Effects of different irrigation methods on energy use, greenhouse gas emissions and profitability of Italian Ryegrass (*Lolium Multiflorum*) production in Thrace Region, Turkey

Recebimento dos originais: 21/08/2022
Aceitação para publicação: 23/03/2023

Ozan Öztürk (Corresponding Author)
PhD in Field Crops
Institution: Atatürk Soil Water and Agricultural Meteorology Research Institute
Address: Atatürk Soil Water and Agricultural Meteorology Research Institute, 39100, Kırklareli, Turkey
E-mail: **ozan.ozturk@tarimorman.gov.tr**

Abstract

This study was carried out in order to determine the energy use efficiency and greenhouse gas emissions of Italian ryegrass, cultivated in the areas irrigated by subsurface drip irrigation and drip irrigation methods and precipitation-based (non irrigated) conditions. Besides, economic analysis was done and the most proper irrigation method was determined. The trial was conducted on the lands of Atatürk Soil Water and Agricultural Meteorology Research Institute located 4 km west of Kırklareli province of Turkey. The energy use efficiency values were found as 7.78, 6.99, 8.05 and 5.50 respectively in the subjects irrigated by subsurface drip irrigation systems placed 20 and 40 cm deep into the soil, drip irrigation and non-irrigated conditions. GHG ratios (per kg) were found as 0.252, 0.281, 0.247 and 0.283 for the subjects respectively. Relative profits were calculated as 1.52, 1.36, 1.57 and 1.49 and the productivity was calculated as 9.60, 8.61, 9.94 and 9.44 kg $\$^{-1}$, respectively. Italian ryegrass farming was determined to be profitable in each production types but it seemed to be more profitable in drip irrigation subject, followed by subsurface drip irrigation systems placed 20 cm deep into the soil. According to the results of this study, it can be said that encouraging the farmers to produce Italian grass as an alternative to the production of conventional forage crops and rotation in roughage production will be beneficial in terms of forage crops.

Keywords: Energy use efficiency. Forage crops. Profitability.

1. Introduction

Animals and animal products are very important factors in terms of the maintenance of human's life and providing convenience. Consequently, stock farming has been one of the earliest agricultural occupation fields and it still maintains this position today. Feeds compose the significant part of the inputs in stock farming and they are divided into two parts such as concentrate feeds and roughage. Concentrate feeds are given in order to balance the daily energy and protein requirements of the animals but roughages are the most essential feed groups in order to increase the animal health and meat-milk yield. Usage of the qualified roughages in animal feeding is significant in terms of the improvement of the performances of the animals, prevention of the many feeding-welded metabolic diseases and obtainment of high qualified animal products.

Italian grass, a forage grass plant originating from Southern Europe, is the only annual species cultivated in the grass genus. It is known that Italian grass was first cultivated in Italy, it can grow to 80 cm and it is considerably rich in terms of green component, protein, mineral matter and water-soluble carbohydrate amount. It was determined that the high amount of dry matter together with the digestibility rate had a positive effect on the live weight gain of animals in fattening (Özkul et al., 2012). It is an important alternative roughage source in areas where barley and oats are grown for feed production in cool and temperate climate regions. Under normal conditions, green grass yields between 15000-25000 kg and dry grass between 5000-8000 kg can be obtained per hectare. In irrigated conditions or in regions where precipitation is sufficient, 2-3 harvestings can be taken, and 4-6 tons of green and 750-1500 kg of dry grass products can be obtained. According to Turkish Statistical Institute Data, 971691 tons of Italian grass was produced on an area of 25328 hectare in Turkey and 6125 tons of Italian grass was produced on an area of 175 hectare in Kırklareli in 2020.

One of the basic conditions of sustainable agriculture is the efficient use of energy. Energy use in agricultural activities is increasing. Limited arable land for increasing population and high living standards, ever-increasing food consumption have caused the intensive use of chemical fertilizers, pesticides, agricultural machinery and other natural resources in agricultural production. Intensive energy use causes problems that threaten human health and natural habitats. The efficient use of energy in agricultural production will minimize environmental problems, prevent damage to natural resources and promote sustainable agriculture as an economic production system (Erdal et al., 2007).

However, more intensive energy use creates important environmental problems that affect human health and such as greenhouse gas (GHG) emissions. For this reason, the efficient use of inputs becomes important for sustainable agricultural production. Greenhouse gas emissions in agricultural production arise due to the use of machinery, diesel fuel consumption, use of chemical fertilizers and electricity consumption, and naturally, greenhouse gas emissions increase with the increase in energy input.

Since the expansion of agricultural lands in our country will not be technically and economically possible, it will be possible to increase production in existing areas, by using quality seeds, conscious agricultural struggle, fertilization and effective soil cultivation, as well as conscious and appropriate irrigation practices. While benefiting from limited irrigation resources in regions located in arid and semi-arid climate zones, irrigation systems where water is taken from the source and transmitted to the plant root zone with minimum loss should be preferred. In this state, drip irrigation methods come to the fore among pressurized irrigation systems. Dissemination of drip irrigation will provide the decrease of water loss and the usage of the saved water in the other sectors. In this respect, the use of pressurized irrigation methods is an important tool for the protection and sustainability of water resources (Aküzüm et al., 2010).

In the evaluation of an agricultural production project in line with the principles of sustainable agriculture in recent years, economy, energy and environment are examined together. In other words, the ratio between the energy equivalent of the product per unit area and the amount of energy consumed for production in any agricultural production branch can be used as an indicator and a benchmark value for a successful and profitable production and it is also important for the effective use of energy today, where environmental awareness is increasing rapidly. In addition, it is an important approach that should be considered together with the cost per unit area in the evaluation of the difference between alternative production techniques (Erdoğan, 2009).

Especially in irrigated areas, it is important to produce Italian grass, which can be harvested more than one in a production season, in the areas where irrigation losses are the least, and where it is irrigated with subsurface drip irrigation and drip irrigation methods. In this study, energy use efficiency and greenhouse gas emissions of Italian ryegrass, cultivated in the areas irrigated by subsurface drip irrigation and drip irrigation methods and precipitation-based conditions, were determined, economic analysis was done and the most appropriate irrigation method was determined.

2. Literature Review

Several research studies were conducted on the determination of energy use efficiency, greenhouse gas emissions and profitability of forage crops.

Khan et al. (2010) examined the energy consumption, energy input-output relationship and benefit/cost ratio of wheat, rice and barley crop production system in Coleambally Irrigation Areas (CIA) and Murrumbidgee Irrigation Area (MIA) of New South Wales, Australia. The values of all energy inputs and output were converted to energy farm. Economic analysis was performed for e ach crop. Results revealed that chemical fertilizer consumed 47, 43 and 29% of the total energy inputs on wheat, rice and barley growing farms, respectively. The benefit-cost ratio was the highest on rice farms (3.33) as compared to wheat (2.82) and Barley (2.50).

Safa et al. (2010) examined the energy consumption of wheat, barley and maize production in Iran (Saveharea). This study was conducted over 28400 ha of irrigated wheat, barley and maize fields and 19300 ha of dry land wheat and barley fields in Saveh, a central city, Iran, in the harvest year of 2003 - 2004. Total energy consumption for irrigated wheat, barley and maize were estimated as 51587, 53529 and 72743 MJ ha^{-1}, respectively. Also energy consumption for wheat and barley in dry land system were estimated as 12543 and 11935 MJ ha^{-1}, respectively.

Bereket Barut et al. (2011) evaluated the effects of differenttillage systems on energy use, the energy output/input ratios and profitability for silage corn (*Zea mays L*) production. The tillage systems were consisted of conventional tillage without stubble (CT), minimumtillage (MT), band tillage (BT), ridge tillage (RT) and no-tillage (NT). The effects of tillage were found to be statistically on energy parameters. The highest energy use efficiency (8.78), energy productivity (2.12 kg MJ^{-1}), and energy profitability (7.78) were in MT while the lowest in NT. The highest benefit/cost ratio and productivity were in the MT (2.13), and followed by NT (2.07).

Pishgar Komleh et al. (2011) determined the energy consumption patterns in different sizes of farms for corn silage production. The most important energy inputs were machinery and chemical fertilizers with 42% and 28% of total energy input, respectively. The total consumption energy was 68,928 MJ ha^{-1} where the output was 148,380 MJ ha^{-1}. The results showed that farms with more than 10 ha used the least amount of total energy per hectare. The economic analysis showed average total cost of production as 1973 \$ ha^{-1} that was higher in large farms; however more yield led to better benefit to cost ratio. The GHG emissions were indicated the high CO_2 output in machinery production.

Rajaniemi et al. (2011) analyzed greenhouse gas (GHG) emissions from oats, barley, spring wheat and rye production in Finland. The GHG emissions were analyzed in a conventional production chain, direct drilling chain and reduced tillage chain. Wheat (2330kg CO_2-eq. ha-1) and rye (2270kg CO_2-eq. ha^{-1}) had higher GHG emissions per hectare than oats and barley. The main reason for this was the higher application rate of N-fertilizer. The emissions of oats and barley were 1800 and 1930kg CO_2-eq. ha^{-1}.

Sefeedpari et al. (2012) determined the input–output energy use and the relationship between energy input levels on yield in southern part of Tehran province, Iran. Besides, the energy analysis was carried out based on different farm operations. The total energy input consumption was 36.5 GJ ha^{-1}; in which chemical fertilizers with 11.8 GJ ha^{-1}(with 32.3%), followed by diesel fuel and water for irrigation (with 26.5% and 24.9%, respectively) were highly contributed to the total energy use. Energy ratio, energy productivity, specific energy and net energy indices were 3.49, 1.45 kg MJ^{-1}, 0.69 MJ kg^{-1} and 90563.3, respectively.

Shamabadi (2012) determined the effect of reduced tillage on energy consumption and wheat yield in Shahrood. This study was about of different tillage methods which affected irrigated wheat yield in potato-wheat rotation. The experimental design was randomized complete block design with 4 replications and 4 treatments. According to the results, it was determined that the use of new methods of irrigation (pressurized irrigation) could increase the energy efficiency.

Ramah and Baali (2013) determined the energy balance of barley and wheat, the main cultivated crops in Morocco. The results indicated that the total energy expenditure was 7480 MJ ha^{-1} for wheat and 3230 MJ ha^{-1} for barley. The energy efficiency in the case of wheat was 3.3 and 4.2 for barley without considering by products (straw, roots).

Baran and Gökdoğan (2014) performed an energy analysis of barley production in Thrace region of Turkey. In barley production, energy input was calculated as 16950.15 MJ ha^{-1} and 1 energy output was calculated as 92233.60 MJ ha^{-1}. Energy use efficiency, energy productivity, specific energy and net energy in barley production were calculated as 5.44; 0.25 kg MJ^{-1}; 2.79 MJ kg^{-1} and 75283.45 MJ ha^{-1}, respectively.

Kardoni et al. (2014) determined energy consumption patterns and the relationship between energy inputs and yield for wheat production in Iranian agriculture during the period 1986 – 2008. The results indicated that total energy inputs in irrigated and dryland wheat production increased from 29.01 and 9.81 GJ ha^{-1} in 1986 to 44.67 and 12.35 GJ ha^{-1} in 2008, respectively. Similarly, total output energy rose from 28.87 and 10.43 GJ ha^{-1} in 1986 to 58.53 and 15.77 GJ ha^{-1} in 2008, in the same period. The results also revealed that non-renewable, direct, and indirect energy forms had a positive impact on the output level.

Nasrollahi-Sarvaghaji et al. (2014) evaluated the energy consumption and output energy for production of grass clover and barley in East of Isfahan province, Iran. Results showed that total energy amount for crops were 70172.05 MJ ha^{-1}. Also, about 24.22% of this energy was related to diesel fuel and 22.37% to chemical fertilizers. Specific energy amount about 2.26 MJ kg^{-1} for clover and about 5.62 MJ kg^{-1} was estimated for barley and eventually energy use efficiency for clover and barley was 4.448 and 0.178, respectively.

Houshyar et al. (2015) analyzed the energy consumption patterns of silage corn production, the corresponding GHG emissions, the relationships between energy inputs and outputs, and the sensitivity of yield-to-energy inputs, using the Cobb–Douglass econometric model and MPP (Marginal Physical Productivity) in the Fars province of southwest Iran. The results showed that around 45–68 GJ ha^{-1} energy was needed to produce 67–85 ton ha^{-1} of silage corn.

Marin et al. (2015) carried out this research on the chromic luvisol of the Moara Domneasc Teaching Farm belonging to the University of Agronomic Sciences and Veterinary Medicine of Bucharest. The soil tillage experimental variants were: a1 - ploughed at 20 cm in depth (control - conventional system); a2 - chisel ploughed at 20 cm in depth; a3 - chisel plough at 40 cm in depth; a4 - disking at 10 cm in depth (minimum tillage system). The biological material was Dropia in winter wheat and the PO216 hybrid in maize (*Zea mays L*.). Energy indicators Ep and ER recorded higher values in minimum tillage, compared with the conventional system in winter crop and lower in maize crop.

Syp et al. (2015) applied data envelopment analysis methodologies to 55 winter wheat farms in three farm sizes in Poland to benchmark the level of operational efficiency for each producers. The results indicated that 55% of the analysed farms operated efficiently. The average greenhouse gas (GHG) emissions were found as 0.448, 0.481, and 0.411 kg CO_2 eq. per kg of grain, for small, medium, and large farms, respectively. The performed analysis shows that GHG emissions per hectare depend on farm size and ranged from 2,378 kg CO_2 eq. for the small farms to 2,759 kg CO_2 eq. for large farms.

Ziaei et al. (2015) conducted this study in order to compare wheat and barley farms of Sistan and Baluchestan province in Iran in relation to various aspects of energy consumption at 2009. Results showed that total energy inputs of wheat and barley fields were 32492.97 and 25655.81 MJ ha^{-1}, respectively. Total energy outputs for wheat and barley fields were 48517.24 and 49800.87 MJ ha^{-1}, respectively. Based on these results the amount of energy use efficiency for wheat and barley fields were 1.49 and 1.94, respectively, and the amount of energy productivity for mentioned fields were 0.056 and 0.066.

Baran and Gökdoğan (2016) made an energy efficiency analysis of different tillage methods on the secondary crop corn silage production during production years in 2011 and 2013. In order to determine energy efficiency of corn, the treatments were performed in Thrace region of Turkey to determine the amount of energy use efficiency for different tillage methods. The tillage methods were consisted of (T1): turnshredder + heavy tine spring cultivator + pneumatic precision drill, (T2): turn shredder + rotory tiler +pneumatic precision drill, (T3): turn shredder +chisel + heavy duty disk harrow + pneumaticprecision drill and (T4): plough + heavy duty diskharrow + pneumatic precision drill. The highest corn yield

67035 kg, energy use efficiency (5.52), energy outputs 2777793.04 MJ ha^{-1}, energy productivity (1.33 kg MJ^{-1}) and net energy (227493.67 MJ ha^{-1}) were found in T4 method.

Kokten et al. (2016) determined an energy balance of common vetch, Hungarian vetch and Narbonne vetch production during the production season of 2015 in Bingol province of Turkey. Energy usage efficiency, specific energy, energy productivity and net energy values related to common vetch, Hungarian vetch and Narbonne vetch production were determined as 3.22, 0.64, 0.81; 5.46 MJ kg^{-1}, 29.98 MJ kg^{-1}, 21.98 MJ kg^{-1}; 0.18 kg MJ^{-1}, 0.03 kg MJ^{-1}, 0.05 kg MJ^{-1} and 28987.50 MJ ha^{-1}, -5715.89 MJ ha^{-1}, -2806.11 MJ ha^{-1} respectively for each type.

Baran (2017) made an energy analysis of winter vetch plant (*Vicia Sativa L.*) production in dry conditions in Thrace region of Turkey during the production season of 2012-2013. Energy usage efficiency, specific energy, energy productivity and net energy in vetch plant production were calculated as 8.05, 0.47 MJ kg^{-1}, 2.12 kg MJ^{-1} and 91343.20 MJ ha^{-1}, respectively. Benefit-cost ratio was calculated as 2.25.

Unakıtan and Aydın (2018) determined the total amount of input usage and peformed the economic comparison of wheat and sunflower production in Thrace Region in Turkey and determined the energy equivalent of these inputs. Energy use efficiency, energy productivity, specific energy and net energy in wheat production were calculated as 3.52, 0.19 kg MJ$^{−1}$, 5.16 MJ kg$^{−1}$ and 58,489 MJ ha$^{−1}$ respectively in wheat production. Benefit-cost ratio was calculated as 1.20 for wheat.

Altuntaş et al. (2019) compared the four different tillage systems (1 (no-tillage (DE) (no till planter); 2) conservational tillage system (KT) (chisel+ disc harrow+planting); 3) reduced soil tillage system (RT) (rotovator+planting); 4) conventional soil tillage system (GT) (mouldboard plough+ disc harrow+planting)] in terms of energy use efficiency under dry farming condition for Bezostaja-1 wheat cultivar in Sivas province. The highest energy input was obtained as fertilizer, seed, and fuel +oil energies in all tillage systems for wheat farming, respectively.

Eren et al. (2019) determined GHG emissions for eleven different plants production (barley, chickpea, corn, cotton, lentil, lupine, rice, sugar beet, sunflower, vetch and wheat) in the different provinces of Turkey. For this purpose, the initial data was collected from references. The results indicated that total GHG emissions for eleven different fruits (barley, chickpea, corn, cotton, lentil, lupine, rice, sugar beet, sunflower, vetch and wheat) production were calculated as 2516.20, 2000.75, 2453.82, 3215.20, 1994.86, 3725.31, 8847.09, 4742.69, 2348.20, 1933.61, 4098.93 kgCO_{2-eq} ha^{-}1, respectively. The GHG ratios were calculated as

0.41, 1.16, 0.04, 0.56, 1.23, 5.07, 1.01, 0.07, 0.04, 0.09 and 0.78 kg $kgCO_{2-eq}$ kg^{-1}, respectively.

Klikocka et al. (2019) compared the effect of traditional tillage system (TRD) and reduced (RED) tillage technology and nitrogen fertilizer (0, 40, 80, 120 kg N ha^{-1}) on grain and bioethanol yield of spring triticale in the south east of Poland. Based on research and calculations, the TRD system and between 40 and 80 kg ha^{-1} of N fertilizer were recommended for use in the cultivation of triticale for bioethanol production purposes. The best ratio of energy efficiency of bioethanol production (EROI—Energy Return on (Energy) Investment or "net energy") was recorded for the TRD system and for the N fertilizer at 40 kg N ha^{-1}.

Çıtıl et al. (2020) determined the mechanization properties and energy efficiency of Italian grass. According to the research results; the highest fuel consumption was determined in the baler machine with 43.2 l ha^{-1} in the harvest group machines and with the plow with 17.2 l ha^{-1} in the soil processing group machines. Total energy output was calculated as 81572.40 MJ ha^{-1} and total energy input was 34197.97 MJ ha^{-1} and accordingly, net energy efficiency was 47374.43 MJ ha^{-1}, energy ratio was 2.39 and energy productivity was 0.14 kg MJ^{-1}. The amount of energy required to obtain a kg product defined as specific energy was calculated as 7.31 MJ kg^{-1}.

Carman et al. (2021) used three different strip tillage applications as an alternative to Conventional Tillage (CT). While Original Strip-Till (OST) machine made by the Maschio Gaspardo was used in one of the applications of the strip tillage, the other two Machines [Horizontal (MHST) and Vertical (MVST) shaft rotary Tillers] were modified and used in strip tillage. The energy ratio, energy productivity, specific energy, net energy gain, and energy intensiveness were calculated. There were significant differences among the treatments in terms of various energy indices and corn silage yields. Energy use efficiency was the highest in the MHST method with hoeing.

Nassir et al. (2021) analysed the consumed energy, energy input-output relation of wheat, barley, and oat production in Al-Qarneh al-Ghamayj. The irrigation consumed 32.99, 31.83 and 31.96% of the total energy inputs on wheat, barley and oat, respectively. Fuel was the second source of consumed energy in tractors, harvesting engines, pumps such as 8466.21 (27.84%), 9415.03(28.45), and 8757.33 (28.41) for wheat, barley, and oats, respectively. The fertilizers consumed energy (nitrogen especially) were 7291.94 (23.98%), 7658.35 (23.14%), and 7444.72 (24.15%) MJ ha^{-1} for wheat, barley, and oats respectively.

3. Materials and Methods

3.1. Materials

The study was carried out in 2018 and 2019 years on the lands of Atatürk Soil Water and Agricultural Meteorology Research Institute located 4 km west of Kırklareli province of Turkey. Kırklareli province is located within 41^{o}42' north latitude and 27^{o}14' east longitude and total surface area of the province is 655036 ha.

The study was carried out according to randomized blocks trial design with four repetitions. In the first year of the trial, second soil tillage was done by cultivator after deep plowing. Thereafter, the seed bed was prepared by harrowing twice. Sowing was done manually between the range of 20 rows and 50 kg seeds were used per hectare. The seeds were pressed by rolling cylinder after sowing. The planting was done on 30 September 2018 in the first year and 30 September 2019 in the second year. In the second year of the trial, deep plowing was not done as the subsurface drip irrigation system was used. Doubling and tripling operations were carried out by tilling the soil to a depth of 15 cm by means of rotary tillers.

The study subjects consisted of parcels grown in precipitation-based conditions, parcels irrigated with drip irrigation method and parcels irrigated with subsurface drip irrigation system placed 20 and 40 cm deep into the soil. The parcels under precipitation conditions, irrigated by drip irrigation method, irrigated by subsurface drip irrigation systems placed 20 cm and 40 cm deep into the soil composed the subjects of the study. Lateral pipes with 40 cm dripper spacing, 4 l/h flow and Ø16 mm diameter were used in the irrigation system.

Soil moisture was monitored by gravmetric method. The missing moisture in the effective root depth of the plant was completed to the field capacity with a 7-day irrigation interval. Heading period was preferred as the harvest time. Harvesting was done with a mower 5 cm above the soil level. In fertilization applications, base fertilizer is given with planting. Other nitrogen fertilizer applications were made with a fertilizer distribution machine.

In both years of the study, the field surface was completely covered with plants, as the plants emerged well. Since there were no weeds and pests that would require chemical control economically, chemical control was not carried out.

3.2. Methods

In the study, firstly, the amounts of inputs (seed, fertilizer, diesel, oil, human labor, machinery, irrigation water, electricity) used in Italian grass production were found. Input amounts were calculated per hectare and then these input data were multiplied by the energy equivalent coefficient. Previous studies were used to determine the energy equivalent coefficients.

Machinery energy input was calculated by the following formula (Yaldız et al., 1990).

$$ME = \frac{\mathrm{W \times E}}{\mathrm{T \times EFC}}$$

ME: Machinery energy input (MJ ha^{-1}),

W: Weight of the tool (kg),

E: Production energy of the agricultural machine (MJ kg^{-1}),

T: Economic life of the tool (h),

EFC: Effective field capacity (ha h^{-1})

E value was taken as 158.5 MJ kg^{-1} for tractor and 121.3 MJ kg^{-1} for machines (Doering, 1980). Fuel consumption was determined by the tank top up method. Oil consumption was taken into account as 4.5% of the diesel fuel consumed.

$$FE = FC \ x \ FEE$$

$$OE = (YT \ x \ 0.045) \ x \ OEE$$

FE = Fuel energy

OE = Oil energy

FC = Fuel consumption (l ha^{-1})

FEE = Energy equivalent of fuel (MJ l^{-1})

OEE = Energy equivalent of oil (MJ l^{-1})

The energy value of one liter diesel fuel was taken as 35.69 MJ and the energy value of one liter oil was taken as 6.51 MJ (Ejilah and Asere, 2008).

Energy use efficiency, specific energy, energy productivity and net energy coefficients were calculated in order to determine the energy use in Italian ryegrass production and the following formulas were used. Energy productivity expresses the product quantity per energy use whereas specific energy expresses the energy quantity per product quantity.

$$Energy\ Use\ Efficiency = \frac{Energy\ Output(MJ\ ha^{-1})}{Energy\ Input\ (MJ\ ha^{-1})}$$

$$Energy\ Productivity = \frac{Yield(kg\ \ ha^{-1})}{Energy\ Input\ (MJ\ ha^{-1})}$$

$$Specific\ Energy = \frac{Energy\ Input\ (MJ\ ha^{-1})}{Yield(kg\ ha^{-1})}$$

$$Net\ Energy = Energy\ Output(MJ\ ha^{-1}) - Energy\ Input\ (MJ\ ha^{-1})$$

The following equation was used to determine the total energy input.

$$\text{AEI} = \sum_{i=1}^{n} R\ (i)\ x\ E_{eq}\ (i)$$

AEI: Agricultural energy input (MJ ha^{-1})

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

E_{eq}(i) : Energy equivalent of i input (MJ $unit_{input}^{-1}$)

The following equation was used to determine the energy output.

$$AEO = Y\ x\ LHV$$

AEO: Agricultural energy output (MJ ha^{-1}),

Y: Yield (kg ha^{-1})

LHV: Lower heating value (MJ kg^{-1})

The energy equivalents of the agricultural inputs and outputs in Italian ryegrass production are given in Table 1.

Table 1: Energy equivalents of inputs and outputs in Italian ryegrass production.

Inputs	**Energy Equivalents (MJ unit^{-1})**	**References**
Human labor (h)	1.96	(Singh, 2002)
Machinery production energy (kg)		
Tractor	158.30	(Doering, 1980)
Soil tillage devices	121.30	(Doering, 1980)
Diesel (l)	35.69	(Karaağaç et al., 2019)
Oil (l)	6.51	(Karaağaç et al., 2019)
Fertilizer (kg)		
Nitrogen	60.60	(Singh, 2002)
Phosphorus	11.15	(Singh, 2002)
Seed (kg)	20.38	(Çıtıl et al., 2020)
Electricity (kWh)	3.60	(Singh, 2002)
Irrigation water (m^3)	0.63	(Yaldız et al., 1990)
Output		
Yield (kg)	17.43	(Çıtıl et al., 2020)

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

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

GHG_h: Greenhouse gas emission ($kgCO_{2-eq}$ ha^{-1})

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

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

GHG emission coefficients of the agricultural inputs are given in Table 2.

Table 2: GHG emission equivalents of the inputs in agricultural production.

Inputs	GHG emission equivalents	References
Human labor (h)	0.700	(Nguyen and Hermansen,2012)
Machinery (MJ)	0.071	(Pishgar-Komleh et al., 2012)
Diesel (l)	2.760	(Clark et al., 2016)
Nitrogen (kg)	4.570	(Anonymous, 2011)
Phosphorus (kg)	1.180	(Anonymous, 2011)
Irrigation water (m^3)	0.170	(Lal, 2004)
Electricity (MJ)	0.167	(Anonymous, 2011)
Seed (kg)	7.630	(Clark et al., 2016)

The variable costs included human labor, machinery, seed, fertilizer, water and electricity, irrigation system maintenance and repair expenses and revolving interest. Daily labor wages were used to calculate the human labor costs and tool-machine rents were used to calculate the machinery costs. The revolving interest was calculated by multiplying half of the interest rate (5%) applied to the vegetative production by Turkish Republic Ziraat Bank.

The fixed costs included general administration expenses, land interest, irrigation systems investment expenses depreciation and interest. General administrative expenses were calculated by taking of 3% of the total variable costs. Irrigation systems investment expenses interest was calculated by applying 5% interest to the half of the machine value. Irrigation systems investment expenses depreciation was accepted as 10% of total capital.

The amount of product harvested is multiplied by the selling price of the product to obtain the gross production value. The gross profit, net profit and relative profit values were calculated by using the following formulas (Kıral et al., 1999).

$$Gross\ profit = Gross\ production\ value - Variable\ costs$$

$$Net\ profit = Gross\ production\ value - Fixed\ costs$$

$$Relative\ profit = Gross\ production\ value\ /\ Variable\ costs$$

4. Results and Discussion

The output amounts and the inputs used in Italian ryegrass production are shown in Table 3. The results disclosed that around 243 kg nitrogen, 92 kg phosphorus, 218.93 l diesel fuel and oil, 368.20 h human labor, 38.20 h tractor and machinery and 50 kg seed were used to produce Italian ryegrass in the area. Around 4601.45 m^3 water for irrigation and 234 Kwh electrical energy per hectare were required to produce Italian grass irrigated by subsurface drip irrigation systems placed in 20 cm deep into the soil. Besides, 4666.05 m^3 water and 237.50 kWh electrical energy were used to produce Italian ryegrass irrigated by subsurface drip irrigation systems placed 40 cm deep into the soil and 4998.15 m^3 water and 254.50 kWh electrical energy were used to produce Italian ryegrass irrigated by drip irrigation.

It was determined that the highest yield in Italian ryegrass production was obtained from drip irrigation subject whereas the lowest yield amount was taken from the subject under non irrigated conditions with the value of 8846.45 kg ha^{-1}.

Table 3: Amounts of the inputs and the outputs in Italian ryegrass production.

Inputs	20 cm	40 cm	Drip Irrigation	Non Irrigation
Human labor (h)	368.20	368.20	368.20	368.20
Tractor + machinery (h)	38.20	38.20	38.20	38.20
Diesel + oil (l)	218.93	218.93	218.93	218.93
Fertilizer (kg)				
Nitrogen	243.00	243.00	243.00	243.00
Phosphorus	92.00	92.00	92.00	92.00
Water (m^3)	4601.45	4666.05	4998.15	0.00
Electricity (kWh)	234.00	237.50	254.50	0.00
Seed (kg)	50.00	50.00	50.00	50.00
Output				
Yield (kg)	14443.00	12988.05	15087.40	8846.45

The energy equivalents of the inputs and output energy equivalent are illustrated in Table 4. Of all the irrigation subjects in Italian ryegrass production, nitrogen consumed the most energy, followed by diesel and oil, water, machinery, tractor, phosphorus, seed, electricity and human labor. In non-irrigated Italian ryegrass production, nitrogen consumed the most energy, followed by diesel and oil, machinery, tractor, phosphorus, seed and human labor. In previous studies, Çıtıl et al. (2020) found the similar results that fertilizers consumed the most energy and human labor consumed the least energy in Italian ryegrass production. The highest energy output per hectare was obtained from Italian ryegrass production irrigated by drip irrigation whereas the lowest value was from Italian ryegrass production under non irrigated conditions.

Table 4: Energy equivalents of the inputs and outputs in Italian ryegrass production (MJ ha^{-1}).

Inputs	20 cm		40 cm		Drip Irrigation		Non Irrigation	
	EE	%	EE	%	EE	%	EE	%
Human labor	721.67	2.23	721.67	2.23	721.67	2.21	721.67	0.48
Tractor	1593.00	4.92	1593.00	4.92	1593.00	4.88	1593.00	5.68
Machinery	1987.90	6.14	1987.90	6.13	1987.90	6.08	1987.90	7.09
Diesel + oil	7538.43	23.30	7538.43	23.26	7538.43	23.07	7538.43	26.90
Fertilizer								
Nitrogen	14725.80	45.52	14725.80	45.44	14725.80	45.07	14725.80	52.55
Phosphorus	1025.80	3.17	1025.80	3.17	1025.80	3.14	1025.80	3.66
Water	2898.91	8.96	2939.61	9.07	3148.83	9.64	0.00	0.00
Electricity	842.40	2.60	855.00	2.64	916.20	2.80	0.00	0.00
Seed	1019.00	3.15	1019.00	3.14	1019.00	3.12	1019.00	3.64
Total energy	32352.91	100.00	32406.21	100.00	32676.63	100.00	28023.60	100.00
Output								
Yield	251741.49		226381.71		262973.38		154193.62	

EE: Energy Equivalent

The energy parameters in Italian ryegrass production are given in Table 5. The energy use efficiency (energy ratio) values in the Italian ryegrass production were found more than 1 in all subjects indicating that energy consumption in Italian ryegrass production in surveyed region is efficient, i.e. energy production was greater than energy utilization. The highest energy use efficiency value in Italian ryegrass production was obtained from drip irrigation subject. In previous investigations, energy efficiency values were found as 2.39 in Italian ryegrass production (Çıtıl et al., 2020), 5.44 in barley production (Baran and Gokdogan, 2014), 1.90 in barley production and 4.45 in clover production (Nasrollahi-Sarvaghaji et al., 2014), 3.49 (Sefeedpari et al., 2012), 2.27 (Pishgar Komleh et al., 2011), 10.71 (Houshyar et al., 2015) in corn silage production, 8.05 in vetch production (Baran, 2017), 1.49 in wheat production and 1.94 in barley production (Ziaei et al., 2015), 1.59 in wheat production, 1.90 in barley production and 1.71 in oat production (Nassir et al., 2021).

Energy productivity is the term used to estimate the yield of marketable product per unit of energy consumption. The average energy productivity of Italian ryegrass production were 0.45, 0.40, 0.46 and 0.32 kg MJ^{-1} for the subjects, respectively. This means that for example in Italian ryegrass production by drip irrigation, 0.46 kg output was obtained per unit energy (MJ). The comparison between the subjects showed that it can be obtained more than 0.01, 0.06 and 0.14 kg output by drip irrigation when compared with the subjects respectively as subsurface drip irrigation systems placed 20 cm deep into the soil, 40 cm deep into the soil, and non-irrigated conditions. Calculation of energy productivity rate is well documented in the literature such as 0.14 in Italian ryegrass production (Çıtıl et al., 2020).

Specific energy indicated the amount of energy spent to produce a unit of marketable product. The specific energy for Italian ryegrass production were 2.24, 2.50, 2.17 and 3.17 MJ kg^{-1} for the subjects, respectively. It can be seen that production of Italian ryegrass by drip irrigation had less energy consumption compared to other subjects. It also implied that to produce 1 kg of Italian ryegrass, the lowest amount of energy input was needed in drip irrigation subject. In previous studies, specific energy was found as 7.31 in Italian ryegrass production which meant that 7.31 MJ energy was needed to obtain one kg of crop (Çıtıl et al., 2020).

Although the net energy values were positive in all subjects, it was concluded that in non-irrigated Italian ryegrass production energy had been lost when compared with the other subjects. The lower value for the net energy in non-irrigated Italian ryegrass production was based on the structure of farming system under dry conditions and consequently, this lower value was considered as reasonable.

Of all the energy parameters, Italian ryegrass by drip irrigation had the highest energy use efficiency, energy productivity and net energy when compared to the other subjects in the study.

Table 5: Energy parameters in Italian ryegrass production.

Energy Parameters	20 cm	40 cm	Drip Irrigation	Non Irrigation
Energy use efficiency	7.78	6.99	8.05	5.50
Energy productivity (kg MJ^{-1})	0.45	0.40	0.46	0.32
Specific energy (MJ kg^{-1})	2.24	2.50	2.17	3.17
Net energy (MJ ha^{-1})	219388.58	193975.50	230296.75	126170.02

The distribution of input energy in Italian ryegrass production according to direct, indirect, renewable and non-renewable energy forms is given in Table 6. Direct energy is the energy that is directly exerted by human labor, diesel, electricity and irrigation water and indirect energy is the energy fertilizers, machinery and seed. Around 62% of total energy, input use in Italian ryegrass production was in the form of indirect energy in the irrigated subjects. In non-irrigated subject, 72.62% of total energy, input use in Italian ryegrass production was in the form of indirect energy.

Renewable energy is the energy in form of human, irrigation water and seed. Whereas, the non-renewable energy is in form of diesel, electricity, fertilizers, machinery and electricity. Results revealed that the total energy inputs used in all subjects, Italian ryegrass production were mostly depended on the nonrenewable form of energy. It was around 85% in the irrigated subjects and 95% in the non-irrigated subject. These results showed that the share of renewable energies in the production of Italian ryegrass under non irrigated conditions was lower than the irrigated subjects in the studied region. Other researchers reported that the ratios of direct, indirect, renewable and non-renewable energy in total energy inputs in Italian ryegrass production were 45.62%, 54.38%, 34.62% and 65.38%, respectively (Çıtıl et al., 2020).

Table 6: Energy input forms of Italian ryegrass production.

Energy Form	20 cm	40 cm	Drip Irrigation	Non Irrigation
Direct energy [a]	12001.41 (37.10%)	12054.71 (37.20%)	12325.13 (37.72%)	7672.10 (27.38%)
Indirect energy [b]	20351.50 (62.90%)	20351.50 (62.80%)	20351.50 (62.28%)	20351.50 (72.62%)
Renewable energy [c]	4639.58 (14.34%)	4680.28 (14.44%)	4889.50 (14.96%)	1152.67 (4.11%)
Non-renewable energy [d]	27713.33 (85.66%)	27725.93 (85.56%)	27787.13 (85.04%)	26870.93 (95.89%)
Total energy input	32352.91 (100.00%)	32406.21 (100.00%)	32676.63 (100.00%)	28023.60 (100.00%)

[a] Includes human labor, diesel, electricity and irrigation water
[b] Includes fertilizers, machinery, seed
[c] Includes human labor, irrigation water, seed
[d] Includes diesel, fertilizers, machinery and electricity

The results of GHG emissions of Italian ryegrass production are shown in Table 7. The total GHG emissions were calculated as 3639.72, 3652.81, 3719.48 and 2506.79 $kgCO_{2\text{-}eq}$ ha^{-1} for the subjects, respectively. The distribution of different inputs in total GHG emissions is illustrated in Figure 1. The results showed that of all the irrigation subjects in Italian ryegrass production, the share of nitrogen in total GHG emissions was the highest in all subjects, followed by water, diesel and oil, seed, human labor and machinery. The shares of phosphorus and electricity in total GHG emissions were around 3% and lower when compared with the other inputs.

In non-irrigated Italian ryegrass production, the share of nitrogen in total GHG emissions was the highest and it was followed by diesel and oil, seed and machinery. The share of phosphorus was around 4% and the share of human labor was approximately 2%. In all subjects, nitrogen had the highest share so better agricultural management in terms of fertilizing can lead to Italian ryegrass production with lower GHG emissions in the research area.

GHG ratios (per kg) were found as 0.252, 0.281, 0.247 and 0.283 for the subjects, respectively. Italian ryegrass by drip irrigation seemed to be advantageous in terms of GHG consumption when compared to the other subjects in the study.

Table 7: Total GHG emissions in Italian ryegrass production (kgCO_{2-eq} ha^{-1}).

Inputs	20 cm		40 cm		Drip Irrigation		Non Irrigation	
	Value	%	Value	%	Value	%	Value	%
Human labor (h)	257.74	7.08	257.74	7.06	257.74	6.93	257.74	1.90
Tractor + machinery (MJ)	254.24	6.99	254.24	6.96	254.24	6.84	254.24	10.14
Diesel + oil (l)	604.24	16.60	604.24	16.54	604.24	16.25	604.24	24.10
Nitrogen (kg)	1110.51	30.51	1110.51	30.40	1110.51	29.86	1110.51	44.30
Phosphorus (kg)	108.56	2.98	108.56	2.97	108.56	2.92	108.56	4.33
Water (m^3)	782.25	21.49	793.23	21.72	849.69	22.84	0.00	0.00
Electricity (kWh)	140.68	3.87	142.79	3.91	153.01	4.11	0.00	0.00
Seed (kg)	381.50	10.48	381.50	10.44	381.50	10.26	381.50	15.22
Total	3639.72	100.00	3652.81	100.00	3719.48	100.00	2506.79	100.00
GHG ratio (per kg)	0.252		0.281		0.247		0.283	

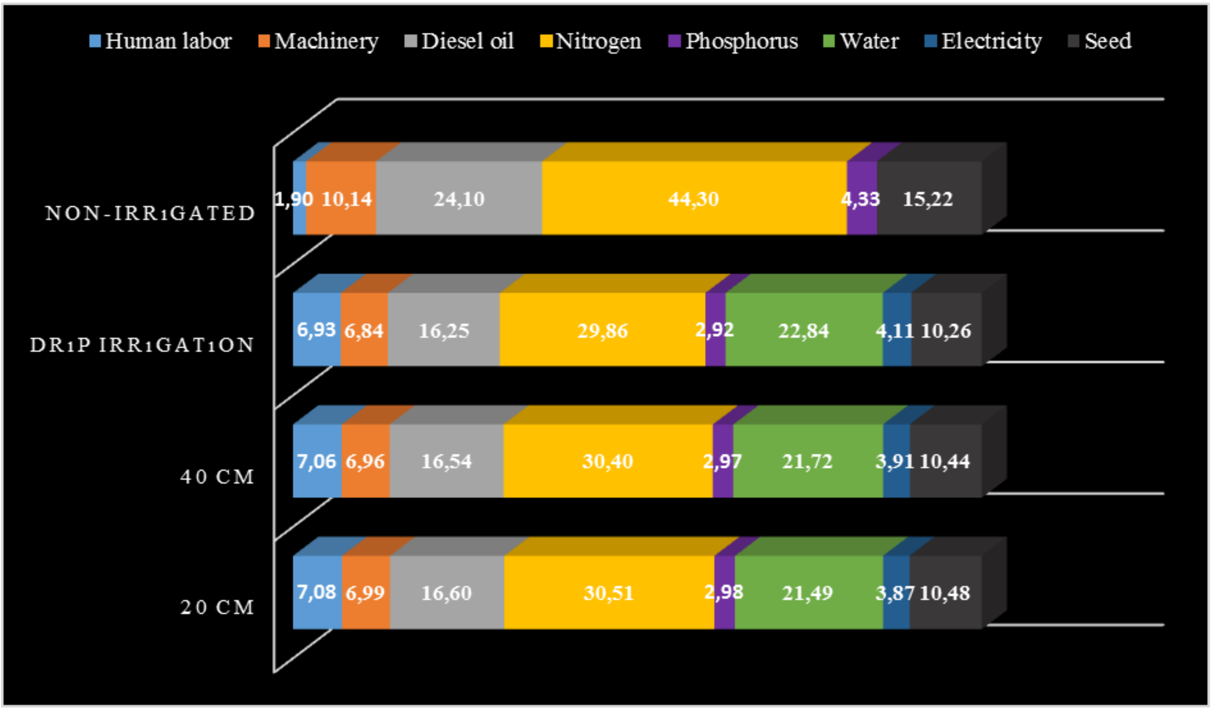

Figure 1: The distribution of the inputs in GHG emissions for 1 ha Italian ryegrass production.

The production cost items and the main economic indicators of Italian ryegrass production are given in Table 8. The total production costs of Italian ryegrass production were calculated as 1504.72, 1507.81, 1517.75 and 931.31 $ ha^{-1} for the subjects, respectively while the highest gross production values was obtained from Italian ryegrass production by drip irrigation found with the value of 2386.71 $ ha^{-1}.

About 80% of the total production costs were variable costs whereas approximately 20% was fixed costs in four types of Italian ryegrass production. The first three highest costs items were machinery, human labor, water and electricity machinery in the irrigation subjects and whereas machinery, land interest and fertilizers were the highest cost items in non-irrigated Italian ryegrass production. In contrast to the share of human labor within total energy input, the cost of this input had the second highest share in total production costs in the irrigated subjects. .

The production costs of one kg of Italian ryegrass were determined as 0.16 $ kg^{-1} in all subjects. Relative profits were calculated as 1.52, 1.36, 1.57 and 1.49 for the subjects, respectively as a result of the economic analysis of Italian ryegrass production.

The productivity was calculated by dividing Italian ryegrass yield by total production costs. Italian ryegrass farming was determined to be profitable in each production types but it seemed to be more profitable in drip irrigation subject, followed by subsurface drip irrigation systems placed 20 cm deep into the soil.

Table 8: Production costs and economic analysis of Italian ryegrass production.

Production Costs	20 cm		40 cm		Drip Irrigation		Non Irrigation	
	Cost	%	Cost	%	Cost	%	Cost	%
Human labor	305.08	20.28	305.08	20.23	305.08	20.10	96.05	10.25
Machinery	389.83	25.91	389.83	25.85	389.83	25.68	389.83	41.59
Seed	90.40	6.01	90.40	6.00	90.40	5.96	90.40	9.64
Fertilizer	133.79	8.89	133.79	8.87	133.79	8.81	133.79	14.27
Water and electricity	201.22	13.37	204.08	13.53	218.63	14.40	0.00	0.00
Maintenance and repair expenses	45.20	3.00	45.20	3.00	45.20	2.98	0.00	0.00
Revolving interest	58.28	3.87	58.42	3.87	59.15	3.90	35.50	3.79
Variable costs	1223.79	81.33	1226.79	81.36	1242.07	81.84	745.56	79.53
General administration expenses	36.71	2.44	36.80	2.44	37.26	2.46	22.37	2.39
Land interest	169.49	11.26	169.49	11.24	169.49	11.17	169.49	18.08

Investment expenses depreciation	57.06	3.79	57.06	3.78	51.75	3.41	0.00	0.00
Investment expenses interest	17.66	1.17	17.66	1.17	17.18	1.13	0.00	0.00
Fixed costs	280.93	18.67	281.02	18.64	275.68	18.16	191.86	20.47
Production costs	1504.72	100.00	1507.81	100.00	1517.75	100.00	937.42	100.00
Yield (kg ha^{-1})	14443.00		12988.05		15087.40		8846.45	
Sale price ($ ha^{-1})	0.10		0.12		0.10		0.11	
Production cost ($ kg^{-1}	0.16		0.16		0.16		0.16	
GPV ($ ha^{-1})	2284.77		2054.61		2386.71		1399.44	
Gross profit ($ ha^{-1})	1060.98		827.82		1144.64		653.88	
Net profit ($ ha^{-1})	780.05		546.80		868.96		462.02	
Relative profit	1.52		1.36		1.57		1.49	
Productivity (kg $$^{-1}$)	9.60		8.61		9.94		9.44	

5. Conclusions

It was observed that the highest energy inputs in all subjects were fertilizer and fuel consumption. In addition, fertilizer and fuel consumption had the highest share in greenhouse gas emissions. In the context of sustainable environment and energy use; Balanced fertilization programs based on soil and plant analyzes can play an important role in reducing greenhouse gas emissions from agricultural activities. In addition, it will be beneficial to use reduced tillage methods in order to reduce fuel-oil input. With this study, it was revealed that new studies should be given importance to reduce both fertilizer consumption and fuel-oil consumption in Italian grass production.

Emissions from mineral fertilizers occur not only after fertilization, but also during the production, transportation and application of the fertilizer. One of the most effective ways to reduce emissions originating from agriculture is to meet the organic matter and mineral needs of the soil, especially by obtaining compost from plant residues. In addition, organic farmyard fertilizers both increase the organic matter content of the soil and improve the physical structure of the soil in the long term. The mineral nutrients in the compost and farmyard manures are of slow-useful nature in the soil, and compost application is not done properly in agricultural soils in Turkey. However, the best methods that can be used to improve the physical, chemical and biological properties of the soil as well as to increase the carbon content is compost, farmyard manure and green manure applications.

When no tillage or reduced tillage methods are used, an increase in the amount of soil organic carbon can be achieved. The effect of reduced tillage on nitrous oxide emissions is generally dependent on soil and climatic conditions. The no-till method also reduces CO_2 emissions from energy use.

According to the results of two-year field studies, it has been proven that Italian grass production with surface and subsurface drip irrigation systems is effective and reliable in terms of energy use and economically in Thrace climatic conditions. It can be said that the surface drip irrigation application in Italian grass production in the Thrace Region is more suitable in terms of energy use and profitability. Although the profitability rate of Italian grass production under precipitation-based conditions is close to that of Italian grass production with subsurface drip irrigation, when the average yield and energy use are taken into account, the subsurface drip irrigation method, which is placed at a depth of 20 cm in the soil, can be considered as an alternative to the surface drip irrigation method.

The availability of agricultural tools and machinery used in the production of cereals or alfalfa without the need for any additional machinery in Italian grass production ensures that there is no additional tool and machine cost. In this respect, as a result, it is thought that encouraging the farmers to produce Italian grass as an alternative to the production of conventional forage crops and rotation in roughage production will be beneficial in terms of forage crops. After the first seed sowing, the vegetation covering the soil surface completely as of November continues until the end of July. In this context, a useful plant will be preferred against wind and water erosion that may occur from the soil surface.

6. References

AKÜZÜM, A.; SELENAY, F.; ÇAKMAK, B. Irrigation Management and Sustainable Water Use. 1st Irrigation and Agricultural Structures Symposium, May 27-29 May, Kahramanmaraş, Turkey, p. 262-278, 2010. (in Turkish with an abstract in English)

ALTUNTAŞ, E.; BULUT, O.N.; ÖZGÖZ, E. Energy use efficiency analysis of wheat production with different soil systems in dry agriculture. *Anadolu J Agr Sci*, v. 34, n. 2019, p. 57-64, 2019. doi: 10.7161/omuanajas.418694 (article in Turkish with an abstract in English)

ANONYMOUS. Harmonised Calculations of Biofuel Greenhouse Gas Emissions in Europe. BioGrace, Utrecht, The Netherlands. 2011.

BARAN, M.F. Energy and economic analysis of vetch production in Turkey: A case study from Thrace Region. *Fresenius Environ Bull*, v. 26, n. 3, p. 1966-1972, 2017.

BARAN, M.F.; GOKDOGAN, O. Energy input-output analysis of barley production in Thrace Region of Turkey. *American-Eurasian J. Agric. & Environ. Sci*, v. 14, n. 11, p. 1255-1261, 2014. doi: 10.5829/idosi.aejaes.2014.14.11.21882

BARAN, M.F.; GOKDOGAN, O. Comparison of energy use efficiency of different tillage methods on the secondary crop corn silage production. *Fresenius Environ Bull*, v. 25, n. 2016, p. 3808-3814, 2016.

BEREKET BARUT, Z., ERTEKİN, C.; KARAAĞAÇ, H.A. Tillage effects on energy use for corn silage in Mediterranean Coastal of Turkey. *Energy*, v. 36, n. 2011, p. 5466-5475, 2011. doi: 10.1016/j.energy.2011.07.035.

CARMAN, K.; CITIL, E.; MARAKOGLU, T. Energy use efficiency of strip tillage systems for corn silage production in Middle Anatolia. J. *Agr. Sci. Tech*, v. 23, n. 2, p. 293-306, 2021.

CLARK, S.; KHOSHNEVISAN, B.; SEFEEDPARI, P. Energy efficiency and greenhouse gas emissions during transition to organic and reduced-input practices: Student farm case study. *Ecological Engineering*, v. 88, p. 186-194, 2016. doi: 10.1016/j.ecoleng.2015.12.036.

ÇITIL, E.; MARAKOĞLU, T.; KIRILMAZ, H.; ÇARMAN, K. Determination of mechanization properties and energy efficiency of Italian grass agriculture. *Harran Journal of Agricultural and Food Science*, v.24, n.3, p. 336-346, 2020. doi: 10.29050/harranziraat.702848. (article in Turkish with an abstract in English)

DOERING, O.C. Accounting for Energy in Farm Machinery and Buildings. In: Pimentel David, editor. Handbook of Energy Utilization in Agriculture. FL, USA: CRC Press, Inc, ISBN 0-8493-2661-3; p. 9-14. 1980.

EJILAH, I.R.; ASERE, A.A. A comparative performance and emission analysis of blended groundnut oil and mineral oil based lubricants using a spark ignition engine. *Agricultural Engineering International: The CIGR Journal EE 07017*, v. 10, p. 1-13, 2008.

ERDAL, G.; ESENGÜN, K.; ERDAL, H.; GÜNDÜZ, O. Energy use and economical analysis of sugar beet production in Tokat province of Turkey. *Energy*, v. 32, p. 35-41, 2007. doi: 10.1016/j.energy.2006.01.007.

ERDOGAN, Y. Developing an Internet Based Software for the Energy Input-Output Analyses in Crop Production. MSc, Çukurova University Graduate School of Natural and Applied Sciences, Adana, Turkey. 2009. (in Turkish with an abstract in English)

EREN, O.; GOKDOGAN, O.; BARAN, M.F. Determination of greenhouse gas emissions (GHG) in the production of different plants in Turkey. *Fresenius Environ Bull*, v. 28, n. 2A, p. 1158-1166, 2019.

HOUSHYAR, E.; ZAREIFARD, H.R.; GRUNDMANN, P.; SMITH, P. Determining efficiency of energy input for silage corn production: An econometric approach. *Energy*, v. 93, n. 2015, p. 2166-2174, 2015. doi: 10.1016/j.energy.2015.09.105.

HUGHES, D.J.; WEST, J.S.; ATKINS, S.D.; GLADDERS, P.; JEGER, M.J.; FITT, B.D. Effects of disease control by fungicides on greenhouse gas emissions by U.K. arable crop production. *Pest Manag. Sci*, v. 67, n. 9, p. 1082-1092, 2011. doi: 10.1002/ps.2151.

KARAAĞAÇ, H.A.; BARAN, M.F.; MART, D.; BOLAT, A.; EREN, Ö. Determination of energy usage efficiency and greenhouse gas (GHG) emissions in chickpea production (The case of Adana Province). *EJOSAT*, v. 16, p. 41-50, 2019. doi:10.31590/ejosat.523080. (article in Turkish with an abstract in English)

KARDONI, F.; AL-AHMADI, M.J.; BAKHSHI, M.R. Energy efficiency analysis and modeling the relationship between energy inputs and wheat yield in Iran. *IJAMAD*, v. 5, n. 4, p. 321-330, 2014.

KHAN, S.; KHAN, M.A.; LATİF, N. Energy requirements and economic analysis of wheat, rice and barley production in Australia. *Soil & Environ*, v. 29, n. 1, p. 61-68, 2010.

KIRAL, T.; KASNAKOGLU, H.; TATLIDİL, F.F.; FİDAN, H.; GÜNDOĞMUŞ, E. Tarımsal Ürünler için Maliyet Hesaplama Metodolojisi ve Veritabanı Rehberi. Tarımsal Ekonomi Araştırma Enstitüsü, Yayın No: 37, Ankara. 1999. (in Turkish with an abstract in English)

KLIKOCKA, H.; KASZTELAN, A.; ZAKREWSKA, A., WYLUPEK, T.; SZOSTAK. B.; SKWARYLO-BEDNARZ, B. The energy efficiency of the production and conversion of spring triticale grain into bioethanol. *Agronomy*, v. 9, n. 423, p. 1-15, 2019. doi: 10.3390/agronomy9080423.

KOKTEN, K.; CACAN, E.; GOKDOGAN. O.; BARAN, M.F. Determination of energy balance of common vetch (*Vicia sativa* L.), hungarian vetch (*Vicia pannonica* C.) and narbonne vetch (*Vicia narbonensis* L.) production in Turkey. *Legume Research*, v. 40, n. 3, p. 1-6, 2016. doi: 10.18805/lr.v0i0.6842.

LAL, R. Carbon emission from farm operations. *Environ. Int*, v. 30, n. 7, p. 981-990, 2004. doi: 10.1016/j.envint.2004.03.005.

MARIN, D.J.; RUSU, T.; MIHALACHE, M.; ILIE, L.; NISTOR, E.; BOLOHAN, C. Influence of soil tillage upon production and energy efficiency in wheat and maize crops. *AgroLife Sci. J*, v. 4, n. 2, p. 43-47, 2015.

NASROLLAHI-SARVAGHAJI, S.; KHAKSAR, J.; NABAVI-PELESARAEI, A.; BORHANI-SGEIDANI, A.; TAVAKOLI, M. An investigation of energy consumption for grass clover and barley farms of Isfahan province, Iran. *Trends Life Sci*, v. 3, n. 2, p. 218-229, 2014.

NASSIR, A.J., RAMADHAN, M.N.; MAJEED ALWAN, A.A. Energy input-output analysis in wheat, barley and oat production. *Indian J. Ecol*, v. 48, n. 1, p. 304-307, 2021.

NGUYEN, T.L.T.; HERMANSEN, J.E. System expansion for handling co-products in LCA of sugar cane bio-energy systems: GHG consequences of using molasses for ethanol production. *Appl. Energy*, v. 89, n. 1, p. 254-261, 2012. doi: 10.1016/j.apenergy.2011.07.023.

ÖZKUL, H.; KIRKPINAR, F.; TAN, K. Utilization of caramba (*Lolium Multiflorum cv. Caramba*) herbage in ruminant nutrition. *Journal of Animal Production*, v. 53, n. 1, p.21-26, 2012. (article in Turkish with an abstract in English)

PISHGAR KOMLEH, S.H.; KEYHANI, A.; RAFIEE, S.; SEFEEDPARI, P. Energy use and economic analysis of corn silage production under three cultivated area levels in Tehran province of Iran. *Energy*, v.36, n.2011, p. 3335-3341, 2011. doi: 10.1016/j.energy.2011.03.029.

PISHGAR KOMLEH, S.H.; SEFEEDPARI, P.; GHAHDERIJANI, M. Exploring energy consumption and CO2 emission of cotton production in Iran. *J. Renew. Sustain. Energy*, v. 4, n. 3, p. 033114-033115, 2012. doi: 10.1063/1.4727906.

RAJANIEMI, M.; MIKKOLA, H.; AHOKAS, J. Greenhouse gas emissions from oats, barley, wheat and rye production. *Agron. Res. Biosystem Engineering Special Issue*, v. 1, p. 189-195, 2011.

RAMAH, M.; BAALI, E.H. Energy balance of wheat and barley under Moroccan conditions. *Journal of Energy Technologies and Policy*, v. 3, n. 10, p. 20-27, 2013.

SAFA, M., MOHTASEBI, S.S.; BEHROOZI LAR, M.; GHASEMI-VARNAMKHASTI, M. Energy consumption in production of grains prevalent in Saveh, Iran. *Afr. J. Agric. Res*, v. 5, n. 19, p. 2637-2646, 2010.

SEFEEDPARI, P.; RAFIEE, S.; PISHGAR KOMLEH, S.H.; GHAHDERIJANI, M. A source-wise and operation-wise energy use analysis for corn silage production, a case study of Tehran province Iran. *Int. J. Sustain. Built Environ*, v. 1, p. 158-166, 2012. doi: 10.1016/j.ijsbe.2013.03.001

SHAMABADI, Z. Evaluation the effect of reduced tillage on irrigated wheat yield and energy efficiency. *Int. J. Agric. Crop Sci*, v. 4, n. 20, p. 1508-1511, 2012.

SINGH, J.M. On farm energy use pattern in different cropping systems in Haryana, India. MSc, International Institute of Management University of Flensburg. Sustainable Energy Systems and Management, Germany. 2002.

SYP, A.; FABER, A.; BORZECKA-WALKER, M.; OSUCH, D. Assessment of greenhouse gas emissions in winter wheat farms using data envelopment analysis approach. *Pol. J. Environ. Stud*, v. 24, n. 5, p. 2197-2203, 2015. doi: 10.15244/pjoes/39682.

UNAKITAN, G.; AYDIN, B. Comparison of energy use efficiency and economic analysis of wheat and sunflower production in Turkey: A case study in Thrace Region. *Energy*, v. 149, n. 2018, p. 279-285, 2018. doi: org/10.1016/j.energy.2018.02.033.

YALDIZ, O.; ÖZTÜRK, H.H.; ZEREN, Y.; BAŞÇETİNÇELİK, A. Türkiye tarla bitkileri üretiminde enerji kullanımı. *Ak. Ü. Zir. Fak. Derg*, v. 3, n. 1-2, p. 51- 62, 1990.

ZIAEI, S.M.; MAZLOUMZADEH, S.M.; JABBARY, M. A comparison of energy use and productivity of wheat and barley (case study). *J. Saudi Soc. Agric. Sci*, v. 14, p. 19-25, 2015. doi: 10.1016/j.jssas.2013.04.002.