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A Survey on Water Use Efficiency of Rice Producers in Kamfirouz Region, Fars Province, Iran

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Abstract Regarding the increase in needs of human societies to agricultural products, increasing water use efficiency can lead to persistent use of limited water resources. Therefore, in this study using Data Envelopment Analysis (DEA), technical, allocative, managerial and economic efficiency and also Optimal level of inputs is surveyed in order to achieve maximum Efficiency in Marvdasht city in 2010. Furthermore, using sub-vector efficiency, Water Use Efficiency (WEU) of rice producers in Kamfirouz region located in Fars province, Iran, is determined. The results showed the average of technical, allocative, economical and managerial efficiency are 72, 40, 28, 79 and 91 percent respectively. Average of WEU with constant and Variable Return to Scale (CRS, VRS) assumptions were 28 and 35 percent, respectively. Rice producers have a potential to reduce the level of water use about 65 percent, without reducing productions. Based on the results, the worst uses of inputs are related to water, area and pesticide uses which are 40, 35 and 39.74 percent respectively. By findings, amendment of Water prices' tariff as well as conducting some training meeting and courses in order to fully introduce scientific principles of planting, conservation and harvest in optimal usage of production factors, specially water ,and also acquirement of farmers about Periodic irrigation instead of dipping irrigation is recommended.

Keywords Water Use Efficiency, Data Envelopment Analysis, Marvdasht.

1 Introduction

Rice is the main food of over three billion people around the world. Through 1.1 billion people of poor people which have daily income less than 1$, approximately 700 million live in rich rice Asian countries [1]. Also, among the agricultural products, the use of rice is the second product after wheat in Iran. According to statistics, in the 2008-2009 year crop, the acreage of grain varieties is estimated at 535 813 hectares, So that the Fars province with 22503 hectares is the most important producers in the country, Iran, after the Northern provinces - Mazandaran, Gilan and Golestan. Furthermore, the paddy production in the province in this year is 105012 tons of grain which the highest share of production, 57135

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tons, belongs to the farmers of Marvdasht city. Major rice in this city is produced in Kamfirouz which is located in the vicinity of a large dam reservoir Doroodzan, that has been constructed on the Kor River [2]. Due to low rainfall in recent years in Fars Province, as well as output reduction in the dam Doroodzan, optimal irrigation facilities are not provided in this area. Water requirement of rice is higher than other grains and its value is dependent on several factors such as cultivar, climate and culture types. Conventional irrigated rice in the rice-rich regions of the country (including the Kamfirouz of Marvdasht city), is permanent flooding with the proper height of water throughout the entire season [3]. Using this method leads to the use of excessive irrigation water and low irrigation water use efficiency [4].

Shortage of water resources and low efficiency in irrigated rice fields, require the optimum use of available resources and increase productivity [3]. Increase water use efficiency can due to increase production per unit of water and also the sustainable use of limited water resources in long term. The importance of this subject is clarified, when it be noted that about 4 billion cubic meters of water a year can be saved for each 5% increase in irrigation efficiency [5].

Therefore, it is worthy that water use efficiency as one of important indicators to measure water use and productivity, Should be considered further, so it can be used in planning [6]. Shakeri and Garshasbi [7] studied the technical efficiency of different varieties of rice in five selected provinces - Gilan, Mazandaran, Golestan, Fars and Khuzestan- using DEA. Adachi et al [8] evaluated technical efficiency of rice production in two regions in Bangladesh Using DEA. The average technical efficiency of these regions is acquired .756 and .721 respectively. Frija et al [9] investigated the efficiency of water use and its affected factors, using DEA, in greenhouses in Tunisia. The results showed that the average water efficiency, in terms of constant and variable returns to scale, is 42 and 52 percent, respectively. Also, training and investment in irrigation technology have a positive effect and the size of land has a negative effect on water efficiency. Speelman et al [10], using DEA, calculated the efficiency of water use and its affected factors in South Africa. The results showed that the averages water efficiency, in terms of constant and variable returns to scale, are 43 and 67 percent, respectively. Factors such as irrigation practices, land ownership, the size of land and product selection were effective on the efficiency of irrigation water.

Few studies have reviewed concerning the performance of rice and water efficiency, from an economic view In Iran. According to the importance of rice in the household food basket, create employment and income for large segments of the agricultural sector of Kamfirouz in Marvdasht city, given what was said, the more it is studied and reviewed of water use efficiency, the better would be the results. The purpose of this study is evaluating the water use efficiency of rice farmers in Marvdasht and determining the optimal amount of inputs (water, Land, pesticides, etc.) to achieve maximum efficiency in the production of this product as well.

2 Material and method

2.1 Data Envelopment Analysis (DEA) Models

Nowadays, two methods are used to calculate the efficiency, parametric or Stochastic Frontier Analysis (SFA) and nonparametric or DEA. SFA Approach is needed to specify the functional form and also, there is a risk of confusion in specifying the model and violations of classical assumptions while calculating the parameters. But the DEA determines the frontier production function based on linear programming techniques. This method is a nonparametric and it does not need to specify the production function to estimate; so there is less prone to error correction model. Another benefit of using DEA is that it can calculate Efficiency for each firm and its components separately [11]. First non-parametric method for determining the Efficiency of a system was introduced by Farrel in 1957 [12]. Then Charnes et al. [13] expressed additional contents of this method and the resulting model known as Charnes Cooper Rhodes (CCR). Bunker et al. [14] extended CCR model regarding VRS assumption, which is named Banker Charnes Cooper (BCC) model.

DEA uses inputs and outputs of each firm for construction a nonparametric production frontier. DEA models can be product-oriented or input-oriented. In output-oriented models aim is maximum production according to a certain amount of inputs and in input-oriented approach aim is minimum use of inputs with respect to a certain level of product. DEA models (both output-oriented and input-oriented) can be both constant returns to scale (CRS) and variable returns to scale (VRS). Factors such as imperfect competition, limited financial resources and so on, cause that all production units do not operate at optimal scale and technical Efficiency in terms of constant returns to scale is not pure and is associated with the Efficiency scale. Therefore in order to separate Technical Efficiency of the Efficiency scale, variable returns to scale model is used to measure pure technical Efficiency [15]. In the present study, to evaluate the technical Efficiency paddy from the DEA model used as follows [9]:

$$Min \quad \theta \tag{1}$$

s.t.

$$\sum_{k=l}^{k} \lambda_k y_{m,k} \geq y_{m,o},$$

$$\sum_{k=1}^{k} \lambda_k x_{n.k} \leq \theta . x_{n,o},$$

$$\sum_{k=1}^{k} \lambda_k = 1,$$

$$\lambda_k \geq 0.$$

The relationship between θ is technical efficiency; x_{nk} and y_{mk} are inputs (N)th and (M)th output for (K)th farm respectively. Constant λ_K, $x_{n,o}$ and $y_{n,o}$ respectively, are input and output vectors for the (i)th farm. Outputs and inputs used in calculating the technical efficiency of each farm are: rice production (kg / ha), water (m), seed (kg / ha), labor (people - day), area (hectares), machinery, chemical fertilizers (kg / ha) and pesticides (liters / ha). The first constraint states that the actual amount of product by unit (k)th can be more by used production factors. The second constraint implies that the production factors used by the unit (k)th should be at least as much as factors used by the reference unit. The third limitation is the convexity constraint which is used for variable returns to scale. This model is a model with input-oriented variable returns to scale, which is obtained by adding constraint $\sum_{k=1}^{k} \lambda_k = 1$ to the model of constant returns to scale.

Returns to scale assumption implies that the size of unit does not consider in evaluating the relative efficiency. The scale efficiency indicates the efficiency of advantages returns to scale by changing the size of the unit and it represents the unit's ability to operate at optimal economic scale [16]. Scale efficiency is defined as the ratio of technical efficiency under constant returns to scale to technical efficiency under variable returns to scale (managerial efficiency).

$$SE = \frac{TE_{CRS}}{TE_{VRS}} \tag{2}$$

In relation 2 TE_{CRS} and TE_{VRS} are technical efficiency in CRS and VRS assumptions. In this study, the minimum of costs method is used in order to evaluate economic efficiency [15]:

$$\begin{aligned} Min_{x_k^* \lambda} \quad & w'_k x_k^* \\ s.t. \quad & -y_k + y\lambda \geq 0, \\ & x_k^* - X\lambda \geq 0, \\ & N1'\lambda = 1, \\ & \lambda \geq 0. \end{aligned} \tag{3}$$

which w_k' is vector of inputs price for (k)th farm, x_k^* is vector of inputs values with the lowest cost for farm (k)th in prices of w_k and y_k is output values for (k)th farm. Output and inputs were described earlier. Cost efficiency or economic efficiency for the field (k)th is as follows [15]:

$$EE = \frac{w'_k x_k^*}{w'_k x_k} \tag{4}$$

Economic efficiency is defined as the minimum cost to observed cost.
Allocative or price efficiency is obtained from equation 5 [15]

$$\mathrm{AE} = \frac{\mathrm{EE}}{\mathrm{TE}} \tag{5}$$

Farrell introduced sub vector performance in a system. Variable t (Farmers cultivated water) is used to determine sub vector efficiency as following model [9]:

$$\begin{aligned} Min \quad & \theta^t \\ s.t. \quad & \\ & \sum_{k=l}^{k} \lambda_k y_{m,k} \geq y_{m,o} \qquad \sum_{k=1}^{k} \lambda_k x_{n-t.k} \leq x_{n,o} \\ & \sum_{k=1}^{k} \lambda_k x_{t.k} \leq \theta^t . x_{t,o} \qquad \sum_{k=1}^{k} \lambda_k = 1 \\ & \lambda_k \geq 0 \end{aligned} \tag{6}$$

θ^t is technical efficiency of input (t) for (k)th farm. In equation 9 $x_{t,k}$ and $x_{t,o}$ do not include the input t and also in equation 8 $x_{n,o}$ and $x_{n-t,k}$. Other variables were described in the above relations. The relations (8) and (9) determine the value of θ^t considering to maximum decrease of variable input t in constant condition of other input and production. θ^t can have values between 0 and 1, value 1 indicates that there is no farms between efficiency and potential boundaries to reduce irrigation water without reducing the level of production. Value less than 1 indicates an inefficiency of use water on farms. In this study, the optimal inputs are estimated to get the existing production and efficiency for regional farmers. Surplus use amount of each input is deducted from the average of real use of each of them (the amount of used inputs) [17].

2.2 Data and Information

In this study, the statistical population, are rice farmers of Kamfirouz in the city of Marvdasht, Fars province. In fact, more than 70 percent of rice of this province grows there [2]. For gathering data, questionnaires were used. Required data were obtained to evaluate the efficiency of rice farms in 2010. Using a simple random sampling method, a subset of individuals chose from a larger set. In this regard, first an initial sample is chosen and using equation 7, the number of members of the original sample, is estimated [18]:

$$n = \left[\frac{z\times s}{r\times y}\right]^2 \Bigg/ \left[1 + \frac{\left[\frac{z\times s}{r\times y}\right]^2}{N}\right] \tag{7}$$

In relation 7, n represents the number of required sample; z is cumulative probability of the corresponding point at 1-α level and standard normal distribution; r is absolute error in estimation, S is primary sample variance, y represent the average of primary sample and N is the number of population.

There are almost 5300 rice producers in this region. After determining the population, 50 initial questionaries were collocated and by calculating the variance at the 5% level, confidence interval, 211 farmers were surveyed. Paying attention to the other studies and region's circumstance, area, labor, machinery, seed, chemical fertilizer - phosphate and nitrate- and pesticide are selected as the variables. Analyze was performed with GAMS and DEAP software.

3 Results and conclusion

Table 1 shows average, maximum, minimum and standard deviation of used variables for rice producers of Marvdasht city. Regarding to the table, the average of harvesting rice is 2.67 per hectare. In area's variable is considered farms profitable area and paying attention to low average of this input, it seems the majority of farmers are yeomen.

Table 1 Statistical description of used variables in the production of rice in Kamfirouz in 2009- 2010

Variable name	Average	Maximum	Minimum	Standard deviation
Production (kg / ha)	2671.22	3500	1200	372.39
Land (hectares)	2.34	8	0.5	1.51
Labor (day - people / acre)	53.76	74	9.5	15.83
Machinery (h / ha)	7.92	10	4.8	0.95
Seed (kg / ha)	111.85	126.25	68.5	10.73
Fertilizer (kg / ha)	515.36	650	110	131
Pesticides (liters / hectare)	1.90	3	0.2	0.54
Water (m / ha)	18987.72	64960	4060	71.12

Table 2 represents the results of calculation of technical, allocative, economic, managerial and scale efficiency with CRS assumption. It is clear that the average of efficiency is equal 72 percent. It can be said that the rice producers have a 28% potential for decreasing of the inputs without any decreasing in the crop. Furthermore, in CRS assumption, 93 percent of the farmers have a technical efficiency more than 50 percent. Scale efficiency is 91 percent as well that indicates the majority of farmers are not in optimal scale. Base on the table, the average of allocative and economic are 28 and 40 percent, respectively.

The average of acquired allocative efficiency in the region shows that however, the rice producers use almost an optimal combination in terms of technical, but not about the cost. Economic efficiency is a kind of index in acquiring income and profitability. The rice producers can reach the allocation of optimal resource so that they can increase their incomes almost 72 percent by accepting technology. The range of variation of economic efficiency between the best and the worst farms due to difference in production costs per hectare is 93 percent and it indicates that there is a big difference between the farmers in terms of profitability. Table 2 shows the results of calculating scale and managerial efficiency. The high amount of managerial efficiency shows that technical knowledge has a significant effect in using of technology regarding available resources. Therefore, it can be mentioned that the rice producers has an acceptable management on the use of inputs in order to reach the maximum of outputs.

Table2 Frequency distribution and statistical description of Efficiency types, Kamfirouz's rice producers

Range of Efficiency changes	Technical Efficiency		Allocative Efficiency		Economic Efficiency		Managerial Efficiency		Scale Efficiency	
	Total	Percent	Total	Percent	Total	Percent	Total	Percent	Total	Percent
0.30 <	-	-	87	41.23	155	73.46	-	-	-	-
0.30- 0.40	2	0.94	57	27. 01	28	27.13	-	-	1	0.47
0.40-0.50	12	5.69	27	12.79	13	16.6	-	-	1	0.47
0.50-0.60	40	18.96	22	10.43	7	32.3	-	-	4	1.89
0.60-0.70	81	38.39	8	3.79	1	47.0	23	90.10	14	6.63
0.70-0.80	51	24.17	4	1.89	3	42.1	119	40.56	36	17.06
0.80-0.90	11	5.21	1	0.47	1	47.0	38	18	69	32.7
0.90-1.00	14	6.63	5	2.37	3	42.1	31	69.14	86	40.76
Average	0.72		0.40		0.28		0.79		0.91	
Maximum	1		1		1		1		1	
Minimum	0.30		0.12		0. 07		0.68		0.37	
Standard deviation	0.14		0.15		0.16		0.09		0.10	

Table 3 shows water use efficiency of the farms. It indicates that the averages of water use efficiency are 28 and 35 percent with CRS and VRS assumptions, respectively. Scale efficiency is 80 percent as well so that it shows the majority of the rice producers operate in optimal scale. Water use efficiency is very low in both CRS and VRS conditions. In CRS 90 percent and in VRS 68 percent of the rice producers, respectively have a level of efficiency less than 50 percent. Based on the results, there is a big difference among the farmers in terms of water use. Additionally, it is clear that the rice producers have a 65 percent potential of decrease in water use without any declining in crop product. Furthermore, there is a possibility of less water use while the product and other inputs are constant. The farmers can save considerable water use by boosting the water use efficiency.

Table 3 Frequency distribution and statistical descriptions of water use efficiency of Kamfirouz's rice producers

Water use efficiency under variable returns		Water use efficiency under constant returns		Range of efficiency changes
Percent	Total	Percent	Total	
57.82	122	69.19	146	0.30 <
9. 95	21	7.11	15	0.30- 0.40
0.47	1	14.22	30	0.40-0.50
20.85	44	2.37	5	0.50-0.60
0.47	1	0.95	2	0.60-0.70
0.47	1	1.42	3	0.70-0.80
-	-	0.47	1	0.80-0.90
9.95	21	4.27	9	0.90-1.00
0.35		0.28		Average
1		1		Maximum
0.062		0.045		Minimum
0.26		o.22		Standard deviation

In table 4, the average of real use and optimal use of inputs are compared. It is observed that the average of inputs use is higher than the optimal level. The results show that seed, chemical fertilizer and machinery toward the other inputs is used closely the optimal level. Overuse of inputs is obvious in irrigation water, area and pesticide. Regarding the amount of real use average and water use surplus, the optimal use of this input is almost 11420 m^3/ha while the real use is about 18988. Moreover, the rice producers could thus reduce the use of 40 percent water, 35 percent pesticide, 39.74 percent area and 5.62 percent labor without decreasing in product.

Table 4 Comparison of average use of inputs and the optimal amount of inputs used the rice production per hectare Kamfirouz

Input	The average of real use	Input slacks	The average of optimal Use	Necessary changes in input
Land (ha)	2.34	0.93	1.41	-39.74
Labor (people- day)	53.76	30.2	50.74	-5.62
Machinery (hr)	7.92	04.0	88.7	-0.51
Seed (kg)	111.85	62.0	33.111	-0.55
Fertilizer (kg)	515.36	68.10	68.504	-2.7
pesticide (Li)	1.90	0.66	1.24	-34.73
Irrigation water (m^3)	72.18987	7595.01	11420.71	-40.0

4 Conclusions and recommendations

In this study, using DEA, technical, allocative, economic and managerial efficiency were calculated and also optimal use of inputs were determined to achieve maximum efficiency in Marvdasht city paddy. Moreover, using the sub-vector Efficiency, water use efficiency of the farmers was determined. The results showed the average of technical, allocative, economic and scale efficiency of Rice producers are 72, 40, 28, 79 and 91 percent, respectively. Based on the results, the average water use efficiency, in terms of variable returns to scale was 35%, which is very low. Rice producers, have a 65 percent potential reduction in water use without reducing crop production. Lack of appropriate price mechanism, low cost pricing of water or having no price of its causes that farmers are not willing to save water use and investment for irrigation systems. This often causes wasting a large part of available water, particularly for farmers who have access to additional water resources. It is expected that, irrigation water price increase, aware of Consumers from water scarcity and on the other hand it makes efficiency improvements, water resources management and motivation. The increase in water prices is not without risk. Water price increases, in terms of social justice, should not be such that damage to low-income individuals. Nonetheless, water pricing makes farmers aware of the scarcity of water resources and encourages them to save water. Rice farmers can take a considerable amount of water savings, by improving the efficiency. Based on the results, the highest rate of non-optimal use of inputs, are related to water, area (land) and pesticide. Farmers can reduce irrigation, area and pesticide use without a reduction in production. According to the findings, tariff reform of water prices and more training to paddy are recommended considering scientific principles of planting, conservation and harvesting in optimal exploitation of production factors especially water and also paying attention to Periodic irrigation instead of flooding irrigation.

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