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RESEARCH ARTICLE

Investigating greenhouse gas dispersions and energy consumptive in tea cultivation

Taner Yıldız*

Ondokuz Mayıs University, Agriculture Faculty, Department of Agricultural Machinery and Technologies Engineering, 55139, Atakum, Samsun, TÜRKİYE

ABSTRACT

The study aimed to uncloak use efficiency of energy and greenhouse gas dispersions in tea cultivation. The study was performed in Rize Province of Türkiye in 2021. In the study, the energy input-output, specific energy, net energy, energy productivity, energy efficiency, types of energy input; greenhouse gas emission, and greenhouse gas emission rates were calculated. A proportional sample survey was used to assess the number of enterprises to be studied for survey and data studies, and face-to-face interviews were held in 2021 with 103 enterprises that could be reached. In the study, energy input was 25686.59 $MJha^{-1}$, output of energy as 10633.04 $MJha^{-1}$, efficiency of energy as 0.41, specific energy as 1.93 $MJkg^{-1}$, productivity of energy as 0.52 $kgMJ^{-1}$, net energy as -15053.55 $MJha^{-1}$. 48.72% of all the inputs used in production consisted of human labor energy by 12513.35 $MJha^{-1}$, 34.40% consisted of the energy of chemical fertilizers by 8835.67 $MJha^{-1}$, 10.02% consisted of diesel fuel by 2573.37 $MJha^{-1}$, 4.41% consisted of electricity by 1134 $MJha^{-1}$, 2.22% consisted of machinery by 570.40 $MJha^{-1}$ and 0.23% consisted of transportation by 59.81 $MJha^{-1}$. 63.15% (16220 $MJha^{-1}$) of the inputs consisted of direct 36.85% (9465.88 $MJha^{-1}$) and consisted of indirect energy, 48.72% (12513.35 $MJha^{-1}$) consisted of renewable energy and 51.28% (13173.24 $MJha^{-1}$) consisted of non-renewable energy. Total greenhouse gas dispersion and greenhouse gas dispersion ratio have been respectively calculated as 551.82 $kgCO_2$eqha^{-1} and 0.04 $kgCO_2$-eqkg^{-1}.

Keywords: Energy consumption; GHG dispersion; GHG ratio; Tea; Türkiye

INTRODUCTION

In order to ensure sustainability in production, it is necessary to determine production inputs and ensure efficiency in energy use. In this case, energy analyzing provides an opportunity for production strategists and politicians to assess the economic outcomes of the energy utilization (Ozkan et al., 2004a; Yılmaz et al., 2010). Today, the profitability of agricultural production should not be considered on its own. At the same time, environmental, social, and agricultural dimensions that must be taken into account, and the preservation of time-consuming natural sources and reduction of environmental pollution should be considered in terms of agricultural sustainability (Yılmaz et al., 2010; Berkman, 1996). Excessive energy use raises important environmental threats such as greenhouse gas (GHG) dispersions that is dangerous for human beings. Hence, efficient use of inputs gains importance regarding sustainable agricultural. Increase in machine power leads to increase in greenhouse in agricultural production, fuel consumption, fertilizer and electricity consumption, and naturally, greenhouse gas dispersions enhance due to the increase in energy input (Altuntaş et al., 2019).

Following the use of mechanization, chemical fertilizers, pesticides and productive varieties in agricultural production in Türkiye, the production system has also developed. Depending on the increase in input use, energy use increases in agriculture. Due to the limited agricultural areas, producers use more inputs and consume more energy to increase efficiency (Karaağaç et al., 2019). With the mechanization practices in agriculture, agricultural production has increased, and new areas have been opened to agricultural production. However, modern technology applications in agricultural production have increased energy consumption. The use of pesticides with agricultural tools and machinery requires the consumption of fossil fuels, which is the most common energy source. Since agricultural systems also encompass natural processes, it is needed to analyze energy use for

***Corresponding author:**
Taner Yıldız, Ondokuz Mayıs University, Agriculture Faculty, Department of Agricultural Machinery and Technologies Engineering, 55139, Atakum, Samsun, TÜRKİYE. **E-mail:** tyildiz@omu.edu.tr

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energy efficiency assessment in the management of natural sources (Öztürk, 2011).

The tea plant began to be grown in China and India for the first time in the World. Today, it grows in tropical regions and in areas with abundant rainfall and hot climate. In order for the plant to develop normally, the yearly total rainfall should not be less than 2000 mm and the rainfall according to the monthly should be regular (FAO, 2020). According to FAO 2020 statistics, the distribution of tea-farming areas in the world in 2018 was; China 56%, India 15%, Kenya 6%, Sri Lanka 5%, Indonesia 3%, Vietnam 3%, Myanmar 2%, Turkey 2% and other producer countries 9% (FAO, 2020). With regards to the 2020 production season in Türkiye, 68.6% of tea production took place in Rize by 905.6 thousand tons, 19.1% took place in Trabzon in Trabzon by 271.6 thousand tons, 16.9% took place in Artvin by 141.4 thousand tons and 3.8% took place in Giresun by 32.1 thousand tons. Tea production in Türkiye increased by 0.7% in the 2020 production season than the former season and reached 1.42 million tons. According to TUIK 2021, 1st herbal production estimation data, the amount of production was declared as 1.40 million tons (Agriculture and Forestry Ministry of Türkiye, 2022).

Various researches have been carried out on energy productivity and greenhouse gaseous dispersions in Türkiye and around the World. One of these studies was conducted out to detailedly optimise energy utilization and decrease the greenhouse gaseous dispersions (GHG) in products in Iran (Mostashari-Rad et al., 2019). Data were obtained through questionnaires from tangerine, hazelnut, garlic, eggplant, tea and kiwi farmers. The highest and lowest energy consumption values were obtained from tea and kiwifruit production. They emphasized that the appropriate use of nitrogen fertilizer and its replacement with organic fertilizer would reduce greenhouse gas dispersions as well as energy consumption. Finally, they emphasized that with energy optimization, GHG dispersions could be reduced in all crops.

Soheili-Fard and Salvatian (2015) surveyed the correlate between energy inputs and tea output in Iran with an artificial neural network (ANN). According to the consequences, they determined consumptive of total energy and tea output as 46144.04 MJha^{-1} and 8419.47 kgha^{-1}, respectively.

Baran et al (2015) calculated the energy efficiency, specific and net energy, energy efficiency values in cotton farming as 1.21, 9.77 MJkg^{-1}, 0.10 kg.MJ^{-1} and 11 366.80 MJha^{-1}, respectively. They calculated the greenhouse gas ratio value as 1.16 kgCO$_2$-eqkg^{-1}.

Vidanagama and Lokupitiya (2018) analyzed greenhouse gas dispersions (GHG) in the tea and rubber sector in Sri Lanka. They specified the purpose of research as a greenhouse gas inventory of CO2, CH4 and NO emissions taking into account a life cycle approach from fields to finished products.

Baran and Gökdoğan (2022) detected the energy use efficiency (EUE), specific energy (SE), net energy values (NE), energy efficiency (EP) as 1.15, 10.23 MJkg^{-1}, 8038.41 MJha^{-1}, 0.10 kgMJ^{-1}, respectively, in cotton production. The total greenhouse gas for cotton cultivation was obtained as 3742.59 kgCO2-equivalentha$^{-1.}$ The greenhouse gas rate value in cotton cultivation was calculated as 0.73 kgCO2-eqkg^{-1}.

Liang et al. (2021) stated that GHG dispersions concerned to tea and processing in China, the leader tea producer in the World, were more than the other parts of the World. They noted potential to significantly decrease greenhouse gaseous dispersions through the adoption of improved practices in their studies. They also emphasized that it is possible to decrease greenhouse gaseous dispersions through the development of organic tea growing systems.

Examples of other different studies conducted by many researchers with various products are as follows; tobacco (Moraditochaee, 2012), lavender (Gökdoğan, 2016), cotton (Yilmaz et al., 2004; Semerci et al., 2019), potato (Özgöz et al., 2017; Gokdogan et al., 2018), sunflower (Bayhan, 2016; Akdemir et al., 2017), black cumin (Yilmaz et al., 2021), guar (Gökdoğan et al., 2017), corn (Barut et al., 2011; Baran and Gökdoğan 2016), wheat (Tipi et al., 2009; Baran and Gökdoğan 2016), quinoa (Dilay and Gokdogan 2021), onion (Arın and Akdemir 1987; Ozbek et al., 2021), black carrot (Celik et al., 2010), pumpkin seed (Gokdogan et al., 2020), field crops (Canakci et al., 2005; Eren et al., 2019), apple (Ekinci et al., 2020), pomegranate (Ozalp et al., 2018), olive (Guzman and Alonso, 2008; Gökdoğan and Erdoğan 2018), mulberry (Gökdoğan et al., 2017), agricultural products (Akbolat et al., 2014), grape (Koçtürk and Engindeniz, 2009; Baran et al., 2017), chestnut (Gökdoğan et al., 2019) etc.

The goal of this study is to designate the EUE and greenhouse gaseous dispersions in tea for Rize Province. Within the scope of this research, energy utilization efficiency, signifyings, energy input types, greenhouse gas dispersions and greenhouse gas emission rate will be determined. The determination of these data is important in terms of taking place in the literature.

MATERIALS AND METHODS

Material

Rize is situated in Northeast Anatolia; towards the East of Eastern Black Sea Coastline, between 40^0-22' and 41^0-28'

East meridians and 40^0-20’ and 41^0-20’ North parallels (Fig. 1).

This study was performed in 2021 in Rize Türkiye. The inquiry, observation and data works were performed in agricultural farms of the Central, Ardeşen, Fındıklı and İkizdere (Fig. 2). The values collected by the study were surveyed from 103 (accessible) farms and observations with proportional sample survey method recommended. (Karagölge and Peker, 2002).

Methods

Energy equilibriums (EE) are indicated in Table 1 and input of total energy was calculated from EE and EI then the total EO was obtained. EE. EUE, SE, EP and NE were determined by Eq. 1-4 (Mandal et al., 2002; Mohammadi et al., 2010).

EI types were separated as DE, IE, RE and N-EN (Mandal et al., 2002; Singh et al., 2003; Koçtürk and Engindeniz,

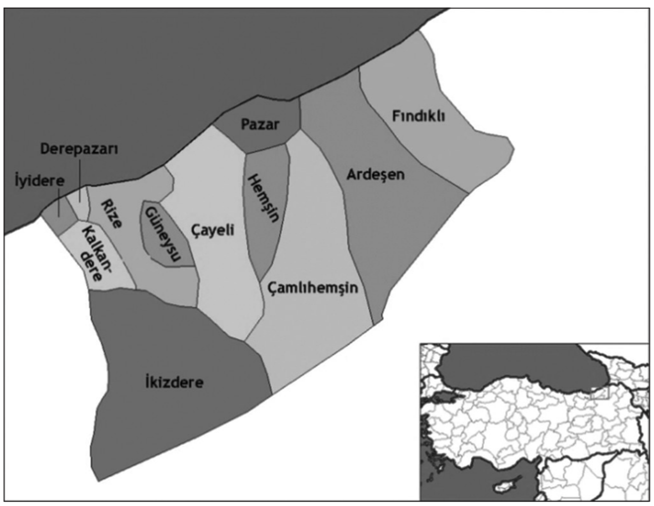

Fig 1. Location of Rize Province in Türkiye.

Fig 2. Views from different tea gardens in the research area.

2009). GHG emissions coefficients of inputs in agricultural production were indicated in Table 2. Energy balance (EB), EUE, EI types, GHG dispersions and GHG ratio calculations were indicated in Tables 3-6.

$$EUE = \frac{\text{Energy output MJha}^{-1}}{\text{Energy input MJha}^{-1}} \quad (1)$$

$$SE = \frac{\text{Energy output MJha}^{-1}}{\text{Production output kgha}^{-1}} \quad (2)$$

$$EP = \frac{\text{Production output kgha}^{-1}}{\text{Energy input MJha}^{-1}} \quad (3)$$

$$NE = \text{Energy output}\left(\text{MJha}^{-1}\right) - \text{Energy input}\left(\text{MJha}^{-1}\right) \quad (4)$$

The consequences of the evaluations are indicated in Table 2. GHG table was performed in production and the GHG ratio was calculated. The calculations were made by Hughes et al. (2011), Karaağaç et al. (2019).

The GHG proportion was the index calculated as the quantity of dispersions per kg yield. In the evaluation of the GHG proportion, the below formula was used, concerned by Houshyar et al. (2015), Khoshnevisan et al. (2014) and according to Karaağaç et al. (2019).

RESULTS AND DISCUSSION

The mean size of the 103 agricultural enterprises in the study area is 0.457 ha. The average tea production was 13291.30 kg.ha^{-1}. The EB in 2021 is indicated in Table 3.

EI and EO were 25686.59 MJha^{-1}, 10633.04 MJha^{-1}, respectively. With regards to all the inputs used in production, 48.72% is human labor energy with 12513.35 MJha^{-1}. The energy for chemicals is 34.40% (8835.67 MJha^{-1}), 10.02% fuel energy with 2573.37 MJha^{-1}, 4.41% electricity energy with 1134 MJha^{-1} 2.22% machine with 570.40 MJha^{-1} and 0.23% transportation energy with 59.81 MJha^{-1}. Human labor use consists of terrace maintenance, hoeing, fertilizing, pruning, harvesting and transportation. The highest human labor input is in the harvesting process with a rate of 41.98%. Electrical energy is used to transport 60% of the harvested tea by cable car. The use of diesel fuel is related to pruning.

Electricity energy was the biggest energy input amongst others. In other studies on agriculture production, such as

Table 1: EE in various products

Input and Output	Unit	Energy equilibrium (MJunit^{-1})	Reference
Worker	h	1.96	[Mani et al., 2007; Karaağaç et al., 2011]
Machines (Wagon)	h	71.30	[Tsatsarelis, 1993; Akcaoz, 2011]
Nitrogen	kg	60.60	[Singh, 2002; Ozalp, 2018]
Phopshorus	kg	11.10	[Ozalp, 2018; Mandal, 2002]
Potassium	kg	6.70	[Ozalp, 2018; Mandal, 2002]
Diesel Fuel	L	56.31	[Singh, 2002; Demircan, 2006]
Electricity	kWh	3.60	[Ozkan et al., 2004b]
Transportation	tonkm	4.50	[Fluck, 1982; Kitani, 1999a]
Output (Tea)	kg	0.80	[Kitani, 1999b; Soheili-Fard, 2015]

Table 2: Coefficients for GHG dispersions

Input	Unit	GHG coefficient (kgCO_2-equnit^{-1})	Reference
Machines	MJ	0.071	[Dyer 2006; Ekinci 2020]
N	kg	1.300	[Lal 2004; Ozalp 2018]
P	kg	0.200	[Lal 2004; Ozalp 2018]
K	kg	0.200	[Taghavifar 2015; Ozalp 2018]
Diesel	L	2.760	[Dyer 2006; Ozalp 2018]
Electricity	kWh	0.608	[Khoshnevisan 2013; Ozalp 2018]
Transport	ton.km	0.150	[Meisterling et al., 2009; Eren et al., 2019]

Table 3: EB in tea farming

Inputs	Unit	EE (MJunit^{-1})	Input (unitha^{-1})	Energy (MJha^{-1})	Ratio (%)
Worker	h	1.96	6384.36	12513.35	48.72
Terrace Maintenance	h	1.96	379.80	744.41	2.90
Hoeing	h	1.96	152.70	299.29	1.17
Fertilization	h	1.96	160.90	315.36	1.23
Pruning	h	1.96	62	121.52	0.48
Harvest	h	1.96	5501.70	10783.33	41.98
Transport	h	1.96	127.26	249.43	0.97
Machinery	h	71.30	8	570.40	2.22
Wagon	h	71.30	8	570.40	2.22
Chemicals	kg	-	220.30	8835.67	34.40
N	kg	60.60	134.20	8132.52	31.66
P	kg	11.10	28.70	318.57	1.24
K	kg	6.70	57.40	384.58	1.50
Diesel Fuel	L	56.31	45.70	2573.37	10.02
Pruning	L	56.31	45.70	2573.37	10.02
Electricity	kWh	3.60	315	59.81	0.23
Transportation*	tonkm	4.50	13.29	1134	4.41
Total	-	-	-	25116.19	100.00
Output	**Unit**	**Energy equilibrium (MJunit^{-1})**	**Yield (unitha^{-1})**	**Energy value (MJha^{-1})**	**Ratio (%)**
Yield (Tea)	kg	0.80	13291.30	10633.04	100.00
Total	-	-	-	10633.04	100.00

*Average distance calculated (13.29 tons, 2.5 km, and 40% product transportation).

Table 4: Calculations of EUE in tea production

Calculations	Unit	Values
Yield	kgha^{-1}	13291.30
EI	MJha^{-1}	25686.59
EO	MJha^{-1}	10633.03
EE	-	0.41
SE	MJkg^{-1}	1.93
EP	kgMJ^{-1}	0.52
NE	MJha^{-1}	-15053.55

Table 5: EI in tea

Energy types	EI (MJha^{-1})	Proportion (%)
DE	16220.71	63.15
IE	9465.88	36.85
Total	25686.59	100.00
RE	12513.35	48.72
N-RE	13173.24	51.28
Total	25686.59	100.00

by Soheili-Fard and Salvatian (2015) obtained the ratio of fertilizers as 85.78% (12779.02 MJha^{-1}) in tea.

Ozbek et al. (2021) calculated the ratio of fertilizers as 60.43% (13574.55 MJha^{-1}) amongst the most used input of

Table 6: GHG dispersions in tea production

Inputs	Unit	GHG Coefficient ($kgCO_2equnit^{-1}$)	Input ($unitha^{-1}$)	GHG dispersions ($kgCO_2$-$eqha^{-1}$)	Ratio (%)
Machines	MJ	0.071	570.40	40.50	7.34
N	kg	1.300	134.20	174.46	31.62
P	kg	0.200	28.70	5.74	1.04
K	kg	0.200	57.40	11.48	2.08
Fuel	L	2.760	45.70	126.13	22.86
Electric	kWh	0.608	315	191.52	34.71
Transport	tonkm	0.150	13.29	1.99	0.36
Total	-	-	-	551.82	100
GHG ratio (per kg)	-	-	-	0.04	-

energy in onion cultivation and Ozalp et al. (2018) assessed ratio of fertilizers as 35.80% (18177.70 $MJha^{-1}$) in energy inputs in pomegranate. EUE, SE, EP and NE were detected as 0.42, 1.89 $MJkg^{-1}$, 0.53 $kgMJ^{-1}$ and -14483.15 $MJha^{-1}$, respectively (Table 4). Soheili-Fard and Salvatian (2015) calculated EUE, EP, SE, NE as 0.18, 0.23 $kgMJ^{-1}$, 4.38 $MJkg^{-1}$, -37724.57 $MJha^{-1}$ in tea production, Şimşek et al. (2022) determined EUE, EP, SE, NE as 8.39, 0.71 $kgMJ^{-1}$, 1.41 $MJkg^{-1}$, 105171.67 $MJha^{-1}$ in grape production and Ozalp et al. (2018) calculated EUE, SE, EP, NE as 1.51, 0.39 $kgMJ^{-1}$, 2.57 $MJkg^{-1}$, 25647 $MJha^{-1}$ in pomegranate.

In the research, the total energy input used were 63.15% (16220.71 $MJha^{-1}$) DE, 36.85% (9465.88 $MJha^{-1}$) IE, 48.72% (12513.35 $MJha^{-1}$) RE and 51.28% (13173.24 $MJha^{-1}$) N-RE (Table 5). Accordingly in other researchs on tea by Soheili-Fard and Salvatian (2015), on lavender production by Gökdoğan (2016) and on onion production by Ozbek et al. (2021). Ozbek et al. (2021) assessed DE proportion to be more than IE. Accordingly in other studies in tea production by Soheili-Fard and Salvatian (2015), on cotton production by Semerci et al. (2019) on potato by Gokdogan et al. (2018) calculated N-RE energy proportion more than RE.

The results are indicated in Table 6. Total GHG emission was 551.82 $kgCO_{2}$-$eqha^{-1}$ for tea production. GHG dispersions were related to electricity by 34.71% (191.52 $kgCO_2$-$eqha^{-1}$), nitrogen by 31.62% (174.46 $kgCO_{2}$-$eqha^{-1}$), diesel fuel by 22.86% (126.13 $kgCO_2$-$eqha^{-1}$), machinery by 7.34% (40.50 $kgCO_2$-$eqha^{-1}$), potassium by 2.08% (11.48 $kgCO_{2}$-$eqha^{-1}$), phosphorous by 1.04% (5.74 $kgCO_{2}$-$eqha^{-1}$) and transmission by 0.36% (1.99 $kgCO_{2}$-$eqha^{-1}$), respectively. GHG dispersion ratio was evaluated as 0.04. In previous studies, Dilay and Gokdogan (2021) found the total dispersion of quinoa as 382.42 $kgCO_{2}$-$eqha^{-1}$, Ozbek et al. (2021) found the total GHG dispersion of onion as 2920.73 $kgCO_{2}$-$eqha^{-1}$ and Gökdoğan et al. (2022) found the sum of gaseous dispersion of pistachio as 1123.72 $kgCO_{2}$-$eqha^{-1}$.

CONCLUSION

This research is focused on EB and GHG dispersions in tea. EI and EO were 25686.59 $MJha^{-1}$ and 10633.04 $MJha^{-1}$, respectively. The highest EI is human labor energy input by 48.72% (12513.35 $MJha^{-1}$). The biggest ratio in the total human labor force belongs to that used for harvesting by 41.98% (10783.33 $MJha^{-1}$). Yield, EUE, SE, EP and NE are calculated as 13291.30 $kgha^{-1}$, 0.41, 1.93 $MJ.kg^{-1}$, 0.52 $kgMJ^{-1}$ and -15053.55 $MJha^{-1}$, respectively. Regarding the results, tea farming was found to be profitless in regards to energy usage.

DE, IE, RE and N-RE energy inputs were calculated 63.15% (16220.71 $MJha^{-1}$), 36.85% (9465.88 $MJha^{-1}$), 48.72% (12513.35 $MJha^{-1}$) and 51.28% (13173.24 $MJha^{-1}$) sum of energy, respectively. Ratio and sum of GHG dispersions were 551.82 $kgCO_2$-$eqha^{-1}$, 0.04 $kgCO_2$-$eq.kg^{-1}$, respectively. The highest greenhouse gas emissions belong to electricity input with 34.71%, nitrogen input with 31.62% and diesel fuel input with 22.86%.

Machinery-use related fuel expenses can be lowered by using renewable terms of energy sources (Akbolat et al., 2014). The potential for energy savings is immense. Observation of optimum requirement levels increases energy efficiency and as a consequence reduces GHG emissions (Imran and Ozcatalbas, 2021).

Better fertilizer management, such as urea, can help reducing indirect energy consumption. More steadiness use of chemical fertilizer and suitable alternation will not only minimize the usage of fertilizers, but also provide financial benefits to farmers and minimize the impacts for environment (Imran et al., 2020). It would be beneficial to apply the above-mentioned recommendations of the researchers in tea production.

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CONFLICTS OF INTEREST

The author declares that there is no conflict of interest.

Author contribution

The author is responsible for all sections of the research.

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