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Original Article

Efficiency Evaluation in Bell Pepper Production of Greenhouses in Iran

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ABSTRACT

In this research a data envelopment analysis (DEA) was applied to optimize the energy efficiencies of greenhouse bell pepper production units and to discriminate efficient producers from inefficient ones in south of Isfahan province in Iran. The degree of pure technical efficiency was investigated by BCC model based on nine energy inputs (water for irrigation, human labor, diesel fuel, machinery, fertilizers, chemicals, seeds, manure and electricity), and output yield values. The data were collected through a face-to-face interviewing from 30 greenhouses in selected area. The results indicated that total energy input was 12972218 MJha-1. The highest percentage of total energy input was consumed by diesel fuel. About 97.52% of the total energy had been consumed by diesel fuel. The results from BCC model indicated that 20 of greenhouses were efficient.
Keywords: Data Envelopment Analysis, Pure Technical Efficiency, Bell Pepper

INTRODUCTION

Agriculture that is both a producer and consumer of energy uses large quantities of non-commercial energies, such as seed, manure and animate energy, and commercial energies directly and indirectly in the form of diesel, electricity, fertilizer, plant protection, chemicals, irrigation water and machinery [1]. Effective energy use in agriculture is one of the conditions for sustainable agricultural production, because it provides financial saving, fossil resources preservation and air pollution reduction [2]. Energy efficiency improvement is an important way for sustainable energy management. For enhancing the energy efficiency, attention to increase the production yield or to conserve the energy input without affecting the yield level, is necessary [3]. Energy use efficiency (output energy to input energy ratio) and specific energy, i.e., input energy to yield ratio (MJ kg_1) of farmers in crop production systems are indices, which can define the efficiency and performance of farms [4]. Data Envelopment Analysis (DEA) technique is a non-parametric linear programming (LP) based technique of frontier estimation for measuring the relative efficiency of a number of decision making units (DMUs) on the basis of multiple inputs and outputs [5]. A main advantage of DEA is that it does not require any prior assumptions on the underlying functional relationships between inputs and outputs [6]. Technical efficiency (weighted output energy to weighted input energy ratio) is a way to explain the efficiency of farmers [7]. DEA models are divided in to two categories on the basis of orientation: input-oriented and output-oriented [8]. The efficient frontier is established by efficient DMUs from a group of observed units and Efficient DMUs are those with the highest level of productive efficiency [9]. Also In the analysis of efficient and inefficient DMUs, the energy saving target ratio can be calculated [10]. There are some researches on the energy use pattern and efficiency analysis of greenhouse crops production. Nassiri et al. [11] analyzed energy use efficiency for paddy crop using DEA technique. Technical, pure technical and scale efficiencies were estimated for farmers category-wise and zone-wise [11]. In another study by Mousavi-Avval et al. [12], the DEA technique was applied for analyses energy use for apple production in Iran. In this study, the technical, pure technical and scale efficiencies of farmers were calculated and the productivity performance of apple producers was analyzed [12]. Malana et al. [5] studied efficiency of selected wheat areas in Pakistan and India using DEA based on three inputs: water for irrigation (m3 ha_1), seeds (kg ha_1) and fertilizer use (kg ha_1). The results indicated that DEA is an effective tool for analysis and benchmarking productive efficiency of agricultural units [5]. In another study, DEA was used to measure the technical efficiency of input use for irrigated dairy farms in Australia [13]. Banaeian et al. (2010), applied DEA

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technique for investigate the efficiency of farmers with respect to energy use for walnut production in Iran. In this study the inputs were human labor, farm yard manure, fertilizers and transportation, and yield as output [14]. This paper illustrates how producers may benefit from applying operational management tools for measure their performance. It focuses on the application of DEA to calculate the technical efficiency of bell pepper growers based on the amount of nine inputs (human labor, fertilizers, chemicals, manure, diesel fuel, water, seed, electricity and machinery) use, and yield of bell pepper as output.

MATERIALS AND METHODS

This study was conducted in the Isfahan Province. The province of Isfahan is the main greenhouse production area in Iran. Isfahan province has a total of 811.5acres of greenhouse production of vegetables, flowers and ornamental plants. Averageannual34605tons of cucumbers, 7975 tons of tomatoes, 750 tons of bell peppers and 215 tons of Strawberry, is generated in this Province [15]. As regard in DEA model the proportion between the number of input and output parameters and the number of decision making are very important for presentation the valid results, it is necessary that the number of units be almost 3 times the total number of input and output parameters [8]:

1) Decision units ≥ 3 (I + O)

In this equation, I parameter is the number of input and O is the number of output. Therefore thirty greenhouses were selected to energy efficiency analysis and inquiries were conducted in a face-to-face interviewing. Data have been used to estimate the energy ratio, energy productivity, net energy and etc. According to the energy equivalents of the inputs and output (Table 1), the energy ratio (energy use efficiency), energy productivity and net energy were calculated [16]:

2) Energy Use Efficiency = Energy output (MJ ha_1)/ Energy Input (MJ ha_1)

3) Energy Productivity = output (kg ha_1) / Energy Input (MJ ha_1)

4) Net Energy = Energy Output (MJ ha_1) - Energy Input (MJ ha_1)

For the growth and development, energy demand in agriculture can be divided into direct and indirect energies or renewable and non-renewable energies [17]. Direct energy (DE) includes human labor, diesel fuel, electricity and water, while indirect energy (IDE) includes seed, fertilizers, chemicals, machinery and farm yard manure. Renewable energy (RNE) consists of human labor, seeds and water for irrigation, whereas non-renewable energy (NRE) includes diesel fuel, electricity, chemicals, chemical fertilizer and machinery [16]

Table 1. Energy forms in bell pepper production

Input	Unit	Energy equivalent (MJ unit^{-1})	Reference
Human labor	H	1.96	[3]
Machinery	Kg		
Tractor		93.61	[18]
Other machinery		62.7	[18]
Fertilizer	Kg		
Nitrogen		60.0	[7]
Phosphate (P2O5)		11.1	[7]
Potassium (K2O)		6.7	[7]
Farmyard manure FYM	Ton	303.1	[19]
Chemicals	Kg		
Fungicides		216	[20]
Insecticides		101. 2	[20]
Diesel fuel	L	43.99	[21]
Electricity	kw h	3.6	[22]
Water for irrigation	m^3	1.02	[23]
Seeds	Kg	1	[19]
Output			
bell pepper	Kg	0.8	[19]

Data envelopment analysis technique

Data envelopment analysis (DEA) is a non-parametric technique for determination both the relative efficiency of a number of decision making units (DMUs) and targets for their improvement [5]. It was introduced in 1978 by Charnes et al. [24] developing Farrell's idea [25] of estimating technical efficiency relation to production frontier. In DEA, an inefficient DMU can be efficient either by reducing the input levels while maintaining the outputs levels (input oriented); or by increasing the output levels while maintaining the inputs levels (output oriented) [26]. DEA has two models including Charnes, Cooper and Rhodes (CCR) and Banker, Charnes, and Cooper (BCC) models. The CCR model assumes constant returns to scale while the BCC model assumes variable returns to scale conditions. The CCR model measures the technical efficiency. BCC model decomposes the technical efficiency into pure technical efficiency for management factors and scale efficiency for scale factors [27]. Scale efficiency gives quantitative information of scale characteristics; it is the potential productivity gain from achieving optimal size of a DMU [12]. Choosing a proper DEA model depends on controlling input and output; therefore, a model would be chosen according to the most controllable input [28]. Because changing the level of input is practicable in this study, so input oriented CCR and BCC models, were used. So the bell pepper yield is hold fixed and the quantity of source wise energy inputs was reduced.

Pure technical efficiency (PTE)

TE can be defined as the ability of a DMU to produce maximum output from a constant level of inputs and technology. The TE score (θ), can be calculated by the ratio of sum of weighted outputs y to the sum of weighted inputs x, as follows [29]: $\theta_j = \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}}$

Where s is the number of outputs, m the number of inputs, n the number of DMUs, θj (j =1, 2,., n) is the technical efficiency of DMUj, ur(r =1, 2,., s) the weighting of output yr, vi (i=1, 2,., m) the weighting of input xi, and yrj and xij represent the values of the outputs and inputs yj and xi for DMUj, respectively. To measure the relative efficiency of a DMUo, the model is structured as a fractional programming problem as follows [8]:

$$\text{Max} \quad \theta = \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}}$$

S .t:

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}}$$

$$u_r \geq 0 \qquad v_i \geq 0$$

Using a linear programming (LP) problem, Eq. can be written as follows [8]:

$$\text{Max} \quad \theta = \sum_{r=1}^{s} u_r y_{ro}$$

s.t:

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0$$

j = 1, 2... n

$$\sum_{i=1}^{m} v_i x_{io} = 1$$

$$u_r \geq 0 \qquad v_i \geq 0$$

The dual linear programming (DLP) problem is simpler to solve than Banker et al model due to fewer constraints. Mathematically, the DLP is written in vector matrix notation [30]:

Min: θ

s.t:

$$y\lambda \geq y_0$$

$$x\lambda - \theta x_o \leq 0$$

$$\boldsymbol{\lambda} \geq 0$$

Where yo is the s ×1 vector of the value of original outputs produced and xo is the m× 1 vector of the value of original inputs used by each DMU. Y is the s×n matrix of outputs and X is the m× n matrix of inputs of all n units. $\boldsymbol{\lambda}$ is a n × 1 vector of weights and θ is a scalar with boundaries of one and zero which determines the technical efficiency score of each DMU. Banker et al. developed a model in DEA, which was called BCC model to calculate the PTE of DMUs. The BCC model is provided by adding a restriction on $\boldsymbol{\lambda}$ ($\boldsymbol{\lambda}$= 1) in model [18], resulting in no condition on the allowable returns to scale. This model assumes variable returns to scale (VRS), indicating that a change in inputs is expected to result in a disproportionate change in outputs.In this study for data analysis, the Microsoft Excel spreadsheet and the DEA SOLVER software were employed.

RESULTS

The results indicated that 287587.2 lit ha-1 of diesel fuel (97.52% of the total energy in operations) was consumed for the heating and machinery purposes. The bulk of diesel fuel was spent for heating the greenhouses and the remaining of it was spent for other operations such as tillage. In order to reduction of diesel fuel consumption, it is suggested that the heating system efficiency is raised or replaced with alternative sources of energy such as solar energy. Total mean input energy was 12972218 MJ ha_1. Similar results were found in the literature indicated that the highest energy item was diesel fuel in agricultural crops production [16, 31, 17]. Second place was awarded to the electricity consumption with 1.679% of total energy input. Electricity used in the greenhouse systems is used for pumping wells, pumping drop systems, heating systems, lighting, and fan and pad systems and etc. Average annual yield of greenhouses investigated was 116200 kg ha_1, and calculated total energy output was 92960MJ ha_1. energy use efficiency (output–input ratio), energy productivity and net energy of bell pepper production were 0.007, 0.009 kg Mj-1 and -12879258 MJ ha_1 respectively that showing the inefficient use of energy in the greenhouse bell pepper production.

Table 2. Energy forms in bell pepper production

Energy forms	Value	Percentage (%)
Direct energy MJ ha^{-1}	12895133	99.41

Indirect energy MJ ha^{-1}	77085	0.594
Renewable energy MJ ha^{-1}	56041.82	0.432
Non-renewable energy MJ ha^{-1}	12916176.32	99.57

Table 2 shows Energy forms used in greenhouses. Portion of Direct, Indirect, Renewable and Non-renewable energies were found 99.41%, 0.594%, 0.432% and 99.57% respectively. Direct energy includes electricity, human labor, diesel fuel, water for irrigation. Indirect energy includes seed, fertilizers, chemicals, machinery and manure. Renewable energy includes seed, human labor, water for irrigation and manure. Non-renewable energy includes diesel fuel, electricity, chemicals, fertilizers, machinery [32]. Cause of increasing the share of Direct and None renewable energy is exposure of the fuel energy in this category of energies. Several researchers have found that the ratio of DE is higher than that of IDE, and the rate of NRE was much greater than that of RE consumption in cropping systems [19, 17 and 32].

The results of BCC model is presented in Table 3. The results revealed that, from the total of 30 producers, 20 producers had the pure technical efficiency score of 1. Average of pure technical was 0.97. Chauhan et al. Estimated the pure technical efficiency of farmers as 0.9249 in paddy production activities in the state of West Bengal in India [7]. In another research, the pure technical efficiency of farmers was found about 0.90 [12]. Nassiri et al. applied the non-parametric method of DEA to calculate the pure technical efficiency of farmers in paddy production in Punjab. They reported that in zone 2, pure technical score were as 0.91 [11]. In another study by Iraizoz et al. the efficiency of tomato and asparagus production in Spain was examined. In this study the pure technical efficiency for tomato production was found 0.80 and for asparagus production as 0.89 [33].

Table 3. Results of efficiency analysis

DMU	Pure Technical efficiency
GH1	1
GH2	0.85
GH3	1
GH4	1
GH5	0.93
GH6	1
GH7	1
GH8	0.92
GH9	1
GH10	1
GH11	1
GH12	0.97
GH13	1
GH14	1
GH15	1
GH16	1
GH17	1
GH18	0.99
GH19	1
GH20	1
GH21	0.69
GH22	1
GH23	0.97
GH24	1
GH25	1
GH26	0.93
GH27	0.93
GH28	0.97
GH29	1
GH30	1
Mean	0.97

DISCUSSION

In this research, the energy requirements of inputs and output for bell pepper production were investigated in Isfahan Province of Iran. On an average, the non-renewable form of energy input was 99.57% of the total energy input used in the bell pepper production. It is clear that the use of renewable energy is very low, indicating bell pepper production depends mainly on fossil fuels. On average, 99.41% of total energy input used in bell pepper production was direct affected, while the contribution of indirect energy was 0.594%. Also the shares of renewable and nonrenewable energy inputs were 0.432% and 99.57%, respectively. The input oriented BCC model was used to estimate the energy efficiencies of producers. The pure technical efficiency score was found to be 0.97. The results of this study indicated that diesel fuel energy had the highest potential for improvement, followed by electricity energy inputs. Applying a better machinery management technique, utilization of alternative sources of energy such as radiant systems to provide energy for heating the greenhouses, organic fertilizers or integrating the legume crops in to the rotation may be useful for improve the energy use efficiency.

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