Selcuk Journal of Agriculture and Food Sciences

http://sjafs.selcuk.edu.tr/sjafs/index

Research Article

SJAFS

(2022) 36 (2), 292-298

e-ISSN: 2458-8377

DOI:10.15316/SJAFS.2022.038

Determination of Energy Use Efficiency and Greenhouse Gas Emission (GHG) of Cotton Cultivation in Batman Province: A Case Study from Beşiri District

Mehmet Fırat BARAN [1,*], Osman GÖKDOĞAN[2]

[1] Siirt University, Faculty of Agriculture, Department of Biosystem Engineering, Siirt, Türkiye

[2] Isparta University of Applied Sciences, Faculty of Agriculture, Department of Agricultural Machinery and Technologies Engineering, Isparta, Türkiye

ARTICLE INFO

Article history:
Received date: 07.06.2022
Accepted date: 08.08.2022

Keywords:
Energy ratio,
Cotton,
GHG ratio,
Specific energy,
Turkey

ABSTRACT

In this research, the energy use efficiency (EUE) and greenhouse gas emissions (GHG) of cotton cultivation in Beşiri district of Batman province in Turkey were determined. This research was conducted through face-to-face surveys with 64 farms selected by simple random sampling method in the 2018-2019 cultivation season. The energy input (EI) and energy output (EO) in cotton cultivation were calculated as 52,302.62 MJ/ha and 60,341.03 MJ/ha. Energy inputs consist of electricity energy with 19,948.86 MJ/ha(38.14%), chemical fertilizers energy with 14,163.83 MJ/ha (27.08%), diesel fuel energy with 13,218.49 (25.27%), irrigation water energy with 2563.79 MJ/ha(4.90%), machinery energy with 1071.14 MJ/ha(2.05%), chemicals energy with 797.96 MJ/ha (1.53%), seed energy with 291.46 MJ/ha (0.56%) and human labour energy with 247.09 MJ/ha(0.47%), respectively. Total energy inputs in cotton cultivation can be categorized as 68.79% direct, 31.21% indirect, 5.93% renewable and 94.07% non-renewable. EUE, specific energy (SE), energy productivity (EP) and net energy (NE) in cotton cultivation were calculated as 1.15, 10.23 MJ/kg, 0.10 kg /MJ and 8038.41 MJ/ ha, respectively. Total GHG was calculated as 3742.59 $kgCO_{2-eq}$ ha^{-1} for cotton cultivation with the greatest share taken by nitrogen (26.19%). Nitrogen was followed by electricity (24.73%), irrigation water (18.48%), diesel fuel (17.31%), seed (5.04%), chemicals (2.93%), phosphorous (2.74%), human labour (2.36%), potassium (0.19%) and machinery (0.03%), respectively. GHG ratio value was calculated as 0.73 $kgCO_{2-eq}$ kg^{-1} in cotton cultivation.

1. Introduction

The cotton plant has a widespread use and its use is often mandatory. It has great economic importance for the producing countries with the added value and employment opportunities it creates. Few countries in the world have ecology suitable for cotton farming. For this reason, approximately 80% of world production is carried out by a small number of countries, including Turkey (Anonym 2019). According to the predictions of the International Cotton Advisory Board (ICAC) for the 2021/22 season, world cotton cultivation areas are 33.2 million ha, yield is 775 kg/ha, and cotton production is 25.7 million tons. It is estimated that the USA will have the largest share in the increase in production, increasing it to 3.96 million tons with an increase of 780 thousand tons compared to the previous season (ICAC 2021; Anonym 2022a). According to ICAC data, cotton consumption in Turkey in 2018/19 season is estimated to increase by 10% compared to the previous year and reach 1.6 million tons. With a production of this scale, Turkey will rank 5th in world cotton consumption. Almost all of the cotton cultivation in Turkey is carried out in the Aegean Region, Southeastern Anatolia Region, Çukurova and Antalya regions (Anonym 2019). Batman / Beşiri district, where the research was conducted, is located in the Southeastern Anatolia Region (Anonym 2022b).

Global warming is the most burning problem of the current century. It is described as the continuous rise in the average temperature of Earth's atmosphere and oceans and is caused by increased concentrations of greenhouse gases in the atmosphere, which are caused by human activities such as deforestation and burning of fossil fuels. On a scientific level, there is a consensus that global warming will continue to be one of the most significant environmental challenges in the future. There is no doubt that greenhouse gases (GHG) originate from fossil fuel consumption (Pathak and Wassmann 2007; Pishgar-Komleh et al. 2012a). Agricultural production

* Corresponding author email: *mfb197272@gmail.com*

in greenhouse is the most intensive global method, owing to its high yield and high amount of energy consumption per hectare (Sethi and Sharma 2007; Pishgar-Komleh et al. 2013). Agricultural production is conducted by using various input types, which consequently lead to some output energies and greenhouse gases (GHGs) in the process. Therefore, energy balance in agricultural crops and GHG emission arising from inputs are as important as the economic aspects of agricultural products. The type of crop has an impact on determining energy use and productivity of agricultural crops (Tsatsarelis, 1991; Afzalinia 2020).

There is no doubt that excessive use of fossil fuels, agrochemicals, machinery, electricity and other such inputs with the sole purpose of achieving a significant increase in food and fibre yield and improving nutrition has led to agricultural intensification. But on the other hand, extensive use of energy poses a threat to human health and the environment. Hence, a precondition of a sustainable agriculture is to ensure more efficient use of energy (Yilmaz et al. 2005; Kazemi et al. 2018). Getting to know the dynamics of energy usage in agricultural production is critical. Energy related problems are too many to mention but the main ones could probably be listed as insufficient resources, high production costs, erroneous resource allocation and the ever-growing national and international competition in agricultural trade. Hence, awareness of such restrictions is vital when it comes to implementing a sustainable agricultural production and self- sufficient resource allocation in cotton production (Dagistan et al. 2009). The efficiency and environmental impacts of a production system is usually determined through an energy input-output analysis. The results of such an analysis are important as they can be used to make the necessary improvements to ensure a more efficient and environment-friendly production system (Ozkan et al. 2003, Ozkan et al. 2004a; Oren and Akturk 2006).

Studies on EUE and GHG emissions have been made and continue to be done in the world and in Turkey. The examples include cotton (Singh et al. 2000; Yilmaz et al. 2005; Oren and Ozturk 2006; Kousar et al. 2006; Dagistan et al. 2009; Khan et al. 2009; Zahedi et al. 2014; Kazemi et al. 2018; Sami and Reyhani 2018; Semerci et al. 2019; Afzalinia 2020), tobacco (Moraditochaee 2012; Loghmanpour-zarini and Abedi-firouzjaee 2013; Baran and Gokdogan 2015), sugar beet (Hacıseferoğulları et al. 2003; Erdal et al. 2007; Baran and Gokdogan 2016), potato (Mohammadi et al. 2008; Pishgar-Komleh et al. 2012a; Gokdogan et al. 2018), sunflower (Baran et al. 2016; Bayhan 2016; Akdemir et al. 2017), canola (Unakitan et al. 2010; Baran et al. 2014), olive (Guzman and Alonso 2008; Gökdoğan and Erdoğan 2021), soybean (Mandal et al. 2002) etc. In the current research, calculations have been made on the EUE of cotton production and the results have been used to make assessments. In the current research area, it is important to make a detailed research on the efficiency of energy use in cotton production and GHG emissions, as it contributes to the literature.

2. Materials and Methods

Batman province is located between 41° 10' and 41° 40' east longitudes and 38° 40' and 37° 50' north latitudes (Anonym 2022b). Beşiri district of Batman, where the research was conducted, is the closest district to the centre and is considered the centre of industry and agriculture in Batman (Anonym 2022c).

This research was carried out with cotton growing agricultural enterprises in Beşiri district of Batman province of Turkey for the 2018-2019 production season and the number of participating enterprises was calculated as 64 according to the simple random sampling method and face-to-face surveys, observations and field studies were conducted with these enterprises.

2.1 Sampling Method

The formula (Eq. 1) of the method that was used to determine is given below (Çiçek and Erkan 1996).

$$n = \frac{N \times s^2 \times t^2}{(N-1)d^2 + (s^2 \times t^2)} \tag{1}$$

In the formula

n = Sample Size

s = Standard Deviation

t = "t value" Related to the Selected Confidence Limit

N = Total Number of Units for Sampling Frame

d = Acceptable margin of error (5%)

Agriculture and Forestry Directorate. previous studies have been used to calculate energy inputs and outputs and to determine the energy equivalent coefficients of inputs and outputs. The energy equivalents of the inputs and outputs used in agricultural production are given in Table 1. Energy output / input ratio (energy use efficiency), specific energy, energy productivity and net energy were calculated using the formulas given below (Equations 2-5) (Mandal et al. 2002; Mohammadi et al. 2008; 2010). All the data obtained in the research were transferred to the Excel program and evaluated.

$$\text{Energy use efficiency} = \frac{\text{Energy output } (\frac{MJ}{ha})}{\text{Energy input } (\frac{MJ}{ha})} \tag{2}$$

$$\text{Specific energy} = \frac{\text{Energy input } (\frac{MJ}{ha})}{\text{Yield output } (\frac{kg}{ha})} \tag{3}$$

$$\text{Energy productivity} = \frac{\text{Yield output } (\frac{kg}{ha})}{\text{Energy input } (\frac{MJ}{ha})} \tag{4}$$

$$\text{Net energy} = \text{Energy output} - \text{Energy input} \tag{5}$$

GHG values are calculated by multiplying the inputs with their GHG equivalent emission values. The results of the calculations are shown in Table 2. A production related GHG table has been composed and the GHG ratio calculation has been made. With regards to Karaağaç et al. (2019); the following formula (Eq. 6) adapted by Hughes et al. (2011) over the suggestion of was used to determine the GHG emission.

$$GHG_{ha} = \sum_{i=1}^{n} R(i) \; x \; EF(i) \tag{6}$$

GHG_{ha}: GHG ($kgCO_{2\text{-eş}}$ ha^{-1})

R(i): Application amount of (i) input ($unit_{input}$ ha^{-1})

EF(i) : GHG emission equivalent of (i) input ($kgCO_{2\text{-eq}}$ $unit_{input}^{-1}$)

GHG ratio is an index defined as GHG emission quantity per kg yield. Calculation of GHG ratio has been based on the formula (Equation 7) given below and adapted by Karaağaç et al. (2019), Houshyar et al. (2015) and Khoshnevisan et al. (2014).

$$I_{GHG} = \frac{GHG_{ha}}{Y} \qquad (7)$$

IGHG: GHG ratio (kgCO2-eş kg-1)

Y : Yield (kg/ ha)

Input energy is classified as direct, indirect, renewable and non-renewable. While indirect energy consists of pesticide and fertiliser, direct energy includes man and animal power, diesel and electric energy used during the production process. Non-renewable energy consists of oil, diesel, electric, chemicals, fertilisers and machinery. Renewable energy, on the other hand, includes man and animal power (Mandal et al. 2002; Singh et al. 2003; Koctürk and Engindeniz 2009). Energy balance, energy use efficiency calculations, energy input types and GHG calculations in cotton production are given in Table3-6.

Table 1
Energy equivalents used in agricultural production

Inputs	Unit	Energy equivalent (MJ/unit)	References
Human labour	h	1.96	Mani et al. (2007); Karaağaç et al. (2011)
Machinery	h	64.80	Singh (2002); Kizilaslan (2009)
Chemicals	kg	101.20	Yaldiz et al. (1993); Ozkan et al. (2004b)
Chemical fertilizers			
Nitrogen	kg	60.60	Singh (2002); Demircan et al. (2006)
Phosphorus	kg	11.10	Mandal et al. (2002); Ozalp et al. (2018)
Potassium	kg	6.70	Mandal et al. (2002); Ozalp et al. (2018)
Micro elements	kg	120	Mandal et al. (2002); Singh (2002); Canakci and Akinci (2006); Banaeian et al. (2011)
Irrigation water	m^3	0.63	Yaldiz et al. (1993); Demircan et al. (2006)
Electricity	kWh	3.60	Ozkan et al. (2004b)
Diesel fuel	l	56.31	Singh (2002); Demircan et al. (2006)
Seed	kg	11.80	Singh (2002); Yilmaz et al. (2005)
Output			
Cotton	kg	11.80	Singh (2002); Yilmaz et al. (2005)

Table 2
GHG emissions coefficients in agriculture production*

Inputs	Unit	GHG coefficients ($kgCO_{2\text{-eq}}$ $unit^{-1}$)	References
Human labour	h	0.700	Nguyen and Hermansen (2012)
Machinery	MJ	0.071	Pishgar-Komleh et al. (2012a)
Chemicals	kg	13.900	BioGrace-II (2015)
Nitrogen	kg	4.570	BioGrace-II (2015)
Phosphorus	kg	1.180	BioGrace-II (2015)
Potassium	kg	0.640	BioGrace-II (2015)
Irrigation water	m^3	0.170	Lal (2004)
Electricity	kWh	0.167	BioGrace-II (2015)
Diesel fuel	l	2.760	Clark et al. (2016)
Seed	kg	7.630	Clark et al. (2016)

*Adapted from Eren et al. (2019)

3. Results and Discussion

The average cotton yield per hectare of the 64 cotton enterprises that took part in the research has been calculated as 5113.65 kg/ ha. Energy balance (EB) in cotton cultivation is given in Table 3. According to Table 2, the inputs in cotton production are electricity energy by 19,948.86 MJ/ha (38.14%), chemical fertilizers energy by 14,163.83 MJ/ ha (27.08%), diesel fuel energy by 13,218.49 MJ/ha (25.27%), irrigation water energy by 2563.79 MJ/ha (4.90%), machinery energy by 1071.14 MJ/ha (2.05%), chemicals energy by 797.96 MJ/ha (1.53%), seed energy by 291.46 MJ/ha (0.56%) and human labour energy by 247.09 MJ/ha (0.47%). Similar results were found in other researches on cotton cultivation. Semerci et al. (2019), Afzalinia (2020) calculated the ratio of electricity as 58.77% among the most used energy inputs. In other researches, Dagistan et al. (2009), Pishgar-Komleh et al. (2012b), Sami and Reyhani (2018) calculated the chemical fertilizers as the most used energy inputs.

Table 3
EB in cotton cultivation

Inputs	Input used per hectare (unit / ha)	Energy value (MJ/ha)	Ratio (%)
Human labour	126.07	247.09	0.47
Machinery	16.53	1071.14	2.05
Chemicals	7.89	797.96	1.53
Chemical fertilizers	313.50	14,163.83	27.08
Nitrogen	214.51	12,999.31	24.85
Phosphorus	87.02	965.92	1.85
Potassium	10.93	73.20	0.14
Micro elements	1.05	125.40	0.24
Irrigation water	4069.52	2563.79	4.90
Electricity	5541.35	19,948.86	38.14
Diesel fuel	234.75	13,218.49	25.27
Seed	24.70	291.46	0.56
Total inputs	-	52,302.62	100.00
Output	Output per hectare (unit/ha)	Energy value (MJ/ ha)	Ratio (%)
Cotton	5113.65	60,341.03	100.00
Total output	-	60,341.03	100.00

In this research, EUE, SE, EP and NE were calculated as 1.15, 10.23 MJ/kg, 0.10 kg/MJ and 8038.41 MJ/ha, respectively (Table 4). In other researches relating to cotton cultivation, Pishgar-Komleh et al (2012b) calculated EUE, SE, EP and NE as 1.85, 9.31 MJ/kg, 0.11 kg/ MJ and 27,218 MJ/ha; Zahedi et al. (2014) calculated EUE, SE, EP and NE as 0.7, 19.2 MJ/kg, 0.1 kg/MJ and -15,625.2 MJ/ha; Dagistan et al. (2009) calculated EUE, SE, EP and NE as 2.36, 4.99 MJ/kg, 0.20 kg/MJ and 26,663 MJ/ha; Sami and Reyhani (2018) calculated EUE, SE and EP as 1.21, 9.8 MJ/kg, 0.1 kg/MJ; Semerci et al. (2019) calculated EUE, SE, EP and NE as 1.11, 10.66 MJ/kg, 0.09 kg/MJ and 6136.29 MJ/ha^{-1}, respectively.

Table 4
Calculations of EUE in cotton cultivation

Calculations	Unit	Values
Cotton	kg/ha	5113.65
Energy input	MJ/ha	52,302.62
Energy output	MJ/ha	60,341.03
Energy use efficiency	-	1.15
Specific energy	MJ/kg	10.23
Energy productivity	kg/MJ	0.10
Net energy	MJ/ha	8038.41

The consumed total energy input was grouped as 68.79% DE, 31.21% IE, 5.93% RE and 94.07% N-RE (Table 5). Similarly, in other researches relating to cotton cultivation, Zahedi et al. (2014), Kazemi et al. (2018), Semerci et al. (2019), Afzalinia (2020), Baran et al. (2021) calculated DE ratio to be higher than IE. Similarly, N-RE energy ratio was calculated to be higher than RE by Dagistan et al. (2009), Yilmaz et al. (2010), Zahedi et al. (2014), Kazemi et al. (2018), Sami and Reyhani (2018), Semerci et al. (2019), Afzalinia (2020), Baran et al. (2021) in cotton cultivation.

Table 5
Calculations of energy input types in cotton cultivation

Energy groups	Energy input (MJ/ha)	Ratio (%)
Direct energy[a]	35,978.23	68.79
Indirect energy[b]	16,324.39	31.21
Total	52,302.62	100.00
Renewable energy[c]	3102.34	5.93
Non-renewable energy[d]	49,200.28	94.07
Total	52,302.62	100.00

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

The GHG emission values are shown in Table 6. Total GHG emissions were calculated as 3742.59 kgCO_{2-eq}ha^{-1} for cotton cultivation and GHG ratio as 0.73. GHG emissions have been related to nitrogen by 26.19%, electricity by 24.73%, irrigation water usage by 18.48%, diesel fuel usage by 17.31%, seed usage by 5.04, chemicals usage by 2.93%, phosphorous usage by 2.74%, human labour usage by 2.36%, potassium usage by 0.19%

and machinery usage by 0.03%, respectively. A study conducted by Pishgar-Komleh et al (2012b) calculated the total GHG emission of cotton cultivation as 1195.25 $kgCO_{2-eq}ha^{-1}$, Sami and Reyhani (2018) calculated the total GHG emission of cotton cultivation as 2075.5 $kgCO_{2-eq}ha^{-1}$, Pishgar-Komleh et al (2012a) calculated the total GHG emission of potato production as 992.88 $kgCO_{2-eq}ha^{-1}$.

Table 6
GHG emissions in cotton cultivation

Inputs	Unit	GHG coefficients ($kgCO_{2-eq}$ $unit^{-1}$)	Input (unit/ha)	GHG emissions ($kgCO_{2-eq}$ ha^{-1})	Ratio (%)
Human labour	h	0.700	126.07	88.25	2.36
Machinery	MJ	0.071	16.53	1.17	0.03
Chemicals	kg	13.900	7.89	109.60	2.93
Nitrogen	kg	4.570	214.51	980.31	26.19
Phosphorus	kg	1.180	87.02	102.68	2.74
Potassium	kg	0.640	10.93	6.99	0.19
Irrigation water	m^3	0.170	4069.52	691.82	18.48
Electricity	kWh	0.167	5541.35	925.41	24.73
Diesel fuel	l	2.760	234.75	647.90	17.31
Seed	kg	7.630	24.70	188.46	5.04
Total inputs	-	-	-	3742.59	100.00
GHG ratio	-	-	-	0.73	-

4. Conclusions

The findings of this study can be summarised as follows.

In this research, total energy input and output were calculated as 52,302.62 and 60,341.03 MJ/ ha, respectively. The electricity energy, chemical fertilizers and diesel fuel had the highest share in energy usage for cotton cultivation, amounting to 19,948.86, 14,163.83, 13,218.49 MJ/ ha. EUE, SE, EP and NE were calculated as 1.15, 10.23 MJ/kg, 0.10 kg/MJ and 8038.41 MJ/ ha, respectively.

The consumed total energy input was grouped as 68.79% DE, 31.21% IE, 5.93% RE and 94.07% N-RE.

Total GHG emissions were calculated as 3742.59 $kgCO_{2-eq}ha^{-1}$ for cotton cultivation and GHG ratio as 0.73.

Efficiency usage of energy source is important to decrease operating cost and decrease emissions of air contaminants and greenhouse gases (Demirbas and Urkmez 2006; Mujeebu et al. 2009a; 2009b; Ekinci 2011). Taking the recommendations proposed by this study into consideration can contribute to better energy use efficiency in the future.

Decreasing electricity, chemical fertilizer and diesel fuel usage are the priorities in cotton cultivation for EUE. For this purpose, according to Pishgar-Komleh et al. (2012b), applying soil analysis to determine soil fertilizer needs (to reduce high chemical fertilizers energy utilization and GHG emission), matching equipment to tractors, fuel efficiency and applying minimum or zero tillage (to reduce diesel fuel utilization) is proposed.

5. Acknowledgements:

This research was submitted as oral abstract in 33th National Agricultural Mechanization and Energy Congress (Online) 1-3 Oct 2021, Isparta, Turkey.

6. References

Afzalinia S (2020). Tillage effects on energy use and greenhouse gas emission in wheat-cotton rotation. Iran Agricultural Research 39(1):13-24

Akdemir S, Calavaris C, Gemtos T (2017). Energy balance of sunflower production. Agronomy Research 15(4):1463-1473

Anonym (2019). T.C. Ticaret Bakanlığı, Esnaf, Sanatkârlar ve Kooperatifçilik Genel Müdürlüğü. 2018 Yılı Pamuk Raporu.https://ticaret.gov.tr/data/5d41e59913b87639ac9e02e8/d0e2b9c79234684ad29baf256a0e7dce.pdf Nisan 2019 Accessed 06 Apr 2022

Anonym (2022a). T.C. Tarım ve Orman Bakanlığı, Strateji Geliştirme Başkanlığı, TEPGE. Tarım Ürünleri Piyasaları, Pamuk (Dr. Tijen Özüdoğru) https://arastirma.tarimorman.gov.tr/tepge/Belgeler/PDF%20Tar%C4%B1m%20%C3%9Cr%C3%BCnleri%20Piyasalar%C4%B1/2022-Ocak%20Tar%C4%B1m%20%C3%9Cr%C3%BCnleri%20Rapor%C4%B1/Pamuk,%20Ocak-2022%20Tar%C4%B1m%20%C3%9Cr%C3%BCnleri%20Piyasa%20Raporu--+.pdf Accessed 06 Apr 2022

Anonym (2022b). T.C. Kültür ve Turizm Bakanlığı, Batman İl Kültür ve Turizm Müdürlüğü.https://batman.ktb.gov.tr/TR-56576/cografya.html Accessed: 05 Apr 2022

Anonym (2022c). T.C. Sanayi ve Teknoloji Bakanlığı. Dicle Kalkınma Ajansı https://www.dika.org.tr/batman/ilceler/sanayi-ve-tarimin-merkezi-besiri Accessed: 05 Apr 2022

Banaeian N, Omid M, Ahmadi H (2011). Energy and economic analysis of greenhouse strawberry production in Tehran province of İran. Energy Conversion & Management 52:1020-1025

Baran MF, Gökdoğan O, Karaağaç HA (2014). Kanola üretiminde enerji kullanım etkinliğinin belirlenmesi (Kırklareli İli Örneği). Türk Tarım ve Doğa Bilimleri Dergisi 1(3):331-337 (in Turkish)

Baran MF, Gokdogan O (2015). Determination of energy input-output of tobacco production in Turkey. American-Eurasian J. Agric. & Environ. Sci. 15(7):1346-1350

Baran MF, Gokdogan O (2016). Determination of energy balance of sugar beet production in Turkey: a case study of Kırklareli Province. Energy Efficiency 9(2): 487-494

Baran MF, Polat R, Gokdogan O (2016). Comparison of energy use efficiency of different tillage methods on the secondary crop sunflower production. Fresenius Environmental Bulletin 25(11):4937-4943

Baran MF, Gökdoğan O, Yilmaz Y (2021). Determination of energy balance and greenhouse gas emissions (GHG) of cotton cultivation in Turkey: A case study from Bismil district of Diyarbakır province. Tekirdağ Ziraat Fakültesi Dergisi 18(2):322-332

Bayhan Y (2016). İkinci ürün ayçiçeği üretiminde farklı toprak işleme ve doğrudan ekim yöntemlerinin enerji kullanım etkinliğinin karşılaştırılması. Tekirdağ Ziraat Fakültesi Dergisi 13(2):102-109 (in Turkish)

BioGrace-II (2015). Harmonised calculations of biofuel greenhouse gas emissions in Europe. BioGrace, Utrecht, The Netherlands. http://www.biograce.net

Canakci M, Akinci I (2006). Energy use pattern analyses of greenhouse vegetable production. Energy 31:1243-56

Clark S, Khoshnevisan B, Sefeedpari P (2016). Energy efficiency and greenhouse gas emissions during transition to organic and reduced-input practices: Student farm case study. Ecological Engineering 88:186-194

Çiçek A, Erkan O (1996). Tarım Ekonomisinde Araştırma ve Örnekleme Yöntemleri. Gaziosmanpaşa Universitesi, Ziraat Fakültesi Yayınları, No:12, Ders Notları Serisi No:6, Tokat, Türkiye (in Turkish)

Dagistan E, Akcaoz H, Demirtas B, Yilmaz Y (2009). Energy usage and benefit-cost analysis of cotton production in Turkey. African Journal of Agricultural Research 4(7):599-604

Demirbas A, Urkmez A (2006). Biomass-based combined heat and power systems. Energy Source, Part B - Economics, Planning and Policy 1(3):245-253

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

Ekinci K (2011). Utilization of apple pruning residues as a source of biomass energy: A case study in Isparta province. Energy Exploration & Exploitation 29(1):87-107

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

Eren O, Gokdogan O, Baran MF (2019). Determination of greenhouse gas emissions (GHG) in the production of different plants in Turkey. Fresenius Environmental Bulletin 28(2A):1158-1166

Gokdogan O, Bagdatli MC, Erdogan O (2018). The determination with geographic information systems (GIS) mapping of the energy use efficiency of potato production areas in Turkey: A study in Nevsehir province. Fresenius Environmental Bulletin 27(12A):8917-8927

Gökdoğan O, Erdoğan, O (2021) .Determining the Energy use efficiency and greenhouse gas emissions (GHG) in olive farming. European Journal of Science and Technology (23):717-724

Guzman GI, Alonso AM (2008). A comparison of energy use in conventional and organic olive oil production in Spain. Agricultural Systems 98:167-176

Hacıseferoğulları H, Acaroğlu M, Gezer İ (2003). Determination of the energy balance of the sugar beet plant. Energy Sources 25:15-22

Houshyar E, Dalgaard T, Tarazgar MH, Jorgensen U (2015). Energy input for tomato production what economy says, and what is good for the environment. Journal of Cleaner Production 89:99-109

Hughes DJ, West JS, Atkins SD, Gladders P, Jeger MJ, Fitt BD (2011). Effects of disease control by fungicides on greenhouse gas emissions by U.K. arable crop production. Pest Manag Sci 67:1082-1092.

ICAC (2021). International Cotton Advisory Committee. Cotton World Statistics, Nov 2021

Karaağaç HA, Aykanat S, Çakır B, Eren Ö, Turgut MM, Barut ZB, Öztürk HH (2011). Energy balance of wheat and maize crops production in Hacıali undertaking. 11th International Congress on Mechanization and Energy in Agriculture Congress, Istanbul, Turkey, 21-23 September, 388-391

Karaağaç HA, Baran MF, Mart D, Bolat A, Eren Ö (2019). Nohut üretiminde enerji kullanım etkinliği ve sera gazı (GHG) emisyonunun belirlenmesi (Adana ili örneği). Avrupa Bilim ve Teknoloji Dergisi (16):41-50 (in Turkish)

Kazemi H, Shokrgozar M, Kamkar B, Soltani A (2018). Analysis of cotton production by energy indicators in two different climatic regions. Journal of Cleaner Production 190:729-736

Khan MA, Khan S, Mushtaq (2009). Energy and economic efficiency analysis of rice and cotton production in China. Sarhad J. Agric. 25(2):291-300

Khoshnevisan B, Shariati HM, Rafiee S, Mousazadeh H (2014). Comparison of energy con-sumption and GHG emissions of open field and greenhouse strawberry production. Renewable and Sustainable Energy Reviews 29:316-324

Kizilaslan H (2009). Input-output energy analysis of cherries production in Tokat province of Turkey. Applied Energy 86:1354-1358

Koctürk OM, Engindeniz S (2009). Energy and cost analysis of sultana grape growing: A case study of Manisa, west Turkey. African Journal of Agricultural Research 4(10):938-943

Kousar R, Makhdum MSA, Yaqoob S, Saghir A (2006). Economics of energy use in cotton production on small farms in district Sahiwal, Punjab, Pakistan. Journal of Agriculture & Social Sciences 2(4):219-221

Lal R (2004). Carbon emission from farm operations. Environment International 30:981-990

Loghmanpour-zarini R, Abedi-firouzjaee R (2013). Energy and water use indexes for tobacco production under different irrigation systems in Iran. International Journal of Agriculture and Crop Sciences 5(12):1332-1339

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

Mani I, Kumar P, Panwar JS, Kant K (2007). Variation in energy consumption in production of wheat-maize with varying altitudes in hill regions of Himachal Prades. India Energy 32:2336-2339

Mohammadi A, Tabatabaeefar A, Shahin S, Rafiee S, Keyhani A (2008). Energy use and economical analysis of potato production in Iran a case study: Ardabil province. Energy Conversion Management 49:3566-3570

Mohammadi A, Rafiee S, Mohtasebi SS, Rafiee H (2010). Energy inputs-yield relationship and cost analysis of kiwifruit production in Iran. Renewable Energy 35:1071-1075

Moraditochaee M (2012). Study energy indices of tobacco production in north of Iran. Agricultural and Biological Science 7(6):462-465

Mujeebu MA, Jayaraj S, Ashok S, Abdullah MZ, Khalil M (2009a). Feasibility study of cogeneration in a plywood industry with power export to grid. Applied Energy 86(5):657-662

Mujeebu MA, Abdullah MZ, Ashok S (2009b). Viability of biomass fueled steam turbine cogeneration with power export for an Asian plywood industry. Energy Exploration & Exploitation 27(3):213-224

Nguyen TLT, Hermansen JE (2012). System expansion for handling co-products in LCA of sugar cane bio-energy systems: GHG consequences of using molasses for ethanol production. Applied Energy 89:254-261.

Oren MN, Ozturk HH (2006). An analysis of energy utilization for sustainable wheat and cotton production in Southeastern Anatolia Region of Turkey. Journal of Sustainable Agriculture 29(1):119-130

Ozalp A, Yilmaz S, Ertekin C, Yilmaz I (2018). Energy analysis and emissions of greenhouse gases of pomegranate production in Antalya province of Turkey. Erwerbs Obstbau 60(4):321-329

Ozkan B, Akcaoz H, Karadeniz F (2003). Energy requirement and economic analysis of citrus production in Turkey. Energy Conversion and Management 45(11-12):1821-1830

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

Ozkan B, Kurklu A, Akcaoz H (2004b). An input-output energy analysis in greenhouse vegetable production: A case study for Antalya region of Turkey. Biomass Bioenergy 26:89-95

Pathak H, Wassmann R (2007). Introducing greenhouse gas mitigation as a development objective in rice-based agriculture: I. Generation of technical coefficients. Agricultural Systems 94:807-825

Pishgar-Komleh SH, Ghahderijani M, Sefeedpari P (2012a). Energy consumption and CO2 emissions analysis of potato production based on different farm size levels in Iran. Journal of Cleaner Production 33:183-191

Pishgar-Komleh SH, Sefeedpari P, Ghahderijani M (2012b). Exploring energy consumption and CO2 emission of cotton production in Iran. Journal of Renewable and Sustainable Energy 4:033115

Pishgar-Komleh SH, Omid M, Heidari MD (2013). On the study of energy use and GHG (greenhouse gas) emissions in greenhouse cucumber production in Yazd province. Energy 59:63-71

Sami M, Reyhani H (2018). Energy and greenhouse gases balances of cotton farming in Iran: A case study. Acta Universitatis Agriculturae Et Silviculturae Mendelianae Brunensis 66(1):101-109

Semerci A, Baran MF, Gokdogan O, Celik AD (2019). Determination of energy use efficiency of cotton production in Turkey: A Case Study From Hatay Province. Fresenius Environmental Bulletin 27(4):1829-1835

Sethi VP, Sharma SK (2007). Greenhouse heating and cooling using aquifer water. Energy 32:1414-21

Singh S, Singh S, Pannu CJS, Singh J (2000) Optimization of energy input for raising cotton crop in Punjab. Energy Conversion & Management 41:1851-1861

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

Singh H, Mishra D, Nahar NM, Ranjan M (2003). Energy use pattern in production agriculture f a typical village in arid zone India: part II. Energy Conversion and Management 44:1053-1067

Tsatsarelis CA (1991). Energy requirements for cotton production in central Greece. Journal of Agricultural Engineering Research 50: 239-246

Unakıtan G, Hurma H, Yılmaz F (2010). An analysis of energy use efficiency of canola production in Turkey. Energy 35:1-5

Yaldiz O, Ozturk HH, Zeren Y, Bascetincelik A (1993). Energy usage in production of field crops in Turkey. 5th International Congress on Mechanization and Energy in Agriculture, İzmir, 11-14 October, 527-536 (in Turkish)

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

Zahedi M, Eshghizadeh HR, Mondani F (2014). Energy use efficiency and economical analysis in cotton production system in an arid region: A case study for Isfahan province, Iran. International Journal of Energy Economics Policy 4(1):43-52.