An Analysis of Energy Use and Input Costs of Cotton Production in Turkey

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Abstract

The aim of this study was to determine input energy use in the cotton production and compare energy use with input costs. The study also seeks to analyse the effect of farm size on energy use and input costs. Data used in this study were collected from sixty-five farmers by using a face-to-face questionnaire. The sample farms were selected through a stratified random sampling technique. The results revealed that cotton production consumed a total of 49736.9 MJha-1 and diesel energy consumption was the maximum (31.1%) followed by fertilizer and machinery energy. Cost analysis showed that net return per kilogram of seed cotton was insufficient to cover economic costs of cotton production in the research area. The most important cost items were labour, machinery, land rent and pesticide costs in cotton production. The results of this study revealed that large farms were more successful both in energy productivity and efficiency and economic performance. It is concluded that energy use management at farm level needs improvement both for efficient and economical use of energy.

Résumé

Cette étude vise à déterminer la consommation d'énergie pour la production de coton et à comparer la consommation d'énergie avec les coûts des intrants. Un autre objectif fixé est l'analyse de l'effet de la taille de l'exploitation agricole sur l'utilisation d'énergie et les coûts des intrants. Les données employées dans cette étude ont été collectées en soumettant un questionnaire face-à-face à soixante-cinq agriculteurs. Les exploitations sélectionnées ont été choisies par la technique d'échantillonnage aléatoire stratifié. Les résultats ont révélé que la production de coton a requis au total 49736,9 MJha-1 et que la consommation d'énergie diesel a été la plus élevée (31,1%), suivie par l'énergie pour les engrais et les machines. L'analyse des coûts a révélé que le bénéfice net par kilogramme de graines de coton ne suffisait pas à couvrir les coûts économiques de la production de coton dans la zone d'étude. Les coûts les plus importants ont été représentés par la main d'œuvre, les coûts des machines, le loyer de la terre et les coûts des pesticides pour la production du coton. Les résultats de cette étude révèlent que les grandes exploitations étaient plus performantes tant du point de vue de la productivité et de l'efficience de l'énergie que de la performance économique. On conclut que la gestion de l'énergie au niveau de l'exploitation agricole nécessite des améliorations en vue de son utilisation efficace et économique

1. Introduction

Cotton produced in Turkey is considered as a fundamental source of material for cotton industry in terms of processing, for textile industry with fibre and both oil and feed industry with its seed. For these reasons cotton production creates an income source for many families. In addition to this, cotton industry is an important source of employment in the country.

The world cotton fibre production is 19 million tons in 33.411.000 hectares. Turkey ranks 6th in terms of cotton cultivation areas and 4th in terms of cotton fibre production after India, USA, China, Pakistan, Uzbekistan, Brazil and Argentina, respectively. Cotton production areas in Turkey are situated in Aegean, Antalya, Cukurova and Southeast Anatolia.

Energy use in agricultural production has become more input use dependent due to the use of modern inputs such as chemical fertilizers, pesticides, machinery and electricity. The intensive energy uses in agriculture and easy access to fossil energy have provided substantial increases in food production. However, intensive energy use has brought up some important human health and environment problems. On the other hand efficient use of inputs is very important in terms of sustainable agricultural production.

Turkey's energy consumption in agriculture has increased in recent years; therefore, the problem associated with energy use in Turkish agriculture has grown. Currently producers use more inputs to increase total output since there is no chance to expand the size of arable lands and producers do not have enough knowledge on alternative and efficient energy inputs. Under these circumstances, an input–output analysis provides planners and policy makers with an opportunity to evaluate economic interactions of energy use [1].

The energy input-output relations in agricultural production are closely related with production techniques, quantity of inputs used by producers and yield level of crops along with the environmental factors such as soil and climate. Therefore, there may appear different energy input and output relationships for the same crop depending on the regions and countries.

Considerable research studies have been conducted on energy use in agriculture [2,3,4,5,6,7,8,9,10,11,12]. However, cotton has been paid relatively little attention in these studies. Furthermore, our study also considers the effect of farm size on energy use and input costs in cotton production in addition to determining energy use in production and comparing energy inputs with input costs. Farm size is another important factor in energy and input use. Singh et al. [13] reported that the total energy requirement was higher

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on medium farms. The cost of energy use per unit area decreased with increase in farm size. It was also reported that large farms used energy in the best possible way to achieve maximum yield [14]. Singh [2] found that maximum energy was required for producing cotton among the wheat, mustard, maize and cluster bean. Yaldiz et al. [5] pointed out that fertilizer and irrigation energy dominates in the total energy consumption in cotton production in Turkey.

The main aim of this research study was to determine energy use in cotton production and compare input energy use with input costs. The study also seeks to analyse the effect of farm size on energy use and input costs on the basis of cotton farms in Antalya province.

2. Material and methods

Data used in this study were collected from 65 farms producing cotton in Central and Serik districts of Antalya province by using a face to face questionnaire. The questionnaire form included information on inputs used for production of cotton as well as economic characteristics of the farms; it was conducted in 2001 production year. In addition to survey results, previous research studies and secondary sources were also used in the research. Sample farms were randomly selected from the villages in the study area by using a stratified random sampling technique. The sample size was calculated by using Neyman method [15] and the farms were classified into three farm size groups as small farms (0.1-5.0 ha), medium farms (5.1-12.0 ha) and large farms (12.1 ha and more). The formula used in this method is illustrated below.

$$n = \left(\Sigma N_h S_h\right)^2 / \left(N^2 D^2 + \Sigma N^h S_h^2\right)$$

where:
n = required sample size
N = number of holdings in population
N_h = number of the population in the stratified h
S_h^2 = variance of the stratified h
$D^2 = d^2/z^2$
d = precision where (x – X)
z= reliability coefficient (1.96 which represents 95% reliability)

Tab. 1. *Energy equivalents of inputs and outputs in agricultural production*

Input (Unit)	Energy Equivalent (MJunit^{-1})	Reference
Chemicals (kg)	101.2	Yaldiz [5]
Human power (hr)	1.96	Yaldiz [5]
Machinery (hr)	64.8	Singh [2]
Nitrogen (kg)	66.14	Shrestha [27]
Phosphorus (kg)	12.44	Shrestha [27]
Potassium (kg)	11.15	Shrestha [27]
Seeds (kg)	11.8	Singh [2]
Water for irrigation (m^3)	0.63	Yaldiz [5]
Diesel(lt)	56.31	Singh [2]
Cotton	11.8	Singh [2]

The permissible error in the sample size was defined to be 5% for 95% reliability and the sample size was calculated as 65 farms.

Energy equivalents of inputs used in the cotton production were 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 different operations. The energy consumed was calculated using conversion factors (1 liter diesel = 56.31 MJ) and expressed in MJha^{-1} [16].

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

$$\text{Energy Productivity} = \frac{\text{Cotton output (kg/ha)}}{\text{Energy input (MJ/ha)}}$$

In the study the input energy was divided into direct and indirect and renewable and non-renewable forms [14,19]. The indirect energy includes pesticides, and fertilizers while direct energy covers human power, diesel and electricity used in the cotton production process. Non-renewable energy includes petrol, diesel, electricity, chemicals, fertilizers and renewable energy consists of human and animal power.

3. Results and discussion

3.1 Socio-economic Characteristics of the Farms

The average size of surveyed farms was 5.5 people, almost the same average (5.4 people) in the rural region of Turkey [20]. Rate of males and females in the surveyed farms was 56%, 44%. In the research area, average size of operated land was 9.9 ha of which 49.5% of the operated

Tab. 2. *Some farm and farmer characteristics of the surveyed farms*

Items	Farm size groups (ha)			Weighted
	0.1-5.0	5.1-12.0	12.1+	Average
Population (person)	4.7	5.6	6.1	5.5
Women	2.0	2.5	2.7	2.4
Men	2.7	3.1	3.4	3.1
Total area (ha)	3.4	8.1	19.5	9.9
Irrigated area (ha)	3.4	8.0	16.9	9.0
Fields crop area (ha)	3.1	6.9	15.3	8.1
Cotton area (ha)	1.9	3.5	10.1	4.9
Wheat area (ha)	0.9	2.7	4.6	2.7
Horticultural crops (ha)	0.2	0.2	4.6	1.4
Second crop (ha)	0.7	1.2	4.1	1.9
Greenhouse (ha)	0.08	0.07	0.14	0.09
Tractor (number)	0.7	0.9	1.6	1.0

land was devoted to cotton production. The share of cotton area in the total farm area varied from 43.2% to 55.9% in the farm size groups. About 90.9% of the farm land was irrigated and in addition to cotton farmers produce wheat, maize (first and second crop), sesame, nut, vegetables (in greenhouse and open field) and citrus. The average number of tractors was 1.0 in the surveyed farms (Table 2).

3.2. Energy and Cost Analysis

In the studied farms, input use in cotton production and cotton yield were given in Table 3. The results showed that 51.3 kg of cotton seeds was used at planting per hectare and Nazilli variety was used widely (56.7%) followed by Caroline (31.7%) and Deltapine (11.6%).

Cotton is one of the highest labour-demanding crops among the field crops produced in Turkey. Average labour used in cotton production was determined as 739.7 hours per hectare of which 21% was provided by the family. The family labour use ratio (30.8%) in small farms (1) was higher than in large farms. The main reason for high labour use in cotton production was mainly hand harvesting. The cotton is harvested by hand only in Turkey and India among the major 10 cotton-producing countries [21]. In recent years, there has been a discussion in Turkey on shifting from hand harvesting to machinery because of difficulties in finding workers for cotton harvest.

Tab. 3. *Inputs and output for cotton production*

Inputs	Farm size groups (ha)			Weighted
	0.1-5.0	5.1-12.0	12.1+	Average
Seeds (kg ha^{-1})	47.7	53.5	52.2	51.3
Labour (hours ha^{-1})	753.9	718.0	755.1	739.7
Land preparation and planting	4.3	3.3	3.1	3.5
Fertilizer application	3.5	3.7	2.4	3.3
Spraying	13.4	6.3	3.6	7.7
Irrigation	51.3	37.7	22.5	37.7
Hoeing	195.7	203.7	247.9	213.7
Harvesting	436.0	426.0	441.2	433.5
Transporting to farm	6.2	3.9	3.5	4.5
Driver	43.5	33.4	30.9	35.8
Fertilizer [1] (kg ha^{-1})	393.6	287.3	356.2	339.8
Nitrogen	266.4	189.2	207.0	218.3
Phosphorus	82.6	50.6	86.7	70.7
Potassium	44.6	47.5	62.5	50.8
Pesticides [2] (gr ha^{-1})	1846.5	2132.3	1993.4	2020.0
Insecticides	1106.9	1245.6	1361.4	1247.3
Fungicides	19.6	58.4	17.6	38.4
Herbicides	720.0	828.3	614.4	734.3
Machinery (hours ha^{-1})	32.0	28.4	26.2	28.9
Plough	3.9	3.8	3.2	3.7
Discing	6.6	4.3	4.9	5.2
Harrow	1.0	1.6	1.9	1.5
Land plane	3.8	3.2	2.8	3.3
Drilling	2.0	1.7	1.7	1.8
Furrow cultivator,	1.1	1.1	1.0	1.1
Fertilizer spreader	1.1	0.8	0.3	0.7
Sprayer	3.0	3.8	1.9	3.0
Hoeing by cultivator	7.7	6.8	7.6	7.3
Trailer	1.8	1.3	0.9	1.3
Diesel (lt ha^{-1})	312.6	275.9	230.8	274.7
Water (m^3 ha^{-1})	7150.0	6700.0	6211.1	6703.1
Cotton yield (kg ha^{-1})	3129.7	3047.9	3187.2	3112.7

[1]: Plant nutrients, [2]: Active ingredients,

In the research area, chemical fertiliser was applied three times in cotton production as one time basal dressing and two times top dressing. The fertilizer amount used as plant nutrition element was an average of 218.3 kgha^{-1} for nitrogen, 70.7 kgha^{-1} for phosphorus and 50.8 kgha^{-1} for potassium as a total of 339.8 kgha-1. As for the major cotton-producing countries, N, P, K amounts as kg basis used for cotton production per ha were 40, 0, 0 in Argentina; 150, 8, 0 in Australia; 25, 50, 30 in Brazil; 100, 0, 0 in China; 40, 20, 20 in India; 112, 45, 0 in Pakistan; 100, 52, 65 in USA and 200, 50, 0 in Turkey [22]. These values indicate that there is an excessive fertilizer use in Turkey. In fact, previous research studies conducted in Izmir and Antalya provinces of Turkey indicated that the use of fertilizer was excessive in cotton production [23,24]. For instance, farmers in Antalya were applying 218.3 kg nitrogen per hectare in cotton production while 159 kilogram nitrogen was recommended. It is known that excessive use of fertilizer would cause negative effects on the environment, human health and energy use efficiency. However, it can be stressed that removing the fertilizer subsidy policy applied till 2000 in Turkey will most likely have a positive effect on the excessive fertilizer use.

Pesticides have become an integral part of Turkish cotton production practices. The research results showed that a total of 2020.0 grha-1 pesticide was used in the sample farms followed by insecticides (1247.3 grha^{-1}), fungicides (38.4 grha^{-1}), and herbicides (734.3 grha^{-1}).

The other major input component in the examined cotton farms was machinery and diesel consumption. The results showed that tractor use was 28.9 hour farms per hectare in the sampled farms and the major part (78.9%) of the machinery use was devoted to land preparation, planting and hoeing.

Energy consumption and output-input ratio values on the basis of farm holding size groups are illustrated in Table 4.

The total energy consumed in cotton production in the study area was estimated as 49736.9 $MJha^{-1}$. This result is quite higher than (22586.7 $MJha^{-1}$) in the previous research study conducted in Turkey [5]. The main reason for this difference could be explained in terms of differences in input use in cotton production. Our research was conducted in Antalya province where input use was quite higher than the country average. Research results revealed that energy use per hectare was 24.6% higher in small farms than in larger farms. Furthermore, energy use value decreases when the farm size group increases. Sing [25] reported that the total energy input for raising cotton was 19 400.6 $MJha^{-1}$ in India and the share of fertilizer energy input in producing cotton was 28.5 % followed by electricity, diesel, human energy, chemicals. The mean yield of seed cotton was 1553.5 $kgha^{-1}$ and weighted energy ratio was found to be 7.0. Comparing two studies, the energy consumption in Turkish cotton production was higher than in the study conducted in India. Our results showed that 49736.5 $MJha^{-1}$ energy was used in cotton production and 3112.7 kg seed cotton was obtained per hectare. In other words 49736.5 $MJha^{-1}$ input energy was used to obtain 36729.9 $MJha^{-1}$ output energy in cotton production. Energy output per hectare was the highest (with 37609 $MJha^{-1}$) in the large farms followed by small and medium farms.

Diesel energy was the maximum (31.1%) in the total input energy consumed in cotton production followed by fertilizers and machinery. The energy equivalent of seeds was estimated as 605.3 $MJha^{-1}$ and it constituted 1.2% of the total energy consumption in cotton production. Energy equivalent of labour use in cotton production was 1449.8 $MJha^{-1}$ its share was 2.9% in the total energy use. Labour energy use in the spraying and irrigation practice decreases as farm size increases. The difference in labour energy used in irrigation came from the high number of irrigation application in small farms.

In the sampled farms, spraying was carried out by plane, tractor and hand spreader. When the farms got larger, spraying was usually applied by plane instead of hand spreader. As mentioned previously, transition in harvest from hand picking to machinery will more likely lead to increase in energy consumption in Turkish cotton production due to mechanical harvesting.

The results indicated that fertilizer energy (14354.1 $MJha^{-1}$) was the second share (28.9 %) in the total input energy used in cotton production. The nitrogen accounted for 92.1% of the total fertilizer followed by phosphorus (5.5%) and potassium (2.4%). The use of total fertilizer and nitrogen energy was highest in the small farms; however, total fertilizer nitrogen and phosphorus energy was minimum in the medium farms. It can be pointed out that the removal of fertilizer subsidy policy pursued in Turkey and the improvement in fertilizer use might lead to significant increases in energy use efficiency.

An average of 426.5 $MJha^{-1}$ pesticide energy was used in cotton production with a share of 0.9% in the total energy consumption. The ratio of insecticides, herbicides and fungicides in the total pesticide energy was 58.2%, 41.0% and 0.8% respectively. The results indicated that small farms use lower energy in comparison to large farms except herbicides. The estimated diesel and machinery energy consumptions were 15468.4 $MJha^{-1}$, 13209.7 $MJha^{-1}$ respectively. It implies that machinery and diesel energy together have a very important role in terms of energy management. The machinery use should be decreased to improve energy efficiency. This could be provided by using herbicide in weed control and reducing heavy traffic used in soil preparation.

It was observed that machinery energy use in small farms was higher based on the farm size groups. Cotton was irrigated by furrow in the examined farms and average irrigation number was found to be 5.16. The irrigation water energy (4223.0 $MJha^{-1}$) was 8.5% of the total input energy used in the cotton production.

The energy output-input ratio was estimated at 0.74 in sampled cotton production. In the sampled farms, higher machinery energy use also causes more diesel energy consumption in small farms. According to farm size groups, energy output-input ratio increases as the farm size increases. These results indicate that energy was used more efficiently in large farms and similar results could be expressed for energy productivity. Average energy productivity was found to equal 0.06 $kgMJ^{-1}$, in other words, cotton yield for 1 MJ energy consumption was calculated as 0.06 kg. This figure ranged between 0.06-0.07 $kgMJ^{-1}$ between the farm size groups (Table 4).

The research results indicate that diesel, fertiliser and machinery management seem the most significant areas for improving energy efficiency in Turkish cotton production.

Economic analysis of cotton production in the study was done by taking different cost components into consideration. The production costs and gross value for cotton production were given in Table 5.

Regarding the economic aspect, farmers spent 1952.6$ to obtain 1677.9$ production value in cotton production. As expected, production cost per unit area decreased as the farm size group increased. The production costs per unit area in large farms were found to be the lowest, production value per unit area for large farms was found to be the highest. As can be seen from the table, labour costs in cotton production were the highest followed by land rent, pesticides and diesel.

The cost of seeds was 18.8$ and its share was 0.96% in the total cotton production costs. The cost of labour as casual and family workers was 484.3$ per hectare. This value accounts for 24.8% of the total cotton production costs. Although foreign labour cost per unit area was the highest in large farms, cost equivalent of family labour in small farms was high. Transition from hand picking to machinery for cotton harvest will likely lower significantly the labour use and this will also affect the cotton production cost positively. According to one research study conducted in Turkey, machine picking will decrease harvesting cost to 29%, and the total production cost to 5% per hectare in Turkey [26].

In contrast to the share of fertilizer energy in the total energy use, fertilizer cost had little share (5.53%) in the total production costs with a value of 108.0$ per hectare.

Pesticide cost was found to be 211.6$ per hectare and its share in the total costs was 10.84%. The share of pesticide costs was rather high compared with its share in the total energy use. The research results showed that pesticide use excess was widespread in Antalya. In fact Turkey ranks first in terms of pesticide expenses per hectare among the 10 major cotton-producing countries [21]. The excessive use of pesticides in cotton production is not only harmful for the environment and human health but it also leads to low efficiency in energy use. Furthermore, high pesticide cost is one of the major factors for planting area decreases in conventional cotton areas in Turkey.

Diesel, repair, depreciation, interest and driver costs were calculated as machinery costs in the study. The share of machinery costs in total costs excluding driver cost was quite high with a share of 24.62%. Total machinery cost per unit area decreased as the farm size group increased. The price paid by farmers for irrigation water in cotton production was 30.1$ per hectare. The share of irrigation water costs (1.54%) in total production costs was rather low when compared with irrigation energy share in the total input energy.

As mentioned previously, the energy use efficiency (EUE) was found as 0. in the sample farms for cotton production and the benefit-cost (BC) ratio of the cotton production was found to be 0.86.

The productivity ratio of cotton production was estimated as 1.59 kg^{-1} ; it ranges between 1.53 and 1.70 kg^{-1} in the farm size groups. Therefore this ratio could be economically interpreted as synonym for the energy productivity. According to farm size groups, when BC and productivity values were taken into consideration, it was observed that economic success increases as the farm size increases.

The total energy input as direct-indirect and renewable-non renewable forms are presented in Table 6. The share of direct input energy was 42.5% in the total energy compared to 57.5 for the indirect energy. The results revealed that energy use in sampled farms was based on non-renewable energy form. On average the non-renewable form of energy input was 87.4% compared to 12.6% for the renewable form.

Tab. 4. *Energy consumption and output for cotton production (MJ ha^{-1})*

Inputs	Farm size groups (ha)			Weighted Average	
	0.1-5.0	5.1-12.0	12.1+	Quantity	(%)
Seeds	562.9	631.3	616.0	605.3	1.22
Labour	1477.6	1407.3	1480.0	1449.8	2.91
Land prep. and planting	8.4	6.5	6.1	6.9	0.01
Fertilizer application	6.9	7.3	4.7	6.5	0.01
Spraying	26.3	12.3	7.1	15.1	0.03
Irrigation	100.5	73.9	44.1	73.9	0.15
Hoeing	383.6	399.3	485.9	418.9	0.84
Harvesting	854.6	835.0	864.8	849.7	1.71
Transporting to farm	12.2	7.6	6.9	8.8	0.02
Drivers	85.3	65.5	60.6	70.2	0.14
Fertilizer	17359.5	12345.4	13925.3	14354.1	28.86
Nitrogen	16143.8	11465.5	12544.2	13229.0	26.60
Phosphorus	916.9	561.7	962.4	784.8	1.58
Potassium	298.8	318.3	418.8	340.4	0.68
Pesticides	393.4	450.4	418.8	426.5	0.86
Insecticides	220.3	247.9	270.9	248.2	0.50
Fungicides	1.8	5.4	1.6	3.5	0.01
Herbicides	171.4	197.1	146.2	174.8	0.35
Machinery	14842.5	12681.5	12178.9	13209.7	26.56
Plough	2183.3	2127.3	1791.4	2071.3	4.16
Discing	2955.9	1925.8	2194.5	2328.9	4.68
Harrow	209.0	334.4	397.1	313.5	0.63
Land plane	2054.0	1729.7	1513.4	1783.7	3.59
Drilling	601.9	511.6	511.6	541.7	1.09
Furrow cultivator	313.5	313.5	285.0	313.5	0.63
Fertilizer spreader	827.6	601.9	225.7	526.7	1.06
Sprayer	451.4	571.8	285.9	451.4	0.91
Hoeing by cultivator	4827.9	4263.6	4765.2	4577.1	9.20
Trailer	418.0	301.9	209.0	301.9	0.61
Diesel	17602.5	15535.9	12996.3	15468.4	31.10
Water for irrigation	4504.5	4221.0	3913.0	4223.0	8.49
Total Energy Input	56743.0	47272.8	45528.3	49736.9	100.00
Total Energy Output	36930.5	35965.2	37609.0	36729.9	-
Energy Output-Input Ratio	0.65	0.76	0.83	0.74	-
Energy Productivity (kg MJ-1)	0.06	0.06	0.07	0.06	-

4. Conclusions

This study presents energy use in cotton production. Data used in this research were collected from the farmers located in the Antalya province of Turkey. The research results indicated that cotton production consumed a total of 49736.9 MJha^{-1}. Results also showed that Turkish cotton production mainly depends on fossil fuels. Diesel energy consumption in the total input energy was the maximum

Tab. 5. *Cotton production costs ($ha^{-1})*

Cost items	Farm size groups (ha)			Weighted Average	
	0.1-5.0	5.1-12.0	12.1+	Quantity	(%)
Variable Costs	1153.2	1204.8	1280.0	1205.5	61.74
Seeds	17.6	18.6	20.1	18.8	0.96
Fertilizers	126.8	97.9	102.1	108.0	5.53
Pesticides	163.8	230.3	237.9	211.6	10.84
Insecticides	160.1	220.1	235.2	205.7	10.53
Herbicides	1.2	6.6	2.5	3.7	0.19
Fungicides	2.5	3.6	0.1	2.2	0.11
Casual workers	356.6	396.3	451.6	395.5	20.26
Water	31.0	28.3	31.7	30.1	1.54
Driver	48.6	37.4	34.6	40.1	2.05
Diesel	220.3	194.5	162.6	193.6	9.91
Oil	20.0	18.6	18.3	18.9	0.97
Repair and maintenance	47.8	41.6	54.4	47.2	2.42
Spraying by plane	3.1	17.0	36.7	18.2	0.93
Others (bags, robe etc.)	3.3	3.4	3.3	3.3	0.17
Operating interest	114.3	120.9	126.8	120.1	6.15
Fixed Costs	887.0	746.8	593.7	747.1	38.26
Family labour	141.3	85.5	35.2	88.8	4.55
Depreciation	152.9	125.9	61.3	116.2	5.95
Interest	138.5	113.3	55.3	104.8	5.37
Land rent	394.9	364.5	387.5	380.5	19.49
General overhead costs	59.5	57.5	54.5	56.8	2.91
Total Production Costs	2040.2	1951.6	1873.8	1952.6	100.00
Total Production Value	1681.2	1640.7	1717.0	1677.9	-
Benefit/cost ratio	0.82	0.84	0.92	0.86	-
Productivity (kg $\$^{-1}$)	1.53	1.56	1.70	1.59	-

followed by fertilizer and machinery energy. The soil preparation, planting and hoeing were the major items for the machinery use in cotton production. The results implied that the application of advanced technologies such as minimum tillage technique should be encouraged in the research area. The energy output-input ratio was found to be quite low (0.74) in cotton production. Furthermore, net return of cotton production was insufficient to cover economic costs in cotton production. The significant cost items were labour, machinery, land rent and pesticide costs in sampled farms. The energy efficiency and energy productivity were higher in the large farms. On the other hand, the values of Benefit-Cost (BC) and economic productivity also showed that large farms were more successful for these success criteria.

It can be pointed out that energy management should be considered as an important aspect in terms of efficient, sustainable and economical use of energy. The current pattern of energy consumption in Turkish cotton production is very sensitive to diesel, fertilizer, pesticide and machinery use. On the other hand, energy use in cotton production is inefficient, expensive and detrimental to the environment mainly due to excessive and unconscious input use. Therefore reducing excessive and improper use of these inputs will have a positive effect by providing efficiency in machinery use and removing the fertilizer subsidy policy. Furthermore, integrated pest control techniques should be put in practice to improve pesticide use. It can be expected that all these measures would be useful not only for reducing the negative effects on the environment, human health, for maintaining sustainability and decreasing production costs but also for providing higher energy use efficiency.

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Tab. 6. *Total energy input in the form of direct, indirect, renewable and non-renewable for cotton production (MJha^{-1})*

Type of Energy	Farm size groups (ha)			Weighted
	0.1-5.0	5.1-12.0	12.1 +	Average
Direct Energy [a]	23584.6	21164.2	18389.3	21141.2
	(41.6) [e]	(44.8)	(40.4)	(42.5)
Indirect Energy [b]	33158.4	26110.6	27139.0	28595.7
	(58.4)	(55.2)	(59.6)	(57.5)
Renewable Energy [c]	6545.0	6259.6	6008.9	6278.1
	(11.5)	(13.2)	(13.2)	(12.6)
Nonrenewable Energy [d]	50198.0	41015.2	39519.4	43458.8
	(88.5)	(86.8)	(86.8)	(87.4)
Total Energy Input	56743.0	47274.8	45528.3	49736.9
	(100.0)	(100.0)	(100.0)	(100.0)

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

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