



Profitability and Resource Use Efficiency of Different Farming Systems in Inland Salt-affected Areas of Haryana

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Abstract

The present study endeavors to evaluate the profitability and resource utilization efficacy across diverse farming systems in the inland salt-affected regions of Haryana, India. Our investigation encompasses three distinct categories of agricultural practitioners: shrimp farmers, proximal agriculture farmers, and distal agriculture farmers. A cohort of 90 farmers was meticulously selected from the Rohtak district of Haryana, with 30 representatives from each category, employing a purposive snowball sampling technique. Structured interviews, tailored specifically for this study, served as the primary data collection method. Employing a multifaceted analytical approach, we subjected the gathered data to rigorous scrutiny utilizing various statistical and econometric tools, including the Benefit-Cost Ratio (B-C ratio), Cobb-Douglas production function, and Data Envelopment Analysis (DEA). Our findings unveil the profitability of all examined farming systems. However, proximal agriculture farmers faced diminished benefits owing to the proximity of shrimp farming activities in adjacent areas, leading to a decline in soil productivity and subsequent yield reduction. Notably, feed costs emerged as the predominant expense, constituting 64% of total costs in shrimp farming, whereas labor costs dominated the expenditure for agriculture farming. Technical efficiency estimations using DEA revealed distal farmers to exhibit superior efficiency (0.88) compared to their shrimp (0.80) and proximal (0.69) counterparts. Similarly, distal farmers demonstrated greater cost-efficiency (0.72) in contrast to shrimp farmers (0.63) and proximal farmers (0.59). Allocative efficiency favoured proximal farmers (0.87), followed closely by shrimp farmers (0.84), while distal farmers exhibited lower allocative efficiency (0.68), indicative of achieving optimal output levels at minimum production costs. To mitigate production costs, farmers are advised to augment their knowledge and managerial acumen in optimizing farm inputs such as seeds, feed, chemicals/medicines, and labor. Additionally, implementing a judicious mix of cultivable species, stocking density regulation, and strategic crop combinations, alongside the presence of nearby feed mills, adoption of Best Management Practices (BMPs) and Good Aquaculture Practices (GAPs), scientific crop management approaches, and the integration of eco-friendly technologies, are plausible avenues for cost reduction. Furthermore, governmental oversight on effluent discharge from shrimp farms, coupled with the provision of effluent treatment facilities on a payment basis, is recommended. In sum, this study underscores the imperative of enhancing agricultural efficiency and sustainability in salt-affected regions, heralding a pathway towards resilient farming practices and enhanced economic prosperity.

Keywords:

Salt-affected land, Benefit-cost ratio, Cobb-Douglas production function, Data envelopment analysis, Technical, allocative and cost efficiency

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Introduction

The beginning of the 21st century is marked by environmental pollution, global scarcity of water resources, and increased soil and water salinization (Shahbaz and Ashraf, 2013). It is projected that by 2050, there will be 9.6 billion people on the planet, and feeding such a huge population will be an open challenge to food policymakers (Hertel, 2015). Currently, the global food production industry is facing difficulty meeting the demands of an ever-increasing population due to the reduced available land for cultivation and the effects of climate

change caused by anthropogenic activities (Kobayashi et al., 2015). Besides these, various environmental stresses like high winds, extreme temperatures, soil salinity, drought and flood have affected agricultural crop production, productivity and cultivation (Kumar and Sharma, 2020).

Soil salinity is also one of the most devastating environmental stresses, causing a reduction in cultivated land area, productivity and quality of crops by rendering significant chunks of land unproductive or less productive (Shahbaz and Ashraf, 2013; Kumar and Sharma, 2020) and is projected to increase in the future under climate change scenarios (Kumar and Sharma, 2020). In salt-affected soils, the salinity of the groundwater and soil is very high, which affects the agricultural output and soil quality by reducing nutrient content and enzyme activity (Xian et al., 2019), inhibiting crop growth, reducing productivity or making it unfit for any culture practices or may results in the abandonment of agricultural lands as well (Allan et al., 2001; Allan et al., 2009; Kaniewski et al., 2016).

According to some estimates, 1128 million ha of salt-affected land worldwide, and 52 million ha (4.60%) of that land is in South Asia (Mandal et al., 2018). In India, around 6.727 million ha (2.1% of the geographical area of the country area is salt-affected), of which 2.956 million ha is saline. The rest 3.771 million ha is sodic (Arora et al., 2016) and prevalent in coastal states and arid and semi-arid regions of Rajasthan, Haryana, Punjab, Uttar Pradesh, Delhi, and Rajasthan (Singh et al., 2020). Around 2.347 million ha of the salt-affected soils occur in the non-coastal Indo-Gangetic plains of the country, covering seven states, including Punjab, Haryana, Rajasthan, Bihar, Uttar Pradesh, Madhya Pradesh and Jammu and Kashmir (Arora et al., 2016) and 0.232, million ha of this land is found in Haryana.

The intensity of salinization ranges from little increment in the salt content of groundwater to completely becoming barren and not used for any cultural practice. In a landlocked environment, pumping out saline groundwater is essential to lower the water table to a safer root zone, which is a difficult task and can only be accomplished by expensive evapotranspiration (Doupe et al., 2003; Chhabra, 2017). This might be made economically feasible, though, by using aquaculture techniques that allow for vast amounts of water to be lost through evapotranspiration from aquaculture ponds while also producing high-value fish, prawn, and other species (Lakra et al., 2014; Akhlakur, 2017).

Inland saline aquaculture is the practical solution and a remedial approach to reduce salinity, increase productivity, and create economic opportunities for the farmers in the affected areas (Akhlakur, 2017). Aquaculture in saline areas has the potential to turn an economic and environmental threat into an opportunity with commercial and environmental benefits (Singh et al., 2020; Akhlakur, 2017) and has

been identified as the suitable and potential option for the utilization of inland saline lands and water resources. *Litopenaeus vannamei* is currently the most preferred cultured species for such systems (Allan et al., 2009; Akhlakur, 2017). In India, ICAR-Central Institute of Fisheries Education (CIFE) has developed a technology for culture of Pacific white shrimp (*Penaeus vannamei*) using inland saline groundwater (Lakra et al., 2014). Besides CIFE, Central Soil Salinity Research Institute (CSSRI) Karnal also has made vigorous efforts to demonstrate the practical feasibility of commercial fish culture in extreme saline environment at Haryana (CSSRI, 2014). CIFE Rohtak Centre at Lahli successfully tested the technology in salt-affected areas in Haryana in 2012-2013. The trials of ISA were initiated in 2014 in around 20 acres of Rohtak and Hisar districts of Haryana, in 2019 more than 450 farmers from different states have adopted the technology in about 1000 acres with production of 22,000 tonnes with average productivity of 2.2 tonnes/acre.

Shrimp farming is being done at par with agricultural crops in salt-affected soils. As inland saline aquaculture is a highly intensive culture practice, it is accompanied by positive and negative impacts on neighboring farms and the environment. From one end, it is regarded as a suitable and potential option for the utilization of inland saline lands and water resources as it converts the barren and idle lands into productive and fertile lands. On the other hand, this farming practice is accompanied by a reduction in the production and productivity of neighboring agriculture farms, more increase in land and water salinity, conflicts between farmers, and loss of biodiversity. Therefore, the present study attempted to unveil the profitability and resource use efficiency in different farming systems and suggest suitable measures for the better utilization of available resources to increase production, efficiency, and farm income.

Methodology

The study was conducted in the Rohtak district of the northern state of Haryana during 2021-2022, where inland saline aquaculture (ISA) has been practiced in inland saline salt-affected areas for the last decade. Rohtak district was selected for the study due to its significant prevalence of salt-affected land and its historical association with the inception of inland saline aquaculture in India. This provides an ideal environment to investigate the impacts of shrimp farming on agricultural practices. Also, it can effectively analyse the interplay between shrimp aquaculture and agriculture, offering valuable insights into sustainable land management practices and potential synergies between the two sectors. Three different categories of farmers were selected and the categorization was done based on the type of farming activity and location of the agriculture farm with reference to the shrimp farm. The categories include shrimp farmers (farmers doing only shrimp farming or

both shrimp farming along with agriculture/ horticulture side by side), proximal agriculture farmers (agri-farmers adjacent to shrimp farmers with a distance of less than 100 meters from shrimp farm) and distal/ farmers (farmers doing only agriculture farming and are at a distant place from the shrimp farmers with a minimum distance of more than 100 meters from nearby shrimp farm). From each category, 30 farmers were selected, making a total of 90 respondents. All the farmers were purposively selected; first, a shrimp farmer from any part of the selected area was selected, and then the proximal and distal agri-farmers were selected accordingly. In the case of shrimp farmers, priority was given to farmers with prior experience in shrimp farming (second year of culture period onwards). The farmers were selected through purposive snowball sampling and using a structured interview schedule; the data was collected on socioeconomic aspects, cost-returns, profitability, and economic efficiency from all the farmers. It is to be noted that the selected farms had the same topographical, geographical, and environmental conditions; however, the presence of shrimp farmers in the adjacent areas was the only differentiating parameter between proximal agriculture farmers and distal agriculture farmers.

Estimation of economic parameters - Cost, revenue and profitability analysis

A farm business analysis was performed to determine the costs and returns involved in shrimp farming and agriculture. The cost of cultivation comprises fixed and variable costs. Total variable costs (TVC) consisted of the costs for the land lease, seeds, feed and fertilizer, fuel (diesel and electricity), labour, agrochemicals, and medicines (including mineral amendments), and interest on working capital at the rate of 12% per annum (Dhande et al., 2023). Fixed costs consisted of annual depreciation on fixed assets (20% for shrimp farming and 8% for agriculture farming), calculated by straight-line method, and interest at 12% per annum on fixed capital assets following Pandey et al., (2023) (investment on pond construction, bore well, electricity connection; and purchase of motor pump set, generator, aerators and other accessories). Yield is the sum of the quantity of the shrimp harvested (Kg/acre) and crops harvested (Kg/acre) at the end of the culture period/ crop season. The gross revenue was calculated by multiplying the total quantity of farm produce with respective farm-gate prices. The financial profitability was calculated by assessing the gross profit (GP), net return or profit (NP), net profit/Kg benefit-cost ratio (BCR), described by Shawon et al., (2018) and Pandey et al., (2023) using the following formulae:

Gross profit (GP) = Gross revenue (GR) – Total variable costs (TVC)

Net return or profit (NP) = Gross revenue (GR) – Total operational costs (TC)

Net profit/Kg = Sales price/Kg – Operational

cost/Kg

Benefit – cost ratio (BCR) = Gross revenue (GR) ÷ Total operational costs (TC)

Factors affecting farmers' income

After estimating the profitability in the different farming systems, factors that are affecting farm income were also analysed by using the Cobb-Douglas production function which is being widely employed in agriculture and allied sectors to determine the technological relationship between the amounts of inputs used and output produced (Nisar et al., (2017); Mugaonkar et al., (2019), Radhakrishna et al., (2021) and Dhande et al., (2023)). Symbolically, the production function is explained as follows;

$$\ln Y_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3$$

$$\ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \mu_i$$

where $\ln Y_i$ is the log of output predictor variable, i.e., gross income; $\ln X_i$ is the log of explanatory variables such as, cost of seeds, feeds/ fertilizer, medicines, agro-chemicals, labour and fuel. β_0 and β_i are the intercept and slope respectively. μ_i is the random errors which are randomly, identically, and normally distributed with mean zero and variance σ^2 . The production function assumes constant return to scale (if $\sum \beta_i = 1$), decreasing return to scale (if $\sum \beta_i < 1$), and increasing return to scale (if $\sum \beta_i > 1$). Goodness of fitted model was assessed by the value of coefficient of multiple determinations (R^2) with adjusted R^2 . More the R^2 value, higher the predicting power of the model will be.

Efficiency among different farming system

The Data Envelopment Analysis (DEA) has been used to assess the efficiency of farmers. DEA is a nonlinear approach for evaluating the performance of decision-making units (DMUs), i.e., farmers, which use a set of inputs to produce a set of outputs (Boussofiane et al., 1991). The DMUs refer to any entity (farmers) that is to be evaluated in terms of its abilities to convert inputs into outputs (Bessent et al., 1983). The efficiency of each DMU is measured in terms of a proportional change in inputs or outputs (Charnes et al., 1997; Al-Durgham and Adeinat, 2021). An input-oriented model, which minimizes inputs while keeping the output unaltered with an assumption of constant returns to scale was used (Charnes et al., 1978). The different efficiencies in DEA are;

Technical efficiency: It refers to the physical relationship between quantities of inputs used to output produced. It reflects the ability of a firm to obtain maximum output from a set of inputs. A farmer is said to be technically efficient if he can produce a given quantity of output at a lowest opportunity cost.

Allocative efficiency: It is the ability of the farmer to use a mix of inputs to produce a desired quantity of

output. It reflects the ability of a firm to use the inputs in optimal proportions, given their respective prices.

Cost efficiency: It is considered as the ability of a producer farmer to use combination of inputs in such a way that the same level of output can be achieved without increasing the inputs/input cost.

Let there be data on K inputs and Q outputs for each DMU consisting of a total of N DMUs. For the i th DMU, these inputs and outputs are represented by the vectors x_i ($K \times N$ input matrix) and y_i ($M \times N$ output matrix), respectively. The θ is a scalar and λ is a $N \times 1$ vector of constants such that the model can be written as:

$$\min_{\theta, \lambda} \theta$$

$$\text{Subject to } -y_i + \sum \lambda_j y_j \geq 0, \theta x_i - \sum \lambda_j x_j \geq 0, \lambda_j \geq 0,$$

The value of θ obtained will be the efficiency score for the i th DMU which usually lies between 0 and 1. The DEA model will construct a non-parametric envelopment frontier over the data points such that all observed points lie on or below the production frontier. Now, suppose that there are ' N ' DMUs, who are producing one output (quantity of fish produced per ha) by using three inputs, namely quantity of seed (no./ha), feed (kg/ha), and total labour days along with their respective prices, then the above DEA model can be worked out for ' N ' DMU given as under:

$$\min_{\theta, \lambda} \theta$$

$$\text{Subject to } -y_i + (y_1\lambda_1 + y_2\lambda_2 + \dots + y_n\lambda_n) \geq 0,$$

$$\theta x_{1i} - (x_{11}\lambda_1 + x_{12}\lambda_2 + \dots + x_{1n}\lambda_n) \geq 0, \dots$$

$$\theta x_{3i} - (x_{31}\lambda_1 + x_{32}\lambda_2 + \dots + x_{3n}\lambda_n) \geq 0$$

$$\lambda_j \geq 0,$$

where $\lambda = (\lambda_1, \lambda_2, \lambda_n, \dots, \lambda_n)'$ are $N \times 1$ vector of constants.

A computer-based program, called Data Envelopment Analysis Program (DEAP version 2.1) developed by Coelli (1996), has been used to obtain technical, allocative, and cost efficiencies of farmers.

Results and discussion

Demographic profile

The socioeconomic characteristics of the farmers are presented in Table 1. It was observed that the majority of the shrimp farmers and proximal agriculture farmers (83.33% and 90%, respectively) were adults aged between 35-59 years. In contrast, in the case of distal agriculture farmers, the majority (76.67%) of farmers were elderly people belonging to the age group of >59 years and the rest (23.33%) were adults. Distal agricultural farmers were elderly people with a mean age of 48.33 years; proximal agriculture farmers had a

mean age of 45.27 years, and shrimp farmers had a mean age of 42 years. The age profile of shrimp farmers shows that they are comparatively younger than agriculture farmers who started their business at a young age, as they are physically strong and can shoulder more family responsibilities and as youngsters, they have also more risk bearing abilities. The implication is that the farmers with more farming experience and who are older are more technically efficient, which may be due to the reason that with experience, the farmers are better able to cope with the limitations that hinder productivity and reduce the errors in farming (Yusuf and Malomo, 2007). Most farmers (93.33% shrimp and 100% agriculture farmers) followed the Hindu religion, and the majority were married. The majority of the farmers (56.67% shrimp farmers and proximal agriculture and 60% distal agriculture farmers) were living in joint families with an average family size of six members. Nisar et al. (2022), in their study on carp culture in Kashmir found that an increase in family size decreases efficiency as more family members indulge in farming practices and ultimately reduces the dependence on hired skilled labour, thus increasing inefficiency. The majority of the farmers (45%) were educated at least up to the secondary level, followed by a higher secondary level (30%). Very few farmers were illiterate; however, the percentage of farmers with primary and graduation level education was also less (12% for both). However, the different farmer categories were similar in their mean years of schooling, which was ten years for all the farmers. Dhande et al., (2023) in the study on polyculture of fishes in Andhra Pradesh found that most respondents were adults in the age group of 41-50 years with varying levels of education and mostly living in nuclear. In their study, Yusuf and Malomo (2007) found that the technical efficiency of farmers was positively affected by education.

The majority of the farmers (100% proximal agriculture farmers, 90% distal agriculture farmers, and 53.33% shrimp farmers) had agriculture as their primary occupation, while 36.67% of the shrimp farmers had shrimp farming as their primary occupation. Also, few farmers were primarily involved in business and government jobs as well. The details of the land holdings owned by the farmers show that the farm area of shrimp farmers was more (18.05 acres) than the agriculture farmers (10 acres). As per the farm area, most of the farmers fell into small and medium farmer categories, which are easy to handle and manage, as shown by the studies of Sharma et al., (1999) and Yin et al., (2005), where the technical efficiency of the farms decreases as the size increases. Around 48% of the land (8.05 acres) possessed by the shrimp farmers was used for shrimp culture. Since shrimp farming has been introduced recently in the salt-affected soil of Haryana, the experience of farmers in shrimp farming ranges from two to nine years, with an average experience of 5 years.

Table 1: Demographic profile of farmers

Particulars	Category	Percentage		
		Shrimp farmers	Proximal agriculture farmers	Distal agriculture farmers
Age	Young (<35 years)	16.67	3.33	0.00
	Adults (35-59 years)	83.33	90.00	23.33
	Elderly (> 59 years)	0.00	6.67	76.67
Religion	Hindu	93.33	100	100
	Sikh	6.67	0.00	0.00
Marital status	Married	90.00	100.00	96.67
	Unmarried	10.00	0.00	3.33
Family Type	Nuclear	43.33	40.00	43.33
	Joint	56.67	60.00	56.67
Education	Illiterate	3.33	0.00	0.00
	Primary	6.67	23.33	6.67
	Up to secondary	43.33	46.67	43.33
	Higher secondary	30.00	23.33	36.67
	Graduation	16.66	6.67	13.33
Primary occupation	Shrimp farming	36.67	0.00	0.00
	Agriculture	53.33	100.00	90.00
	Business	6.67	0.00	6.67
	Job	3.33	0.00	3.33
Total size of farm area owned (acre)		18.55	10.87	11.5
Area under agriculture (acre)		8	10.67	11.27
Area under shrimp farming (acre)		12.22	0	0

Financial profitability of different farming systems

The details of various costs incurred by farmers in different farming systems of Rohtak, Haryana are given in Table 2. The total costs incurred in the farming activities were classified into two major categories: variable costs and fixed costs. In the case of shrimp farming, a depreciation value of 20% per annum and interest on the fixed capital investment of 12% per annum were considered for the study following Pandey et al., (2023), while in the case of agriculture farming, depreciation value of 8% per annum and interest on the fixed capital investment of 12% per annum following Dhande et al., 2023. In shrimp farming, the depreciation rate is higher than in agriculture because of more wear and tear due to continuous usage of assets in shrimp farming, while in agriculture, due to

less usage, there is minor wear and tear and thus low depreciation. Various expenditures considered for calculating the fixed cost for shrimp farming include farm machinery, pond preparation, generators, borewells, and aerators. Agriculture includes expenditure on farm machinery, borewells, and lease value. In case of variable cost expenditures in shrimp farming include feed cost, seed (PL) cost, medicine cost, labor cost, fuel cost, and interest payable on working capital, while in agriculture, it includes fertilizer cost, agrochemical cost, labor cost, fuel cost and interest payable on working capital. In shrimp farming, initial investments in infrastructure like aerators and pond preparation drive up production costs. The ongoing need for inputs such as electricity, aeration, and feeding further adds to these expenses, making it a costly endeavour (Miao and Wang, 2020).

Table 2: Economics and profitability of different farming systems

Cost Types	Cost Details (Rs.)	Shrimp farmers	Proximal farmers	Distal farmers
Fixed cost	A1. Depreciation on fixed investment	63,114	7,168	9,286
	A2. Interest on fixed capital	37,868	9,557	8,918
A. Total fixed cost (A1+A2)		1,00,982	16,724	18,204
Variable cost	Seed cost (INR 0.65/PL8 seed)	59,555	1,743	1,581
	Feed/ Fertilizer cost	3,43,873	39,88	3,247
	Medicine/ Agro-chemicals and pesticides	27,073	3,763	3,231
	Labour charges	29,926	16,173	12,863
	Fuel - diesel and electricity expenses	57,474	4,904	3,562
	Interest on working capital @12%/ year	64,300	2,326	1,832
	Land leasing cost (INR)	17,935	0	0
B. Total Variable Cost (TVC)		6,26,723	32,898	26,316
Total Operational Cost (A+B)		7,27,705	49,622	44,520
Gross Profit	Gross Revenue (GR)	13,59,098	91,365	1,06,702
	Total Variable cost (TVC)	7,27,705	49,622	44,520
	GP (GR-TVC)	6,31,393	41,743	62,182
Net Return	GR-TC	7,32,376	58,467	80,387
Net profit Per kg	Area in acre	12.22	10.67	11.27
	Production per acre in tons	3.32	3.653	4.51
	Total production in kg	3320	3653	4510
	Sale Price per kg	397.23	24.43	24.43
	Total operation cost	7,27,705	49,622	44,520
	Operational Cost per Kg	219.19	13.58	9.87
	NP/Kg	178.04	10.85	14.56
BCR	GR/TC	1.87	1.84	2.40

In the case of shrimp farming, from the total average per acre expenditure on fixed cost (Rs. 3.156 lakhs) assets, 47% of the share was from aerators (Rs.1.45 lakhs), and 40% expenditure was on pond preparation (Rs.1.30 lakhs) and rest from borewell and others. A significant investment in shrimp farming was made in aerators since each pond is about one hectare and requires at least four aerators to maintain the required supply of oxygen. In the case of agriculture farms, the fixed costs include the investments made in farm machinery and borewells, while the variable costs include the investments made in fertilizers, agrochemicals, labor, fuel, and interest payable on working capital. A significant investment in agriculture is being made in farm machinery -tractors, ploughs,

weeders, etc., frequently used for farming activities. In proximal agriculture farmers, the average per acre expenditure on fixed assets was Rs.1.18 lakhs, and more than 90% of the investment was used for farm machinery (Rs. 1.10 lakhs) and the rest on the borewell and other equipment. While in distal farmers, the per acre expenditure made on the fixed assets was Rs.1.29 lakhs, and here also, a significant share was spent on farm machinery (Rs. 1.17 lakh, 91%) followed by borewell (8%).

The details of different costs taken under variable costs are also shown in Table 2. In shrimp farming, all the nutritional requirements of the shrimp have to be supplied from external feeding. Vannamei feed is

expensive at Rs. 94 per kg due to the high protein and fat content required for shrimp nutrition. Of the total variable cost per acre basis (Rs. 6.26 lakhs), the expenditure on feed was the highest (Rs. 3.4 lakhs) and contributed around 64% to the total variable cost, followed by seed (PL-8 onwards), where the total expenditure was Rs. 59,555 which contributes about 11.5 % of the total variable cost. Other variable costs include the cost of fuel and electricity, medicinal costs, labor costs, etc. In the case of agriculture, the labor cost shares almost half of the share in the variable costs (49.61%) for both proximal and distal agriculture farmers because of their involvement in all activities from farm preparation to crop harvesting. The expenditure on fuel and electricity is also more variable cost as most of the farmers were using diesel motor-driven borewells to irrigate their fields. The expenditure on fertilizers and agrochemicals like fungicides, insecticides and pesticides also significantly contributes to the variable cost. Nisar et al., 2021 in their study found that major investment in shrimp farming was being made on feed and along with seed and labour it affected the production.

The average yield in the shrimp farming system was overwhelming, with 3.32 tons per acre (3320 kg), possibly because of more experience in shrimp farming, easy access to lab facilities, and no occurrence of diseases. Since vannamei is a highly demanded

commodity in foreign markets, it also fetches a reasonable farm gate price, and the average price per kilogram of vannamei was Rs. 397.23. In the case of agriculture farmers, rice and wheat were the major agricultural crops grown, and every farmer used to produce these crops alternatively in addition to mustard, sugarcane, and cotton. While calculating the economics of agriculture farms (both proximal and distal), we have only focussed on their major cropping pattern, i.e., paddy and wheat. For proximal agriculture farmers, the average production was 3.653 tons/acre (3650 Kg), and for distal agriculture farmers, the average production was 4.51 tons/acre (4510 kg); however, the aggregate price per kilogram was Rs. 24.43. The lower productivity of proximal farmers than distal farmers can be attributed to the decline in production by the negative effects of shrimp farming as they are adjacent to the shrimp farmers and are getting affected by the direct discharge of effluents since the rest of the topographical and geographical condition are similar in the area. The estimated acre wise gross returns of shrimp farmers were Rs. 13.60 lakhs with a net return of Rs. 7.32 lakhs. In contrast, distal agriculture farmers had received a per acre gross return of Rs. 91,365 with a net return of Rs. 58,467, while the lowest values were for proximal agriculture farmers with a gross return of Rs. 1.06 lakh and a net return of Rs. 80,387. The benefit-cost ratio (BCR) of farming, which is the ratio of gross returns and total

Table 3. Factors affecting farmers' income

	Shrimp farmers			Proximal agriculture farmers			Distal agriculture farmers		
	β	Std. Error	Sig.	β	Std. Error	Sig.	β	Std. Error	Sig.
(Constant)	-.044	1.157	.970	-2.973	2.407	.222	-2.117	2.019	.299
Seed cost	.047	.326	.885	0.42	.309	.861	0.44	.329	.807
Feed Cost	1.038	.420	.017	-.597	.600	.324	.517	.320	.112
Medicine Cost	.008	.130	.951	-.068	.403	.867	-.109	.380	.775
Labour cost	-.015	.109	.891	.394	.661	.554	.534	.713	.457
Fuel cost	-.042	.163	.799	1.670	.502	.002	.390	.537	.470
Model Summary									
R			.913 ^a			.720 ^a			.727 ^a
R Square			0.834			0.519			0.529
Adjusted R Square			0.818			0.484			0.494
F value			54.208			14.838			15.133
Sig.			<0.01			<0.01			<0.01

costs, was calculated. For shrimp farming, BCR was 1.87, which means that for every one-rupee investment, there will be a return of 1.87 rupees. For proximal agriculture, the BCR was 1.84, while it was highest for distal agriculture farmers with a value of 2.40. The low BCR values for proximal farmers can be attributed to their low production because of shrimp farms adjacent to them. From the values of BCR, it can be inferred that all the farming systems are highly profitable, with distal farmers being at the top and proximal farmers at the lowest, while for shrimp farmers, it was in between the two. Thus, it is concluded that shrimp farming must not be promoted inadvertently without thinking about the consequences it has on agri-productivity as empirically proved by looking at economics of proximal farmers. Dhande et al., (2024), also reported that farming in inland low saline water is profitable for different farmer categories and net returns are proportional to the area under culture.

Factors affecting farm production and farmers income

The factors affecting the productivity of farms and farm income were analysed with the help of the Cobb-Dougllass production function, which is being widely used in agriculture and allied sectors to determine the technological relationship between the amounts of inputs used and output produced. The results of the production function are summarized in Table 3.

Results of Cobb-Douglas production function for shrimp farmers revealed that from all the variable costs, expenditure on feed only had a significant effect on shrimp farming income. The coefficient value for feed connotes that a unit increase in the quantity of feed leads to weight gain in shrimp, increasing the shrimp production and, thereby, farmers' income. The predictability of the fitted model (R^2) was found to be 0.864 (86%); hence, it is the best fit. The sum of elasticity coefficients (β) found to be 1.037 implies that shrimp farming exhibits constant returns to scale which means that increase in inputs results in a proportional increase in outputs. For proximal agriculture farmers, the results reveal that only fuel expenditure had a significant effect on agriculture farming income. The sum of elasticity coefficients (β) was found to be 1.399 and implies that proximal agriculture farmers exhibit increasing returns to scale. For distal agriculture farmers, all the regressors, viz fertilizers, agrochemicals, labor, and fuel, did not show any significant effect on the income of distal agriculture farmers. However, it can be inferred that the negative value of elasticity coefficients (β) for agrochemicals depicts that an increase in investment will lead to a proportionate reduction in net returns. As for fuel and labor, the coefficient of elasticity (β) shows positive values for both states, which means that an increase in investment in them will have a positive effect on production and net returns. The sum of elasticity coefficients (β) was found to be 1.333 and

implies that distal agriculture farmers exhibit increasing returns to scale. Srinivasan (2012); Kumar and Singh (2019) and Dhande et al., (2023) in their respective studies, reported constant returns to scale in paddy cultivation in Kerala and Andhra Pradesh. Dhande et al., (2023) in their study found that the polyculture was exhibiting a decreasing return to scale in Andhra Pradesh. Nisar et al., 2021 observed that aquaculture exhibited decreasing returns to scale for *Penaeus monodon* and *Litopenaeus vannamei* farming in India. However, Mugaonkar et al., (2019) observed an increasing return to scale in pangasius fish culture in Andhra Pradesh. Also, it was observed by Dhande et al., (2023) that feed had a positive effect on the production and income of farmers in carp culture, while as Nisar et al., (2017) found that in Jammu and Kashmir, labour had a positive effect on income of fish farmers. Safadule et al., (2013) found that cost of seed, quantity of feed, and culture period were the most pertinent factors for determining the production of shrimp in Maharashtra. While as Shrivastav et al., (2017) found that there was inverse association between yield and cost of production in all the agricultural crops of India

Efficiency of farmers in different farming systems

Data Envelopment Analysis (DEA) was employed to investigate the efficiencies of different farming systems under the assumption of constant returns to scale. DEA facilitates us to classify the farmers based on their cost, allocative, and technical efficiency. The allocative efficiency of each farmer under different farming systems was obtained by estimating the cost efficiency and technical efficiency. The cut score for efficient farming was decided following Nisar et al., 2017 and Dhandi et al., (2023), where the efficiency scores range from 0 to 1. A score of 0.7 - 1 is considered as efficient, 0.5 - 0.7 is considered as moderately efficient, and <0.5 is considered as less efficient or inefficient. The results for different efficiencies under different farming systems are discussed in Table 4.

The technical, allocative, and cost efficiency scores denoted in Table 4 are found to vary in different ranges among farmers depending upon their farming skills, experience, and use of a combination of various inputs. From the table, it can be inferred that the technical efficiency of the majority of the shrimp farmers and distal farmers (96.67%) is the same and lies in the range of 0.71-1, which means that their technical efficiency is high. In the case of proximal farmers, the technical efficiency scores depict that half of the proximal farmers (50%) have a moderate level of technical efficiency lying in the range of 0.51-0.7, while only 23.31% have high efficiency lying in between 0.71-1 and rest (26.64%) were least efficient.

The cost efficiency of the majority of the shrimp farmers (60%) and distal agriculture farmers (60%) is in the range of 0.71-1, which means that they are highly cost-effective. In comparison, a significant portion of shrimp farmers (36.63%) and distal

agriculture farmers (33.33%) were moderately cost-efficient, and the rest were less efficient. In the case of proximal farmers, the cost efficiency scores depict that half of the proximal farmers (50%) were moderately cost efficient while 42.33% had high-cost efficiency and 6.66% were least cost-efficient. Farmer category-wise details reveal that shrimp farmers were comparatively more efficient in their cost efficiency while the cost efficiency of proximal farmers is less possibly because they are struggling with poor yield and higher inputs due to salt affected soils.

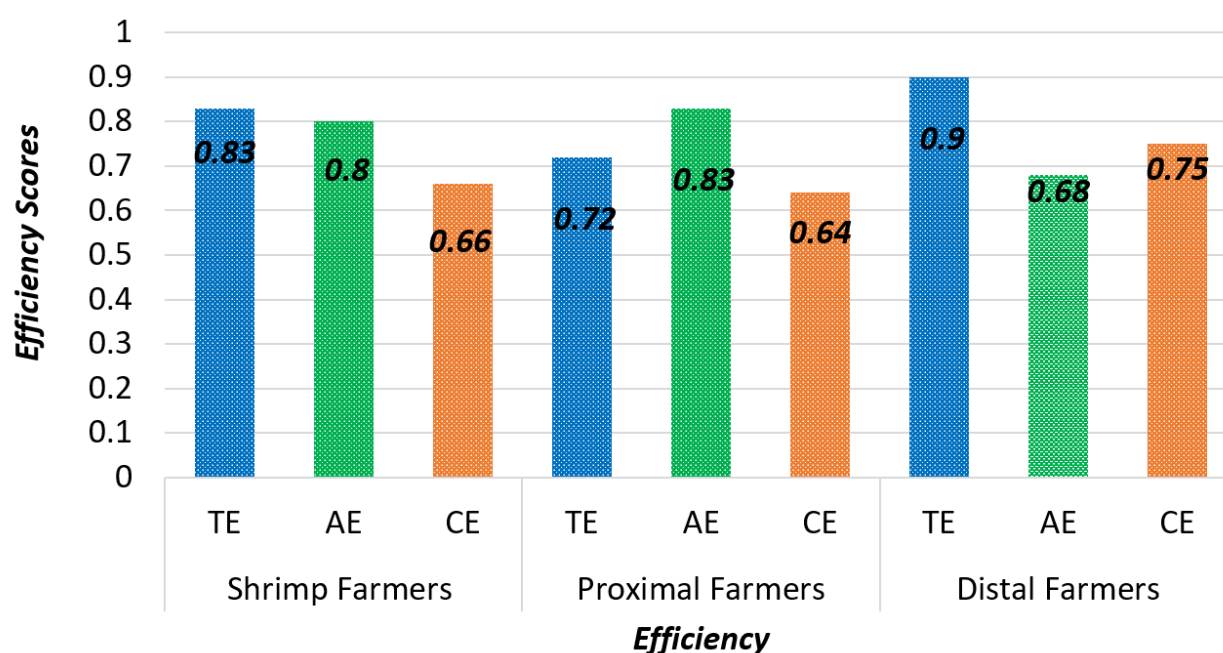
The allocative efficiency of farmers was calculated to see how efficiently the resources have been allocated in different farming activities. It has been found that for the majority of the farmers from all three

categories (96.67% shrimp farmers, 83.33% proximal agriculture farmers, and 70% distal agriculture farmers), the allocative efficacy scores lie between 0.71-1, i.e., their allocative efficacy is high. Meanwhile, only 3.33% of shrimp farmers, 16.56% of proximal agriculture farmers, and 26.65% of distal agriculture farmers were moderately efficient, with efficiency scores ranging between 0.51-0.7. It is pertinent to mention here that only 3.3% of distal farmers have less allocative efficiency, and no other farmer had allocative efficiency scores less than 0.5. This can be attributed to their higher technical efficiency and lower cost efficiency.

Fig.1 summarizes the efficiencies of different farming systems, and it is visible that the cost efficiencies are

Table 4: Technical, allocative and cost efficiencies of farmers

Range	Technical Efficiency Scores			Allocative Efficiency Scores			Cost Efficiency Scores		
	Shrimp farmers	Proximal farmers	Distal farmers	Shrimp farmers	Proximal farmers	Distal farmers	Shrimp farmers	Proximal farmers	Distal farmers
<0.5	-	8 (26.64)	-	-	-	1 (3.33)	1 (3.33)	2 (6.66)	2 (6.66)
0.51 - 0.70	1 (3.33)	15 (50)	1 (3.33)	1 (3.33)	5 (16.65)	8 (26.65)	11 (36.63)	15 (50)	10 (33.33)
0.71 - 1.00	29 (96.67)	7 (23.31)	29 (96.67)	29 (96.67)	25 (83.33)	21 (70)	18 (60)	13 (42.33)	18 (60)
Sample size (n)	30	30	30	30	30	30	30	30	30



(TE = Technical Efficiency, AE = Allocative Efficiency, CE = Cost Efficiency)

Fig. 1. Average technical, allocative, and cost efficiency score of farmers

comparatively lower than technical efficiency and allocative efficiency for different farming categories. In the case of technical efficiency, distal farmers are more efficient (0.88), followed by shrimp farmers (0.80), while proximal farmers have less technical efficiency (0.69). It suggests that distal farmers could have produced the same level of output with 12% fewer inputs or indicating that the farms achieved 88% of the maximum possible output from a given set of inputs. Similarly, there was the possibility of reducing inputs by 20% for shrimp farmers and 31% for proximal agriculture farmers. Kumaran et al., (2016) in their study found also that the mean technical efficiency of vannamei farms in India was 0.90, and indicated that shrimp stocking density, feed quantity and its management, cropping intensity, and duration of the culture were the significant determinants of TE. Similar results were reported by Zhang et al., (2022) where the estimated technical efficiency was 98% for Jammu and 97% for Kashmir in polyculture of exotic carp. Dhande et al., (2023) also reported that the technical efficiency score of polyculture farmers in Andhra Pradesh was found to be 82%.

Cost efficiency or economic efficiency is the combination of technical and allocative efficiencies. Also, in the case of cost efficiency, distal farmers are more cost efficient (0.72), followed by shrimp farmers (0.63), and proximal farmers (0.59), having less cost efficiency. The allocative efficiency was higher for proximal farmers (0.87), followed by shrimp farmers (0.84), while distal farmers had less allocative efficiency (0.68). It shows that farmers must use a combination of inputs (feed, seed, labour, etc.) to produce the same level of yield at the lowest possible cost of production.

However, Sharma et al., (1999) reported that allocative efficiency and cost efficiency in Chinese polyculture were 0.87 (87%) and 0.74 (74%), respectively. In contrast, Zhang et al., (2022) estimated allocative efficiency as 92% and 84% with cost efficiency as 0.75 (75%) and 0.74 (74%) for Jammu and Kashmir, respectively in polyculture of exotic carp. In Andhra Pradesh, Dhande et al., (2023) found that the cost efficiency and allocative efficiency of polyculture carp farms were 0.65 (65%) and 0.81 (81%), respectively.

Farmers, in order to reduce the cost of production, are suggested to acquire knowledge and managerial skills on efficient use of farm inputs such as seed, feed, chemicals/ medicines, and labour. The scientific mix of cultivable species, stocking density and proper combination of crops for the efficient use of resources, availability of feed mills in the nearby areas, adopting BMPs and GAPs for shrimp farming, scientific crop management strategies, and use of ecofriendly technologies are probable ways to reduce the cost of production. Government should put a checkmark on the effluent discharge from the shrimp farms as they are using the aqua-chemicals inadvertently which further deteriorates the effluents. Besides, they should provide them with facilities for the effluent treatment

on a payment basis as it was seen during data collection that none of the shrimp farmers follow this ETP rule etc

Conclusion

This study compares the profitability and efficiencies of different farming systems in inland salt-affected areas of Haryana. Shrimp farmers, proximal agriculture farmers, and distal agriculture farmers were the three farming categories taken for this study. The BCR results revealed that all the farming systems are profitable. Cost analysis depicts that for shrimp farmers, the major cost was on feed (64%), while in the case of agriculture, the major expenditure was on labour (50%), and these factors significantly affected the farmer's income. Cobb-Douglas production function reveals that shrimp farming exhibits constant returns to scale, and agriculture farmers exhibit increasing returns to scale. In the case of technical efficiency, distal farmers were more efficient (0.88), followed by shrimp farmers (0.80), and proximal farmers (0.69) with less technical efficiency. Also, in the case of cost efficiency, distal farmers are more cost efficient (0.72), followed by shrimp farmers (0.63), and proximal farmers (0.59), having less cost efficiency. The allocative efficiency was higher for proximal farmers (0.87), followed by shrimp farmers (0.84), while distal farmers had less allocative efficiency (0.68). To maintain farmers' technical efficiency, it is recommended that the extension organizations instruct the farmers on input optimization, energy conservation, and better management practices. Ensuring disease-free seed supply, cost-effective feed and fertilizers, proper supply of electricity to shrimp farms, and popularising HDPE (high-density polyethylene) lining of pond bottom would aid in sustaining the efficiencies of production and sustainability of the farming system in inland salt-affected areas. This will also reduce the negative externalities of shrimp farming on the adjacent farmers and nearby surroundings. Besides this, the government should put a tick mark on the effluent discharge from shrimp farms and provide them with facilities for the effluent treatment on a payment basis; farmers are advised to acquire knowledge and managerial skills on optimal use of farm inputs such as seed, feed, chemicals/medicines, and labour in order to lower the cost of production.

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