Renewable Energy 36 (2011) 1639–1644

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

Technical Note

Comparison of energy inputs in glasshouse double crop (fall and summer crops) tomato production

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ARTICLE INFO

Article history:
Received 24 February 2010
Accepted 11 November 2010
Available online 9 December 2010

Keywords:
Glasshouse tomato
Energy analysis
Output–input ratio
Antalya

ABSTRACT

The study examines energy use patterns and the relationship between energy inputs and yield for double crop (fall and summer) glasshouse tomato production in Antalya province, where is one of the most important greenhouse centres in Turkey. The data of the study was retrieved from 37 fall and 25 summer glasshouse tomato producers via face to face survey in 2007. The research findings revealed energy use values for inputs such as manure, electricity, chemical fertilizer and fuel. While the average yield per hectare is 25025.4 kg for enterprises involved in tomato production in fall, it is 22392.9 kg for summer production. The overall energy consumption is higher in fall production with 81362.2 MJ ha^{-1} in comparison to summer production 63023.2 MJ ha^{-1}. In addition, the specific energy requirement is 3521.2 MJ t^{-1} and 2814.4 MJ t^{-1} for fall and summer production in order and the energy efficiency was found out to be 0.31 kg MJ^{-1} and 0.36 kg MJ^{-1} respectively. Finally, the energy relationship was tested using the production relationship. The findings indicated that direct energy sources are effective in tomato yield for both of the two seasons. More clearly, the most significant energy input was electrical energy for summer production and a combination of electrical energy, human power and machinery for fall production. Yet, excess and unconscious use of chemical ingredients in glasshouse tomato production was confirmed as energy derived from chemical drugs leaded a declination in the yield for fall season. Therefore, the paper revealed energy relationship for double crop glasshouse tomato production in Antalya, being a reference for similar production methodologies.

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1. Introduction

Energy consumption in agriculture has developed in response to rising population in around the world, limited supply of arable land, and desire for an increasing life standard. These factors have encouraged a rise in energy inputs to maximize yields, minimize labour-intensive practices, or both in almost everywhere [1].

Energy has a key role in economic and social development but there is a general lack of rural energy development policies that focus on agriculture. Agriculture has a dual role as user and supplier of energy. This energy function of agriculture offers important rural development opportunities as well as climate change mitigation by substituting bio-energy for fossil fuels [2].

However, energy is one of the most valuable inputs in agricultural production. It is invested in various forms such as mechanical (farm machines, human power, and animal draft), chemical fertilizer (pesticides and herbicides) and electrical. The amount of energy used in agricultural production, processing and distribution needs to be adequate in order to feed the rising population and to meet other social and economic goals. Sufficiency of energy and its effective and efficient use are prerequisites for improved agricultural production. It was realized that crop yields and food supplies are directly linked to energy [3]. In developed countries, rise in crop yields were mainly attributed to rise in use of improved commercial energy inputs in addition to improved crop varieties [4].

It needs to be acknowledged that 50% of covered production areas of Turkey, of which is recorded as a sum of 49.700 ha in 2006, is in Antalya province. The share of covered area in total agricultural lands of Antalya is 4.07%. While 76.99% of vegetables in Antalya is being produced with covered production techniques, 23.01% of the production is pursued in open lands. Yet, 50.92% of the covered area is composed of greenhouses while 35.02% constitutes glasshouses and 12.16% constitutes plastic tunnels [5]. When the share of Antalya in terms of covered production among Turkey is considered, it is understood that 84.87% of glasshouses and 45.03% of greenhouses of Turkey is situated in Antalya [6]. With regards to the relevant data, it is understood that Antalya is a centre for covered

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doi:10.1016/j.renene.2010.11.022

production in Turkey and analysis of production relationships for either glass or greenhouses in Antalya may play a significant role in evaluation of these productive processes from an energy oriented point of view.

Turkey's energy consumption in agriculture has increased in recent years; therefore, associated problems have grown. Generally, producers use more energy to increase total output since there is no chance to expand the size of arable lands and producers do not have enough knowledge on more efficient energy inputs. Under these circumstances, input–output energy analyses provide researchers, planners and policy makers with opportunities to evaluate economic interactions of energy use [7].

Some research has been conducted on energy use and energy input–output analysis in agriculture in Turkey and other countries [7–17]. In all these related studies, energy ratio (energy use, efficiency) and energy productivity were measured. However, measuring energy use and efficiency of glasshouse tomato production in Turkey was considered as a special case to interpret the region and the sector as a whole.

The main objective of the study is to develop and estimate an econometric model for glasshouse tomato production in Antalya province of Turkey for summer and fall production periods. Prior to composition and estimation of the model, the main indicators of energy equivalents of inputs and produced amount are calculated and demonstrated through an energy auditing study. The preliminary calculation reveals the input–output relationships for the sample glasshouse tomato farms. After the productive relationship based on energy equivalents is estimated, the model is expected to show the relationship between energy inputs and yield, providing energy input elasticity in yield. Furthermore, this study seeks to analyze the effect of indirect and direct energy consumption on yield using a specific production function. In addition to these, it is also aimed with this study to investigate input–output ratios for summer and fall glasshouse tomato production in Antalya and energy efficiency and specific energy requirements respectively in a comparative manner.

2. Materials and methods

The data of the study is retrieved from glasshouses in Central, Kumluca and Serik towns of Antalya for summer and fall production periods via face to face survey. 37 fall producers and 25 summer producers were interviewed during surveying period. The questionnaires were implemented in June 2007 via face to face survey.

The enterprises that are registered to the covered production system were clustered into three with respect to greenhouse area. This clustering enabled homogenisation of enterprises through grouping of enterprises by size. The sample size was determined by Stratified Sampling using 'Neyman Method' in the framework list [18]. The following formulas (1–3) were used in a consecutive order with 95% confidence interval and 5% margin of error and the sample size was determined as 37 and 25 respectively for fall and summer.

$$n = \frac{\left(\sum N_h S_h\right)^2}{N^2 D^2 + \sum N_h S_h^2} \tag{1}$$

n denotes the required sample size; N denotes the number of holdings in target population; N_h denotes the number of population in the layer h; S_h denotes the variance of the layer h

$$D^2 = \frac{d^2}{Z^2} \tag{2}$$

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

Input (Unit)	Energy equivalent (MJ unit^{-1})	Reference
Chemicals (kg)	101.20	[19]
Human power (h)	2.30	[19]
Machinery (h)	64.80	[14]
Nitrogen fertilizer (kg)	66.14	[20]
Phosphorus (kg)	12.44	[20]
Potassium (kg)	11.15	[20]
Manure (tons)	303.10	[19]
Diesel-oil (l)	56.31	[14]
Electricity (kWh)	3.60	
Water for irrigation (m^3)	0.63	[19]
Tomato	0.80	

d denotes the precision where (x–X); Z denotes the reliability coefficient (1.96 which represents the 95% reliability)

The following equity was used in distribution of the sample size into layers (n_h)

$$n_h = \frac{N_h S_h}{\sum N_h S_h} n \tag{3}$$

The amount of inputs used (chemicals, fertilizers, fuel, electricity, irrigation water, human power, machine power) in double crop glasshouse tomato production was found in the study in order to calculate the energy equivalents. In calculation of the input amounts, the units demonstrated in Table 1 were incorporated. The input amounts used per hectare were found and then the data were multiplied with the energy equivalent quotient. Previous studies and resources were used in determination of energy equivalent quotients and they were indicated in Table 1. The energy equivalents of all inputs were indicated in mega joules (MJ). Total input equivalent was calculated by summation of energy equivalents.

The input energy can be examined in four classes as direct, indirect, renewable and non-renewable [1,14,21,22]. While indirect energy embraces pesticides and fertilizers used for energy production during production phase, direct energy refers to electricity, fuel and human power. However, non-renewable energy resources are fuel, electricity, chemicals and fertilizers while renewable energy sources are human and animal power [21,22].

$$\text{Output} - \text{input ratio} = \frac{\text{Energy output(MJ/ha)}}{\text{Energy input(MJ/ha)}}$$

$$\text{Specific energy} = \frac{\text{Enery input (MJ/ha)}}{\text{Tomato output } (t/\text{ha})}$$

$$\text{Energy productivity} = \frac{\text{Tomato output(kg/ha)}}{\text{Enery input (MJ/ha)}} \tag{4}$$

After the energy equivalents of the inputs and outputs produced are calculated with formulas denoted with (4) and interpreted, the relationship between inputs and outputs were investigated by using a-priori production relationships. Considering the energy equivalences, the proper functional form was thought to be Cobb–Douglas production function. The main objective in estimation of this production function is to search for the elasticity relationships and returns to scale in double crop glasshouse tomato production. The methodology has been applied to seek for theoretical assumptions for sign of the inputs in determining the optimal output level in various studies [10,14,23].

Accordingly, the functional representation of the energy equivalent relationship is as following (5).

$$Y = \beta_0 * \Pi X^{\beta j}_{ji} e^{ui}, (i: 1, \ldots 85; j: 1, \ldots, 10) \quad (5)$$

or in linear Cobb–Douglas form;

$$Y = \beta_0 + \beta_1 \ln X_{1i} + \beta_2 \ln X_{2i} + \beta_3 \ln X_{3i} + \beta_4 \ln X_{4i} + \beta_5 \ln X_{5i} + \beta_6 \ln X_{6i} + \beta_7 \ln X_{7i} + \beta_8 \ln X_{8i} + \beta_9 \ln X_{9i} + \beta_{10} \ln X_{10i} + u_i$$

where;

Y_i: Yield at farm i (kg/ha)
X_{1i}: Energy equivalent of machinery per hectare at farm i
X_{2i}: Energy equivalent of electricity per hectare at farm i
X_{3i}: Energy equivalent of human power per hectare at farm i
X_{4i}: Energy equivalent of nitrogen per hectare at farm i
X_{5i}: Energy equivalent of potassium per hectare at farm i
X_{6i}: Energy equivalent of phosphor per hectare at farm i
X_{7i}: Energy equivalent of chemicals (herbicides, pesticides) 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 SPSS statistical package.

3. Results and discussion

3.1. Socio-economic characteristics of the glasshouse tomato farms producing in fall and summer seasons

Greenhouse production is generally carried out by small family farms in the research area and the number of large greenhouse holdings using modern technology is limited. Yet, glasshouses are considered to be more technologically oriented for the region. In order to provide an abstraction of the sector, socio-economic characteristics of the fall season glasshouse producers are provided in Table 2. The average size of investigated farms was 0.36 ha. The average size of farm family in the research was found to be formed from 4.0 people. The average age of the farmers was 42.2 and average experience of farmers in agriculture was 15.0 years. Research results demonstrated that 59.5% of the farmers in the sample are primary school graduates, 8.1% are middle school graduates, 21.6% are high school, 5.4% are university graduates, 2.7% are illiterate and 2.7% are literate only (Table 2). The labour in the surveyed farms is mainly supplied by family members and major part of family income comes from mainly glasshouse tomato production activities.

In addition, the socio-economic characteristics of summer season glasshouse enterprises were provided in Table 3. The average farm size was 0.35 ha. The average number of people in the farm family was 3.9. The average age and experience of the farmers was 39.8 and 15.5 years. Research results demonstrated that 68.0% of the farmers in the sample are primary school graduates, 16.0% are middle school graduates, 8.0% are high school and 8.0% are university graduates.

Table 2
Socio economic characteristics of glasshouse tomato farms (fall crops).

Features	Means	%
Land (ha)	0.36	
Farmers' age	42.2	
Farmers' experience in agriculture (year)	15.0	
Number of persons in family	4.0	
Farmers' education level (person)	37	100.0
Illiterate	1	2.7
Literate	1	2.7
Primary school	22	59.5
Middle school	3	8.1
High school	8	21.6
University	2	5.4

Table 3
Socio economic characteristics of glasshouse tomato farms (summer crops).

Features	Means	%
Land (ha)	0.35	
Farmers' age	39.8	
Farmers' experience in agriculture (year)	15.5	
Number of persons in family	3.9	
Farmers' education level (person)	25	100.0
Illiterate	–	–
Literate	–	–
Primary school	17	68.0
Middle school	4	16.0
High school	2	8.0
University	2	8.0

3.2. Energy inputs and outputs in glasshouse tomato production in fall season

The energy consumption values recorded for glasshouses that are involved in production during fall and summer seasons were provided in Tables 4 and 5. Energy sources are given as direct–indirect and renewable-non-renewable forms. Physical energy inputs consist of diesel, fertilizer, electricity, chemicals, human power, machinery and water irrigation.

Using the conversion factors of Table 1 energy inputs and outputs were determined (Table 4). For glasshouse tomato production in fall season, the amount of chemical drugs and chemical fertilizers utilized per hectare are 12.9 kg and 867.3 kg respectively. In addition, the share of phosphor, potassium and nitrogen were 40.6%, 29.8% and 29.6% consecutively in terms of chemical fertilizer use.

The total energy used in the investigated farms for producing tomato in glasshouse for fall season was 81362.2 MJ ha^{-1}. Out of all the farm operations in producing glasshouse fall tomato, total fertilizer (29.80%) consumed the most energy, followed by electricity (15.40%). The fuel energy was mainly utilized for operating tractors for performing the various farm operations. As can be seen from the Table 4, chemicals, human power, machinery, farmyard manure, fuel and water for irrigation consumed, respectively, 1.60%,

Table 4
Energy inputs, outputs and output–input ratio in glasshouse tomato production (fall crops).

Input (Unit)	Quantity used per unit area (ha)	Total energy equivalent (MJ ha^{-1})	%
Chemicals (kg)	12.9	1300.7	1.60
Human power (h)	3495.7	8040.0	9.88
Machinery (h)	7.2	466.7	0.57
Total fertilizer (kg)	867.3	24243.8	29.80
Nitrogen fertilizer (kg)	256.7	16981.1	20.87
Phosphorus (kg)	352.0	4378.8	5.38
Potassium (kg)	258.6	2883.9	3.54
Manure (tons)	279	8453.5	10.39
Diesel-oil (l)	37.0	2080.8	2.56
Electricity (kWh)	3481.4	12532.9	15.40
Water for irrigation (m^3)			0.00
Total energy input (MJ/ha)		81362.2	100.00
Yield (kg/ha)	25025.4	20020.3	
Energy output–input ratio		0.2	
Energy productivity (kg MJ^{-1})		0.31	
Specific energy (MJ t^{-1})		3251.2	

Table 5
Energy inputs, outputs and output–input ratio in glasshouse tomato production (summer crops).

Input (Unit)	Quantity used per unit area (ha)	Total energy equivalent (MJ ha^{-1})	%
Chemicals (kg)	3.6	361.4	0.57
Human power (h)	454.8	1045.9	1.66
Machinery (h)	0.3	19.4	0.03
Total fertilizer (kg)	839.7	22500.0	35.70
Nitrogen fertilizer (kg)	231.4	15303.1	24.28
Phosphorus (kg)	321.2	3996.3	6.34
Potassium (kg)	287.1	3200.6	5.08
Manure (tons)	19.2	5829.6	9.25
Diesel-oil (l)	10.7	603.1	0.96
Electricity (kWh)	2823.3	10163.8	16.13
Water for irrigation (m^3)			0.00
Total energy input (MJ/ha)		63023.2	100.00
Yield (kg/ha)	22392.9	17914.3	
Energy output–input ratio		0.3	
Energy productivity (kg MJ^{-1})		0.36	
Specific energy (MJ t^{-1})		2814.4	

9.88%, 0.57%, 10.39% and 2.56% of the energy. The average yield of tomatoes was 25 tonnes and its energy equivalent was calculated to be 20020.3 MJ per hectare.

Output–input ratio is one of the important indicators in maintaining efficiency of glasshouse tomato production in the fall season. The energy output–input ratio was found out to be 0.2 in glasshouse fall crop tomato production. Energy efficiency quotient referring to amount of output obtained in response to energy amount used per unit area was calculated as 0.31 kg MJ^{-1} and specific energy ass 3.251 MJ t^{-1}.

3.3. Energy inputs and outputs in glasshouse tomato production in summer season

Similarly, using the conversion factors of Table 1, energy inputs and outputs were calculated (Table 5). It is found out that 3.6 kg of chemical drugs and 839.7 kg of chemical fertilizers are used for glasshouse tomato production in summer. The share of phosphor, potassium and nitrogen was 38.3%, 34.2% and 27.6% in terms of chemical fertilizer.

The total energy used in the surveyed farms was 63023.2 MJ ha^{-1}. Out of all the farm operations in producing glasshouse summer tomato, fertilizers (35.70%) consumed the most of the energy, followed by electricity (16.13%). The fuel energy was mainly utilized for operating tractors for performing various farm operations. As can be seen from the Table 5, chemicals, human power, machinery, farmyard manure, diesel fuel and water for irrigation consumed, respectively, 0.57%, 1.66%, 0.03%, 9.25% and 0.96%. The average tomato yield was 22 tonnes and its energy equivalent was 17914.3 MJ per hectare.

The energy output–input ratio was found out to be 0.3 in glasshouse summer crop tomato production. Energy efficiency quotient referring to amount of output obtained in response to energy amount used per unit area was 0.36 kg MJ^{-1} and specific energy as 2.814 MJ t^{-1}.

The classification of inputs used for glasshouse tomato production in fall season as direct, indirect, renewable and non-renewable energy was indicated in Table 6. It is observed that while the ratios of direct and indirect energy resources are compatible, ratios of renewable and non-renewable energy resources are significantly different from each other. The rate of renewable energy composed out of human power and farm manure is considerably low (20.27%). Yet, 49.93% of energy resources used for the examined enterprises was non-renewable.

Table 6
Energy consumption under different modes of energy sources for glasshouse tomato production (fall crops).

Energy forms	MJ ha^{-1}	Percentage of Total energy input[a] (%)	Inputs
Direct energy	22653.7	27.84	Human, diesel, electricity
Indirect energy	34464.7	42.36	Fertilizers, farmyard manure, chemicals, machinery
Renewable energy	16493.5	20.27	Human, farmyard manure
Non-renewable energy	40624.9	49.93	Diesel, electricity, chemicals, fertilizers, machinery
Commercial energy	40624.9	49.93	Diesel, electricity, chemicals, fertilizers, machinery
Non-commercial energy	16493.5	20.27	Human, farmyard manure
Total energy input	81362.2		

[a] Energy equivalent of water for irrigation is not included.

The classification of inputs used for glasshouse tomato production in summer as direct, indirect, renewable and non-renewable energy groups was indicated in Table 7. The same trend regarding the compatibility is observed in summer production as well. However, the rate of renewable energy stemmed from human power and farm manure is considerably low (10.91%). Yet, 53.39% of energy resources used for these enterprises was non-renewable.

3.4. Analysis of the production relationship

After disaggregation of the energy impact of relevant inputs, the production function was estimated by using the energy equivalent measures of inputs against to yield per surveyed farms respecting the seasonal differences. Accordingly, for proper assessment of the variations, the data retrieved from farms were processed through two separate equations.

3.4.1. Findings for summer season

Initially, a regression setting forward the productive relationship relying on energy equivalents was estimated for 25 enterprises making production in summer. The problem of lack of data leaded to elimination of energy equivalents of machinery, use of manure and fuel in the glasshouses as explanatory variables. The main reason is the lack of explanatory power of these variables as a complete set for 25 enterprises.

The remaining explanatory variables indicated in the methodology section were checked with regards to possible multicollinearity between variables. The findings indicated that specific variables of nitrogen, potassium and phosphor found out to induce

Table 7
Energy consumption under different modes of energy sources for glasshouse tomato production (summer crops).

Energy forms	MJ ha^{-1}	Percentage of Total energy input[a] (%)	Inputs
Direct energy	11812.8	18.74	Human, diesel, electricity
Indirect energy	28710.4	45.56	Fertilizers, farmyard manure, chemicals, machinery
Renewable energy	6875.5	10.91	Human, farmyard manure
Non-renewable energy	33647.7	53.39	Diesel, electricity, chemicals, fertilizers, machinery
Commercial energy	33647.7	53.39	Diesel, electricity, chemicals, fertilizers, machinery
Non-commercial energy	6875.5	10.91	Human, farmyard manure
Total energy input	63023.2		

[a] Energy equivalent of water for irrigation is not included.

Table 8
Productive relationship for fall crops regarding energy equivalents.

$\ln y = b_1 + b_2 \ln \text{power} + b_3 \ln \text{chem.fert} + b_4 \ln \text{chem.drugs}$		
Variable	Parameter	Significance
Constant	5.51	0.006
Power	0.48	0.00
Chemical fertilizers	0.34	0.89
Chemical drugs	−0.53	0.68
R^2 (Adjusted)	%43	
F-statistic	10.144	0.00

the relationship in the same way. Accordingly, the specific amounts of chemical fertilizers are aggregated under the name of chemical fertilizers using the energy equivalents and incorporated in the equation as chemical fertilizers.

After completion of diagnostic checks, the relationship of explanatory variables in the form of electrical energy, human power, chemical drugs and chemical fertilizers with the yield was produced and indicated in Table 8.

Besides being in line with the expectations, the parameters of the variables are found out to be insignificant other that electrical energy. However, as the variables were found out to be significant together, the partial insignificance can be attributed to major contribution of electrical energy and labour force as being the energy accounts and to limitations of the data set. However, the findings also indicated that the largest energy contribution is from the chemical drugs used with a parameter value of 0.83 followed by labour force with the value of 0.66. Yet, the controversy of below unity contributions also leaded us to conclude with recognition of the inelastic energy structure of summer production.

3.4.2. Findings for fall season

Similar with the summer season production, the data for 37 glasshouses that make production in fall season needed to be revised. In contrast to summer enterprises, it was understood that machinery was effective in determining the energy use in fall. However, fuel use and manure and their contribution to energy use was compatible with summer season and these variables were eliminated from the production equation.

After the multicollinearity check was made, it was understood that main energy accounts as human power, machinery use and direct use of electricity were correlated. These variables were aggregated under the name of power as a newly derived variable. Similarly, the chemical fertilizers were correlated and they were aggregated under a derived variable of chemical fertilizers for the fall season.

After the diagnostic checks were made for these variables and the equation as a whole, the energy relationship was estimated taking power, chemical drugs and chemical fertilizers as explanatory variables. The relationship indicated an unexpected outcome with respect to the theory of production in terms of use of chemical drugs. More clearly, the produced coefficient had negative impact over the yield. The findings indicated that the direct energy accounts have more impact over yield in contrast to fertilizers and drugs and their energy impact. In addition, the significance of the derived power variable also revealed that the energy contribution is maintained by the direct resources as indicated in Table 9.

Table 9
Productive relationship for summer crops regarding energy equivalents.

$\ln y = b_1 + b_2 \ln \text{elt} + b_3 \ln \text{lab} + b_4 \ln \text{chem.fert} + b_5 \ln \text{chem.drugs}$		
Variable	Parameter	Significance
Constant	4.09	0.30
Electrical energy	0.419	0.00
Human power	0.66	0.77
Chemical fertilizers	0.134	0.66
Chemical drugs	0.83	0.30
R^2 (Adjusted)	%55	
F-statistic	10.872	0.00

4. Conclusions

The main objective of this study is to calculate energy use per hectare of double crop (fall and summer) glasshouse tomato production in Central, Kumluca and Serik towns of Antalya province of Turkey, where is a centre for green/glasshouse production in Turkey. The total mean of energy inputs as direct–indirect and renewable-non-renewable forms were also examined in the study through an energy audit of the accounts.

The findings indicated that, the fundamental energy using procedures in double crop glasshouse tomato production were chemical fertilizer, electricity, farm manure and fuel (diesel-oil). The share of energy retrieved from chemical drugs, machinery and labour was found out to be lower for both two production periods. While the average yield was 25025.4 kg per hectare for fall production and the energy consumed was 81362.2 MJ per hectare, the same figures were 22392.9 kg per hectare and 63023.2 MJ per hectare for summer production respectively. In addition, specific energy for fall and summer production periods were calculated as 3521.2 MJ t^{-1} and 2814.4 MJ t^{-1} respectively and energy efficiency was found out as 0.31 kgM J^{-1} and 0.36 kgM J^{-1}. The energy output–input coefficient calculated by rating energy equivalent of production of both two periods against the energy equivalent of inputs in fall and summer production period is 0.2 and 0.3 respectively. It was seen that the 49.93% of energy used for tomato production in fall and 53.39% in summer period were retrieved from non-renewable energy resources.

The overall elasticity of the inputs was more than unit for summer production (2.043) and clearly below unit (0.29) for fall production. These indicate increasing returns to scale for summer production, while it is decreasing for fall production with regards to energy use. Subsequently, considering the bulk of energy consumed was non-renewable, transfer of some of the energy to renewable accounts may lead to rise in the efficiency of production. In other words, direct energy contributes more to rise in the productivity in glasshouses respecting the sample farms.

In the study, the low energy output–input ratio reached for both two production periods infer inefficient use of inputs and the related energy. Inefficient use of inputs also leads to some serious problems. Specifically, unconscious use of drugs and fertilizers both lead to damages in human health and in environment and to input waste. Accordingly, the producers need to be trained more on use of inputs with regards to amount and techniques.

Finally, the study examined the productive relationship between energy equivalents of inputs and the energy equivalent of yield per hectare in the surveyed enterprises. In order to infer some specific findings for the production periods, the analysis was made separately for summer and fall production periods. It was understood that the energy relationships of both of the two production periods were significant due to direct sources of energy. The most significant energy source for summer season was found as electrical energy while it was a derived variable of 'power' referring to all electrical energy, machinery used and human power incorporated. However, the explanatory powers of the variables as a whole were relatively low. The variation of energy inputs for summer season explained 55% of the variation in produced energy, while the percentage for fall season was 43%. Yet, the factors were significant with increasing returns to scale trend for summer and vice versa for fall. The equations also leaded the same finding with the energy audit that the indirect energy sources such as use of fertilizers

and chemical ingredients were not completely determinative in the amount of energy produced. This also calls for the need to conscious building in use of the chemical add-ons for the covered production of tomato in Antalya as a sample place for widespread glasshouse production.

Acknowledgements

This research was supported by TUBITAK (The Scientific and Technological Research Council of Turkey), Project number: TOVAG 106O026.

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