RESEARCH ARTICLE Bhartiya Krishi Anusandhan Patrika, Volume 40 Issue 3-4: 317-325 (September and December 2025)

# Economic Inter-linkage Analysis of Dairy-based Integrated Farming Systems and Pathways to Profitability in the Coastal Region of West Bengal

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10.18805/BKAP872


## ABSTRACT

**Background:** Dairy-based integrated farming systems in the coastal region of West Bengal act as a climate-resilient agriculture practice. The present study examined four predominant dairy-based integrated farming systems (IFS) adopted in coastal West Bengal, focusing on the economic analysis of their interconnected components and pathways to profitability.

**Methods:** The study used stratified random sampling methods to collect 150 farmers from 25 villages in Coastal West Bengal. To quantify the interdependence amongst various components of farming systems, Leontief static input-output model has been used. Stochastic profit frontier model had been used for analysing the profit efficiency.

**Result:** The study found Dairy + Fishery farming system had the highest profitability of INR 328139 /ha/annum. However, it has shown the lowest mean profit efficiency (0.55). This system can increase its profitability by the more veterinary expenditure per SAU and area under fishery (Ha) in IFS model. Among all the linkages of various enterprises in IFSs, crop-to-dairy linkage in Dairy + Crop + Fishery (Input-output coefficient: 0.09) farming system was the strongest one. The study recommends targeted policy support, including subsidies on fish feed and fingerlings and financial assistance for small and marginal farmers, to foster the growth of the dairy-based farming systems.


**Key words:** Dairy-based integrated farming system, Maximum likelihood estimates, Profit efficiency, Standard animal unit (SAU), Stochastic frontier.

## INTRODUCTION

India has the world's largest livestock population, with 535.78 million headcounts, contributing 30% to the Gross Value Added (GVA) of the agriculture and allied sectors and 6% to the national GVA (BAHS, 2023). Whereas, 69% of the livestock population owned by landless agricultural labourers, marginal and small farmers (NSS 77$^{th}$ Round, 2021). Therefore, structural transformation of agriculture can be achieved through the development of livestock-based farming systems.

Among its states, West Bengal ranks first in cattle population (19 million) and second in goat population (16 million), recording a 23% increase in total livestock population between the 19$^{th}$ and 20$^{th}$ Livestock Census. The coastal region of the state has shown an increasing trend in milk production, contributing 16% of the state's total milk output (NDDB, 2017). Although the region is endowed with rich agricultural resources, it is frequently affected by environmental challenges such as cyclones, water salinity and floods. Furthermore, the fragmentation of land holdings poses a significant threat to the *via*bility, food security and profitability of the agricultural sector (Paramesh *et al.,* 2022). Crop production is predominantly cereal-based, with most marginal farmers relying on monocropping practices. Consequently, the risks associated with climate anomalies have further exacerbated income instability for farming households. These challenges often prevent farmers from earning a sustainable livelihood, pushing many into poverty (Kumar *et al.,* 2018). In this context, diversification rather than specialisation in farming enterprises has been recommended as a strategy to reduce risk and enhance farm income (Barman *et al.,* 2024; Dasgupta *et al.,* 2021; Sarangi and Burman, 2016).

Given these opportunities and challenges, dairy-based integrated farming systems (IFS) present a promising strategy for enhancing farm income (Shruthi and Desai, 2021). While both "integrated farming" and "mixed farming" involve diversification, they differ conceptually. IFS places strong emphasis on the interconnectedness of

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**How to cite this article:** Barman, S., Malhotra, R., Sen, B., Mondal, I. and Paul, S. (2025). Economic Inter-linkage Analysis of Dairy-based Integrated Farming Systems and Pathways to Profitability in the Coastal Region of West Bengal. *Bhartiya Krishi Anusandhan Patrika*. **40(3-4):** 317-325. doi: 10.18805/BKAP872.

**Submitted:** 24-07-2025 **Accepted:** 23-09-2025 **Online:** 28-10-2025

components, promoting the recycling of waste and byproducts within the system. Mixed farming, on the other hand, may lack this level of integration (Sharma *et al.,* 2017; Behera *et al.,* 2018).

In this light, the present study aims to (i) identify major dairy-based integrated farming systems based on specific criteria, (ii) analyse the interlinkages among different components to understand resource flows within the farming system and (iii) determine the level of profit efficiency among farmers and the factors influencing profitability. The conclusions of this study will be valuable to both farmers and policymakers, as they offer insights into adjusting current farming practices to enhance long-term farm income and employment opportunities.

## MATERIALS AND METHODS

### Sampling plan

A multi-stage stratified random sampling method was employed to collect data in FY 2023-24. Out of the six agro-climatic zones of West Bengal, the Coastal Zone was purposively selected because of its high environmental vulnerability and potential for integrated farming. This zone comprises three districts along the Bay of Bengal: Purba Medinipur, North 24 Parganas and South 24 Parganas. Within these districts, blocks were selected using the probability proportional to size (PPS) method. Purba Medinipur has six coastal blocks (Khejuri, Contai I, Contai II, Ramnagar I, Ramnagar II and Nandigram I); South 24 Parganas has thirteen coastal blocks (Sagar, Namkhana, Kakdwip, Patharpratima, Kultali, Mathurapur I, Mathurapur II, Joynagar I, Joynagar II, Canning I, Canning II, Basanti and Gosaba); while North 24 Parganas has six coastal blocks (Hingalganj, Hasnabad, Sandeshkhali I, Sandeshkhali II, Haroa and Minakhan). Since the number of coastal blocks in South 24 Parganas is nearly double that of either Purba Medinipur or North 24 Parganas, a total of eight sample blocks were chosen, of which four came from South 24 Parganas and two each from Purba Medinipur and North 24 Parganas. In the next stage, village clusters were randomly selected from within each chosen block. Finally, a total of 150 farmers were surveyed, comprising 75 from South 24 Parganas and 75 from Purba Medinipur and North 24 Parganas. Each chosen farmer possessed a minimum of two cattle, with each integrated farming system (IFS) component contributing between 10% and 90% to household income.

### Quantification of linkages in IFSs

To quantify the linkages among various components of different farming systems, data were collected through interviews with sampled farmers. The collected information was then used to estimate the linkages among different components of the farming systems. These linkages were analysed and quantified based on the interactions between outputs, inputs, labour, home consumption and market sales within the farming systems. To quantify the interdependence amongst various components of farming systems, Leontief static input- output model has been used.

The model may be described as:

$$S_i = \sum_i S_{ij} + H_i \ (i = 1,2,3 \ldots, m; j = 1,2,3 \ldots n) \quad \ldots(1)$$

Where,

$S_i$ = Output of any intermediate sector.

$S_{ij}$ = Component flows from ith sector to jth sector

$H_i$ = Final output for household consumption and market.

Equation (1) can also be expressed as a transaction matrix. It shows the value of output flows from the producing sectors to the consuming sectors of farm unit. The relationship thus obtained can be expressed in terms of production coefficients ($a_{ij}$) and may be described as follows:

$$a_{ij} = \frac{S_{ij}}{S_j} \ (i = 1,2,3 \ldots m; j = 1,2,3 \ldots n) \quad \ldots(2)$$

$S_j$ = Total output of $j^{th}$ sector.

$a_{ij}$ = Value of ith sector input to produce one unit of $j^{th}$ sector output.

### Analysis of profit efficiency in IFSs

Profit efficiency can be defined as a firm's ability to achieve the highest possible profit, given the prices of inputs and outputs and levels of fixed factors of that firm.

The stochastic profit function is defined as:

$$\pi_i = f(p_{ij}, Z_{ik}; \beta_i). \exp(\varepsilon_i) \quad \ldots(3)$$

Where,

$\pi_i$ = Normalised profit of the $i^{th}$ farm is defined as gross revenue with less total variable cost divided by farm-specific output price.

$P_{ij}$ = The price of $j^{th}$ variable input faced by the $i^{th}$ farm divided by output price.

$Z_{ik}$ = The level of the $k^{th}$ fixed factor on the $i^{th}$ farm.

$\beta_i$ = Vectors of parameters.

$\varepsilon_i$ = Stochastic disturbance term.

i = 1, 2…, 150 is the number of farms in the sample.

The error term is assumed to behave in a manner consistent with the frontier concept (Ali and Flinn, 1989), *i.e.*,

$$\varepsilon_i = \upsilon_i + \mu_i \quad \ldots(4)$$

Where $\vartheta_i$ are assumed to be independently and identically distributed random errors, having normal distributions, independent of the $\mu_i$. The $\mu_i$ are profit inefficiency effects, which are assumed to be non-negative truncation of the half-normal distribution, N ($\mu_i$, $\sigma^2$).

The choice between the Cobb-Douglas and Translog production functions for the stochastic frontier model depends on the specific characteristics of the data being analysed. However, the Cobb-Douglas function is often preferred for small sample sizes due to its simplicity and ease of estimation (Pechrova and Simpach, 2020). The Translog function, on the other hand, is more flexible and can capture more complex relationships between inputs and outputs, but it requires larger sample sizes. In this

study, different farming systems' sample sizes are small, so the Cobb-Douglas profit function has been used in the stochastic frontier model. The general form of the Cobb-Douglas stochastic profit function is as expressed below:

$$\ln(\pi) = \ln(\beta_0) + \beta_1 \ln(P_1) + \beta_2 \ln(P_2) + \beta_3 \ln(P_3) + \beta_4 \ln(P_4) + \beta_5 \ln(P_5) + \beta_6 \ln(P_6) + \beta_7 \ln(Z_1) + \beta_8 \ln(Z_2) + \upsilon_i + \mu_i \quad ....(5)$$

Where,

$\pi'$ = Restricted profit.

$P'_i$ = Price of the $i^{th}$ input ($P_i$) normalised by the output price ($P_y$).

$P_1$ = Normalised feed price (INR).

$P_2$ = Normalised veterinary charge/SAU (INR).

$P_3$ = Normalised labour wage (INR).

$P_4$ = Normalised seed price (INR).

$P_5$ = Normalised manures and fertiliser price (INR).

$P_6$ = Normalised fingerling price (INR).

$Z_1$ = Area under crop (Ha).

$Z_2$ = Quantity of fixed inputs (INR).

$\upsilon_i$ = Two-sided random error.

$\mu_i$ = One-sided half-normal error.

The inefficiency model ($\mu_i$)is defined by:

$$\mu_i = \delta_0 + \delta_{1i} W_{1i} + \delta_{2i} W_{2i} + \delta_{3i} W_{3i} + \delta_{4i} W_{4i} + \delta_{5i} W_{5i} + \delta_{6i} W_{6i} \quad ....(6)$$

Where,

$\mu_i$ = Profit inefficiency expressed in percentage.

$W_1$ = Farming experience (year).

$W_2$ = Age (year).

$W_3$ = Level of education (years of schooling).

$W_4$ = Standard animal unit (SAU).

$W_5$ = Access credit (yes =1, no = 0).

$W_6$ = Access to extension services (yes=1, no=0).

## RESULTS AND DISCUSSION

### Identification of dairy-based integrated farming systems

Four major integrated farming systems were identified in the study area: Dairy + Crop, Dairy + Fishery, Dairy + Crop + Fishery and Dairy + Crop + Goat (Fig 1). In the coastal region of West Bengal, farmers owned indigenous, crossbreed and some non-descriptive cattle, which had significantly lower productivity than cattle in other states. As a result, farmers experienced relatively lower returns and profits from their dairy enterprises. Farmers mostly used rice-based cropping methods for their crops, including rice-rice, rice-fallow and rice-vegetables (Mandal *et al.,* 2022). The fish component had a comparative advantage because of its greater market demand and geographical position in the Coastal region and Black Bengal is most famous goat breed because of its low input cost.

### Quantification of linkages among various components of different integrated farming systems

To quantify the linkages among various components of different farming systems, the following information was obtained:

a) Information on the total output from each component of different farming systems was gathered. This includes the crop produce, livestock products and other outputs generated by the farmers.

b) Details were obtained regarding the feeds and fodder used for livestock, both sourced from the farming system itself and purchased from the market. The total value of purchased inputs from the market was also recorded.

c) Data on the total employment of family labor in the farming system and the associated cost of hired labor were collected. This includes labor used for various activities related to crop cultivation, livestock care and other farming operations.

d) Information was gathered on the total consumption of household products from each component of the farming system. Additionally, the total value of products sold in the market was recorded.

e) Data on the utilization of farmyard manure derived from livestock and the purchase of inputs for crop production were documented.

The collected information was then used to estimate the linkages among different components of the farming systems. These linkages were analysed and quantified based on the interactions between outputs, inputs, labour, consumption and sales within the farming systems. Fig 2 shows the resource flow linkage among different components of farming systems.

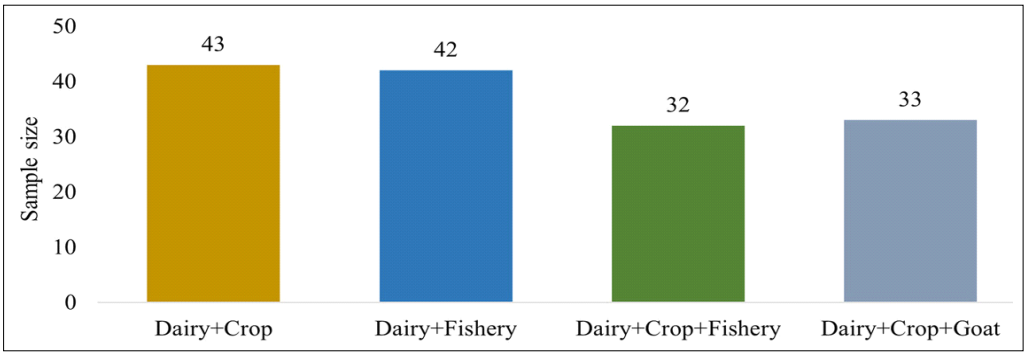



**Fig 1:** Frequency distribution of different dairy-based IFSs.

Table 1 provides information about two enterprises (dairy, crop) in Dairy + Crop (D + C) farming system, including producing sectors (dairy, crop, household) and consumption sector (dairy, crop, household). The dairy sector had a gross return of INR 162186/Ha/year. It required INR 7577/year of input from the crop sector (paddy straw), INR 25923/year from the household sector (imputed family labour) and INR 2936/year from the dairy sector (value of milk consumed by calf, cow dung for fuel, the value of calf) to produce its output. The market-oriented variable input (green fodder, dry fodder, concentrate, mineral mixture, veterinary and medicine) provided to the dairy sector was INR 48698/year, while the fixed cost was INR 20438/year. The crop sector reaped a gross return of INR 157808/year. It required INR 4122 /year of input from the dairy sector (cow dung), INR 21918/year from the household sector (imputed family labour) and INR 4214/year from the crop sector (seed) to produce its output. The market-oriented variable input (seed, fertilizer and plant protection chemical) provided to the crop sector was INR 52929/year and the fixed input was INR 27205/year. According to the input-output coefficients for D + C farming system, for generating every rupee of the dairy sector's gross return, home labour, market-oriented inputs and crop sector contributed 16%, 30% and 5%, respectively. Based on the analysis presented above, it can be inferred that there are considerable linkages between cattle and crop enterprises within the D + C farming system. The connections from crop-to-dairy sectors were stronger than the linkages from dairy-to-crop sectors.

Similar way the transaction matrix for Dairy + Fishery enterprise can be shown in Table 2. The corresponding input-output coefficient figures indicate that for every rupee

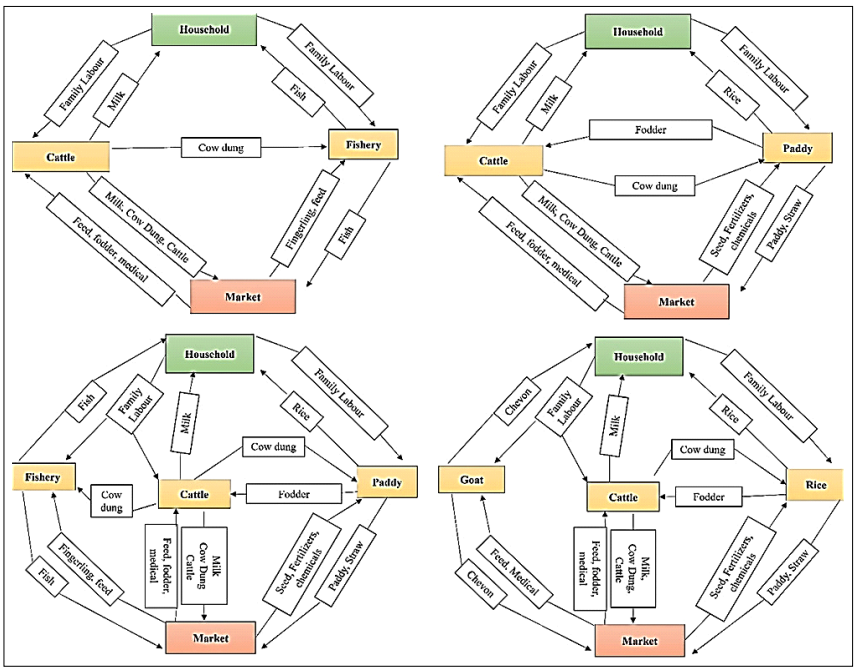



**Fig 2:** Resource flows in the farming system.

**Table 1:** Transaction matrix under Dairy + Crop (D + C) farming system (INR/Ha/year).

| | | Consuming sectors | | | Marketable surplus | Gross returns |
|---|---|---|---|---|---|---|
| | | Dairy | Crop | Household | | |
| Producing sectors | Dairy | 2936 | 4122 | 15013 | 140114 | 162186 |
| | | (2%) | (3%) | | | |
| | Crop | 7577 | 4214 | 44346 | 101674 | 157808 |
| | | (5%) | (3%) | | | |
| | Household | 25923 | 21918 | | | |
| | | (16%) | (14%) | | | |
| Market-oriented inputs | | 48698 | 52929 | | | |
| | | (30%) | (34%) | | | |
| Fixed cost | | 20438 | 27205 | | | |
| Total cost | | 105572 | 110388 | | | 104034* |

Figures in parentheses are input-output coefficients in percentage and * Indicates profit of the farming system.

of the dairy sector's gross return, home labour, market-oriented inputs and the dairy sector contributes 23%, 36% and 5%, respectively. For every rupee of the fishery sectors' gross return, the dairy and household sector contribute 1% and 10%, respectively. It is clear from the results of linkage coefficients that the dairy to fishery sector has a linkage, but there is no evidence of fishery to dairy sector linkage. In this farming system, the percentage of marketed surplus of milk is high as farm households consume more fish for protein fulfilment.

According to the transaction matrix given in Table 3, the gross return in dairy, crop and fishery enterprises in IFS model were INR 124814, INR 113612 and INR 166432, respectively per year per ha. For the production of a rupee of the dairy sector's gross return, home labour, market-oriented inputs, crop sector and dairy sector contributed 22%, 33%, 9% and 4%, respectively. In the crop sector, to produce one rupee of gross return, the household, dairy sector, crop sector and market-oriented inputs contributed 16%, 2%, 2% and 38%, respectively. One rupee of gross return in the fishery sector requires 2% contribution from the dairy sector and 10% from the household sector. Here also, crop to dairy linkage is higher than dairy to crop linkage.

Table 4 presents data on producing and consuming sectors, such as dairy, crops, goat and households. The goat sector reaped an annual revenue of INR 272872. It relied on INR 10995 per year from the goat sector and INR 106702 per year from the household sector to produce its output. Input-output coefficient indicates goat sector has little linkage with another sector as this sector does not produce much manure.

**Analysis of frontier profit function (MLE estimates)**

The OLS function was used to estimate the average profit function, while the MLE model was employed to estimate the stochastic profit frontier. Using the frontier obtained from the MLE technique, the farm's efficiency was estimated. The parameter estimates resulting from this MLE method are presented in Table 5. Table 5 shows the effect of each normalised input price on normalised profit. Based on the Table 5, the value of the sigma square ($\sigma^2$) in the case of the D + C farming system is 0.10 and significant

**Table 2:** Transaction matrix under dairy + fishery (D + F) farming system (INR/Ha/year).

| | | Consuming sectors | | | Marketable surplus | Gross returns |
|---|---|---|---|---|---|---|
| | | Dairy | Fishery | Household | | |
| Producing sectors | Dairy | 8577 | 5964 | 6700 | 146064 | 167304 |
| | | (5%) | (1%) | | | |
| | Fishery | 0 | 0 | 164767 | 402538 | 567305 |
| | | (0%) | (0%) | | | |
| | Household | 38368 | 57978 | | | |
| | | (23%) | (10%) | | | |
| Market-oriented inputs | | 59393 | 82342 | | | |
| | | (36%) | (15%) | | | |
| Fixed cost | | 17739 | 136109 | | | |
| Total cost | | 124077 | 282393 | | | *328139 |

Figures in parentheses are input-output coefficients in percentage and * Indicates profit of the farming system.

**Table 3:** Transaction matrix under dairy + crop + fishery (D + C + F) farming system (INR/Ha/year).

| | | Consuming sectors | | | | Marketable surplus | Gross returns |
|---|---|---|---|---|---|---|---|
| | | Dairy | Crop | Fishery | Household | | |
| Producing sectors | Dairy | 5588 | 1933 | 2665 | 8399 | 106228 | 124814 |
| | | (4%) | (2%) | (2%) | | | |
| | Crop | 11775 | 1737 | 0 | 33789 | 66311 | 113612 |
| | | (9%) | (2%) | (0%) | | | |
| | Fishery | 0 | 0 | 0 | 46142 | 120290 | 166432 |
| | | (0%) | (0%) | (0%) | | | |
| | Household | 28015 | 18242 | 16037 | | | |
| | | (22%) | (16%) | (10%) | | | |
| Market-oriented input | | 40980 | 42901 | 46445 | | | |
| | | (33%) | (38%) | (28%) | | | |
| Fixed cost | | 15906 | 19638 | 42508 | | | |
| Total cost | | 102264 | 84451 | 107656 | | | *110487 |

Figures in parentheses are percentage of input-output coefficients and * indicates profit of the farming system.

at a 5 per cent level, so the Alternative hypothesis ($H_1$) is accepted as $\sigma^2 > 0$ and Null hypothesis ($H_0$) rejected, which means the efficiency factors best fit the model. The evaluation of the presence of inefficiency can be checked by the value of gamma ($\gamma$) and likelihood ratio (LR) value. The gamma ($\gamma$) value is 0.52, which is significant at a 5 per cent level, which indicates that the respondents of this farming system have not been able to reach 100 per cent efficiency. The variation of the error term in the model is caused by inefficiency, which is 52 per cent and the remaining 48 per cent is caused by random errors or noise. The likelihood ratio (LR) value (23.26) is higher than the critical value obtained from a table by Kodde and Palm (1986), which indicates that there is a statistical difference between the restricted model (OLS) without inefficiency term and the unrestricted model (MLE) with inefficiency term and unrestricted model is best fitted. Likewise, in the case of another farming system, the model is best fitted, as evidenced by the sigma-square ($\sigma^2$) value.

Veterinary charge (INR)/SAU is positively significant at a 1 per cent level of significance in the case of Dairy + Crop and Dairy + Fishery farming systems, which implies that as the veterinary charge increases by one per cent, normalised profit will increase by 0.79 per cent and 0.78 per cent, respectively. This region is vulnerable to extreme weather events such as floods and droughts. These events might lead to stress and disease in cattle. Salinity and freshwater shortages are very prominent in this region, which may be why contaminated water can lead to cattle disease. However, this is speculative and requires further

**Table 4:** Transaction matrix under dairy + crop + goat (D + C + G) farming system (INR/Ha/year).

| | | Consuming sectors | | | | Marketable | Total |
|---|---|---|---|---|---|---|---|
| | | Dairy | Crop | Goat | Household | surplus | returns |
| Producing sectors | Dairy | 7858 | 5161 | 0 | 18491 | 168444 | 199954 |
| | | (4%) | (2%) | (0%) | | | |
| | Crop | 12080 | 3757 | 0 | 70538 | 134282 | 220657 |
| | | (6%) | (2%) | (0%) | | | |
| | Goat | 0 | 2791 | 10995 | 11515 | 247571 | 272872 |
| | | (0%) | (1%) | (4%) | | | |
| | Household | 47076 | 32585 | 106702 | | | |
| | | (24%) | (15%) | (39%) | | | |
| Market-oriented input | | 81079 | 90356 | 55939 | | | |
| | | (41%) | (41%) | (21%) | | | |
| Fixed cost | | 29410 | 42882 | 9649 | | | |
| Total cost | | 177502 | 177531 | 183286 | | | *155165 |

Figures in parentheses are percentage of input-output coefficients and * Indicates profit of the farming system.

**Table 5:** Estimates MLE parameters of stochastic Cobb-Douglas profit frontier for different farming systems.

| Variable name | MLE | | | |
|---|---|---|---|---|
| | D+C | D+F | D+C+F | D+C+G |
| Constant | 7.81***(1.04) | 5.95***(1.21) | 5.22***(0.70) | -6.75***(0.92) |
| Feed price for dairy (INR) | 0.10**(0.05) | 0.18(0.35) | 0.08(0.25) | 0.15(0.14) |
| Veterinary charge (INR)/SAU | 0.79***(0.13) | 0.78***(0.12) | 0.12(0.11) | -0.09(0.10) |
| Labour wage (INR) | -0.16(0.32) | -0.11(0.16) | 1.17***(0.27) | 0.65***(0.19) |
| Seed price (INR) | -0.13(0.09) | - | -0.91***(0.24) | 0.49***(0.15) |
| Manures and fertiliser price (INR) | -0.28***(0.10) | - | -0.03(0.23) | 0.02(0.21) |
| Fingerling price (INR) | - | 0.18***(0.06) | - | - |
| Feed price for fishery (INR) | - | -0.08(0.41) | -0.72***(0.10) | - |
| Area under fishery (ha) | - | 0.38**(0.15) | -0.53***(0.10) | - |
| Area under crop (ha) | 0.40***(0.13) | - | 0.55***(0.13) | -0.24(0.14) |
| Farm fixed capital (INR) | -0.18***(0.09) | 0.13(0.11) | 0.11**(0.05) | 1.33***(0.10) |
| $\sigma^2$ | 0.10** | 0.20** | 0.03*** | 0.08** |
| $\gamma$ | 0.52** | 0.99** | 0.58** | 0.99*** |
| Log likelihood function | -4.01 | -5.61 | 10.72 | 19.60 |
| LR test of the one-sided error | 23.26 | 35.91 | 40.57 | 33.00 |
| Chi-square ($\chi^2$) critical value | 17.75 | 17.75 | 20.97 | 17.75 |

Figures in parentheses are standard errors; *Significant (P<0.1), **Significant (P<0.05) and ***Significant (P<0.01.

research. Some previous studies also found that veterinary charge positively impacts the farming system's gross return (Das *et al*., 2024; Pattihal, 2015). The coefficient of manures and fertiliser price (INR) is negative and significant at 1 per cent in the Dairy + Crop farming system. It implies that if manures and fertilizer prices (INR) increase by 1 per cent, profit will reduce by 0.28 per cent. Farmers use different size of fingerling in fishery farming and their quality and cost differ. This difference is prominent in fish enterprises of various scales. This point of view supports the result that if the fingerling price and area under fish farming increase by 1 per cent, profit will increase by 0.18 per cent and 0.38 per cent, respectively, in the Dairy + Fishery farming system. So, it says that in the Dairy + Fishery farming system, there is the scope for an increase in profit by increasing area distribution in the fish enterprise. Likewise, the area under crop (Ha) significantly positively affects the Dairy + Crop and Dairy + Crop + Fishery farming systems. Previous research also reports similar results (Patowary *et al.,* 2024; Lalrinsangpuii, 2017), where they reported that increasing the area under crop enterprise can be an option for some farming systems to increase profit.

### Farm-specific profit efficiencies

The frequency distribution of farm-specific profit efficiency in different farming systems is shown in Fig 3. The D+C farming system exhibited a relatively higher proportion of farmers with more profit efficiency levels compared to the other systems. The D+F system demonstrated a mean profit efficiency of 0.55, with a larger concentration of farmers falling within the 0.31-0.60 efficiency range. In contrast, the D+C+F and D+C+G systems displayed a higher concentration of farmers within the 0.61-0.90 efficiency interval, indicating comparatively better performance in terms of profit efficiency.

### Determinants of profit inefficiency

Table 6 shows the parameter estimates for the factors affecting profit inefficiency in different farming systems. Farming experience (year) and standard animal unit (SAU) are negatively significant in most farming systems, *i.e.*, as farming experience and SAU increase, profit inefficiency reduces (or profit efficiency increases). The study by Rahman (2003) supports this claim that farming expertise negatively impacts profit inefficiency. In the Dairy + Crop + Goat farming system, if farming experience increases by 1 unit, profit efficiency increases by 0.08 percentage unit. In Dairy + Fishery and Dairy + Crop + Fishery farming systems, age is positively significant, *i.e.*, high-aged persons are more profit inefficient than low-aged farmers. It interprets that fish farming requires good market information, proper species selection and, in some cases, new innovative

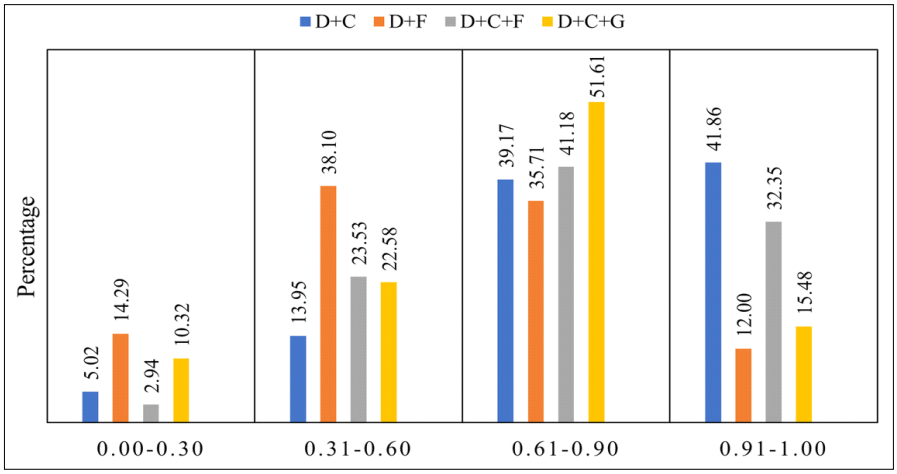



**Fig 3:** Frequency distribution of profit efficiency of different farming systems.

**Table 6:** Determinants of profit inefficiency for different farming systems.

| Variables | Coefficients | | | |
|---|---|---|---|---|
| | D+C | D+F | D+C+F | D+C+G |
| Constant | 2.90***(0.73) | -0.55(1.22) | 0.45(0.48) | 1.01(0.99) |
| Farming experience (year) | -0.05***(0.02) | 0.01(0.02) | -0.06***(0.02) | -0.08***(0.02) |
| Age (year) | -0.01(0.01) | 0.04***(0.02) | 0.03**(0.01) | 0.01(0.02) |
| Standard animal unit (SAU) | -0.47***(0.17) | -0.06(0.06) | -0.02(0.02) | -0.08*(0.04) |
| Education level (years of schooling) | -0.04(0.05) | -0.19(0.15) | -0.16(0.10) | 0.06(0.10) |
| Access to credit (Yes=1, No=0) | -0.07(0.24) | -0.22(0.28) | 0.10(0.21) | -0.17(0.29) |
| Access to extension service (Yes=1, No=0) | 0.26(0.24) | 0.16(0.35) | -0.27*(0.16) | -0.08(0.21) |

Figures in parentheses are standard errors; *Significant (P<0.1), **Significant (P<0.05) and ***Significant (P<0.01).

techniques for the fish enterprise. In that situation, lower-aged farmers may be motivated to apply the new technique compared to high-aged farmers.

## CONCLUSION

The current study provided significant insights into the economic performance of the four major dairy-based integrated farming systems that operate in the Coastal region of West Bengal. The analysis included the evaluation of linkage and profit efficiency. A significant contribution of the research is that it explores the economic performance of the different dairy-based integrated farming systems and the factors affecting profit efficiency and inefficiency. Among all the linkages of various enterprises, crop-to-dairy linkage in Dairy + Crop + Fishery (Input-output coefficient: 0.09) farming system was the strongest one. In all farming systems, crop-to-dairy linkage was stronger than dairy-to-crop linkage. Stochastic profit function revealed that in most farming systems, farm capital (INR) positively affected profit efficiency, where manures and fertiliser prices and seed prices were negatively related to the normalised profit. Farm experience, education level, access to credit and access to extension service were negatively associated with profit inefficiency.

In policy implication, as the number of the cross-bred cow was very less in saline areas, so breed improvement through the production of superior quality bulls, production of superior quality semen and an artificial insemination programme may be undertaken. Veterinary and extension services did not reach small and marginal farmers in remote areas. To address this issue, the suggested policy is establishing a comprehensive rural veterinary care to ensure accessible services for small and marginal farmers in remote areas which can increase profit efficiency among the farmers.

## ACKNOWLEDGEMENT

The present study was supported by the National Dairy Research Institute, Karnal, Haryana.

### Disclaimers

The authors' views are their own and do not reflect their institutions. They ensure accuracy but are not liable for any losses from this content's use.

### Informed consent

This study does not involve any experiments on animals. Therefore, ethical approval for animal use was not required.

### Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

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