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A Comparative Economic Analysis of the Identified Integrated Farming Systems in Coastal West Bengal

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Climate change presents a significant danger to the way of life and livelihoods of the farmers in coastal regions. One effective approach to mitigate the negative impacts of climate change on farmers' income is to diversify their farm income through the adoption of Integrated Farming Systems (IFS). This research aimed to evaluate the economic feasibility of integrated farming systems, considering various economic indicators, such as productivity, net farm income, the elasticity of substitution between labor and capital, and returns per rupee of expenses. The analysis was conducted based on data collected through a stratified random sampling method for the 2023 production year, involving 200 farmers who had implemented Integrated Farming Systems in coastal West Bengal. Six different integrated farming systems were identified. Among these, the Dairy + Fishery system demonstrated the highest net farm income (INR 311244 ha^{-1} yr^{-1}), returns per rupee of expenses (1.74), and elasticity of substitution between labor and capital (0.83). Although all farming systems in this study exhibited returns per rupee of expenses greater than one, the Dairy + Crop and Dairy + Fishery systems had higher returns per rupee of expenses, which likely contributed to their greater adoption by farmers. Furthermore, this study provides valuable insights into the economic aspects of integrated farming systems in the coastal West Bengal.

(***Key words:*** *Constant elasticity of substitution, Coastal West Bengal, Integrated farming system, Production function*)

West Bengal had just 0.77 hectares of average operational holding in 2015-16, while across India it decreased from 2.28 hectares in 1970-71 to 1.08 hectares in 2015-16 (GoI, 2019). This fragmentation of land and a higher percentage of small and marginal farms pose a serious threat to the sustainability and profitability of agriculture in the future. As a result, there is no more room for agriculture to expand horizontally. Consequently, there is an urgent need for the vertical integration of numerous farm enterprises. While the terms "integrated farming" and "mixed farming" are often used interchangeably, there are distinctions between them. Integrated farming systems (IFSs) emphasize the interaction among different components within the system in a linked manner, including the recycling of waste and by-products within the system. However, this feature may be absent in mixed farming (Behera *et al.,* 2018).

In the coastal region of West Bengal, integrated farming systems (IFSs) have gained popularity as a sustainable and climate-resilient approach to agriculture. The coastal region of West Bengal possesses abundant agricultural resources, but it is also prone to cyclones, water salinity, and floods, which are major environmental anomalies. Therefore, in this region, people prefer diversifying different farming enterprises rather than specializing in any one farming enterprise. So, the objective of the study was to estimate the profitability and elasticity of substitution between labor and capital of various integrated farming systems in coastal West Bengal. This is a research question of great importance to farmers and policy makers, as it will help them adjust current farming practices, leading to increased long-term farm revenue and employment opportunities.

MATERIALS AND METHODS

Multistage stratified random sampling technique was used in the study where population was divided into subgroups or strata based on some common characteristic and then randomly selected the sample

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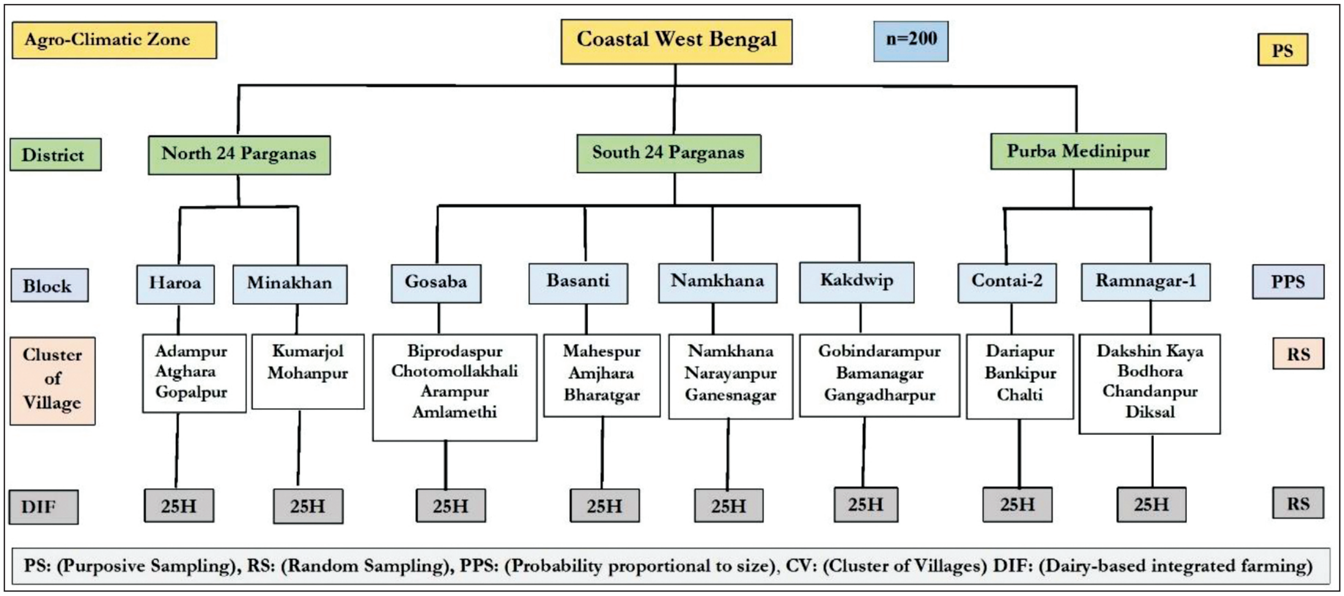

Fig. 1. *Sampling Plan*

from each stratum. The coastal region of West Bengal was selected purposively for the population based on the regions witnessing maximum environmental hazards. This region has three districts *e.g.,* Purba Medinipur, South 24 Parganas, and North 24 Parganas. Purba Medinipur has six coastal blocks (consisting of Khejuri, Contai I, Contai II, Ramnagar I, Ramnagar II, and Nandigram I). South 24 Parganas has thirteen coastal blocks (Consisting of Sagar, Namkhana, Kakdwip, Patharpratima, Kultali, Mathurapur I, Mathurapur II, Joynagar I, Joynagar II, Canning I, Canning II, Basanti, Goasaba). North 24 Parganas has six coastal blocks (consisting of Hingalganj, Hasnabad, Sandeshkhali I, Sandeshkhali II, Haroa, and Minakhan). As the total number of coastal blocks in South 24 Parganas is almost double the number of coastal blocks in rest two districts, *i.e.*, Purba Medinipur and North 24 Parganas, therefore, using probability proportional to size sampling method, out of the total 8 sample blocks, 4 blocks were chosen from South 24 Parganas and 2 blocks each were chosen from the other two districts. In the next stage, village clusters were selected randomly from each block (Fig. 1). In the last stage, 25 agricultural households from each cluster of villages were selected randomly. In this way, a total of 200 agricultural households were selected in the sample based on the following two selection criteria:

1. The farming household reared at least 2 cows in an integrated farming system;
2. Each component of the farming system contributed between 10% and 90% to the gross income of the household.

The identified integrated farming systems (IFSs) had different components, each with its own variable and fixed cost structure. Therefore, in order to calculate the costs and returns of the IFS, it was necessary to calculate the costs and returns of each component separately in various IFSs. The dairy component of an IFS includes only cattle. The variable cost incurred in dairy components was calculated based on the prevailing market price in that area, while fixed cost was calculated using the Capital Recovery Cost (CRC) method, with an interest rate of 8% per annum and useful life of fixed and livestock assets was considered as 10 years for local cow, 8 years for cross breed cows, 50 years for pucca cattle shed and 10 years for Katcha cattle shed, *etc.,* as suggested by Rao (1991). Returns from the dairy component came from two sources, milk and dung, and were calculated based on the farm gate price reported by the respondents.

Similarly, the crop, fishery, poultry, and goat components in the IFSs included *Rabi* and *Kharif* paddy, general carp fish (*Catla, Rohu, Mrigal, Common Carp, Silver Carp, Grass Carp, etc.*), broiler and layer, and Black Bengal goat, respectively. Variable cost for each enterprise was calculated based on the prevailing market price in that area, while fixed cost was calculated using the straight-line method. Returns was calculated based on the farm gate price reported by the respondents. Meat production for goats and poultry was calculated by multiplying the body weight with dressing percentage. For this study, the dressing percentages considered for Black Bengal goat and poultry were 44.62% (Singh and Sengar, 1979) and 76.07% (Sundi *et al.,* 2018), respectively.

Net Returns from an IFS = Summed up gross returns from different components - Total costs of different components.

$$\text{Returns per rupee of expenses} = \frac{\text{Summed up gross returns form different components}}{\text{Total costs of different components}} \quad ...(1)$$

Using labor (N) and capital (C) as the two components of production, the elasticity of substitution (σ_{NC}) is symbolically expressed by:

$$\sigma_{NC} = \frac{\left(\frac{C}{N}\right) d\left(\frac{N}{C}\right)}{\left(\frac{f_n}{f_c}\right) d\left(\frac{f_c}{f_n}\right)} \quad ...(2)$$

where f_n and f_c stand for the marginal products of labor and capital, respectively. The proportionate change in relative factor inputs to a proportional change in the marginal rate of substitution between labor and capital is known as the elasticity of substitution. One of the key metrics for gauging production efficiency is substitution elasticity (also known as technical efficiency). If, σ_{NC} is large, then a given change in the labor-capital ratio is more likely to result in a significant change than for a smaller σ_{NC}.

A CES (constant elasticity of substitution) production function was applied to measure the elasticity of substitution for this study.

The static CES production function is:

$$Q = \gamma\{kC^{-\rho} + (1–k)\, N^{-\rho}\}^{-v/\rho} \quad ....(3)$$

The four parameters are γ, *k*, *v*, and *ρ*, where γ is a scale parameter, *k* is a distributive parameter, *v* is the degree of homogeneity of the function or the degree of return to scale, and *ρ* is the substitution parameter equal to (1-σ)/σ, where σ is the elasticity of substitution. In this example, Q, C, and N stand for output, capital, and labor, respectively. After that, we can get σ = 1/ (1+ρ).

The logarithmic transformation of the CES production function is:

$$\log(Q) = \log(\gamma) – v/\rho \log\{kC^{-\rho} + (1–k)\, N^{-\rho}\} \quad ...(4)$$

This production function's main issue is figuring out how to estimate the parameters γ, *k*, *ρ*, and *v* given input data on labor, capital, and output. Equation (4) cannot be solved using a straight forward least-squares approach because the phrase $\{kC^{-\rho} + (1\text{-}k)N^{-\rho}\}$ contains unknown parameters.

Substituting equation (3) with its linearly-proportional approximation that is linear with respect to *ρ* allows for a more straight forward estimation of the CES production function's parameters. (5) can be obtained by applying Taylor's Series formula (Kmenta, 1967), (3) extending log(Q) around ρ=0, and removing the elements involving power of ρ greater than one.

$$log(Q) = log(\gamma) + vk\, log(C) + v\,(1–k) log(N) – {}^{1}/_{2}\, vk\rho\,(1–k)\,\{log(C) + log(N)\}^2 \quad ...(5)$$

The empirical estimate for the unconstrained version (6) is as follows:

$$log(Q) = \beta_1 + \beta_2\, log(C) + \beta_3\, log(N) – \beta_4\, \{log(C) + log(N)\}^2 \quad ...(6)$$

The coefficients of equation (6) and the parameters of equation (5) are connected in the following way

$$\gamma = \text{antilog} \qquad \gamma = \beta_2 + \beta_3$$

$$k = \frac{\beta_2}{(\beta_2 + \beta_3)} \qquad \rho = \frac{2\,\beta_4(\beta_2 + \beta_3)}{(\beta_2\ \beta_3)}$$

RESULTS AND DISCUSSION

Identification of farming systems

In the study area, six major integrated farming systems were identified, namely Dairy-Crop, Dairy-

Table 1. *Farming systems identified in the study area (n=200)*

Integrated Farming Systems	Frequency	Frequency (%)
Dairy + Crop (D + C)	43	21.5
Dairy + Fishery (D + F)	42	21.0
Dairy + Crop + Fishery (D + C +F)	34	17.0
Dairy + Crop + Goat (D + C + G)	32	16.0
Dairy + Crop + Poultry (D + C + P)	27	13.5
Dairy + Crop + Fishery + Goat (D + C + F + G)	22	11.0
Overall	200	100.0

Fishery, Dairy-Crop-Fishery, Dairy-Crop-Goat, Dairy-Crop-Poultry, and Dairy-Crop-Fishery-Goat (Table 1). In the coastal region of West Bengal, farmers owned indigenous, cross-breed, and some non-descriptive cattle, which had significantly lower productivity compared to cattle in other states. As a result, farmers experienced relatively lower returns and profits from their dairy enterprises. Farmers mostly used rice-based cropping systems for their crops, including rice-rice, rice-fallow, rice-vegetables (Mandal *et al.,* 2022). The cultivation of salt-tolerant indigenous rice varieties like *Dudheswar, Lal Swarna, Rupshal, Sabita*, *etc.*, was prevalent among farmers. Fish component had a comparative advantage because of its greater market demand and also due to the geographical position of the coastal region. It was also found that in this region people convert less profitable but sustainable agricultural lands to unsustainable capitalistic shrimp aquaculture lands (Goswami and Ghosal, 2022). Poultry birds were reared mainly for egg production, but some farmers reared them commercially to sell chicken. Black Bengal was the most famous goat breed in this area because of its low overall input cost.

Average productivity of different components across different IFSs

Table 2 presents the average productivity of various components within the farming system. In the study area, the average productivity of rice was recorded at 4.57±1.58 t ha^{-1}. The farming system of D + C + F + G exhibited the highest average rice productivity, reaching 4.94 ± 2.01 t ha^{-1}. Fish productivity, was 3.82 ± 0.97 t ha^{-1} in the study area, with the D + F farming system having the highest productivity. In terms of milk production, the crossbred cows produced an average of 6.95 L milk day^{-1}, compared to the local cows' 2.06 L day^{-1}. Additionally, the chicken productivity was determined to be 1.18 kg 42 days^{-1}, and the productivity of goat was 7.76 kg 6 months^{-1}.

Table 2. *Average productivity of cattle, crop, fishery, poultry and goat (n=200)*

Farming systems	Average rice productivity (t ha^{-1})	Average fish productivity (t ha^{-1})	Average milk productivity/ milch animal (L day^{-1})		Goat meat (kg 6 months^{-1})	Poultry meat (kg 42 days^{-1})
			CB cows	Local cows		
D + C	4.67 (0.92)	-	6.39 (1.93)	1.87 (0.75)	-	-
D + F	-	4.02 (1.19)	7.86 (2.86)	2.25 (1.63)	-	-
D + C + F	4.17 (1.69)	3.75 (9.69)	6.48 (1.95)	1.67 (0.49)	-	-
D + C + G	4.54 (1.50)	-	6.54 (2.02)	1.90 (0.60)	8.19 (2.04)	-
D + C + P	4.54 (1.77)	-	7.72 (3.03)	2.18 (0.67)	-	1.18 (0.34)
D + C + F + G	4.94 (2.01)	3.71 (0.75)	6.75 (2.75)	2.54 (1.90)	7.33 (3.73)	-
Average	4.57 (1.58)	3.82 (0.97)	6.95 (2.43)	2.06 (1.00)	7.76 (2.88)	1.18 (0.34)

Table 3. *Net returns and return per rupee of expenses of different integrated farming systems (INR ha^{-1} yr^{-1})*

Integrated Farming Systems	Components	Variable cost	Fixed cost	Total cost	Gross returns	Profit	Returns $rupee^{-1}$	Gross total cost	Gross total returns	Returns $rupee^{-1}$	Total net returns
D + C	Dairy	80011	20437	100449	162186	61737	1.61	219441	319994	1.46	100553
	Crop	91787	27205	118992	157808	38817	1.33				
D + F	Dairy	106336	23036	129376	167304	37928	1.29	423366	734609	1.74	311244
	Fishery	157880	136109	293990	567305	273316	1.93				
D + C + F	Dairy	79293	15907	95200	124814	29616	1.31	292646	404858	1.38	112212
	Crop	67712	19638	87350	113612	26262	1.30				
	Fishery	85527	28191	110096	166432	27114	1.51				
D + C + G	Dairy	140800	29412	170212	199954	29742	1.17	537447	693483	1.29	156036
	Crop	141075	42882	183957	220657	36700	1.20				
	Goat	173625	9653	183278	272872	89594	1.49				
D + C + P	Dairy	184462	39390	223852	260062	36210	1.16	726452	959492	1.32	233040
	Crop	159529	43309	202838	261097	58259	1.29				
	Poultry	277381	22381	299762	438333	138571	1.46				
D + C + F + G	Dairy	100165	23021	123188	148071	24885	1.20	577232	752166	1.30	174935
	Crop	102177	29354	131531	162610	31079	1.24				
	Fishery	99072	74754	173827	224932	51106	1.29				
	Goat	144655	4030	148686	216553	67868	1.46				

For the analysis of costs and returns ha^{-1}, constant return to scale had been assumed

Net returns and returns per rupee of expenses of IFSs

Integration across different enterprises in the IFS model ensures increased productivity, profitability, sustainability, and risk reduction. Profitability can be enhanced by increasing output or reducing expenses. Decision-makers need to analyze various cost components across different farming systems in order to maximize profitability.

The cost and returns for different farming systems are presented in Table 3. The most profitable farming system was Dairy + Fishery (INR 311244 ha^{-1} yr^{-1}), followed by Dairy + Crop + Poultry (INR 233040 ha^{-1} yr^{-1}), Dairy + Crop + Fishery + Goat (INR 174935 ha^{-1} yr^{-1}), Dairy + Crop + Goat (INR 156036 ha^{-1} yr^{-1}), Dairy + Crop + Fishery (INR 112212 ha^{-1} yr^{-1}) and Dairy + Crop (INR 100553 ha^{-1} yr^{-1}). High profitability was recorded in Dairy + Fishery system due to its productive fishery and crossbreed cattle.

Additionally, a prior study in the coastal region of West Bengal reported that higher net returns result from intensifying cropping system, especially when fisheries were incorporated (Mandal *et al.,* 2017). The returns per rupee of expenses were calculated by dividing gross returns by total cost. The Dairy + Fishery system had the highest returns per rupee of expenses (1.74), followed by the Dairy + Crop system (1.46), Dairy + Crop + Fishery system (1.38), Dairy + Crop + Poultry system (1.32), Dairy + Crop + Fishery + Goat system (1.30), and Dairy + Crop + Goat system (1.29). A high return per rupee of expenses indicates that a farming system is economically viable and capable of generating value beyond its cost. In this case, all farming systems had a benefit-cost ratio greater than one, indicating that good returns on investment are anticipated. Dairy + Fishery, Dairy + Crop and Dairy + Crop + Fishery farming systems had higher returns per rupee of expenses ratio, making all three systems attractive investment opportunities for the farmers.

Elasticity of substitution of IFSs

In the Indian agriculture sector, the elasticity of substitution between labor and capital showed lower (0.44) and temporally unchanged as compared to other countries (Wei, 2013). So, IFS can be the option to increase the elasticity of substitution in the agriculture sector.

Tables 4 and 5 show the parameter values and their significance indicator. The farming system that combines dairy and fishing had the highest labor-capital substitution elasticity in integrated farming. It was found that the values of elasticity in Dairy + Crop, Dairy + Crop + Fishery and Dairy + Crop + Goat farming systems were less than 0.5 ($\delta < 0.5$), while it was

Table 4. *Findings from the CES production function estimation*

Farming systems	β_1	β_2	β_3	β_4	F	R^2	n
D + C	-2.041 (-1.84)	0.381 (2.32)	0.918 (5.00)	-0.212 (-1.69)	70.19	0.84	43
D + F	1.774 (0.71)	0.162 (0.45)	0.814 (1.79)	-0.014 (-0.107)	15.50	0.55	42
D + C + F	-2.174 (-1.30)	0.479 (1.44)	0.838 (2.47)	-0.242 (-0.68)	27.40	0.73	34
D + C + G	0.546 (0.65)	0.249 (1.82)	0.790 (6.34)	-0.409 (-2.39)	101.71	0.91	32
D + C + P	1.028 (0.86)	0.760 (4.17)	0.234 (1.06)	-0.062 (-0.33)	46.79	0.85	27
D + C + F + G	1.075 (0.74)	0.543 (2.49)	0.454 (1.94)	-0.041 (-0.12)	38.20	0.86	22

Table 5. *Estimated parameters of the CES production function*

Farming systems	γ	K	V	ρ	δ
D + C	0.130	0.293	1.299	1.575	0.388
D + F	5.894	0.166	0.976	0.207	0.828
D + C + F	0.114	0.364	1.317	1.588	0.386
D + C + G	1.726	0.240	1.039	4.321	0.188
D + C + P	2.795	0.765	0.994	0.693	0.591
D + C + F + G	2.930	0.545	0.997	0.332	0.751

greater than 0.5 ($\delta > 0.5$) in the Dairy + Fishery, Dairy + Crop + Fishery + Goat and Dairy + Crop + Poultry farming systems. A high elasticity of substitution means that farms can adjust their combination of labor and capital relatively easily in response to changes in input prices. This can lead to a more efficient allocation of resources and may result in higher levels of output. It was observed that Dairy + Fishery and Dairy + Crop + Fishery + Goat farming systems were more profitable compared to other farming systems because of the high elasticity of substitution, which allows optimizing resource allocation by choosing the most cost-effective combination of labor and capital for producing output.

CONCLUSION

Among all identified IFSs, the farming systems that combine Dairy-Crop and Dairy-Fishery had the highest adoption rates, possibly due to their favourable returns per rupee of expenses. The study found that all IFSs had more than one returns per rupee of expenses. This can lead to increased adoption of integrated farming systems by farmers, which can have a positive impact on food security, livelihoods, and the environment. Dairy + Fishery, Dairy + Crop + Poultry and Dairy + Crop + Fishery + Goat farming systems generated higher net returns, which signifies increased productivity or reduced production costs through the farming system's recycling of leftovers and by-products from many components. Dairy + Fishery, Dairy + Crop + Poultry and Dairy + Crop + Fishery + Goat farming systems had more than 0.5 elasticity of substitution, which indicates greater flexibility and adaptability in the use of labour and capital resources and optimizing production level, ensuring that they can adapt to changing market conditions and constraints.

CONFLICTS OF INTEREST

The authors assert that they have no conflicts of interest to disclose.

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