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Energy input–output analysis in Turkish agriculture

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Abstract

The objective of this study is to determine the energy use in the Turkish agricultural sector for the period of 1975–2000. In the study, the inputs in the calculation of energy use in agriculture include both human and animal labor, machinery, electricity, diesel oil, fertilizers, seeds, and 36 agricultural commodities were included in the output total. Energy values were calculated by multiplying the amounts of inputs and outputs by their energy equivalents with the use of related conversion factors. The output–input ratio is determined by dividing the output value by the input value. The results indicated that total energy input increased from 17.4 GJ/ha in 1975 to 47.4 GJ/ha in the year 2000. Similarly, total output energy rose from 38.8 to 55.8 GJ/ha in the same period. As a consequence, the output–input ratio was estimated to be 2.23 in 1975 and 1.18 in 2000. This result shows that there was a decrease in the output–input energy ratio. It indicates that the use of inputs in Turkish agricultural production was not accompanied by the same result in the final product. This can lead to problems associated with these inputs, such as global warming, nutrient loading and pesticide pollution. Therefore, there is a need to pursue a new policy to force producers to undertake energy efficient practices to establish sustainable production systems.
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Nomenclature

ME	machine energy (MJ/ha)
G	weight of tractor (kg)
E	constant that is taken to be 158.3 Mj/kg for tractor
T	economic life of tractor (h)
C_a	effective field capacity (ha/h)
W	working width (m)
S	working speed (km/h)
E_f	field efficiency

1. Introduction

Energy in agriculture is important in terms of crop production and agroprocessing for value adding. Human, animal and mechanical energy is extensively used for crop production in agriculture. Energy requirements in agriculture are divided into two groups being direct and indirect. Direct energy is required to perform various tasks related to crop production processes such as land preparation, irrigation, interculture, threshing, harvesting and transportation of agricultural inputs and farm produce [1]. It is seen that direct energy is directly used at farms and on fields. Indirect energy, on the other hand, consists of the energy used in the manufacture, packaging and transport of fertilizers, pesticides and farm machinery [2,3]. As the name implies, indirect energy is not directly used on the farm. Major items for indirect energy are fertilizers, seeds, machinery production and pesticides. Calculating energy input in agricultural production is more difficult in comparison to the industry sector due to the high number of factors affecting agricultural production [4]. However, considerable studies have been conducted in different countries on energy use in agriculture [3,5–11].

Energy use in the agricultural sector depends on the size of the population engaged in agriculture, the amount of arable land and the level of mechanization. The agricultural sector is vital in the Turkish economy. It is still Turkey's largest employment provider and a significant contributing sector to GDP, imports and exports. The share of agriculture in 2000 in GDP at current prices was 14.1%. The contribution of agricultural commodities in total exports was 10.6% and more than 40% of the total population was engaged in agriculture. However, the importance of agriculture has declined in relation to the rapid increase observed in the industry and service sectors [12,13].

The number of farms is increasing in Turkey in contrary to developed countries. The number of farms was 3.1 million in 1963 and it reached 4.1 million in 1991. The number of plots is rather high and as a result of this the average plot size is very small (1.09 ha). About 92.57% of the farms are family owned. Although the average farm size was 7.73 ha in 1950, it decreased to 5.69 ha in 1991. Crop and livestock production are carried out together in the majority of farm households (72.7%). The share of crops value in the total agricultural production value is 66.0% [14]. As of 1997, the total agricultural land was 28 million ha in Turkey of which 69.3% was for the area sown, 18.3% for the fallow area, 2.9% for the vegetable area, 5.1% for the fruit area, 2.4% for olives and 2.0% for the orchard area [15]. In 1975, the total production area for the major crops examined in the study was 18.5 million ha and it reached to 20.5 million ha in 2000 with an increase of 1.1%.

Cereals are of great importance in Turkish agriculture. In 2001, cereal production was nearly 30 million tones. Wheat takes the most important place in cereals with a share of 64.5%, barley ranks second with 25.5% and is followed by maize with a share of 7.5%. The remaining 2.5% consists of the production of other crops. Turkey is also one of the most important fresh fruit and vegetable producing countries with 41 million tonnes. Turkish fresh fruit production in the year 2000 was around 11 million tones. Turkey’s share in the world fresh fruit production is 2.5%. Total vegetable production in the world is nearly 628 million tones of which 5% is provided by Turkey [13].

As a result of development, Turkey’s energy consumption has increased in recent years; therefore, the problem associated with energy use in Turkish agriculture has grown. If the increase in the energy use in the agricultural industry continues, the only chance of producers to increase total output will be using more input as there is no chance to expand the size of arable lands. Under these circumstances, an input–output analysis provides planners and policy-makers an opportunity to evaluate economic interactions of energy use.

The aim of this study is to provide a descriptive analysis of energy use in Turkish agriculture in the period 1975–2000. This analysis is important to perform necessary improvements that will lead to a more efficient and environment-friendly production system. It is expected from the study to fill a gap in determining a production system that involves the sustainable use of energy in Turkish agriculture.

2. Data and method

The energy ratio between output and input in Turkish agricultural production is calculated for the period 1975–2000. In the calculation of the energy ratio both human and animal labor, machinery, electricity, diesel oil, seed and fertilizer amounts and yield values of 36 crops have been used. In the study, energy equivalents of inputs and outputs were used to estimate the energy ratio. Energy equivalents of inputs and outputs are given in Appendix 1. The data were converted into suitable energy units and expressed in GJ/ha. The data used in the study were collected from various statistical resources such as the Statistical Yearbook of Turkey published by the State Institute of Statistics (SIS) under the Prime Ministry of the Republic of Turkey [15–21] and the Special Privatization Commission Reports by the State Planning Organization under the Prime Ministry [22]. The study has also benefited from previous researches and studies conducted on energy analysis in agriculture.

Energy ratio of input–output is determined by calculating energy equivalents of yields gained from major crops produced and that consumed inputs in production. In the study, 36 crops were taken into account to estimate output energy values. These crops are wheat, rye, barley, oat, maize, rice, dry beans, lentils, chickpeas, sugar beet, tobacco, cotton, sunflower, seed cotton, pears, apples, figs, apricots, cherries, peaches, grapes, oranges, tangerines, grapefruits, lemons, nuts, tomatoes, cucumbers, peppers, eggplants, carrots, water melon/melons, onions, potatoes, olive and tea. The inputs used in the calculation of agricultural energy use include both human and animal labor, machinery, electricity, diesel oil, fertilizers and seeds.

In order to make an energy analysis it is necessary to consider the use of human and animal power in agricultural processes [15–18,21]. The economically active agricultural population is considered to be above 12 years old in the examined years except the year 2000 in which the economically active agricultural population is considered to be above 15 years old by SIS. For the estimation of gross energy input for agriculture, working days of agricultural workers are taken as 210 days assuming an average of 8 h of work a day, and the number of working hours of animals in agricultural production are taken as 360 h annually [15,23].

To calculate the energy used in agricultural production or repair of machinery, the following formula was used [4].

$$ME = (G \times \mathrm{E})/(T \times C_a) \quad (1)$$

where ME, machine energy (MJ/ha); G, weight of tractor (kg); E, constant that is taken 158.3 MJ/kg for tractor; T, economic life of tractor (h); C_a, effective field capacity (ha/h).

For calculation of C_a, the following equation was used.

$$C_a = (S \times W \times E_f)/10 \quad (2)$$

where C_a, effective field capacity (ha/h); W, working width (m); S, working speed (km/h); E_f, field efficiency.

In the calculation of tractor manufacturing and repair costs, a single-wheeled 40 kW-power tractor with 60–70 hp of an average weight of 2500 kg was taken as default [24]. Data on electricity use in agriculture were collected from the statistical yearbook of SIS [15–18,21]. These data were given in terms of energy used in agriculture, and did not separate the energy used for personal purposes from that used for commercial purposes.

Since there are no data available for diesel consumption for machinery used in agriculture, the total diesel energy input was calculated from the diesel consumption of tractors used during the examined period. Therefore, in the calculation it was assumed that a 40 kW tractor consumes 4.8 l diesel per h with a 40% loading capacity [25] and that its average use on the field is 720 h [26].

There are no data available for the application of pesticides. In the calculation of chemical energy input information on individual fertilizer materials used was not available; therefore, amounts of three main kinds of fertilizers (nitrogen, phosphate and potash) were used in the estimation [15–18,21]. Since the largest energy input is in the form of nitrogen fertilizer, total energy input calculated by summating the energy amounts of individual fertilizers was converted to N equivalent.

In order to be able to make the analysis, it is essential to consider biochemical energy sources, i.e. the amount of energy stored in the seed. Energy equivalents for selected crop seeds were taken to be equal to the energy equivalent of the product itself. Energy output from selected seeds of agricultural commodities was calculated by multiplying the production amount by its corresponding equivalent. In the study, wheat, barley, oats, rye, maize, rice, dry beans, lentils and chickpeas, potatoes and sunflowers were considered in the calculation of biochemical energy.

Energy output arises mainly from the product itself and from the byproducts. Energy output from main products is calculated by multiplying production and their corresponding energy equivalent [23]. In calculation of byproduct husk of the commodity is taken as 30% of the grain and straw equal to the weight of grain. Cob corn is calculated for maize as 0.8 times of maize grain equivalent. Energy output from selected byproducts of agricultural commodities was calculated by multiplying the byproduct amount by its corresponding equivalent. In the study wheat, barley, maize, rice and seed cotton were considered in the calculation of byproduct energy.

3. Results and discussion

In the study output–input energy ratios were calculated by using energy consumptions of labor, machinery, electricity, diesel oil, fertilizer, seeds used in agricultural production and of examined crops and their byproducts.

The main physical power sources of Turkish agriculture were examined and results are presented in Table 1. Inputs such as human labor, animal power, and machinery used in agriculture were expressed as physical power sources. The results indicated that a decrease was observed in the agricultural labor for the period under study. As can be seen in Table 1, the active agricultural population decreased from 11.7 million in 1975 to 7.1 million in 2000. Similarly the total human power in agriculture decreased from 10.5 million hp in 1975 to 6.4 million hp in 2000. This result indicates that a decrease of about 39% occurred in the active population and total human labor.

With the increase of technology in agriculture, the use of animal power in this industry decreased year by year. The reason for the fall in the number of animals used in agricultural production can be attributed to the increase observed in the level of mechanization. In the period under study, the average animal power dropped from 38.1 to 23.2 million hp. The highest value in total human power was 11.3 million hp in 1990, and the highest value for animal power was 41.6 million hp in 1980. As a result, the decrease in total animal power was nearly 39% in the last 25 years.

In the calculation of energy consumption of machinery in agriculture only tractors were considered. The number of tractors rose from 243 000 in 1975 to 942 000 in the year 2000 growing at a four-fold rate. In the study period, the average power calculated for tractors increased from 38.5 to 58.7 hp. Total physical power calculated for agricultural labor, animal power and machinery is given in Table 1. As can be seen, total physical power rose from 58 million hp in 1975 to 84.9 million hp in the year 2000. It shows that the horse power of tractors increased 1.5-fold during

Table 1
Availability of physical power sources in Turkish agriculture

Years	Agricultural labor		Animal									Mechanical			
	No (million)	Av. pow. (hp)	Total human av. pow. (million hp)	Horse (million)	Av. pow. (hp)	Mule and donkey (million)	Av. pow. (hp)	Cattle (million)	Av. pow. (hp)	W. buf. (million)	Av. pow. (hp)	Total animal av. pow. (million hp)	Tractor (thousand)	Av. pow. (hp)	Total physical power av. (million hp)
1975	11.7	0.9	10.5	0.9	3.8	1.8	1.5	13.8	1.9	1.1	5.7	38.1	243 066	38.5	58.0
1980	11.1	0.9	10.0	0.8	3.8	1.6	1.5	15.9	1.9	1.0	5.7	41.6	436 369	49.4	73.1
1985	12.1	0.9	10.9	0.6	3.8	1.4	1.5	12.5	1.9	0.6	5.7	31.2	583 974	51.3	72.1
1990	12.5	0.9	11.3	0.5	3.8	1.2	1.5	11.4	1.9	0.4	5.7	27.5	692 454	54.1	76.2
1995	8.6	0.9	7.7	0.4	3.8	0.9	1.5	11.8	1.9	0.3	5.7	26.8	776 863	57.4	79.1
2000	7.1	0.9	6.4	0.3	3.8	0.6	1.5	10.8	1.9	0.1	5.7	23.2	941 835	58.7	84.9

Table 2
Estimated physical energy input in Turkish agriculture

Years	Human avg. annual work (10^{15} J)	Animal avg. annual work (10^{15} J)	Tractor man. and repair energy	Electricity (10^{15} J)	Petroleum (10^{15} J)	Total physical energy input (10^{15}J)
1975	45.2	34.0	1.41	3.2	47.3	131.1
1980	42.9	36.9	1.48	7.8	84.9	174.0
1985	46.8	28.6	1.55	13.4	113.6	204.0
1990	48.3	25.4	1.64	24.7	134.8	234.8
1995	33.2	25.0	1.57	65.0	151.2	276.0
2000	27.4	21.9	1.56	104.0	183.3	338.2

the last 25 years. This increase can be attributed to increase in the number of tractors and the development in horse power of tractors.

Input values of physical energy in agriculture are illustrated in Table 2. Total physical energy input consists of human labor, animal power, machinery power, electricity and diesel oil consumptions. It was observed that there was a decrease in the energy input value for human labor and animal power, while there was an increase for machinery power, electricity and diesel oil in the study period. The input value of physical energy was estimated to be 131.1×10^{15}J in 1975 and it reached 338.2×10^{15} J in 2000. This shows that physical input value used in the agricultural industry increased by 158% in the last 25 years. At the beginning of the examined period the shares of human and animal power, tractor manufacture and repair energy, electricity and diesel oil energy in total power were 34.5, 25.9, 1.1, 2.4 and 36.1%, respectively. Due to a reduction in the shares of human and animal power, the tractor manufacture and repair energy in the total energy in 2000 took shares of 8.1, 6.5 and 0.5%, respectively. However, there was an increase in electricity and diesel oil consumption with shares of 30.8 and 54.2%.

In the calculation of fertilizer energy input in agricultural production, N, P_2O_5 and K_2O were taken into account and estimated values were summarized in Table 3. As

Table 3
Fertilizer energy input in Turkish agriculture

Years	N (000 tons)	Energy from N	P_2O_5 (000 tons)	Energy from P_2O_5	K_2O (000 tons)	Energy from K_2O	Total energy input (10^{12} J)	N equivalent (10^6 kg)
1975	1750.2	112 712.0	1909.8	22 841.3	31.6	211.9	135 765.1	2108.2
1980	3038.6	195 683.6	2839.9	33 965.7	89.0	596.2	230 245.5	3575.2
1985	4383.7	282 307.6	2800.1	33 488.9	67.8	454.3	316 250.7	4910.7
1990	5711.6	367 827.4	3671.1	43 906.0	126.8	849.6	412 583.0	6406.6
1995	5016.6	323 069.0	3405.4	40 728.6	134.2	899.1	364 696.8	5663.0
2000	6563.3	422 676.5	3697.4	44 220.9	164.2	1100.1	467 997.6	7267.0

can be seen from the table, there was a 3.75-fold increase in terms of fertilizer energy input for N, 1.94-fold for P_2O_5, and 5.19-fold for K_2O. Total fertilizer energy input in agricultural production was calculated as 135 765.1 $\times 10^{12}$ J in 1975 and it reached 467 997.6 $\times 10^{12}$ J in 2000. If total fertilizer energy input value was expressed in terms of N equivalent, it would equal 7262.0 $\times 10^6$ kg in 2000.

Seed use amounts, seed energy values and energy equivalent value sourced from seed use were also examined in the period 1975–2000 (Table 4). The energy equivalent value for seed use was 56 026.8 $\times 10^{12}$ J in 1975 and it increased to 165 778.5 $\times 10^{12}$ J in 2000. In 1975, cereal and pulses have the highest ratio in the total amount of seeds with 69.7%, followed by 22.5% for oil seeds and 7.8% for tubers. In 2000, cereal and pulses, oil seeds, and tubers constitute the total amount of seed consumed with shares of 83.6, 12.3 and 4.1%, respectively. This result showed that there was an increase regarding seed use for the examined crops. This increase in the use of seed indicates an increase in the energy equivalent values. Total input energy increased by approximately 172.4% from 1975 to 2000 (17.4 GJ/ha in 1975 as compared to 47.4 GJ/ha in 2000). Physical power, fertilizer and seed sources of input energy have a linear increase, although increase determined input costs during 1975–2000 period. Physical energy, fertilizer and seed consumption increased over the study period.

Production values of selected crops and their energy equivalents are given in the Table 5. Total grain equivalent of selected crops are as 33 215 $\times 10^3$ tons for cereal and pulses, 6439.3 $\times 10^3$ tons for sugar beet, 11.4 $\times 10^3$ tons for tobacco, 706.4 $\times 10^3$ tons for cotton, 3563 $\times 10^3$ tons for oil seed, 1554.6 $\times 10^3$ tons for tubers, 4098.2 $\times 10^3$ tons for fruits, 1489.8 $\times 10^3$ tons for vegetables, 1444.9 $\times 10^3$ tons for olives and 41.3 $\times 10^3$ tons for tea in 2000. Total grain production rose from 321186.7 $\times 10^3$ tons in 1975 to 52 563.8 $\times 10^3$ tons in the year 2000. In 1975, the production value of cereals and pulses has the highest ratio with 45.4% followed by vegetables with 15.4%, sugar beet with 14.2% and fruits with 12.8%. The shares of cereals, vegetables, sugar beet and fruits in 2000 were 35, 20.2, 19.8 and 11.1%, respectively. The most significant increase over the study period was in olive production with a 3.2-fold increase. The production increases are 2.9% for tea, 2.7% for sugar beet, 2.5% for vegetables, 2.4% tubers, 1.8% for cotton, 1.7% for oil seeds

Table 4
Seed energy input in Turkish agriculture

Years	Cereals and pulses (000 tones)	Oil seed (000 tones)	Tuber (000 tones)	Grain equivalent (10^6 kg)	Energy eqv. (10^{12} J)
1975	2416.6	781.4	269.0	3811.3	56 026.8
1980	2420.9	815.0	275.0	3874.3	56 952.2
1985	2601.7	849.5	311.0	4122.5	60 601.0
1990	2583.3	1064.4	280.0	4462.0	65 591.5
1995	2846.3	1304.8	400.0	5163.3	75 900.5
2000	8939.1	1311.6	440.0	11 277.4	165 778.5

Table 5
Production values of major crops and their energy equivalents

Crop (1000 tones)	1975	1980	1985	1990	1995	2000
Cereals and pulses	22 202.0	24 698.0	27 424.0	31 964.0	29 660.0	33 215.0
Sugar beet	6948.6	6766.0	9830.1	13 985.7	11 170.6	18 781.4
Tobacco	199.9	234.0	170.5	296.0	204.4	208.5
Cotton	480.0	500.0	518.0	654.6	851.5	879.9
Oil seed	1256.0	1550.0	1628.8	1907.4	2187.5	2095.1
Tuber	3160.0	3960.0	5370.0	5850.0	7600.0	7570.0
Fruits	6264.5	7473.0	7596.0	8751.0	9519.0	10 500.0
Vegetables	7548.0	9810.0	12 735.0	13 753.0	15 980.0	19 159.0
Olive	561.0	1350.0	600.0	1100.0	515.0	1800.0
Tea	261.8	476.1	624.2	608.4	523.5	758.0
Total grain eqv. (10^6 kg)	32 186.7	36 446.7	40 085.6	47 551.2	45 035.1	52 563.8
Total energy eqv. (10^{15} J)	473.1	535.8	589.3	699.0	662.0	772.7

and fruits, 1.5% for cereal and pulses, while tobacco production was stagnant in the period under study.

These figures indicate that there was increase in the output of examined crops (Table 5). Energy equivalents of examined crops were calculated by using equivalent value of each crop. The results showed that the total output energy equivalent is estimated to be 473.1×10^{15} J in 1975 and it has increased 772.7×10^{15} J in 2000 and this increase is realized as 163%.

Total output energy is influenced by weather, yield, price and technology. Weather conditions influence output energy level and yield. Output energy however increased over 25 years study period low energy returns generated low crop yields according to input use amounts. Output energy level is adversely affected by changes in commodity price in terms of farmer preferences to choose the crop sown for the next growing period. New technologies have also affected energy output. Newly developed seed varieties have increased the yield, but not at desired levels because of the use of old growing systems.

A comparison of output energy vs. input energy was performed. The energy ratio was found by dividing total input energy ratio into total output energy. The results of input–output values in per hectare basis for Turkish agriculture are presented in Table 6. As can be seen, the size of arable land for Turkey has increased from 18.5 million ha in 1975 to 20.5 million ha in 2000. Physical power availability per ha and physical energy input were found to be 4.1 hp and 16.5 GJ/ha, respectively. The total output energy was as 38.8 GJ/ha in 1975 and it has increased to 55.8 GJ/ha in 2000. This result shows that output–input ratio has declined from 2.23 in 1975 to 1.18 in 2000. The percentage change in the energy ratio from 1975 to 2000 for Turkey per hectare basis was -47.1%. This result indicated that input energy value has shown faster increase compared to output energy value.

Table 6
Energy input and output values in Turkish agriculture (per hectare)

	Years					
	1975	1980	1985	1990	1995	2000
Area sown (million ha)	18.5	19.4	20.3	21.4	20.5	20.5
Available physical power (hp/ha)	3.1	3.8	3.6	3.6	3.9	4.1
Estimated physical energy input (GJ/ha)	7.1	9.0	10.0	11.0	13.5	16.5
Fertilizer input in nitrogen equivalent (kg/ha)	114.0	184.3	241.9	299.4	276.2	354.5
Fertilizer energy input (GJ/ha)	7.3	11.9	15.6	19.3	17.8	22.8
Seed energy input (GJ/ha)	3.0	2.9	3.0	3.1	3.7	8.1
Total energy input (GJ/ha)	17.4	23.8	28.6	33.4	35	47.4
Production value of major crops in grain equivalent (ton/ha)	1.7	1.9	2.0	2.2	2.2	2.6
Production value of major crops in energy equivalent (GJ/ha)	25.6	27.6	29.0	32.7	32.3	37.7
By product energy equivalent (GJ/ha)	13.2	13.9	14.6	16.1	15.7	18.1
Total output in GJ/ha	38.8	41.5	43.6	48.8	48.0	55.8
Output input ratio	2.23	1.74	1.52	1.46	1.37	1.18

4. Conclusions

The aim of this study is to calculate the output–input ratio in Turkish agriculture to explore the current and past trends in respect of energy use. The methodology used in calculation of energy use was broken down into two groups, namely inputs and outputs. The total input energy consisted of the sum of all components of energy used in production of outputs. The energy ratios in this study are based on the total input and output in the primary agricultural sector. The major inputs used in agricultural production and the output for the 36 crops were multiplied by their energy equivalents for the period of 1975–2000.

The results showed that total input energy consumption and output energy increased during the years 1975–2000. The input energy value rose from 17.4 GJ/ha in 1975 to 47.4 GJ/ha in the year 2000. Similarly, total output energy increased from 38.8 GJ/ha in 1975 to 55.8 GJ/ha in 2000. The output–input ratio was found by dividing output energy into input energy. The energy ratio was estimated to be 2.23 in 1975 and 1.18 in 2000. Hence, the energy declined by 47% over the study period. It indicates a poor development in the energy use efficiency due to the decrease of the energy ratio. The reason for this development stems mainly from the fact that total output energy overall is not increasing at a faster rate than total input energy in Turkish agriculture.

It was observed that the share of human and animal power (animate) went from 60.4 to 14.6% during the period of 1975–2000, whereas mechanical and electrical power (inanimate power) increased from 39.6 to 85.5% in the same period. This shows the development of mechanical and electrical power in the agricultural industry. Although the production area for the crops increased and rose from 18.5 to 20.5

million ha from 1975 to 2000, the intensive input use was not accompanied by the expected output increase. When the ratios of input energy values per hectare are examined, in 2000 fertilizer energy value has the highest share with 48.1% followed by physical energy value with 34.8%, and seed energy value with 17.1%. The shares of output yield energy and by product energy constituting the total output energy value were 67.6 and 32.4%, respectively.

During the last 25 years the increase in physical input, fertilizer and seed energy input values was estimated as 2.3-, 3.1- and 2.7-fold, respectively, although it has been realized as 1.5-fold for yield energy value and 1.4-fold for by product energy value. This result indicates that use of inputs in Turkish agricultural production was not accompanied by the same results in the final product. It implies that producers are not undertaking more efficient production practices as decreases in the ratio seem to be resulting from increases in inputs that are faster compared to outputs. This means that the use of inputs is still increasing and energy-related problems associated with agricultural production are still occurring. For this reason it is necessary to promote development of new technologies and use of alternative energy sources. It is suggested that some specific policies be taken to reduce the negative effects of energy use, such as pollution, global warming and nutrient loading. Within this framework, energy analysis is important to make improvements that will lead to more efficient and environment-friendly production systems.

Appendix 1

Energy equivalents of inputs and outputs

	Unit	Equivalent energy (MJ)	
Input			
1 Human labor	hour	2.3	0.9 hp
2 Animal labor			
a Horse	hour	10.10	3.8 hp
b Mule	hour	4.04	1.5 hp
c Donkey	hour	4.04	1.5 hp
d Cattle	hour	5.05	1.9 hp
e Water buffalo	hour	7.58	5.7 hp
3 Electricity	kWh	11.93	
4 Diesel	liter	56.31	
5 Chemicals, fertilizers			
a Nitrogen	kg	64.4	
b P_2O_5	kg	11.96	
c K_2O	kg	6.7	
6 Seed			
a Cereals and pulses	kg	25	
b Oil seed	kg	3.6	

c Tuber	kg	14.7
Output		
7 Major products		
a Cereal and pulses	kg	14.7
b Sugar beet	kg	5.04
c Tobacco	kg	0.8
d Cotton	kg	11.8
e Oil seed	kg	25
f Fruits	kg	1.9
g Vegetables	kg	0.8
h Water melon/melon	kg	1.9
i Onion	kg	1.6
j Potatoes	kg	3.6
k Olive	kg	11.8
l Tea	kg	0.8
8 Byproducts		
a Husk	kg	13.8
b Straw	kg	12.5
c Cob	kg	18.0
d Seed cotton	kg	25.0

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