ELSEVIER

Energy Conversion and Management 45 (2004) 1821–1830

ENERGY CONVERSION & MANAGEMENT

www.elsevier.com/locate/enconman

Energy requirement and economic analysis of citrus production in Turkey

Burhan Ozkan *, Handan Akcaoz, Feyza Karadeniz

Faculty of Agriculture, Department of Agricultural Economics, University of Akdeniz, Antalya 07070, Turkey

Received 7 February 2003; received in revised form 18 July 2003; accepted 14 October 2003

Abstract

The aim of this research was to examine the energy requirements of the inputs and output in citrus production in the Antalya province of Turkey. Data for the production of citrus fruits (orange, lemon and mandarin) were collected from 105 citrus farms by using a face to face questionnaire method. The research results revealed that lemon production was the most energy intensive among the three fruits investigated. The energy input of chemical fertilizer (49.68%), mainly nitrogen, has the biggest share in the total energy inputs followed by Diesel (30.79%). The lemon production consumed a total of 62 977.87 MJ/ha followed by orange and mandarin with 60 949.69 and 48 838.17 MJ/ha, respectively. The energy ratios for orange, mandarin and lemon were estimated to be 1.25, 1.17 and 1.06, respectively. On average, the non-renewable form of energy input was 95.90% of the total energy input used in citrus production compared to only 3.74% for the renewable form. The benefit–cost ratio was the highest in orange production (2.37) followed by lemon. The results indicate that orange production in the research area is most remunerative to growers compared to lemon and mandarin.

Keywords: Energy requirement; Energy ratio; Citrus production; Economics; Turkey

1. Introduction

Agriculture is an important economic sector in Turkey despite its share having diminished over time. It accounted for 14% of gross national product in 2000. The contribution of agricultural commodities in total exports is 10.6%. About 45% of the total population of the country is engaged in agriculture, operating on four million farm holdings [1].

* Corresponding author. Tel.: +90-242-310-2475; fax: +90-242-227-4564.
E-mail address: bozkan@akdeniz.edu.tr (B. Ozkan).

0196-8904/$ - see front matter
doi:10.1016/j.enconman.2003.10.002

Nomenclature

n	required sample size
N	number of holdings in target population
Nh	number of population in the h stratification
Sh^2	variance of the h stratification
d	precision where $(x - X)$
z	reliability coefficient (1.96 which represents the 95% reliability)
D^2	d^2/z^2

Citrus production is very important for Turkey in terms of both domestic consumption and exports. The citrus fruits production ranks fourth place in the total fresh produce in Turkey. As of 2000, about 2 168 000 tonnes of citrus fruits were produced, and 20% of the total citrus was exported. The province of Antalya has a significant share in the total citrus production in Turkey. The production quantities of orange, lemon and mandarin in Antalya province were 266 824, 32 532 and 19 211 tonnes, respectively. In other words, Antalya realizes 31.3% of the orange production, 8.2% of the lemon production, 4% of the mandarin production in Turkey [2]. The share of the three citrus fruits in the total gross value of field crops was 6.5% [3].

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 [4]. Energy analysis can be divided into two parts as direct and indirect energy [5,6]. Direct energy is directly used at the farm and on fields for crops, but indirect energy is not directly consumed at the farm. However, both direct and indirect forms of energy are required for agricultural production in terms of its development and growth. On the other hand, despite its importance, energy use can be very costly. Energy input–output analysis is usually used to evaluate the efficiency and environmental impacts of production systems. Considerable researches have been conducted on energy use in agriculture [7–23]. However, the authors have not found a thorough publication analysing energy input and output in citrus production. Therefore, there was an immediate need to conduct such an analysis for future steps to be taken for any improvement in citrus production. On this basis, this study is aimed at preparing an energy audit for citrus production.

2. Materials and methods

In this study, citrus growers were surveyed in Kemer, Kumluca, Finike, Manavgat and Serik counties of Antalya province. Data were collected from the growers by using a face to face survey in the 2000 production year. In addition to the survey results, previous research studies and secondary sources were also used in the study.

Taking actual citrus orchard size as the variable, a total 105 citrus growers was randomly selected by using stratified random sampling [24]. The permissible error was defined to be 5% for 95% reliability.

Table 1
Energy equivalents of different input and output values used different farming system

Input	Energy equivalent (MJ/unit)	Reference
Human labour (h)	1.96	[21]
Machinery (h)	62.70	[21]
Chemical fertilizers (kg)		
Nitrogen	60.60	[21]
Phosphorus	11.10	[21]
Potassium	6.70	[21]
Farm yard manure (kg)	0.3	[21]
Chemicals (kg)		
Pesticides (general)	199	[25]
Fungicides	92	[25]
Herbicides	238	[25]
Diesel-oil (l)	56.31	[21]
Electricity (kWh)	11.93	[21]
Water for irrigation (m^3)	0.63	[14]
Output (kg)		
Orange	1.9	[19]
Lemon	1.9	[19]
Mandarin	1.9	[19]

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

Energy equivalents of the inputs used in the citrus production are illustrated in Table 1. The data on energy use have been taken from a number of sources, as indicated in the table. The sources of mechanical energy used on the selected farms included tractor and Diesel. The mechanical energy was computed on the basis of total fuel consumption (l ha^{-1}) in the different operations. The energy consumed was calculated using conversion factors (1 l Diesel = 56.31 MJ) and the same was expressed in MJ/ha.

The basic information on energy inputs and crop yields were entered into Excel spreadsheets. Based on the energy equivalents of the inputs and outputs, the metabolizable energy was calculated. The energy ratio was found by dividing the total energy equivalents of the inputs by the total energy equivalent of the yields for orange, lemon, mandarin. Evaluation of the questionnaire results has been performed, and the tables were prepared using the MS Excel software package and SPSS 10 package.

3. Results and discussion

The research results cover three main components; namely energy requirements of the citrus fruits along with the energy input–output relationships, energetics of producing citrus fruits and economic analysis of the citrus fruits. The results of this study are presented here under three major headings as follows.

3.1. Energy requirements and input–output relationships of citrus fruits

Generally, the 240 Massey Ferguson brand tractor was used for tillage and other land preparation operations. Tillage activities are performed mainly between March and October (Table 2). In the research, the most commonly used operations and equipments were taken as the base for the research sample. The first tillage in the research region starts in March and continues till September–October. Most citrus orchards in the region are irrigated by irrigation channel, but some citrus operators use pumps to bring water to their orchard.

Both chemical fertilizers and farm yard manure are used among the surveyed citrus growers. The research results showed that growers use fertilizer four times during the production period. It was observed that spraying for weeds was not high, but hoeing was a very common practice for weeds.

The inputs used in orange production and their energy equivalents, output energy equivalent and energy ratio are illustrated in Table 3. The results revealed that 824.2 h of man power and 12.56 h of machinery power per hectare are needed to produce oranges in the research area. The

Table 2
Management practices for the citrus fruits

Agronomic practices/ operations	Orange	Lemon	Mandarin
Common varieties	Washington, valencia, yafa and local varieties	Enterdonat, kıbıs limonu and karalimon	Satsuma, clemantine and rice
Number of trees (ha)	260–330	250–300	280–350
Land preparation tractor used: 240 MF 49 hp	Tilling is carried out between March and September using disc harrow, plough etc.	Tilling is carried out between March and September using disc harrow, plough etc.	Tilling is carried out between February and October using disc harrow, plough etc.
Average tilling number	3.03	3.34	3.17
Irrigation border period	March–October	April–June	April–June
Number of irrigation borders	3.82	3.79	2.72
Fertilization period	January–June	February–April	March–June
Average number of fertilization	3.74	3.86	3.03
Spraying period	January–August	February–June	February–November
Average number of spraying	4.23	4.29	3.66
Hoeing period	February–July	March–June	March–June
Average number of hoeing	1.68	1.53	1.84
Irrigation period	March–June	March–October	April–August
Average number of irrigation	1.06	1.06	1.00
Liming period of trees	April–June	January–June	April–June
Average number of liming	1.00	1.00	1.00
Harvesting period	Starts with washington variety and finishes in June–July with valencia	Starts in October	Starts in September

Table 3
Energy consumption and energy input–output relationship for orange production

Input	Quantity per unit area (ha)	Energy equivalent (MJ/unit)	Total energy equivalent (MJ)	Percentage of total energy input (%)
Human labour (h)	824.20	1.96	1615.43	2.65
Land preparation	37.00	1.96	72.52	0.12
Cultural practices	465.80	1.96	912.97	1.50
Harvesting	321.40	1.96	629.94	1.03
Machinery (h)	12.56	62.70	787.51	1.29
Land preparation	2.67	62.70	167.41	0.27
Cultural practices	4.04	62.70	253.31	0.42
Transportation	5.85	62.70	366.80	0.60
Chemical fertilizer (kg)	693.20		27 073.00	44.42
Nitrogen	406.80	60.60	24 652.08	40.45
Phosphorus	114.10	11.10	1266.51	2.08
Potassium	172.30	6.70	1154.41	1.89
Farm yard manure (kg)	2533.20	0.30	759.96	1.25
Chemicals (kg)	12.30		1321.30	2.17
Pesticides (general)	1.50	199.00	298.50	0.49
Fungicides	10.60	92.00	975.20	1.60
Herbicides	0.20	238.00	47.60	0.08
Diesel-oil (l)	337.50	56.31	19 004.63	31.18
Electricity (kWh)	852.70	11.93	10 172.71	16.69
Water for irrigation (m^3)	341.50	0.63	215.15	0.35
Total energy input (MJ)			60 949.69	100.00
Yield (kg)	40 000.00	1.90	76 000.00	
Energy output–input ratio			1.25	

cultural practices account for about 56.52% of the total man power, followed by harvesting (38.99%) and land preparation (4.49%). Transportation has the biggest proportional share (46.58%) of the total machinery power used in orange production.

Chemical fertilization usage in the investigated orchards was found to be 693.2 kg/ha. The shares of nitrogen, potassium and phosphorus in the total chemical fertilizer were 58.68%, 24.86% and 16.46%, respectively.

The total energy used in the various farm operations for producing orange fruits was 60 949.69 MJ/ha. Out of all the farm operations in producing oranges, chemical fertilization consumed the most, energy (44.42%), followed by Diesel (31.18%). Nitrogen has the biggest share (40.45%) in the total energy input. The Diesel energy was mainly utilized for operating tractors for performing the various farm operations. As can be seen from the table, the irrigation, machinery, farm yard manure, spraying and man power operations consumed, respectively, 0.35%, 1.29%, 1.25%, 2.17% and 2.65%. It is clear that the mean yield of these inputs remained at low levels compared to the fertilizer applications and Diesel consumption. The mean yield of oranges was 40 tonnes with a weighted mean energy ratio of 1.25 (Table 3).

The input–output relationship and their energy equivalents of the lemon fruits are presented in Table 4. The research results indicate that about 789.10 kg chemical fertilizers and 14.30 kg of chemicals per hectare were used among the surveyed lemon growers. Out of the total chemical fertilizers, nitrogen takes the biggest share (45.43%) in the total energy consumption followed by

Table 4
Energy consumption and energy input–output relationship for lemon production

Input	Quantity per unit area (ha)	Energy equivalent (MJ/unit)	Total energy equivalent (MJ)	Percentage of total energy input (%)
Human labour (h)	702.10	1.96	1376.12	2.19
Land preparation	45.50	1.96	89.18	0.14
Cultural practices	396.60	1.96	777.34	1.23
Harvesting	260.00	1.96	509.60	0.81
Machinery (h)	8.64	62.70	541.73	0.86
Land preparation	3.15	62.70	197.51	0.31
Cultural practices	4.00	62.70	250.80	0.40
Transportation	1.49	62.70	93.42	0.15
Chemical fertilizer (kg)	789.10		31 290.97	49.68
Nitrogen	473.20	60.60	28 675.92	45.53
Phosphorus	113.30	11.10	1257.63	2.00
Potassium	202.60	6.70	1357.42	2.16
Farm yard manure (kg)	3312.10	0.30	993.63	1.58
Chemicals (kg)	14.30		1719.30	2.73
Pesticides (general)	3.50	199.00	696.50	1.11
Fungicides	10.60	92.00	975.20	1.55
Herbicides	0.20	238.00	47.60	0.08
Diesel-oil (l)	344.40	56.31	19 393.16	30.79
Electricity (kWh)	624.90	11.93	7455.06	11.84
Water for irrigation (m^3)	330.00	0.63	207.90	0.33
Total energy input (MJ)			62 977.87	100.00
Yield (kg)	35 000.00	1.90	66 500.00	
Energy output–input ratio			1.06	

potassium (2.16%) and phosphorus (2.00%). The usage of farm yard manure was 3312.1 kg/ha. The research revealed that 702.10 h of man power were used in lemon production. The majority of the man power is devoted to cultural practices (56.49%) followed by harvesting (37.03%) and land preparation (6.48%).

The total energy used in the various farm operations for lemon production was 62 977.87 MJ/ha. The chemical fertilizers were the highest in the total energy consumption with the value of 31 290.97 MJ/ha followed by Diesel (19 393.16 MJ/ha) and electricity (7455.06 MJ/ha). In other words, the share of chemical fertilizers, Diesel and electricity inputs in the total energy consumption for lemon production were 49.68%, 30.79% and 11.84%, respectively. The contributions of irrigation, machinery, farm yard manure, spraying and man power operations inputs remained at relatively low levels. The mean yield of lemons per hectare was 35 tonnes with the weighted mean energy ratio of 1.06 (Table 4).

The energy consumption of mandarin production in the surveyed farm holdings is illustrated in Table 5. The man power use in mandarin production was estimated to be 553.3 h per hectare. The cultural practices take the biggest share (61.96%) in the total man power use among the surveyed farms, followed by harvesting (30.72%) and land preparation (7.32%). About 12.65 h of machinery power per hectare were needed to produce mandarin fruits, and the cultural practices have the highest share (37.15%) in the machinery power usage.

Table 5
Energy consumption and energy input–output relationship for mandarin production

Input	Quantity per unit area (ha)	Energy equivalent (MJ/unit)	Total energy equivalent (MJ)	Percentage of total energy input (%)
Human labour (h)	553.30	1.96	1084.47	2.22
Land preparation	40.50	1.96	79.38	0.16
Cultural practices	342.80	1.96	671.89	1.38
Harvesting	170.00	1.96	333.20	0.68
Machinery (h)	12.65	62.70	793.16	1.62
Land preparation	3.45	62.70	216.32	0.44
Cultural practices	4.70	62.70	294.69	0.60
Transportation	4.50	62.70	282.15	0.58
Chemical fertilizer (kg)	559.50		22 364.50	45.79
Nitrogen	338.70	60.60	20 525.22	42.03
Phosphorus	81.80	11.10	907.98	1.86
Potassium	139.00	6.70	931.30	1.91
Farm yard manure (kg)	2129.10	0.30	638.73	1.31
Chemicals (kg)	19.10		2003.30	4.10
Pesticides (general)	2.30	199.00	457.70	0.94
Fungicides	16.80	92.00	1545.60	3.16
Herbicides	0.00	238.00	0.00	0.00
Diesel-oil (l)	254.70	56.31	14 342.16	29.37
Electricity (kWh)	622.20	11.93	7422.85	15.20
Water for irrigation (m^3)	300.00	0.63	189.00	0.39
Total energy input (MJ)			48 838.17	100.00
Yield (kg)	30 000.00	1.90	57 000.00	
Energy output–input ratio			1.17	

Total chemical fertilizer use in mandarin production was 559.50 kg/ha. The share of nitrogen was 60.54% in the total fertilizer use, followed by potassium (24.84%) and phosphorus (14.62%), respectively. The chemicals use was found to be 19.10 kg/ha in the surveyed farms. The research results indicate that the average mandarin yield for the examined farm holdings was 30.0 tonnes/ha.

Total energy consumption of mandarin production for the examined farm holdings was 48 838.17 MJ/ha. Of this total, the chemical fertilizer has a significant share with (45.79%), and almost half of the total energy consumption stems from nitrogen (42.03%). The use of Diesel input was the second highest one with 29.37%.

The share of spraying use in mandarin production was found as 4.10% of the total input energy. Mandarin yield was 30.0 tonnes/ha, and the energy value of this output was 57 000 MJ/ha. The output–input ratio for mandarin production was determined as 1.17 (Table 5).

3.2. Energetics of producing citrus fruits

The total mean energy input as direct and indirect, renewable and non-renewable, forms is illustrated in Table 6. As can be seen, the maximum energy is required in lemon production followed by orange. However, the maximum direct energy is used in orange production. The share of indirect energy input is higher in lemon and mandarin production compared to orange

Table 6
Total energy input in the form of direct, and direct renewable and non-renewable for citrus fruits

Citrus fruits	Total energy input MJ/ha	Energy forms (MJ/ha)			
		Direct energy[a]	Indirect energy[b]	Renewable energy[c]	Non-renewable energy[d]
Orange	60 949.69	30 792.77 (50.52)[e]	29 941.77 (49.13)	2375.39 (3.90)	58 359.15 (95.75)
Lemon	62 977.87	28 224.34 (44.82)	34 545.63 (54.85)	2369.75 (3.76)	60 400.22 (95.91)
Mandarin	48 838.17	22 849.48 (46.79)	25 799.69 (52.83)	1723.20 (3.53)	46 925.91 (96.08)
Mean value	57 588.57	27 288.86 (47.39)	30 095.70 (52.26)	2156.11 (3.74)	55 228.43 (95.90)

[a] Includes: human, animal, diesel, electricity.
[b] Includes: seeds, fertilizers, manure, chemicals, machinery.
[c] Includes: human, animal, seeds, manure.
[d] Includes: diesel, electricity, chemical, fertilizers, machinery.
[e] Figures in parentheses indicate percentage of total energy input.

production. On average, the share of direct energy in citrus production was 47.39% while indirect energy was 52.26%. Direct inputs are mainly oil based fuels for field operations, and the indirect inputs are dominated by fertilizer use. In other words, citrus production is highly dependent on both as fuel and in the production of indirect inputs. It can be pointed out that fertilizer management, particularly in the use of nitrogen, to reduce the indirect energy requirements for fertilizer manufacture and tractor selection and operation to reduce the direct use of Diesel seem to be the most significant areas for improving overall energy efficiency of the Turkish citrus fruit industry.

The results indicate that the current energy use pattern among the investigated farms is based on non-renewable energy in the citrus production. In other words, the proportion of renewable energy use in the surveyed farms is very low. As can be seen from the table, on average, the non-renewable form of energy input was 95.90% of the total energy input compared to only 3.74% for the renewable form. This indicates that citrus production depends mainly on fossil fuels in the research area. Therefore, it implies that Turkish citrus production is very sensitive to possible changes in the price of fossil fuels and their supply availability.

3.3. Net return and benefit–cost ratio of the citrus fruits

The cost and return of the citrus fruits are given in Table 7. The results showed that the highest cost of production per hectare was in oranges, being TL 4223.9 million, followed by lemon at TL 3700.5 million and mandarin at TL 3459.5 million (1 US$ = TL 1 700 000 in December 2002). The net return of fruits was calculated by subtracting the production costs from the gross value of the product. As can be seen from the table, the highest net return (TL 5776 million) was obtained from orange production followed by lemon. In the research, the benefit–cost ratios (B–C) of the citrus fruits grown was calculated by dividing the gross value of product by the total cost to

Table 7
Economic analysis of citrus fruits

Fruits	Cost of production (million TL/ha)	Gross value of production (million TL/ha)	Net return (million TL/ha)	Benefit/cost ratio
Orange	4223.9	10 000.0	5776.1	2.37
Lemon	3700.5	7000.0	3299.5	1.89
Mandarin	3459.5	6500.0	3040.5	1.88

(1 US$ = TL 1 700 000 in December 2002).

determine economic efficiency. The B–C ratio revealed that the highest B–C ratio was in orange (2.37) production, followed by lemon (1.89).

4. Conclusions

In this research, the energy requirements of inputs and outputs for citrus production were examined in the Antalya province of Turkey. Data for the production of citrus fruits (orange, lemon and mandarin) were collected from 105 citrus farms by a face to face questionnaire technique. The research results revealed that lemon production was the most energy intensive among the three fruits investigated. The energy input of chemical fertilizer (49.68%), mainly nitrogen, has the biggest share in the total energy inputs followed by Diesel (30.79%). The lemon production consumed a total of 62 977.87 MJ/ha followed by orange and mandarin with 60 949.69 and 48 838.17 MJ/ha, respectively. The results indicate that the level of fertilizer input, particularly nitrogen, was one of the most significant determinants of total energy input to citrus farms. Diesel input was the second most important one in the citrus production. The energy ratios for orange, mandarin and lemon were estimated to be 1.25, 1.17 and 1.06, respectively. The benefit–cost ratio was the highest in orange production (2.37) followed by lemon (1.89). It can be concluded that orange production in the research area is most remunerative to the growers compared to the lemon and mandarin fruits due its higher energy use efficiency and benefit–cost ratio.

On average, the non-renewable form of energy input was 95.90% of the total energy input used in the citrus production compared to only 3.74% for the renewable form. It is clear that the use of renewable energy in Turkish citrus production is very low, indicating citrus production depends mainly on fossil fuels. Furthermore, it implies that Turkish citrus production is very sensitive to possible changes in prices and supply availability of fossil fuels. On the other hand, the consumption of fossil energy results in direct negative environmental effects through release of CO_2 and other combustion gases.

Acknowledgement

This paper was supported by the Scientific Research Projects Administration Unit of Akdeniz University.

References

[1] Ozkan B, Akcaoz H, Fert C. Energy input output analysis in Turkish agriculture. Renewable Energy 2004;29(1):39–51.
[2] SIS. Agricultural structure and production. Ankara: SIS Publications; 1998 (in Turkish).
[3] Anonymous. Working report for 2000, Ministry of Agriculture and Rural Affairs of Turkey, Provincial Directorate of Antalya, Antalya (in Turkish), 2000.
[4] Pervanchon F, Bockstaller C, Girardin P. Assessment of energy use in arable farming systems by means of an agro-ecological indicator: the energy indicator. Agric Syst 2002;72:149–72.
[5] Risoud B. Dévelopment durable et analyse energétique d'exploitations agricoles. Econ Rur 1999;252:16–27.
[6] Uhlin H. Why energy productivity is increasing: an I–O analysis of Swedish agriculture. Agric Syst 1998;56(4):443–65.
[7] Ram RA, Raghuvanshi NK, Arya, SV. Study on energy cost requirements for wheat cultivation, Paper No: 80–105, Presented at ISAE. XVII Annual Convention, New Delhi, February 6–8, 1980.
[8] Pimentel D, Berardi G, Fast S. Energy efficiency of farming systems: organic and conventional agriculture. Agric, Ecosys Environ 1983;9:359–72.
[9] Pathak B, Binning AS. Energy use pattern and potential for energy saving in rice–wheat cultivation. Agric Energy 1985;4:271–8.
[10] Yadav RN, Singh RKP, Prasad S. An economic analysis of energy requirements in the production of potato crop in Bihar Sharif Block of Nalanda Districh (Bihar). Econ Affair, Kalkatta 1991;36:112–9.
[11] Singh S, Singh G. Energy input crop yield relationship for four major crops of Northern India. Agric Mech Asia, Africa Latin America 1992;23(2):57–61.
[12] Pimentel D. Economics and energetics of organic and conventional farming. J Agric Environ Ethics 1993;6(1):53–9.
[13] Thakur CL, Mishra BL. Energy requirements and energy gaps for production of major crops in Madhya Pradesh. Agric Situation India 1993;48:665–89.
[14] Yaldiz O, Ozturk HH, Zeren Y, Bascetincelik A. Energy use in field crops of Turkey, V International Congress of Agricultural Machinery and Energy, 12–14 October 1993, Kusadası (in Turkish).
[15] Shapouri H, Duffield JA, Graboski MS. Estimating the net energy balance of corn ethanol, US Department of Agriculture, Economic Research Service, Office of Energy. Agricultural Economic Report No: 721, 1995.
[16] Baruah DC, Bhattacharya PC. Utilization pattern of human and fuel energy in tea plantation. J Agric Soil Sci 1995;8(2):189–92.
[17] Franzluebbers AJ, Francis CA. Energy output–input ratio of maize and sorghum management systems in Eastern Nebraska. Agric, Ecosys Environ 1995;53(3):271–8.
[18] Singh S, Verma SR, Mittal JP. Energy requirements for production of major crops in India. Agric Mech Asia, Africa Latin America 1997;28(4):13–7.
[19] Chandra H, Dipanker D, Singh RS. Spatial variation in energy use pattern for paddy cultivation in India, Proc. of National Workshop on Energy and Environment Management for Sustainable Development of Agriculture and Agro Industrial Sector (July 8–9, 2001), pp. 48–51.
[20] Singh JM. On farm energy use pattern in different cropping systems in Haryana, India, Master of Science, International Institute of Management University of Flensburg, Germany, 2002.
[21] Singh H, Mishra D, Nahar NM. Energy use pattern in production agriculture of a typical village in Arid Zone India—Part I. Energy Convers Manage 2002.
[22] Mandal KG, Saha KP, Ghosh PK, Hati KM, Bandyopadhyay KK. Bioenergy and economic analysis of soybean-based crop production systems in central India. Biomass Bioenergy 2002;23(5):337–45.
[23] Gezer I, Acaroglu M, Haciseferogullari H. Use of energy and labour in apricot agriculture in Turkey. Biomass Bioenergy 2003;24(3):215–9.
[24] Yamane T. Elementary sampling theory. Englewood Cliffs, NJ, USA: Prentice Inc.; 1967.
[25] Helsel ZR. Energy and alternatives for fertiliser and pesticide use. In: Fluck RC, editor. Energy in world agriculture, 6. Elsevier Science Publishing; 1992. p. 177–210.