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An Input–Output Energy Analysis in Intensive Agro-ecosystems: A Case Study of Greenhouse Cucumber Production in Varamin County of Tehran Province, Iran

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Abstract

The aim of this study was to examine the energy equivalents of input and output in greenhouse cucumber production in Varamin County of Tehran Province, Iran. A survey methodology with a sample of 200 greenhouse farms was employed in 2010. The results showed that the output–input ratio, specific energy and energy productivity were 0.017, 46.84MJ/kg and 0.02 kg/MJ, respectively. In this sense, diesel (99.03%), human labour (0.37%) and fertilizer (0.34%), had the highest proportion of energy consumption. Based on the results obtained, two strategies including input substitution and using technical progress were recommended for the best energy efficiency.

Keywords: Input–output energy ratio, Energy productivity, Cucumber, Varamin.

تحلیل انرژی‌های ورودی و خروجی در بوم نظام‌های فشرده کشاورزی
(مطالعه موردی: گلخانه خیار در منطقه ورامین)

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چکیده

هدف از انجام این مطالعه اندازه‌گیری میـزان انـرژی‌هـای ورودی و خروجی در گلخانه‌های خیار در شهرستان ورامین واقع در استان تهران بود. بر همین اساس ۲۰۰ نفر از گلخانه داران ورامـین در سـال ۲۰۱۰ انتخاب شدند. نتایج نشان داد که میزان کارایی انرژی، انرژی خالص و بهره‌وری انرژی به ترتیب ۰/۰۱۷، ۴۶/۸۴ مگاژول بر کیلوگرم و ۰/۰۲ کیلوگرم بر مگاژول می باشد. همچنین نتایج نشان داد کـه سـوخت (۹۹/۰۳٪)، نیروی کارگری (۰/۳۷٪) و انواع کودها (۰/۳۴٪) بیشترین سهم را در میزان مصرف انرژی دارند. بر اساس نتایج به دست آمده دو استراتژی جانشینی نهاده‌ها در کشاورزی و استفاده از پیشرفت‌های فنی به منظور افزایش کارایی انرژی پیشنهاد شد.

کلمات کلیدی: نسبت انرژی های ورودی و خروجی ،بهـره‌وری انرژی، خیار، ورامین.

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Introduction

Energy use in Iranian agriculture has become more intensive after the Green Revolution led to the increasing use of high yielding seeds, fertilizers and chemicals as well as diesel and electricity. Also, the use of intensive inputs in agriculture and access to plentiful fossil energy has led to an increase in food production and standard of living (Adem Hatirli *et al*., 2006). However, the increase of agricultural production relies heavily on the consumption of non-renewable fossil fuels. Since the consumption of fossil energy results in direct negative environmental impacts, such as emissions of CO_2 and other greenhouse gases, a sufficient supply of energy along with its efficient use are needed for an improved agricultural production system (Stout, 1990; Mohammadi & Omid, 2010). Accordingly, during recent years, different kinds of energy analysis have been employed to investigate and assess energy use efficiency, environmental issues and their relationship to sustainability in agricultural ecosystems (Beheshti Tabar *et al*., 2010).

One method is to use the analytic theory of the energy scenario. First, the agriculture sector is divided according to the procedure or the product. Then, different future energy consumption is forecast for each energy scenario set on the basis of the procedure's or the product's energy consumption. Finally, the future energy consumption is forecast for each energy scenario (Yanzheng Lu *et al*., 2011). The other method is to use the input-output model which was initially proposed by Leontief (1936). This method inputs some parameters that are relative to energy consumption, and outputs the energy consumption. The input-output model reflects the relationship of the inputs and the output. For instance, Ozakan *et al*., (2004) used the input-output model to analyze agricultural energy consumption. In their study, the inputs included both human and animal labour, machinery, electricity, diesel oil, fertilizers and seeds while 36 agricultural commodities were considered as outputs. Energy values were calculated by multiplying the amounts of input and output by their energy equivalents using related conversion factors. Karkacier and Goktolga (2005) have analyzed the structural interdependency of the agricultural and energy sectors in Turkey. The input-output model used in their study was an accounting system showing how economic transactions and the relationships between agriculture and energy could be expressed in concept (Karkacier & Goktolga, 2005). The input-output model's method largely was dependent on the values of the inputs. The value of the output might be greatly changed, even if the values of the inputs change little.

Nowadays, 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. For this aim, input–output analysis was usually used to evaluate energy efficiency and the environmental impacts of the greenhouse production systems. In this sense, several research studies have been conducted on the energy use pattern in greenhouse production using the input–output model (Ozkan *et al.,* 2004 & Adem Hatirli *et al.,* 2006). In this study, by employing the input–output model, the energy use patterns of cucumber greenhouses were examined and an input–output energy analysis was performed.

Materials and Methods

Data were collected in 2010 from 200 greenhouse cucumber growers in Varamin County, Tehran Province using a questionnaire. This county is located to the Southeast of Tehran (Fig. 1). The survey was carried out in 10 villages where major production units are running.

With regard to the sample size based on the farmer population (700), and accepting a 5% error from the mean (e) and a 95% confidence interval (t ¼ 1.64), a sample of 200 operators was selected by stratified sampling in location under the study. For growth and development, energy demand in agriculture can be divided into direct, indirect, renewable, and non-renewable energy sources (Alam *et al*., 2005). The energy efficiency of the agricultural system was evaluated according to the energy ratio between output and input. Human labour, machinery, diesel oil, fertilizer, pesticide and seed rate were considered as inputs and cucumber yield was

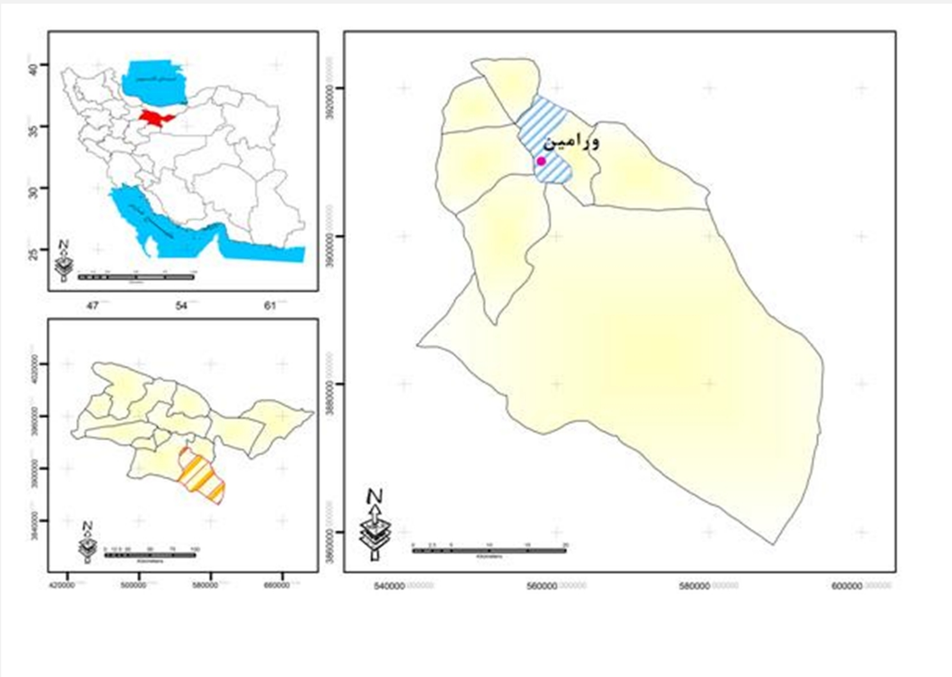

Figure 1: Map of study sites by country and by study location

applied to estimate the energy ratio; energy equivalents shown in Table 1 were used for estimation. The sources of mechanical energy used on the selected greenhouses included tractors and diesel oil. The energy from machinery was computed on the basis of total fuel consumption (L ha^{-1}) in different operations. Accordingly, the energy consumed was calculated using conversion factors (1L diesel =56.31 MJ) and expressed in MJ ha^{-1} (Tsatsarelis, 1991):

$$\text{Energy Efficiency} = \frac{\text{Total energy output (MJ/ha)}}{\text{Ttal energy intput (MJ/ha)}} \quad (1)$$

$$\text{Energy Productivity} = \frac{\text{yield (kg/ha)}}{\text{Total energy intput (MJ/ha)}} \quad (2)$$

$$\text{Specific Energy} = \frac{\text{Total energy intput (MJ/ha)}}{\text{yield (kg/ha)}} \quad (3)$$

Net Energy=Energy output (MJ/ha)-Energy input (MJ/ha) (4)

Indirect energy included energy embodied in seeds, fertilizers, manure, chemicals, machinery while direct energy covered human labour and diesel were used in the greenhouse cucumber production. In the end, a cost analysis of greenhouse cucumber production was done, (Demircan *et al.*, 2006; Ozkan *et al.*, 2004).

All analyses were carried out using the SPSS statistical software and Microsoft Excel program 2007. Also, all maps were produced using ArcView GIS software.

Results

Demographic and Descriptive Characteristics of Farmers

The average age of framers was 39.47.48, and

Table 1- Energy Coefficients Used in Energy Calculation

Energy Source	Energy Coefficient (MJ/unit)	Reference
Human labour	1.96 MJ/hr	Gundogmus (2006)
Fertilizer		Gundogmus (2006)
N	60.60 MJ/kg	
P	11.10 MJ/kg	
K	6.70 MJ/kg	
O	0.30 MJ/kg	
Pesticide		Gundogmus (2006)
Insecticide	199 MJ/kg	
Fungicide	92 MJ/kg	
Herbicide	238 MJ/kg	
Diesel	56.31 MJ/kg	Gundogmus (2006)
achinery	62.70 MJ unit_1/h	Gundogmus (2006)
Water	0.63 MJ unit_1/h	Gundogmus (2006)
Electricity	11.93 MJ unit_1/h	Gundogmus (2006)
Cucumber	0.80 MJ unit_1/h	Ozkan et al. (2004)
Seed	1.00 MJ unit_1/h	Ozkan et al. (2004)

their average years of farming experience were 4.29 years, the average family sizes in the survey households were 2.02 people, and the average work experience of the growers was 4.29 years.

Energy use Pattern in the Cucumber Production Greenhouses

The energy consumption for greenhouse cucumber production and its sources are presented in Table 2. As can be seen in Table 2, 441.42 kg nitrogen, 385.6 kg phosphorus, 364.5 kg potassium, 31101.66 kg manure of farm fertilizer, 205939.36 L diesel fuel, 89.47 kg pesticide, 4669.2 m^3 water, 22175.55 h human labour, 107.873 h machinery, 577.78KW h electrical energy per hectare are employed for the cucumber production. The average annual yield in the enterprises analyzed was found to be 250000kg ha^{-1}.

The total energy used in various farm operations during cucumber production was 11709452.43 MJ/ha^1, comprising 0.08% pesticide (the share of insecticides, herbicides and fungicides of total energy were 0.03%, 0% and 0.05%, respectively), 0.37% human labour, 0.05% machinery, 0.34% fertilizers,0.05 % electricity, 0.02% water and 99.03% diesel oil inputs.

As this shows, diesel has the biggest share in the total energy with 99.03%. The diesel energy was mainly used for heating, operating tractors and performing various greenhouse operations. These findings are consistent with the findings of Adem Hatirli *et al.*, (2006) and Ozkan *et al.* (2004). Diesel energy is followed by human labour (0.37%). Energy for fertilizer is ranked third (0.34%): energy used in the production of fertilizers accounts for about 40% of total energy used in agricultural production in developed countries according to Singh *et al.,* (2001). Most of this energy was consumed in the production of nitrogen, phosphorus and potassium fertilizers. In this study, nitrogen, phosphorus and potassium were considered as chemical fertilizer inputs. Fertilizer energy, including chemical fertilizer and manure, accounted for 0.34% of total energy inputs.

Both the direct and indirect and renewable and non-renewable energy forms used in greenhouse cucumber production are also investigated (Table 3). The results show that the share of direct input energy was 99.46% of the total energy input compared to 0.53% for indirect energy. On the other hand, non-renewable and renewable energies contributed to 99.54 and 0.45% of the total energy input, respectively. It is clear that the proportion of non-renewable energy use in the surveyed greenhouse holdings is very high. This result indicates that the greenhouse cucumber production depends mainly on fossil fuels in the research area.

Energy Use Efficiency (Energy ratio)

The energy ratios in agricultural production are closely related to production techniques, the quantity of inputs used by producers and the yield level of crops along with environmental factors such as soil and climate. Therefore, there is a range of energy input and output relationships for the same crop depending on the region (Yilmaz & Ozkan, 2005).

Energy efficiency is the most important index between all energy indices which, in this research was 0.017. This index in Turkey was calculated at

Table 2- Energy inputs, outputs and the output–input ratio in greenhouse cucumber production units of the studied area

Energy Source	Quantity used per unit area (ha)	Energy equivalent (MJ /ha)	Accumulative energy (%)
Inputs			
Human labour	22175.5	43464.07	0.37
Machinery	107.8	6763.44	0.05
Fertilizer(kg)			
Nitrogen (kg)	441.4	26750.05	0.22
Phosphorus (kg)	385.6	4280.16	0.03
Potassium (kg)	364.5	2442.15	0.02
Manure (kg)	31101.6	9330.5	0.07
Insecticides (kg)	17.8	3560.11	0.03
Fungicides	71.58	6585.36	0.05
Herbicide	0	0	0
Diesel oil (l)	205939.3	11596441.9	99.03
Electricity (kWh)	577.7	6892.91	0.05
Irrigation water (m3)	4669.2	2941.6	0.02
Seed (kg)	0.1	0.1	0.00
Total energy input (MJ/ha)		11709452.43	100
Outputs Yield (kg)	250000	200000	
Net Energy		-11509452.4	
Specific energy (MJ Kg^{-1})		46.84	
Energy Efficiency		0.017	
Energy productivity (kg MJ^{-1})		0.02	

Table 3- Total energy inputs in the form of direct, indirect, renewable and non-renewable energy for cucumber.

	(MJ /ha)	%
Direct energy	11646798.96	99.46
Indirect energy	62653.47	0.53
Renewable energy	52794.67	0.45
Non-renewable energy	11656657.76	99.54

0.76 for greenhouse cucumber (Ozkan *et al.,* 2004), and it was calculated for Iran as 1.32 for wheat, 0.38 for cucumber and 0.47 for tomato (Beheshti tabar *et al.,* 2010). It was 0.96 for cherries in Turkey (Halil Kizilaslan, 2011).

In Figure 2, the highest level of energy efficiency was found in a few regions of central Varamin County because diesel has the biggest share in the total energy, at 99.03%, and it is a very important input in the region. Therefore this indicator was good only in a few regions in this area.

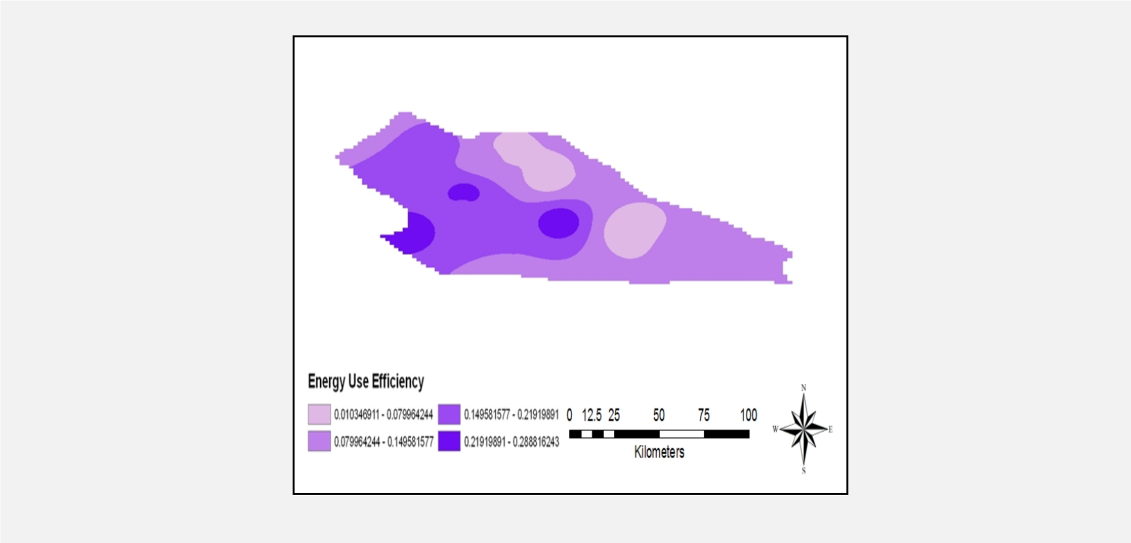

Figure 2. Map of energy use efficiency in the study area (scale of map 1/250000).

Specific Energy

Specific energy is an index which shows how much energy has been used to produce a single unit of a disposable product. In this study, the aforementioned index has been calculated at 46.84 $MJ\ kg^{-1}$ which demonstrated the quality of poor output rather than input in the farm. In the research studies done on greenhouse tomato, the index has been calculated at 12/380 $MJ\ kg^{-1}$ (Adem, 2006). In Figure 3, the highest amount of specific energy was in a few of the northern and eastern regions of Varamin County because these areas were well situated of the amount of consumption of energy.

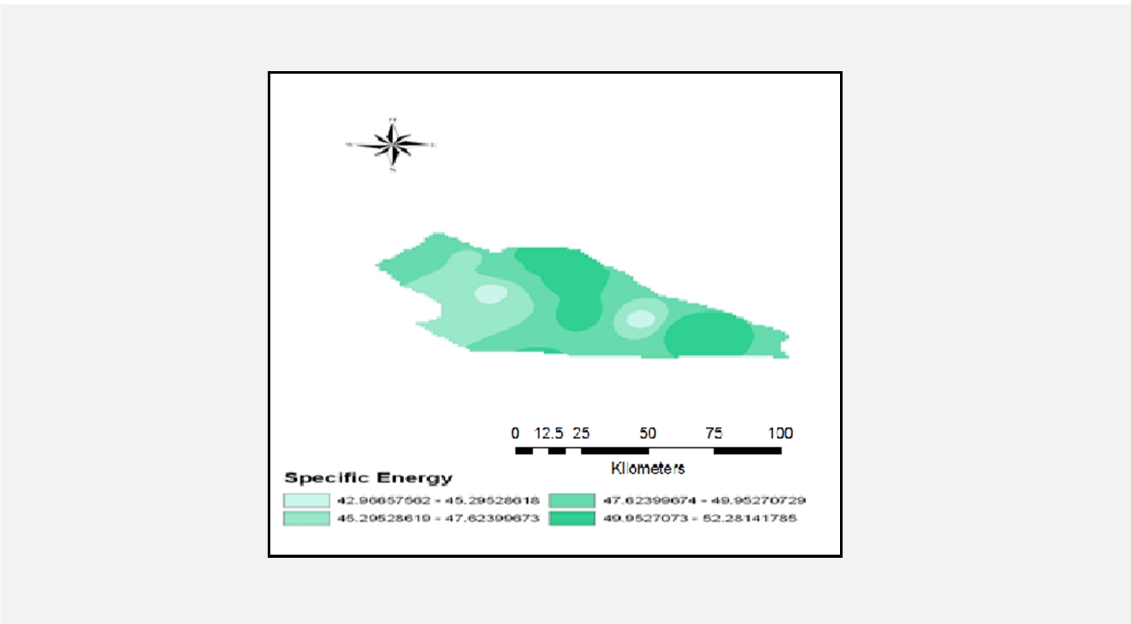

Figure 3. Specific energy map of the study area (scale of map 1/250000).

Energy Productivity

The energy productivity (EP) has shown an increasing trend reflecting increasing energy efficiency, at 0.02 kg/MJ having been calculated previously at 0.27 kg/ MJ in Iran for some plants (Beheshti tabar, 2010). In Figure 4 the highest amount of energy productivity was in a few central and western regions of Varamin County.

Conclusion

The agro-ecosystem is both a producer and a consumer of energy, and the energy flows among various agricultural subsystems within a country or region can significantly influence energy-use efficiency, productivity, food security, and ecosystem sustainability (Caoa *et al.,* 2010). In this paper, we estimated total energy productivity, using an input–output model, and measured output–input energy, specific energy and energy productivity. Accordingly, the results showed that:

1. The energy input use on greenhouse cucumber was 11709452.43 MJ/ha. In this, the energy input of diesel oil (99.03%), human labour (0.37%) and fertilizer (0.34%) were the major contributors of total energy use in greenhouse cucumber production, with diesel having by far the biggest share in the total energy. These findings are in accordance with the findings of Adem Hatirli *et al*., (2006) and Ozkan *et al.,* (2004), who asserted that the diesel energy is mainly used for heating, operating tractors and performing various greenhouse operations.
2. Average annual yield of the greenhouses investigated was 250000kg ha^{-1}, and the total energy output calculated was 200000 MJ ha^{-1}. The results indicate that total energy output on greenhouse cucumber from Varamin is higher than the average values of total energy output in Iranian agriculture overall (36876 MJ ha^{-1}) as reported by Beheshti Tabar *et al.,* (2010).

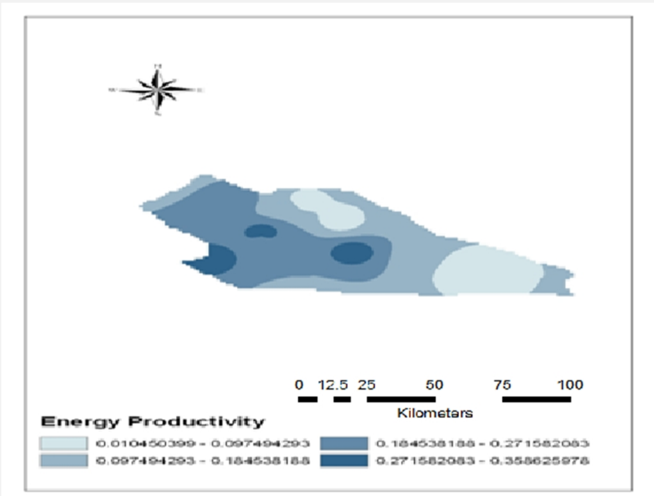

Figure 4. Energy productivity map of study area (scale of map 1/250000).

3. The energy output/input ratio in the production of cucumber greenhouse was found to be 0.017. This value is lower than the average values for the output/input ratio in Iranian agriculture (1.07) and revealed that production techniques, the quantity of inputs used by producers and the yield level of crops, along with environmental factors such as soil and climate, are far from a sustainable condition. Given the highest share of diesel (99.03) in energy input, the use of renewable energy rather than diesel would reduce the input energy and, as a result, the energy output/input ratio will be raised.
4. The Specific energy (energy intensity) was calculated at 46.84MJ/kg which was higher than the average amount of energy required to produce 1 kg of crop (3.69 MJ) in Iran. Therefore, it can be argued that the environmental effects associated with the production of greenhouse cucumber are greater than the optimum intensity of land and crop management from an ecological point of view.
5. The energy productivity was 0.02 kg/MJ which was lower than that of the average energy productivity for Iran agriculture according to Beheshti Tabar *et al.,* (2010) who reported the value of 0.27 as the average energy productivity of farms in Iran.

The results of the sensitivity analysis for indicators revealed that high input energy to the system was the main cause for low ratings of energy indicators. In this sense, as Schneider and smith (2009) asserted two strategies including several options were recommended for the reduction of energy use:

Input substitution in agriculture

Agricultural energy consumption can also be reduced with existing technologies through the substitution of inputs (Edwards *et al.,* 1996). Possible input substitution options involve the use of high-productivity varieties of crops to increase energy output-input ratios, fertilization (Tzilivakis *et al.,* 2005), (Deike *et al.,* 2008), and the level of mechanization (Nkakini *et al.,* 2006); the early retirement of fuel inefficient machinery and the use of circulation fans to achieve a consistent environment with minimized energy inputs can also be helpful (ECG091, 2004). New policy approaches, such as replacing fossil fuels with more renewable energy (Ozkan *et al.,* 2004), were also recommended to force producers to undertake energy efficient practices for increasing yield without diminishing natural resources.

Technical progress in agriculture

Technical progress can be achieved with respect to the energy efficiency of all major inputs. To this end, the principal strategies available include more efficient fertilizer application, better use of diesel fuel, more efficient machinery (Glancey and Kee, 2003), more efficient heating systems (Sakellarious- Makrantonaki *et al*., 2007) and the use of more efficient heating equipment for reducing wasted energy.

References

Adem Hatirli, S., B. Ozkan and C. Fert (2006). Energy inputs and crop yield relationship in greenhouse tomato production. Renewable Energy, 31: 427–438.

Alam, M.S., M.R. Alam and K.K. Islam(2005). Energy Flow in Agriculture: Bangladesh. American Journal of Environmental Sciences, 1(3): 213-220.

Beheshti Tabar, I., A. Keyhani and S. Rafiee (2010). Energy balance in Iran's agronomy. Renewable and Sustainable Energy Reviews, 47(18-19): 849–855.

Caoa, S., G. Xieb and L. Zhenb (2010). Total embodied energy requirements and its decomposition in China's agricultural sector. Ecological Economic, 69: 1396 – 1404.

Demircan, V., K. Ekinci, H.M. Keener, D. Akbolat and C. Ekinci (2006). Energy and economic analysis of sweet cherry production in Turkey: A case study from Isparta province. Energy Conversion and Management, 47 (13-14): 1761–1769.

Deike, S., B. Pallutt and O. Christen (2008). Investigations on the energy efficiency of organic and integrated farming with specific emphasis on pesticide use intensity. European Journal of Agronomy, 28(4): 461-470.

Edwards, B.K., R.E. Howitt and S.J. Flaim (1996). Fuel, crop, and water substitution in irrigated agriculture. Resource and Energy Economics, 18(3): 311-331.

Gundogmus, E. (2006). Energy use on organic farming: A comparative analysisnon organic versus conventional apricot production on small holding in Turkey. Energy Conversion and Management, 47(18-19), 3351-3359.

Glancey, J. L. and K. Edwin (2003). Technical and strategic advances in mechanization. Hortscience, 38(7):1365–1369.

Kizilaslan H. (2009). Input–output energy analysis of cherries production in Tokat Province of Turkey, Applied Energy, 86(7-8): 1354–1358.

Karkacier,O. and Z. Gokalp Goktolga (2005). Input-output analysis of energy use in agriculture. Energy Conversion and Management, 46(9-10):1513-1521.

Mohammadi A., M. Omid (2010). Economical analysis and relation between energy inputs and yield of greenhouse cucumber production in Iran. Applied Energy, 87(1): 191–196.

Nkakini, S.O., M.J. Ayotamuno, S.O.T. Ogaji and S.D. Probert (2006). Farm mechanization leading to more effective energy-utilizations for cassava and yam cultivations in Rivers State, Nigeria. Applied Energy 83 (12), 1317-1325.

Ozkan, B., H. Akcaoz and C. Fert (2004). Energy input-output analysis in Turkish agriculture. Renewable Energy, 29(1): 39-51.

Ozkan, B., H. Akcaoz and F. Karadeniz (2004). Energy requirement and economic analysis of citrus production in Turkey. Energy Conversion & Management, 45: 1821-1830.

Schneider, U.A. and P. Kumar (2008). Greenhouse Gas Mitigation through Agriculture. Choices, 23(1): 19-23.

Singh, S.P., R.G. Reynolds and S. Muhammad (2001). A gender-based performance analysis of micro and small enterprises in Java, Indonesia. Journal of Small Business Management, 39(2): 174–182.

Stout B.A. (1990). Handbook of energy for world agriculture. London: Applied Science.

Sakellariou-Makrantonaki, M., D. Papalexis, N. Nakos and I.K. Kalavrouziotis (2007). Effect of modern irrigation methods on growth and energy production of sweet sorghum (var. Keller) on a dry year in Central Greece. Agricultural Water Management, 90(3): 181-189.

Tsatsarelis, C.A. (1991). Energy requirements for cotton production in central Greece. Journal of Agricultural. Engineering Research, 50(3): 239–246.

Tzilivakis, J., D.J. Warner, M. May, K.A. Lewis and K. Jaggard (2005). An assessment of the energy inputs and greenhouse gas emissions in sugar beet (Beta vulgaris) production in the UK. Agricultural Systems, 85(2): 101-119.

Yilmaz L.,H. Akcaoz and B. Ozkan (2005) An analysis of energy use and input costs for cotton production in Turkey. Renewable Energy, 30 (2):145–55.

Yanzheng l., M. Hailin and L. Huanan (2011). An Analysis of Present Situation and Future Trend about the Energy Consumption of Chinese Agriculture Sector. Procedia Environmental Sciences, 11(3):1400-1406.