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Conservation Tillage Can Reduce Energy Consumption and Carbon Emissions in the Production of Rainfed Sunflower

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ABSTRACT

In order to assess the environmental impact of agricultural activity, the long-term sustainability should be considered. In order to achieve solutions to reduce energy consumption and carbon emissions in the production of rainfed sunflower, this assessment was conducted in the North East of Iran. Four production methods, i.e. conventional tillage (CT), tow reduced tillages (RT1and RT2) and direct seeding (NT) were evaluated. The highest energy consumption (12.3 GJ.ha^{-1}) and carbon emissions (248 kg C-eq ha^{-1} and 155 kg C-eq t^{-1}) were related to the conventional method. The least energy input (9.12 GJ ha^{-1}) and carbon emission (183.3 kg C-eq ha^{-1} and 118.6 kg C-eq t^{-1}), were related to NT method. The greatest amount of sustainability index (I_s) was related to NT method, followed by RT2 (1.96), RT1 (1.79) and CT (1.53). In farm operations, fuel and nitrogen fertilizer were the key factors relating to energy use and carbon emission. In comparison of production methods, the conservation tillage was significantly more efficient. In conservation tillage, input energy and fuel consumption per hectare were 30% and 90% lower than conventional method, respectively, but there was no reduction in yield and energy output. Based on the lower power consumption and greater energy efficiency, conservation tillage methods (in particular, reduced tillage and no-tillage) was recommended to replace the conventional tillage.

***Keywords**:* Carbon emission, Energy, Environment, Sunflower, Tillage

INTRODUCTION

There is worldwide trend towards increasing consumption of fossil energy in the production of necessary foodstuffs. Excess energy use creates two problems related to agricultural sustainability. First, fossil energy is a limited resource and will eventually be exhausted. The other problem, is related to serious environmental hazards such as acidification, higher level of CO2, soil losses and pollution (Hosseini, 2011).

The main objective in agriculture production, so far, had focused mostly on the increase of yield and production. Meanwhile, economic production and sustainable agriculture are in regard to improvement in product quality, reduction in production inputs, conservation the natural resources, and environmental wariness gain importance. (Ulusoy, 2001). Tillage practices, are needed to increase agronomic stability and productivity, meanwhile, the environmental risks should be reduced (Hatfield *et al*., 1998).

Sustainable agriculture and conservation tillage is widely being developed, because clearly reduces production cost relative to conventional tillage (Devita *et al.,* 2007).

Energy is required for farm operations such as tillage, sowing, harvesting and transport or stationary operations such as pumping water and drying grain. In addition, energy is needed for manufacturing, packing and storage of fertilizers and pesticides and for activities such as acquisition of raw materials and fabrication of equipment and farm buildings (Lal, 2004).

Direct and indirect consumption of fossil fuels leads to emissions of greenhouse gases, namely carbon dioxide (CO2), nitrous oxide (N2O) and methane (CH4). Greenhouse gas (GHG) from agriculture and other human activities, atmospheric infrared radiation and absorb heat are warming the Earth's surface. This warming effect has led to an increase in the global temperature during the 20^{th} century (Snyder *et al.,* 2009). Combustion of fossil fuels cause over 75% of greenhouse gas emissions caused by humans and changes in land use (primarily deforestation) is responsible for the remainder (Snyder *et al.,* 2009). Reducing the use of fossil energy in agriculture, mainly because of problems caused by the publication of greenhouse gases is a fascinating subject. Also, the sustainable production of agricultural products (to minimize production costs and preserve limited fossil fuel reserves for future generations) is very important (Pervanchon *et al.,* 2002; Rathke and Diepenbrock, 2006). To develop production systems that require less fossil energy and at the same time maintain satisfactory performance and reduce greenhouse gas emissions, requires efficient use of fossil energy in agricultural systems (Rathke and Diepenbrock, 2006; Tzilivakis *et al.,* 2005; Dalgaard, 2000).

In order to prevent the loss of soil, greenhouse gas emissions and conserving soil moisture conservation tillage is known as soil management practices to minimize soil damage (Samarajeewa *et al.,* 2006). Maintaining of crop residues on the soil surface is widely recognized for its positive effects on soil and water conservation. Benefits of residue cover left on soil include improved soil water storage, enhanced organic matter content of soil (reducing Carbon emission), nutrient recycling and protection against water and wind erosion (Hatfi *et al.,* 1998, Lipiec *et al.,* 2006, Lopez *et al.,* 2003). Also, conservation tillage system may contribute to less use of fossil fuels and reduce the need for labor, reduce environmental problems such as soil degradation and loss of biodiversity and contribute to intensive cultivation (Chen *et al.,* 2004, Fernande *et al.,* 2007; Nakamato *et al.,* 2006).

In a survey of agricultural opportunities to reduce greenhouse gas emissions ,Johnson *et al,* (2007) stated that still in some geographic regions, there are farming systems that are not designed well with regard to greenhouse gas emissions. They stressed the need to estimate greenhouse gas emissions and global warming potential across a wide range of farming systems. Sustainable agriculture and increased fuel costs in tillage, encourage farmers to change farming practices and find replaced economic plowing. Minimum tillage and direct seeding are some ways that farmers are applying recently to reduce soil erosion and fuel costs (Bayhan *et al.,* 2006; Yalcin and Cakir, 2006). Sustainable use of soil, water and other non-renewable resources implies: (1) an efficient use of all inputs, (2) minimal losses through leaching, volatilization and erosion, (3) maintenance or enhancement of soil quality, and (4) minimal risks of environmental degradation such as pollution of water and emission of GHGs into the atmosphere. Agricultural land use and land cover changes, account for about 20 percent of annual global emissions of carbon dioxide (CO2) covers. A significant portion of CO2 emissions due to agricultural activity can be reduced by conservation agriculture (IPCC, 2010).

Assessment of energy consumption and its environmental impacts in terms of greenhouse gas emissions is a necessity. So that future steps should be taken to improve the production of sunflower in this regard. The aim of this study was to evaluate the effects of farm operations on fuel consumption and energy flow in different tillage methods in the northeastern part of Iran. Also, the effect of tillage on carbon emissions and sustainability indicators were identified. Reduced tillage and no-tillage methods were compared with conventional tillage system.

MATERIALS AND METHODS

The study was conducted in the Kalpoosh region, Semnan province, Iran. The area along the south-east of the Alborz Mountains is located in northeastern Iran. Total annual precipitation is 380 mm. Mean annual temperature is 17.6 °C. Sunflower is planted in May and is harvested in September. After sunflower harvesting, wheat is usually planted as a second crop in the rotation. Thus, the growing season is limited and the cropping system is intensive. Barley, lentil and bean are other crops sown in the region. In this evaluation, the flow of energy, carbon and sustainability indicators in four sunflower productions methods were analyzed and compared. The experimental design was RCBD, with 4 replications and 5 treatments. The treatments (Table 1) were conventional tillage (CT), two reduced tillages (RT1 and RT2), and direct seeding (NT). All operations were conducted with MF285 tractor, except direct seeding that conducted with New-Holland tractor). Statistical analysis of variance for yield and yield components carried out with MSTAT software.

CT indicates common practice that is applied by the majority of farmers (about 70%) in the region. In this way, seed and base fertilizer are added to the soil by hand or fertilizer applicator and mixed with soil by harrow. NT is a low-input production method, which usage of machinery is minimum and seedbed preparation and sowing is performed simultaneously. Conservation tillage such as CT or RT isn't common in the region due to a lack of necessary machinery including high power tractors and direct seeding machine. The specifications of the equipments used in experiment are given in Table 2.

Table1. Tillage methods and equipment used in the experiment

Tillage methods	Tools
Conventional tillage (CT)	Moldboard plough+ Disk harrow+ Seed broadcaster+ Disk harrow
Reduced tillage (RT1)	Disc harrow (two time)+ Row planting machine
Reduced tillage (RT2)	Chisel plough + Row planting machine
Direct seeding (NT)	Direct seeding machine

Table 2. The specification of the tools used in experiment

Tool	Type	Working depth (cm)	Working width (cm)	Field capacity (hah^{-1})
Moldboard plough	Three bottom	15-20	90	0.29
Heavy disc harrow	24 disk-tandem	12-15	250	0.85
C. Tillage equipment	Chisel packer	15-20	140	0.4
Row planter	Four row	4-6	200	0.75
Direct planter	Semeato	4-6	2.25	0.67

In CT method, plowing was conducted with three–bottom moldboard plough to 20 cm depth, followed by disc harrowing. In the no- tillage, the plant residues were left on the soil surface until sowing date. Some data about the farming operations and used equipment's in conventional method were obtained from consulting with local agricultural organizations, consultants and agricultural experts. Common fertilizers used included nitrogen (N 46%), triple superphosphate (46% $P2O5$), potassium chloride (60% $K 2O$) and complete macro fertilizer (8% $P2O5$; 15% N; 15% $K2O$), respectively. Number of agricultural operations for sunflower oil production are given in Table 3.

Consumption and Efficiency of Fuel

In order to compare the tillage methods, fuel consumption were measured for each method. Fuel consumptions per area and effectiveness of each method were determined. For measuring the fuel consumption of equipments and machines used in the test, full tank method was used. The fuel tank of the tractor was filled full before the study and after the study; the fuel consumption was determined by measuring the amount of the fuel added to the tank. Number of operations, was determined by using a stopwatch. In the study, standard plots (66.5 m x 105 m) were used for number of operations and fuel consumption (Sessiz *et al.*, 2008).

Energy Analysis

Method of energy analysis (Rathke and Diepenbrock, 2006; Tzilivakis *et al.*, 2005; Soltani *et al.*, 2013), that included fossil energy, but labor power or solar energy not included was used. However, human labor energy was calculated here for comparison purposes. Energy inputs for storage was not considered, but the energy required to transport the grain from the field to the local storages/silos was calculated. Energy released from the soil, in the form of plant nutrients and organic matter or energy was not considered (Rathke and Diepenbrock, 2006). In this study sunflower seed yield was considered as output in the energy estimation. Output energy was calculated by multiplying the yield with its corresponding energy equivalent. Energy conversion factors are shown in Table 4.

Fossil energies were included in the forms of direct and indirect. Direct energy includes energy of human, diesel and electricity and indirect energy includes energy of seed, fertilizer, chemicals and machinery. Amounts of inputs were converted to energy values, using appropriate energy coefficients. The energy used in applying each machine in each operation, was calculated from the total weight and the economic life of the machine and the time needed to complete that operation. Energy efficiency, energy productivity, energy intensity and energy gain were calculated based on the energy equivalents of the inputs and output as below (Mahmoodi *et al.*, 2008):

$$E_e = \frac{E_O}{E_I} \tag{1}$$

Where, E_e= energy efficiency, E_O = output energy (MJ.ha^{-1}) and E_I = input energy (MJ.ha^{-1}).

$$E_p = \frac{Y}{E_I} \tag{2}$$

Where, E_p = energy productivity (MJ.kg-1) and Y = crop yield (kg.ha^{-1}).

$$E_T = \frac{E_I}{Y} \tag{3}$$

Where, E_T = energy intensity (kg.MJ^{-1}).

$$N_e = E_O - E_I \tag{4}$$

Where, N_e = energy gain (MJ.ha^{-1}).

Table 3. Agricultural operations carried out in the experiment

Operations	Unit	Methods			
		(CT)	(RT1)	(RT2)	(NT)
Plowing	time	1	-	1	-
Disking	time	1	2	-	-
Sowing	time	1	1	1	1
Fertilization	time	1	1	1	1
Weed Control	time	-	-	-	1
Harvest	time	1	1	1	1

Table 4. Energy content of inputs and outputs

	Unit	Energy equivalent (MJ/unit)	Reference
Inputs			
Human labor	hr	1.96	Yilmaz *et al.* (2005); Canakci *et al*. (2005)
Seed	kg	11.8	Mehrabi-boshrabadi and Esmaeli, (2011)
Machinery	hr	142.7*	Erdal *et al.* (2007); Kaltsas *et al*. (2007)
N fertilizer	kg N	60.6	Ozkan *et al*. (2004)
P fertilizers	kg P2O5	11.1	Ozkan *et al*. (2004)
K fertilizers	kg K	6.7	Ozkan *et al*. (2004)
Pesticide	kg		Mohammadi *et al*., 2008
Herbicide	kg	237	Rathke *et al*. (2006); Tzilivakis *et al.* (2005)
Output			
Sunflower seed	kg	11.8	Mehrabi-boshrabadi and Esmaeli, (2011)

*Includes energy for manufacturing (86.38MJ.kg^{-1}), for repairs and maintenance (0.55× energy for manufacture) and for transportation(8.8 MJ.kg^{-1}).

Carbon Emission

Carbon emission amount due to energy consumption was calculated by multiplying the energy consumption in Equivalent of its carbon emission (kg CE). Carbon emission from each Gigajoule (GJ) energy consumption was considered 20.15 kg CE (Fluck, 1992; Lal, 2004).

Data were analyzed with regard to consumption of inputs, energy of inputs and carbon emission from consumption energy.

Sustainability of systems was assessed by evaluating temporal changes in the output/input or (output-input)/input ratios of C using by equations 5 and 6 (Lal, 2004):

$$I_s = \frac{C_O}{C_I} \tag{5}$$

$$I_s = \frac{C_O - C_I}{C_I} \tag{6}$$

Where, I_S is the index of sustainability, C_O is the sum of all outputs expressed in C equivalent, and C_I is the sum of all inputs expressed in C equivalent.

RESULTS AND DISCUSSION

Number of Operations and Fuel Consumption

Required number of operations and fuel consumption for production operations are shown in Table 5. The highest (10 hha^{-1}) and the lowest (5 hha-1) of farm operations number were related to CT and NT procedures, respectively. Similar results have been reported by other researchers (Tipi *et al*., 2009; Canakci *et al*., 2005;Sessiz *et al.*,2008; Bonari *et al.*, 1995). Results (Table 5) indicated that there was a direct relation between farm operation number and fuel consumption. Rajabi *et al.* (2011) reported similar results. Maximum (109.75 Lha^{-1}) and minimum (57.1Lha^{-1}) fuel consumption were related to CT and NT, respectively (Table 5).

In CT method, tillage had the greatest amount of fuel consumption (60%). Also, Harvesting (34%) was one of the major energy consumer of this method. In RT1 and RT2, the greatest amount of fuel consumption (50%) was related to harvesting. In NT, the greatest amount of fuel consumption (65%) was also related to harvesting. In all production methods, fertilizer broadcasting had the lowest amount of fuel consumption. Similar results have been reported by other researchers (Solhjou, 1998; Canakci *et al*., 2005; Tipi *et al*., 2009; Soltani*et al*., 2013; Canakci*et al*., 2005; Safa*et al*., 2010).

Energy of inputs

Used material in production procedures are given in Table 6. In CT method, mean of seed weight used was 50% higher than other methods. In CT method, higher amount of seed used was related to scattering of seed and uneven sowing depth. Fuel consumption in NT method, was significantly lower than other production methods. Lower fuel consumption in NT was related to omitting tillage. Similar results was reported by Rahimi-zadeh *et al.* (1997).

Total fertilizer energy input was equal in all methods. In all methods, the highest energy consumption was related to fuel consumption, and then fertilizer, herbicide and seed had the highest consumption of energy. However, energy use in the conventional method was 90% higher than no-tillage**.**

Table 5. Time of performing operations and fuel consumption for each farm operation

Farm operation	Operation time				Fuel c			
	CT	RT1	RT2	NT	CT	RT1	RT2	NT
Plowing	3.5	−	2.5	−	34.65	−	24.5	−
Disking	2.5	2.5	−	−	22.5	22.5	−	−
Sowing	1	1	1	1.5	11.2	9.8	9.8	11.8
Fertilizing	0.5	0.5	0.5	0.5	3.9	3.9	3.9	3.9
Weed control	−	−	−	0.5	−	−	−	3.9
Harvesting	2.5	2.5	2.5	2.5	37.5	37.5	37.5	37.5
Total	10	6.5	6.5	5	109.75	73.7	75.7	57.1

CT= Conventional tillage, RT1= Reduced tillage, RT2= Reduced tillage, and NT= direct seeding

Table 6. Inputs used and the energy inputs (MG ha^{-1}) in sunflower production methods

Item	Unit	Production method				Energy input			
		CT	RT1	RT2	NT	CT	RT1	RT2	NT
Seed	kg ha^{-1}	12	7	7	7	141.6	82.6	82.6	82.6
Fuel	L ha^{-1}	109.8	73.7	75.7	57.1	5246.1	3522.9	3618.5	2729.4
N Fertilizer	kg N ha^{-1}	75	75	75	75	4545	4545	4545	4545
P Fertilizer	kg P_20_5 ha^{-1}	50	50	50	50	555	555	555	555
K Fertilizer	kg K_2O ha^{-1}	40	40	40	40	268	268	268	268
Herbicide	kg ha^{-1}	−	−	−	0.7	−	−	−	165.9

Total Energy Used in Production Methods

Total energy used in production methods and their preparations are shown in Table 7. The maximum (12308 MJ.ha^{-1}) and minimum (9122 MJ.ha^{-1}) energy consumptions, were related to conventional and no-till methods, respectively. In RT1 and RT2 methods, the amounts of energy consumption were 9983.3 and 1028.3 MJ ha^{-1}, respectively. By comparing the input energy, in CT method the maximum amount of energy (42.6%) was related to fuel, followed by N fertilizer (36.9%) and machinery (11.6%). While in conservation methods (RT and NT), the greatest amount of energy consumption (45% and 49%) were related to nitrogen fertilizer, followed by fuel (36% and 29.9%) and machinery (9% and 7.8%). Jokiniemi *et al.* (2012) reported similar results. Manpower and seed had the least proporation of used energy (≤1.15%) in all production methods.Direct and indirect energy used in different methods of sunflower production is presented in Figure 1.

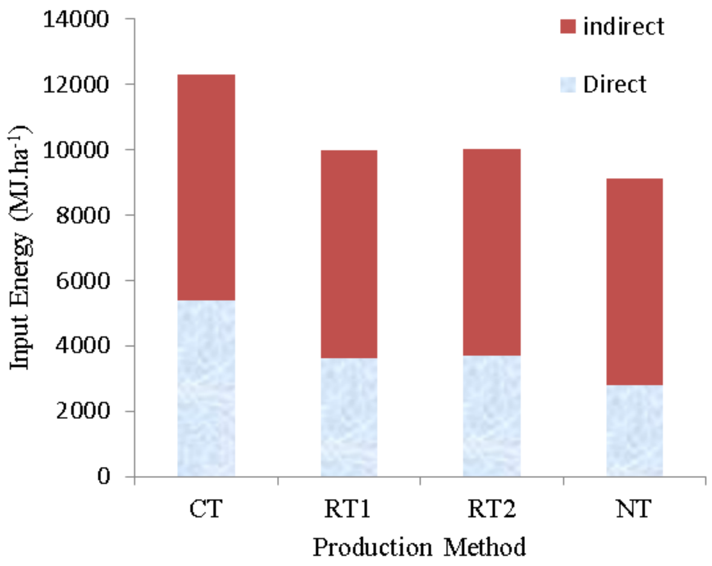

Figure 1. Total energy input as direct and indirect energy in each production method of sunflower.

Table 7. Energy inputs (MJ ha-1) and energy proportion (%) for each sunflower production method

Item	CT		RT1		RT2		NT	
	Mean	Prop (%)	Mean	Prop (%)	Mean	Prop (%)	Mean	Prop (%)
Labor	125.44	1.02	82.32	0.82	74.48	0.74	62.72	0.69
Seed	141.6	1.15	82.6	0.83	82.6	0.82	82.6	0.91
Machinery	1427	11.59	927.55	9.29	884.74	8.82	713.50	7.82
Fuel	5246.05	42.62	3522.86	35.29	3618.46	36.08	2729.38	29.92
N Fertilizer	4545	36.93	4545	45.53	4545	45.32	4545	49.82
P Fertilizer	555	4.51	555	5.56	555	5.53	555	6.08
K Fertilizer	268	2.18	268	2.68	268	2.67	268	2.94
Pesticide	-	-	-	-	-	-	165.9	1.82
Total	12308.1	100.00	9983.33	100.00	10028.28	100.00	9122.1	100.00

Energy Output and Energy Indices

Energy output and indices are shown in Table 8. The highest yield (1662 kg ha^{-1}) belonged to RT2 method. Sharma *et al.* (2011) reported similar results. After RT, the highest grain yield was related to CT method (1599 kg ha^{-1}). Grain yield in RT1 and NT were 1517 and 1549 kgha^{-1}, respectively. The lowest grain yield (1517 kg ha^{-1}) and output energy (17900 MJha^{-1}) belonged to RT1 method. Although in CT method yield and output energy were higher than RT1 and NT, but due to higher input energy, the least energy efficiency (output/input ratio) belonged to CT (1.53), that was lower than other methods. Saving in energy consumption is one of the main advantages of conservation tillage. Similar results have been reported by Sayfi *et al*. (2010).

The highest energy efficiency (output/input ratio) belonged to NT method, which was greater than other methods. Due to lower input energy in NT method (especially reduction of fuel consumption in seed bed preparation), its energy efficiency was higher than other methods. These values were 1.96 and 1.76 for RT2 and RT1 methods, respectively (Table 8). Maximum and minimum values of energy intensity belonged to CT (7.7 MJ ha^{-1}) and NT (5.9 MJ ha^{-1}). While CT method produced 3% more grain yield than the NT method, its net energy production was 40% lower than NT method. RT2 and NT methods were the best production methods with regard to energy efficiency and net energy used (Table 7). These methods produced 46% and 40% more net energy than the CT method, respectively. The average energy productivity was 0.15 kg MJ^{-1}. The NT method had the least energy intensity (5.9 MJ kg^{-1}) and the greatest energy productivity (0.17 kg MJ^{-1}).

Carbon Emission and Sustainability Index

Estimates of carbon emissions in different production methods are presented in Table 9. The estimate of carbon emission was 183.8 kg C-eq ha^{-1} for NT method (the least rate). RT1 and RT2 methods had greater carbon emissions, 201.2 and 202.1 kg C-eq ha^{-1}, respectively. The highest amount of carbon emission (248 kg C-eq ha-1) was related to CT method, which was 35% more than NT method. Thus the NT method produced 35% lower carbon gas per hectare than the CT method. Similar results have been reported by other researchers (Lal, 2004; Marland *et al*., 2003).

Tillage, by affecting the soil, climate and other environment, had a significant effect on agricultural sustainability. Govaerts *et al*. (2009) and Engel *et al.* (2008) reported similar results. Atreya *et al*. (2008) reported that conservation tillage systems are increasingly considered as sustainable options in order to reduce the aftermaths of improper soil tillage (such as; increasing greenhouse gases (GHGs), soil compaction and erosion, nutrient losses).

Also, carbon emission per ton of harvested grain is an important factor. This value is in CT method was 55 kg C-eq t-1 (Table 9). RT1 method (132.4 kg C-eq t-1) and the RT2 method (121.7 kg C-eq t-1) had 17% and 27% lower carbon emission per ton of harvested grain than CT method, respectively. NT method produced 31% less C gas per ton of harvested grain (118.6 kg C-eq t-1), which was significantly lower than CT method.

In comparing the sustainability index (Is), the greatest amount of Is was related to NT method (2.00), followed by RT2 (1.96), RT1 (1.79) and CT (1.53). In NT method was, sustainability index was 30% higher than CT method. Higher Is in NT method related to lower inputs, but in RT2, higher was related to higher yield. Due to higher inputs in CT, the least was related to this method.

Table 8. Energy output and energy indices for each sunflower production method

Item	Production method			
	CT	RT1	RT2	NT
Output				
Grain yield (kg ha^{-1})	1599	1517	1662	1549
Total energy (MJ ha^{-1})	18868.2	17900.6	19611.6	18278.2
Indices				
Output/input ratio	1.53	1.79	1.96	2.00
Energy productivity (kg MJ^{-1})	0.13	0.15	0.17	0.17
Energy intensity (MJ kg^{-1})	7.70	6.58	6.03	5.89
Energy gain (GJ ha^{-1})	6560.11	7917.27	9583.32	9156.10

Table 9. Carbon emission and sustainability index

Item		Production method			
		CT	RT1	RT2	NT
per unit weight (kg eq-C t^{-1})		155	132.4	121.7	118.6
C_O (kg C-eq ha^{-1})		380.19	360.70	395.17	368.31
C_I (kg C-eq ha^{-1})		248.01	201.16	202.07	183.81
I_S	Eqs.(5)	1.53	1.79	1.96	2.00
	Eqs.(6)	0.53	0.79	0.96	1.00

CONCLUSION

In various crop production methods, attention to the crop yield alone isn't sufficient, and topics of energy and environmental factors should be considered. For sunflower production in CT method, tillage operation have consumed the greatest amount of fuel and energy. Therefore, in order to control high energy consumption, reducing the use of energy in seedbed preparation should be the prime objective in all programs. Results showed that, Soil tillage by affecting environment, had a significant effect on the agricultural sustainability. Conservation tillage systems are increasingly considered as sustainable options in reducing of aftermaths of improper soil tillage such as; increasing greenhouse gases (GHGs) and environment pollution. For the sunflower production methods, maximum and minimum values of total energy input (12.3 and 9.12 GJ ha^{-1}) were related to CT and NT, respectively. The highest carbon emission was 248 kg C-eqha^{-1} in CT method and the least amount was 183.8 kg C-eqha^{-1}in NT method. An important finding of this study was that conservation tillage methods (RT2 and NT) consumed 35% less input energy compared to the CT production method, while the yields were equal to conventional methods. These production methods (RT2 and NT) also resulted in 25% less carbon emission per hectare and 29% less carbon emission per ton of grain than the CT production method. Also, the least value of sustainability index belonged to CT method (1.53). Thus, improvement of crop management can be considered as an important strategy to reduce energy use and carbon emission and to increase crop yield and sustainability index. There are two possible ways for reducing of environmental stresses with maintaining yield of sunflower. First, for crop production, the number of required operations and farm traffic should be reduced to the minimum possible number. Secondly, reduce fossil energy inputs (especially fuel input). The use of conservation tillage in addition to saving energy reduces soil erosion and increases the production. Due to lower energy consumption and higher energy efficiency, conservation tillage methods (in particular, reduced tillage and no-tillage), are recommended as an alternative to conventional tillage.

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