Optimizing Energy Consumption in Producing Cucumber and Tomatoes Crops of Greenhouses in Khuzestan by DEA

Vahid Dehghani, Nima Nasirian, Mohammad javad Sheyk Davoudi

Abstract

Although Agricultural activities, the main producer of food supplies, consume energy, they are considered as the major biological energy producer. The aim of this study is comparing and analyzing the energy productivity of greenhouse tomatoes and cucumbers production in Khuzestan province. A data envelopment analysis approach has been used to determine the efficiencies of farmers with regard to energy use. For this purpose, data were collected from farmers using a face to face questionnaire. Since the decision maker units should be 3 times as large as the total number of input and output parameters, therefore, all greenhouse units were considered through the study. Investigated inputs were: labor, machinery and equipment, fuel, chemical pesticides, chemical and organic fertilizers, electricity and water. Energy equivalent of each input was calculated by multiplied amount of each input consumption by its energy equivalent. The results showed that the total energy input for the production of greenhouse cucumber and tomatoes were (40,272,528/28 MJ) and (62,645,439/03 MJ) respectively. In production of cucumbers and tomatoes, fuel and electricity were the main energy consumption inputs. The ratio of energy for cucumbers and tomatoes systems was 0/015 and 0/014, respectively. The results showed that the technical efficiency for cucumbers and tomatoes production were 0/935 and 0/915, respectively. About 0/015 of cucumber and 0/014 of tomato producers were efficient in terms of energy consumption. The results demonstrated that with respect (observance) to DEA recommendations total energy input can be reduced about 0/13.5 for tomatoes and 0/10.5 for cucumbers in greenhouse unit productions. Net technical and scale efficiency were 0/943 and 0/97 for tomato’s production units, moreover, they were 0/978 and 0/95 for cucumber’ units, respectively.

Introduction

Energy has an important and crucial role in developing and improving nations. It can be said that without energy, modern cities could not be formed. Every society including traditional and industrial ones, energy access rather than the costs create crisis. Energy management is the only and closest way for exploiting more energy sources and present fuels. In addition to short time economic advantages, opportunity and time for transporting other forms of energy is provided. These concepts have increasing importance in empowering human being for fighting against job creation, food and security of future generation (Shahnaz et al., 1376).

Since agricultural part, on one hand, has faced with limitations of production sources and from the other hand, security provider of the population is improving, so there must be a balance between exploiting the sources and amount of crop production. In fact, exploiting production sources must be in a way that in addition to meeting food requirements of present generation, food security of next generation would not be put in danger.

This issue is the base of what is called stable agriculture today. In order to meet the goal, it is inevitable to exploit huge amount of energy in different input forms which doubles the need for exploitation management.

Increase cost of fuel carriers leads to increase in production costs which in turn increase costs of fuel, watering, fertilizers, toxins, transportation and food production processes. Energy balance is a useful tool for estimating return of energy and crops. This method has been used in 1970s at the time of oil crisis all over the world (Nasirian, 1382).
The amount of energy which is used in various crop production systems depends not only to the crop but also to the type of used materials. So, the behavior of various agricultural systems has been different in using inputs and energy sources. Each production system, energy efficiency is different so that it can lead to instability of agriculture. One of the useful methods of analyzing and evaluating stability in agriculture is using energy as a measurement tool. Agriculture section is one of the most important economic sections which depend on reproducible and irreproducible energies (Ghahdrijani, 1386).

Analyzing mechanization and energy indices is one of the necessities of agricultural projects. By analyzing consume patterns it is possible to stop loss of energy and move toward improving present situation by introducing optimization solutions. We need using modeling and optimizing tools to reach proper efficiency in agricultural projects.

Research models:
In this research we have used DEA to investigate greenhouse energy consumption. This method uses all the collected data for measuring efficiency. DEA optimizes each observation compared to efficiency and uses all the information completely. This technique, n operation is investigated by constructing and solving n model. This method has constructed a visual unit with highest efficiency by combining all the units and measures inefficient units by it. This method has two models of CCR and BCC with non-radial and entry based measurement (by DEA-solver software). BCC model is a combination of IRS and DRS and CCR model is an intermediate of IRS and DRS model (Ghasiri et al. 1386).

CCR model is useful when positive scales for inputs and outputs of DMU do not have efficiency scalability (Pardaloz and Razand, 2002). In addition, multi- product moods and multi- factors has changed to simple and uni-factor. After determining efficiency border, this model determines the place of decision-making units all over this border and which units of inputs and outputs must be used to reach efficiency border. This is possible by determining input and output coefficients for each unit. Milestone of CCR model is that is can calculate related coefficients by linear planning method. On the other hand, BCC model or variable scale returns with calculating technical efficiency based on efficiency amounts of scale and management provides pure technical efficiency. This model is used when equal scaling and lower or higher than maximum amounts have been witnessed for each input and outputs. Analyzing the amount of efficiency for each unit in fixed input mood compared to CRS scale can be set as long term objective and in variable output compared to VRS scale can be set as short term objective of inefficient units.

Research method:
This research is descriptive and survey based on the data collection method. Descriptive research includes a combination of methods which aim at describing the condition or investigated phenomenon. One of the descriptive types is survey. Survey research is used for distribution features of a population.

Sample volume:
The information needed for this study is gathered from April to September of 2013. Since the balance between input and output parameters of a DEA model and the number of decision making units must be evaluated, they play an important role in results of the study. So the number of decision making units bigger or equal three is same as the sum of input (Xk) and output (Yk) parameters (Emami Meybodi, 1379). So in order to perform this research with DEA-Solver software, the number of units must be more than 20. So we have to evaluate all greenhouse units of this state.

Calculating energy indexes:
The goal of energy calculation is calculating energy indexes. These indexes are calculated for producing greenhouse cucumbers and tomatoes and the results are shown in tables below, respectively.

<table>
<thead>
<tr>
<th>percent</th>
<th>average</th>
<th>total</th>
<th>units</th>
<th>indexes</th>
</tr>
</thead>
<tbody>
<tr>
<td>99</td>
<td>9960511.93</td>
<td>39878047/7</td>
<td>MJ</td>
<td>direct energy</td>
</tr>
<tr>
<td>1</td>
<td>78896/11599</td>
<td>394480/58</td>
<td>MJ</td>
<td>indirect energy</td>
</tr>
<tr>
<td>-</td>
<td>015/0</td>
<td>42634/0</td>
<td>-</td>
<td>energy ratio</td>
</tr>
<tr>
<td>-</td>
<td>02/0</td>
<td>53385/0</td>
<td>kg/MJ</td>
<td>energy efficiency</td>
</tr>
<tr>
<td>-</td>
<td>-1417138/64</td>
<td>-39679882/01464</td>
<td>MJ/ha</td>
<td>net added</td>
</tr>
</tbody>
</table>

Direct energy includes: human force, fuel, electricity, watering.
Indirect energy includes: seeds, chemical fertilizers, chemical pesticides, organic fertilizer, and equipment.
Indexes in producing greenhouse tomato energy

<table>
<thead>
<tr>
<th>percent</th>
<th>average</th>
<th>total</th>
<th>units</th>
<th>indexes</th>
</tr>
</thead>
<tbody>
<tr>
<td>99</td>
<td>15535675/87</td>
<td>62142703/47229</td>
<td>MJ</td>
<td>direct energy</td>
</tr>
<tr>
<td>1</td>
<td>100547/11</td>
<td>502735/55648</td>
<td>MJ</td>
<td>indirect energy</td>
</tr>
<tr>
<td>-</td>
<td>0147/0</td>
<td>44324/0</td>
<td>-</td>
<td>energy ratio</td>
</tr>
<tr>
<td>-</td>
<td>018/0</td>
<td>55497/0</td>
<td>Kg/MJ</td>
<td>energy efficiency</td>
</tr>
<tr>
<td>-</td>
<td>-20572663/53</td>
<td>-61717905/85467</td>
<td>MJ/ha</td>
<td>net added</td>
</tr>
</tbody>
</table>

Direct energy includes: human force, fuel, electricity, watering.
Indirect energy includes: seeds, chemical fertilizers, chemical pesticides, organic fertilizer, and equipment.

Efficiency of tomato units in BCC model

Efficiency percent and the number of greenhouse units can be seen in charts. 11 units had the score of 100 and others had efficiency less than 100. In order to reach efficiency level they have to reduce their inputs. In this model unit 24 with efficiency score of 0/8 is the most inefficient unit which its resource units are 11, 15 and 21. Fuel inputs with 100302/65 mega Jules and chemical fertilizer with 2027/55 mega Jules have the highest consumption level. Unit 21 with 17 times repetition and unit 15 with 15 times repetition are the most efficient units. In order to be efficient, mentioned points in this section must be considered. It should also be mentioned that the reason for higher consumption is reminded, too.

Efficiency of tomato units in CCR model

Efficiency percent and the number of tomato greenhouse units are illustrated in chart. 11 units had the score of 100 and others are inefficient. So they have to reduce their input. In this model, unit 25 with 13 times repetition and unit 4 with 8 times repetition are the most efficient units. Unit 11 with efficiency score of 8/0 is the most inefficient one and at the last ranking. Its resource units are units 25 and 4 in which fuel inputs with 49/100069 mega Jules and electricity with 53/2034 mega Jules had the highest consumption.

Investigating efficiency by DEA method

The data gathered by questionnaire and by DEA method and DEA-SOLVER software is analyzed. Inefficient units were determined and efficiency of them is explained. Data analysis is done by CCR constant scale regression model and BCC variable scale regression model. First data are entered into excel file so that DESOLVER software can read them.

Determining technical, net technical and scale efficiency of tomato
The mean of technical, net technical and scale efficiency for all 30 units is 0/943, 0/915 and 0/97 respectively.

<table>
<thead>
<tr>
<th>efficiency</th>
<th>mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>net technical efficiency</td>
<td>0/943</td>
</tr>
<tr>
<td>efficiency (BCC model)</td>
<td>0/915</td>
</tr>
<tr>
<td>technical efficiency</td>
<td>0/97</td>
</tr>
<tr>
<td>model efficiency (CCR)</td>
<td></td>
</tr>
<tr>
<td>index efficiency</td>
<td></td>
</tr>
</tbody>
</table>

**Table of mean efficiency of greenhouses**

<table>
<thead>
<tr>
<th>efficiency</th>
<th>mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>net technical efficiency</td>
<td>0/978</td>
</tr>
<tr>
<td>efficiency (BCC)</td>
<td>0/935</td>
</tr>
<tr>
<td>technical efficiency (model efficiency CCR)</td>
<td>0/95</td>
</tr>
</tbody>
</table>

**Determining technical, net technical and scale efficiency of cucumber**

The mean of technical, net technical and scale efficiency for all 28 units is 0/978, 0/935 and 0/95 respectively.

**Research objective:**

The aim of this paper is to investigate the amount of energy consumption in cucumber and tomato production in Khuzestan state and suggesting solutions for optimizing energy in tomato and cucumber production by studying and analyzing following issues:

1. Investigating the present situation of energy consumption in greenhouses of Khuzestan.
2. Determining the amount of consumption input of greenhouse cucumber and tomato production.
3. Determining energy indexes including energy ratio, energy efficiency and net added of energy.
4. Introducing optimized consumption pattern and output energy ratio (performance) compared to input or using DEA.
5. Suggesting solutions and management recommendation for correcting units and reaching efficiency point.

**Research hypotheses:**

1. The amount of energy consumption and energy indexes in cucumber and tomato greenhouse units.
2. DEA can be used as a proper tool for determining agricultural efficiency in energy consumption.
3. Agricultural efficiency is different in terms of energy consumption in tomato and cucumber greenhouses.

**Conclusion:**

Total energy consumption in greenhouse cucumber and tomato production is 402772528/28 and 62645439/0/28 mega Jules, respectively.

Fuel energy from among all the energies in greenhouse tomato and cucumber production has the highest consumption rate with 39374333/91 and 61470822/762 mega Jules respectively.

Energy ratio, energy efficiency and net energy increase for producing greenhouse cucumber is 0/015 and 0/02 Kg in mega Jules and -1417138/643 mega Jules in Kg, respectively.

In addition, these indexes for tomato production are 0/014, 0/02 kg in mega Jules, respectively. Energy efficiency of cucumber and tomato production with 9 human force input, chemical toxins, machine and seed as input and output energy of cucumber and tomato as output were evaluated based on two BCC-I and CCR-I models.
model. The mean of technical efficiency and net technical efficiency and efficiency scale of tomato were 0.943, 0.915 and 0.97 and 0.978, 0.935 and 0.95 for cucumber, respectively.

Based on two models of BCC-I and CCR-I, units 11 and 9 of greenhouse were efficient. Mean efficiency of inefficient greenhouses was 0.932 which could save more than 7 percent of input energy.

Based on two models of BCC-I and CCR-I, units 11 and 16 of tomato greenhouse were efficient. Efficiency mean of inefficient greenhouses were 0.879 which could save more than 12 percent of their input energy by optimized amount of input.

Based on the tables it is indicated that greenhouse is related to fixed amount of production and cultivation ratio and increased scale indicates that changing cultivation can increase production.

In other words, more than 90% of tomato and cucumber greenhouse perform based on optimized scale.

Suggestions:
1. In investigated greenhouse units, fuel has the most portion of energy input which can use gas log heating systems to prevent energy loss.
2. Recording the amount of energy input exactly is recommended for more exact and efficient results.
3. Using fine nets for covering roofed greenhouses for keeping the temperature at proper level.
4. Using a blower in upper part of the greenhouse so that the hot weather in upper level can be distributed all over the greenhouse. As a result of reaching hot weather to heat system sensors, the stop command will be sent to the system. So, the greenhouse temperature will be fixed at standard level.
5. Double- gazing the parapet (25 cm)
6. Suing glass or rattle parapets.
7. Making a groove in the floor of the greenhouse so that % 5 of input water can easily enter.
8. Using Hydro-penetic cultivation.
9. Equipping heat systems with intelligent sensors.

REFERENCES


