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Economic Analysis of Dryland Integrated Production System in Western Agroclimatic Zone of Tamil Nadu, India: A DEA Approach

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ABSTRACT

Background: Efficiency of production system is calculated by the input spent to amount of output produced. The Agronomic efficiency has been found to be below 48% than the world efficiency standard of 40 kg ha^{-1}. The average fertilizer usage of India is 133 kg ha^{-1}, 232% higher than the global standard fertilizer of 40 kg ha^{-1}. The certified seeds and agriculture machinery usage has been increased by 15% and 13% in India but the efficiency of farm stays behind.

Methods: With this back ground the present study applied cost approach variable return to scale Data Envelopment Analysis (DEA) model to evaluate the Indian farms resource using 200 rural farms of Tamil Nadu state. The data envelopment analysis models have the advantage of simultaneous measure of technical, allocative and cost efficiency of the individual farms.

Result: The cost efficiency among the respondents ranged from 0 to 1 with a mean efficiency of 0.66. The study found that Decision-Making Units (DMU) have cost inefficiency, suggesting that most of the DMU operated very far away from the efficiency frontier. Allocative inefficiency (0.55) is worse than the technical inefficiency (0.80), implying that the lower economic efficiency is the result of high allocative inefficiency.

Key words: Allocative efficiency, Data envelopment analysis (DEA), Dryland farms, Economic efficiency, Integrated production system (IPS), Technical efficiency.

INTRODUCTION

Efficiency is concerned with performance of the farm which transforms input into output. The measurement of efficiency is important because it is a success indicator for transformation of given input to the output. The farm inputs mainly denote the seeds, fertilizers, machine and human labour. In India, farm machinery, equipment, human labors and seed availability is higher (Anonymous, 2022). However major decline was observed with the farmer creditability and soil fertility (Anonymous, 2021). Individual to get a yield of 1000 kg, Indian farms need to be supplied the fertilizer amount equal to 74 kg, higher than the global average (50 kg/1000 kg). It is shocking to find that efficiency of farms is low while the farms can meet its own fertilizer requirement through proportionate livestock number.

The production efficiency of farms can be measured technically, allocatively and economically. These three measures of production efficiency give overview of farmers' resource utilization in the production process. The technical efficiency is the ability of farm to produce maximum possible frontier. Allocative efficiency is the farmers' ability to produce output with cost minimizing input values. Economic efficiency is the farmers ability to produce target quantity of output at minimum cost of available technology. Economic efficiency is the product of technical and allocative efficiency (Bhat and Bhat, 2014). This study uses the cost approach, variable return to scale data envelopment analysis models. The model offers flexible approach with the use of diverse data and provide information on decision variables acting at optimum scale or others, respectively.

The major crop cultivated in dryland area of western zone of Tamil Nadu was sorghum. Nearly 85% of the population depend on the agricultural activities in western zone. Most farmers followed the crop with livestock production system. This was similar with the findings of Saikia *et al.,* (2017). The major nutrient such as nitrogen, phosphorous and potassium are not attained self-sufficiency in the production system and found deficient. Efficiency of the farm not alone limited to the nutrient self-sufficiency but also with market price fluctuation, technology available, technology adoption and awareness of farmers. The research

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on efficiency analysis is limited at the regional and state levels. Recognizing this as a possible area for improvement, the current study was designed with the goals of evaluating the relationship between farm component drivers along with the technical, allocative and cost efficiency of the farm to enhance profit and sustain productivity.

MATERIALS AND METHODS

The study was carried out at Department of Agronomy, Tamil Nadu Agricultural University (TNAU), Coimbatore between 2020-2022 to improve farm income and to sustain the farm productivity. Considering the significance in the Agricultural Production, Western Agroclimatic Zone (WACZ) of Tamil Nadu has purposely been selected as a study area. Western zone comprises of Coimbatore, Tirupur, Erode, Namakkal, Karur, Dindigul and Theni district. This zone constitutes an area of 15,678 sq.km (15,67,800 ha). The area under cultivation is 6,98,105 hectares, which is 44.5% of the total area. Major soils of the zone were red loamy and black soil. The average rainfall of this agroclimatic zone is 715 mm.

Two hundred dryland farms were selected across the major dryland blocks of WACZ Tamil Nadu. The data was collected with the aid of structured questionnaire in the year of 2020-2021 and these questions were structured as to elicit answers on the objectives of the study. Data were collected on socio economic characters of farmers, types of crops grown, inputs used with quantities and unit prices, quantities of output produced and unit prices. Sample community was dispersed into five major farming system groups. This was based on crop grown and farm components (Livestock, Birds, supplementary and complementary units). The stratified five dominant farming system group were arable crop growers alone (HC) (sorghum, maize and groundnut and other vegetables, plantation crops), crop with livestock holders (HCL), crop with livestock, birds holders (HCLB), crop with livestock, birds, supplementary unit holders (HCLBS), crop with birds, supplementary unit holders (HCBS).

Data analysis

Data envelopment analysis (DEA) were opted to analyze the efficiency level of farms and descriptive statistics consisting of simple percentages and proportions were used to examine the socio-economic characteristics of the dryland farms related to farm efficiency.

Data envelopment analysis (DEA) is a non-parametric and deterministic measure of efficiency. Input-oriented method is adopted to calculate cost efficiency in this paper. This technique is selected because in agricultural production farmers have more control on their inputs than output (Coelli *et al*., 2005). This was also supported by the methodology followed by Koc *et al*., (2011).

$$\text{Minimize } \theta, \lambda^{\theta}$$

$$\text{Subject to: } -yi + Y\lambda \geq 0$$

$$xi - X\lambda \geq 0; \; NI\,\lambda = 1; \; \lambda \geq 0$$

x and y denote inputs and output matrices of the DMU to be calculated. θ is the efficiency score for the ith DMU and having a value $0 \leq \theta \leq 1$. The value of θ equals 1, implies that the farm is on the frontier (farm is cost efficient); NI is convexity constraint; the vector λ is an N × 1 vector of weights, defines the linear combination of the peers of the ith DMU.

The analysis was performed using software designed by (Coelli, 1996) which encompasses technical efficiency, allocative efficiency and economic efficiency. The term technical efficiency indicates the ability of the farm to produce maximum output from a given set of inputs, whereas cost efficiency requires achieving the lowest possible cost, given the current prices and output. Allocative efficiency or otherwise called as pricing efficiency relies on cost of inputs. Therefore, Cost efficiency refers to the product of technical and allocative efficiencies Dryland farms were considered as decision making units (DMUs) and groupwise efficiency analysis were constructed. To ascertain the efficiency, production frontier was constructed in DEA approach based on linear programming (Suresh and Chandrakanth, 2016).

The term envelopment is derived from production frontier, which envelops the set of observations, for each DMU, crop, livestock and birds (output category), seed, fodder, fertilizer, human labour, machine labour and their corresponding unit prices (input category) were considered in the calculation of cost- DEA efficiency score. The best DMU operates at 100% technical efficiency (efficiency score=1) and the DMU with lower technical efficiency (score<1) works at a percentage less than 100.

RESULTS AND DISCUSSION

Technical, allocative and cost efficiency

The results of the study revealed that, the mean scores of technical efficiencies of farmer were found to be 0.98 for HC group, 1 for HCBS, 0.89 for HCL, 0.80 for HCLB and 0.96 for HCLBS (Table 1). Technical efficiency among the respondents varied substantially between 0.46 to 1.00, indicating that they are not obtaining maximal output from their given quantum of inputs. This implies that the technical efficiency among the respondents can be increased by 54% through better use of available production resources, given the current state of technology. This would enable the farmer to obtain the maximum output from the given quantum of inputs and increased farm income. This was in pattern of findings with (Bhat and Bhat, 2014). production efficiency was low due to quantities of inputs used were higher or lower than the required to achieve present level of output. Terin *et al.,* (2017) stated that, the lack of correct knowledge about the input uses among some producers could possibly be one of the main obstacles against the efficient input uses.

Majority of the respondents operates in allocative efficiency between of 0 to 1. The mean value of allocative efficiency of HC group was 0.60, for HCBS group was 0.92, for HCL group was 0.55, for HCLB group was 0.75 and for HCLBS group 0.63. The result showed that majority of

respondents across the different production system were not allocatively efficient in the use of production resources. This can be the result of utilization of inputs in the wrong proportions at a given input prices, hence higher input costs combination reduced the returns. Furthermore, allocative efficiency among the respondents varied widely between 0.55 (HC) to 0.92 (HCBS). This implies that allocative efficiency among the respondents could be increased between 44% and 8% in the area through better utilization of resources in optimal proportion given their respective prices and given the current state of technology. This was agreed with the findings of Pandey *et al.,* (2022) and Tesema, (2021), overuse of fertilizer, labor force and non-farm integration in the region implies the allocative inefficiency. Allocative inefficiency, implying the inappropriateness of input mixes given their respective prices was found to be the primary cause for inefficiency (Long, 2022).

The economic efficiency among the respondents varied widely ranging between 0 and 1 across the production system. The mean economic efficiency of HC group was 0.59, for HCBS group 0.92, for HCL group 0.50, for HCLB group 0.66 and HCLBS group 0.62. This result suggests that the farmers in the study area are not able to minimize the cost of production and found economically inefficient. The intimation is that overall economic efficiency among the respondents could be increased by 44% in the area through the reduction in production costs. This would occur if production were allocatively and technically efficient at the given state of technology. This agrees with the observation of (Birhanu and Yehuala, 2022). Guha *et al.,* (2020), stated that increase use of modern inputs to get farm output increases the cost of production and reduce the farm efficiency.

As the alarming situation of climate change is taking place at global level, it is important to evaluate the efficiency estimates in different agro-climatic zones to produce agricultural crops. This work was recommended as future scope of research for sustainable development of agricultural production in the study area.

Relationship of farm efficiency with socio-economic profile

Average age group of household head in the study area was 50 and found that majority of farms are headed by middle aged farmer between 46 to 55 years (Table 2). Further the estimates shows that cost efficiency increases with the age of the farmer. This implies that aged farmers were more economically efficient in production. The fact that farming experience of household increases with the age as well as resource empowerment leads to the increase in cost efficiency. The farming experience ranged from 15 to 34 in different production system group of study area. The positive influence between the farm experience and cost efficient are observed with HCBS group and confirms agricultural experience increases the cost efficiency of study area.

The average members of household are three. Among them family labor were two. It has also been found that

Table 1: Technical efficiency, allocative efficiency and cost Efficiency of different dryland farms in WACZ of TN.

DEA efficiency	HC			HCBS			HCL			HCLB			HCLBS		
score	TE	AE	CE	TE	AE	CE	TE	AE	CE	TE	AE	CE	TE	AE	CE
No. of efficient farmers (100%)	15 (88)	7 (41)	7 (41)	8 (100)	6 (75)	6 (75)	44 (58)	6 (8)	6 (8)	36 (51)	10 (14)	11 (15)	24 (86)	7 (25)	8 (2 8)
(90%-99%)	1 (5)	0 (0)	0 (0)	0 (0)	1 (12.5)	1 (12.5)	27 (35)	26 (34)	4 (5)	8 (11)	3 (4)	0 (0)	1 (4)	1 (4)	1 (4)
Below 90%	1 (5)	10 (59)	10 (59)	0 (0)	1 (12.5)	1 (12.5)	5 (7)	44 (58)	66 (87)	27 (38)	58 (82)	60 (85)	3 (10)	20 (71)	19 (68)
Mean	0.985	0.600	0.594	1	0.923	0.923	0.894	0.556	0.501	0.800	0.754	0.660	0.966	0.637	0.627
Minimum	0.833	0.00	0.00	-	0.443	0.443	0.462	0	0	0.464	0	0	0.612	0.345	0
Maximum	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

* HC: Household+crop, HCBS: Household + crop+Birds + Supplementary, HCL: Household+crop + Livestock, HCLB: Household+crop + Livestock + Birds, HCLBS: Household + crop + Livestock + Birds+Supplementary.
* Values in the parenthesis represents the percentage contribution to total farmers in individual group.
* TE: Technical efficiency; AE: Allocative efficiency and CE: Cost efficiency.

Table 2: Socio economic profile and yield of study area (Average).

	No. of sample farmers	Age HH head (years)	No. of HH member	Farm experience (years)	No. of family labour	Average land area (ha)	Sorghum grain yield (kg/acre)	Sorghum straw yield (kg/acre)	Maize grain yield (kg/acre)	Maize straw yield (kg/acre)	Groundnut grain yield (kg/acre)	Groundnut straw yield (kg/acre)	Milk yield (Litre/day/ farm)	Total farm income (Rs)
HC	17	46.18	3.24	15.65	2.06	1.15	804.45	2122.27	2000.00	3480.00	662.50	1000.00	0	68,088
HCBS	8	55.50	3.75	34.25	2.75	1.77	686.00	1940.00	1780.00	3040.75	0.00	0.00	0	93,453
HCL	76	50.72	3.74	26.34	2.42	1.57	841.77	2376.76	1532.81	2684.67	727.69	1053.00	20	1,32,808
HCLB	71	50.86	3.34	27.46	2.45	1.70	823.78	2275.48	1573.71	2740.24	707.14	1050.71	23	1,49,742
HCLBS	28	46.93	4.00	24.54	2.50	2.18	912.74	2482.48	1609.41	2727.24	730.00	1045.00	34	2,12,371

HC: Household+crop, HCBS: Household+crop + Birds+Supplementary, HCL: Household + crop+Livestock, HCLB: Household+crop + Livestock + Birds, HCLBS: Household + crop + Livestock + Birds+Supplementary.

diversified farm had the higher family labor than the undiversified farm. This is most likely because farmers with large household sizes strive for higher output in order to meet their subsistence needs. Furthermore, a large household size necessitates a labor resource to implement farm management decisions. Sekaran *et al.,* (2021) stated that integrated production is profitable and sustainable when it holds a family labor as a component in the system and proves farm to be economical efficient. It was observed that the farm size of the study area had a favorable impact on technical efficiency Table 2. This implies that smaller farms are more technically effective than larger farms. The possible reason for this result is that farmers cultivating smaller land area tend to maintain land more indigenously and this to a certain extent minimizes soil fertility loss, makes them more efficient.

Table 2 reflects the yield of farms. In general yield of all the farms were higher as compared to the national average. The possible reason for considerable yield may due to minimum farm size, holding livestock and birds as component in a production system which help to cycle the farm resource Further to it farm with allied component get constant income around the year that helps to meet out timely credit requirement of farm management. Sharma *et al.,* (2022) given that credit availability helps to make timely farm operation. HCLBS group recorded the highest average milk yield (34.46 l/day/farm). Due to credit availability the care, management and herd size of farm is better than the other existing group. These findings were also supported by Singh, (2016). Further higher milk yield is achieved due to increased farm principal crop yield which supply the fresh and required green fodder to cattle.

The farm income varied between 0.68 lakh Rs to 2.12 lakh Rs per annum Table 2. Credit availability is positively associated with cost efficiency. Increasing farmers access to credit raises the cost-efficient level of dryland farms. Farm credit helps to diversify the agricultural system and helps to stabilize and improve farm productivity (Kumar *et al*., 2015).

CONCLUSION

This study confirmed the existence of economic inefficiency in dryland farms, suggesting that most of the respondents operated far away from the frontier function. This negative performance of farms may due to wrong selection of allied enterprise, unoptimized usage of inputs and improper resource managements. This erroneous selection may due to lack of knowledge on resource allocation and market price fluctuations. Though the farms are functioning with lesser profit the extent of positive impact made by it on the farming community is substantial. Keeping in this view to improve economic performance of farms optimized management through existing available resource should be done. Solving the allocative inefficiency problem may be a major challenge in farm resource management.

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