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ENERGY EFFICIENCY ANALYSIS OF COTTON PRODUCTION IN TURKEY: A CASE STUDY FROM AYDIN PROVINCE

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ABSTRACT

The purpose of this study is to make an energy efficiency analysis of cotton production during the production season of 2013 in Aydın province of Turkey. In order to determine the energy input-output of cotton, data provided by Aydın-Nazilli Cotton Research Institute have been availed of. The energy input and output in cotton production have been calculated as 29138.11 MJ ha^{-1} and 56050 MJ ha^{-1}, respectively. Energy inputs consist of 38.65 % (11262 MJ ha^{-1}) diesel fuel energy, 36.94 % (10764 MJ ha^{-1}) chemical fertilizers energy, 9.05 % (2637.36 MJ ha^{-1}) machinery energy, 8.65 % (2520 MJ ha^{-1}) irrigation energy, 2.85 % (831.63 MJ ha^{-1}) human labour energy, 2.64 % (769.12 MJ ha^{-1}) chemicals energy and 1.21 % (354 MJ ha^{-1}) seed energy. Energy efficiency, specific energy, energy productivity and net energy in cotton plant production have been calculated as 1.92, 6.13 MJ kg^{-1}, 0.16 kg MJ^{-1} and 26911.89 MJ ha^{-1}, respectively.

KEYWORDS:
Cotton, energy efficiency, energy productivity, specific energy, Turkey

INTRODUCTION

Cotton is an important product, as it contributes greatly to the textile industry by it's fibre, to oil industry by it's seed, to stockbreeding by it's pulp, as well as enhancing our foreign trade through exportation. Furthermore, cotton creates important employment opportunities in producer countries. The cotton plant is mostly planted for cotton fibre, which is the raw material of textile industry. As well as textile industry, cotton fibre is also being used as a raw material in approximately 50 branches of industry, which include gunpowder and film material production, among others. Oil, acquired from cotton seed as an alternative to petrol, is increasingly being used as raw material in bio-diesel production too. In addition, the increasing population levels and higher life standards makes the demand for cotton plant increase on a daily basis. Cotton is being planted in various geographical regions, mostly in Asia, but also in the continents of America, Africa and Australia. In world scale, the size of the area where cotton is being planted is approximately 34 million hectares, where the approximate total yield is 26 million tons of fibre cotton. The leading cotton producers are India, China, USA, Pakistan, Brazil, Uzbekistan and Turkey. Turkey's share in world cotton production is approximately 3 % and is ranked seventh [1].

In Turkey, cotton farming takes place in four main regions, South-eastern Anatolia, Aegean, Cukurova and Antalya, in a total area size of 468.000 ha, where the total fibre cotton produced is 846.000 tons. In Aegean region, plantation takes place in an area of 94.000 ha, yielding 181.000 tons of fibre cotton. The province of Aydın has a plantation area of 58.000 ha, which makes up 62 % of the total plantation area in the Aegean region, and with a fibre production level of 114.000 tons, it makes up 63 % of the total fibre production in the Aegean region [2]. The province of Aydın is located within the Aegean region of Turkey. Aydın has fertile plains in central and western sections, is surrounded by mountains in north and south. It is located on the Buyuk Menderes basin, covering an area of 8.007 km^2. 55 % of the population is depending on farming for their livelihood. Aydın has a major role in Turkey in terms of national agriculture, as indicated by the fact that the province is ranked within the top ten producers in 25 different products [3]. Efficient use of the energy resources is vital in terms of increasing production, productivity, competitiveness of agriculture, as well as ensuring sustainability of rural living. Energy auditing is one of the most common approaches to examining energy efficiency and environmental impact of the production system. It enables researchers to access output-input ratio, relevant indicators, and energy use patterns in an agricultural activity. The energy audit provides sufficient data to establish functional forms to investigate the relationship between energy inputs and outputs [4].

Energy consumption per unit area in agriculture is directly related to the development of farming technology and production level. Energy use is one of the key indicators for developing more sustainable agricultural practices [5, 6]. The amount of energy used in agricultural production, processing, and distribution is significantly high. A sufficient supply of the right amount of energy and its effective and efficient use are necessary for an improved agricultural production [6, 7]. Several researches have been conducted on cotton plant's energy input-output analysis in agricultural production. Some of these researches may be listed as those on the energy usage activities of cotton [8, 9, 10, 11, 12, 13, 14].

No researches related to the energy efficiency of cotton plant production in Aydın province has been contained in this study. Cotton plant is the most important plant in macro and micro terms, and defining the energy efficiency is the aim of this study.

MATERIALS AND METHODS

The research has been conducted for the whole Aydın province of Turkey (N 37º-51´; E 27º-51´; 40 m above sea level). In order to determine the energy efficiency of cotton plant, data have been provided by Aydın-Nazilli Cotton Research Institute, for the production season of 2013. Total energy input in unit area (ha) constitutes each total of input energy. Human labour, machinery, chemicals, chemical fertilizers, diesel fuel, irrigation energy and seed were the calculated inputs. Cotton plant was the calculated output.

In Table 1, the agricultural production inputs, energy equivalents of input and output have been taken as energy values. Energy efficiency calculations were made to determine the productivity levels of cotton plant production. The units shown in Table 1 have been used to find out the input values in cotton plant production. Input amounts have been calculated and then these input data have been multiplied by the energy equivalent coefficient. When determining the energy equivalent coefficients, previous energy analysis sources were used. By adding energy equivalents of all inputs in MJ unit, the total energy equivalent was found. For example, in order to determine the energy efficiency in wheat production, Mohammadi et al. [5] reported that, "The energy ratio (energy use efficiency), energy productivity, specific energy and net energy have been calculated by using the following formulates" [15, 16].

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

$$\text{Specific energy} = \frac{\text{Energy input } (\frac{\text{MJ}}{\text{ha}})}{\text{Cotton output } (\frac{\text{kg}}{\text{ha}})} \quad (2)$$

$$\text{Energy productivity} = \frac{\text{Cotton output } (\frac{\text{kg}}{\text{ha}})}{\text{Energy input } (\frac{\text{MJ}}{\text{ha}})} \quad (3)$$

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

Following the analysis of data through Microsoft Excel program, by referring to the inputs, the results were tabulated. Cotton plant input-output values were determined and the calculations are given in Table 2.

TABLE 1
Energy equivalents of inputs and outputs in production of cotton plant.

Inputs and outputs	Unit	Energy equivalent coefficient	Sources
Inputs	**Unit**	**Values (MJ unit^{-1})**	**Sources**
Human labour	h	1.96	[19, 20]
Machinery	h	64.80	[21, 22]
Chemical fertilizers			
Nitrogen	kg	60.60	[22]
Phosphorous	kg	11.10	[22]
Potassium	kg	6.70	[22]
Chemicals	kg	101.20	[23]
Diesel fuel	l	56.31	[22, 24]
Irrigation	m^3	0.63	[23]
Seed	kg	11.80	[8, 22]
Outputs	**Unit**	**Values (MJ unit^{-1})**	**Sources**
Cotton	kg	11.80	[8, 22]

Kocturk and Engindeniz [17] reported that; "The input energy can also be classified into direct and indirect, and renewable and non-renewable forms. The indirect energy consists of pesticide and fertilizer while the direct energy includes human and animal power, diesel and electricity energy used in the production process. On the other hand, non-renewable energy includes petrol, diesel, electricity, chemicals, fertilizers, machinery, while renewable energy consists of human and animal labour" [15, 18].

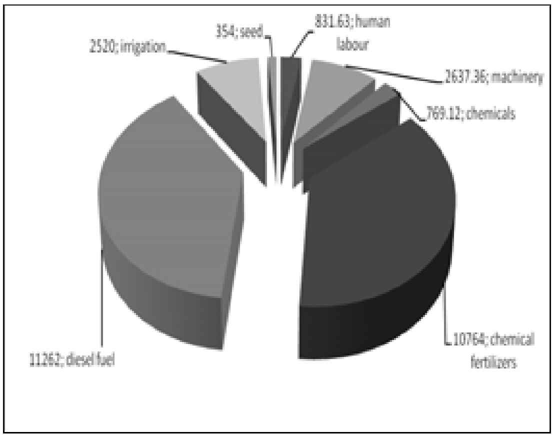

FIGURE 1
Energy input ratio in cotton plant production (MJ ha^{-1}, %).

RESULTS AND DISCUSSION

The amount of cotton plant produced per hectare during the 2013 production season has been calculated as an average of 4750 kg. For the 2013 cotton plant production season, the energy output-input analysis of cotton plant production related to this study are provided in Table 2, while the percentage distributions of the inputs are provided in Figure 1. It can be seen from these tables that the first, second and third highest energy inputs in cotton plant production were diesel fuel energy by 38.65 %, chemical fertilizers energy by 36.94 % and machinery energy by 9.05 %, respectively. If the average values are examined by referring to Table 2, it can be seen that the highest energy inputs in cotton plant production are diesel fuel energy by 11262 MJ ha^{-1} (38.65 %), chemical fertilizers energy by 10764 MJ ha^{-1} (36.94 %), machinery energy by 2637.36 MJ ha^{-1} (9.05%), irrigation energy by 2520 MJ ha^{-1} (8.65 %), human labour energy by 831.63 MJ ha^{-1} (2.85 %), chemicals energy by 769.12 MJ ha^{-1} (2.64 %) and seed energy by 354 MJ ha^{-1} (1.21 %), respectively. In this study, diesel fuel energy had the biggest share by 11262 MJ ha^{-1} (38.65 %). Similarly, in previous studies, Yilmaz et al. [8] concluded in his cotton study that the diesel fuel energy had the biggest share by 15468.40 MJ ha^{-1} (31.10 %) and Zahedi et al. [14] concluded in his cotton study that the diesel fuel energy had the biggest share by 24863 MJ ha^{-1} (47.40 %). Yilmaz et al. [8] and Zahedi et al. [14] concluded in their cotton study that the fertilizer application energy had the second share 14354.10 MJ ha^{-1} (28.86 %), 10401.20 MJ ha^{-1} (19.80 %) by respectively.

As can be seen from Table 2, human labour energy input was calculated 831.63 MJ ha^{-1}. Diesel fuel energy input was calculated as 11262 MJ ha^{-1}. Human labour and diesel fuel energy were used for tractor and farm operations.

TABLE 2
Energy input-output analysis in cotton plant production.

Inputs	Unit	Energy equivalent (MJ unit^{-1})	Input used per hectare (unit ha^{-1})	Energy value (MJ ha^{-1})	Ratio (%)
Human labour	h	1.96	424.30	831.63	2.85
Machinery	h	64.80	40.70	2637.36	9.05
Chemicals	h	101.20	7.60	769.12	2.64
Chemical fertilizers			280	10764	36.94
Nitrogen	kg	60.60	160	9696	33.27
Phosphorous	kg	11.10	60	666	2.28
Potassium	kg	6.70	60	402	1.39
Diesel fuel	l	56.31	200	11262	38.65
Irrigation	m^3	0.63	4000	2520	8.65
Seed	kg	11.80	30	354	1.21
Total inputs				29138.11	100.00
Outputs	**Unit**	**Energy equivalent (MJ unit^{-1})**	**Output per hectare (unit ha^{-1})**	**Energy value (MJ ha^{-1})**	**Rate (%)**
Cotton plant	kg	11.80	4750	56050	
Total outputs				56050	100.00

TABLE 3
Energy input-output and efficiency calculations in cotton plant production.

Calculations	Unit	Values
Cotton plant	kg ha^{-1}	4750
Energy input	MJ ha^{-1}	29138.11
Energy output	MJ ha^{-1}	56050
Energy use efficiency		1.92
Specific energy	MJ kg^{-1}	6.13
Energy productivity	kg MJ^{-1}	0.16
Net energy	MJ ha^{-1}	26911.89

The amount of chemical fertilizers used for cotton plant growing was 280 kg ha^{-1}. Nitrogen was the most common chemical fertilizer used in cotton plant production, by 160 kg ha^{-1}, followed by phosphorus, 60 kg ha^{-1} and followed by potassium, 60 kg ha^{-1}.

Energy input-output and efficiency calculations in cotton plant production are given in Table 3.

According to Table 3, cotton plant, energy input, energy output, energy efficiency, specific energy, energy productivity and net energy in cotton plant production have been calculated as 4750 kg ha^{-1}, 29138.11 MJ ha^{-1}, 56050 MJ ha^{-1}, 1.92, 6.13 MJ kg^{-1}, 0.16 kg MJ^{-1} and 26911.89 MJ ha^{-1}, respectively. In previous studies, Yilmaz et al. [8], Polat et al. [10], Khan et al. [11], Dagistan et al. [12], Sehri [13], and Zahedi et al. [14] calculated the energy efficiency in cotton studies as 0.74; 2.52; 1.63; 1.51; 2.36 and 0.70 respectively

The distribution of inputs, used in the production of cotton plant, in accordance with the direct, indirect, renewable and non-renewable energy groups are given in Table 4. As can be seen from Table 4, the total energy input consumed in cotton plant production could be classified as 50.15 % direct and 49.85 % indirect. As can be seen from Table 4, the total energy input consumed in cotton plant production could be classified as 12.72 % renewable and 87.28 % non-renewable. Similarly, it was concluded that the ratio of non-renewable energy was higher than the ratio of renewable energy in cotton [8, 11, 12, 13, 14]. The reason for chemical fertilizers energy being so high is due to the fact that chemical fertilizers were used, instead of the farm fertilizers.

CONCLUSION

Energy use in agriculture has been increasing in response to increasing population, limited supply of arable land, and a desire for higher standards of living. Continuous demand in increasing food production has resulted in intensive use of chemical fertilizers, pesticides, agricultural machinery, and other natural resources. However, intensive usage of energy causes problems, which threaten public health and environment. Efficient use of energy in agriculture may minimize environmental problems, may prevent destruction of natural resources and promote sustainable agriculture as an economical production system [25]. In this research, the energy efficiency of cotton plant production in Aydın province has been defined. According to the evaluated results, cotton plant production is a profitable production in terms of energy usage. The research results indicate that the ratio of non-renewable energy is higher than the ratio of renewable energy. Farm fertilizers can also be used in cotton plant production, instead of chemical fertilizers, which make up an important part of the inputs. Baran and Gokdogan [26] reported that, "The use of renewable energy is very low, indicating wheat production depends mainly on fossil fuels. Continuously rising fossil fuel prices have necessitated more efficient use of diesel, chemicals and fertilizers for wheat production. Efficient use of energy helps to achieve increased production and productivity levels, and contributes to economy, profitability and competitiveness of agricultural sustainability in rural life. Energy management should be considered as an important field in terms of an efficient, sustainable and economical use of energy [27]".

TABLE 4
Energy input in the form of direct, and direct renewable and non-renewable energy for cotton plant production

Type of energy	Energy input (MJ ha^{-1})	Ratio (%)
Direct energy [a]	14613.63	50.15
Indirect energy [b]	14524.48	49.85
Total	29138.11	100.00
Renewable energy [c]	3705.63	12.72
Non-renewable energy [d]	25432.48	87.28
Total	29138.11	100.00

[a] Includes human labour, diesel fuel and irrigation; [b] Includes seed, chemical fertilizers, chemicals and machinery;
[c] Includes human labour, seed and irrigation; [d] Includes diesel fuel, chemicals, chemical fertilizers and machinery.

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