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Non-Parametric Energy Use Efficiency, Energy Ratio and Specific Energy for Irrigated Wheat Crop Production

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ABSTRACT-In this paper, non parametric Data Envelopment Analysis (DEA) was subjected to the energy data of wheat producers in Punjab state, India, and technical, pure technical and scale efficiencies were calculated for farms both category wise and zone wise. The main objective was to determine the strength of the correlation between non-parametric efficiencies and indices such as energy ratio and specific energy. Results revealed that larger farms had a higher energy ratio and lower specific energy as compared to smaller ones. Frequency distribution of technical efficiency scores revealed that large farms were more consistent on efficiency scores, and the dispersion of technical efficiency was highest on medium farms followed by semi Medium and small farms. The correlation coefficients between energy ratio and each technical, pure and scale efficiency, as well as those between specific energy and each technical, pure and scale efficiency showed that energy ratio and specific energy are not appropriate indices for explaining farm efficiencies in different farm categories and zones.

Keywords: Data Envelopment Analysis, Energy-ratio, Specific energy, Technical efficiency, Wheat

INTRODUCTION

Wheat is one of the important crops of Punjab (India). Mittal (16) reported that the energy requirement for various farm operations was highest for Punjab (7925 MJ/ha) and minimum (4670 MJ/ha) for Madhya Pradesh. He also reported that small farms have been attributed to more intensive use of inputs, particularly human labor. Singh et al. (22) observed that the energy-ratio (the ratio of output to input energy) for growing maize-wheat crop rotation was 6.62 in zone 2 due to higher yield as compared to zones 1 and 3 in Punjab (Fig 1). Singh et al. (20) pointed out that the energy-ratio and specific energy (amount of consumed energy for one kg of produce, MJ/kg) for cultivating the wheat crop was 2.1 and 11.4 MJ/kg, respectively, in a typical arid zone in central India. Singh et al. (25) applied the Cobb-Douglas frontier function to model the yield of different category wheat farms in Punjab, India. The model established using the yield (kg/ha) as output and human, animal, diesel fuel,

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electricity, seeds, farmyard manure, fertilizer, chemicals and machinery in the form of energy (MJ/ha) as inputs. The results revealed that large farms used energy in the best possible way to achieve maximum productivity.

Technical efficiency can be calculated by non-parametric methods. A study was carried out by Bhushan (3) to estimate the productivity growth in wheat production for the major producing states of India from 1982-83 to 1999-2000 with the help of the Data Envelopment Analysis (DEA) non-parametric approach. Recalling that technical efficiency is defined as the ratio of the sum of weighted outputs to the sum of weighted inputs, the DEA approach was applied on some studies to determine farm energy use efficiency in agricultural systems ((1), (7), (12), (13), (18), (26)). However, from an energy point of view, energy-ratio and specific energy are indices used for determining the efficiency and performance of the farms in crop production systems ((4), (5), (6), (10), (15), (21), (23)). Therefore, in this study attempt has been made to show that such indices are not good parameters for representing farm performance. The idea was followed by determining the strength of the correlation between technical, pure technical and scale efficiencies (as non-parametric efficiencies), and energy-ratio and specific energy, pair-wise.

MATERIALS AND METHODS

The data for the study were taken from the “All India Co-ordinate Research project on Energy Requirement in Agriculture Sector” for different farm categories and zones growing wheat during the years 1997-2000. Farm category comprised of marginal (less than 1 ha), small (1 to < 2 ha), semi-medium (2 to < 4 ha), medium (4 to < 10 ha) and large (10 ha and more) farms, and agro-climatic region consisted of zones 1, 2, 3, 4 and 5 (Fig. 1 and Table 1) (24). The data included used hours of power source, amount of inputs used from different sources and the yield. The data were transformed to energy terms by appropriate energy conversion factors recommended by Singh et al. (24), Table 2. The values for the inputs and output energy per unit area (MJ/ha) and the yield (kg/ha) were used to obtain the energy–ratio (ratio of output energy to total input energy) and specific energy (ratio of total input energy to yield, MJ/kg). The homogeneity of the groups (either zone-wise or category-wise) were checked using Leven`s test with SPSS software version 11.5 (SPSS Inc., USA 1989-2002). Based on the homogeneity or heterogeneity of the groups (either farm categories or zones), suitable post-tests were chosen to assess the significant differences between groups (Tukey test for homogeneous groups and Tamhan test for heterogeneous groups), (9). Technical, pure technical and scale efficiency of each farm (Decision Making Units, DMUs) were computed by the non-parametric method i.e. DEA. Energy inputs (MJ/ha) and yield (kg/ha) as output were used to calculate the technical, pure technical and scale efficiencies.

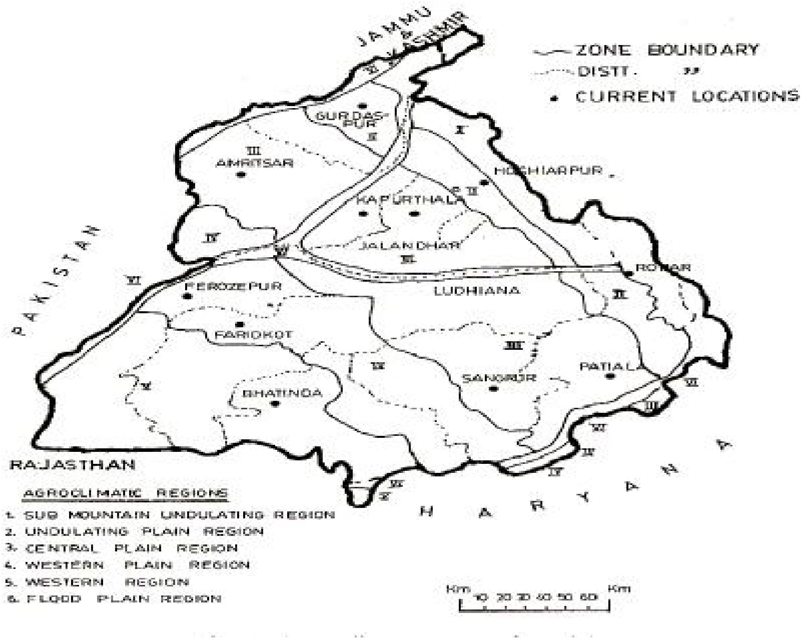

Fig. 1. Different agro-climatic zones of Punjab state (India)

Table 1. Different agro-climatic zones of Punjab state (India) and their specifications

zone	Region	Specifications
1	**Sub-mountains undulating**	**Soil erosion by water, poor soil fertility and shortage of irrigation water**
2	**Undulating plain**	**Soil erosion by water, poor soil fertility and shortage of irrigation water**
3	**Central plain**	**Excessive seepage loss of water, nutrition deficiencies, soil salinity**
4	**Western plain**	**Soil erosion by wind, poor quality of under-ground water**
5	**Western**	**Soil erosion by wind, poor quality of under-ground water**

Technical Efficiency

Technical efficiency can be expressed as the ratio of the sum of weighted outputs to the sum of weighted inputs and can be shown mathematically as the following equation (11):

$$TE_j = \frac{u_1 y_{1j} + u_2 y_{2j} + \ldots + u_n y_{nj}}{v_1 x_{1j} + v_2 x_{2j} + \ldots + v_m x_{mj}} = \frac{\sum_{r=1}^{n} u_r y_{rj}}{\sum_{s=1}^{m} v_s x_{sj}} \qquad (1)$$

Where, ‘x’ and ‘y’ are input and output and ‘v’ and ‘u’ are input and output weights, respectively, ‘s’ is the number of inputs (s =1,2,…,m), ‘r’ is the number of outputs (r =1,2,..,n) and ‘j’ represents *jth* of DMUs (j=1,2,…,k). The value of technical efficiency varies between zero and one. To solve equation 1, the CCR model, a linear program developed by Charnes, Cooper and Rhodes (8), was followed:

$$\begin{aligned} \text{Maximize} \quad & q = u_1 y_{10} + u_2 y_{20} + \ldots + u_r y_{r0} \\ \text{Subject to} \quad & v_1 x_{10} + v_2 x_{20} + \ldots + v_s x_{s0} = 1 \\ & u_1 y_{1j} + u_2 y_{2j} + \ldots + u_r y_{rj} \le v_1 x_{1j} + v_2 x_{2j} + \ldots + v_s x_{sj} \\ & u_1, u_2, \ldots, u_r \ge 0 \\ & v_1, v_2, \ldots, v_s \ge 0 \text{ , and} \quad (j=1, 2, \ldots, k) \end{aligned} \tag{2}$$

Where, θ is technical efficiency score. In the present study inputs were the energy from human, animal, diesel fuel, electricity, machinery, seeds, fertilizers and chemicals, and output was wheat yield. The value of inputs and output weights are calculated while the linear program is being solved in such a way that the value of technical efficiency approaches its maximum value.

Table 2. Energy equivalents of inputs and output

Particulars	Unit	Equivalent energy, MJ	Remarks
Human labor-adult man	**Man-h**	**1.96**	
Woman	**Woman-h**	**1.57**	**1 adult woman = 0.8 man**
Children	**Child-h**	**0.98**	**1 child = 0.5 adult man**
Animal – Bullock (large)	**Pair-h**	**14.05**	**Body weight above 450 kg**
Bullock (medium)	**-do-**	**10.10**	**Body weight 350-450 kg**
Bullock (small)	**-do-**	**0.07**	**Body weight less than 350 kg**
He-buffalo	**-do-**	**15.15**	**Equal to 1.5 medium bullocks pair**
Camel/horse	**Animal-h**	**10.10**	**Equal to medium bullocks pair**
Mules	**-do-**	**4.04**	**Equal to 0.4 medium bullocks pair**
Other small animal	**-do-**	**4.04**	**-do-**
Diesel fuel	**Liter**	**56.31**	**Includes cost of lubricants**
Petrol	**-do-**	**48.23**	**-do-**
Kerosene	**-do-**	**43.00**	
Electricity	**kWh**	**11.93**	
Machinery- Electric motor	**kg**	**64.8**	**Distribute the weight of the machinery equally over the total life of the machine in hours**
Prime movers	**-do-**	**58.4**	**-do-**
Farm machinery	**-do-**	**62.7**	**-do-**
Chemicals fertilizer-Nitrogen	**-do-**	**60.0**	**Estimate the quantity of nitrogen, P2O5, K20 in fertilizer and compute the energy input**
Phosphorus	**-do-**	**11.1**	**kg**
Potash	**-do-**	**6.7**	**Dry matter basis**
Zinc Solphate	**-do-**	**20.9**	
Superior chemicals	**kg/l**	**120**	**Chemical requiring dilution**
Inferior chemicals	**-do-**	**10.0**	**DDT, Gypsum or any other chemical not requiring dilution**
Wheat			
Grain	**kg**	**14.7**	**Straw/grain ratio=1.0 at 0.1**
By product	**do**	**12.5**	**moisture content**

Pure Technical Efficiency

In 1984, Banker, Charnes and Cooper introduced a model in DEA called the BCC model. The model could be used to compute the technical efficiency of decision making units (2). This efficiency is called pure technical efficiency and can be expressed by following a dual linear program:

$$\begin{aligned} &\text{Maximize} && z = uy_i - u_0 && (3)\\ &\text{Subject to} && vx_i = 1 \\ &&& -vX + uY - u_0 e \leq 0 \\ &&& v \geq 0\ ,\ u \geq 0 \quad \text{and}\ \ u_0\ \ \text{free in sign} \end{aligned}$$

where 'z' and 'u_0' are scalar and free in sign. 'u' and 'v' are output and inputs weight matrixes, and 'Y' and 'X' are corresponding output and inputs matrixes. The letters x_o and y_o refer to inputs and output of *ith* DMU.

Scale Efficiency

The pure technical efficiency indicates how much energy is consumed by each inefficient decision making unit with respect to an efficient one, whilst scale efficiency shows the inefficiency of farms as compared to efficient ones from a size point of view. In other words, pure technical efficiency deals with the excess use of energy inputs while scale efficiency deals with the farm size. Cooper (11) stated that:
Technical efficiency = Pure technical efficiency × Scale efficiency … 4

Hence, technical efficiency is affected by both pure technical and scale efficiencies, each determined by using DEA Solver Professional Release 4.1 (SAITECH, Inc., U.S.A.). The non-parametric Kruskal-Wallis post-test was used to assess the difference among groups of technical and pure technical efficiencies for different farm categories and zones ((9), (14), (19)). The Karl Pearson's correlation coefficients between energy-ratio and each technical, pure technical and scale efficiency, as well as specific energy and each technical, pure technical and scale efficiency were calculated for different farm categories and zones.

RESULTS AND DISCUSSION

Farm size category

An increasing trend was observed between total energy input and the size of the farms (Table 3). Marginal and small farms had the lowest energy input (12534 MJ/ha and 12200 MJ/ha, respectively) whereas the large ones had the highest (15261 MJ/ha). Fertilizers and chemicals, diesel fuel, seeds and electricity contributed about 93% of the total energy input, while fertilizers and chemicals alone contributed 49.7%. The correlation coefficient between the combined energy inputs of fertilizers and chemicals and the yield was r = 0.99. In other words, 98 percent of the variation in yield can be explained by fertilizers and chemicals energy.

The frequency distribution of technical efficiency revealed that the majority of farms in each category had a technical efficiency of less than 60%, as shown in Table 4. It was also observed that small farms with 1.8% efficiency ranked first among farm categories followed by medium (1.7%), marginal (1.5%) and semi-medium farms (1.2%). About 87.1% of all farm categories had an efficiency of less than 60%. Results in Table 4 also show that large farms were more consistent on efficiency scores and the dispersion of technical efficiency was the highest at medium farms followed by semi-medium and small farms. However, Kruskal-Wallis statistic showed that there was significant difference among technical efficiency of farms at different farm categories and emphasized that smaller farms had lower technical efficiency as compared to larger ones.

Table 3. Energy use (MJ/ha) and productivity of farms on different farm categories

	Marginal	Small	Semi-medium	Medium	Large
Human	587 [a*]	499 [bc]	537 [ab]	462 [c]	400 [d]
Animal	63 [ab]	118 [a]	91 [a]	23 [b]	0.4 [c]
Diesel fuel	3081 [a]	3179 [ab]	3327 [ac]	3479 [bd]	3619 [cd]
Electricity	1318	1054	1135	1269	1201
Machinery	309 [a]	300 [a]	381 [b]	495 [c]	598 [d]
Seed	1470 [ad]	1457 [abe]	1433 [bcf]	1414 [c]	1435 [ef]
Fertilizer & Chemicals	5684 [a]	5582 [a]	6896 [b]	7837 [c]	8004 [c]
Total	**12534 [a]**	**12200 [a]**	**13813 [b]**	**14982 [c]**	**15261 [c]**
Yield (kg/ha)	2929 [a]	2759 [a]	3510 [b]	4009 [c]	3897 [c]
Energy-ratio	6.2 [a]	6.0 [a]	6.9 [b]	7.3 [c]	7.0 [b]
Specific energy, MJ/kg	4.8 [a]	5.1 [a]	4.2 [b]	3.8 [b]	4.0 [b]

[*]Different letters witnin a row show significant difference of means at 5% level

Table 4. Frequency distribution of technical efficiency (CCR model) and pure technical efficiency (BCC model) of farms for different farm categories

		CCR model					
		Marginal	**Small**	**Semi-medium**	**Medium**	**Large**	**Total**
Efficient		2	3	3	5	-	**13**
Inefficient	**> 90 %**	-	1	-	4	-	**5**
	80 - 90 %	1	1	4	3	-	**9**
	70 - 80 %	2	7	6	9	2	**26**
	60 - 70 %	11	10	15	22	7	**65**
	< 60%	120	143	214	246	75	**798**
Number of Farms		**136**	**165**	**242**	**289**	**84**	**916**
Median of efficiency scores		**0.458 [a]**	**0.437 [a]**	**0.460 [a]**	**0.492 [b]**	**0.478 [ab]**	
		BCC model					
		Marginal	**Small**	**Semi-medium**	**Medium**	**Large**	**Total**
Efficient		7	12	10	16	1	**46**
Inefficient	**> 90 %**	12	17	21	19	10	**79**
	80 - 90 %	26	36	29	60	24	**175**
	70 - 80 %	28	59	81	95	35	**298**
	60 - 70 %	60	40	97	95	14	**306**
	< 60%	3	1	4	4	-	**12**
Number of Farms		**136**	**165**	**242**	**289**	**84**	**916**
Median of efficiency scores		**0.713 [a*]**	**0.762 [b]**	**0.712 [a]**	**0.743 [ab]**	**0.792 [b]**	

[*]Values with same letters are not significantly different at the 5% level

Frequency of pure technical efficiency (BCC model) in Table 4 represents that some CCR-inefficient farms moved on the BCC-efficient frontier. Small farms had the highest shift followed by medium, marginal, semi-medium and large farms. It is clear that these farms could not utilize energy from different sources efficiently.

Unskilled laborers and machine operators and inefficient machines might be the sources of this inefficiency. The BCC-inefficient farms, which build about 95% of the total, had technological and scale inefficiencies. In other words, there was a mismatch between energy inputs and the size of farms. It was observed that semi-medium and medium farms had more scale efficiency than others. Analysis of the data showed that farm size dispersion was the lowest in semi-medium and medium farms. Large farms had heavy tractors, and the mismatch between machinery and tractors caused an increase in fuel consumption. Data in Table 5 reveals that medium and semi-medium farms had the highest scale efficiency than others, and marginal farms had the lowest scale efficiency. It can be concluded that in marginal farms 50% of energy inputs were technologically wasted due to the inappropriate size of the farm.

Table 5. Technical, pure and scale efficiency of farms on different farm categories

Efficiency	Marginal	Small	Semi-medium	Medium	Large
Technical	0.46±0.14	0.45±0.16	0.47±0.13	0.51±0.14	0.48±0.10
Pure technical	0.75±0.12	0.79±0.11	0.74±0.11	0.77±0.10	0.79±0.09
Scale	0.50±0.10	0.69±0.12	0.72±0.08	0.76±0.09	0.65±0.06

Correlation coefficients between energy ratio and technical, pure technical and scale efficiency were calculated and found to be 0.92, -0.08 and 0.58, respectively. Regardless of direction of correlation, the same trend was also observed for specific energy and the aforementioned efficiencies. The correlation coefficients were -0.90, 0.06 and -0.50 for technical, pure technical and scale efficiency, respectively. As a result, energy ratio could be strongly explained by technical efficiency (R^2= 0.84) when energy ratio was regressed on technical efficiency.

Agro-climatic zone

he share of individual energy input from different sources was 49.7%, 24%, 10.3%, 8.6%, 3.6%, 3% and 0.4% for fertilizers and chemicals, diesel fuel, seeds, electricity, human, machine and animal, respectively, for all zones (Table 6). Farms in zone 4 and 5 consumed the highest value of N, P, K fertilizers (8977 and 7734 MJ/ha, respectively) because of the deficiency of soil nutrients. Farms in zone 2 consumed 8783 MJ/ha energy through fertilizers and chemicals. It is interesting to note that for zones 2, 4 and 5 the crop yield was higher than other zones, mainly due to the higher than recommended dose of fertilizers 7700 MJ/ha.

Diesel fuel was the second highest source of energy mainly for tractors, stationary diesel engines and combines. Analysis of the data revealed that the fuel consumption differed among the various zones at the 5% level of significance. Farms in zone 4 used 4039 MJ/ha energy from diesel fuel followed by zone 2 (3755 MJ/ha), zone 3 (3667 MJ/ha) and zone 1 (2498 MJ/ha). Farms in zone 4 used farm machinery and heavy tractors as well as combine harvesters, thereby consuming more diesel fuel energy. The equivalent energy from seeds was almost the same for all zones. Electricity used up 16% of the total energy for wheat production in zone 1 (1615 MJ/ha). The higher use of electricity in zone 1 was due to the use of heavy electric motor-pump sets (above 40 hp) for irrigation purposes. There was a large variation in electricity use among all zones.

Table 6. Energy use (MJ/ha) and productivity of farms in different agro-climatic zones

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Human	492 [a*]	636 [b]	365 [c]	564 [d]	368 [c]
Animal	80 [a]	157 [b]	41 [a]	9 [cd]	10 [d]
Diesel fuel	2498 [a]	3755 [bc]	3667 [c]	4039 [d]	2929 [e]
Electricity	1615 [a]	957 [b]	1208 [c]	2429 [d]	146 [e]
Machinery	247 [a]	326 [b]	449 [c]	690 [d]	377 [e]
Seed	1471 [a]	1460 [a]	1474 [a]	1344 [b]	1459 [a]
Fertilizer & Chemicals	3659 [a]	6150 [b]	8783 [c]	8977 [c]	7734 [d]
Total	**10061 [a]**	**13440 [b]**	**16073 [c]**	**18060 [d]**	**13022 [e]**
Yield (kg/ha)	1773 [a]	3508 [b]	4363 [c]	4825 [d]	3410 [b]
Energy-ratio	4.8 [a]	7.1 [b]	7.4 [b]	7.3 [b]	7.2 [b]
Specific energy, MJ/kg	6.2 [a]	3.9 [b]	3.7 [c]	3.8 [bc]	3.9 [b]

[*]Different letters witnin a row show significant difference of means at the 5% level

The electricity was not the main source of energy for irrigation due to canalled irrigation system in zone 5. Zone 4, with the total energy input of 18060 MJ/ha, was the highest energy consuming zone followed by zone 3 (16073 MJ/ha), zone 2 (13440 MJ/ha), zone 5 (13022 MJ/ha) and zone 1 (10061 MJ/ha). This was influenced by the energy inputs of fertilizers and chemicals. Although farms in zone 1 consumed less energy for wheat cultivation, considering the value of yield in this zone against other zones, it can be said that they wasted energy due to the topography of the lands and rain-fed conditions. This fact is confirmed by the value of specific energy.

The yield was maximum in zone 4 (4825 kg/ha) followed by zone 3 (4363 kg/ha), zone 2 (3508 kg/ha), zone 5 (3410 kg/ha) and zone 1 (1773 kg/ha) as mentioned in Table 5. The high value of yield in zone 4 may be due to more usage and impact of fertilizers and the consumption of more energy through the irrigation water. The energy-ratio revealed that wheat cultivators in zone 3 (7.3) had more efficiency than others. Among all other zones, farms in zone 2 had the lowest specific energy use (3.4 MJ/kg) whereas this was 3.8 MJ/kg for zone 4, 3.9 MJ/kg for zone 5, 4.0 MJ/kg for zone 3 and 6.2 MJ/kg for zone 1. It could be concluded that farms in zone 2 have used energy more efficiently than others.

The technical efficiency scores showed that farms in zone 4 have used energy to produce wheat in a more efficient way as compared to other farms (Table 7). Nearly 82% of the farms in zone 5 had technical efficiency scores less than 0.50. The poor soil quality (light soil) was the main problem of this zone, hence the framers could not reach acceptable levels of production, in spite of low energy consumption for irrigation due to the use of canal water. Farms in zone 2 had less technical efficiency than zone 4 due to lower irrigation, and less application of fertilizers and chemicals. The energy-ratio and specific energy also followed the same trend, though the difference was not significant. The number of efficient farms in zone 1 increased sevenfold when they were referenced by the BCC-efficient frontier, and tripled for zone 5. Farms in zone 1 had the high increment from technical efficiency 0.370 to pure technical efficiency 0.815. This implies that most farms could perform near the BCC envelop line, which in turn resulted in higher efficiency. It also indicates that the size of farms in zones 1 and 5 were almost the same with a low standard deviation. Data in Table 8 shows that farms in zones 3 and 4 had the highest scale efficiency than others, while farms in zone 1 had the lowest. This might be due to the huge variation in the size of farms in zone 1 (0.7±0.47 ha) as compared to those in zones 3 and 4, being 2.9±2.9 and 5.6±3.9 respectively. It can be concluded that 50% of the energy can be saved if the size of farms can be optimized with appropriate schemes.

Table 7. Frequency distribution of technical efficiency (CCR model) and pure technical efficiency (BCC model) of farms in different agro-climatic zones

		CCR model					
		Zone1	Zone 2	Zone 3	Zone 4	Zone 5	Total
Efficient		3	2	2	1	5	13
Inefficient	> 90 %	1	-	2	1	1	5
	80 - 90 %	5	-	2	2	-	9
	70 - 80 %	3	2	7	12	2	26
	60 - 70 %	17	13	7	18	10	65
	50 - 60 %	34	72	7	92	28	233
	< 50 %	115	140	29	74	207	565
Number of Farms		178	229	56	200	253	916
Median of efficiency scores		0.370 [a*]	0.477 [b]	0.495 [bc]	0.525 [c]	0.414 [a]	
		BCC model					
		Zone1	Zone 2	Zone 3	Zone 4	Zone 5	Total
Efficient		21	2	3	5	15	**46**
Inefficient	> 90 %	25	5	10	9	30	**79**
	80 - 90 %	46	16	7	18	88	**175**
	70 - 80 %	59	63	15	61	100	**298**
	60 - 70 %	26	141	21	98	20	**306**
	50 – 60 %	1	2	-	9	-	**12**
	< 50 %	-	-	-	-	-	-
Number of Farms		178	229	56	200	253	916
Median of efficiency scores		0.815 [a]	0.686 [bc]	0.740 [a]	0.70 [c]	0.807 [a]	

[*]Values with same letters are not significantly different at the 5% level

Table 8. Technical, pure and scale efficiency of farms in different agro-climatic zones

Efficiency	Zone1	Zone 2	Zone 3	Zone 4	Zone 5
Technical	0.42±0.18	0.49±0.09	0.57±0.17	0.55±0.10	0.44±0.13
Pure technical	0.82±0.11	0.70±0.08	0.78±0.12	0.72±0.10	0.82±0.09
Scale	0.50±0.15	0.69±0.05	0.72±0.09	0.76±0.03	0.53±0.10

Nearly 47 percent of the change in technical efficiency and 49 percent of the scale efficiency can be explained by energy ratio when technical and scale efficiencies were regressed on energy ratio individually. The correlation coefficients of 0.69, -0.50 and 0.70 were obtained among energy ratio and technical, pure technical and scale efficiencies, respectively. Corresponding values for specific energy were -0.68, 0.51 and -0.70. These values were low as compared to the corresponding values for the category-wise study mentioned earlier. The difference might be due to higher variation in the range of means in category-wise and zone-wise results as given in Tables 5 and 8. However, the trend of correlation was completely different in these studies (specially, the relation between the pair of pure technical efficiency-energy ratio and pure technical efficiency-specific energy). This means that if the technical efficiency is the concern of a farm manager, the value of energy ratio can not be used as a powerful index. Results also show that the methodology of the study (zone-wise or category-wise) has considerable effect on correlation values. This variation refers to frontiers (different datum) of non-parametric efficiencies. On the other hand, the values for energy ratio and specific energy for a farm are constant regardless of the kind of classification.

CONCLUSIONS

Correlation coefficients for pairs of energy ratio-technical efficiency, energy ratio-pure technical efficiency, energy ratio-scale efficiency, specific energy-technical efficiency, specific energy-pure technical efficiency, and specific energy-scale efficiency showed that energy ratio and specific energy are not good indices for precise decision making about the energy scenario in farms (either category-wise or zone-wise), and only show the overall view about energy consumption in farms.

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کارایی غیر پارامتریک مصرف انرژی، نسبت انرژی و انرژی ویژه برای تولید گندم آبی

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چکیده - در این مقاله روش غیر پارامتری تحلیل پوششی داده ها برای محاسبه کارایی های تکنیکی، تکنیکی خالص و مقیاس زارعان گندم کار ایالت پنجاب هند در دو روش تحقیق بر اساس مساحت سطح کشت و منطقه کشت مورد استفاده قرار گرفت. هدف اصلی این تحقیق تعیین شدت همبستگی بین کارایی های غیر پارامتریک و شاخص های نسبت انرژی و انرژی ویژه بود. نتایج نشان داد که کشاورزان با مزارع بزرگ نسبت انرژی بالاتر و انرژی ویژه پایین تری را نسبت به کشاورزان خرده مالک داشتند. توزیع فراوانی مقادیر کارایی تکنیکی پراکندگی کمتری را در این مقادیر برای بزرگ مالکان نشان داد، و بیشترین پراکندگی در مزارع متوسط و نیمه متوسط و کوچک بدست آمد. ضریب همبستگی بین نسبت انرژی و هرکدام از راندمان های تکنیکی، تکنیکی خالص و مقیاس، و همچنین انرژی ویژه و هرکدام از کارایی های تکنیکی، تکنیکی خالص و مقیاس برای هر دو نوع روش تحقیق نشان داد که نسبت انرژی و انرژی ویژه شاخص های مناسبی برای بیان کارایی های مختلف زارعان گندم کار نمی باشند.

واژه های کلیدی: انرژی ویژه، تحلیل پوششی داده ها، ، راندمان تکنیکی، گندم، نسبت انرژی

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*به ترتیب استادیار و استاد

**مکاتبه کننده