Bulletin of Environment, Pharmacology and Life Sciences
Bull. Env. Pharmacol. Life Sci., Vol 7 [SPL 1] 2018 : 44-52

Online ISSN 2277-1808
Journal's URL:http://www.bepls.com
CODEN: BEPLAD
Global Impact Factor 0.876
Universal Impact Factor 0.9804
NAAS Rating 4.95

ORIGINAL ARTICLE **OPEN ACCESS**

Technical, Allocative, Scale and Economic Efficiencies of Paddy Production farms in Terai and Coastal Zones of West Bengal using Data Envelopment Analysis

G. Samba Siva[1], D. S. Gupta[2], S. Bask[3], S. C. Sarker[4], A. Saha[5] and M. K. Debnath[6]

Gutti Samba Siva (Ph.D Research Scholar)
Department of Agricultural Statistics
Uttar Banga Krishi Viswavidyalaya, CoochBehar, West Bengal-736 165.
E-Mail: shivagutti1410@gmail.com

ABSTRACT
The dream of agricultural growth in less developed countries with given scanty resource endowment and limited technology could be achieved by enhancing the efficiency of production. Data envelopment analysis is used to estimate the technical, allocative, economic and scale efficiencies of farms under paddy production in terai and coastal agro-climatic zones of West Bengal. The results revealed that most of the fields have high mean technical (≥ 0.90) and scale (≥ 0.93) efficiencies, implying that inputs are used in minimum levels necessary to achieve given output levels. On the other hand, most of the fields' exhibited allocative (≥ 22%) and economic (≥ 28%) inefficiencies imply that the existence of inefficiency in application of inputs necessary to achieve cost minimization. The paddy farms in terai zone have exhibited high efficiency scores compared to the farms in coastal zone.
Keywords: *Data Envelopment analysis, Technical efficiency, Scale efficiency, Allocative efficiency and Economic efficiency, Malmquist Productivity Index (MPI).*

Received 12.05.2018 Revised 29.05.2018 Accepted 11.07.2018

INTRODUCTION

Agriculture and allied sectors play a vital role in the Indian economy and account for approximately 13.9 percent of the national Gross Domestic Product. In view of the predominant position of the agricultural sector in the overall economy, an accurate and up-to-date information or knowledge of cost structure of crops is, therefore, necessary for the policy planners to advise the farmers to allocate their scarce resources in an efficient way. In 1970-71, the Government of India, on basis of the recommendations of the Standing Technical Committee on Indices of Input Costs, initiated "The Comprehensive Scheme for Studying Cost of Cultivation or Production of Principal crops (CCPC)" in India with an objectives to collect data on the use of inputs and outputs, both in physical and monetary terms, and to estimate the cost of cultivation per hectare and cost of production per quintal of various crops (GOI, 1980).

The farm level efficiency has been conventionally assessed through the concept of efficiency. A farm is said to be efficient if its objective of maximization of production is met and inefficient if they are not (Fare *et al.,* 1994). The farm level efficiency of agricultural produce is measured in different types such as allocative efficiency, technical efficiency, scale efficiency and economic efficiency. The efficiency issue needs a special attention while taking into consideration the concept of agricultural productivity in the system of agricultural production, particularly when resources are constrained and opportunities of adopting better technologies are competitive (Gaddi *et al.,* 2002). A change in productivity can be caused not only by a change in efficiency but also by a change in the production technology and the environment in which the production unit operates.

MEASUREMENT OF PRODUCTION EFFICIENCY

The methodology behind efficiency measurement begins with the work of Farrell (1957). Farrell introduced the notion of relative efficiency in which the efficiency of a particular decision making unit (paddy fields in the present study) may be compared with another DMU within a given group. Technical efficiency (TE) measures the ability of a DMU to produce the maximum feasible output from a given bundle of inputs (output oriented) or produce a given level of output using the minimum feasible amounts of inputs (input oriented). Allocative efficiency (AE) measures the ability of a technically efficient DMU to use inputs in proportions that minimize production costs at given input prices. Economic efficiency (EE) is calculated as the ratio of the minimum feasible costs and the actual observed costs for a DMU and it is the product of both TE and AE (Farrell, 1957).

The efficiency measures proposed by Farrell assume a known production function for the fully efficient DMU. The production function of a DMU is generally unknown in practice, and relative efficiencies must be measured from the sample data available. Two approaches are used to estimate relative efficiency indices: the parametric or stochastic frontier production approach (SFA) and the nonparametric or DEA approach (Coelli, 1995). The disadvantage of SFA is that it imposes specific assumptions on both the functional forms of the frontier and the distribution of the error term. In contrast, DEA uses linear programming methods to construct a piecewise frontier of the data. Because it is nonparametric, DEA does not require any assumptions to be made about functional form or distribution type. It is thus less sensitive to misspecification relative to SFA. However, the deterministic nature of DEA means all deviations from the frontier are attributed to inefficiency. The study uses data envelopment analysis (DEA) to obtain technical, allocative, economic and scale efficiency score for paddy production in terai and coastal zones of West Bengal at the field level, because it imposes no a priori parametric restriction on the underlying technology (Fletschner and Zepeda, 2002; Lansink, Pietola, and Backman, 2002; Wu and Prato, 2006).

DEA Model Specifications for Technical, Economic and Allocative Efficiency

Using the DEA model specification, the TE score for a given field *n* is obtained by solving the following LP problem:

$$\mathrm{TE}_{crs\,(n)} = \min_{\lambda_i \theta_n} \theta_n \qquad \dots (1)$$

Subject to:

$$\sum_{i=1}^{I} \lambda_i x_{ij} - \theta_n x_{nj} \leq 0$$

$$\sum_{i=1}^{I} \lambda_i y_{ik} - y_{nk} \geq 0$$

$$\sum_{i=1}^{I} \lambda_i = 1$$

$$\lambda_i \geq 0$$

Where *i* = one to *I* fields; *j* = one to *J* inputs; *k* = one to *K* outputs; λ_i = the non-negative weights for *I* fields; x_{ij} = the amount of input *j* used on field *i;* x_{nj} = the amount of input *j* used on field *n*; y_{ik} = the amount of output *k* produced on field *i;* y_{nk} = the amount of output *k* produced on field *n* and θ_n = scalar $\leq$ one that defines the TE of field *n*, with a value of one indicating a technically efficient field and a value less than one indicating a technically inefficient filed with the level of inefficiency equal to 1-TE_n (Coelli, 1995). The constraint $\sum_{i=1}^{I} \lambda_i = 1$ in equation (1) ensures the TE_n is calculated under the variable returns to scale (VRS) assumption proposed by Banker, Charnes, and Cooper (1984). When the constraint $\sum_{i=1}^{I} \lambda_i = 1$ is omitted the TE_n is calculated under the constant returns to scale (CRS) assumption proposed by Charnes, Cooper, and Rhodes (1978). Because the VRS DEA model is more flexible and envelops the data in a tighter way than the CRS DEA model, the VRS technical efficiency score is equal to or greater than the CRS or overall TE score.

If one has price information and is willing to consider a behavioral objective, such as cost minimization or revenue maximization, then one can measure both technical and allocative efficiencies. For the case of VRS cost minimization, one would run the following input-oriented cost minimizing LP model

$$\mathrm{MC}_n = \min_{\lambda_i x_{nj}^*} \sum_{j=1}^{J} P_{nj} x_{nj}^* \qquad \dots (2)$$

Subject to

$$\sum_{i=1}^{I} \lambda_i x_{ij} - x_{nj}^{*} \leq 0$$

$$\sum_{i=1}^{I} \lambda_i y_{ik} - y_{nk} \geq 0$$

$$\sum_{i=1}^{I} \lambda_i = 1$$

$$\lambda_i \geq 0$$

Where MC_n= the minimum total cost for field *n*; P_{nj}= the price for input *j* on field *n*; and x_{nj}^{*} =the cost-minimizing level of input *j* on filed *n* given its input price and output levels. Economic efficiency $(\mathrm{EE_n})$ for each filed is then calculated using the following equation:

$$\mathrm{EE_n} = \frac{\sum_{j=1}^{J} P_{nj} x_{nj}^{*}}{\sum_{j=1}^{J} P_{nj} x_{nj}} \quad \dots (3)$$

Where the numerator $\sum_{j=1}^{J} P_{nj} x_{nj}^{*}$= the minimum total cost obtained for field *n* using MC_n and the denominator $\sum_{j=1}^{J} P_{nj} x_{nj}$ = the actual total cost observed for field *n*. The AE score for field *n* can be determined given both the EE and TE for the field *n* using the following relationship given by Farrell (1957).

$$\mathrm{AE_n} = \frac{\mathrm{EE_n}}{\mathrm{TE_n}} \quad \dots (4)$$

Like with $\mathrm{TE_n}$, the values for $\mathrm{EE_n}$ and $\mathrm{AE_n}$ will be equal to one meaning the field is efficient and the values less than one meaning the field is inefficient with the level of inefficiency equal to 1 – $\mathrm{EE_n}$ or 1- $\mathrm{AE_n}$ respectively. The Scale Efficiency of farms can be measured by using the relationship between technical efficiency of the farms under CRS and VRS scale:

$$\mathrm{SE} = \frac{\mathrm{TE_{crs}}}{\mathrm{TE_{vrs}}} \quad \dots (5)$$

SE = 1 implies scale efficiency or CRS while SE < 1 indicates scale inefficiency that can be due to the existence of either increasing or decreasing returns to scale. As a consequence, some units that are VRS efficient can be inefficient under the CRS scheme because their size deviates from the optimal scale. One shortcoming of this measure of scale efficiency is that the value does not indicate whether the DMU is operating in an area of increasing or the decreasing returns to scale. This may be determined by running an addition DEA problem with non-increasing returns to scale (NIRS) imposed. This can be done by altering the $\sum_{i=1}^{I} \lambda_i = 1$ restriction with $\sum_{i=1}^{I} \lambda_i \leq 1$, to provide:

$$\mathrm{SE}_{(n)} = \min_{\lambda_i \theta_n} \theta_n$$

Subject to:

$$\sum_{i=1}^{I} \lambda_i x_{ij} - \theta_n x_{nj} \leq 0$$

$$\sum_{i=1}^{I} \lambda_i y_{ik} - y_{nk} \geq 0$$

$$\sum_{i=1}^{I} \lambda_i \leq 1$$

$$\lambda_i \geq 0$$

The nature of scale inefficiencies (i.e. due to increasing or decreasing returns to scale) for a particular DMU can be determined by, If $\mathrm{TE_{nrs}} = \mathrm{TE_{vrs}} \neq \mathrm{TE_{crs}}$ then the units are producing at decreasing returns to scale (Larger than optimal Scale); If $\mathrm{TE_{nrs}} \neq \mathrm{TE_{vrs}} = \mathrm{TE_{crs}}$ then the units are producing at increasing returns to scale (Sub-optimal scale) (Coelli, Rahman, and Thirtle,2002). In the input-oriented case, the DEA method defines the frontier by seeking the maximum possible proportional reduction in input usage, with output levels held constant, for each unit. In the output-oriented case, the DEA method would seek the maximum proportional increase in output production, with input level held fixed. The two measures provide the same technical efficiency scores when constant returns to scale technology applies, but are unequal when variable returns to scale are assumed.

Malmquist Productivity Index (MPI)

This Index was originally introduced by Caves, Christensen and Diewert (1982) and it is a total factor productivity index based on the ratio of two distance functions. This approach measures the productivity change by comparing observed change in output with the imputed change in output that would be possible from the observed input changes. This imputation is based on the production possibilities set for either the current or the subsequent period.

Let's suppose having for each time period $t = 1,\ldots,T$ a certain production technology S^t that transform the inputs x^t into outputs y^t

$$S^t = \{(x^t, y^t)\}$$

This means that the technology at t consists of the set of all possible input or output pairs. At time t there will be an output distance function $D^t(x^t, y^t)$ for every set of input or output belonging to S^t. To define the Malmquist index we need to define distance functions comparing output at one period with the technology of another period such as $D^t(x^{t+1}, y^{t+1})$.

The Malmquist Productivity Index (MPI) is equal to

$$MPI^t = \frac{D^t(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)}$$

If $MPI^t > 1$ productivity has increased between t and t+1. Alternatively it is possible to define another *MPI* using S^{t+1} as the reference technology:

$$MPI^{t+1} = \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t+1}(x^t, y^t)}$$

As previously stated, the Malmquist Productivity Index is calculated as geometric means of the two indexes above

$$MPI = \left[\frac{D^t(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} . \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t+1}(x^t, y^t)}\right]^{1/2}$$

This expression can be factored as

$$MPI = \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)}\left[\frac{D^t(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t+1}, y^{t+1})} . \frac{D^t(x^t, y^t)}{D^{t+1}(x^t, y^t)}\right]^{1/2}$$

Where it is possible to separate the change in relative efficiency and the shift in technology between the two period's *t* and *t*+1

$$\text{Efficiency change} = \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)}$$

$$\text{Techncal change} = \left[\frac{D^t(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t+1}, y^{t+1})} . \frac{D^t(x^t, y^t)}{D^{t+1}(x^t, y^t)}\right]^{1/2}$$

The change in relative efficiency is the change in the distance of observed production from maximum feasible production between *t* and *t*+1. Efficiency and technical changes indices exceeding unity reflect gains in those components. It is important to note that if $x^t = x^{t+1}$ and $y^t = y^{t+1}$ there has been no change in inputs and outputs between the periods and the productivity change index signals no change, so $MPI = 1$. In this case the component measures of efficiency change and technical change are reciprocals but not necessarily equal to one, because a change in efficiency might exactly offset a technological change.

Data

The data collected by the comprehensive scheme (CCPC) through three-stage stratified PPSWR followed by stratified WOR sampling design over the period from 2009-11 has been utilized for the present study to measure the production efficiency of farms under paddy in terai and coastal zones of West Bengal. The state of West-Bengal has acquired an important position in the agricultural scenario of the country and farmers with modest holding were able to derive the benefits of increases in production. Paddy is the major crop grown in the state. Instead of considering paddy grown in three different season's paddy production figure is considered as a whole. The other important crops like wheat, potato, jute and oilseeds are also cultivated in the state after paddy.

Input quantities, inputs costs, prices, and output data for the DEA analysis are obtained from 64 rice fields in terai zone and 49 rice fields in coastal zone collected by the comprehensive scheme. Inputs for the DEA analysis includes field size (hectares), irrigation (hrs), nitrogen (kgs), phosphorus (kgs), and potassium (kgs), seed (kgs), labour, bullock and machine (man hrs) and insecticidal cost (Rs). Output for the DEA analysis is measured as the value of paddy production (paddy yield (Qtls.Ha^{-1}) * Price (Rs.Qtl^{-1}) * Field size (Ha)). Input prices for irrigation water, nitrogen, phosphorus, potassium, and seed are also obtained from the farmer's fields for the EE and AE analyses. A land charge of 25 percent of rice value was assumed for the value of land in the EE and AE analyses. The summary statistics of inputs, input prices and outputs are presented in the table-1.

Table-1: Summary statistics of output, inputs and input prices of paddy crop used for DEA analysis in and Terai and Coastal agro-climatic zones of West Bengal.

Output	Terai Zone						Coastal Zone					
	Mean	SD	CV (%)	min	Median	Max	Mean	SD	CV (%)	Min	Median	Max
Production Value (Rs.)	81618	59699	73	1629	66213	263113	34538	24859	72	749	32120	97118
Inputs												
Field Size (Ha.)	2.25	1.56	69	0.06	2.00	6.73	1.27	1	78	0.03	1.28	4.67
Labour (Hrs.)	2444	1692	69	49	2176	7844	1188	904	76	19	1115	3651
Bullock (Hrs.)	150	146	97	0	116	582	9	19	208	0	0	84
Machine (Hrs.)	22	55	248	0	12	580	18	20	112	0	14	98
Nitrogen (Kgs.)	125	125	100	2	68	516	87	76	87	1	61	336
Phosphorous (Kgs.)	75	70	94	0	51	290	33	28	84	0	29	110
Potassium (Kgs.)	83	86	103	0	52	380	42	45	107	0	32	163
Seed (Kgs.)	140	113	81	3	105	480	94	75	79	3	91	310
Irrigation (Hrs.)	180	233	129	0	49	883	32	68	211	0	0	308
Insecticides (Rs.)	718	609	85	0	563	3565	227	493	217	0	0	2350
Input Prices												
Land charge (Rs./Ha.)	10717	2446	23	4944	10998	17056	9877	2922	30	3852	9827	17629
Labour price (Rs./Hrs.)	15.90	3.33	21	9.88	15.64	22.16	16.75	3.50	21	10.70	15.75	25.25
Bullock price (Rs./Hrs)	22.42	16.85	75	8.77	16.21	84.00	9.40	18.00	193	10.00	13.77	84.00
Machine price (Rs./Hrs.)	187.70	162.69	87	3.00	175	600	118.40	60.40	51	3.00	145	172
Nitrogen price (Rs./Kg.)	13.00	0.79	6	11.39	13.00	19.46	14.00	1.35	10	11.43	14.00	18.50
Phosphorous price (Rs./Kg.)	24.50	3.66	15	19.40	24.00	34.24	24.35	9.40	39	20.65	26.50	41.40
Potassium price (Rs./Kg.)	12.45	2.75	22	8.12	12.34	24.26	9.65	6.75	70	10.00	11.75	19.25
Seed price (Rs./Kg.)	20.00	3.00	15	11.50	20.00	26.00	23.40	6.55	28	15.00	22.00	60.00
Irrigation price (Rs./Hr.)	24.60	24.00	98	1.00	25.79	87.74	10.40	18.15	174	1.00	39.84	50.00

Summary statistics calculated from farm fields surveyed in terai and coastal agro-climatic zones of West Bengal (2009-2011).Paddy Production Value = paddy yield (Qtls.Ha^{-1}) * Price (Rs.Qtl^{-1}) * Field size (Ha.).Input levels for nitrogen, phosphorus and potassium are in elemental levels, Land charge =25percent of rice production value.DEA (Data Envelopment Analysis), SD (Standard Deviation), CV (Coefficient of Variation in percentages).

The aim of the study is to measure and compare changes in efficiency levels at two agro climatic zones of West Bengal. For this the study basically entails estimation and comparison of efficiency measures calculated for two agro climatic zones at two years i.e., 2009-10 & 2010-11.

RESULTS

Technical, Allocative, Economic, and Scale Efficiency Scores

The distribution of technical, allocative, economic and scale efficiency scores of the farms under paddy production along with summary statistics are obtained by using DEA are presented in table 2 and 3. Tim

J. Coelli, DEAP Version 2.1 (Data Envelopment Analysis Computer Program) was used to conduct the DEA linear programming analysis (Coeli, 2008) for each field in the present study.

Technical efficiency score summary statistics are presented under both CRS and VRS. In terai zone, the mean TE_{CRS} score is 0.91 and ranges from 0.54 to 1.00, whereas the mean TE_{VRS} score 0.94 and ranges from 0.63 to 1.00. The median TE_{CRS} and TE_{VRS} scores are 0.94 and 1.00 respectively, and indicate that over half fields in these agro-climatic zones have TE score of 0.94 or higher under CRS and achieve full technical efficiency under VRS. Thus, most of the farmers fields selected under comprehensive scheme achieve high technical efficiency. Similarly, in coastal zone, the mean TE_{CRS} score is 0.85 and ranges from 0.62 to 1.00, whereas the mean TE_{VRS} score is 0.90 and ranges from 0.73 to 1.00. The median TE_{CRS} and TE_{VRS} scores are 0.82 and 0.94 respectively. It is observed that farmers cultivating paddy in terai zone are technically efficient than the farmers cultivating paddy in coastal zone (both CRS and VRS). Higher TE scores are precedent in the studies of Tipi *et al*., (2009) for rice producers in Marmara region of Turkey, whereas the studies of Wadud (2003) and Khan *et al*., (2010) for rice producers in Bangladesh; Chauhan *et al*., (2006) for rice producers in India reported the mean TE scores above 0.88.

The mean scale efficiency score in terai zone is 0.96 and the median SE score of paddy fields is 0.99 and are ranging from 0.66 to 1.00. On the other hand the mean SE score on coastal zone is 0.93 and the median score is 0.94, which is identical to the mean score. The SE scores in coastal zone ranges from 0.62 to 1.00. the mean and median SE score are similar to the mean SE values reported in rice production efficiency studies of Dhungana *et al*., (2004) in Nepal, Krasachat (2004) in Thailand, Wadud (2003) Coelli *et al*., (2002) in Bangladesh and Tipi *et al*., (2009) in Turkey.

From the table-2, it is observed that higher mean SE scores indicate most of the farmer's fields operate at close to optimal scale i.e., operate at close to optimal field size in both the agro-climatic zones. Although small, mean scale inefficiency on an average is approximately four percent for the paddy fields in terai zone and seven percent in case of coastal zone paddy fields.

Table-2: Efficiency score summary statistics of paddy fields in Terai and Coastal agro-climatic zones of West Bengal.

Efficiency	**Terai Zone**						**Coastal Zone**					
	Mean	SD	CV (%)	Min	Median	Max	Mean	SD	CV (%)	Min	Median	Max
TE_{CRS}	0.91	0.11	12	0.54	0.94	1.00	0.85	0.09	11	0.62	0.82	1.00
TE_{VRS}	0.94	0.10	10	0.63	1.00	1.00	0.90	0.09	10	0.73	0.94	1.00
SE	0.96	0.07	7	0.66	0.99	1.00	0.93	0.07	8	0.62	0.94	1.00
AE	0.76	0.18	24	0.35	0.79	1.00	0.78	0.13	17	0.44	0.79	1.00
EE	0.72	0.20	28	0.35	0.79	1.00	0.71	0.16	22	0.42	0.67	1.00

TE, Technical Efficiency; AE, Allocative Efficiency; EE, Economic Efficiency ; SE, Scale Efficiency; CRS, Constant Returns to Scale; VRS, Variable Returns to Scale. SD, Standard Deviation; CV, Coefficient of Variation.

Table-3: Distribution of efficiency scores across the paddy fields in Terai and Coastal agro-climatic zones of West Bengal

Efficiency	**Terai Zone**					**Coastal Zone**				
	TE_{CRS}	**TE_{VRS}**	**SE**	**AE**	**EE**	**TE_{CRS}**	**TE_{VRS}**	**SE**	**AE**	**EE**
1.00	24 (37)	40 (63)	25 (39)	6 (9)	6 (9)	7 (14)	16 (33)	7 (14)	6 (12)	6 (12)
0.90–0.99	19 (30)	13 (20)	31 (48)	15 (23)	10 (16)	8 (16)	12 (25)	35 (72)	2 (4)	1 (2)
0.80–0.89	11 (17)	4 (6)	5 (8)	11 (17)	16 (25)	19 (39)	11 (22)	4 (8)	14 (29)	6 (12)
0.70–0.79	4 (6)	4 (6)	1 (2)	8 (13)	4 (6)	14 (29)	10 (20)	2 (4)	15 (31)	11 (23)
0.60-0.69	5 (8)	3 (5)	2 (3)	10 (16)	8 (12)	1 (2)	-	1 (2)	8 (16)	14 (29)
0.50 – 0.59	1 (2)	-	-	9 (14)	8 (12)	-	-	-	1 (2)	8 (16)
0.40 - 0.49	-	-	-	4 (6)	10 (16)	-	-	-	3 (6)	3 (6)
< 0.40	-	-	-	1 (2)	2 (4)	-	-	-	-	-
Sum	64 (100)	64 (100)	64 (100)	64 (100)	64 (100)	49 (100)	49 (100)	49 (100)	49 (100)	49 (100)

From the table-4, it is observed that most of the scale inefficiency arises from fields exhibiting IRS (fields at sub optimal size), nearly 45 percent and 41 percent of the fields in terai and coastal zones respectively exhibits IRS, whereas 39 percent and 16 percent of fields exhibit CRS (operate at optimal field size) and DRS (operate at larger than optimal field size) respectively in terai zone. Similar to the terai zone, slightly equal to 30 percent of fields' exhibits CRS and DRS in coastal zone of West Bengal.

Table-4: Returns to scale summary statistics of Paddy fields in Terai and Coastal zones of West Bengal.

Scale Classification	Terai Zone		Coastal Zone	
	Number	Percent	Number	Percent
CRS	25	39%	15	30%
IRS	29	45%	20	41%
DRS	10	16%	14	29%
Total	**64**	**100%**	**49**	**100%**

CRS, Constant Returns to Scale; IRS, Increasing Returns to Scale; DRS, Decreasing Returns to Scale

The mean AE score across the paddy fields in terai zone is 0.76 and are ranging from 0.35 to 1.00. It is observed from the table-2, the mean AE score in coastal zone (0.78) is slightly higher than the mean AE score of terai zone and are ranges from 0.44 to 1.00. The median AE score is 0.79 in both the agro-climatic zones. The mean AE scores imply that on an average, farmers' in terai and coastal zones are not using inputs in cost-minimizing levels of the given input prices to achieve given output levels and the same output levels could be achieved by reducing the average costs by approximately a maximum of 24 percent. Similar mean AE scores are observed across the rice production efficiency studies of Coelli *et al*., (2002) in Bangladesh and Xu and Jeffrey (1998) for conventional rice producers in China.

The mean EE score across the farms in terai and coastal zones are 0.72 and 0.71 respectively and are ranges from 0.35 to 1.00 in case of terai zone and 0.42 to 1.00 in case of coastal zone. The median EE scores are 0.79 and 0.67 in terai and coastal zones respectively. These results indicate that paddy fields in these zones are economically inefficient on average basis and the total cost of production for each field could be reduced on an average by approximately 28 percent to achieve the same level of output. The results are inconsistent with the rice production efficiency studies of Wadud (2003) and Huang *et al*., (2002).

The Malmquist productivity index

This study also analyzes productivity growth in paddy farms over two consecutive years. The output oriented Malmquist Total Factor Productivity (TFP) indexes based on the DEA like linear programming (Fare *et al*., 1994) is used to measure the technical efficiency, scale efficiency and total factor productivity changes. The indexes of TFP are decomposed into indexes of technological change and technical efficiency change (TECH) i.e. relative to CRS technology and pure technical efficiency change (PTECH) i.e. relative to VRS technology and scale efficiency change (SECH). This performance is mainly relative to the best practice or frontier. The annual average Malmquist index value or any of its components is less than one denotes the deterioration in performance and value greater than one denotes improvement in performance.

Malmquist TFP index values showed that the farms under paddy production in terai zone are performed well compared to the paddy farms in coastal zone (Table-5). An examination of the components of Malmquist TFP index for the farms in terai zone revealed that there is a gain in the technological (1.04), technical (1.05), pure technical (1.01) and scale efficiency (1.03) components, where the index values are greater than unity. On the other hand the farms in coastal zone showed an improvement in the technological (1.10), pure technical (1.04) and scale efficiency (1.05) components, whereas the technical component (0.90) has shown deterioration in performance. The total Malmquist TFP index values showed that the farms in terai zone are having higher TFP index values (1.10) compared to coastal zone farms (0.98) with a maximum TFP change of nearly 10 percent.

Table-5: Summary of Malmquist Productivity Index components of farms under paddy production in Terai and Coastal zones of West Bengal

S.No	Agro-Climatic Zone	Terai Zone	Coastal Zone
1.	EFFCH	1.04	1.10
2.	TECHCH	1.05	0.90
3.	PTECH	1.01	1.04
4.	SECH	1.03	1.05
5.	TFPCH	1.10	0.98

EFFCH, Technological change; TECHCH, Technical Efficiency change; PTECH, Pure Technical Efficiency change; SECH, Scale Efficiency change; TFPCH, Total Factor Productivity change

SUMMARY AND CONCLUSIONS

The results of efficiency study revealed that most of the fields are having higher mean technical and scale efficiency. Over 84 percent of the fields in terai zone and 70 percent of the fields in coastal zone of West Bengal achieved higher technical efficiency (TE > 0.80), whereas 85 percent of the fields exhibit high scale efficiency (SE > 0.90) (Table-3), implying that necessary inputs are used in minimum levels to achieve given levels of output and fields are operate nearly optimal in scale (field size). This is the indication that the most of the farms under paddy production in these zones are on or very close to the to the average production frontier. However, most of the fields under paddy production in terai zone exhibited allocative (24%) and economic inefficiencies (28%) on average basis. Although the results reflect high mean technical and scale efficiencies for the paddy fields in comparison of allocative and economic efficiencies revealed that the existence of inefficiencies with regard to use of inputs in the right combinations necessary to achieve cost minimization. The farms under paddy production have shown low TFP change (10%) in terai zone and deterioration of TFP change (2%) in coastal zone. This change in levels is may be less for long duration but these changes are considered to be more for two consecutive years.
As far as the West Bengal state is concerned, the agricultural universities *viz;* Uttar Banga Krishi Viswavidyalaya in Terai zone and Bidhan Chandra Krishi Viswavidyalaya nearer to coastal zone and research stations under these universities could play an important role in bridging the gap between laboratory research and field application by the farmers. However, the high TE and SE results could also be a reflection of the success of these universities, which is aimed as applying extension recommendations to achieve specific rice yield goals on farmers' field.

ACKNOWLEDGEMENTS

The authors are grateful to the Department of Science and Technology- Innovative Science Pursuit for Inspired Research (DST-INSPIRE), Govt. of India for encouraging and providing financial support for the research. The authors are also thankful to Department of Agriculture and Cooperation, Directorate of Economics and Statistics (CS Division), Ministry of Agriculture for providing us permission for utilization of cost of cultivation data.

REFERENCES

1. Banker, R.D., Charnes, A. & Cooper, W.W. (1984). Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis. Management Science., 30:1078–1092.
2. Caves, D.W., Christensen, L.R & Diewert, W.E. (1982). The Economic Theory of Index Numbers and the Measurement of Input, Output, and Productivity. Econometrica., 50:1393-1414.
3. Charnes, A., Cooper, W.W and Rhodes, E. (1978). Measuring the Efficiency of Decision Making Units. European Journal of Operational Research., 2:429–444.
4. Chauhan, N.S., Mohapatra, K.J.P.K.J & Pandey, K.P. (2006). Improving Energy Productivity in Paddy Production through Benchmarking-An Application of Data Envelopment Analysis. Energy Conservation and Management., 47:1063–1085.
5. Coelli, T.J. (1995). Recent Developments in Frontier Modeling and Efficiency Measurement. Australian Journal of Agricultural Economics., 39:219–245.
6. Coelli, T.J., Rahman, S & Thirtle, C. (2002). Technical, Allocative, Cost and Scale Efficiencies in Bangladesh Rice Cultivation: A Non-parametric Approach. Journal of Agricultural Economics., 53:607–626.
7. Coelli T.J. (2008). Centre for Efficiency and Productivity Analysis (CEPA) Working Papers: A Guide to DEAP Version 2.1: A Data Envelopment Analysis (Computer) Program., 96:1-50.
8. Dhungana, B.R., Nuthall, P.L & Nartea, G.V. (2004). Measuring the Economic Inefficiency of Nepalese Rice Farms Using Data Envelopment Analysis. The Australian Journal of Agricultural and Resource Economics., 48:347–369.
9. Fare, R.S., Grosskopf, S., Norris, M & Zhang, Z. (1994). Productivity Growth, Technical Progress, and Efficiency Changes in Industrialised Countries. American Economic Review., 84:64-83.
10. Farrell, M.J. (1957). The measurement of productive efficiency. Journal of the Royal Statistical Society., 120(3):253-290.
11. Fletschner, D.K & Zepeda, L. (2002). Efficiency of Small Landholders in Eastern Paraguay. Journal of Agricultural and Resource Economics., 27:554–572.
12. Gaddi, G.M., Mundinamani, S.M & Patil, S.A. (2002). Yield gaps, constraints and potential in cotton production in North Karnataka- An econometric analysis. Indian journal of Agricultural Economics., 57(4): 722-734.
13. Government of India. (1980). Report of the Special Expert Committee on Cost of Production Estimates. Department of Agriculture and Cooperation, Ministry of Agriculture.
14. Huang, M., Huang, C.J & Fu, T. (2002). Cultivation Arrangements and the Cost Efficiency of Rice Farming in Taiwan. Journal of Productivity Analysis., 18:223–239.
15. Khan, A., Huda, F.A & Alam, A. (2010). Farm Household Technical Efficiency: A Study on Rice Producers in Selected Areas of Jamalpur District in Bangladesh. European Journal of Soil Science., 14:262–271.
16. Krasachat, W. (2004). Technical Efficiencies of Rice Farms in Thailand: A Non-parametric Approach. Journal of American Academy of Business., 4:64–69.

17. Lansink, A.O., Pietola, K & Backman, S. (2002). Efficiency and Productivity of Conventional and Organic Farms in Finland 1994–1997. European Review of Agriculture Economics., 29:51–65.
18. Tipi, T., Yildiz, N., Nargeleçekenler, M & Çetin, B. (2009). Measuring the technical efficiency and determinants of efficiency of rice (*Oryza sativa*) farms in Marmara region, Turkey. New Zealand Journal of Crop and Horticultural Science. 37(2):121-129.
19. Wadud, A. (2003). Technical, Allocative and Economic Efficiency of Farms in Bangladesh: A Stochastic Frontier and DEA approach. Journal of Developing Areas. 37:109–126.
20. Wu, S & Prato, T. (2006). Cost Efficiency and Scope Economies of Crop and Livestock Farms in Missouri. Journal of Agricultural and Applied Economics., 38:539–553.
21. Xu, X & Jeffrey, S.R. (1998). Efficiency and Technical Progress in Traditional and Modern Agriculture: Evidence from Rice Production in China. Agricultural Economics., 18: 157–165.