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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Determination of Energy Balance and Greenhouse Gas Emissions (GHG) of Cotton Cultivation in Turkey: A Case Study from Bismil District of Diyarbakır Province

Türkiye'de Pamuk Yetiştiriciliğinin Enerji Bilançosu ve Sera Gazı Emisyonlarının Belirlenmesi: Diyarbakır İli Bismil İlçesi Örneği

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Abstract

In this study, the energy balance and Greenhouse Gas Emissions (GHG) of cotton cultivation in Bismil district of Diyarbakır province in Turkey was defined. The energy balance and GHG of cotton cultivation was computed by conducting face to face surveys with 73 farms in the 2018-2019 cultivation season, which were selected by simple random sampling method. The energy input and output in cotton cultivation were computed as 54 617.62 MJ ha^{-1} and 65 984.42 MJ ha^{-1}, respectively. Energy inputs occurs of electricity energy with 18 608.40 MJ ha^{-1} (34.06%), chemical fertilizers energy with 15 254.67 MJ ha^{-1} (27.93%), diesel fuel energy with 14 364.68 (26.30%), irrigation water energy with 3 559.50 MJ ha^{-1} (6.53%), machinery energy with 1 152.79 MJ ha^{-1} (2.11%), chemicals energy with 1 075.76 MJ ha^{-1} (1.96%), seed energy with 307.98 MJ ha^{-1} (0.57%), human labour energy with 293.84 MJ ha^{-1} (0.54%), respectively. Total energy inputs in cotton cultivation can be classified as 67.43% direct, 32.57% indirect, 7.62% renewable and 92.38% non-renewable. Energy use efficiency, specific energy, energy productivity and net energy in cotton cultivation were computed as 1.21, 9.77 MJ kg^{-1}, 0.10 kg MJ^{-1} and 11 366.80 MJ ha^{-1}, respectively. Total GHG emissions were computed as 6 482.36 $kgCO_{2-eq}ha^{-1}$ for cotton cultivation with the greatest input part for electricity with 47.94% (3 107.60 $kgCO_{2-eq}ha^{-1}$). The electricity followed up nitrogen with 16.29% (1 055.67 $kgCO_{2-eq}ha^{-1}$), irrigation water with 14.82% (960.50 $kgCO_{2-eq}ha^{-1}$), diesel fuel with 10.86% (704.08 $kgCO_{2-eq}ha^{-1}$), seed with 3.07% (199.14 $kgCO_{2-eq}ha^{-1}$), chemicals with 2.28% (147.76 $kgCO_{2-eq}ha^{-1}$), phosphorous with 1.78% (115.64 $kgCO_{2-eq}ha^{-1}$), human labour with 1.62% (104.94 $kgCO_{2-eq}ha^{-1}$), machinery with 1.26% (81.85 $kgCO_{2-eq}ha^{-1}$) and potassium with 0.08% (5.18 $kgCO_{2-eq}ha^{-1}$), respectively. Additionally, GHG ratio value was computed as 1.16 $kgCO_{2-eq}kg^{-1}$ in cotton cultivation.

Keywords: Energy use efficiency, Energy productivity, GHG ratio, Net energy, Specific energy

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Özet

Bu çalışmada Türkiye'nin Diyarbakır ilinin Bismil ilçesinde pamuk yetiştiriciliğinin enerji bilançosu ve sera gazı emisyonlarının belirlenmesi amaçlanmıştır. 2018-2019 yetiştiricilik sezonunda basit tesadüfi örnekleme yöntemine göre seçilen 73 işletme ile yüzyüze anket yapılarak pamuk yetiştiriciliğinin enerji bilançosu ve sera gazı emisyonu hesaplanmıştır. Pamuk yetiştiriciliğinde enerji girdisi ve enerji çıktısı sırasıyla 54 617.62 MJ ha^{-1} ve 65 984.42 MJ ha^{-1} olarak hesaplanmıştır. Girdiler sırasıyla 18 608.40 MJ ha^{-1} (34.06%) ile elektrik enerjisi, 15 254.67 MJ ha^{-1} (27.93%) ile kimyasal gübre enerjisi, 14 364.68 (26.30%) ile dizel yakıt enerjisi, 3 559.50 MJ ha^{-1} (6.53%) ile sulama suyu enerjisi, 1 152.79 MJ ha^{-1} (2.11%) ile makine enerjisi, 1 075.76 MJ ha^{-1} (1.96%) ile kimyasal enerji, 307.98 MJ ha^{-1} (0.57%) ile tohum enerjisi, 293.84 MJ ha^{-1} (0.54%) ile insan işgücü enerjisinden oluşmaktadır. Pamuk yetiştiriciliğinde toplam girdi enerjisinin %67.43'ü doğrudan, %32.57'si dolaylı, %7.62'si yenilenebilir ve %92.38'i ise yenilenemez olarak sınıflandırılabilir. Pamuk yetiştiriciliğinde enerji kullanım etkinliği, spesifik enerji, enerji verimliliği ve net enerji sırasıyla 1.21, 9.77 MJ kg^{-1}, 0.10 kg MJ^{-1} ve 11 366.80 MJ ha^{-1} olarak hesaplanmıştır. Pamuk yetiştiriciliğinde toplam sera gazı emisyonu 6 482.36 $kgCO_{2\text{-eş}}ha^{-1}$ olarak hesaplanmış olup, en büyük oran %47.94 (3 107.60 $kgCO_{2\text{-eq}}ha^{-1}$) ile elektrik olarak hesaplanmıştır. Elektriği sırasıyla %16.29 (1 055.67 $kgCO_{2\text{-eş}}ha^{-1}$) ile azot, %14.82 (960.50 $kgCO_{2\text{-eş}}ha^{-1}$) ile sulama suyu, %10.86 (704.08 $kgCO_{2\text{-eş}}ha^{-1}$) ile dizel yakıt, %3.07 (199.14 $kgCO_{2\text{-eş}}ha^{-1}$) ile tohum, %2.28 (147.76 $kgCO_{2\text{-eş}}ha^{-1}$) ile kimyasallar, %1.78 (115.64 $kgCO_{2\text{-eş}}ha^{-1}$) ile fosfor, %1.62 (104.94 $kgCO_{2\text{-eş}}ha^{-1}$) ile insan işgücü, %1.26 (81.85 $kgCO_{2\text{-eş}}ha^{-1}$) ile makine ve %0.08 (5.18 $kgCO_{2\text{-eş}}ha^{-1}$) ile potasyum takip etmiştir. Ayrıca pamuk yetiştiriciliğinde GHG oranı 1.16 $kgCO_{2\text{-eş}}kg^{-1}$ olarak hesaplanmıştır.

Anahtar Kelimeler: Enerji kullanım etkinliği, Enerji verimliliği, GHG oranı, Net enerji, Spesifik enerji

1. Introduction

Cotton is one of the most important products in the world agriculture, industry and trade because of its very different and important utilization areas. In addition to the increasing world population, the increasing needs of human beings for consumption increase, the importance of this versatile plant day by day. Growing interest in natural fibers and rising living standards in the world increases the demand for cotton plants (Anonymous, 2020a). According to the data of the International Cotton Advisory Committee (ICAC), 32.825 million hectares of cotton were cultivated in the world in the 2018/19 cultivation period. In this season, 37% of the 32.825 million hectares of cotton cultivated in India. India is followed by the USA, China, Pakistan and Brazil in the width of the cultivation areas. As the result of the expansion of cotton cultivation areas in African countries in recent years, despite the grow, Turkey has ranked 11th in terms of world cotton cultivation area (Anonymous, 2020b).

It is an important industrial plant that constitutes the raw materials with fiber in textile industry, oil obtained from its core in vegetable oil industry, aperture and pulp in animal feed industry, linters in paper, furniture and cellulose industry. Cotton is an important and strategic product that provides great benefits to our country's economy with this wide area of use, added value and employment opportunities. Due to these features, it has a contribution to the development of both agriculture and industry of the regions and countries grown (Anonymous, 2020c). Areas where have intensive cotton cultivation in Turkey; Aegean, Çukurova, Southeastern Anatolia Regions and Antalya. In the 2017/18 cotton season, in 502 thousand hectares 882 thousand tons of cotton fiber cultivation was made, and about 1 million 571 thousand tons of cotton was consumed in Turkey. In the 2017/18 cotton cultivation season, in return to 882 thousand tons of fiber cotton, 2.5 million tons of seed cotton was cultivated, and fiber cotton yield was 1 820 kg ha^{-1}. Şanlıurfa, Aydın, Hatay, Diyarbakır, Adana and İzmir have 6 provinces in Turkey that meets 88% of cultivation, respectively. Şanlıurfa province alone meets 42% of all production. The share of the other 23 cotton cultivating provinces in cultivation is between 0.1% and 1.3% (Anonymous, 2020d). Since cotton is a selective plant in terms of climate characteristics, it can be grown in limited places in our country (Karademir et al. 2015).

Semerci et al. (2019) reported that; "Agricultural production is widely mechanised which is powered by fossil fuels. Although this provides more income, it decreases the level of labor force usage. Especially in developed countries, fossil fuel usage levels in agricultural production are quite high, and the side effects of unconscious energy consumption makes planned energy consumption inevitable (Öztürk et al., 2015; Çelen, 2016)". In order to evaluate productivity, it is a more practical approach to check the total energy value that is used in agricultural production, to the energy value that is used from agricultural production (Öztürk, 2011). In production efficiency is defined as the ratio of the sum of weighted outputs to the sum of weighted inputs or as the ratio of the actual output to the optimal output. The weights for inputs and outputs are guessed to the best benefit for each unit so as to maximize its relative efficiency (Mukherjee, 2008; Mousavi-Avval et al., 2011). Rising the usage of energy inputs in agriculture led to numerous environmental issues like high consumption of non-renewable energy resources, loss of biodiversity, pollution of the aquatic environment by the nutrients N and P as well as by pesticides (Nemecek et al., 2011; Khoshnevisan et al., 2013). Global warming is one of the most important subjects in the last time. Agricultural GHG emissions account for 10-12% of all anthropogenic GHG emissions (Brown et al., 1998; Khoshnevisan et al., 2013).

Several studies were performed on cotton agriculture energy balance in agricultural production. Studies were done on energy balance of cotton (Singh et al., 2000; Yılmaz et al. 2005; Ören and Öztürk, 2006; Polat et al. 2006; Dağıstan et al. 2009; Şehri 2012; Zahedi et al. 2014; Baran, 2016; Semerci et al., 2019). Many studies were performed on energy balance in agricultural products. For example, studies were done on energy use efficiency of maize (Konak et al., 2004), wheat (Tipi et al., 2009; Çiçek et al., 2011; Gökdoğan and Sevim, 2016; Unakıtan and Aydın, 2018), legume (Ertekin et al., 2010), lentil (Asakereh et al., 2010), corn silage (Barut et al., 2011), sunflower (Bayhan, 2016; Akdemir et al. 2017; Unakıtan and Aydın, 2018), chickpea (Marakoğlu and Çarman, 2009; Marakoğlu et al., 2010; Karaağaç et al., 2019), sesame (Baran and Gokdogan, 2017), tomato (Hatırlı et al., 2005; Esengün et al., 2007; Saltuk, 2019). For example, studies were performed on GHG of cotton (Pishgar-Komleh et al., 2012a), potato (Pisghar-Komleh et al., 2012b), wheat (Khoshnevisan et al., 2013), rice (Maraseni et al., 2018), field crops (Eren et al., 2019) etc. No studies related to the energy balance and GHG of cotton cultivation in Diyarbakır province has been covered in this study. In this study, it was aimed to define the energy balance and GHG in cotton cultivation in Bismil district of Diyarbakır province.

2. Materials and Methods

Diyarbakır province is in the central part of the Southeastern Anatolia Region at the northern end of Mesopotamia. Siirt, Muş from the east; Mardin from the south; Şanlıurfa, Adıyaman, Malatya from the west; It is surrounded by the provinces of Elazığ and Bingöl from the north. Its area is 1 516 200 km^2, between 37.905199 and 40.231934 north latitudes and 40.37 and 41.20 east longitudes. It is surrounded by mountains that are not too high and its middle is hollow. It is covered with 37% of mountains and 31% of plains. The plains are suitable for agriculture and fertile. These fertile lands are irrigated by the Tigris River and its tributaries. It is 650 m above sea level. This height is 640 m in some places and 660 m in some places (Anonymous, 2020e). Main material of this study consisted of primary data that were collected from 73 cotton farms in Bismil district of Diyarbakır province in Turkey by face to face in 2018-2019 cultivation season. Data of the study were collected from cotton farms which were defined by the Simple Random Sampling Method. The equation 1 of the method that was used to define the sample size was given below (Çiçek and Erkan, 1996).

$$n = \frac{N \times s^2 \times t^2}{(N-1)d^2 + (s^2 \times t^2)} \qquad \text{(Eq.1)}$$

In the formula; n, is the required sample size; N, the number of total farms in the region; s, standard deviation; t, the reliability coefficient (1.96 which represents, 95% confidence); d, acceptable error (5% deviation). The acceptable error value was defined to be 5%, and the sample size was computed as 73. In order to define the sample villages and farms, the Simple Random Sampling Method was used by means of data that were obtained from the Farmers' Registration System records of the Agriculture and Forestry Directorate. In *Table 1*, energy equivalents of inputs and output were given as energy values in cotton cultivation. Energy balance computations were performed to define the productivity levels of cotton cultivation. Input amounts were computed and then these inputs data were multiplied by the energy equivalent coefficient. When defining the energy equivalent coefficients, previous energy balance studies were used. By adding energy equivalents of all inputs in MJ unit, the total energy equivalent was defined. Energy use efficiency, specific energy, energy productivity and net energy were computed by using the following equations 2,3,4,5 (Mandal et al. 2002; Mohammadi et al. 2008; Mohammadi et al., 2010).

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

$$\text{Specific energy} = \frac{\text{Energy input } (\frac{MJ}{ha})}{\text{Product output } (\frac{kg}{ha})} \qquad \text{(Eq.3)}$$

$$\text{Energy productivity} = \frac{\text{Product output } (\frac{kg}{ha})}{\text{Energy input } (\frac{MJ}{ha})} \qquad \text{(Eq.4)}$$

Net energy = Energy output (MJ ha^{-1}) - Energy input (MJ ha^{-1}) (Eq.5)

In this study, greenhouse gas emissions (GHG) coefficients of inputs in cotton cultivation were given in *Table 2*. Eren et al. (2019) reported that; "The GHG emissions (kgCO$_{2\text{-eq}}$ha^{-1}) associated with the inputs to growing 1 ha of plant were calculated as following adapted by Hughes et al. (2011). ∑ where R(i) is the application rate of input i (unit$_{input}$ha^{-1}) and EF(i) is the GHG emission coefficient of input i (kgCO$_{2\text{-eq}}$unit$_{input}$$^{-1}$). Morever, an index is defined to evaluate the amount of emitted kgCO$_{2\text{-eq}}$ per kg yield as following adapted Houshyar et al. (2015) and Khoshnevisan et al. (2014). Where I_{GHG} is GHG ratio and Y is the yield as kg per ha".

$$GHG_{ha} = \sum_{i=1}^{n} R(i)\ x\ EF(i) \qquad \text{(Eq.6)}$$

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

Energy balance of cotton cultivation were defined were given in *Table 3*. Koçtürk and Engindeniz (2009) 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 (Mandal et al. 2002; Singh et al. 2003)". Energy use efficiency computations in cotton cultivation were given in *Table 4*. Energy inputs of cotton cultivation in the form of direct, indirect, renewable and non-renewable energy were given in *Table 5*.

Table 1. Energy equivalents in cotton cultivation

Inputs and outputs	**Unit**	**Energy equivalent coefficient**	**References**
Inputs	**Unit**	**Values (MJ unit^{-1})**	**References**
Human labour	h	1.96	Mani et al. 2007; Karaağaç et al., 2011
Machinery	h	64.80	Singh 2002; Kızılaslan, 2009
Chemical fertilizers			
Nitrogen	kg	60.60	Singh 2002
Phosphorous	kg	11.10	Singh 2002
Potassium	kg	6.70	Singh 2002
Chemicals	kg	101.20	Yaldız et al. 1993
Microelements	kg	120	Mandal et al., 2002; Singh, 2002; Çanakcı and Akıncı, 2006; Banaeian et al., 2011
Diesel fuel	L	56.31	Singh, 2002; Demircan et al. 2006
Electricity	kWh	3.60	Özkan et al., 2004
Irrigation water	m^3	0.63	Yaldız et al., 1993
Seed	kg	11.80	Singh, 2002; Yılmaz et al. 2005;
Output	**Unit**	**Values (MJ unit^{-1})**	**Reference**
Cotton	kg	11.80	Singh, 2002; Yılmaz et al. 2005

Table 2. Greenhouse gas (GHG) emissions coefficients in cotton cultivation

Inputs	**Unit**	**GHG coefficient (kgCO$_{2\text{-eq}}$unit^{-1})**	**References**
Human labour	h	0.700	Nguyen, T.L.T. and Hermansen, 2012; Eren et al., 2019
Machinery	MJ	0.071	Pishgar-Komleh et al., 2012b; Eren et al., 2019
Nitrogen	kg	4.570	BioGrace-II, 2015; Eren et al., 2019
Phosphorous	kg	1.180	BioGrace-II, 2015; Eren et al., 2019
Potassium	kg	0.640	BioGrace-II, 2015; Eren et al., 2019
Chemicals	kg	13.900	BioGrace-II, 2015; Eren et al., 2019
Diesel fuel	L	2.760	Clark et al., 2016; Eren et al., 2019
Electricity (for Turkey)	MJ	0.167	BioGrace-II, 2015; Eren et al., 2019
Irrigation water	m^3	0.170	Lal, 2004; Eren et al., 2019
Seed	kg	7.630	Clark et al., 2016; Eren et al., 2019

3. Results and Discussion

According to surveys in cotton farms, the average amount of cotton cultivated per hectare during 2018-2019 cultivation season was computed as 5 591.90 kg ha^{-1}. If the average values are examined by referring to *Table 3*, it can be seen that the highest energy inputs in cotton cultivation were electricity energy with 18 608.40 MJ ha^{-1} (34.06%), chemical fertilizers energy with 15 254.67 MJ ha^{-1} (27.93%), diesel fuel energy with 14 364.68 MJ ha^{1} (26.30%), irrigation water energy with 3 559.50 MJ ha^{-1} (6.53%), machinery energy with 1 152.79 MJ ha^{-1} (2.11%), chemicals energy with 1 075.76 MJ ha^{-1} (1.96%), seed energy with 307.98 MJ ha^{-1} (0.57%), human labour energy with 293.84 MJ ha^{-1} (0.54%), respectively. In previous studies, Singh et al. (2000), Dağıstan et al. (2009) and Baran (2016) concluded in their cotton study that the chemical fertilizers energy usage had the first part 51.32%, 45.31% and 30.15% by respectively. Polat et al. (2006), Ören and Öztürk (2006) and Zahedi et al. (2014) concluded in their cotton study that the diesel fuel energy usage had the first part 27.47%, 41.24% and 47.40% by respectively. Yılmaz et al. (2005) concluded in their cotton study that the irrigation water energy usage had the first part 31.10%, Semerci et al. (2019) concluded in their cotton study that the electricity energy usage had the first part 36.61%.

Table 3. Energy balance in cotton cultivation

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	149.92	293.84	0.54
Soil preparation	h	1.96	8.13	15.94	
Sowing	h	1.96	1.37	2.69	
Hoeing	h	1.96	114.92	225.24	
Fertilization	h	1.96	1.32	2.59	
Spraying	h	1.96	6.78	13.29	
Irrigation	h	1.96	14.28	27.99	
Harvest	h	1.96	3.12	6.12	
Machinery	h	64.80	17.79	1 152.79	2.11
Soil preparation	h	64.80	5.12	331.78	
Sowing	h	64.80	1.11	71.93	
Hoeing	h	64.80	3.69	239.11	
Fertilization	h	64.80	1.21	78.41	
Spraying	h	64.80	4.71	305.21	
Harvest	h	64.80	1.95	126.36	
Chemicals	kg	101.20	10.63	1 075.76	1.96
Chemical fertilizers				15 254.67	27.93
Nitrogen	kg	60.60	231	13 998.60	
Phosphorous	kg	11.10	98	1 087.80	
Potassium	kg	6.70	8.10	54.27	
Microelements	kg	120	0.95	114	
Diesel fuel	L	56.31	255.10	14 364.68	26.30
Electricity	kWh	3.60	5169	18 608.40	34.06
Irrigation water	m^3	0.63	5650	3 559.50	6.53
Seed	kg	11.80	26.10	307.98	0.57
Total inputs				**54 617.62**	**100**
Output	**Unit**	**Energy equivalent (MJ unit^{-1})**	**Output per hectare (unit ha^{-1})**	**Energy value (MJ ha^{-1})**	**Ratio (%)**
Cotton	kg	11.80	5 591.90	65 984.42	100
Total output				**65 984.42**	**100**

Cotton, energy input, energy output, energy use efficiency, specific energy, energy productivity and net energy in cotton plant cultivation were computed as 5 591.90 kg ha^{-1}, 54 617.62 MJ ha^{-1}, 65 984.42 MJ ha^{-1}, 1.21, 9.77 MJ kg^{-1}, 0.10 kg MJ^{-1} and 11 366.80 MJ ha^{-1}, respectively (*Table 4*). In previous studies, Singh et al. (2000) defined energy use efficiency as 10.20, Yılmaz et al. (2005) as 0.74, Ören and Öztürk (2006) as 2.38, Polat et al. (2006)

as 2.52, Dağıstan et al. (2009) as 2.36, Şehri (2012) as 1.63, Zahedi et al. (2014) as 0.70, Baran (2016) as 3.79, Semerci et al. (2019) as 1.11, respectively.

Table 4. Energy use efficiency computations in cotton cultivation

Computations	Unit	Values
Cotton	kg ha^{-1}	5 591.90
Energy input	MJ ha^{-1}	54 617.62
Energy output	MJ ha^{-1}	65 984.42
Energy use efficiency		1.21
Specific energy	MJ kg^{-1}	9.77
Energy productivity	kg MJ^{-1}	0.10
Net energy	MJ ha^{-1}	11 366.80

The part of energy inputs, used in the cotton cultivation, in accordance with the direct, indirect, renewable and non-renewable energy groups were given in *Table 5*. As can be examined from *Table 5*, the total energy input used in cotton cultivation can be classified as 67.43% direct and 32.57% indirect. As can be examined from *Table 5*, the total energy input used in cotton cultivation can be classified as 7.62% renewable and 92.38% non-renewable. Similarly, it was defined that the ratio of non-renewable energy was higher than the ratio of renewable energy in cotton Singh et al. (2000), cotton (Yılmaz et al., 2005), cotton (Ören and Öztürk, 2006), cotton (Polat et al., 2006), cotton (Dağıstan et al., 2009), cotton (Şehri, 2012), cotton (Zahedi et al., 2014), cotton (Baran 2016), cotton (Semerci et al., 2019). Greenhouse gas emissions (GHG) of inputs in cotton cultivation were given *Table 6*.

Table 5. Energy inputs types for cotton cultivation

Type of energy	Energy input (MJ ha^{-1})	Ratio (%)
Direct energy [a]	36 826.42	67.43
Indirect energy [b]	17 791.20	32.57
Total	**54 617.62**	**100**
Renewable energy [c]	4 161.32	7.62
Non-renewable energy [d]	50 456.30	92.38
Total	**54 617.62**	**100**

Table 6. Greenhouse gas emissions (GHG) of inputs in cotton cultivation

Inputs	Unit	GHG coefficient ($kgCO_{2-eq}unit^{-1}$)	Input used per area (unit ha^{-1})	GHG emissions ($kgCO_{2-eq}ha^{-1}$)	Ratio (%)
Human labour	h	0.700	149.92	104.94	1.62
Machinery	MJ	0.071	1 152.79	81.85	1.26
Nitrogen	kg	4.570	231	1 055.67	16.29
Phosphorous	kg	1.180	98	115.64	1.78
Potassium	kg	0.640	8.10	5.18	0.08
Chemicals	kg	13.900	10.63	147.76	2.28
Diesel fuel	L	2.760	255.10	704.08	10.86
Electricity	MJ	0.167	18 608.40	3 107.60	47.94
Irrigation water	m^3	0.170	5650	960.50	14.82
Seed	kg	7.630	26.10	199.14	3.07
Total				**6 482.36**	**100**
GHG ratio (per kg)				1.16	

Total GHG emissions were computed as 6 482.36 $kgCO_{2-eq}ha^{-1}$ for cotton cultivation with the greatest input part for electricity (47.94%). The electricity followed up nitrogen (16.29%), irrigation water (14.82%), diesel fuel (10.86%), seed (3.07%), chemicals (2.28%), phosphorous (1.78%), human labour (1.62%), machinery (1.26%)

and potassium (0.08%), respectively. Additionally, GHG ratio value was computed as 1.16 $kgCO_{2-eq}kg^{-1}$ in cotton cultivation. In previous studies, Pishgar-Komleh et al. (2012a) computed the total GHG emission of cotton cultivation as 1 195 $kgCO_{2-eq}ha^{-1}$, Pishgar-Komleh et al. (2012b) computed the total GHG emission of potato cultivation as 992.88 $kgCO_{2-eq}ha^{-1}$, Khoshnevisan et al. (2013) computed the total GHG emission of wheat cultivation as 2 711.58 $kgCO_{2-eq}ha^{-1}$, Mohammadi-Barsari et al. (2016) computed the total GHG emission of watermelon cultivation as 461.41 $kgCO_{2-eq}ha^{-1}$, Eren et al. (2019) computed the total GHG emission of sugar beet cultivation as 4 742.69 $kgCO_{2-eq}ha^{-1}$ etc.

4. Conclusions

Based on this study following conclusions were defined on cotton cultivation.

The energy inputs of electricity energy 18 608.40 MJ ha^{-1} (34.06%), chemical fertilizers energy with 15 254.67 MJ ha^{-1} (27.93%) and diesel fuel energy with 14 364.68 (26.30%) were the first, second and third part in the total energy inputs. Reducing of the electricity usage, chemical fertilizers usage and diesel fuel usage are the most suitable ways of energy management in this study.

Energy use efficiency, specific energy, energy productivity and net energy in cotton cultivation were computed as 1.21, 9.77 MJ kg^{-1}, 0.10 kg MJ^{-1} and 11 366.80 MJ ha^{-1}, respectively. Total energy inputs in cotton cultivation can be classified as 67.43% direct, 32.57% indirect, 7.62% renewable and 92.38% non-renewable. Reducing of chemical fertilizers (nitrogen, phosphorous and potassium) inputs and increasing of energy use efficiency is important for energy balance. Thus, farmyard manure usage should be increased.

Total GHG emissions were computed as 6 482.36 $kgCO_{2-eq}ha^{-1}$ for cotton cultivation with the greatest part for electricity 3 107.60 $kgCO_{2-eq}ha^{-1}$ (47.94%). The electricity followed up nitrogen 1 055.67 $kgCO_{2-eq}ha^{-1}$ (16.29%), irrigation water 960.50 $kgCO_{2-eq}ha^{-1}$ (14.82%), the second and third part in the total GHG emissions, respectively.

Applying soil analysis to specify the soil fertilizer needs (to reduce high chemical fertilizer energy usage and GHG emissions), usage efficient electric pumps for irrigation, changing the traditionally irrigation systems to modern ones and usage wheat variety with high productivity are strongly submitted (Khoshnevisan et al., 2013). By following these recommendations yield and energy ratio will increase in cotton cultivation.

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