheses indicate percentage to total

Table 4 Existing farming systems by farmer category

Sl. No.	Farming systems	Code	Marginal farmers	Small farmers	Semi-medium farmers	Total Farmers	Percentage
1.	C+V	FS-I	9	7	0	16	8.89
2.	C+F	FS-II	13	5	7	25	13.89
3.	C+F+Po	FS-III	3	2	0	5	2.78
4.	C+V+D	FS-IV	4	2	0	6	3.33
5.	C+V+F	FS-V	9	4	2	15	8.33
6.	C+V+D+F	FS-VI	2	3	4	9	5.00
7.	V+F	FS-VII	14	0	0	14	7.78
8.	C+V+S+D	FS-VIII	4	3	0	7	3.89
9.	C	FS-IX	7	17	10	34	18.89
10.	C+D	FS-X	9	10	4	23	12.78
11.	C+G	FS-XI	2	5	0	7	3.89
12.	C+D+F	FS-XII	1	9	1	11	6.11
13.	C+D+G	FS-XII	1	3	0	4	2.22
14.	C+D+F+P	FS-XIV	1	3	0	4	2.22
		Total	79	73	28	180	100.00

Note C=Cereals, D=Dairy, F=Fish, V=Vegetables, S=Sugarcane, Po=Poultry

Almost all the farmers cultivate kharif paddy. In the rabi season, however, the soil salinity increases, and most of the land lies fallow—except the upland, where vegetables are cultivated. We estimated that the sample farmers averaged a net return of INR 24,739.29 per acre. The farmers who adopted mixed farming systems earned INR 27,295.38 per acre; those who practised diversified farming INR 15,550.58 per acre; and specialized farmers INR 8,612.25/acre.

Documenting the major farming systems

We identified and documented 14 major farming systems in the study area (Table 4). Most sample farmers (18.89%) practise a cereal-based farming system limited to monocropping of kharif paddy; 13.89% farm cereals and fish; and 12.78% farm cereals and dairy.

Costs and returns structure of the farming systems

The sample farmers practise various farming systems

(FS); Table 5 compares the economics of the systems. The net income is largest in FS-III (INR 67,247.26); FS-VII generates INR 35,307.35, and FS-VIII generates INR 26,924.94. Including a poultry unit is most remunerative, followed by vegetable enterprise and sugarcane production. But FS-VII uses the most resources. Rice ensures the food security of the farming community, and the farmers grow paddy in the kharif season because the lowland is inundated in the other seasons.

Including a piggery enterprise, along with the traditional enterprises, increased the net income in FS-XIV significantly; the sample farmers earned an additional net return of INR 21,015.66 per acre. All the identified farming systems were typical and had their own merits. All the 14 farming systems generated higher returns over costs, but the return-to-cost ratio was most remunerative in FS-VII (2.78), FS-III (2.55), FS-X (2.39), FS-VIII (2.38), and FS-XIII (2.04).

Table 5 Average costs and returns structure of farming systems

(Rs./acre)

Particulars	FS-I	FS-II	FS-III	FS-IV	FS-V	FS-VI	FS-VII	FS-VIII	FS-IX	FS-X	FS-XI	FS-XII	FS-XIII	FS-XIV
Costs														
Total variable costs	11,622.1	8,912.47	20,775.23	11,339.83	10,904.11	10,273.72	16,159.25	15,822.14	8,625.72	6,144.02	8,788.75	8,359.90	8,604.24	31,095.90
Total fixed costs	2,220.66	1939.94	22,473.45	2,996.1	2,623.37	3,934.63	3,714.5	3,721.84	954.78	2,597.86	1,244.65	1,868.41	3,248.09	6,435.07
Total costs	13,842.75	10,852.41	43,248.68	14,335.93	13,527.48	14,208.35	19,873.75	19,479.22	9,580.50	8,741.88	10,033.40	10,228.32	11,852.33	37,564.60
Returns														
Gross returns	28,440.25	19,133.25	110,495.9	23,798.96	22,797.24	22,382.19	55,181.1	46,404.16	17,774.87	20,895.60	17,150.05	19,796.19	24,150.00	58,546.74
Net returns	14,597.49	8,280.84	67,247.26	9,463.03	9,269.76	8,173.84	35,307.35	26,924.94	8,164.37	12,153.72	7,116.65	9,567.88	12,297.68	21,015.66
Return-to-cost ratio	2.13	1.76	2.55	1.66	1.69	1.58	2.78	2.38	1.85	2.39	1.71	1.94	2.04	1.56

Optimizing the identified farming systems and formulating an alternative farm plan

The sample farmers practise a variety of farming systems. We develop the optimum plans at the existing level of resources (M-I) and at the enhanced level of resources (M-II) for all the farming systems to explore whether reorganizing farm resources in the study area would increase income.

Optimum farm plans for FS-I and FS-II

Table 6 presents the normative farm plans for FS-I and FS-II. Plan M-I suggests that in FS-I, farmers should stop cultivating boro paddy and raise the area they grow vegetables on from 0.35 acre (21.14%) to 0.67 acre (40.12%). Reducing the area under kharif paddy from the current 1.07 acre (64.08%) to 1.00 acre (59.88%) in M-I will augment net returns by 54.23%. Altering the area under kharif paddy to 0.89 acre (53.29%) and vegetables to 0.78 acre (46.71%) in M-II would raise income by 3.11% over M-I.

In M-I, reducing the area under boro paddy in FS-II from 0.94 acre to 0.45 acre, and increasing the area under kharif paddy (from 0.81 acre to 1.16 acre) and fisheries (from 0.19 acre to 0.33 acre), would increase the net return by 39.37%—from INR 14,226.04 per acre to INR 19,827.00 per acre.

In Optimum Plan M-II, the area under boro paddy was reallocated to fish farming; the net return increased by

Table 6 Optimum farm plans for FS-I and FS-II

Particulars	FS-I (C+V)						FS-II (C+F)					
	Existing system		M-I		M-II		Existing system		M-I		M-II	
	Area/No.	Percent	Area/No.	Percent	Area/No.	Percent	Area/No.	Percent	Area/No.	Percent	Area/No.	Percent
Kharif paddy	1.07	64.08	1.00	59.88	0.89	59.88	0.81	41.75	1.16	59.79	1.57	80.93
Boro paddy	0.45	14.79					0.94	48.45	0.45	23.19		
Vegetables	0.35	21.14	0.67	40.12	0.78	40.12						
Fish							0.19	9.80	0.33	17.02	0.37	19.07
Gross cropped area	1.67	100.00	1.67	100.00	1.67	100.00	1.94	100.00	1.94	100.00	1.94	100.00
Net return (Rs.)	14,613.59		22,538.87		23,239.33		14,226.04		19,827.00		20,523.41	
Net income over existing (%)				54.23		59.02				39.37		44.27
Net income over M-I (%)						3.11						3.51

Area in acre, Dairy = No. of animal, Poultry = No. of unit (1,000 birds). C=Cereals, D=Dairy, F=Fish, V=Vegetables, S=Sugarcane, Po=Poultry.

3.51% over M-I and 44.27% over the existing farming system.

Optimum farm plans for FS-III and FS-IV

Table 7 presents the alternative farm plans that would increase the profitability of FS-III and FS-IV.

In M-I, increasing the kharif paddy and fish area, and decreasing the area under boro paddy, could increase the net returns by 7.25% over the existing farming system. This incremental income is directly dependent on increasing the number of poultry units (1,000 birds) from 2.33 to 2.67.

In M-II, farmers would increase their net income by 14.56% over the existing income if they increased the number of poultry units to 3.00, decreased the kharif paddy area from 1.00 acre to 0.89 acre, and increased the area under boro paddy to 1.5 acre.

In M-I, farmers practising FS-IV did not cultivate boro paddy; they increased the area under kharif paddy from 0.77 acre to 1.09 acre (61.93%) and under vegetables from 0.33 acre to 0.67 acre (38.07%). Raising the number of cows—from 3.67 to 4.33—would generate an additional net return of INR 2,214.77 (13.90%) over the existing system.

In M-II, decreasing the kharif paddy area, and increasing the area under vegetables, yielded 3.14% more profit over M-I.

Optimum farm plans for FS-V and FS-VI

In M-I, the area under boro paddy in FS-V was decreased from 0.76 acre (33.93%) to 0.32 acre (14.29%); it was eliminated in M-II. The area under kharif paddy was decreased in M-I but increased to 1.17 acre in M-II. The area under vegetable crops was increased from 0.26 acre in the existing model to 0.67 acre in M-I and to 0.74 acre in M-II. In M-I, the area under fish was increased by 14.73% over existing plan; it was not changed in M-II. The net income, INR 21,097.84 in the existing plan, increased 46.82% to INR 30,976.30 in M-I and 51.14% to INR 31,887.09 in M-II; the increase in M-II over M-I was about 3.00% (Table 8). The vast increase was due mainly to the increase in the area under vegetable crops.

Plan M-I suggests that the area under boro paddy in FS-VI, 1.12 acre, be reduced to 0.65 acre. However, the area under kharif paddy was increased from 2.09

Table 7 Optimum farm plans for FS-III and FS-IV

Particulars	FS-III (C+F+Po)						FS-IV (C+V+D)					
	Existing system		M-I		M-II		Existing system		M-I		M-II	
	Area/No.	Percent	Area/No.	Percent	Area/No.	Percent	Area/No.	Percent	Area/No.	Percent	Area/No.	Percent
Kharif paddy	0.75	43.60	1.00	58.14	0.89	51.74	0.77	43.75	1.09	61.93	0.93	52.84
Boro paddy	0.67	38.95	0.39	22.67	0.50	29.07	0.66	38.07				
Vegetables							0.33	18.18	0.67	38.07	0.83	47.16
Fish	0.30	17.45	0.33	19.19	0.33	19.19						
Gross cropped area	1.72	100.00	1.72	100.00	1.72	100.00	1.76	100.00	1.76	100.00	1.76	100.00
Dairy							3.67		4.33		4.33	
Poultry	2.33		2.67		3.00							
Net return (Rs.)	37,141.32		39,895.50		42,549.66		15,933.21		18,147.98		18,824.12	
Net income over existing (%)				7.25		14.56				13.90		18.14
Net income over M-I (%)						6.65						3.72

Area = acre, Dairy = No. of animal, Poultry = No. of unit (1,000 birds). C=Cereals, D=Dairy, F=Fish, V=Vegetables, S=Sugarcane, Po=Poultry.

Table 8 Optimum farm plans for FS-V and FS-VI

Particulars	FS-V (C+V+F)						FS-VI (C+V+D+F)					
	Existing system		M-I		M-II		Existing system		M-I		M-II	
	Area/No.	Percent	Area/No.	Percent	Area/No.	Percent	Area/No.	Percent	Area/No.	Percent	Area/No.	Percent
Kharif paddy	1.03	45.98	0.92	41.07	1.17	52.23	2.09	53.45	2.21	56.52	2.24	57.29
Boro paddy	0.76	33.93	0.32	14.29			1.12	28.63	0.65	16.63	0.71	18.16
Maize							0.16	4.08	0.33	8.44		
Vegetables	0.26	11.61	0.67	29.91	0.74	33.04	0.36	9.21	0.47	12.02	0.63	16.11
Fish	0.19	8.48	0.33	14.73	0.33	14.73	0.17	4.63	0.25	6.39	0.33	8.44
Gross cropped area	2.24	100.00	2.24	100.00	2.24	100.00	3.91	100.00	3.91	100.00	3.91	100.00
Dairy							3.83		4.71		5.17	
Net return (INR)	21,097.84		30,976.30		31,887.09		39,454.64		49,704.82		57,245.03	
Net income over existing (%)				46.82		51.14				25.98		45.09
Net income over M-I (%)						2.94						15.17

Area = acre, Dairy = No. of animal, Poultry = No. of unit (1,000 birds). C=Cereals, D=Dairy, F=Fish, V=Vegetables, S=Sugarcane, Po=Poultry.

acre in the existing plan to 2.21 acre (56.62%) in M-I and to 2.24 acre (57.29%) in M-II. An increase was proposed in the area under vegetables and fish and in the number of dairy units in M-I over the existing model. The increase in net income over the existing model was 25.98% in M-I and 45.09% in M-II.

Optimum farm plans for FS-VII and FS-VIII

The area under vegetables in FS-VII decreased from 0.29 acre (80.55%) in the existing model to 0.19 acre (52.78%) in M-I and to 0.13 acre (36.11%) in M-II. The area under fish production was reduced from 0.07 acre (19.4%) in the existing model to 0.17 acre (47.22%) in M-I and to 0.23 acre (63.29%) in M-II. The net income of the existing model in FS-VII grew 44.63% in M-I and 71.55% in M-II (Table 9).

The area under boro paddy in FS-VIII was reduced from 42 acre (30.66%) in the existing plan to 0.17 acre (11.68%) in M-I; it was eliminated in M-II. The area under kharif paddy, vegetables, and sugarcane, and the number of cattle, increased in M-I and M-II over the existing model. The variation in income was due mainly to the alteration in the area allocated to sugarcane and vegetables. The net income increased from INR 37,662.77 in the existing model to INR 44,818.62 (19.00%) in M-I and to INR 48,321.41 (28.30%) in M-II.

Optimum farm plans for FS-IX and FS-X

The alternative farm plans for FS-IX and FS-X revealed that the main feature of FS-I was that paddy was grown in both seasons (Table 9). The sample farmers earned a higher profit by cultivating boro paddy instead of kharif paddy. Thus, a decrease in area allocated for kharif paddy (1.92 acre) to 1.50 acre in M-I and 1.25 acre in M-II with a simultaneous increase in boro paddy area from 0.69 acre (26.44%) in the existing system to 1.11 acre (42.53%) in M-I and 1.36 acre (52.11%) in M-II would ensure higher net returns amounting INR 22,106.41 and INR 22,582.78 respectively over the existing net return of INR 21,274.71 (Table 10).

The designed normative farm plans, M-I, and M-II for farming system-X, were the same as that of system-IX. To achieve that result, the area of boro paddy needed to be increased from 0.5 acre (24.39%) in existing system to 0.83 acre (40.49%) in M-I and to 0.96 acre (46.83%) in M-II. The number of dairy

Table 9 Optimum farm plans for FS-VII and FS-VIII

Particulars	FS-VII (V+F)						FS-VIII (C+V+S+D)					
	Existing system		M-I		M-II		Existing system		M-I		M-II	
	Area/No.	Percent	Area/No.	Percent	Area/No.	Percent	Area/No.	Percent	Area/No.	Percent	Area/No.	Percent
Kharif paddy							0.44	32.12	0.55	40.14	0.63	45.98
Boro paddy							0.42	30.66	0.16	11.68		
Sugarcane							0.24	17.52	0.33	24.09	0.37	27.01
Vegetables	0.29	80.55	0.19	52.78	0.13	36.11	0.27	19.70	0.33	24.09	0.37	27.01
Fish	0.07	19.45	0.17	47.22	0.23	63.89						
Gross cropped area	0.36	100.00	0.36	100.00	0.36	100.00	1.37	100.00	1.37	100.00	1.37	100.00
Dairy							4.5		4.91		5.33	
Net return (Rs.)	16,088.85		23,269.65		27,601.12		37,662.77		44,818.62		48,321.41	
Net income over existing (%)				44.63		71.55				19.00		28.30
Net income over M-I (%)						18.61						7.81

Area = acre, Dairy = No. of animal, Poultry = No. of unit (1,000 birds). C=Cereals, D=Dairy, F=Fish, V=Vegetables, S=Sugarcane, Po=Poultry.

Table 10 Optimum farm plans for FS-IX and FS-X

Particulars	FS-IX (C)						FS-X (C+D)					
	Existing system		M-I		M-II		Existing system		M-I		M-II	
	Area/No.	Percent	Area/No.	Percent	Area/No.	Percent	Area/No.	Percent	Area/No.	Percent	Area/No.	Percent
Kharif paddy	1.92	73.56	1.50	57.47	1.25	47.89	1.55	75.61	1.22	59.51	1.09	53.17
Boro paddy	0.69	26.44	1.11	42.53	1.36	52.11	0.50	24.39	0.83	40.49	0.96	46.83
Gross cropped area	2.61	100.00	2.61	100.00	2.61	100.00	2.05	100.00	2.05	100.00	2.05	100.00
Dairy							3.69		4.23		4.59	
Net return (Rs.)	21,274.71		22,106.41		22,582.78		24,367.22		26,844.42		27,972.58	
Net income over existing (%)				3.91		6.15				10.17		14.80
Net income over M-I (%)						2.15						4.20

Area = acre, Dairy = No. of animal, Goat = No. of animal, Pig = No. of animal. C=Cereals, D=Dairy, F=Fish, G=Goat, P=Pig.

animals should also be increased from 3.69 units to 4.23 units in M-I and 4.59 units in M-II. This manipulation of operational area will give 10.17% additional net return in M-I and 14.80% of net returns in M-II over present net income of INR 24,367.22.

Optimum farm plans for FS-XI and FS-XII

The region is monocropped, and cultivated with kharif paddy; and the alternative farm plans for FS-XI depicted that change in the area under kharif paddy was not possible as the. So, the only option remained was to increase in the number of dairy animals keeping in view the constraints to increase the profitability. Thus the increase in number of dairy unit from 3.60 to 6.79 in M-I and 7.49 in M-II would likely to increase the profitability by 18.83% in M-I and 22.96% in M-II over the existing net returns of INR 13,177 per farm (Table 11).

If the farmers had sufficient fund to grow boro paddy, then the returns can be increased as in alternative plans of M-I and M-II for FS-XI. An increase in the area under boro paddy from 0.55 acre to 0.83 acre, fishery from 0.15 to 0.33 acre and number of cattles from 3.38 to 5.16 units coupled with a deceleration in the area under kharif paddy from 2.08 acre to 1. 62 acre in M-I would increase the net returns from INR 28,110.39 to INR 37,600.11 (33.76%). Further increase in area of boro paddy to 0.95 acre, number of cows to 6.37 units with a decline of kharif paddy area to 1.5 acre would increase the net returns by 40.79% over the existing model.

Optimum farm plans for FS-XIII and FS-XIV

The M-I and M-II plans suggest that boro paddy not be cultivated in FS-XIII and kharif paddy be cultivated in that area instead, and the number of livestock be increased (Table 12).

In M-I, increasing the number of dairy units from 2.33 to 3.47, and the number of goats from 4.33 units to 6.11 units, would increase the net returns by 27.28%.

In M-II, keeping the area under kharif paddy constant, and increasing the number of cows to 4.67 units and the number of goats to 7.39 units, would increase the net income by 10.67% over M-I.

In M-I, the net return increased 29.84% by reducing the area under boro paddy from 1.45 acre to 1.31 acre,

Table 11 Optimum farm plans for FS-XI and FS-XII

Particulars	FS-XI (C+G)						FS-XII (C+D+F)					
	Existing system		M-I		M-II		Existing system		M-I		M-II	
	Area/No.	Percent	Area/No.	Percent	Area/No.	Percent	Area/No.	Percent	Area/No.	Percent	Area/No.	Percent
Kharif paddy	1.87	100.00	1.87	100.00	1.87	100.00	2.08	74.82	1.62	58.27	1.50	53.96
Boro paddy							0.55	19.78	0.83	29.86	0.95	34.17
Fish							0.15	5.40	0.33	11.87	0.33	11.87
Gross cropped area	1.87	100.00	1.87	100.00	1.87	100.00	2.78	100.00	2.78	100.00	2.78	100.00
Dairy							3.38		5.16		6.37	
Goat	3.60		6.79		7.49							
Net return (Rs.)	13,177.01		15,658.13		16,202.57		28,110.39		37,600.11		39,576.62	
Net income over existing (%)				18.83		22.96				33.76		40.79
Net income over M-I (%)						3.48						5.26

Area = acre, Dairy = No. of animal, Goat = No. of animal, Pig = No. of animal. C=Cereals, D=Dairy, F=Fish, G=Goat, P=Pig.

Table 12 Optimum farm plans for FS-XIII and FS-XIV

Particulars	FS-XIII (C+D+G)						FS-XIV (C+D+F+P)					
	Existing system		M-I		M-II		Existing system		M-I		M-II	
	Area/No.	Percent	Area/No.	Percent	Area/No.	Percent	Area/No.	Percent	Area/No.	Percent	Area/No.	Percent
Kharif paddy	1.00	59.88	1.67	100.00	1.67	100.00	2.13	54.76	2.13	68.64	2.00	72.75
Boro paddy	0.67	40.12					1.45	37.28	1.31	19.79	1.00	15.68
Fish							0.31	7.96	0.45	11.57	0.45	11.57
Gross cropped area	1.67	100.00	1.67	100.00	1.67	100.00	3.89	100.00	3.89	100.00	3.45	100.00
Dairy	2.33		3.47		4.67		4.67		5.17		6.24	
Goat	4.33		6.11		7.39							
Piggery							11.00		17.67		19.33	
Net return (INR)	21,323.60		27,139.62		30,035.45		74,487.70		96,712.74		101,073.50	
Net income over existing (%)				27.28		40.86				29.84		35.69
Net income over M-I (%)						10.67						4.51

Area = acre, Dairy = No. of animal, Goat = No. of animal, Pig = No. of animal. C=Cereals, D=Dairy, F=Fish, G=Goat, P=Pig

keeping the area under kharif paddy constant, raising the area under fishery from 0.31 acre to 0.4 acre, and increasing the number of cows from 4.67 units to 5.17 units and the number of pigs from 11.00 units to 17.67 units.

In M-II, reducing the area under kharif paddy to 2.00 acre and the area under boro paddy to 1.00 acre, and simultaneously increasing the number of cows to 6.24 units and pigs to 19.33 units, would have raised the net returns to INR 101,073.50 per acre—35.69% higher than the existing system and 4.51% higher than M-I.

[Table 12 here]

Conclusion

The enterprise of kharif paddy predominates the farming systems in the study area; the agroecological conditions, and the imperative of family food security, leave farmers no option. Boro paddy generates higher gross returns, but it is more capital-intensive and resource-exhaustive.

In most farming systems, reallocating resources and rearranging enterprises offer scope for enhancing income. Most alternative farm plans to boost agricultural income suggest that farmers reallocate their existing resource base fully or partly to dairy, fishery, poultry, allied enterprises or alternative enterprises like vegetable farming, sugarcane plantation, poultry farming, and rearing of dairy animals.

Adopting the Optimum Model-I, at the current level of resources, can increase net income by more than 25%. Adopting the Optimum Model-II, at an enhanced level of resources, and rearranging the enterprise would increase net income by more than 45% over the existing plan; extending farmers easy credit and finance will help them improve their net income by another 20% over the Optimum Model-I.

Diversifying enterprises and, especially, including livestock and other allied activities helps to increase farm income and generates employment within or outside the farming sector. Training extension agencies in various enterprises will help them suggest to farmers an enterprise mix that would minimize their risk. Promoting land-based production technology like land shaping technology, and distributing quality seeds, creating seed village, building vermicomposting units, and cultivating vegetables in ridges may augment the productivity of farming systems and improve net farmer incomes.

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