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Full Length Research Paper

Input-output and economic analysis of soybean production in the main cultivation areas in Iran

Dehshiri Abbas[1]* and Aghaalikhani Majid[2]

[1]Seed and Plant Certification and Registration Research Institute, Karaj, Iran.
[2]Department of Agronomy, Faculty of Agriculture, Tarbiat Modarres University, P. O. Box 14115–336, Tehran, Iran.

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Vegetable oil consumption in Iran is about 1.4 million tons per year of which more than 90% is obtained from imports. Therefore, development of oilseed crops especially soybean cultivation is particularly important to reach food security. Since the technical and economic justification are the first requirements in introducing new crops, the aim of this study was to evaluate different inputs, energy use efficiency (EUE), and economic aspects of soybean production in Iran. Necessary data were collected from 30 soybean farms in two main climatic locations of the country via face to face questionnaire method based on statistical information of the year 2011. The results revealed that soybean production consumed a total of 29895.49 MJ ha^{-1}, of which the share of diesel fuel and chemical fertilizer energy consumption were 67.47 and 9.5%, respectively. About 68.4% of the total energy inputs used in soybean production was direct (human labor, diesel) and the rest (31.6%) was indirect (seeds, fertilizers, manure, chemicals, machinery). Nonrenewable energy sources have 93% share of total input energy. So it was concluded that soybean production needs to improve the efficiency of energy consumption and to employ renewable energy as much as possible. Mean grain yield which was rain-fed farming was about 1850 kg ha^{-1}. In this current study, total output energy and net energy was estimated as 54131 and 24235.5 MJ ha^{-1}, respectively. Also, energy productivity value and EUE was determined as 0.062 kg MJ^{-1} and 1.81, respectively. According to economic analysis of soybean production, total expenditure, gross income, net income, and benefit-cost ratio (BCR) were calculated as 920 \$ ha^{-1}, 1239 \$ ha^{-1}, 319 \$ ha^{-1}, and 1.35, respectively. Regarding to high EUE and BCR of soybean production in Iran, technical guidance should be considered. Early sowing date, proper plant rotation (wheat-soybean) and application of combine vehicle were severely recommended to minimize fossil fuels consumption and more sustainable soybean production.

Key words: Energy use efficiency, soybean, benefit-cost ratio (BCR), energy sources.

INTRODUCTION

Energy has a significant impact on development of key sectors of economic importance such as industry, transportation, and agriculture. This has motivated many researchers to focus their studies on energy management. Energy has been a key input of agriculture since the age of subsistence agriculture. It is an established fact worldwide that agricultural production is positively correlated with energy input (Singh, 1999).

In the agricultural sector, energy is an input which is used for various reasons such as increasing productivity, enhancing food security, and contributing to rural economic development (FAO, 2000).

Energy use in agriculture has been increased in response to increasing population, limited supply of arable lands, and a desire for higher standards of living. Tendency towards intensive use of energy in agricultural systems is mainly due to mechanization, using chemical fertilizers, high-yielding seeds, and synthetic pesticides. On the other hand, dependence of conventional agricultural systems to intensive using of energy is one of

*Corresponding author. E-mail: ab_dehshiri @yahoo.com.

the main reasons that is creating environmental problems such as global warming in most developing and developed countries. Therefore, resource and energy use efficiency should be considered as one of the principal requirements of eco-efficient and sustainable agriculture (Jonge, 2004).

Many researchers have studied energy and economic analysis to estimate the energy use efficiency in production of oilseed rape in Germany (Rathke and Diepenbrock, 2006), sugar beet, maize, sunflower, and winter cereal, in Italy (Triolo et al., 1987), greenhouse vegetable and some field crops and vegetable in Turkey (Demircan et al., 2006), soybean, maize and wheat in Italy (Sartori et al., 2005), soybean based production system, potato in India (Mandal et al., 2002; Yadav et al., 1991), wheat, maize, sorghum in United States (Franzluebbers and Francis, 1995), cotton, sunflower in Greece (Tsatsarelis, 1991; Kallivroussis et al., 2002), and rice in Malaysia (Bockari-Gevao et al., 2005). Okurut and Odogola (1999) stated that besides land, farm power is the second most important input to agricultural production. Generation and development of appropriate technology must be improved to increase the fertilizer use efficiency to meet the challenge of feeding increased population (Borlaug and Dowswell 1993). Alam (2005) developed a simulation model of input energy structure of Bangladesh agriculture to evaluate the effectiveness of various agricultural energy inputs.

Soybean (*Glycine max* L.) is an important oilseed crop in Iran's agriculture. The cultivation of this crop due to biological nitrogen fixation, enhance agricultural soil fertility. The annual worldwide production of soybean grain is approximately 250 million tons on 101.4 million hectares and ranks first in the production of world's oilseed crops (FAO, 2008). Soybean production from 1975 to 2005 has increased from 64.2 million tons to about 213.9 million tons. Development of oil seeds cultivation in Iran began in 1961 with the development of cotton cultivation and continued with sunflower and soybean cultivation in 1967. Soybean production increased from 2000 tons in 1967 to around 190000 tons in 2009 (Anonymous, 2005). Cultivation of soybean mainly is restricted in Golestan (North east), Mazandaran (North, Caspian seashore), and Ardebil (North West) provinces. Soybean grain yield per unit area in Iran (1850 $kg.ha^{-1}$) is relatively good performance and is higher than global average. No irrigation and less nitrogen fertilizer are two important advantages of soy farming in these areas that reduce energy consumption in comparison to other areas and other crops.

Vegetable oil consumed in Iran is about 1.4 million tons and more than 90% of it comes from imports. So, to insure food security, developing oilseeds, especially soybean cultivation is particularly important. But the first requirement in developing a culture is technical and economic justification. A benefit-cost ratio (BCR) is an indicator, used in the formal discipline of cost-benefit analysis that attempts to summarize the overall value for money of a project or activity. All benefits and costs should be expressed in discounted present values. In the absence of funding constraints, the best values for economic activities are those with the highest net present value (NPV). Where there is a budget constraint, the ratio of NPV to the expenditure falling within the constraint should be used. In practice, the ratio of PV of future net benefits to expenditure is expressed as a BCR.

One of the most important indicators for determining the crop production is related to its energy consumption and energy use efficiency. The relation between agriculture and energy is very close. Effective energy use in agriculture is one of the conditions for sustainable agricultural production, since it provides financial savings, fossil resources preservation, and air pollution reduction (Uhlin, 1998).

A significant objective in agricultural production is decreasing the costs and increasing the yield. In this respect, the energy budget is important. Energy budget is the numerical comparison of the relationship between input and output of a system or agricultural business in terms of energy units, therefore, the objective of this study was to determine the input and output energy rates, in soybean fields at its main planted areas in Iran.

MATERIALS AND METHODS

Golestan (North east) and Mazandaran (North, Caspian seashore) provinces are the main soybean cultivation area in Iran. Necessary information about input and output were collected from the 30 growers in each area by using a face-to-face questionnaire. The collected data belonged to the 2008 to 2009 growing season of soybean. In order to investigate total inputs and output energy, equivalents listed in Table 3 and amounts of inputs and outputs (Table 4) were used. Based on the energy equivalents of the inputs and output, the energy use efficiency, energy productivity, and the specific energy were calculated as follow (Demircan et al., 2006; Sartori et al., 2005):

$$\text{Energy use efficiency} = \text{Energy output (MJ ha}^{-1}\text{)} / \text{Energy input (MJ ha}^{-1}\text{)} \quad (1)$$

$$\text{Energy productivity} = \text{Grain output (kg ha}^{-1}\text{)} / \text{Energy input (MJ ha}^{-1}\text{)} \quad (2)$$

$$\text{Specific energy} = \text{Energy input (MJ ha}^{-1}\text{)} / \text{Grain output (kg ha}^{-1}\text{)} \quad (3)$$

$$\text{Net energy} = \text{Energy output (MJ ha}^{-1}\text{)} - \text{Energy input (MJ ha}^{-1}\text{)} \quad (4)$$

Energy demand in agriculture can be divided into direct and indirect, renewable, and non-renewable energies (Alam et al., 2005). Human labor, machinery, diesel oil, fertilizer, pesticides, and seed amounts are inputs and outputs used to produce grain and straw yield. Indirect energy consists of seeds, fertilizers, manure, pesticide, and machinery energy, while direct energy covered human labor and diesel fuel used in the soybean production. Nonrenewable energy includes all fossil fuel derived energy sources and renewable energy consists of human labor and seeds.

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

Inputs and outputs	Unit	Equivalent (MJ^{-1})	References
Inputs			
1. Human labor	h	1.96	Ozkan et al. (2004a), Yilmaz et al. (2005),
2.Machinery	h	62.7	Erdal et al. (2007a), Singh (2002a), Singh (2002b)
3. Diesel fuel	L	56.31	Erdal et al. (2007a), Singh (2002a), Singh (2002b)
4. Chemical fertilizers	kg		
(a) Nitrogen (N)	-	66.14	Esengun et al. (2007), Yilmaz et al. (2005)
(b) Phosphate (P_2O_5)	-	12.44	Esengun et al. (2007), Yilmaz et al. (2005)
(c) Potassium (K_2O)	-	11.15	Esengun et al. (2007), Yilmaz et al. (2005)
5. Chemicals	kg	120	Canakci et al. (2005), Mandal et al. (2005), Singh (2002)
6. Seed	kg	30.6	Koocheki and Hosseini (1995)
Outputs			
1. Grain	kg	18.76	Computed based on energy produced from components
2. Straw	kg	10.5	Computed based on energy produced from components

Table 2. Some indices of soybean production.

Practice/operation	Properties
Names of varieties	Sari, Talar, 032, 033, Sahar, Vilyams, Gorgan3
Land preparation tractor used	MF285, 75 hp – Romany 75 hp
Land preparation period	15 April-30 may
Average tilling number	1
Planting period	5 May - 10 July
Fertilization period	15 April - 30 May
Average number of fertilization	1
Average number of irrigation	1 - 3 complimentary in seedling and flowering stages
Spraying period	July - September
Average number of spraying	3
Harvesting period	October, November
Average number of harvesting	1

Human labor (hours per hectare) will be used for management, and for conducting some agricultural operations and tractor driving.

Applied machinery (tractor) power computed based on spent hours of tractor power per hectare for any cultural practices. Fuel consumption was computed taking into account the number of hours of operation, the amounts of power and fuel consumption per hour of the tractor and other machinery. Consumed energy through the amount of applied seed was calculated based on total energy of grain compounds. Used energy via applied pesticides, herbicides and fungicides was computed according to consumed energy for their production, transportation and application. Grain and straw is the main product and by product of the soybean yield, respectively. These amounts have been considered as outputs for computing produced energy amounts. Table 1 shows the energy equivalent of inputs and outputs in general agricultural practices which have been used by several researchers worldwide.

We undertake economic analyses of soybean production in Iran to compare costs with benefits and determine whether it has an acceptable return. The costs and benefits of soybean production therefore must be identified. Furthermore, once costs and benefits are known, they must be priced, and their economic values determined.

RESULTS AND DISCUSSION

Common pattern for crop rotation in studied areas included: wheat-soybean, soybean-canola, and cotton-wheat-soybean. Important details on soybean cultural practices are summarized in Table 2. The observed pests in soybean fields were included as *Hylemya cilicrura* R., *Agrotis segetum* Schiff., *Thrips* species, *Spodoptera exigua* Hb., *Prodenia litura* Fabricious*., Tetranychus telarius*, *Heliothis dipsacea L.*, *Phytophtora* rot *(Phytophtora sojae), Rhizoctonia* root and stem Rot *(Rhizoctonia soloni* Feuhn*),* and Charcoal rot (*Sclerotium bataticola* Taub)*.* The average of land size of soybean in studied areas is 1.9 ha. All soybean fields are private. The amounts of inputs and outputs for soybean production in the studied areas are listed in Table 3. Land preparation and soil tillage were mostly accomplished by a Massey Ferguson, 75 hp along with using moldboard plow, disc harrows, and land leveler. Also, trailed

Table 3. Amounts of inputs and outputs in soybean production.

A-Inputs	Quantity per unit area (ha)
Labor (h ha^{-1})	138.5
Land preparation	13.8
Seeding	9.2
Fertilizer application	5
Spraying	12.5
Harvesting	65
Transporting	15
Machinery (h ha^{-1})	67.7
Land preparation	12.8
Seeding	8.3
Fertilizer application	5
Spraying	12.5
Harvesting	18.9
Transporting	10.2
Diesel (L ha^{-1})	358.2
Land preparation	58.8
Seeding	49.8
Fertilizer application	18
Spraying	56.4
Harvesting	30
Transporting	60
Fertilizers (kg ha^{-1})	125
Nitrogen (N)	25
Phosphorus (P_2O_5)	50
Potassium (K_2O)	50
Chemicals (kg ha^{-1})	4.5
Seeds (kg ha^{-1})	60
Outputs	
1- grain (kg ha^{-1})	1850
2-Straw (kg ha^{-1})	1850

centrifuge fertilizer spreader was used for spraying fertilizer. Furthermore, pre-planting herbicides (narrow weed killer) was applied through trailed and hand herbicide spreader. Phosphorous, potassium, and urea fertilizers were applied before planting during soil preparation. According to high mean annual precipitation (600 mm), there is no need for supplementary irrigation to be performed on soybean fields. Result revealed that total energy equivalent of inputs was 29895.5 MJ ha^{-1}. Diesel fuel had the highest share of energy consumption (67.47%), followed by machinery (14.21%) (Table 4). So, it could be suggested that specific policies (using electricity power instead of diesel fuel, using combine vehicle for doing different agricultural operation at the same time and consequences reducing the hours of tractor activity), could be taken to reduce the fuel consumption. In this manner, the negative environmental impacts of energy inputs, such as pollution, global warming, and nutrient loading would consequently be minimized. Within this framework, energy flow analysis is an important task that will lead to develop more efficient, economic, and environment friendly agricultural production system in Iran. The energetic efficiency of the agricultural system has been evaluated by the energy ratio between output and input.

Analysis of input–output energy use in soybean production

According to the summarized results of our calculations in Table 4, soybean production consumed a total of 29895.5 MJ ha^{-1} of which diesel fuel and machinery consumption was 67.47 and 14.21%, respectively. The total output energy, net energy was estimated to be 54131 and 24235.5 MJ ha^{-1}, respectively. Shahan et al. (2008) reported that total energy inputs, total energy outputs, and net energy for wheat production in Iran were 47078.5, 92785.56, and 45707.1 MJ ha^{-1}, respectively.

The specific energy and energy use efficiency of soybean production were 16.16 MJ kg^{-1} and 1.81, respectively. Canakci et al. (2005) reported specific energy for field crops and vegetable production in Turkey, as 5.24 for wheat, 11.24 for cotton, 3.88 for maize, 16.21 for sesame, 1.14 for tomato, 0.98 for melon, and 0.97 for water- melon.

Energy productivity value in this study was determined as 0.062 kg MJ^{-1} (Table 5). Calculation of energy productivity rate is well documented in the literatures such as stake-tomato (1.0) (Erdal et al., 2007b), cotton (0.06) (Yilmaz et al., 2005), and sugar beet (1.53) (Erdal et al., 2007a).

About 68.4% (20441.7 MJ) of the total energy inputs used in soybean production was direct and 31.6% (9453.79) was indirect (Table 6). Approximately, 93% of the total energy input was obtained from nonrenewable and 7% from renewable energy sources. So, it can be concluded that soybean production needs to improve the efficiency of energy consumption in production and to employ renewable energy.

Economic analysis of soybean production

The total expenditure (variable and fixed costs) for soybean production was calculated as 920 \$ ha^{-1} (Table7). The land rental cost is considered as one of the fixed expenditures index that was exerted. Gross income, net income, and benefit-cost ratio (B:C ratio) were calculated as 1239 \$ ha^{-1}, 319 \$ ha^{-1}m, and 1.35

Table 4. Amounts of inputs and outputs in soybean production.

Inputs and outputs	Quantity per unit area (ha)	Total energy equivalent (MJ ha^{-1})	Percentage of the total energy input (%)
Inputs			
1. Human labor (h)	138.5	271.46	0.9
2. Machinery (h)	67.7	4244.79	14.21
3. Diesel fuel (L)	358.2	20170.24	67.47
4. Chemical fertilizers (kg)	125	2833	9.5
(a) Nitrogen (N)	25	1653.5	5.5
(b) Phosphate (P_2O_5)	50	622	2.1
(c) Potassium (K_2O)	50	557.5	1.9
5. Chemicals (kg	4.5	540	1.81
6. Seeds (soybean) (kg)	60	1836	6.11
Total energy input (MJ)	-	29895.49	100
Outputs			
1. Grain (kg)	1850	34706	64.12
2. Straw (kg)	1850	19425	35.88
Total energy output (MJ)	-	54131	100

Table 5. Energy input–output ratio in soybean production.

Items	Unit	Value
Energy input	MJ ha^{-1}	29895.49
Energy output (grain and straw)	MJ ha^{-1}	54131
Grain yield	kg ha^{-1}	1850
Energy use efficiency	-	1.81
Specific energy	MJ kg^{-1}	16.16
Energy productivity	kg MJ^{-1}	0.062
Net energy	MJ ha^{-1}	24235.5

Table 6. Share percentage of direct, indirect, renewable, and nonrenewable energy sources for soybean production (MJ ha^{-1}).

Form of energy	Value (MJ ha^{-1})	Percentage[a]
Direct energy[b]	20441.7	68.4
Indirect energy[c]	9453.79	31.6
Renewable energy[d]	2107.46	7
Non-renewable energy[e]	27787	93
Total energy input	29895.49	100

[a]Indicates percentage of total energy input. [b]Includes human labor, diesel. [c]Includes seeds, fertilizers, chemicals, machinery. [d]Includes human labor, seeds. [e]Includes diesel, chemical, fertilizers, machinery.

respectively (Table 7). The results were compared and were consistent with the finding reported by other authors, such as 1.43 for wheat (Shahan et al., 2008), 0.86 for cotton (Yilmaz et al., 2005), 1.17 for sugar beet (Erdal et al., 2007a), 2.53 for sweet cherry (Demircan et al., 2006), 2.37 for orange, 1.89 for lemon, and 1.88 for mandarin (Ozkan et al., 2004b), 1.03 for stake-tomato Esengun et al., 2007).

Conclusion

The results show that the most important energy consumption part in soybean production for the studied area is diesel fuel (67.47%). If diesel fuel consumption is reduced, then non-renewable forms of energy consumption would decline. Application of combine vehicle for doing different agricultural operations at the same time

Table 7. Economic analysis of soybean.

Cost and return components	Value
Major product yield (kg ha^{-1})	1850
Byproduct yield (kg ha^{-1})	1850
Sale price of major product ($ ha^{-1})	1054
Sale price of byproduct ($ ha^{-1})	185
Total gross value of production ($ ha^{-1})	1239
Total cost of production ($ ha^{-1})	920
Net return ($ ha^{-1})	319
Benefit to cost ratio	1.35

and consequently reducing the hours of tractor activity is necessary to reduce the fuel consumption and reduce costs. Harvest procedure has a considerable share in soybean production cost. Cost of harvest is so high due to the absence of appropriate harvest combine vehicle. The amount of crop residue is high and is usually collected by the farm workers, which increases energy consumption and associate costs. Therefore, using of appropriate combine harvester can reduce costs and energy consumption in harvesting. Early sowing date and proper plant rotation (wheat-soybean) could be considered as another ways to reduce energy consumption attributed to reduced chemicals (pesticides and herbicides). Furthermore, integrated pest control techniques should be put in practice to improve pesticide use.

Indeed, all these management improvements would guarantee human health, maintaining sustainability and reduce environmental impacts, and also, lower production costs, and higher energy use efficiency, would be expected.

REFERENCES

Alam MR (2005). Computer simulation of input energy structure of Bangladesh agriculture. M. Sc Thesis. Dept. Electrical and Electronic, Chittagong University of Engineering and Technology, Chittagong p.6.

Alam MS, Alam MR, Islam KK (2005). Energy Flow in Agriculture: Bangladesh. Am. J. Environ. Sci. 1(3):213-220.

Anonymous, (2005). Annual Agricultural Statistics. Ministry of Jihad-e-Agriculture of Iran. <www.maj.ir>.

Bockari-Gevao SM, Wan Ishak WI, Azmi Y, Chan CW (2005). Analysis of energy consumption in lowland rice-based cropping system of Malaysia. Sci. Technol. 27(4):819-826.

Borlaug NE, Dowswell CR (1993). To nourish infertile soil that feed a fertile population that crowds a fragile world. Fertilizer News 38:11-20.

Canakci M, Topakci M, Akinci I, Ozmerzi A (2005). Energy use pattern of some field crops and vegetable production: case study for Antalya region, Turkey. Energy Convers. Manag. 46:655-666.

Demircan V, Ekinci K, Keener HM, Akbolat D, Ekinci C (2006). Energy and economic analysis of sweet cherry production in Turkey: A case study from Isparta province. Energy Convers. Manag. 47:1761-1769.

Erdal G, Esengun K, Erdal H, Gunduz O (2007a). Energy use and economical analysis of sugar beet production in Tokat province of Turkey. Energy 32:35-41.

Erdal G, Esengun K, Erdal H, Gunduz O (2007b).An economic analysis and energy use in stake-tomato production in Tokat province of Turkey. Renew. Energy 32: 1873-1881.

Esengun K, Gunduz O, Erdal G (2007). Input-output energy analysis in dry apricot production of Turkey. Energy Convers. Manag. 48:592-598.

FAO (2000). The energy and agricultural nexus. Environment and natural resources working paper no. 4, Rome.

FAO (2008). Homepage. Available in: (www.fao.org).

Franzluebbers AJ, Francis CA (1995). Energy output-input ratio of maize and sorghum management systems in Eastern Nebraska. Agric Ecosys. Environ. 53(3):271-278.

Jonge AM (2004). Eco-efficiency improvement of a crop protection product: the perspective of the crop protection industry. Crop Prot. 23:1177-1186.

Kallivroussis L, Natsis A, Papadakis G (2002). The Energy Balance of Sunflower Production for Biodiesel in Greece. Biosyst. Eng. 81(3):347-354.

Koocheki A, Hosseini M (1995). Energy efficiency in agroecosystems. Ferdowsi University of Mashad Press, Mashad, Iran (in Persian).

Mandal KG, Saha KP, Ghosh PK, Hati KM, Bandyopadhyay KK (2002). Bioenergy and economic analysis of soybean-based crop production systems in centralIndia. Biomass Bioenergy 23(5):337-345.

Okurut S, Odogola WR (1999). Farm power development in Uganda: Past, present and future trends. Proc. 99 Int. Conf. Agril. Engg. Beijing, China 1:232.

Ozkan B, Akcaoz H, Fert C (2004a). Energy input–output analysis in Turkish agriculture. Renew. Energy 29:39-51.

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

Rathke GW, Diepenbrock W (2006). Energy balance of winter oilseed rape (*Brassica napus* L.) cropping as related to nitrogen supply and preceding crop. Eur. J. Agron. 24:35-44.

Sartori L, Basso B, Bertocco M, Oliviero G (2005). Energy Use and EconomicEvaluation of a Three Year Crop Rotation for Conservation and Organic Farming in NE Italy. Biosyst. Eng. 91(2):245-256.

Shahan S, Jafari A, Mobli H, Rafiee S, Karimi M (2008). Energy use and economical analysis of wheat production in iran: A case study from Ardabil province. Agric. Technol. 4(1):77-88.

Singh G (1999). "Relationship between mechanization and productivity in various parts of India", A paper presented during the XXXIV Annual Convention, Indian Society of Agricultural Engineers, CCSHAU, Hisar, December pp.16-18.

Singh JM (2002a). On farm energy use pattern in different cropping systems in Haryana, India. Master of Science. Germany: International Institute of Management, University of Flensburg.

Singh RB (2002b). The state of food and agriculture in Asia and Pacific. First version published by IFA and FAO, Parries, France, April 2002. pp 1-21. www.agroindonesia.com/Publications/2002_Singh. pdf.

Triolo L, Unmole H, Mariani A, Tomarchio L (1987). Energy analyses of agriculture:the Italian case study and general situation in developing countries. In: Third international symposium on mechanization and energy in agriculture, Izmir, Turkey, October 26-29. pp.172-84.

Tsatsarelis CA (1991). Energy requirements for cotton production in central Greece. J. Agric. Eng. Res. 50:239-246.

Uhlin H (1998). Why energy productivity is increasing: an I–O analysis of Swedish agriculture. Agric. Syst. 56(4):443-465.

Yadav RN, Singh RKP, Prasad S (1991). An economic analysis of energy requirements in the production of potato crop in bihar sharif block of nalanda districh (Bihar). Econ Affair Kalkatta 36:112-119.

Yilmaz I, Akcaoz H, Ozkan B (2005). An analysis of energy use and input costs for cotton production in Turkey. Renew. Energy 30:145-155.