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DETERMINATION OF ENERGY UTILIZATION EFFICIENCY AND GREENHOUSE GAS (GHG) EMISSIONS FOR FORAGE PEA PRODUCTION AT MUS PROVINCE IN TURKEY

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Abstract

The study's goal is to assess the energy balance of fodder pea crop production.and greenhouse gas (GHG) emission under Muş conditions, Turkey in 2020. Basic information such as the economic life of the instruments and machines utilized in the study, work success, fuel-oil consumption, machine weights and the amount of used fertilizer and seed were obtained by current measurements, from other studies, various sources and catalogs. The evaluations resulted in the determined energy output/input ratio, the specific energy value, and energy productivity. and the net energy efficiency values for feed pea crop production were 5.10, 3.65 MJ kg^{-1}, 0.27 kg MJ^{-1} and 35636.85 MJ ha^{-1}, respectively. The fertilizer energy had the highest energy utilization rate of the overall energy inputs for feed pea production, with 31.35%.. This was followed by seed energy with 25.77%, fuel energy with 21.40%, machine energy with 14.93% and human energy with 6.55%, respectively. Total GHG emission for forage pea crop production was calculated as 1533.81 $kgCO_{2\text{-}eq}ha^{-1}$. The highest share in total GHG emissions was at seedconsumption (59.69%). The seed was followed by human labor (13.23%), nitrogen fertilizer consumption (9.12%), phosphate fertilizer consumption (6.02%), machinery use (6.0%) and diesel fuel consumption (5.94%). Furthermore, the GHG ratio in the production of fodder pea crops was calculated to be 0.65 kgCO2-eqkg-1. As a result, fertilizer energy had the biggest share of production inputs, followed by seed, fuel, machinery, and human labor energies, respectively. Total GHG emission and the GHG ratio was calculated as 1533.81 $kgCO_{2\text{-}eq}ha^{-1}$ and 0.65 $kgCO_{2\text{-}eq}kg^{-1}$, respectively.

Key words: Forage pea, Energy balance, Greenhouse gas (GHG) emissions, GHG ratio.

Introduction

Fodder pea is an annual legume plant with fewer acres in Turkey than food pea. It can be grown as a green manure, for seed and grass production, for grazing, or as a silage crop alone or in combination with cereals. It is cultivated sole or mixed with cereals as an early spring pasture for animal grazing especially in coastal regions (Anon., 2021a).

The livelihood of Turkey's Eastern Anatolia Region is mostly based on crop and animal production, and the winter months are lengthy and bitterly cold. As a result, animals must be fed in shelters for extended periods of the year. However, the production of high quality roughage in the region is insufficient, whichnegatively affects the livestock enterprises due to shortage of roughage. This deficit becomes more evident especially during winter months (Anon.. 2021b). Thoughthe natural meadows and pasturesare the main feed source of the country's livestock but presently the production area forage crops remarkably decreased to 14-15 million hectares from44 million hectares value inthe 1940s.

Leguminous forage crops account for a large portion of the world's forage crop production and can be fed to animals as dry or green grass. Leguminous forage crops fix atmospheric nitrogen by *Rhizobium* bacteria, and improve physical and chemical properties of the soils. Their production is higher as first or second crop in regions with temperate climates such as Central Anatolia, Mediterranean, Black Sea, Aegean, and Marmara in Turkey. Leguminous forage crops, which can meet almost all the nitrogen demand of the host plant, are also used as green manure in organic farming systems (Tosun, 1996).

Peas are generally collected under the *Pisum sativum* (L.) species (Açıkgöz, 2001). One of the most important legumes in the world is the pea, which is a vital source of protein for animals. Pea is a legume that originated in South-West Asia and was one of the first cultivated crops.. World pea production is 5389 ha and Canada, China, India and the Russian Federationarethe top producing countries which cover 70% of the total acreage. It is consumed as green vegetables (whole pod or mature seed) in Asian countries, and as dried seeds in Europe, Australia, America and Mediterranean regions. Peas ranks the third place in the world for the total production among legumes (Özeroğlu, 2021). Climatic conditions and variety characteristics are very important factors for the productivity of the pea crop.

Feed pea reduces incidence of diseases, pests and weeds by changing the physical, chemical and biological structure of the soil by crop rotation. Crop rotation also significantly reduces erosion (Açıkgöz, 2001). Protein is abundant in pea grains. While there is 20% crude protein in the dry grass of the fodder pea when cut at correct stage, it contains 20%-30% crude protein in the grains. Fodder pea can also be utilised as a green manure crop, and can be used as green grass or dry grass (Özeroğlu, 2021; Açıkgöz, 2001).

Energy use, greenhouse gas (GHG) emissions and their potential effects on global climate change are among the current discussions. In this context, increased energy consumption leads to significant environmental issues such as greenhouse gas emissions that harm human health. So, more economical use of inputs is becoming important in terms of sustainable agricultural production (Şanli *et al.,* 2017). However, increased energy use causes severe environmental concerns that harm human health, therefore effective input use becomes critical for sustainable agricultural production.. Greenhouse gas emissions in agricultural production arise due to the use of machineries, diesel-fuel consumption, use of chemical fertilizers, electricity consumption, and naturally emissions of GHG with the increase in energy input.

In order to increase the energy efficiency value, it is necessary to either increase the efficiency or decrease the inputs. In particular, fuel, chemical fertilizers, agricultural pesticides, machinery and tractor inputs have a large place in the total energy input which should be reduced. Increasing efficiency can be achieved within certain limits. However, the energy use efficiency value can be reduced by proper usage of the inputs (spraying, mechanization and fertilization) (Çelen, 2016).

Energy consumption efficiencies for barley production have been determined in certain research. (Baran & Gökdoğan, 2014), sugar beet (Baran & Gökdoğan, 2016a), second crop silage maize (Baran & Gokdogan, 2016b), maize (Kökten *et al.,* 2018; Abbas *et al*., 2018), bitter vetch and forage pea (Kökten *et al.*, 2017a), common vetch and Hungarian vetch (Kökten *et al.,* 2017b), vetch (Baran, 2016), guar (Gökdoğan *et al.*, 2017a), faba bean (Petkova *et al.*, 2017). In addition, in some studies in barley (Eren *et al*., 2019a), fodder peas (Elhami *et al*., 2016; Eren *et al*., 2019a), sunflower (Baran *et al.*, 2016), corn (Eren *et al*., 2019a), fruits (Eren *et al.*, 2019b) were used to determine GHG emissions. The energy use efficiency and GHG emissions of feed pea production in Muş province for 2020 were attempted to be revealed in this study.

Materials and Method

Study area: Muş locates in the Eastern Anatolia Region of Turkey between 39°29' and 38°29' north latitudes and 41°06' and 41°47' east longitudes. Surface area is 8196 km^2. It covers 1.1 percent of Turkey's surface area. Districts bordering Muş are Patnos and Tutak (Ağrı) from the east; Ahlat and Adilcevaz (Bitlis) from the east; Karayazı, Hınıs, Tekman, Karaçoban (Erzurum) from the North; Karlıova and Solhan (Bingöl) from the west; Kulp (Diyarbakır), Sason (Siirt) and Güroymak and Mutki (Bitlis) from the south. Muş is established on the north-facing slopes of Kurtik Mountain, one of the important peaks of the Haçreş Mountains, which is the extension of the Southeastern Taurus Mountains, and between the valleys where the Çar and Karni streams flow (Anon., 2021c).

Climatic characteristics of the research area: The altitude of Muş province is 1350 meters. The plains, which are covered with young and fertile alluvium, cover 27.2% of the province's surface area. Murat valley divided the province lands in east-west direction. Generally, plateaus at an altitude of 1500-1700 meters cover 37.9% of the province area (Anon., 2021d). In the province of Muş, where the typical continental climate is dominant, the average rainfall for long term average was 74.50 mm, the relative humidity was 61.99%, and the temperature was 8.10°C. In the first year of the research, the highest relative humidity was measured in January and February (86.20 and 90.10%, respectively). Temperature was generally low during these months (Table 1).

The average temperature, precipitation and relative humidity of the first research year (2019) were above the long term averages, while the average values of the precipitation and relative humidity of the second year were below the long term averages. In addition, the average values of temperature, precipitation and relative humidity of the first year were higher than the average values of those in the second year (Table 1). Despite the hot and dry summer months of Muş province in the Eastern Anatolia Region, the trial plots were harvested without irrigation.

In the study, the various values for input and the obtained output used in the production of forage peas were obtained from different sources (Turkish Statistical Institute, previous related or similar studies). The technical data on agricultural tools and machinery were taken from the applications and catalogs in the region.

Table 1. Temperature, precipitation and relative humidity values of the research area*.

Months	Temperature (°C)			Precipitation (mm)			Relative humidity (%)		
	LYA**	2019	2020	LYA**	2019	2020	LYA**	2019	2020
September	21.13	21.70	21.10	20.16	5.40	0.00	32.76	36.30	32.40
October	13.54	14.50	15.40	65.87	129.60	37.00	53.12	58.80	50.10
November	5.56	7.00	6.20	65.24	77.80	27.20	67.91	76.20	6.80
December	-1.62	2.70	2.80	99.36	188.00	74.40	80.23	88.10	83.10
January	-5.25	-3.60	-5.00	113.30	84.80	36.80	82.09	86.20	84.10
February	-2.87	-4.30	-3.40	86.69	59.60	89.20	77.9	90.10	78.50
March	3.78	2.10	4.10	104.27	122.60	198.00	67.56	78.90	81.30
April	10.58	8.30	10.10	90.63	110.60	117.00	57.9	70.90	65.90
May	15.28	16.90	15.70	69.22	85.40	113.20	57.42	51.60	57.70
June	20.91	23.40	21.00	30.28	10.40	29.00	43.02	39.10	42.60
Total/Average	8.10	8.87	8.80	74.50	87.42	72.18	61.99	67.62	58.25

*Meteorological Service of Muş. **LYA: Long years' average (2009-2020)

Table 2. Energy equivalents of inputs and outputs in agricultural production

Inputs	Energy equivalent coefficient(MJ unit^{-1})	References
Human Labor(h)	1.96	Baran *et al.*, 2019
	Machinery production energy(kg)	
Machine	64.80	Singh *et al*, 2002
	Fuel(L)	
Diesel	56.31	Singh *et al*., 2002; Demircan *et al*., 2006
	Chemical fertilizers (kg)	
Nitrogen (N)	60.60	Singh *et al*., 2002; Demircan *et al*., 2006
Phosphorus (P_2O_5)	11.10	Singh *et al*., 2002; Bayhan, 2016
	Seeds (kg)	
Forage pea	18.65	Kökten *et al.*, 2017a
	Output	
Forage pea	18.65	Kökten *et al*., 2017a

Inputs used in the study: The sowing norm varies between 100-150 kg ha^{-1} depending on the inter row, intra row spacings and seed size. In this study, the sowing norm was taken as 120 kg ha^{-1}. The amount of used fertilizer was calculated as 78.2 kg ha^{-1} pure phosphorus, and 30.6 kg ha^{-1} pure nitrogen. Weed control was not carried out in the forage pea experiment. In fodder pea production, 1 driver worked for the tillage, 3 workers for the usage of hand marker, 1 driver and 1 assistant worker for planting and fertilization, 3 workers for manual harvesting and 1 worker for machine harvesting. In order to calculate the energy efficiency of feed pea production in Muş, in the first stage, energy inputs and energy outputs must be calculated.

Energy inputs consist of human power energy, machine energy, fuel-oil energy, seed energy, water energy, fertilizer energy and pesticides energy. The following equation adapted from Farrell *et al*., (2006) was used to determine the energy input:

$$TEG = \sum_{i=1}^{n} R(i)\, x\, E_{eş}(i) \quad (1)$$

Here;
TEG: Agricultural energy input (MJ ha^{-1}),
R(i): Application amount of input i(unit$_{input}$ ha^{-1}),
E_{eq}(i): Energy equivalent of input i(MJ unit$_{input}$$^{-1}$).

The energy output consists of the product and by-product obtained from the unit area. The following equation was used to determine the energy output:

$$TEÇ = Y * LHV \quad (2)$$

Here;
TEÇ: Agricultural energy output (MJ ha^{-1}),
Y: Yield (kg ha^{-1})
LHV: Lower calorific value (MJ kg^{-1}).

The energy equivalent coefficients of agricultural inputs and outputs are given in Table 2.

In order to determine the energy use efficiency in feed pea production, formulas 3, 4, 5 and 6 below, adapted from Yılmaz *et al*., (2010), were used.

$$\text{Energy ratio} = \frac{\text{TEÇ}}{\text{TEG}} \quad (3)$$

$$\text{Specific energy (MJ } kg^{-1}) = \frac{\text{TEG}}{\text{Y}} \quad (4)$$

$$\text{Energy productivity (kg } MJ^{-1}) = \frac{\text{Y}}{\text{TEG}} \quad (5)$$

$$\text{Net energy efficiency (MJ } ha^{-1}) = \text{TEÇ} - \text{TEG} \quad (6)$$

The following equation adapted from Hughes *et al*., (2011) was used to determine the GHG emission:

$$GHG_{ha} = \sum_{i=1}^{n} R(i)\, x\, EF(i) \quad (7)$$

Here;
GHG_h: Greenhouse gas emission (kg$CO_{2\text{-}eq}$ ha^{-1}),
R(i): Application amount of input i(unit$_{input}$ ha^{-1}),
EF(i): GHG emission equivalent of input i(kg$CO_{2\text{-}eq}$unit$_{input}$$^{-1}$)

G HG emission coefficients of agricultural inputs are given in Table 3.

Table 3. GHG emission equivalents of inputs in agricultural production.

Inputs	Unit	GHG emission equivalents (kg$CO_{2\text{-}eq}$unit^{-1})	References
Human labor	h	0.700	Nguyen & Hermansen, 2012
Machine	MJ	0.071	Pishgar-Komleh *et al.*, 2012
Diesel fuel	L	2.760	Clark *et al*., 2016
Nitrogen (N)	kg	4.570	BioGrace-II, 2015
Phosphorus (P_2O_5)	kg	1.180	BioGrace-II, 2015
Seed	kg	7.630	Clark *et al.*, 2016

Table 4. Energy balance in forage pea production.

Inputs	Unit	MJ/br	Input used per hectare (unit ha^{-1})	Energy value (MJ ha^{-1})	Ratio (%)
Human labour	h	1.96	290.00	**568.40**	6.55
Machinery	h	64.80	20.00	**1296.00**	14.93
Chemical fertilizers	kg		108.80	**2722.38**	31.35
Nitrogen	kg	60.60	30.60	1854.36	21.36
Phosphorous	kg	11.10	78.20	868.02	10.00
Diesel fuel	l	56.31	33.00	**1858.23**	21.40
Seed	kg	18.65	120.00	**2238.00**	25.77
Total inputs				**8683.01**	**100.00**
Outputs	**Unit**	**MJ/br**	**Output per hectare (unit ha^{-1})**	**Energy value (MJ ha^{-1})**	**Ratio (%)**
Yield	kg	18.65	2376.40	**44319.86**	**100.00**

The GHG ratio is an index defined as the amount of GHG emissions per unit kg of yield. It was calculated with the following equation adapted from Houshyar *et al*., (2015) and Khoshnevisan *et al*., (2014):

$$I_{GHG} = \frac{GHG_{ha}}{Y} \qquad (8)$$

Here;
I_{GHG}: GHG ratio ($kgCO_{2\text{-}eq}kg^{-1}$)
Y: Yield (kg ha^{-1})

In addition, energy inputs in feed pea production were calculated in two groups as direct and indirect energy inputs. The energy value of fuel and oil consumed by agricultural tools and machinery in feed pea production was considered as direct energy input, and the energy values consumed for human labor, agricultural tools and machinery, fertilizers, pesticides and seeds used were considered as indirect energy inputs (Koçtürk & Engindeniz, 2009).

Results and Discussion

Energy utilization efficiency: The results revealed, table 4 shows the energy balance in forage pea production in Muş, and Table 5 shows the energy use efficiency values in forage pea production.. The results revealed that, the total 568.40 MJ ha^{-1} human energy was consumed per unit area, and the ratio of this value to the total energy input constituted the lowest input with 6.5% (Table 4). In the production of forage peas, 1296.0 MJ of energy was consumed for 1 ha area in tool/machine energy, and this value corresponds to 14.93% of the total energy. Among all inputs, energy consummption for the fertilizer was 2722.38 MJ ha^{-1}, which recieved the highest rate (31.35%). The fuel energy input corresponded to 21.40% with 1858.23 MJ ha^{-1}.

In feed pea production, the seed energy input value and rate was 2238.00 MJ ha^{-1} and 25.77%, respectively. In feed pea production, the agricultural energy input and agricultural energy output was determined as 8633.01 MJ ha^{-1} and 44319.86 MJ ha^{-1}, respectively (Table 5).

Energy utilization efficiency (Energy ratio): The energy for fodder pea production in Muş was calculated as 5.10, while the energy ratio determined in this study was 5.10 (Table 6). Klimeková & Lehocká (2007) found the energy ratio in organic and conventional pea production as 0.92 and 0.89, Baran & Gökdoğan (2017) found the energy ratio in chickpea production in Adıyaman as 2.58; Karaağaç *et al*., (2019) determined the energy ratio in chickpea production in Adana as 1.82; Baran *et al*., (2019) determined the energy ratio in peanut production in Adana as 1.94; Kökten *et al*. (2017a) recorded the energy ratio in feed pea production in Bingöl as 2.53.

Table 5. Energy utilisation efficiency calculations in forage pea production.

Calculations	Unit	Values
Yields	kg ha^{-1}	2376.40
Energy input	MJ ha^{-1}	8683.01
Energy output	MJ ha^{-1}	44319.86
Energy utilization efficiency		5.10
Specific energy	MJ kg^{-1}	3.65
Energy productivity	kg MJ^{-1}	0.27
Net energy	MJ ha^{-1}	35636.85

Table 6. Energy input in the form of direct, and direct renewable and non-renewable energy for forage pea production.

Type of energy	Energy input (MJ ha^{-1})	Ratio (%)
Direct energy [a]	2426.63	4.64
Indirect energy [b]	6256.38	11.96
Total	8683.01	100.00
Renewable energy [c]	2806.40	32.32
Non-renewable energy [d]	5876.61	67.68
Total	**8683.01**	**100.00**

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

Discussion

Specific energy: Specific energy was determined as 3.65 kg MJ^{-1} for fodder pea production under Muş conditions. The specific energy value was determined as 7.38 kg MJ^{-1} for feed peas (Kökten *et al*., 2017a), and 22.52 kg MJ^{-1} for (Gökdoğan *et al.,* 2017).

Energy productivity: Energy productivity in the production of fodder peas under Muş conditions was determined as 0.27 kg MJ^{-1}, considering only the amount of seeds harvested from the unit production area (ha). In the production of fodder peas under Muş conditions, 0.27 kg of fodder pea seeds are produced in exchange for 1 MJ of energy consumption. When other studies are examined, it is informed by Kökten *et al*., (2017a) as 0.14 in feed peas, by Gökdoğan *et al*., (2017b) as 0.04 in beans, by Karaağaç *et al*., (2019) as 0.10 in chickpea and by Gökdoğan *et al*., (2017a) as 0.17 in buckwheat.

Net energy: Net energy efficiency was defined as the difference between the total amount of energy gained as a consequence of production and the total amount of energy used in production operations. (MJ ha^{-1}) (Baran *et al.*, 2016). Net energy efficiency in fodder pea production under Muş conditions was calculated as 35636.85 MJ ha^{-1}, considering only the amount of seeds taken from the unit production area (ha). The net energy value was determined by Petkova *et al*., (2017) with an average of 44135.53 MJ ha^{-1} for six different feed pea varieties, Kökten *et al.*, (2017a) as 21675.59 MJ ha^{-1} for fodder peas, Kökten *et al*., (2017b) as 28987.50 MJ ha^{-1} for common vetch, Baran (2016) as 76360.66 MJ ha^{-1} for vetch. Gökdoğan *et al.*, (2017) recorded the highest value of 29147.24 MJ ha^{-1}.

Direct, indirect, renewable and non-renewable energy rates in forage pea cultivation were calculated as 4.64, 11.96, 32.32 and 67.68%, respectively (Table 6). Kökten *et al*., (2017a) also found that indirect energy was lesser than direct energy, and renewable energy was lower than non-renewable energy, in the study on feed peas.

Greenhouse gas (GHG) emission: The GHG emission results of forage pea production are given in Table 7. Total GHG was calculated as 1533.81 $kgCO_{2\text{-}eq}ha^{-1}$. The highest share among the total GHG emission inputs was the seed input with a share of 59.69%. This was followed by human labor (13.23%), chemical fertilizer inputs (15.14%) and diesel fuel (5.94%). The GHG ratio (per kg yield) was determined as 0.65 $kgCO_2$-eq kg^{-1}. In similar studies, Karaağaç *et al*., (2019) determined the total GHG emission for chickpea as 1638.85 $kgCO_{2\text{-}eq}ha^{-1}$; Eren *et al*., (2019) determined total GHG emission as 2075 $kgCO_{2\text{-}eq}ha^{-1}$ and GHG ratio as 1.16 $kgCO_{2\text{-}eq}kg^{-1}$; Elhami *et al*., (2016) determined total GHG emission as 6884.14 $kgCO_{2\text{-}eq}ha^{-1}$ and GHG ratio as 3.03 $kgCO_{2\text{-}eq}kg^{-1}$; Ozbek *et al*., (2021) determined total GHG emission for onion as 2920.73 $kgCO_{2\text{-}eş}$ ha^{-1} ve GHG oranın 0.094 $kgCO_{2\text{-}eq}kg^{-1}$; Baran *et al*., (2021) determined total GHG emission for cotton as 6 482.36 $kgCO_{2\text{-}eq}$ ha^{-1} and GHG ratio a -1.16 $kgCO_2$-eq kg^{-1}.

Table 7. Total GHG emissions in forage pea production.

Inputs	**Unit**	**Amount per hectare (unitha^{-1})**	**GHG Emissions (kg $CO_{2\text{-}eq}$ ha^{-1})**	**Ratio (%)**
Human	h	290.00	203.00	13.23
Machinery	MJ	1296.00	92.02	6.00
N	l	30.60	139.84	9.12
P	kg	78.20	92.28	6.02
Diesel	kg	33.00	91.08	5.94
Seed	kg	120,00	915.60	59.69
Total	-		**1533.81**	**100.00**
GHG ratio (per kg)			**0.65**	-

Conclusions

In this study, energy use efficiency and GHG emission were determined in the production of feed peas in the 2020 production season in Muş province. The energy ratio in feed pea companies was determined to be 5.10. According to the calculations, fertilizer energy received the biggest percentage of production inputs, followed by seed, fuel, machinery, and human labor energies,, respectively. Total GHG emission and the GHG ratio was calculated as 1533.81 $kgCO_{2\text{-}eq}ha^{-1}$ and 0.65 $kgCO_{2\text{-}eq}kg^{-1}$, respectively. The highest energy consumption in fuel-oil input was at tillage. In addition, it was determined that human labor and fertilizer energy recieved the second and third place for energy consumption. To improve agricultural energy consumption efficiency, highly energy efficient technologies should be preferred for mechanization applications in enterprises, appropriate power source capacity for tools/machines should be selected, and essential power optimization should be supplied for enterprises. In order to increase the rate of renewable energy, it is necessary to reduce the non-renewable energy inputs and to include the use of farm manure in the production of forage crops.Based on these findings, it is possible to conclude that methods such as the application of new tillage systems in large agricultural areas, introduction of different agricultural and alternative fertilizer use methods and widespread use of alternative energy sources in agriculture can be important factors in reducing energy consumption in agriculture. For this reason, Different and alternative tillage and fertilization strategies are being researched in order to draw conclusions for minimizing fuel-oil input and fertilizer energy requirement in feed pea production.

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