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EVALUATION OF THE EFFICIENCY OF GREENHOUSES IN GUILAN PROVINCE USING DATA ENVELOPMENT ANALYSIS (DEA)

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ABSTRACT: This research examines the financial performance of greenhouses in Guilan province in Iran. In order to do the research, questionnaires from 60 greenhouses were collected and features such as the general specifications of greenhouses, type of greenhouse covers, surface areas, infrastructure facilities, input raw material, energy and fuel costs, personal cost, production rate, sales prices of the produced products were considered. A financial performance measure developed from data envelopment analysis (DEA). According to the results, 7% of the greenhouses had an efficiency of 20%-40%, 22% between 40%-60%, 33% between 60%-80%, and 38% had more than 80%.

Keywords : *Data envelopment analysis, food security, greenhouse.*

Population growth and consequently, the demand for providing agricultural products and also the seasonal production of these products have caused strategies to be considered for meeting people's needs so that not only the production level is increased, but also producing out-of-season products would be possible. One of these strategies is to cultivate agricultural products (such as fruits and vegetables) in greenhouses. By doing so, besides the increased production rate, some production measures can be taken in all seasons as well.

Using environmental factors - controlling techniques is beneficial especially in regions, where the natural conditions of the essential factors of plant growth (soil and water) can be made suitable only by irrigation, weeding, applying fertilizers, etc. However, controlling and regulating the ambient temperature and light is beyond a farmer's capabilities and interfering with them is not possible; while in greenhouse cultivation, these two factors can be completely controlled and regulated for the desirable growth of a plant. It's been years since greenhouse cultivation is being practiced in Europe with many economic and profitability justifications (Sharifi, 13).

Optimum allocation of resources in an organization, enterprise or industry requires a continuous assessment of the performance of its units. Performance evaluation is one of the elements of the productivity improvement process because without measurement, making judgments would not be feasible and as a result, a proper controlling and planning could be impossible for the organization. Measuring the mentioned concepts have always been as object of attention for experts of different sciences including management, accounting, economics, engineering and mathematics and many researches have been done in this regard in a way that since 1965, when the first productivity measurement model was proposed by Kendrick-Creamer, many productivity and efficiency - measurement models have been presented by different individuals and global organizations. One of these models is the mathematical model of data envelopment analysis (DEA) (Motameni, 10). This method is based on linear programming and since it's an optimization method, it is advantageous over other efficiency analysis methods. With consideration of the characteristics of DEA and its being capable of providing a comprehensive and conclusive method for every unit of multiple inputs and outputs, it seems to be a suitable method for computing the efficiency of economic enterprises. Moreover, the possibility of considering variables for this model and using shadow prices causes it to be applied for assessing the efficiency of service-providing, non-profit-making and governmental sectors as well (Rahmanian, 12).

Efficiency and Data Envelopment Analysis

Efficiency is the explanation of the concept that with what quality an organization has used its resources for having the best production performance during a given period of time (Piece, 11). In fact, efficiency is the criterion for an organization's performance, which is established upon the amount of resources (inputs). In other words, it is the amount of resources that are used to produce a certain amount of a product. Generally, efficiency is calculated by the

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relationship between the output-input proportions (Mehrgan, 9).

Data envelopment analysis is a method which is applied to assess the efficiency and productivity of units that are responsible for using resources to obtain a desirable output. It may include several inputs and outputs without the need for predetermined weights (e.g. index method) and the clear specifications of the relationships between inputs and outputs (e.g. the regression method) (Bowlin, 3). DEA is a linear programming method which forms an efficient frontier using information from organizations and production units as decision-making units (DMUs). The frontier is created based on information in the form of inputs and outputs and according to the results of a consecutive linear programming. In fact, it is the inefficiency degree of each DMU to the distance between this unit and the efficiency frontier (Emami Meibodi, 4). Due to its unique capabilities, data envelopment analysis has become one of the common methods for performance evaluation and many of the researches in this field use it for this purpose and for assessing productivity as well. These capabilities have caused the said model to be used in the industry sector, financial services (banks, insurance, etc) and transportation, educational and research centers, health and treatment centers and so on. 'Measuring the Technical Efficiency in Malaysian Manufacturing Industries Using the Deterministic Production Frontier Function' is one of the researches in which this method was used by Wadonda (14). In this research, the efficiency of several industries including tea-producing factories in Malaysia during 1984-1988 was assessed using DEA technique. Obtained results revealed that the highest efficiency of the tea-producing industry was 72% in 1984, while the lowest efficiency was 44% in 1988 (Wadonda, 14).

Recently, various studies about data envelopment analysis (DEA) were done in Iran. For example, Kavousi and Ebrahimpour (5) conducted a research on effective factors of rice transformation industries productivity' using DEA method and the production function. This research was done on 130 rice transformation enterprises in Iran and its results showed that 19 enterprises were on the efficiency frontier. Some of the factors which affected the efficiency were also analyzed. Ghasemi *et al.* (6) used the same method for alfaalfa production in the Hamedan province, Iran. The results showed that from the total of 80 farmers, considered for the analysis, 46% and 69% were found to be technically and pure technically efficient, respectively. Mousavi *et al.* (8) studied energy use for barberry production in individual farms. The results indicated that total energy input and yield value of small farms were higher than those of large farms. Mohammadi *et al.* (7), assessed 82 rice paddy fields for spring and summer growing seasons in north of Iran. They used the combined implementation of Life Cycle Assessment (LCA) and Data Envelopment Analysis (DEA). Results showed average reduction levels of up to 20% and 25% per material input for spring and summer systems, leading to impact reductions which ranged from 8% to 11% for spring farms and 19% to 25% for summer farms depending on the chosen impact category. Bolandnaza *et al.* (2) used face to face questionnaire from 60 greenhouse cucumber farmers applying DEA method. The results indicated that greenhouse cucumber production consumed a total energy of 306,117.57 MJ ha^{-1} from which 58.5% was provided by diesel fuel.

MATERIALS AND METHODS

Assessing the efficiency of greenhouses in Guilan province in 2008 was the main objective of this research. In 2004, a total of 284 greenhouses were active in different towns of the Guilan province; however, due to the heavy snow in that year, only 120 of them remained of which 64 greenhouses were active and under cultivation in 2009, when questionnaires were distributed and thus, the required data were collected. These 64 identified active units were considered as the statistical population. After determining the needed population, a questionnaire was designed in which many aspects such as the general specifications of greenhouses, type of greenhouse covers, their surface areas, infrastructure facilities, raw materials to be applied, energy and fuel costs, working manpower number and cost, production rate, sales prices of the produced products, etc. were taken into account. Required data were collected by distributing questionnaires among the said units. Due to not having access to greenhouse owners and some incomplete questionnaires, four questionnaires were eliminated. After processing the data, EMS software was used for the DEA model.

Research Model

The modified BCC envelopment model of the input axis was used in this research. In the model, shows the proportion of the reduction of the studied unit's inputs for improving efficiency. Here, a unit is efficient only when the two following conditions exist:

(a) $\theta^{x} = 1$, and

(b) All the auxiliary variables have zero values.

$$\min\ y_0 = \theta - \sum_{y=1}^{x} \varepsilon s_y^+ - \sum_{j=1}^{m} \varepsilon s_i^- \qquad \ldots(1)$$

$$\sum_{j=1}^{x} \lambda_j\ y_n - s_\gamma^+ = y_{\gamma 0} \qquad \ldots(\gamma = 1 \ldots s)$$

$$\sum_{j=1}^{x} \lambda_j\ x_n + s_i^- = \theta x_{\iota 0} \qquad \ldots(i = 1 \ldots m)$$

$$\Sigma\lambda j = 1\theta = \text{Free for mathematical signal}$$

$$s_j^+, s_j^- \geq 0 \qquad \ldots(j = 1 \ldots n)$$

By solving the above-mentioned model for the studied units, two 'Efficient' and 'Inefficient' groups were identified. Those units whose efficiency score was 1 were determined as efficient units. Inefficient units could be rated by getting efficiency scores; however, units whose efficiency score was 1 could not be rated using classic DEA models. Therefore, the AP model was proposed by Andersen and Petersen (1), which made determining the most efficient units possible. Using this technique, the score of efficient units could be more than 1 (100%).In order to assess the efficiency by the DEA method, suitable inputs and outputs were selected first. Then, research inputs and outputs were selected to assess the efficiency of greenhouses as follows:

Inputs

L: Manpower cost; a payable value (in Iranian Rials) for rewarding the workers in 2008.

M: Value of production inputs (seeds, herbicides and pesticides, fertilizers and minerals) in Iranian Rials.

E: Energy; total payable cost for energy consumption in 2008.

H: Cultivated area (in meters).

Output

Y: Income; value of various greenhouse products in 2008 (in Iranian Rials).

Objective Function

Q: Efficiency of greenhouses in 2008.

RESULTS AND DISCUSSION

After distributing and collecting the questionnaires, 60 of the completed and received questionnaires were studied for assessing the efficiency and also for rating greenhouse units. Some of the questionnaires were received as incomplete, which after more visits, they were modified and completed. Of the existing models, the modified BCC envelopment model of the input axis of the data envelopment analysis was selected to assess the efficiency of greenhouse units in Guilan province. The reason for selecting BCC model was that according to the opinions of experts in this industry, increasing inputs does not lead to output increase in the same proportion, which means the variability of efficiency with scale. Furthermore, since several inputs and only one output is considered for assessing the efficiency, the input axis model, which reduces inputs by keeping the output constant was selected.

By solving the above-mentioned model for greenhouses, the efficiencies of 18 units became 1 or 100% (Q= 1) and formed the efficiency frontier. Forty-two other greenhouses had efficiency values of less than 1 (or <100%) (Q<1), which was an indication of their inefficiency. Then, by solving the AP model for 18 greenhouses, whose objective function equaled 1, the ratings of efficient units was done and therefore, all greenhouses were rated. The output related to solving the aforesaid models is given in Table 1.

Columns 1 and 4 of Table 1 indicate the number of DMUs. Columns 2 and 5 show the efficiency of those units, while columns 3 and 6 show the reference units or the pattern for each unit. In other words, for an inefficient unit in the above table to become efficient and be transferred to the efficiency frontier, a convex composition of its reference units should be found. This composition in the model has the same value of the coefficient of reference units multiplied by the values of the given unit's inputs. As mentioned before, units whose efficiency scores are less than 1 are identified as inefficient and can be rated by getting an efficiency score. However, units whose efficiency score is 1 (100%) can't be rated using classic DEA models. Therefore, efficient units have been rated by the AP model, proposed by Andersen and Petersen (1).

To analyze the software's output, at first, the modified BCC model of the input axis was implemented for all greenhouses (60 units) using EMS software and then, outputs obtained from solving the models were taken. Solving all 60 research models provided different information. As seen, 18 greenhouses, *i.e.,* 3, 4, 13, 15, 20, 23, 27, 28, 31, 32, 35, 39, 40, 41, 48, 51, 52 and 59 with values of 100% or more had the highest efficiencies. Also, the AP model was used for rating 18 units that were on the efficient frontier. Based on this rating, greenhouse number 3 was at the highest level. Average efficiency in this industry is 75.30%.

The efficiency of the existing greenhouses is given in four classifications in Table 2. As per observations (Table 2) no greenhouse has an efficiency less than 20%, 7% of them have an efficiency of 20%-40%, the efficiency of 22% of the greenhouses is at the range of

Table 1: Efficiencies of decision-making units (DMU_S).

Reference Units	Efficiency	Greenhouses	Reference Units	Efficiency	Greenhouses
18	120.49%	31	23, 27	80.00%	1
6	102.86%	32	23, 31	79.87%	2
23, 31, 35, 41	74.42%	33	14	1176.47%	3
13, 40, 48, 51	91.93%	34	3	100,00%	4
20	115.37%	35	23, 32, 48	62.66%	5
3, 40, 48	77.78%	36	3, 20, 23, 35, 51	59.34%	6
3, 40, 48, 51	83.29%	37	3, 23, 41, 51	54.92%	7
23, 27, 31	58.18%	38	13, 40, 48, 51	54.06%	8
1	102.59%	39	40, 48, 51	77.90%	9
9	102.42%	40	20, 23, 31	67.04%	10
4	140.88%	41	3, 23, 27, 35	51.48%	11
13, 23, 35, 48, 51	75.25%	42	13, 40, 48, 51	30.40%	12
3, 35, 41, 48, 51	90.54%	43	18	107.55%	13
13, 40, 48, 51	62.98%	44	13, 20, 35, 51	59.39%	14
13, 31, 35, 48	68.32%	45	3	100.00%	15
13, 23, 35, 48, 51	71.12%	46	13, 40, 48, 51	60.11%	16
23, 31, 32	25.69%	47	13, 23, 35, 48, 51	68.68%	17
23	264.67%	48	3, 20, 23, 35, 51	76.08%	18
3, 48, 51, 52	82.34%	49	3, 20, 35, 51	58.10%	19
20, 23, 31	37.94%	50	15	132.03%	20
25	100.00%	51	3, 20, 23, 35, 51	64.12%	21
1	291.67%	52	23, 27, 31, 35	36.52%	22
20, 23, 31, 51	59.74%	53	21	385.26%	23
3, 35, 48	49.57%	54	13, 23, 35, 48, 51	72.55%	24
3, 20, 23, 35, 51	61.73%	55	13, 31, 48, 51	56.86%	25
31, 35, 39	79.31%	56	31	54.28%	26
3, 27, 35	74.12%	57	5	129.69%	27
13, 20, 31, 51	72.81%	58	3	100.00%	28
4, 13, 15, 20, 28, 32, 48	100.00%	59	3, 40, 48, 51	88.66%	29
13, 20, 23, 35, 51	56.17%	60	31, 35, 41	51.84%	30

Table 2 : Classification of the efficiencies of greenhouse units.

Classification	Efficiency (%)	Frequency of Greenhouses (N)	Frequency of Greenhouses (%)
1	0-20	0	0
2	20-40	4	7
3	40-60	13	22
4	60-80	20	33
60	100	*Total*	

40%-60%, 33% of them have an efficiency of 60%-80%, while the efficiency of 38% of the greenhouses is more than 80%. The following diagram is given for a better comparison.

Regarding the efficiency, most of the greenhouse units are in the 80-100 classification (23 greenhouses, 38%). The detailed is shown is the Figure 1.

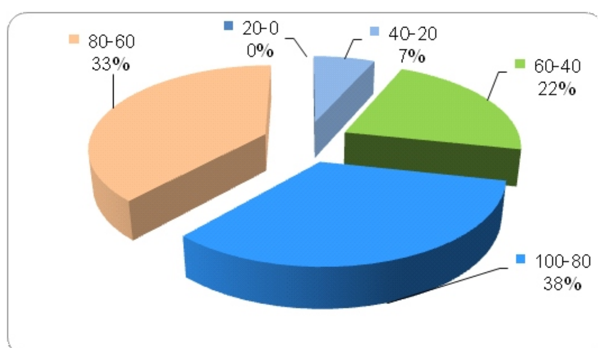

Figure 1 : Classification of the efficiencies of greenhouse units.

Then, in order to apply the results obtained from the DEA method, the interpretation of the software's output is expressed. Thus, output information obtained from solving the model for greenhouse number 5 (DMU 5) is analyzed:

1. The objective function's value, that shows efficiency, is Q= 62.66%, i.e. the company's efficiency is 62.66%. In other words, it is inefficient.
2. With consideration of the model's output shown in Table 2, the reference units of greenhouse number 5 are greenhouse numbers 23, 32 and 48. Thus, inputs of the virtual unit 5 are computed as follows:

$$D_{23}\ \text{(inputs of unit 23)} + D_{32}\ \text{(inputs of unit 32)} + D_{48}\ \text{(inputs of unit 48)}$$

$$0.81\begin{bmatrix}1{,}60{,}00{,}000\\ 13{,}25{,}000\\ 2{,}00{,}000\\ 700\end{bmatrix} + 0.15\begin{bmatrix}1{,}25{,}00{,}000\\ 2{,}160{,}000\\ 20{,}00{,}000\\ 500\end{bmatrix}$$

$$+\ 0.04\begin{bmatrix}6{,}40{,}00{,}000\\ 42{,}50.000\\ 30{,}00{,}000\\ 500\end{bmatrix} = \begin{bmatrix}57{,}31{,}000\\ 15{,}67{,}250\\ 5{,}82{,}000\\ 662\end{bmatrix}$$

This output expresses that for greenhouse 5 to reach the efficiency frontier, it should cause its input values to be equal to that of the virtual unit. In other words, it must reduce its manpower cost to IRR. 5,731,000. Moreover, it should reduce its fertilizer, seeds and minerals consumption to IRR. 1, 567,250, its payable cost of energy to IRR. 582,000 and its cultivated area to 662 mcompared with the amount of the harvested product. This interpretation is applicable to all DMUs so that managers can be informed of how to efficiently use their production resources.

CONCLUSION

Studying the trend of the population growth in the world and as a result, increased demands for food and agricultural products along with the damages caused by the population growth, mankind's greed and also the intensive destruction of the environment have made the use of new agricultural methods unavoidable. In fact, the global community has no choice but to use methods alternative to traditional agricultural methods including greenhouse cultivation.

However, continuous application of these methods irrespective of the efficiency of production units causes them to become uneconomic and as a result, they cannot be used. Hence, the efficiency of greenhouse units in the geography of Guilan province in Iran has been measured here, the results of which indicate that only about 30% of the greenhouse units are efficient and that necessary attempts should be made to improve the efficiency of the rest of the greenhouses.

Also, for the research results to be applicable, optimum production input values for inefficient units have been computed and suggested as well.

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