Energy use efficiency and economic analysis of greenhouse cucumber farming in Turkey: case of Thrace Region

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Ülviye Kamburoğlu Çebi
PhD in Soil Science
Institution: Atatürk Soil Water and Agricultural Meteorology Research Institute
Address: Atatürk Soil Water and Agricultural Meteorology Research Institute, 39100, Kırklareli, Turkey
E-mail: ulviyecebi@yahoo.com

Başak Aydın
PhD in Agriculture Economics
Institution: Atatürk Soil Water and Agricultural Meteorology Research Institute
Address: Atatürk Soil Water and Agricultural Meteorology Research Institute, 39100, Kırklareli, Turkey
E-mail: basakaydin_1974@yahoo.com

Recep Çakır
PhD in Soil Science
Institution: Çanakkale 18 Mart University
Address: Çanakkale 18 Mart University, Lapseki Vocational High School, Çanakkale, Turkey
E-mail: crec56@yahoo.com

Süreyya Altıntaş
PhD in Horticulture
Institution: Namık Kemal University
Address: Namık Kemal University, Faculty of Agriculture, Department of Horticulture, 59030, Değirmenaltı, Tekirdağ, Turkey
E-mail: saltintas@nku.edu.tr

Abstract

This study was carried out in a plastic covered unheated greenhouse on the lands of Atatürk Soil Water and Agricultural Meteorology Institute in Kırklareli. Energy use efficiency and economic analysis of greenhouse cucumber farming were determined in the study. According to the results, total energy input, energy output, energy output/input ratio, energy productivity, specific energy and net energy in greenhouse first crop cucumber farming were determined as 45452.43 MJ ha^{-1}, 88303.20 MJ ha^{-1}, 1.94, 2.43 kg MJ^{-1}, 0.41 MJ kg^{-1} and 42850.77 MJ ha^{-1}, respectively. Total energy input, energy output, energy output/input ratio, energy productivity, specific energy and net energy in greenhouse second crop cucumber farming were determined as 50470.11 MJ ha^{-1}, 58534.40 MJ ha^{-1}, 1.16, 1.45 kg MJ^{-1}, 0.69 MJ kg^{-1} and 8064.29 MJ ha^{-1}, respectively. Total expenses, gross output value, gross profit, net profit and relative profit of first crop cucumber farming were calculated as 54423.08 $ ha^{-1}, 100802.74 $ ha^{-1}, 61760.96 $ ha^{-1}, 46379.66 $ ha^{-1} and 1.85, respectively. The same economic indicators of second crop cucumber farming were calculated as 58299.69 $ ha^{-1}, 66820.09 $ ha^{-1}, 24014.61 $ ha^{-1}, 8520.40 $ ha^{-1} and 1.15, respectively. According to energy use efficiency and economic

analysis results, cucumber farming in plastic covered unheated greenhouses in the region of the study appeared to be a profitable agricultural activity.

Keywords: Cost. Cucumber. Energy Analysis. Greenhouse. Profitability.

1. Introduction

Greenhouse production is one of the most intensive parts of the World agricultural production. It is intensive not only in the sense of yield and annual production, but also in the sense of the energy consumption, investments and costs (Omid, 2011). Greenhouse farming enables the evaluation of small areas by providing high yields per unit area and besides it is one of the most significant agricultural activities in our country as it provides a regular labor use. On the other hand, restricted water sources, increase of water demand, expected problems based on global warming necessitate the profitable use of the water resources. Greenhouse production technology leads to increase the efficiency of limited water and soil resources.

Greenhouse farming is executed as single and double cropping in our country. Single cropping is generally done in glass covered greenhouses and mono crop is obtained in a year. Double cropping is done in plastic covered greenhouses and the first crop is obtained in autumn and the second crop is obtained in spring. By 2016, approximately 7.16 million tons of crops have been grown in the greenhouses in Turkey in 691707 da area and approximately 16 billion liras of vegetative production income have been obtained. A major part of the crops in the greenhouses are consumed in domestic markets in Turkey and approximately 15% of these crops are exported. Greenhouse farming rapidly increases in Turkey because it can be obtained more crops from unit area and the farmers earn high incomes from small areas. Greenhouse farming was executed in 51 provinces of Turkey in 2011 and this number increased to 70 provinces in 2014. Greenhouse farming is a new agricultural activity in Thrace Region and it rapidly increases due to the big consumption center, İstanbul, in the region. In Thrace Region, total of 8952 tons of greenhouse farming was done in 464 da areas in Thrace Region (Anonymous, 2017).

In Turkey, tomato, cucumber, pepper and eggplant production are dominant in greenhouse production with the share of 97.1% in the total area. Among the four crops, tomato production takes the biggest share with 51%. The shares of cucumber, pepper and eggplants in the total area are 20.2%, 17.3% and 8.6%, respectively. Other vegetable kinds such as melon, bean, and squash kinds are grown in the greenhouses with the share of 2.9%.

Besides, lettuce-cucumber farming is mostly done in order to evaluate the cold periods in vegetable greenhouses.

Greenhouse production amounts in Kırklareli province are shown in Table 1. As seen from the table, cucumber farming is generally done in the greenhouses in Kırklareli. The cucumber is a widely cultivated plant in the gourd family Cucurbitaceous which include squash and the same genus as the muskmelon. It is one of the most important vegetable products in Turkey and the other regions of the World.

Table 1: Greenhouse production amounts in Kırklareli Province

Years	Lettuce (ton)	Cucumber (ton)	Other (ton)	Total
2012	95	637	28	760
2013	23	301	8	332
2014	96	147	10	253
2015	104	181	10	295
2016	123	167	13	303

Energy use in a high-yield agro ecosystem such as a greenhouse is becoming more energy intensive due to the use of energy intensive inputs. Efficient use of energy resources is vital in terms of increasing the production, productivity, and competitiveness of agriculture. Besides, efficient use of energy in agriculture will minimize environmental problems, prevent destruction of natural resources, and promote sustainable agriculture as an economical production system (Dalgaard et al. 2001). Greenhouse production is one of the most intensive plant production system and energy-consuming branch in agriculture. In this respect, the energy budget is important. Energy budget is the numerical comparison of the relationship between input and output of a system in terms of energy units (Çanakçı and Akıncı, 2006).

There is a very close relation between agriculture production system and energy consumption. Effectiveness and efficient energy use are the main keys for enhanced sustainable agricultural production (Mohammadi and Omid, 2010). Energy use in agricultural production has become more intensive due to the use of fuel, fertilizers, pesticides, machinery and electricity. Intensive energy use has caused important human health and environment problems, so efficient use of inputs has become important in terms of sustainable agricultural production (Yılmaz et al. 2005).

Energy productivity is an important index for more efficient use of energy although higher energy productivity does not mean more economic possibility. However, the energy analysis shows the methods to reduce the energy inputs and consequently to enhance the energy productivity (Fluck and Baird, 1982).

Increase in energy efficiency in greenhouse farming is of the most important energy studies in agriculture, and any success in increasing energy efficiency in greenhouse farming can cause efficient use of energy resources. For this aim, input-output analysis is used to evaluate the energy use efficiency and the environmental impacts of the greenhouse farming systems.

In the view of this information, the aim of this research was to determine energy use pattern and energy use efficiency in greenhouse cucumber production in Kırklareli province of Turkey. Besides, economic analysis of cucumber farming was performed.

2. Literature Review

Several research studies were conducted on the energy use efficiency and economic analysis of greenhouse and open field vegetables. Cetin and Vardar (2008) examined direct and indirect input energy in per hectare in tomato (industrial type) production and compared it with production costs. Output–input energy ratio and energy productivity were found to be 0.80 and 0.99 kg MJ^{-1}, respectively. Cost analysis revealed that the most important cost items were labor costs, machinery costs, land rent and pesticide costs.

According to the benefit–cost ratio, large farms were more successful in energy use and economic performance. The aim of the research conducted by Mihov and Tringovska (2010) was to improve the tomato production energy effectiveness by using new technology conventional fertilization based on soil analysis and novel biofertilizers instead of manure. Two biofertilizers were used bacterial fertilizer BioLife (USA) and mycorrhizal inoculum Media Mix (USA). The application of biofertilizers to improve soil fertility combined with optimized use of synthetic fertilizers can increase the energy output with the yield which leads to an increased energy output-input ratio to 1.19 and 1.11 respectively.

Rezvani Moghaddam et al. (2011) compared open field and greenhouse tomato production systems in terms of energy efficiency, energy intensiveness, energy productivity, benefit to cost ratio and amount of renewable and non-renewable energy uses. Energy use efficiency was achieved 1.42 and 0.18 in open field and greenhouse, respectively. The benefit to cost ratios of 2.33 in open field and 3.06 in greenhouse was recorded. Jadidi et al. (2012) determined energy consumption of input and output used in tomato production and optimized the energy inputs in the Marand region, Iran. The results revealed that tomato production consumed a total of 65238.9 MJ ha^{-1} of which fertilizers were 50.98% followed by water for irrigation (20.67%). Output-input energy and energy productivity were found to be 0.59 and 0.74 kg MJ^{-1}, respectively.

Sepat et al. (2013) estimated the amount of input and output energy per unit area and made an economic analysis of tomato production in green house and open field conditions at Nubra valley of Ladakh in India. The results showed that the total energy requirement was lower under open field (60492.21 MJ ha^{-1}) as compared to greenhouse production system (312055.90 MJ ha^{-1}). Energy use efficiency was higher in open field (2.74) as compared to greenhouse production system (1.36). The benefit cost ratio in open field was 16.52. Taki et al. (2013) determined the energy balance between the input and the output energies per unit area for greenhouse tomato production. The results indicated that a total specific input energy of 116768.4 MJ ha^{-1} was consumed for tomato production. The ratio of output energy to input energy was approximately 0.92. Cost analysis revealed that total cost of production for 1 ha greenhouse tomato production was around US$ 34939.

In the study conducted by Dimitrijevic et al. (2015), the influence of tomato production technology and greenhouse construction type on production energy efficiency was analyzed. Influence of greenhouse construction on energy consumption was estimated for four different double plastic covered greenhouses: a tunnel type, covered with 180 µm PE UV IR outside folia, a gutter connected plastic covered greenhouse with 50 µm inner folia and 180 µm outside folia, a multi-span greenhouse with four bays with 50 µm inner folia and 180 µm outside folia and a multi-span greenhouse with thirteen bays were used.

Specific energy input, energy output-input ratio and energy productivity were estimated. Results showed that there were differences in the open field and greenhouse tomato production. The lowest energy input was measured for the open field tomato production (18.02 MJ/m^2) while in greenhouses in average was 24.13 MJ/m^2. Concerning the greenhouses alone, the highest energy input was calculated in the case of tunnel structure, 26.87 MJ m^2. The lowest yield was observed in the open field tomato production (1.89 kg/m^2). Mohammadi et al. (2008) determined energy consumption of input and output used in potato production and made an economic analysis in Ardabil, Iran.

The results indicated that total energy inputs were 81624.96 MJ ha^{-1}. The ratio of energy outputs to energy inputs was found to be 1.25. Cost analysis revealed that total cost of production for one hectare of potato production was 3267.17 $. Benefit–cost ratio was calculated as 1.88. Zangeneh et al. (2010) determined the amount of input–output energy used in potato production and made an economic analysis of potato production in Hamadan province, Iran. The population investigated was divided into two groups. Group I was consisted of 68 farmers (owner of machinery and high level of farming technology) and group II of 32 farmers (non-owner of machinery and low level of farming technology). The net energy of potato production in group I and group II was 4110.95 MJ ha^{-1} and −21744.67 MJ ha^{-1}, respectively.

Cost analysis showed that total cost of potato production in groups I and II were 4784.68 and 4172.64 $ ha^{-1}, respectively. The corresponding, benefit to cost ratio from potato production in the surveyed groups were 1.09 and 0.96, respectively. Mohammadi and Omid (2010) determined the energy balance between the input and the output per unit area for greenhouse cucumber production. The ratio of energy output to energy input was approximately 0.64. Results indicated 10.93% and 89.07% of total energy input was in renewable and non-renewable forms, respectively. Econometric analysis indicated that the total cost of production for one hectare of cucumber production was around 33425.70 $.

Accordingly, the benefit–cost ratio was estimated as 2.58. Monjezi et al. (2011) used data envelopment analysis in order to estimate the energy efficiencies of cucumber producers based on eight energy inputs including human power, diesel fuel, machinery, fertilizers, chemicals, water for irrigation, electricity and seed energy and single output of production yield. Total energy input and output were calculated as 163994 MJ ha^{-1} and 62496 MJ ha^{-1}, respectively, whereas diesel fuel consumption with 45.15% was the highest level between energy inputs.

Pahlavan et al. (2011) analyzed the energy use and investigated the influences of energy inputs and forms on output levels for greenhouse cucumber production in Iran. The energy use efficiency, specific energy and net energy were found as 0.27, 2.99 MJ kg^{-1} and -352591 MJ ha^{-1}, respectively. Econometric analysis indication of the benefit–cost ratio was estimated as 2.7. Darijani et al. (2012) examined the energy equivalents of input and output in greenhouse cucumber production in Varamin County of Tehran Province, Iran. The results showed that the output–input ratio, specific energy and energy productivity were 0.017, 46.84 MJ kg^{-1} and 0.02 kg MJ^{-1}, respectively.

Yousefi et al. (2012) compared the energy flow in greenhouse and open-field cucumber production systems in Iran. The results revealed that total energy consumption amount in greenhouse systems was 11709452.43 MJ ha^{-1} while in open-field systems it was

78476.33 MJ ha^{-1}. Kuswardhani et al. (2013) estimated energy consumption per unit floor area of greenhouse and open field for tomato, chili and lettuce production. The ratio of output to input energy was higher in greenhouse production (0.85, 0.45 and 0.49) than open field vegetable production (0.52, 0.175 and 0.186) for tomato, chili medium land and chili highland, respectively, but output–input ratio of lettuce open field production was twice as that of greenhouse vegetable production.

Financial analysis revealed higher mean net returns from greenhouse vegetable production as 7043 \$ ha^{-1} (922–15.299 \$ ha^{-1}) when compared to 571 \$ ha^{-1} (44–1172 \$ ha^{-1}) from open field vegetable production. Özkan et al. (2004) examined the energy equivalents of inputs and output in greenhouse vegetable production in the Antalya province of Turkey. The output–input energy ratio for greenhouse tomato, pepper, cucumber and eggplant were estimated to be 1.26, 0.99, 0.76 and 0.61, respectively. Çanakçı and Akıncı (2006) investigated the energy use patterns in greenhouse vegetable production, determined the energy output–input ratio and their relationships in Antalya province.

The energy ratio of four major greenhouse vegetables—tomato, pepper, cucumber and eggplant were 0.32, 0.19, 0.31, 0.23, respectively. The net return of the vegetable production was found in the 595.6–2775.3 \$/1000 m^2 ranges. Among the greenhouse vegetables, tomato cultivation resulted in being the most profitable. Taki et al. (2012) determined the energy consumption and evaluation of inputs sensitivity for greenhouse vegetable production in the Esfahan province of Iran. The energy ratio (energy use efficiency) for greenhouse tomato and cucumber were estimated to be 0.92 and 0.56 respectively. The benefit–cost ratio for these productions were 2.74 and 1.79, respectively.

Pahlavan et al. (2012) determined a relationship between energy input and yield in greenhouse basil production in Esfahan Province, Iran. The energy ratio, productivity, specific, and net energies were found out as 0.25, 0.11 kg MJ^{-1}, 9 MJ kg^{-1} and -177377 MJ ha^{-1}, respectively. In the study conducted by Dimitrijevic et al. (2010), the influence of greenhouse construction on energy efficiency in winter lettuce production was estimated for different double plastic covered greenhouses in Serbia region. On the basis of lettuce production output and the energy input, specific energy input, energy output-input ratio and energy productivity were estimated. Results showed that the lowest energy consumption was obtained for gutter connected greenhouse with two bays, 3.11 MJ/square meter. The highest energy consumption was multi-span greenhouse with thirteen bays, 3.30 MJ/square meter.

The highest value for output-input ratio was calculated for the multi-span greenhouse with thirteen bays, 0.85 and the lowest for the tunnel structure, 0.47.

3. Materials and Methods

3.1. Materials

The research was carried out for three years in a plastic covered unheated greenhouse in Atatürk Soil Water and Agricultural Meteorology Research Institute land in Kırklareli province. Kırklareli province is located within 41^{o}42' North latitude and 27^{o}14' east longitude and total surface area of the province is 655036 ha.

The trial was carried out according to split parcels trial design with three replications. Maraton F1 cucumber plants were used as a material of the trial. The mention cultivar is mostly preferred by the farmers because of high fruit quality, high fruit set percentage, seedless fruit formation.

3.2. Methods

The data included the quantity of various energy inputs used per hectare of greenhouse cucumber production including; human power, machinery, diesel fuel, chemicals, fertilizers, manure, water for irrigation, electricity and seed and the production yields as outputs. The amounts of the inputs and the outputs were calculated per hectare and then, these inputs and outputs data were multiplied by the energy equivalent coefficients. Calculations were done according to the averages of three years data.

Energy equivalents of the inputs and outputs for greenhouse cucumber production were obtained from the previous studies (Table 2). The source of mechanical energy included direct use of tractors and consumed diesel oil. The mechanical energy was computed on the basis of total fuel consumption (L ha^{-1}). Therefore, the energy consumed was calculated using conversion factors and was expresses in MJ ha^{-1}. The energy equivalences of the inputs were expressed in mega joule (MJ).

Table 2: Energy equivalents of inputs and outputs in cucumber production

	Energy Equivalent (MJ unit^{-1})	References
Inputs		

Human labor (h)	1.96	(Mandal et al. 2002 ; Singh, 2002)
Machinery (h)	64.80	(Singh, 2002; Baran et al. 2017)
Manure (t)	303.10	(Mohammadi et al. 2008)
Pesticides (kg)		
Insecticides	101.20	(Rafiee et al. 2010)
Fungicides	216.00	(Rafiee et al. 2010)
Fertilizer (kg)		
Nitrogen	60.6	(Singh, 2002)
Phosphorus	11.15	(Singh, 2002)
Potassium	6.70	(Singh, 2002)
Diesel fuel (l)	56.31	(Singh, 2002)
Seed (kg)	1.00	(Singh, 2002)
Electric (kWh)	3.60	(Mohammadi et al. 2008)
Irrigation water (m^3)	0.63	(Yaldız et al. 1993)
Output		
Cucumber (kg)	0.80	(Yaldız et al. 1993)

Following the calculation of energy input and output equivalents, the energy use efficiency, energy productivity, specific energy and net energy were calculated according to the following formulas (Mandal et al., 2002).

$$Energy\ Use\ Efficiency = \frac{Energy\ Output(MJ\ ha^{-1})}{Energy\ Input\ (MJ\ ha^{-1})}$$

$$Energy\ Productivity = \frac{Yield(kg/ha^{-1})}{Energy\ Input\ (MJ\ ha^{-1})}$$

$$Specific\ Energy = \frac{Energy\ Input\ (MJ\ ha^{-1})}{Yield(kg/ha^{-1})}$$

$$Net\ Energy = Energy\ Output(MJ\ ha^{-1} - Energy\ Input\ (MJ\ ha^{-1})$$

Energy demand in agriculture can be divided into direct and indirect energies or alternatively as renewable and non-renewable energies (Kızılaslan, 2009). The direct energy includes human labor, diesel fuel, water for irrigation and electricity. The indirect energy consists of pesticides, fertilizers, manure, seed and machinery. On the other hand, renewable energy includes human labor, manure, seed and water for irrigation whereas non-renewable energy consists of diesel fuel, fertilizers, pesticides, machinery and electricity.

The economic analysis of cucumber production was done. The economic inputs of cucumber production systems consisted fixed and variable costs. The variable costs included the costs of chemicals, fuel, human labor, seed, fertilizers, irrigation water, electricity, repair and maintenance and revolving interest. The revolving interest was calculated by subjecting half of the interest rate (5%) applied to the vegetable production loans. The fixed costs included general administration expenses, interest on land value, irrigation machine tools interest, irrigation machine tools depreciation value, the amortization of facility costs, the facility capital interest. 3% of the total variable cost and it reflects the opportunity cost of capital for production activity. The interest of land value was calculated by taking 5% of the current trading value of bare land in the region (Kıral et al. 1999). The facility capital interest was calculated by implementing 5% interest to the half of facility costs.

The following formulas were used in the calculation of gross, absolute and relative profit indicators (Kıral et al. 1999).

$$Gross\ production\ value\ = Yield\ x\ cucumber\ price$$

$$Gross\ profit\ = Gross\ production\ value - variable\ costs$$

$$Net\ profit\ = Gross\ production\ value - production\ costs$$

$$Relative\ profit\ = \frac{Gross\ production\ value}{Production\ costs}$$

4. Results and Discussion

4.1 Analysis of energy use in greenhouse cucumber production

The physical inputs and outputs and their energy equivalences used in the production of first and second crop greenhouse cucumber are given in Table 3. As seen in Table 3, 10900.10 h human labor, 15.20 h machinery, 35.30 l diesel fuel, 95.80 kg nitrogen, 29.70 kg phosphorus, 67.60 kg potassium, 25 t manure, 13.50 kg pesticide, 6.20 kg fungicides, 3000 m^3 water, 650.30 kWh electricity, 12 kg seed per hectare were used for the first crop cucumber production. The average yield was found to be 110379 kg ha^{-1} for the first crop cucumber.

When the physical inputs and output in the production of second crop cucumber was examined, it was determined that 11550.50 h human labor, 15.20 h machinery, 35.30 l diesel fuel, 135.50 kg nitrogen, 40.60 kg phosphorus, 85.40 kg potassium, 25 t manure, 15.50 kg pesticide, 7.50 kg fungicides, 3400 m^3 water, 750.60 kWh electricity, 12 kg seed per hectare were used. The average yield was found to be 73168 kg ha^{-1} for the first crop cucumber.

The total energy equivalent of inputs for first crop cucumber was calculated as 45452.43 MJ ha^{-1} whereas this amount was 50470.11 MJ ha^{-1} for second crop cucumber. Human labor had the highest share with 47%, followed by manure (16.67%), nitrogen fertilizer (12.77%), pesticides (5.96%), electricity (5.15%), diesel fuel (4.37%) and water for irrigation (4.16%), respectively for first crop cucumber. The energy inputs of seed, phosphorus and potassium fertilizers and machinery were found to be low compared to the other inputs. Human labor had the highest share with 44.86%, followed by nitrogen fertilizer (16.27%), manure (15.01%), pesticides (6.32%), electricity (5.35%), water for irrigation (4.24%) and diesel fuel (3.94%), respectively for second crop cucumber. The energy inputs of seed, phosphorus and potassium fertilizers and machinery were found to be low compared to the other inputs. In this study, the energy equivalents of the yield for first and second crop cucumber productions were calculated as 88303.20 MJ ha^{-1} and 58534.40 MJ ha^{-1}.

Table 3: The physical inputs and outputs and their energy equivalences for cucumber production

Inputs	First crop cucumber			Second crop cucumber		
	Quantity per unit area (ha)	Total energy equivalent (MJ)	Percentage of total energy input (%)	Quantity per unit area (ha)	Total energy equivalent (MJ)	Percentage of total energy input (%)
Human labor (h)	10900.10	21364.20	47.00	11550.50	22638.98	44.86
Machinery (h)	15.20	984.96	2.17	15.20	984.96	1.95
Diesel fuel (l)	35.30	1987.74	4.37	35.30	1987.74	3.94
Fertilizer (kg)						
Nitrogen	95.80	5805.48	12.77	135.50	8211.30	16.27
Phosphorus	29.70	331.16	0.73	40.60	452.69	0.90
Potassium	67.60	452.92	1.00	85.40	572.18	1.13
Manure (t)	25.00	7577.50	16.67	25.00	7577.50	15.01
Pesticides (kg)						
Insecticides	13.50	1366.20	3.01	15.50	1568.60	3.11
Fungicides	6.20	1339.20	2.95	7.50	1620.00	3.21
Water (m^3)	3000.00	1890.00	4.16	3400.00	2142.00	4.24
Electricity (kWh)	650.30	2341.08	5.15	750.60	2702.16	5.35
Seed (kg)	12.00	12.00	0.03	12.00	12.00	0.02
Total energy inputs (MJ/ha)		45452.43	100.00		50470.11	100.00
Outputs						
Yield (kg)	110379.00	88303.20		73168.00	58534.40	

In heated greenhouses, the diesel fuel is mostly consumed for heating. The research was carried out in a plastic covered unheated greenhouse so low percentage of fuel consumption in the greenhouse of the studied region could be attributed to not use of heaters. In order to improve energy use, it is suggested that the production is done in unheated greenhouses or, if not possible, the heating system efficiency is raised or replaced with alternative energy sources such as natural gas and solar energy (Omid et al. 2011).

The energy use efficiency, energy productivity, specific energy and net energy of cucumber productions are given in Table 4. Energy use efficiency was calculated as 1.94 and

1.16 for first and second crop cucumber, respectively. This shows the efficiency use of energy in greenhouse cucumber production. Other results in different vegetable crops such as 0.27 for greenhouse cucumber (Pahlavan et al. 2011), 0.017 and 0.33 for greenhouse and open field cucumber productions (Yousefi et al. 2012), 0.64 for greenhouse cucumber production (Mohammadi and Omid, 2010; Omid et al. 2011), 0.32, 0.19, 0.31 and 0.23 for greenhouse tomato, pepper, cucumber and eggplant productions (Çanakçı and Akıncı, 2006), 0.38 for greenhouse cucumber (Monjezi et al. 2011), 0.56 and 0.92 for greenhouse cucumber and tomato productions (Taki et al. 2012), 1.26, 0.99, 0.76 and 0.61 for greenhouse tomato, pepper, cucumber and eggplant productions (Özkan et al. 2004), 0.92 for greenhouse tomato (Taki et al. 2013).

The energy productivity of the crops were calculated as 2.43 and 1.45 kg MJ^{-1} respectively. This means that 2.43 and 1.45 unit outputs were obtained per unit energy. Specific energy is an index which shows how much energy is used to produce a single unit of a product. The specific energy was calculated as 0.41 MJ kg^{-1} for first crop cucumber and 0.69 MJ kg^{-1} for second crop cucumber. In this case, the required energy quantity for producing one kg of cucumber was 0.41 MJ kg^{-1} and 0.69 MJ kg^{-1}, respectively. Net energy points out the difference between the used energy and the output energy. Net energy of greenhouse cucumber production were calculated as 42850.77 MJ ha^{-1} and 8064.29 MJ ha^{-1}, respectively. Net energy values were positive. Therefore, it could be concluded that in cucumber production, energy was not being lost.

Table 4: Parameters of the energy analysis for cucumber production

Items	Unit	First crop cucumber	Second crop cucumber
Energy use efficiency	-	1.94	1.16
Energy productivity	kg MJ^{-1}	2.43	1.45
Specific energy	MJ kg^{-1}	0.41	0.69
Net energy	MJ ha^{-1}	42850.77	8064.29

Energy inputs as direct, indirect, renewable and non-renewable forms are given in Table 5. The results showed that shares of direct and indirect input energy in first crop cucumber production were found as 60.69% and 39.31%, respectively while these amounts were 58.39% and 41.61%, respectively, for second crop cucumber production. On the other hand, in first crop cucumber production, renewable and non-renewable energy contributed to 67.86% and 32.14% of the total energy input, respectively, while these amounts were 64.14% and 35.86% for second crop cucumber, respectively.

Table 5: Types of energy forms for cucumber production

Type of energy	First crop cucumber		Second crop cucumber	
	MJ ha^{-1}	%	MJ ha^{-1}	%
Direct energy [a]	27583.02	60.69	29470.88	58.39
Indirect energy [b]	17869.41	39.31	20999.23	41.61
Renewable energy [c]	30843.69	67.86	32370.48	64.14
Non-renewable energy [d]	14608.74	32.14	18099.63	35.86
Total energy input	45452.43	100.00	50470.11	100.00

[a] Includes human labor, diesel, electricity and irrigation
[b] Includes chemical fertilizers, pesticides, manure, seed and machinery
[c] Includes human labor, manure, seed and irrigation
[d] Includes diesel, pesticides, chemical fertilizers, machinery and electricity

Renewable energy sources are clean sources of energy that have a much lower impact on the environment than do conventional energy technologies. Renewable energy sources do not damage the nature and the share of these sources were higher than non-renewable sources in greenhouse cucumber production. Non-renewable sources are limited and many of these sources are harmful to the environment. Intensity of renewable energy consumption resulted from less fertilizer, diesel fuel and machinery use in production. The results showed that greenhouse cucumber production depended on mainly human labor and less machinery use.

4.2. Economic analysis of greenhouse cucumber production

The cost items used in the production of greenhouse cucumber are given in Table 6. The total costs per hectare in first crop cucumber and second crop cucumber were calculated as 54423.08 $ and 58299.69 $, respectively. The ratios of the variable costs in total production costs for first and second crop cucumber were determined as 71.74% and 73.42%, respectively and the ratios of fixed costs were determined as 28.26% and 26.28%, respectively. More than the half of the production costs was constituted by the variable costs in greenhouse cucumber farming. Several studies were reported that the ratio of variable costs was higher than fixed costs in cropping systems (Cetin and Vardar, 2008; Esengün et al. 2007; Pahlavan et al. 2011; Taki et al. 2012). Besides, the higher construction cost of greenhouse was the main reason for high production costs.

The gross output value of production was found by multiplying the cucumber yield by cucumber price and the gross output values for first and second crop cucumber were calculated as 100802.74 and 66820.09 $ ha^{-1}, respectively. The gross profit value was found by subtracting the variable costs from the gross output value and it was calculated as 61760.96 and 24014.61 \$ ha^{-1}, respectively for the first and second crop cucumber. In order to obtain net income in an enterprise, gross profit value should be higher than the fixed costs. According to the result, the gross output values of first and second crop cucumber were determined to be higher than the fixed costs.

Table 6: Production cost items and economic analysis of greenhouse cucumber production

Production cost items (\$ ha^{-1})	First crop cucumber		Second crop cucumber	
	Cost	%	Cost	%
Human labor	20319.63	37.34	22146.12	37.99
Diesel fuel	82.19	0.15	82.19	0.14
Seed	6210.05	11.41	6210.05	10.65
Fertilizer	2968.04	5.45	3881.28	6.66
Pesticides	4063.93	7.47	4337.90	7.44
Water and electricity	3310.50	6.08	3881.28	6.66
Repair costs	228.31	0.42	228.31	0.39
Revolving interest (5%)	1859.13	3.42	2038.36	3.50
Variable costs	39041.78	71.74	42805.48	73.42
General administration expenses (3%)	1171.25	2.15	1284.16	2.20
Interest on bare land	2054.79	3.78	2054.79	3.52
Amortization of facility costs	6105.02	11.22	6105.02	10.47
The facility capital interest	2808.22	5.16	2808.22	4.82
Irrigation machine-tool depreciation	2214.61	4.07	2214.61	3.80
Irrigation machine-tool interest	1027.40	1.89	1027.40	1.76
Fixed costs	15381.30	28.26	15494.21	26.58
Production costs (\$ ha^{-1})	54423.08	100.00	58299.69	100.00
Yield per hectare (kg ha^{-1})	110379.00		73168.00	
Selling price per kilogram (\$ kg^{-1})	0.91		0.91	
Gross output value per hectare (\$ ha^{-1})	100802.74		66820.09	
Production cost per kilogram (\$ kg^{-1})	0.49		0.80	
Gross profit value per hectare (\$ ha^{-1})	61760.96		24014.61	
Net profit value per hectare (\$ ha^{-1})	46379.66		8520.40	
Relative profit	1.85		1.15	

The net profit value was found by subtracting the production costs from the gross output value and it was calculated as 46379.66 and 8520.40 \$ ha^{-1}, respectively for the first and second crop cucumber. Based on these results, the relative profit values of greenhouse cucumber production were determined as 1.85 and 1.15, respectively. According to economic analysis results, cucumber farming in plastic covered greenhouses in the region of the study appeared to be a profitable agricultural activity. In previous studies conducted to determine profitability of some crops, the relative profit was determined as 1.68 for cucumber and 3.28 for tomato (Heidari and Omid, 2011), 2.74 for greenhouse tomato and 1.79 for greenhouse cucumber (Taki et al. 2012), 2.70 for greenhouse cucumber (Pahlavan et al. 2011), 24.02 for open field tomato and 9.30 for greenhouse tomato (Sepat et al. 2013), 2.74 for greenhouse tomato (Taki et al. 2013), 2.33 for open field tomato and 3.06 for greenhouse tomato (Rezvani Moghaddam et al. 2011).

5. Conclusion

Greenhouse farming in the research area is a developing agricultural activity, for this reason there are some complications about greenhouse farming. One of those is the type of production. In the study, cucumber crop was chosen as its market value is high and double cropping was done instead of mono cropping. As seen from the results, energy use efficiency was determined to be high for each crops. Energy use efficiency of first crop cucumber was determined to be higher than second crop cucumber. Because, day and night temperature differences occur in the period when the highest yield amount is obtained and by decrease of the green component out of the greenhouse, detrimental effects in the greenhouse are observed more. In each period, before the harvesting open field crops, early harvesting is done for first crop cucumber and late harvesting is done for second crop cucumber and this increases the demand and the value of the crop in the markets. According to the results, greenhouse cucumber farming as double cropping is suggested in Kırklareli province and Thrace Region.

The results of this research can be used for effective and more efficient energy use by the farmers in order to increase the sustainability in agricultural systems. The farmers must be provided with educational opportunities in the use of efficient inputs and this must be provided by the experts and the engineers in the research area. Besides, there is a requirement to develop a new policy in order to be able to force the farmers to use all the inputs on time for increasing energy use and obtaining high qualified crops.

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