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Sustainability assessment of an agricultural system based on environmental indicators, Khuzestan province, Iran

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Abstract

This study investigates the energy inputs and crop yield relationship in greenhouse cucumber production in different production systems in Iran. Data were collected using face-to-face surveys from 18 farms producing greenhouse cucumbers in north and south of Khuzestan province. The results indicated the total average energy input of 565 MJ/m^2 and 400 MJ/m^2 for greenhouse cucumber production in northern and southern area respectively. The highest share in energy consumption belonged to diesel fuel (97%). The lowest total energy input belonged to cucumber production in 3000 m^2 (345 MJ/m^2) and 1000 m^2 (376.6 MJ/m^2) area in the southern part, whereas the highest energy consumption observed for cucumber production in the north part of the province as 614.5 MJ/m^2 in 3000 m^2 area. Results also determined the highest value of energy productivity in 3000 m^2 (0.025 kg/MJ) and 1000 m^2 (0.024 kg/MJ) for cucumber production in the southern part. In addition, the Cobb Douglas production function was applied to test the relationship among different forms of energy consumption. The regression results revealed that the coefficients of determination (R^2) between yield and total energy input for cucumber in greenhouse production were 0.95. In addition, the contribution of diesel (at the 5% level), electricity and chemical (at the 1% level) energies for cucumber production were significant.

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Introduction

Cucumber is the major greenhouse vegetables products worldwide. In Iran, cucumber production were 1.53 million tons which was cultivated on 63652 ha in 2012. From 2002 to 2010, greenhouse areas of Iran increased from 3380 ha to7700 ha at an increasing rate of 56%. Khuzestan province was one of the seven main provinces within Iran which were produced more than 50% of the total greenhouse tomato and cucumber production (www.maj.ir).

The use of intensive inputs in agriculture and access to plentiful fossil energy has provided an increase in food production and standard of living. However, some problems in agricultural production are mainly due to the high level of dependency on fossil energy. The problems with the use of fossil energy came into focus during the oil embargo of 1973 and the subsequent increase in energy prices (Hatirli *et al.*, 2007). In Iran, total energy consumption was about 1.90 million barrels in 1971 and it rose considerably to 4.7 million barrels in 2001. As regards to the rate of domestic energy consumption, it is predicted that Iran will be an oil importer in the year 2018 (www.worldenergyoutlook.org). Therefore, efficient use of the energy resources is indispensable in terms of increasing production, productivity, competitiveness of agriculture as well as sustainability of rural living.

Energy auditing is one of the most common approaches to examining energy efficiency and environmental impact of the production system. It enables researchers to calculate output–input ratio, relevant indicators, and energy use patterns in an agricultural activity (Hatirli *et al.*, 2006). In addition, financial assessments are vital to justify acceptable economic efficiency and energy productivity simultaneously in any agricultural production system.

Although many experimental works have been conducted on energy use in cucumber production (Omid *et al.*, 2011, Mohammadi *et al.*, 2011, and Khoshnevisan *et al.*, 2013), there are few studies on the energy and econometric analysis of greenhouse crops production. Ananasius *et al.*, 1997, studied the impact of the greenhouse cover on the cucumber production, its growth, productivity and energy consumption. Khoshnevisan *et al.*, 2013, observed the energy consumption and the production of greenhouse gases in greenhouse cucumber production in Yazd province, Iran.

This study investigated cucumber production in different greenhouse sizes for their energy use, energy productivity and their economic performance when produced in south and north of Khuzestan province, Iran.

Material and methods

Regional description

In this study, Khuzestan province as a main greenhouse tomato and cucumber production area in Iran was selected for energy and economic analysis. Khuzestan province is located in south-west of Iran within 47° 37' - 50° 39' longitude and 29° 57' - 33° 00' latitude (www.gsi.ir). The average annual temperature of the two northern and southern research area are 22.3^{oC} and 29^{oC} respectively (www.weather.ir).

Data collection and statistical analysis

Data were collected randomly from 18 greenhouses in Khuzestan province via face-to-face surveys. The questionnaire was structured using our research objectives, and the views of experts in the international and national literature. Regarding our objectives, we selected greenhouses according to the nested-factorial experimental design. Research factors were zones (northern, and southern), and size of greenhouses (1000, 3000 and 5000 m^2) respectively. Each treatment was repeated 3 times and grouped in the mentioned design. The data were numerically coded, entered into a database, and analyzed using MSTAT statistical software for Windows. Analysis of variance and Duncan comparison of mean test tables were used to analyze the characteristics of the cucumber production farmers.

Analytical framework

The analytical framework consists of two approaches: (a) an accounting approach that provides some basic measures of energy productivity; (b) an econometric estimation of the crop yield and energy inputs. The details are as follows.

Energy Auditing

In order to quantify energy consumption from the case study farms selected, following methodology was selected for performing energy audit:

1. Determine a boundary around the particular process to be evaluated.
2. Identify and quantify all inputs and output crossing the boundary.
3. Assign energy values to all inputs, including both direct and indirect inputs.

The input energy was divided into direct and indirect energies. Indirect energies included energy embodied in chemical fertilizers, organic fertilizer, pesticides, seed, and machineries while direct energy enveloped electricity, diesel, human labor, and water used in greenhouse production systems. All inputs were quantified and converted to an energy equivalent using values from current literatures. These values and the sources are shown in table 1. The energy input amounts per hectare were determined and multiplied by the energy equivalent quotient. The energy equivalents of all inputs were reported in mega joule (MJ) units. Energy indices such as energy productivity and net energy gain were calculated as followed equations:

Energy productivity = crop yield (kgha^{-1}) / Energy input (MJha^{-1}) (1)

Table 1. Energy Equivalents of inputs and outputs in agricultural production

Item	Unit	Energy Intensity (MJ unit^{-1})	References
Seed Cucumber	kg	1	(Singh *et al.*, 2002, Ozkan *et al.*, 2004)
Cucumber	kg	0.8	(Hatirli *et al.*, 2007)
Machinery	kg	62.7	(Hatirli *et al.*, 2007, Singh *et al.*, 2001)
Tractor	kg	93.61	(Canankci *et al.*, 2006)
Fuel	l	56.31	(Singh *et al.*, 2004)
Nitrogen (N)	kg	66.14	(Unakitan *et al.*, 2010)
Phosphate (P_2O_5)	kg	12.44	(Esengum *et al.*, 2007)
Potassium (K_2O)	kg	11.15	(Esengum *et al.*, 2007)
Farmyard manure	kg	0.3	(Mohammadi *et al.*, 2011, Athansios *et al.*, 1997)
Chemicals	kg	120	(Mohammadi *et al.*, 2011, Canankci *et al.*, 2006)
Human labor	hr	1.96	(Singh *et al.*, 2002, Ozkan *et al.*, 2004)
Electricity	kWh	3.6	(, Ozkan *et al.*, 2004, Canankci *et al.*, 2006)
Water for irrigation	m^3	0.63	(Hatirli *et al.*, 2007, Singh *et al.*, 2001)

Econometric model

In order to analyze the relationship between energy inputs and yield and to establish best fit of them several mathematical functions were tried. Cobb–Douglas function yielded better estimates in terms of statistical significance and expected signs of parameters. The main objective to estimate this production function was to search for the elasticity relationships and return to the production scale in the crop production systems. This methodology has been applied to investigate theoretical assumptions for signs of energy input in determining the optimal output levels (Ozkan *et al.*, 2004). It is important to observe that the production function describes technology, not economic behavior (Kuswardhani *et al.*, 2013).

Cobb–Douglas production function is expressed as:

$$Y=f(x) \exp (u) \quad (2)$$

The function can be written as:

$$Y_i = \beta_0 + \beta_1 lnX_{1i} + \beta_2 lnX_{2i} + \beta_3 lnX_{3i} + \beta_4 lnX_{4i} + \beta_5 lnX_{5i} + \beta_6 lnX_{6i} + \beta_7 lnX_{7i} \quad (3)$$

Where:

Y_i = Yield at farm i (kg/ha)

X_{1i} = Energy equivalent of human power per hectare at farm i

X_{2i} = Energy equivalent of diesel per hectare at farm i

X_{3i} = Energy equivalent of organic fertilizer per hectare at farm i

X_{4i} = Energy equivalent of chemical fertilizer per hectare at farm i

X_{5i} = Energy equivalent of electricity per hectare at farm i

X_{6i} = Energy equivalent of water per hectare at farm i

X_{7i} = Energy equivalent of chemical per hectare at farm i

The results were interpreted with regards to the contribution of energy equivalents of inputs into the yield level including comparison of signs of coefficients. The analysis was performed with utilization of Minitab statistical package.

Results and discussion

Energy auditing and balancing

Energy source and consumption, energy output and energy productivity for greenhouse cucumber production are presented in table 2. Energy sources were reported as direct-indirect forms. Total physical energy input consist of electricity, chemical, organic fertilizer, chemical fertilizer, diesel fuel, human labor and water. Because of the specific structure of the greenhouses, the utilization of tractors and other machineries was limited. The conversion factors given in table 1 were used to determine energy inputs and outputs.

Table 2. Duncan comparison of mean of region, and cultivated area on energy inputs (MJ/m²), energy output (MJ/m²), and energy productivity.

Geographical Region	Cultivated area (m²)	Electricity	Water	Chemical	Fuel	Human labor	Fertilizer	Organic fertilizer	Input energy	Output energy	Energy produ-ctivity (kg/MJ)
North region	**1000**	5.912a	0.15bc	0.44abc	600.8a	2.468abc	3.021cde	1.65c	614.5a	7.853a	0.015d
	3000	5.485a	0.14cd	0.49abc	541.1b	2.091cd	3.239abcd	2.217a	554.8b	7.729ab	0.017bc
	5000	4.888b	0.12d	0.40bc	513.5bc	2.12cd	2.925cde	1.88bc	525.9b	7.298abc	0.017bc
South region	**1000**	4.921b	0.13d	0.64ab	363.2d	2.422abcd	3.972ab	1.65c	376.6d	7.253bc	0.024a
	3000	4.147c	0.18ab	0.43abc	332.6d	2.041d	3.295bcd	2.30a	345d	6.971c	0.025a
	5000	4.056c	0.17b	0.25c	469c	2.087cd	2.483de	1.74bc	479.8c	6.916c	0.018b

The results indicated the average value of energy consumption in the north region of Khuzestan province was 565 MJ/m² and this value was 400 MJ/m² for cucumber production in the south part of Khuzestan province. Differences in energy consumption pattern (29%) between north and south parts of province was related to different average temperature where north part showed lower average of temperature about 7°C. Mohammadi *et al.*, 2011, expressed that total energy input of cucumber production in Tehran province of Iran was 148836.76 MJ/ha.

The total average energy input for greenhouse cucumber production in 1000 m², 3000 m² and 5000 m² area were 495.55 MJ/m², 449.9 MJ/m² and 502.85 MJ/m², respectively. Diesel fuel had the highest average energy consumption share as 98% of total energy use for cucumber production. The result of this study were similar to that of Mohammadi *et al.*, 2011, where diesel fuel had the highest contribution of cucumber production in Tehran province, Iran. The comparison of energy consumption in different greenhouse sizes revealed that 3000 m^2 greenhouse area had the best energy input value, followed by 1000 m^2 and 5000 m^2) area.

As can be seen from table 2 among energy sources, the highest energy consumer was diesel fuel, followed by electricity and chemical fertilizer. Ozkan *et al.*, 2004, concluded that bulk of energy was consumed in fertilizer (38.22%), electricity (27.09%), manure (17.33%) and diesel-oil (13.65%) for greenhouse tomato production in Antalya province, Turkey. Meanwhile, among different greenhouses, the lowest diesel fuel consumption were related to cucumber production in 3000 m^2 (332.6 MJ/m^2) and 1000 m^2 (363.2 MJ/m^2) area in the south region followed by cucumber production in 5000 m^2 (469 MJ/m^2) area in the same region of Khuzestan province.

The comparison of energy consumption in different systems showed that cucumber production in 3000 m^2 (345 MJ/m^2) and 1000 m^2 (376.6 MJ/m^2) area in the southern part had the lowest energy input, whereas the highest energy input observed for cucumber production as 614.5 MJ/m^2 in 1000 m^2 area in north region of Khuzestan province.

Table 2 shows energy productivity in different systems. Energy productivity is one of the important indicators to maintain efficiency of inputs application in greenhouse production. The energy productivity refers to output obtained in response to energy used per unit area. The results indicated the average energy productivity of 0.022 kg/MJ and 0.016 kg/MJ in south and north of the province for cucumber production respectively which showed energy use in south region was more efficient in the research area. The results of energy productivity were lower than that Ozkan *et al.*, 2011, (0.94 kg/MJ) and Mohammadi *et al.*, 2011, (0.80 kg/MJ) for tomato and cucumber production in Antalya province, Turkey and Tehran province, Iran respectively. By using less energy in diesel fuel more energy productivity would be observed. The highest value of energy productivity was observed in 3000 m^2 (0.025 kg/MJ) and 1000 m^2 (0.024 kg/MJ) for cucumber production in the southern part Khuzestan province. In addition, the energy productivity rate for cucumber production in 1000 m^2 of the northern part was the lowest among different systems. This decline in the energy productivity for similar cucumber cultivated areas in the south and north regions, despite an equal output, presented a double increase in consuming diesel fuel energy to heat greenhouses.

Energy input and crop yield relationship

Relationship between the energy inputs and yield was estimated using Cobb–Douglas production function for the cucumber crop on different categories of greenhouses. The coefficients of determination (R^2) between yield and total energy input for cucumber in greenhouse vegetable production were 0.95. It implies that the variation in total energy input for cucumber had a major influence on the yield. The product yield was assumed to be a function of inputs including human labor, diesel fuel, organic fertilizer, chemical fertilizer, electricity, water, and chemical (eq. (3)).

Regression results for these models are shown in Table 3. It can be seen form the Table 3 that the contribution of diesel (at the 5% level), electricity and chemical (at the 1% level) energies for cucumber production are significant. This indicates that with an additional use of 1% for each of these inputs would lead, respectively, to 0.85%, 1.9% and 0.35% for cucumber, increase in yield. Hatirli *et al.*, 2007, estimated an econometric model for greenhouse tomato production in Antalya province of Turkey. They concluded that among the energy inputs, human energy was found as the most important input that influences yield. Mohammadi *et al.*, 2011, concluded that for greenhouse cucumber production in Tehran province of Iran, the impact of human, machinery, diesel fuel, manure, chemical, water and electricity were significant to greenhouse cucumber production.

Table 3. Econometric estimation results of inputs.

Variable	Cucumber	
	β_i	significance
human power (X_{1i})	0.623	0.383
diesel (X_{2i})	0.853	0.02**
organic fertilizer (X_{3i})	0.3	0.212
chemical fertilizer (X_{4i})	0.171	0.605
electricity (X_{5i})	1.90	0.000***
water (X_{6i})	0.456	0.146
chemical (X_{7i})	0.351	0.009***
R^2 (adj)	0.95	-
F-statistics	51.58	0.000***

*significance at 10% level
**significance at 5% level
***significance at 1% level

Conclusion

Based on this study following conclusion are drawn:

1. Total energy input in greenhouse production of cucumber production in the north region was higher than that in the southern part of the province, which is mainly due to fuel diesel input.

2. Average value of energy productivity for cucumber production in the north and south regions were 0.016 kg/MJ and 0.022 kg/MJ, respectively which showed energy use in cucumber production in the north region was more efficient in the research area. The highest value of energy productivity was observed in 3000 m² (0.025 kg/MJ) and 1000 m² (0.024 kg/MJ) for cucumber production in the southern part.

3. The coefficients of determination (R^2) between yield and total energy input for cucumber in greenhouse vegetable production were 0.95. Regression results indicated that the contribution of diesel (at the 5% level), electricity and chemical (at the 1% level) energies for cucumber were significant.

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