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Technical, economic and allocative efficiencies of rice farms in Nalgonda district of Telangana state

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ABSTRACT

Increasing the efficiency in production assumes greater significance in attaining potential output at the farm level. An attempt has been made in this study to estimate the technical, economic and allocative efficiencies of rice farms using stochastic frontier approach. The influence of socio-economic factors on the technical efficiency was measured using regression analysis. The mean technical, economic and allocative efficiencies were found to be 92.44, 81.68 and 88.36 per cent respectively. The results revealed that 63 and 76 per cent of technical and economic inefficiencies respectively were largely within the control of individual farmers. Human labour was found to be the major determinant of rice productivity in the region. One per cent increase in the prices of human labour, machine labour and fertilizers was found to reduce the profits by 0.25, 0.46 and 0.18 per cent respectively at their mean levels. Education level of a farmer, experience in rice cultivation, membership in cooperative society and access to institutional credit were the most influential determinants of technical efficiency. The mean technical efficiency values of greater than 90 per cent for majority (55.83%) of the rice farmers indicated that there was little scope for improving the efficiencies of these farmers with the existing technology as the farmers were already operating near the frontier. Hence new location-specific technologies should be developed and transferred to farmers. However, for farms operating at lower levels of efficiency, sufficient potential also exists for improving the productivity of rice by proper management and allocation of the existing resources and technology.

Keywords: Technical efficiency, economic efficiency, allocative efficiency, rice, Nalgonda, Telangana, stochastic frontier approach

Improvement in farm economic efficiency is a very important factor of productivity growth especially in developing economies, where resources are meager and opportunities for developing and adopting better technologies have lately started dwindling. (Ali and Chaudhry, 1990). An important source of growth for the agricultural sector is efficiency gain through greater technical and allocative efficiency by producers in response to better information and education.

The concept of efficiency is the core of economic theory. The crucial role of efficiency in increasing agricultural

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output has been widely recognized by researchers and policy makers alike. Therefore considerable efforts have been put forth to the analysis of farm level efficiency in developing countries. If farmers are not making efficient use of existing technology, the efforts designed to improve efficiency would be cost-effective than introducing new technologies as a means of increasing agricultural output. (Bravo-ureta and Evenson, 1994).

Therefore, increasing the efficiency in production assumes greater significance in attaining potential output at the farm level. The economic efficiency is composed of technical efficiency and allocative efficiency. Technical efficiency (TE) is defined and measured as the ratio of the farm's actual output to its own maximum possible frontier output for a given level of inputs and the chosen technology (Kalirajan and Shand, 1994). Allocative efficiency reflects the ability of a farm to use the inputs in optimal proportions given their respective prices. Both are important to achieve the overall farm economic efficiency. Hence, improvement in efficiency is the key for meeting the growing food grain demand in the years to come.

Rice is the most important and extensively grown food crop in the world. Rice is a primary food source for more than one-third of the world's population and grown in 11 per cent of the world's cultivated area. India is one of the leading rice producing countries in the world with a cultivated area of 43.94 million hectares and production of 106.54 million tonnes in the year 2013-14. India was the largest exporter of rice (10.14 million tonnes) in 2013-14 followed by Thailand, Vietnam and U. S. A. Rice plays a vital role in the national food grain supply and is the main driver of India's food security.

Despite having a firm footage on rice cultivation, India is facing a formidable challenge to feed its burgeoning population. Population explosion is exerting more pressure on food security in India. At the current population growth rate of 1.5 per cent, the rice requirement of India by the year 2030 would be around 260 million tonnes (Reddy and Sen, 2004). The opening of the agricultural sector for exports has aggravated the problem and has increased the pressure on the Indian farmers to produce more.

However, in Indian context, land is a shrinking resource for agriculture owing to competing demand for its use. Hence further increase in agricultural production has to be achieved by increasing the productivity of land. Productivity can be increased through one or combination of its determinants – the technology, the quantities and types of resources used and the efficiency with which the resources are used. Embarking on new technologies is meaningless unless the existing technology is used to its full potential (Kalirajan *et al.*, 1996). Of the various determinants, improvement in the efficiency of the resources already at the disposal of the farmers is of great concern. Hence, raising efficiency offers more immediate goals at modest costs if there are substantial inefficiencies present in agricultural production (Goyal *et al*., 2006).

An estimate on the extent of efficiency can help to decide whether to improve efficiency or to develop new technologies to raise agricultural production. Inefficiencies may also arise due to socio-economic and demographic conditions (Shanmugam, 2002). Hence this study attempts to determine the farm level efficiencies as well as the socio-economic factors affecting efficiency at the farm level.

Description of the study area

Telangana state is situated on the Deccan Plateau covering 114,840 square kilometres and bordered by the states of Maharashtra to the north, Chhattisgarh to the north east, Karnataka to the west, Rayalaseema region to the south west and coastal Andhra region to the south east. The region is drained by two major rivers, with about 79% of the Godavari river catchment area and about 69% of the Krishna river catchment area and several minor rivers such as the Bhima, the Manjira and the Musi. The region is semi-arid and has a predominantly hot and dry climate.

The economy of Telangana region is mainly driven by agriculture with rice as the major food crop and staple food of the state. Other important crops include maize, tobacco, mango, cotton and sugarcane. There are many irrigation projects in the region including Godavari River Basin Irrigation Projects and Nagarjuna Sagar Dam, the world's highest masonry dam.

Nalgonda is one of the ten districts in the Telangana state. It is bounded on the north by Warangal and Medak districts, on the south by Guntur and partly by

Mahbubnagar districts, on the west by Rangareddy and Mahbubnagar districts and on the east by Khammam and Krishna districts. The geographical area of the district is 14,240 square kilometers. Nalgonda is located in Southern Telangana zone which receives 700-900 mm rainfall. Agriculture is one of the main occupations in Nalgonda. It is supported by a well- planned irrigation system which includes 26 lift irrigation and 1,16,007 irrigation wells. Nagarjuna Sagar, the major irrigation project provides irrigation facilities to the extent of 1.24 lakh hectares in the district. Major crops grown in the district include rice, pulses, mousambi or lime, millets and oilseeds.

Database and Methodology

Multistage stratified random sampling technique was adopted for selection of the sample with district as the first stage unit, mandals/tehsils as the second stage units, villages as the third stage units and farm holdings as the final and ultimate stage units. In the first stage, one district with highest production of rice was selected based on the average of five years' data on rice production i.e., from 2008-09 to 2012-13. Accordingly Nalgonda district was chosen for the study. The criterion for selection of the district is shown in Table 1.

Table 1: District-wise average of 5 years' rice production ('000 tonnes) in Telangana State

District	2008-09	2009-10	2010-11	2011-12	2012-13	Avg last 5 years
Adilabad	198	98	255	199	187	187.40
Nizamabad	680	389	844	972	736	724.20
Karimnagar	1176	513	1351	1120	1027	1037.40
Medak	358	232	515	407	373	377.00
Hyderabad	0	0	0	0	0	0.00
Rangareddy	92	93	136	103	98	104.40
Mahbubnagar	421	401	546	397	381	429.20
Nalgonda	1150	1083	1324	964	684	**1041.00**
Warangal	690	316	860	574	689	625.80
Khammam	596	306	704	412	2473	898.20

Source: Agricultural Statistics at a Glance: Andhra Pradesh

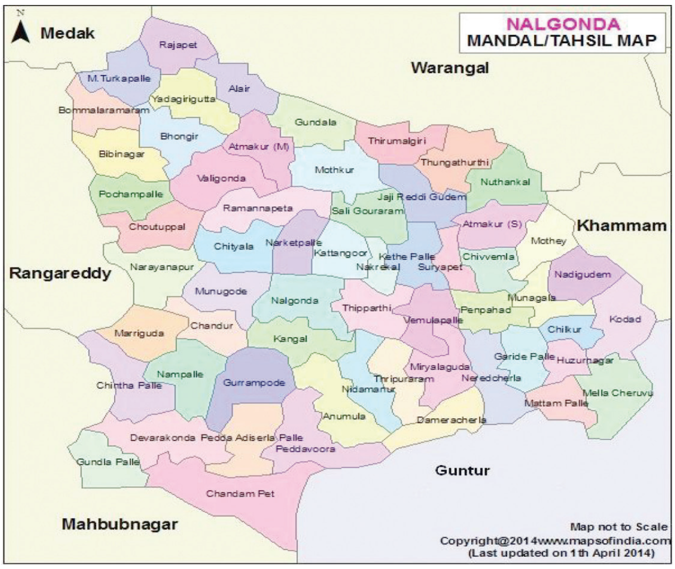

Fig. 1: Mandal map of Nalgonda district

Considering district as a unit, two prominent rice growing mandals namely Miryalguda and Nidamanur were selected based on three years' average rice production i.e., from 2010-11 to 2012-13. From each mandal three villages were selected randomly. Thus a total of six villages were selected for the study. From each village 20 rice farmers were selected randomly. Thus the sample consisted of 1 district, two mandals, six villages (three villages from each mandal) and 120 rice farmers (twenty from each village). The primary data of the selected rice farmers were obtained through personal interview method with the help of pre-tested comprehensive interview schedule for the agricultural year 2013-14 based on farmer's recall.

Method of analysis

In the present study, stochastic frontier production function was used to measure the farm specific technical efficiency (Aigner *et al.*, 1977; Kalirajan and Shand, 1989; Sharma and Dutta, 1997) while stochastic frontier profit function was used to estimate economic efficiency of sample rice farms (Ali and Flinn, 1989; Rahman, 2003; Galawat and Yabe, 2012). Allocative efficiencies were estimated by dividing economic efficiency with technical efficiency.

Stochastic frontier production function

Stochastic frontier production function approach was used to measure technical efficiency of rice farms. The estimation of production frontiers has proceeded along two general paths:

(i) Deterministic frontier which forces all observations to be on or below the production frontier so that all deviations from the frontier are attributed to inefficiency.

(ii) Stochastic frontier, where disturbance term consists of two components, a one sided component representing technical inefficiency and a symmetric component representing the random effects outside the control of the farmer such as weather, plant disease, drought, floods etc. including the statistical noise contained in every empirical relationship.

The advantage of stochastic frontier over the deterministic frontier is that farm-specific efficiency and random error effect can be separated.

The stochastic frontier model is called a 'composed' model because the error term is composed of two independent elements, namely:

$$\Sigma\, i = v_i - u_i \qquad i = 1,\ldots n$$

The term v_i is the symmetric component and permits random variation in output due to factors like weather and plant disease. It is assumed to be identically and independently distributed $v_i \approx N\ (0, \sigma^2 v)$. A one-sided component ($u_i \geq 0$) reflects technical efficiency relative to stochastic frontier $Qi = Q\ (Xki, \beta)\ e^{vi}$. Thus $u_i = 0$ for any farm lying on the frontier while $ui > 0$ for any farm lying below the frontier. Hence expression (u_i) represents the amount by which the frontier exceeds realized output. The distribution of u_i is assumed to be half-normal.

Specification of the Model

The stochastic frontier production function of the Cobb-Douglas type was specified for this study (Kalirajan and Flinn, 1983; Dawson and Lingard, 1989; Bravo-Ureta and Evenson, 1994).

The model used is:

$$\ln Y_i = b_0 + b_1 \ln X_1 + b_2 \ln X_2 + b_3 \ln X_3 + b_4 \ln X_4 + b_5 \ln X_5 + V_i - U_i$$

where,

Y_i = Output of rice (Quintals ha^{-1})

X_1 = Quantity of seed (kg ha^{-1})

X_2 = Human labour (mandays ha^{-1})

X_3 = Machine labour (hrs ha^{-1})

X_4 = Quantity of fertilizers (kg ha^{-1})

X_5 = Quantity of pesticides (l ha^{-1})

V_i = Random variable

U_i = Farm specific technical efficiency related variable

Stochastic frontier profit function

The stochastic frontier profit function was estimated as:

$$\Pi_i = f\ (X_i, P_i) + (\nu_i - u_i)$$

where,

Π_i is the normalized profit of the i^{th} farmer defined as gross revenue less variable cost divided by farm-specific output price.

X_i is the vector of variable input prices faced by the i^{th} farm divided by output price.

P_i is the vector of fixed factor of the i^{th} farm.

ν_i represents random error due to factors outside the control of the farmers.

u_i is a non-negative random variable associated with economic inefficiency component.

The economic efficiency in relation to the stochastic profit frontier is given by:

$$EE_i = \exp(u_i)$$

Specification of the model

$$\ln \Pi_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + V_i - U_i$$

Π_i = Restricted profit (Current revenue less current variable cost), normalized by the price received per quintal of output of i^{th} farm.

X_1 = Seed price per kg normalised by output price

X_2 = Human labour wage rate per day normalised by output price of i^{th} farm

X_3 = Machine labour wage rate per hour normalised by output price of i^{th} farm (Some of the farmers have also employed bullocks and to avoid statistical problems, wherever bullock labour was used it has been converted to machine labour, using a conversion factor of one hour tractor use is equivalent to ten hours of bullock labour.)

X_4 = Price of fertilizer per kilogram normalized by the output price of i^{th} farm.

X_5 = Price of pesticides per litre normalized by the output price of i^{th} farm.

V_i = Random variable

U_i = Farm-specific economic efficiency related variable

Normalised price is obtained by dividing the price of input with the output price.

Allocative efficiency was estimated by dividing economic efficiency with technical efficiency for each farm.

$$AE_i = EE_i/TE_i$$

Determinants of Efficiency

A positive relationship between technical efficiency and the socio-economic variables have been showed by several studies (Kalra *et al.*, 2015; Mohapatra, 2013; Thean *et al.* 2012; Rahman *et al.*, 2012; Khai and Yabe, 2011; Kalirajan, 1990; Bravo-Ureta and Evenson, 1994; Parikh and Shah, 1994; Shanmugham, 2003; Bhende and Kalirajan, 2007).

In the present study, the farm-specific factors such as area under the rice crop, age of the farmer, educational qualification, experience in rice cultivation, family size, membership in cooperative society and access to formal credit have been considered which affect the level of efficiency of rice crop production.

To study the effect of socio-economic factors on inefficiency, a linear regression model was used where the maximum likelihood estimates of technical efficiency were regressed against the socio-economic characters of the farmers.

$$TE_i = \alpha + \Sigma \beta_j X_{ij}$$

Where,

X_{ij} is the j^{th} socio-economic character of the i^{th} farmer.

X_1= Area under the rice crop (ha)

X_2= Age of the farmer (Years)

X_3= Educational Qualification (in years of education)

X_4= Experience in rice cultivation (in years)

X_5= Family size (Nos)

X_6= Membership in cooperative society (ies)

X_7= Access to formal credit (ies)

α = Intercept term

β_1 to β_7 = Coefficients of respective factors influencing the technical efficiency.

Results and Discussion

Estimation of Stochastic Frontier Production Function

Maximum likelihood estimates (MLE) of stochastic frontier production function along with mean technical efficiency are given in Table 2.

A high value of γ (0.6341) in the district indicates the presence of significant inefficiencies in the production of rice crop. It indicates that 63 per cent of differences between the observed and maximum production frontier outputs were due to the factors which were under farmer's control. The stochastic frontier analysis has further shown that 63 per cent of observed inefficiency was due to farmer's inefficiency in decision-making and only 37 per cent of it was due to random factors outside their control in the case of all farms. Thus, the one sided-error u_i dominated the symmetric error v_i and the short fall of realized productivity from the frontier was largely due to technical inefficiency and was mainly within the control of individual farmers.

Table 2: Estimates of stochastic frontier production function

Variables	Coefficient	Standard Error
Constant	3.8904***	0.6611
Seed	-0.0712	0.1069
Human labour	0.0535**	0.0235
Machine labour	0.0406	0.0445
Fertiliser	0.0529	0.0501
Pesticides	0.0527	0.0495
Sigma square	0.0160***	0.0057
Gamma	0.6341**	0.2862
Log likelihood function	109.617	
Mean TE	92.44	

Note: *** and ** indicate significance at 1% and 5% levels respectively.

Further, the results have shown that the estimated value of coefficient of human labour was positive and highly significant, indicating this variable to be productive input for successful production of rice crop. Statistically significant and positive value of the estimated coefficients indicated that farmers could increase per hectare yield by applying more units of these inputs. The coefficients of machine labour, fertilizer and pesticides were positive though non-significant. The estimated value of seed was negative, indicating overuse of the factor in producing the crop.

The estimate of σ^2 (0.0160) was highly significant suggesting that the technical inefficiency effects were a momentous component to the total variability in the yield of rice crop. The log likelihood function (109.617) was large and significantly different from zero indicating a good fit and the correctness of the specific distribution assumption.

Technical Efficiency of Sample Farms

The frequency distribution of sample farms by the level of technical efficiency in raising the rice crop is shown in Table 3. There were wide variations in the level of technical efficiency across the sample farms in raising the rice crop. The average level of technical efficiency has been estimated as 92.44 per cent for farms as a whole, implying that on an average the sample farmers tend to realize around 92 per cent of their technical abilities. Hence, on an average, approximately only 8 per cent of the technical potentials were not realized. Therefore, it is possible to improve the yield by 8 per cent by following efficient crop management practices without increasing the level of inputs application.

Table 3: Distribution of sample rice farmers under different levels of technical efficiency

TE (%)	Number of farms	Percentage to total
60.01-70	1	0.83
70.01-80	4	3.33
80.01-90	48	40.00
> 90	67	55.83
Total	120	100.00
Mean TE (%)	92.44	

It was also observed that a majority of the farms (55.83 percent) were operating close to the frontier with the technical efficiency of more than 90 per cent. 40 per cent of the rice farms lied between 80 to 90 per cent of the technical efficiency level. Further, the analysis revealed that only 3.33 and 0.83 percent of the sample farmers were operating at technical efficiency levels of 70 to 80 per cent and 60 to 70 per cent respectively. The results revealed that 95.83 per cent of the rice farms were operating at technical efficiency levels of greater than 80 per cent.

Estimation of Stochastic Frontier Profit Function

The maximum likelihood estimates of the stochastic profit frontier function are reported in Table 4. The coefficients of prices of human labour (-0.2532), machine labour (-0.4599) and fertilizers (-0.1877) showed a significant negative effect on the profits. The results showed that one per cent increase in the prices of human labour, machine labour and fertilizers will reduce the profits by 0.25, 0.46 and 0.18 per cent respectively at their mean levels.

Table 4: District-wise estimates of stochastic profit frontier function

Variables	Coefficient	Standard Error
Constant	1.6069**	0.6847
Seed price	-0.1453	0.0990
Human labour price	-0.2532**	0.1059
Machine labour price	-0.4599***	0.0974
Fertiliser price	-0.1877*	0.1037
Pesticides price	-0.0943	0.0712
Sigma square	0.1061***	0.0336
Gamma	0.7639***	0.1842
Log likelihood function	8.3735	
Mean EE	81.68	

Note: ***, ** and * indicate significance at 1%, 5% and 10% levels respectively.

The estimated value of γ was 0.76 and strongly statistically significant at 1 per cent level indicating the existence of high level of economic inefficiencies among sample rice farmers. These results reveal that 76 per cent of the observed economic inefficiencies were mainly due to the factors within the control of farmers. Only 24 per cent of the farmers' inefficiencies were due to random factors outside their control. Therefore, profit can be optimized if the inefficiency effects among farmers are minimized.

Economic efficiency of sample farms

The mean economic efficiency of the sample farms was 81.68 per cent which means, in principle that the sample farms can potentially reduce their overall cost of rice production, on average, by 18 per cent and still achieve the existing level of output. These results indicate the potential to further improve the economic efficiency by 18%.

An examination of the Table 5 indicates that majority (32.50%) of the farmers in sample operated at economic efficiency levels of 70-80 per cent followed by 30.83% of the farmers with economic efficiency of 80-90 per cent. Only 12.5% of the farmers achieved higher efficiency levels of greater than 90 per cent. About 15, 7.5 and 1.67% of the farmers registered efficiency levels of 60 to 70, 50 to 60 and 40 to 50 per cent respectively.

Table 5: Frequency distribution of sample rice farmers under different levels of economic efficiency

EE (%)	Number of farms	Percentage to total
40.01-50	2	1.67
50.01-60	9	7.50
60.01-70	18	15.00
70.01-80	39	32.50
80.01-90	37	30.83
> 90	15	12.50
Total	120	100
Mean EE	81.68	

Allocative efficiency of sample farms

The mean allocative efficiency was found to be 88.36 per cent indicating that there was a chance to increase the allocative efficiency by nearly 12%. Majority (40% per cent) of the sample farmers achieved allocative efficiency of 80 to 90 per cent whereas 35 per cent of the farms reported efficiency levels of greater than 90 per cent. About 21 per cent of the farms achieved 70 to 80 per cent efficiency levels. Thus three-fourth of the sample farms achieved efficiency levels of greater than 80 per cent.

Table 6: Frequency distribution of sample rice farmers under different levels of allocative efficiency

AE (%)	Number of farms	Percentage to total
50.01-60	1	0.83
60.01-70	4	3.33
70.01-80	25	20.83
80.01-90	48	40.00
> 90	42	35.00
Total	120	100
Mean AE	88.36	

Determinants of Technical Efficiency

Given a particular technology to transform physical inputs into outputs, some farmers were able to achieve maximum technical efficiency, while others were found relatively inefficient. This divergence could be due to many factors. Therefore, it is important to identify the factors which cause the difference in farm specific technical efficiency. A number of studies (Kalirajan, 1991, Kalirajan and Shand, 1989 and Shanmugam and Venkataramani, 2006) have suggested that efficiency of farmers is determined by various socio-economic factors.

The results of regression analysis carried out in this regard are presented in Table 7.

The results have shown that the education qualification of a farmer, experience in rice cultivation, membership in cooperative society and access to institutional credit were the positive and significant factors affecting technical efficiency, their coefficients being 0.0155, 0.0073, 0.1033 and 0.1827 respectively. This implies that farmers with higher educational level, greater experience in rice cultivation, having membership in cooperative society and access to institutional credit were more efficient in producing rice.

Table 7: Factors affecting technical efficiency in rice production

Variables	Coefficient	Standard Error
Constant	3.3467***	0.2205
Area (ha)	-0.0114**	0.0056
Age	0.0005	0.0023
Educational Qualification	0.0155**	0.0073
Experience in rice cultivation	0.0073**	0.0035
Family size	0.0586	0.0423
Membership in Cooperative Society	0.1033***	0.0444
Credit access	0.1827***	0.0794
R^2	0.7987	

Note: ***, ** and * denote 1%, 5% and 10% level of significance.

Area under the rice crop exhibited a significant negative (-0.0114) influence on the technical efficiency indicating that small and marginal farms were technically more efficient which may be attributed to their motivated family labour compared to their larger counterparts. Completion of farm operations during the specific time period is very crucial, however, it becomes increasingly difficult to complete some of the critical farm operations within time as farm size increases. The delay in timely application of inputs and completion of farm operations during critical periods on large farms might influence efficiency negatively.

Education enhances the acquisition and utilization of information on improved technology by the farmers as well as their innovativeness. Hence educated farmers were more efficient than illiterate farmers. An experienced farmer has the past experience to rearrange and make best use of his inputs to obtain higher output levels with a given technology. Membership in cooperative society affords the farmers the opportunity of sharing information and 'how to' knowledge on modern rice practices by interacting with other farmers thus helping in enhancing efficiency. Farmers' access to institutional credit enhances their timely acquisition of production inputs that enhance productivity via efficiency.

Conclusion

The mean technical, economic and allocative efficiencies were 92.44, 81.68 and 88.36 per cent respectively. By proper management and proper allocation of the existing resources and technology, sufficient potential exists for improving the productivity of rice. The results revealed that 63 and 76 per cent of technical and economic inefficiencies respectively were largely within the control of individual farmers.

Human labour has been found to be the major determinant of rice productivity in the region. The coefficients of prices of human labour (-0.2532), machine labour (-0.4599) and fertilizers (-0.1877) showed a significant negative effect on the profits.

Further, education level of a farmer, experience in rice cultivation, membership in cooperative society and access to institutional credit have been identified as the most influential determinants of technical efficiency. These are also the shifting factors of the production frontier. The study has revealed that the area under rice cultivation has significant negative impact on technical efficiency. Hence large farmers can emulate the practices followed by small and marginal farms to reap higher yield.

To improve the productivity via technical efficiency, access to formal credit, education and encouraging the small and marginal farmers have to be considered on priority basis by increasing the farm credit allocations, implementing compulsory education programmes and including the small and marginal farmers in all the Government programmes to make efficiency sustainable.

Majority of the farms (55.83 percent) were operating close to the frontier with the technical efficiency of more than 90 per cent indicating that there is little scope for improving the efficiencies of farmers with the existing technology as the farmers are already operating near the frontier. Hence new location-specific technologies should be developed and transferred to farmers. However, sufficient potential also exists for improving the productivity of rice by proper management and allocation of the existing resources and technology for farms operating at lower levels of efficiency.

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