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Technical Efficiency of Rice Farms under Irrigated Conditions of North West Himalayan Region - A Non-Parametric Approach

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I

INTRODUCTION

Uttaranchal is one of the newly formed states of the Indian Union which falls under the North Western Himalayan (NWH) zone. Even though Uttaranchal state as a whole is surplus with food production, the hill districts depicts a different picture. They face a shortage of about 29 thousand tonnes of foodgrains (2001-01).[1] Eleven out of the 13 districts in Uttaranchal come under hilly area of NWH region. Rice is an important staple foodgrain for the people of the hills. It is grown in an area of about 300 thousand hectares. The average productivity for the state as a whole is around 1900 kg/ha, whereas in the hills of Uttaranchal the average productivity is only 1091 kg/ha, which is almost half of the national productivity (2,086 kg/ha). The analysis of growth rate of rice productivity in Uttaranchal reveals that the growth rate was positive and significant in the last three decades (1970 -2001). The growth rate is around 1.2 per cent per annum (see Annexure 1). The five yearly moving average of productivity over the last three decades also depicts the same trend (see Annexure 2). During the eighties, rice productivity in Uttaranchal showed higher growth compared to succeeding and preceding decades. The spread of improved varieties with higher productivity levels over local varieties was one of the major reasons for improvement in the growth rate in the eighties. Many improved varieties in rice like VL 82, VL 62, Pant Dhan 11, Pant Dhan 12 were released especially for the irrigated conditions in hill areas.

Hill agriculture is practiced under tough conditions because of its unique character. The hill and mountain ecosystem is unique because of topographical features and climatic variations along the gradient. In general, hills receive 750 to 1250 mm precipitation; however, only about 10 per cent of the area is under irrigation in Uttaranchal hills that too confined to the lower valleys. Sub-optimal hydro-thermal regimes and shallow soil depths thwart further extension of cultivated land. Small and scattered land holdings and limited land use is also the main feature of hill agriculture. Therefore, the food produced is not sufficient to sustain for the whole

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year. These biophysical and socio-economic constraints result in low technical efficiency as well as discourage farmers to bear the risk. In this context increasing technical efficiency assumes significance. Improving efficiency levels under these conditions is a big challenge for farmers in the NWH region. Rice being the most important staple food in NWH region, improvement in efficiency levels is one of the major means of sustaining their staple food production and thereby ensuring food security.

Changes in productivity occur due to changes in technology and changes in technical efficiency. Since changes in technology have been introduced in the NWH region by introducing improved varieties, the major challenge is to improve the technical efficiency. The concept of technical efficiency relates to whether a firm uses the best available technology in its production process (Chavas and Cox, 1988). Technical efficiency may be defined as the ability of the firm to produce as much output as possible with a specified level of inputs, given the existing technology. There have been many parametric studies on assessing the technical efficiency of farms in the Indian context. Sarker and De (2004) and Chattopadhyay and Sengupta (2001) pointed out features of the non-parametric and parametric studies. They used non-parametric analysis and found that they are valid not only under very restrictive assumptions such as constant returns to scale (CRS) but also under variable returns to scale (VRS). Therefore, in this study we made use of the non-parametric analysis.

This study was taken up to determine the efficiency of rice cultivation under irrigated conditions in NWH region. Moreover, the study also explores the possibility, if any, the difference in technical efficiency levels between the local and improved technology (i.e., variety) in rice growing farms. The factors associated with inefficiency are also analysed. This paper is arranged in four sections. The next section discusses the analytical framework and suitability of methods used. Section III describes the data and regional characteristics of the study area. The fourth part deals with empirical results. The final section concludes the study with suggestions.

II

ANALYTICAL FRAMEWORK

In this study, estimation of the efficiency levels of individual farms using Data Envelopment Analysis (DEA) approach has been used. DEA has been extensively used for benchmarking performance. Benchmarking is a procedure for improving the performance by identifying the best practice, and measuring performance against the best practice. The best benchmark represents an amalgam of the best practices of one or more farms. DEA is based on linear programming technique. The use of linear programming to measure technical efficiency is usually attributed to Charnes *et al.* (1978), who coined the term data envelopment analysis. Since then, there have been a large number of papers which have extended and applied the DEA methodology.

Charnes *et al.* (1978) proposed a model which had an input orientation and assumed constant returns to scale (CRS). Subsequent papers have considered alternative set of assumptions, such as Banker *et al.* (1984) proposed a variable returns to scale (VRS) model. Coelli (1995), among many others indicated that DEA approach has two main advantages in estimating the efficiency scores. First, it does not require the assumption of functional form to specify the relationship between inputs and outputs. Second, it does not require the distributional assumption of the inefficiency term. Whenever there are data limitations and production technologies are not well understood as the case in NWH region, a non-parametric technique like DEAP will be more appropriate (Llewelyn and Williams, 1996).

DEA model assuming constant returns to scale (CRS) is appropriate only when the firm is operating at an optimal level. But since imperfect conditions, like imperfect competition, financial constraints, government interventions in input and output market for rice are more common, the farm may not be operating at an optimal level in practice. This situation is more predominant in hill conditions. Therefore, applying CRS DEA model may not be very appropriate. Instead, a variable returns to scale (VRS) DEA model as proposed by Banker *et al.* (1984) has been used for this study. Fare *et al.* (1985), Coelli *et al.* (1998) and Krasachat (2003) have refined the original Bankers *et al.* (1984) model for wider application.

One of the advantages of using DEA (Non-parametric) methodology is the focus on individual farms. The results of DEA can be used to identify the best farm management practices. By studying the management practices of these farms the extension worker can disseminate the inputs to the other farms, which require to improve the efficiency level. Thus the estimates obtained through DEA approach can serve as a potential tool for farm management. The DEA result relating to scale efficiency determines whether a farm is operating at an optimal scale or not.

The VRS model, which is being used in this study, is discussed below:

Let us assume that data are available on K inputs and M outputs in each of the N farm units. Input and output vectors are represented by vectors x_i and y_i respectively for the i-th farm. The data for all the farms may be denoted by the K x N input matrix (X) and M x N output matrix(Y). The envelopment form of input-oriented VRS DEA model is specified as:

$$\begin{aligned}
&\text{Min} \quad \theta, \lambda\ \theta, \\
&\text{st} \\
&-y_i + Y\lambda \geq 0, \\
&\theta x_i - X\lambda \geq 0, \\
&N1'\lambda = 1 \\
&\lambda \geq 0, \qquad \qquad \dots (1)
\end{aligned}$$

where, θ is the input technical efficiency (TE) score having a value $0 \leq \theta \leq 1$. If the θ value is equal to one, indicating the region is on the frontier, the vector λ is a N x 1 vector of weights which defines the linear combination of the peers of the i-th farm.

Thus, the linear programming problem needs to be solved N times and a value of θ is provided for each farm in the sample.

The VRS DEA is more flexible and envelops the data in a tighter way than the CRS DEA. The relationship that is used to measure the scale efficiency (SE) of the i-th farm is given as

$$SE_i = \frac{TE_{i,CRS}}{TE_{i,VRS}}$$

where, SE =1 implies scale efficiency or CRS and SE < 1 indicates scale inefficiency. However, scale inefficiency can be due to the existence of either increasing or decreasing returns to scale. This may be determined by calculating an additional DEA problem with non-increasing returns to scale (NIRS) imposed. This can be conducted by changing the DEA model in Equation (1) by *replacing the N1'λ = 1 restriction* with N1'λ ≤1. The NIRS DEA model now is specified as:

$$\begin{aligned}
\text{Min} \quad & \theta,\lambda\ \theta, \\
\text{st} \quad & -y_i + Y\lambda \geq 0, \\
& \theta x_i - X\lambda \geq 0, \\
& N1'\lambda \leq 1 \\
& \lambda \geq 0,
\end{aligned}$$

If, NIRS TE score is unequal to the VRS TE score, it indicates that increasing returns to scale exists for that region. If they are equal, then decreasing returns to scale apply. The efficiency scores in this study are estimated separately for local and improved variety growing farmers using the computer program, DEAP Version 2.1 described in Coelli (1996).

To identify the possible factors related to inefficiencies, the efficiency indices determined from the DEAP program are regressed on explanatory variables, i.e., age, education, farm size, and number of scattered fields. A linear Tobit regression equation is used to identify the factors associated with efficiency.

$$EFi = a + b_1 Age_i + b_2 (Age_i)^2 + b_3\,EDi + b_4\,FSi + b_5 NSFi + e_i \qquad \text{....(2)}$$

Where,

EF_i is Efficiency Index for farmer 'i',
Age_i is farmer's age in years,
Edi is Years of schooling,
FSi is the farm size in hectares,
NSFi is the number of scattered fields,
a is the intercept,
e_i is the error term.

The hypothesis assumed here is that the younger and better educated farmers are more efficient due to better access to information and inclination to adopt new technologies. Farm size will positively affect efficiency. In the hills, the nature of farm holdings has a major influence on the efficiency of farms. Given the same farm size between two farms, a farmer with fewer number of scattered holdings is bound to be more efficient than a farmer having a larger number of scattered fields. Tobit analysis is used because the dependent variable in this case are, centered variables having an upper limit of 1.00. This analysis can be helpful in targeting extension activities to deal with technical inefficiencies in production.

III

DATA AND REGIONAL CHARACTERISTICS

The farms studied in this analysis come under Bageswer district in Uttaranchal. The villages taken for the survey include Purura, Tallihat and Phulwari-gunth coming under Garur block. These villages were under the IVLP (Institute Village Link Programme) initiated during 1995-96 and funded by ICAR. The cultivated area under these villages is about 168.3 hectares of which around 41 per cent is irrigated. The local variety of irrigated rice grown in this area is popularly known as *Tapacheni.* The improved varieties which were introduced and grown are Pant Dhan 11, VL Dhan 206 and VL -82. Out of the total area of 60 hectares grown under irrigated rice, now around 82 per cent of the area is sown under improved varieties giving higher yields (Ved Prakash *et al.,* 2005).

Crop cultivation along with animal husbandry is the primary occupation of the population. A direct interview survey was carried out on 50 randomly selected rice farm households (25 farms growing improved varieties and 25 growing local varieties) in the three villages of Garur block. Out of these 5 respondents in each category were omitted because of lack of adequate information. So the effective sample size was 40. The summary statistics of sample farmers are given in Annexure 3. The cropping pattern of irrigated area of these villages is predominantly rice-based. The three villages are identical with respect to soil and climatic conditions. The information on crop activities pertained to the agricultural year 2004-05. The analysis in this study was based on one output and seven input production system. The data include 1. Output (kgs), 2. Farmyard manure (quintals), 3. Fertiliser (kg), 4. Chemicals (ml), 5. Land (ha), 6. Irrigation (hours), 7. Seed (kg) and 8. Human labour (hours). Information regarding age, education, farm size, nature of holdings (number of scattered fields), were also collected from the farmers in the study area.

IV

ANALYSIS OF RESULTS

Local Rice Farms

The DEA results of irrigated rice farms growing local varieties are summarised in

Table 1. The average measure of overall technical efficiency is estimated at 75 per cent. The overall technical efficiency of rice farm is the product of its scale efficiency

TABLE 1. EFFICIENCY MEASURES OF RICE FARMS GROWING LOCAL VARIETY

(1)	Overall technical efficiency (2)	Scale efficiency (3)	Pure technical efficiency (4)
Average	75	81	94
Minimum	17	27	21
No of efficient farms	6	6	12
Standard deviation	0.30	0.18	0.26

and its pure technical efficiency. Average scale efficiency is estimated at 81 per cent while average pure technical efficiency is estimated at 94 per cent. The average level of the overall technical inefficiency for irrigated rice farms is 25 per cent. The results also indicate that in case of local rice farms scale inefficiency is contributing more towards the overall inefficiency than the technical inefficiency. This implies that the rice farms can, on an average, reduce their inputs by upto 25 per cent by operating at an optimal scale and by eliminating pure technical efficiencies through the adoption of the best practices of efficient rice farms. The scale efficiency of local rice farms are summarised in Figure I. The DEA results suggest that, 30 per cent of local farms are operating at optimal scale, 70 per cent are operating at sub-optimal scale and none of the farms are operating above the optimal scale. This indicates that the largest increase in overall technical efficiency can be achieved by eliminating the problem of increasing returns to scale. This implies that from an agricultural policy point of view increasing share of rice cultivation in total farm area can bring about an improvement in the overall technical efficiency.

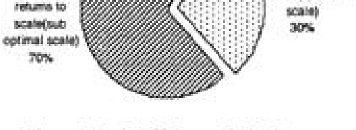

Figure 1: Scale Efficiency of Rice Farms
Growing Local Varieties

The frequency distribution of local rice farms by level of efficiency is summarised in Table 2. The overall technical efficiency of 50 per cent and above is for 75 per cent of rice farms growing local varieties. The pure technical efficiency of 50 per cent and above is found in more than 95 per cent of the local rice farms.

TABLE 2. FREQUENCY DISTRIBUTION OF LOCAL RICE FARMS BY LEVEL OF EFFICIENCY

Efficiency	< 0.5	0.5 -0.75	0.75 – 0.95	>0.95
(1)	(2)	(3)	(4)	(5)
Overall TE	5 (25)	2 (10)	5 (25)	8 (40)
Scale	3 (15)	2 (10)	6 (30)	9 (45)
Pure TE	1 (5)	- (0)	5 (25)	14 (70)

Figures in parentheses are percentage of farms n = 20.

Improved Rice Farms

The average measure of overall technical efficiency is estimated at 92 per cent in farms where improved rice technology (i.e., improved varieties like Pant Dhan 11, VL 82 etc.) have been adopted by the farmers (Table 3). The average scale efficiency is estimated at 97 per cent while the average pure technical efficiency is estimated at 95 per cent. The overall technical efficiency of 8 per cent implies that farms growing improved rice varieties can reduce their inputs by 8 per cent. This can be achieved through operating at an optimal scale and by the adoption of best practices of the efficient improved rice farms. Of the overall technical inefficiency of improved rice farms, scale inefficiency and technical inefficiency contribute 3 and 5 per cent, respectively. The results also indicate that the pure technical inefficiency makes a greater contribution to the overall inefficiency. This indicate that in the absence of environmental differences like differences in soil quality and climate, absence of measurement errors, pure technical inefficiency would reflect departures from the best practice of farm management. Thus, the way to eliminate the pure technical inefficiency in improved rice farms would be to adopt the practices of efficient farms.

TABLE 3. EFFICIENCY MEASURES OF RICE FARMS GROWING IMPROVED VARIETY

(per cent)

	Efficiency		
	Overall technical efficiency	Scale efficiency	Pure technical efficiency
(1)	(2)	(3)	(4)
Average	92	97	95
Minimum	60	84	67
No. of efficient farms	10	10	12
Standard deviation	0.11	0.08	0.05

The scale efficiency of improved rice farms indicate that 50 per cent of farms are operating at optimal scale, 45 per cent are operating at sub optimal scale and 5 per cent of farms are operating above the optimal scale (Figure 2).

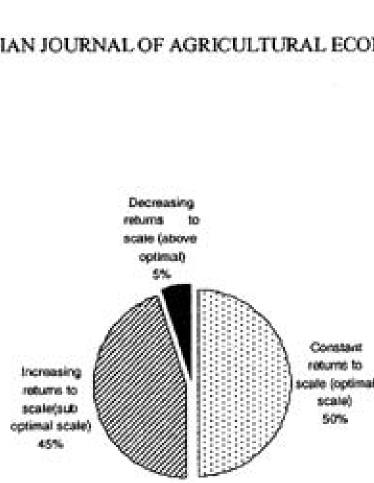

Figure 2 : Scale Efficiency of Rice Farms Growing Improved Varieties

In case of improved rice farms the overall technical efficiency of 50 per cent and above is found in all the farms growing improved varieties of rice (Table 4).

TABLE 4. FREQUENCY DISTRIBUTION OF IMPROVED RICE FARMS BY LEVEL OF EFFICIENCY

Efficiency (1)	< 0.5 (2)	0.5 -0.75 (3)	0.75 – 0.95 (4)	>0.95 (5)
Overall TE	-	1 (5)	6 (30)	13 (65)
Scale	-	-	4 (30)	16 (65)
Pure TE	-	1 (5)	4 (30)	15 (65)

Figures in parentheses are percentage of farms n = 20.

Similarly pure technical efficiency of 50 per cent and above is found in 100 per cent of the improved farms growing improved varieties of rice. Scale efficiency was found to be more than 75 per cent in all farms growing improved varieties of rice.

Factors Associated with Inefficiency

A Tobit regression is used to estimate the factors associated with technical efficiencies. The Tobit regression defined in Equation (2) was estimated using the Tobit procedure in LIMDEP (version 7.0). Efficiency measures are regressed on age, farm size, education and number of scattered fields per farm.

Farmers' age shows a significant quadratic relationship with overall technical efficiency and scale efficiency (Table 5). Efficiency increases with age and then eventually declines. Education, which is measured by the number of years of schooling, is found to be statistically significant with respect to overall technical efficiency. The value of the estimated coefficient is positive indicating that higher the education of the respondent farmer, more will be the technical efficiency. The farm size shows a significant and positive relationship with regard to scale and overall technical efficiency. No statistical relationship is found to exist between pure

TABLE 5. REGRESSION ANALYSIS TESTING INEFFICIENCY OF IRRIGATED RICE FARMS

Variable	Overall technical efficiency	Pure technical efficiency	Scale efficiency
(1)	(2)	(3)	(4)
Intercept	-0.791*	0.940*	-0.285*
	(0.35)	(0.17)	(0.26)
Age	0.068*	0.0008	0.048*
	(0.02)	(0.01)	(0.01)
Age^2	-0.0007*	-1.3 E-05	-0.00053*
	(0.00)	(0.00)	(0.00)
Education	0.029*	0.008	0.011
	(0.01)	(0.00)	(0.00)
Farm size	0.962*	-0.027	0.742*
	(0.01)	(0.02)	(0.07)
Number of scattered fields	-0.064*	-0.002	-0.044*
	(0.10)	(0.00)	(0.01)
Sigma	0.114	0.0687	0.0852
Log-likelihood	-352.53	50.39	-349.69

Figure in parentheses denotes standard error.
* indicate level of significance at 5 per cent level.

technical efficiency and farm size. Number of scattered fields per farm showed a negative yet significant relationship with regard to both overall and scale efficiency. The negative coefficient confirms that more the number of scattered fields lesser will be the efficiency. With regard to pure technical efficiency, none of the variables were found to have a statistically significant relationship.

V

SUMMARY AND CONCLUSIONS

Improving the efficiency levels in crop husbandry in north western hill situation is a major challenge due to its inherent limitations. Under irrigated conditions rice production is the major crop which accounts for the maximum area. Moreover, the farmers growing irrigated rice are more market-oriented and enterprising, the efficiency levels are supposed to be higher. To work out the efficiency, farm level data is used to analyse the various efficiency measures of rice in irrigated conditions in North Western Himalayan (NWH) region.

The overall technical efficiency in the case of improved rice growing farms is higher than that of rice farms growing local varieties. The results also indicate that in case of local rice growing farms, the scale inefficiency contributes more to the overall technical inefficiency. From the policy point of view, increasing the share of rice cultivation under irrigated situation in the total farm area can bring about improvement in the overall technical efficiency. With regard to farms growing improved rice varieties, pure technical inefficiency makes the greatest contribution to the overall inefficiency. By emulating the best practices of relevant efficient farms, less efficient farms growing improved rice varieties can eliminate pure technical inefficiency under irrigated conditions.

The study also suggests that efficiency initially increases and eventually declines with age. Moreover, higher education was found to be associated with higher efficiency levels. So, targeting younger and older farmers with low education level could increase the level of technical efficiency relative to middle aged farmers. The number of scattered fields per farm is associated with lower levels of technical efficiency. From policy point of view consolidation of land holdings can improve the *efficiency levels of rice farms in NWH region. Since consolidation is a long term* measure, another alternative could be to educate and motivate farmers through rigorous extension, to adjust and pool the land among themselves to create bigger fields for higher overall efficiency.

NOTE

1. This was worked out on the basis of food requirement of 176.3 kg/capita/annum in perspective plan of Vivekananda Parvatiya Krishi Anusandhan Sansthan (ICAR).

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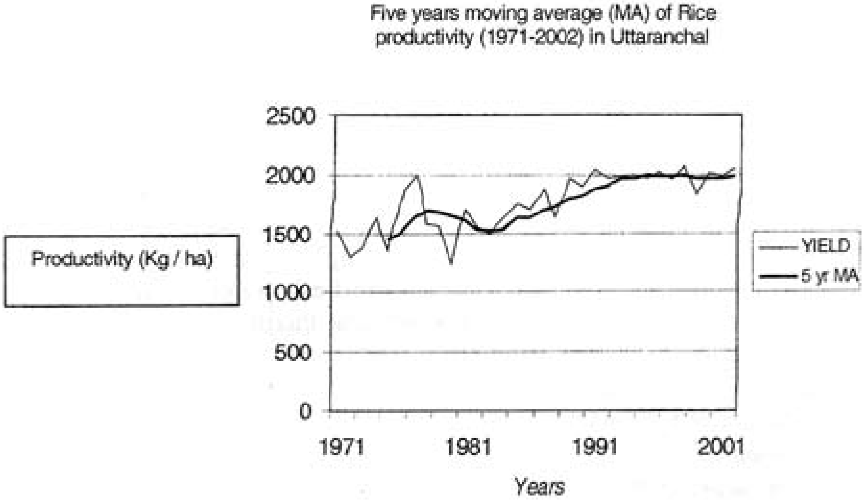
ANNEXURE 1

GROWTH RATE OF RICE IN UTTARANCHAL

Sr No (1)	Decade (2)	CAGR (per cent) (3)
1	1971-1981	0.65
2	1981-1991	2.10*
3	1991-2001	-0.04
4	Overall (1971 – 2001)	1.20*

* indicates level of significance at 5 per cent.

ANNEXURE 2



ANNEXURE 3

SUMMARY STATISTICS OF SAMPLE FARMERS GROWING IRRIGATED RICE

Variable (1)	Mean (2)	SD (3)	Minimum (4)	Maximum (5)
Output(kg)	202.85	201.79	80	1012
FYM(qtls)	3.99	8.65	0.1	40
Fertiliser(kg)	3.63	2.27	1	8
Chemical (ml)	102.00	96.62	1	400
Land (ha)	0.05	0.05	0.02	0.24
Irrigation(hrs)	5.95	4.19	1	15
Human labour(hrs)	63.82	34.72	12	123
Seed (kg)	4.10	1.97	1	8