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# Resource use Efficiency and its Determinants in Major Farming Systems of Srikakulam District of Andhra Pradesh

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**ABSTRACT**

The present study was conducted in Srikakulam district of Andhra Pradesh by taking a sample of 120 farmers. The district comprises of 6 farming situations based on the reports of DAATT Centre, Srikakulam. The Data Envelopment Analysis (DEA) technique was used to find the resource use efficiency in major farming systems of Srikakulam. The number of efficient farms were more in FS-II (crops + dairy) under Constant Returns to Scale (CRS), whereas the number of efficient farms were more in FS-III (crops+ poultry) under Variable Returns to Scale (VRS) assumption. About 40 per cent of farms operated in optimal region and 35 per cent were operated at sub-optimal region. The FYM had positively significant influence on resource use efficiency in FS-II (crops + dairy), FS-IV (crops + Sheep&goat) and FS-V (crops + dairy + poultry) of Srikakulam district respectively.

**Keywords:** *CRS, DEA, Farming system, Srikakulam and VRS.*

When GoI (Government of India) announced its vision of doubling the farmer's income by 2022, the focus on Farming System Approach (FSA) gradually gained momentum. Farming system refers to a combination of enterprises involving raising of crops and non crop enterprises like dairy, poultry, sheep & goat rearing, sericulture, mushroom culture *etc*., together. Different components of farming system are originally linked in such a way that there would be material flows from one component to another component. The output of one component of the farming system serves as an input for the other component. Thus, Farming System Approach (FSA) is a feasible solution and viable option for income enhancement at farm level by efficient utilization of inputs generated within the system (Rao *et al*. 2017). In India, farming systems are characterized by small holdings, scarcity of resources, inadequate capital and lack of knowledge on FSA. Hence, an attempt is made in the present study to estimate the resource use efficiency in major farming systems practiced by the farmers of Srikakulam districts with following objectives.

1. To identify existing farming systems in the Srikakulam district;
2. To analyze the resource use efficiency in major farming systems;
3. To study the impact of determinants on resource use efficiency in major farming systems.

## MATERIAL AND METHODS

Srikakulam district was purposively selected due to the variable climatic conditions of the district comprising of coastal corridor, high altitude zone and plains. The DAATT Centre of Srikakulam divided the district in to six farming situations based on the irrigation and soil conditions. The mandals under each situation were listed out and the mandal with highest area was selected. Similarly, two villages from each mandal were selected and a sample of 10 farmers were selected randomly from each village. Thus, a sample of 120 farmers were finalized for the study. The primary data on input utilization was collected through well structured pre tested questionnaire. For analyzing resource use efficiency, Data Envelopment Analysis technique was employed.

**Data Envelopmet Analysis**

The DEA method is a frontier method that does not require specification of a functional or distributional form, and can accommodate scale issues. This approach did not receive wide attention till the publication of the paper by Charnes *et al.* (1978), which coined the term data envelope analysis. A large number of papers have extended and applied the DEA technology in the western world. Very few studies have used this approach in India, especially in agriculture or horticulture for measuring resource use efficiency. DEA method has the disadvantage that it does not explicitly accommodate the effects of data noise. Charnes *et al.* (1978) proposed a model which had input orientation and assumed Constant Returns to Scale (CRS). Later, in the subsequent papers, Banker *et al.* (1984) who proposed Variable Returns to Scale (VRS) model. The DEA was applied by using both classic models CRS (constant returns to scale) and VRS (variable returns to scale) with input orientation, in which one seeks input minimization to obtain a particular product level. Under the assumption of constant returns to scale, the linear programming model for measuring the efficiency of farming systems are (Coelli *et al.*, 1998):

$$\text{Min } \theta, \lambda\ \theta$$
$$\text{Subject to } -y_i + Y\lambda \geq 0$$
$$\theta x_i - X\lambda \geq 0$$
$$\lambda \geq 0 \ldots\ldots\ldots\ldots(1)$$

where,

$y_i$ is a vector (m × 1) of gross output of the i[th] farm,

$x_i$ is a vector (k × 1) of inputs of the i[th] farm unit,

Y is a gross output matrix (n × m) for n farms,

X is a farm input matrix (n × k) for n farms,

$\theta$ is the efficiency score, a scalar whose value will be the efficiency measure for the i[th] farm. If $\theta$ =1, farm will be efficient; otherwise, it will be inefficient, and

$\lambda$ is a vector (n × 1) whose values are calculated to obtain the optimum solution. For an inefficient farm, the $\lambda$ values will be the weights used in the linear combination of other, efficient, farms, which influence the projection of the inefficient farm on the calculated frontier.

The specification of constant returns is only suitable when the firms work at the optimum scale. Otherwise, the measures of technical efficiency can be mistaken for scale efficiency, which considers all the types of returns to production, *i.e.*, increasing, constant and decreasing. Therefore, the CRS model was reformulated by imposing a convexity constraint. The measure of technical efficiency obtained in the model with variable returns is also named as 'pure technical efficiency', as it is free of scale effects. The following linear programming model estimated it:

$$\text{Min } \theta, \lambda\ \theta$$
$$\text{Subject to } -yi + Y\lambda \geq 0$$
$$\theta x_i - X\lambda \geq 0$$
$$N_1\ \lambda = 1$$
$$\lambda \geq 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

where, $N_1$ is a vector (n × 1) of ones. When there are differences between the values of efficiency scores in the models CRS and VRS, scale inefficiency is confirmed, indicating that the return to scale is variable, *i.e.*, it can be increasing or decreasing (Färe and Grosskopf, 1994). The scale efficiency values for each analyzed unit can be obtained by the ratio between the scores for technical efficiency with constant and variable returns as follows:

$\theta_s = \theta_{CRS}(X_K, Y_K)/\theta_{VRS}(X_K, Y_K)$ …………….(3)

where,

$\theta_{CRS}(X_K, Y_K)$ = Technical efficiency for the model with constant returns,

$\theta_{VRS}(X_K, Y_K)$ = Technical efficiency for the model with variable returns, and

$\theta_s$ = Scale efficiency.

It was pointed out that model (2) makes no distinction as to whether farm is operating in the range of increasing or decreasing returns. The only information one has is that if the value obtained by calculating the scale efficiency in Equation (3) is equal to one, the farm will be operating with constant returns to scale. However, when $\theta_s$ is smaller than one, increasing or decreasing returns can occur. Therefore, to understand the nature of scale inefficiency, it is necessary to consider another problem of linear programming, *i.e.*, the convexity constraint of model (2), $N_1\lambda = 1$, is replaced by $N_1\lambda \leq 1$ for the case of non-increasing returns, or by $N_1\lambda \geq 1$, for the model with non-decreasing returns. Therefore, in this work, the following models were also used for measuring the nature of efficiency. Non-increasing returns:

$\text{Min}_{\theta,\lambda}\ \theta$

Subject to $-y_i + Y\lambda \geq 0$

$\theta x_i - X\lambda \geq 0$

$N_1\lambda \leq 1$

$\lambda \geq 0$ ……………………(4)

Non-decreasing returns:

$\text{Min}_{\theta,\lambda}\ \theta$

Subject to $-y_i + Y\lambda \geq 0$

$\theta x_i - X\lambda \geq 0$

$N_1\lambda \geq 1$

$\lambda \geq 0$ ……………………(5)

It is to be stated here that all the above models should be solved n times, *i.e.*, the model is solved for each farm in the sample.

Farming system gross income (Rs.) was used as an output (Y) in the present case and total human labour (man-days), total machine labour (hr), seed (kg), farm yard manure (t), total fertilizers (kg) and plant protection chemicals (l) as inputs (X) in case of cropping alone. Farming systems having dairy, poultry and sheep & goat were additionally included with inputs like fodder (q), feed (kg) and veterinary medicines (Rs.). The models were solved using the DEAP version 2.1 taking an input orientation to obtain the efficiency levels.

**Determinants of Technical Efficiency**

Ray (1991) and Worthington and Dollery (1999), used traditional DEA in the first stage to estimate the technical efficiency and in the second stage estimated the determinants of technical efficiency from the factors contributing to this technical efficiency by using econometric procedure. In the present study, the technical efficiency values obtained from the DEA model considering the CRS input-oriented model were used for examining the relationship between the technical efficiency and factors influencing it. The technical efficiency score from CRS model was chosen as the dependent variable for its high accuracy in discriminating efficiency as compared to variable returns to scale. The above inputs are considered as explanatory variables. The traditional method of regression was used for this purpose and OLS analysis was carried out to estimate the regression equation. The regression model specified for the present study is given in the following equation:

$$Y = a\, X_1^{b1}\, X_2^{b2}\, X_3^{b3}\, X_4^{b4} X_5^{b5}\, X_6^{b6}\, X_7^{b7}\, X_8^{b8} X_9^{b9} \mu$$

where,

Y = Technical efficiency scores (CRS),

$X_1$ - Human labour (MD)

$X_2$ - Machine labour (hr)

$X_3$ - Seed (kg)

$X_4$ - FYM (t)

$X_5$ - Fertilizer Quantity (kg)

$X_6$ - Plant protection chemicals (l)

$X_7$ -Fodder (q) (In case of dairy and sheep & goat)

$X_8$- Feed (kg) (In case of dairy, poultry and sheep & goat)

$X_9$ - Veterinary expenses (Rs.) (In case of dairy, poultry and sheep & goat)

µ - Error term

a and $b_i$ are the constant and the coefficients respectively, which were estimated through the OLS analysis after appropriate log conversion.

## RESULTS AND DISCUSSION

The results pertaining to the identification of different farming systems and the corresponding resource use efficiencies are discussed in this section.

It could be observed from Table 1 that a total of nine farming systems *viz*., FS-I: Crops alone (23.33%), FS-II: Crops + Dairy (30.83%), FS-III: Crops + Poultry (12.50%), FS-IV: Crops + Sheep & goat (9.17%), FS-V: Crops + Dairy + Poultry (17.50%), FS-VI: Crops + Dairy + Sheep & goat (1.67%), FS-VII: Crops + Poultry + Sheep & goat (1.67%), FS-VIII: Crops + Dairy + Poultry + Sheep & goat (2.5%) and FS-IX: Crops + Mushroom (0.83%) were practiced by the sample respondents of Srikakulam district. A sample more than 10 respondents practicing any of the nine farming systems were considered as major farming systems for further analysis i.e., farming systems practicing by less than 10 respondents were not considered as major farming systems. Thus, the major farming systems identified in Srikakulkam district were Crops + Dairy (FS-II: 37 No.), followed by Crops alone (FS-I: 28 No.), Crops + Dairy + Poultry (FS-V: 21 No.), Crops + Poultry (FS-III: 15 No.) and Crops + Sheep & goat (FS-IV: 11 No.).

### Technical efficiency in major farming systems of Srikakulam district

To obtain efficiency levels of each of the farms as decided by the physical inputs (quantities), DEA models, which are input-oriented were used at different production scales under the assumption of constant returns to scale (CRS). After introducing convexity in the CRS model, the variable returns to scale (VRS) were estimated. By using the efficiency levels of these CRS and VRS models, the scale efficiency for each farm was obtained. The results on efficiency measures (with constant and variable returns) and the descriptive statistics for major farming system farms in the district of Srikakulam are given in Table 2. The criterion used by Ferreira (2005) was used in the present study to decide the cut-off score for efficient farms. Farms that operated at 0.90 or more score were considered as 'efficient farms'.

It is observed from the Table 2, only 53.57 per cent of farms under assumption of Constant Returns to Scale (CRS) were operated with an efficiency level of 0.90 or more in FS-I (Crops only). The range of technical efficiency scores were from 0.578 to 1. The average efficiency score was 0.865 which means the remaining 46.43 per cent farms which were not operated at maximum efficiency level could reduce their input usage by 13.50 per cent to reach maximum level of efficiency as obtained by 53.57 per cent farms. When Variable Returns to Scale (VRS) was calculated by relaxing the assumption of constant returns, the mean technical efficiency score increased to 0.931 by increasing number of efficient farms to 75 per cent. The better results from the VRS were achieved due to inclusion of scale efficiency in the model. Regarding scale efficiency, nearly 64.29 per cent of farms were operated at optimal level of efficiency (Ÿe”0.90).

Under the assumption of CRS, 62.16 per cent of farms in FS-II were operated at optimum efficiency levels with scores of 0.90 or above (23 farms out of 37). The average technical efficiency score was 0.877 which means there was a scope to reduce input level by 12.30 per cent. In case of VRS, the average efficiency score was increased to 0.945 and nearly 28 farms were performed at maximum efficiency level (75.68 %). As regards to the scale efficiency, 68.42 per cent (26 farms out of 37) were operated at optimum level of efficiency with mean technical efficiency score of 0.9196.

The mean technical efficiency value was 0.853 which implied the excess usage of inputs in FS-III under CRS. When the VRS assumption was introduced, 86.68 per cent of farms *i.e.,* 13 out of 15 farms performed at maximum efficiency level with an average technical efficiency score of 0.944. Nearly 66.67 per cent of farms (10 out of 15) were having efficiency levels of 0.90 or more under scale efficiency.

The mean technical efficiency value (0.848) under CRS assumption confirmed that there was a scope to reduce the input level by 15.20 per cent. Nearly 45.45 per cent of farms in FS-IV, which didn't operate at efficiency level, could reduce input usage by 15.20 per cent to get same level of income which was being received by 54.55 per cent of efficient farms. Under VRS, the mean technical value increased to 0.926 and the number of farms performed at maximum efficiency level rose to 72.73 per cent. Regarding scale efficiency, 72.73 per cent farms operated at optimum level of efficiency *i.e.,* $Q \geq 0.90$.

The mean technical efficiency value increased to 0.960 from 0.881 when the CRS assumption changed to VRS in FS-V. The number of farms performed at maximum efficiency level also increased to 17 (VRS) from 13 (CRS). The minimum efficiency score recorded under CRS was 0.557 against the maximum 1. Nearly 71.43 per cent of farms operated at optimum efficiency level under scale efficiency.

**Regions of operation in the production frontier**

After calculating the technical efficiency of farms, extent of inefficiency and optimum scale of operation, it is also important to know the distribution of farms on three zones production frontier *i.e.,* number of farms under decreasing, increasing and constant returns to scale. These are estimated through the convexity constraint of LP as given in methodology.

Majority of farms in all farming systems in Srikakulam district except FS-I were operated in constant region of frontier *i.e.,* at optimum scale of production. Nearly 34.82 per cent of farms (39 of total 112) under major farming systems were operated in the region of increasing returns or sub-optimal region (Table 3.). The income of these farms could be increased by increasing input usage as they were performing below optimal production scale. Nearly 28 per cent of farms in major farming systems were found to be decreasing returns or supra-optimal region. The farms could increase their resource use efficiency by reducing input usage as these farms operated above optimal scale of production. More inputs should be provided to the farms operated at IRS and same should be reduced to farms operated at DRS.

**Determinants of resource use efficiency in major farming systems**

Log linear regression model was used to analyze the determinants of RUE of major farming

**Table 1. Farming systems practiced by the sample respondents in Srikakulam**

| S.No | Farming systems (FS) | Srikakulam (N=120) | |
|---|---|---|---|
| | | No. | % to total |
| I | C | 28 | 23.33 |
| II | C+D | 37 | 30.83 |
| III | C+P | 15 | 12.5 |
| IV | C+S&G | 11 | 9.17 |
| V | C+D+P | 21 | 17.5 |
| VI | C+D+S&G | 2 | 1.67 |
| VII | C+P+S&G | 2 | 1.67 |
| VIII | C+D+P+S&G | 3 | 2.5 |
| IX | C+Mu | 1 | 0.83 |
| X | C+F | - | - |
| | Total | 120 | 100 |

Note: C= Crops, D= Dairy, P= Poultry, S&G= Sheep & Goat, Mu= Mushroom unit, F=Floriculture

**Table 2. Efficiency measures and descriptive statistics across major farming systems in Srikakulam district according to scale of operations**

| Scale of operations | No. of respondents | Efficient farms ($\Theta \geq 0.90$) | | Efficiency measures | | | |
|---|---|---|---|---|---|---|---|
| | | No. | % | Mean | SD | Max. | Min |
| FS-I | | | | | | | |
| Technical efficiency (CRS) | 28 | 15 | 53.57 | 0.865 | 0.137 | 1 | 0.578 |
| Technical efficiency (VRS) | | 21 | 75 | 0.931 | 0.099 | 1 | 0.652 |
| Scale efficiency | | 18 | 64.29 | 0.927 | 0.084 | 1 | 0.714 |
| FS-II | | | | | | | |
| Technical efficiency (CRS) | 37 | 23 | 62.16 | 0.877 | 0.155 | 1 | 0.497 |
| Technical efficiency (VRS) | | 28 | 75.68 | 0.945 | 0.101 | 1 | 0.614 |
| Scale efficiency | | 26 | 68.42 | 0.92 | 0.124 | 1 | 0.557 |
| FS-III | | | | | | | |
| Technical efficiency (CRS) | 15 | 9 | 60 | 0.853 | 0.18 | 1 | 0.527 |
| Technical efficiency (VRS) | | 13 | 86.68 | 0.944 | 0.107 | 1 | 0.662 |
| Scale efficiency | | 10 | 66.67 | 0.9 | 0.139 | 1 | 0.552 |
| FS-IV | | | | | | | |
| Technical efficiency (CRS) | 11 | 6 | 54.55 | 0.848 | 0.189 | 1 | 0.495 |
| Technical efficiency (VRS) | | 8 | 72.73 | 0.926 | 0.151 | 1 | 0.524 |
| Scale efficiency | | 8 | 72.73 | 0.915 | 0.125 | 1 | 0.665 |
| FS-V | | | | | | | |
| Technical efficiency (CRS) | 21 | 13 | 61.9 | 0.881 | 0.151 | 1 | 0.557 |
| Technical efficiency (VRS) | | 17 | 80.95 | 0.96 | 0.082 | 1 | 0.713 |
| Scale efficiency | | 15 | 71.43 | 0.914 | 0.109 | 1 | 0.668 |

**Table 3. Distribution of respondents in major farming systems of Srikakulam district according to type of returns among different scale of operations**

| Type of returns to scale | FS-I | FS-II | FS-III | FS-IV | FS-V | Total |
|---|---|---|---|---|---|---|
| Increasing (IRS) | 9 (32.14) | 14 (37.84) | 6 (40) | 3 (27.27) | 7 (33.33) | 39 (34.82) |
| Constant (CRS) | 9 (32.14) | 16 (43.24) | 6 (40) | 5 (45.45) | 9 (42.86) | 45 (40.18) |
| Decreasing (DRS) | 10 (35.72) | 7 (18.92) | 3 (20) | 3 (27.27) | 5 (23.81) | 28 (25) |
| Total | 28 (100) | 37 (100) | 15 (100) | 11 (100) | 21 (100) | 112 (100) |

Note: Figures in parentheses indicate percentage to the respective FS total

**Table 4. Determinants of Resource Use Efficiency (CRS) in major farming systems of Srikakulam district.**

| Variables | FS-I | FS-II | FS-III | FS-IV | FS-V |
|---|---|---|---|---|---|
| Intercept | 0.836 | 0.938 | 0.916 | 0.93 | 1.059 |
| Human labour (Man-days) | -0.0007 | 0.0447 | 0.0002 | 0.002 | -0.0475 |
| | (0.0130) | (0.2170) | (0.0004) | (0.0710) | (0.9190) |
| Machine labour (hrs) | 0.5621** | -0.1179 | -0.0184 | -0.0143 | 0.0093* |
| | (0.0770) | (0.5180) | (0.0050) | (1.1590) | (0.0040) |
| Seed (kgs) | -0.0112 | 0.0918* | 0.0001 | -0.9159** | 1.884 |
| | (0.3370) | (0.0440) | (0.1180) | (0.0790) | (1.2250) |
| FYM (t) | 1.2766* | 0.0052** | 0.0056 | 0.0219** | 0.0277** |
| | (0.5910) | (0.0020) | (1.0040) | (0.0070) | (0.0040) |
| Fertilizers (kgs) | 2.447 | -0.1982** | 0.2446 | -0.4489 | -0.5571 |
| | (2.2280) | (0.0440) | (0.2650) | (0.7720) | (0.8150) |
| PPCs (lts) | -0.5592 | 0.0021* | -0.0005 | 2.4418 | 0.7404 |
| | (0.6620) | (0.0011) | (0.0310) | (1.6600) | (0.9830) |
| Fodder | - | 2.1944 | - | -1.0078 | 0.1088** |
| | | (1.5510) | | (1.9150) | (0.0370) |
| Feed | - | 0.5144* | 2.1691** | -0.0166 | 0.0555 |
| | | (0.2110) | (0.7170) | (0.6710) | (0.8220) |
| Veterinary medicine | - | -0.0155 | 0.0006 | 1.2125** | 1.1174* |
| | | (0.1740) | (0.5050) | (0.0970) | (0.5150) |
| $R^2$ value | 0.63 | 0.73 | 0.76 | 0.81 | 0.69 |

Note: Figures in parentheses indicate standard errors of respective variables,

(*,** significance at 5 and 1 per cent levels respectively) systems of north coastal Andhra Pradesh. The inputs considered for DEA analysis were again used as influential factors for CRS obtained for major farming systems. The results of regression are presented in Table 4.

The analytical findings from Table 4. revealed that the models were statistically significant across all farming systems as indicated by high $R^2$ values in Srikakulam district. The variable FYM was found to be positively significant at 1 per cent in FS-II, FS-IV and FS-V. This was due to the presence of dairy and sheep & goat components in those farming systems. Machine labour was positively significant in FS-I (1%) and FS-V (5%). The variable fertilizer was negatively significant in FS-II. Saikumar (2005) in his study expressed similar view on fertilizers. PPCs and feed were positively significant at 5 per cent level in FS-II. Kumara (2011) also reported significantly positive impact of feed on gross income of farming systems. The variable cost of veterinary medicine was positively significant at 1% and 5% level in FS-IV and FS-V respectively. The $R^2$ value ranged from 0.63 (FS-I) to 0.81 (FS-IV) in major farming systems of Srikakulam.

## CONCLUSION

Technical and scale efficiencies were estimated for farms in major farming systems in Srikakulam district using DEA approach and the factors which influence the resource use efficiency were also estimated by regression equation. The resource use efficiency was highest in FS-III and FS-V under VRS assumption with mean technical efficiency scores of 0.94 and 0.96 respectively. About 25 per cent farms (28) were found to be operated in decreasing returns or in supra-optimal region. The variables including FYM, feed and veterinary medicines have significant positive impact on technical efficiency scores (CRS). The farming systems with allied activities were found to be good in resource utilization than cropping alone.

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