Research Article

Assessing Sustainability of Rainfed Wheat (Triticum Aestivum) Production under Various Soil Tillage Systems: An Energy and Economic Analysis

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Abstract | Energy management is an essential component in sustainable agricultural production systems. The study was mainly designed to evaluate the impact of four kind of soil tillage as; No/zero tillage (ZT), conservational tillage (PT), reduced tillage (RT) and conventional tillage (CT) on wheat yield, fuel usage and energy use efficiency under rainfed agriculture systems for Chakwal-50 wheat cultivator at Koont research station of PMAS-Arid Agriculture University, Rawalpindi during 2018 and 2019 wheat seasons. The study treatments were evaluated in term of energy analysis and economics of wheat production. Highest energy inputs obtained were fertilizer, seed and fuel + oil energies in all tillage systems for wheat sowing, respectively. Results interpretation indicated that the highest (2,300 $kgha^{-1}$ and 40.56 lha^{-1}) and lowest (1,930 $kgha^{-1}$ and 8.97 lha^{-1}) wheat yields were measured in CT and ZT farming treatments, respectively. The maximum and lowest energy values were calculated in PT (6.03) and CT (5.14), respectively. The maximum specific energy measured was (7.17 MJ kg^{-1}) in ZT treatment, while the least specific energy was calculated in the RT (6.54 MJ kg^{-1}). Soil tillage systems have sequence in term of net energy values (MJ) as PT> RT> CT> ZT. The profitability of ZT, PT, RT and CT were 0.95, 0.69, 0.52 and 0.32. The economic analysis results described that intense application of agricultural machinery and operations were caused more energy consumption and reduction of energy use efficiency and may compromised on net energy and profitability of agroecosystems eventually. In rainfed agriculture system, all types of tillage as zero, reduced, and conservational systems could be applied instead of conventional tillage system in wheat farming according to studied energy parameters.

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Introduction

In recent years, sustainable agricultural practices have been brought to the agenda in order to protect the natural ecosystem and especially the more sensitive agroecosystem both in the world and in our country, in order to protect soil and increase soil fertility. Sustainable agriculture; soil, water and air, considering environmental factors, human, plant and animal health is the idea of producing production

(Chappell *et al*., 2011; Noor *et al*., 2020a).

Efficiency increases with the increase in energy input. However, the excessive increase in energy input may cause some economic damages. For energy efficiency, either efficiency should be increased, or inputs should be reduced. Increasing efficiency can be achieved within certain limits (Noor *et al*., 2020b). However, since energy efficiency can be reduced by the conscious application of inputs, it is important to calculate the energy balance of the systems used in production (Smith *et al*., 2015).

Usage of energy resources efficiency is the leading protocol for sustainable agricultural production systems which ensured; fossil resources are conserved, and it is possible to reduce air pollution. In order to increase energy efficiency, steps should be taken to improve the production efficiency or to preserve energy-input without compromising efficiency (Muhammadi *et al*., 2011). Energy saving is therefore having a prior importance for overall sustainable agricultural production (Kang *et al*., 2009).

Efficient and effective energy use for improved crop production is necessary to supply the optimum energy (Muhammadi and Omid, 2010). In the recent practices of agriculture production, crop seed, fertilizer and chemicals are the main crop inputs that consume energy in the shape of fuel, electricity (Hatirli *et al*., 2006). Tillage system is considered as the biggest energy and labor consumer in agricultural production i.e. the primary tillage requires 75% of the total energy consumed prior to plantation (Noor *et al*., 2019). Therefore, by choosing the suitable tillage system; environmental pollution control of systems and determination of energy protection (Tabatabaeefar *et al*., 2009).

Moitzi *et al*. (2006) stated that 30% of filed energy is consumed in tillage; Jacobs *et al*. (2010) found that reducing tillage reduces fuel consumption by 55% having no significant effect of yield; Taner *et al*. (2015), direct planting and reduced tillage systems with 84% and 54% reduction in the use of towing energy reported (Tabatabaeefar *et al*., 2009).

Marakoglu and Carman (2010) investigated the energy budget of spinner and spine planting methods in wheat agriculture, they stated that the energy ratio was 6.63 in spike planting and 5.29 in spine planting. Jin *et al*. (2007) conducted the comparative study on the energy efficiency for wheat production under different soil tillage by comparing, they determined the energy ratio for traditional and direct planting as 3.65 and 4.87, respectively. Aslam *et al*. (2020a) stated that direct sowing with the highest output/input ratio is a more profitable production technique in their studies where 5 different tillage systems determine the energy balance in wheat production.

Similar results were obtained in another study that the output/input ratio in direct sowing practices in wheat production was determined as 2.81 (Marakoglu and Carman, 2010). Sharma *et al*. (2011) stated that for winter wheat, 315.32 MJ Mg^{-1} was spent in Conventional Tillage and 192.38 MJ Mg^{-1} expenditure was used for conservation tillage while 39.1% savings were achieved in direct sowing system and 85.1% savings were achieved with 47.14 MJ Mg-1 (Tabatabaeefar *et al*., 2009).

Alluvione *et al*. (2011) compared energy efficiency in wheat production in different climatic regions and assessed the energy, economy and environmental benefits resulting from selected energy conservation measures. They predicted different energy conservation measures depending on climate and country. They stated that indirect and direct energy inputs are largely specific to geographic location and climate zones, and that the increase in efficiency in climate zones is parallel to the increase in total energy inputs. They stated that energy consumption and energy saving potential in each agricultural production system differ in specific geographical areas and climate regions (Aslam *et al*., 2020b).

Sustainable agricultural production system in wheat cultivation under dry farming conditions as the main product, energy management is an essential component (Noor *et al*., 2020c). Therefore, we studied the impact of four soil tillage methods on wheat yield, fuel usage and energy use efficiency under rainfed agriculture systems. This study performed complete energy and economic budget in order to recommend a sustainable and economical practice for wheat sowing in rainfed agriculture system.

Materials and Methods

Study area

These study trails were carried out during 2017-18

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and 2018-19 wheat seasons at Koont research station Chakwal, PMAS-Arid Agriculture University, Rawalpindi. The farm location on the world globe is between 33° 1' to 33° 6' N and 73° 30' to 73° 45' E. Soil texture type was sandy clay loam (56% sand, 22.8% silt, 21.2% clay) with a pH of 7.7 at experimental site. Average rainfall and temperature during the crop seasons were shown in Figure 1. The soil physio-chemical properties of trail field were presented in Table 1. The climatic condition is semi-arid sub humid while the rainfall is in bi-seasonal with maturity in late summer and winter. Monsoon season generally have 60-70% of total rainfall (15th June – 15th September). However, winter rain occurs as gentle showers persist prolong, and thus, are more favorable in aspect of agricultural production (Shafiq *et al*., 2005). Average monthly rainfall and temperature data were also monitored.

Table 1: *Some soil characteristics at the beginning of the study.*

Soil characteristics	Soil depth	
	0-15 cm	15-30 cm
Soil moisture content (%)	14.73	14.73
Soil bulk density (g cm^{-3})	1.45	1.45
Soil pH	7.7	7.6
Total salt (%)	0.01	0.02
Lime (%)	9.81	9.67
Soil organic matter (g $100g^{-1}$)	5.9	5.8
Total nitrogen (μg g-1)	4.9	4.2
Available phosphorus (P2O5, μg g^{-1})	3.2	3.0
Available potassium (K2O, μg g^{-1})	142	139

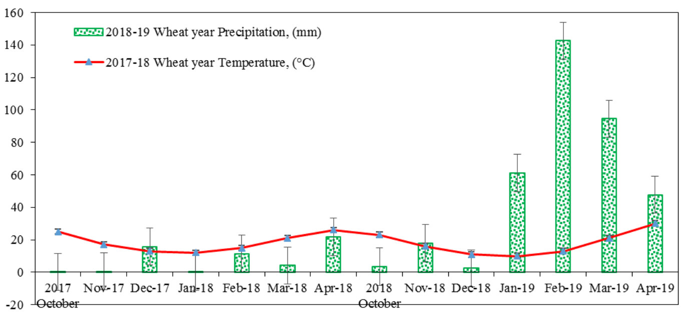

Figure 1: *Temperature and precipitation data of the trial area.*

Soil tillage systems

The experiment was conducted in 12 subplots of area 2,023 m^2 (0.5 acre) each with 3 replications laid out as completely randomized design (CRD). Study consisted of conventional tillage (CT), conservational tillage (PT), reduced tillage (RT) and zero/no tillage (ZT). Zero tillage included directly seeding with no soil disturbance. RT treatment was performed one (1) pass mouldboard plough and wheat seed drill. The PT system included once Chisel plow, disc harrow and seed drill. In CT systems was applied using once mouldboard ploughing at 30-35 cm depth, one pass Chisel plough, one pass disc harrow for soil pulverizing before drill sowing. Agricultural equipment used for plant protection, harvesting and transporting were same in all tillage systems. Fait 385 4WD tractor with 85 HP power was used for all operations in the experiment. The list of Agricultural machinery used in this experiment were given in the Table 2.

Table 2: *Some features of the machines used in the study.*

Machine	No. of units	Width (cm)	Depth (cm)*	Weight (kg)
Tractor, 685S, 4WD	-	-	-	3011
M.B. plow	3 furrows	90	25	355
Chisel plow	9 tines	270	25-40	350
Rotovator	54 blades	214	15	585
Disc harrow	20 Disc	290	100-150	555
Zero-till drill	11 rows	250	6	250
Wheat drill	11 rows	250	5-8	300
Reaper	6 crop dividers	147	10-30***	116

: Values applied in the experiment; **: ASAE (2011); *: cutting height from ground level.*

The sowing process was carried out at 125 kg/ha seed rate and 5cm sowing depth. The sowing tractor speed was measured 5.1 km/h by measuring time to cover 100 meters (Soomro *et al*., 2009). ASAE 1999 and ASAE 2011 standards were followed for feed rate of other agricultural machinery. Chakwal-50 wheat variety was used in this study. The suggested 120, 30 and 33 $kgha^{-1}$ of N, P and K, respectively were fed to the field as Urea-fertilizer (46 % nitrogen), diammonium phosphate (18% N and 20% P) and potash (50% K) (Yadava *et al*., 2016).

Wheat yield and fuel consumptions

Yield was calculated as kg/ha by harvesting all the plants in the middle two rows of each parcel. Fuel consumption values of tillage and sowing machinery were measured using the following equations (Mileusnić *et al*., 2010). The fuel consumptions of centrifugal manure spreader and combine harvester, lubrication oil consumption was taken as 5% of fuel consumed (Fluck, 1985).

$$Di = F_i \times \{A_m + (B_m \times S) + (C_m \times S_2)\} \times WT \quad ...(1)$$

$$PT = (D_i \times S) / (3.6\, E_m E_t) \quad \ldots (2)$$

$$Q_d = PT \{2.64\, (PT / PT_m) + 3.91 - 0.203\sqrt{738\, (PT / PT_m) + 173} \quad \ldots (3)$$

$$C_a = (S \times W \times E_f) / 10 \quad \ldots (4)$$

Where;

D_i= traction force (N), F_i= soil textural class (dimensionless), A_m B_m C_m= specified parameter specified for agricultural machinery, S=operating speed Kmh^{-1}, W= implement working width (m), T= implement depth (cm), E_m= mechanical efficiency of tractor (0.96), E_t= draft efficiency, Q_d= diesel consumption (1/h), PT=total power required for work (kW), PT_m= maximum power at PTO (kW), C_a= field capacity hah^{-1} and E_f= field efficiency.

Quantity of diesel fuel consumed per unit field area (l/ha) was measured by multiplication of fuel consumption per unit time (Equation 3) and fied capacity (Equation 4). The numerical values of all parameters were mentioned in Table 3.

Table 3: *The numerical values of the machine's parameters used in the calculation of fuel consumption.*

	A	B	C	F_i	E_t	Ef
M.B. plow	652.00	0.00	5.10	0.70	0.77	0.85
Chisel plow	91.00	5.40	0.00	0.85	0.77	0.85
Rotovator	600.00	0.00	0.00	1.00	0.77	0.85
Disc harrow	216.00	11.20	0.00	0.88	0.75	0.80
Wheat seed drill	300.00	0.00	0.00	1.00	0.75	0.70
Direct seeder	720.00	0.00	0.00	0.79	0.77	0.70

(ASAE, 1999; ASAE, 2011).

Energy analysis

Total production energy (MJ) (inputs and outputs energies) consumed in each treatment was calculated per unit area (hectare). Table 4 showed all energy equivalents for all crop factors used in the wheat production under various farming treatments. Energy indices were measured by applying energy inputs, energy output and grain yield given in the equation below (Khan *et al*., 2009; Pishgar *et al*., 2012; Yousefi *et al*., 2014b).

Energy ratio= Total energy (output) / Total energy (input) …(5)

Specific energy ($MJkg^{-1}$)= Total energy (input) / wheat yield …(6)

Energy efficiency ($kgMJ^{-1}$)= Wheat yield / Total energy (input) …(7)

Net energy ($MJha^{-1}$)= Total energy (output) – Total energy (input) …(8)

Energy profit= Net energy / Total energy (input) … (9)

Economic analysis

The economic analysis for different farming treatments included total costs, gross return, net return, profitability and net energy value were calculated by equations 10-12.

Net return (\$ ha^{-1})= gross return–Total input cost …(10)

Profit = Net return / Total input cost … (11)

Net specific energy (\$$MJ^{-1}$)=Total costs/Net energy …(12)

Statistical analysis

The obtained research data was analyzed under ANOVA and multiple comparison test using SPSS-22 statistical software.

Results and Discussion

Wheat yield and fuel consumptions

Wheat yield harvested from different soil tillage treatments was presented in Table 5. The wheat yield ($P < 0.01$) was significantly affected by various soil tillage practices. Highest wheat yield was found in conventional tillage (2,300 $kgha^{-1}$) and the minimum wheat yield was observed in direct sowing system (1,930 $kgha^{-1}$). The treatments RT-PT, CT-RT and PT-ZT showed no significant difference as given in Table 5 (Soomro *et al*., 2009).

Table 5 showed the fuel consumption and working time values in all the processes applied until the harvest in the treatments where soil tillage systems were applied. The sequence for fuel consumption in different tillage systems were found as CT> RT> PT> NT during both wheat seasons. Among the machines used, the M.B. plow was the implement with the highest fuel consumption. Compared to conventional tillage, average fuel consumption in RT, PT and NT systems were 46.95%, 47.04% and 77.88% during both wheat seasons, respectively (Table 6).

Energy analysis

Energy used for wheat production under different treatments was presented in Table 6. In this study, it was determined that the highest input share under all treatments was in fertilizer + manure energy and followed by seed, fuel + lubricating oil and machinery manufacturing energy. Soil cultivation systems were

Table 4: *List of energy equivalents for input and outputs in wheat production.*

Crop production parameters (units)	Enerfy equivalents (MJ unit^{-1})	Source
Human labor (h)	1.96	Muhammadi and Omid, 2010
Agricultural machinery (h)	62.7	Samavatean *et al*., 2010
Tractor (h)	158.3	Samavatean *et al*., 2010
Diesel fuel (I)	51.33	Samavatean *et al*., 2010
Chemical fertilizer (kg)		
Nitrogenous	66.14	Erdal *et al*., 2007
Phosphorus (P_2O_5)	12.44	Erdal *et al*., 2007
Potassium (K_2O)	11.15	Erdal *et al*., 2007
Farmyard manure (kg)	0.3	Esengun *et al*., 2007
Lubrication oil (I)	42.5	Samavatean *et al*., 2010
Pesticides (kg)		
Herbicides	101.2	Ghiyasi *et al*., 2008
Insecticides	199	Gundogmus, 2006
Electricity (kWh)	3.6	Rafiee *et al*., 2010
Irrigation water (m^3)	1.02	Samavatean *et al*., 2010
Seed+fungicides (kg)	17.6	Ghiyasi *et al*., 2008
Wheat grain (kg)	14.7	Yousefi *et al*., 2016
Straw (kg)	12.5	Yousefi *et al*., 2016

Table 5: *Wheat yield and fuel consumption values in soil tillage systems.*

Soil tillage Systems (Treatments)	Yield (kg ha^{-1})*	Fuel consumption (l ha^{-1})	Field Capacity (h ha^{-1})
Zero tillage system (ZT)	1 930 c	8.97	3.50
Conservational tillage system (PT)	2135 bc	21.50	5.00
Reduced tillage system (RT)	2 222 ab	22.73	4.90
Conventional tillage system (CT)	2300 a	40.56	5.76

** There is no statistical difference between the applications indicated by the same letter in the column.*

Table 6: *Total energy used under different soil treatments of wheat production (MJ ha^{-1}).*

Inputs and outputs	Soil tillage systems			
	ZT	PT	RT	CT
Human labor force	7.3	10.44	10.21	12.06
Machinery manufacturing	664.87	591.22	612.73	662.79
Fuel + Oil	483.45	1158.78	1225.06	2186.04
Fertilizer + manure	10477.95	10477.95	10477.95	10477.95
Seed	2200	2200	2200	2200
Total inputs	13833.5716	14438.38	14525.96	15538.842
Wheat	28,371.00	31,384.50	32,663.40	33,810.00
Straw	47375	55700	54300	46062.5
Total output	75,746.00	87,084.50	86,963.40	79,872.50

listed as CT >RT >PT >ZT in terms of total energy inputs. The input that makes a difference in the energy inputs of the tillage systems was fuel+lubricating oil, machinery manufacturing and manpower energy input. Fuel + lubricating oil energy input % of total energy input in the ZT system 3.49, while constituting 8.03%, 8.43% and 14.07% of the PT, RT and CT systems, respectively (Table 6). Similarly, the highest proportion as total energy input in wheat production were both fertilizer input and seed oil input and fuel oil energy input, respectively (Marakoglu and Carman, 2010). The percentage share of different energy input sources in wheat production under various tillage systems were shown in Figure 2.

Table 7: *Energy analysis of tillage systems under wheat production.*

Energy parameters	Soil processing systems			
	ZT	PT	RT	CT
Energy Ratio	5.48b	6.03a	5.99a	5.14b
Specific Energy (MJ kg^{-1})	7.17a	6.76a	6.54c	6.76b
Energy Efficiency (kg MJ^{-1})	0.14a	0.15a	0.15a	0.15a
Net Energy (MJ ha^{-1})	61912.43b	72646.12a	72437.44a	64333.66b
Energy Profitability	4.48b	5.03a	4.99a	4.14c

Table 8: *Economic analysis of wheat production under ZT, RT and CT systems.*

Cost and revenues	ZT	RT	PT	CT
Wheat yield (kg/ha)	1 930	2135.00	2 222	2300.00
Straw yield (kg/ha)	3790.00	4456.00	4344.00	3685.00
Sale price ($/1000 kg)				
Wheat grain	240	240	240	240
Wheat straw	50	50	50	50
Net energy (MJ/ha)	61912.43	72646.12	72437.44	64333.66
Input costs ($/1000 kg)				
Agricultural machinery and diesel	60.00	70.00	80.00	90.00
Fertilizer (manure + chemical)	45.00	45.00	45.00	45.00
Human labor	22.00	35.00	46.00	66.00
Pesticides	12.00	12.00	12.00	12.00
Water and electricity	0.00	0.00	0.00	0.00
Seed + fungicides	13.00	13.00	13.00	13.00
Transportation	2.00	2.00	2.00	2.00
Total cost of production	154.00	177.00	198.00	228.00
Revenues ($/1000 kg)				
Grain yield	250.00	250.00	250.00	250.00
Straw yield	50.00	50.00	50.00	50.00
Gross return	300.00	300.00	300.00	300.00
Net return	146.00	123.00	102.00	72.00
Profitability	0.95	0.69	0.52	0.32
Net energy value ($/MJ)	0.002	0.002	0.003	0.004

Ghorbani *et al.* (2011) calculated the total energy in wheat production under irrigated and rainfed conditions were 45,367 MJha-1 and 9,354 MJha-1, respectively. Yuan *et al.* (2018) measured the total input energies in wheat production were 18,392.10 MJ ha^{-1}at flat sowing and 18,494.01 MJ ha^{-1} at ridge. In our study, when the energy output values were examined, the optimal output energy was gained from PT and RT systems while, the lowest energy output was obtained in the ZT system as in the efficiency values (Table 6). In order to express how efficiently the input sources were used in wheat production and how effectively it was transformed to output, soil tillage systems should be compared according to the energy parameters given in Table 8. The ANOVA results depicted a significant impact on the energy parameters of soil tillage systems statistically P <0.01 level. Multiple comparison test results and average values to see the difference between tillage systems (Table 7). The highest energy ratio was measured in PT (6.03) and RT (5.99) treatments while, the lowest energy ratio was in the CT treatment. Although the yield was the highest in the Conventional Tillage system, the high energy input has caused the energy rate to be lower than other systems. Although the efficiency was low in the NT application, the low energy input has also increased the rate. Ghorbani *et al.* (2011) determined the energy ratios was 3.38

and 1.44 in rainfed and irrigated wheat production, respectively.

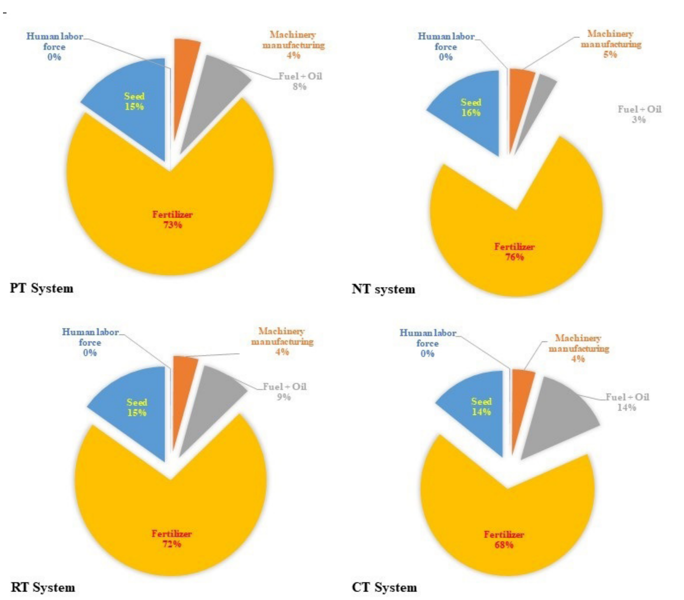

Figure 2: *The (%) share of different energy input sources in ZT, PT, RT and CT systems (Human labor force energy equivalent in all soil tillage systems were measured below 1% of total input energy for wheat production).*

Soil cultivation treatments were found in the sequence as PT> RT> ZT > CT in terms of energy ratio. To produce 1 kg wheat yield, the energy requirement was 6.54 MJ and 6.76 MJ in RT and CT treatments, whereas in PT and ZT systems 6.76 MJ and 7.17 MJ energy were required (Table 7). In the study of Marakoglu and Carman (2010) stated that the energy value 2.08 MJ in the flat sowing method, while it was 2.61 MJ in the back sowing method, and (Sial, 2005) 6.20 MJ.

According to the results of the study, 0.15 kg wheat was produced with 1 MJ energy in CT, RT and PT systems, and this value was determined as 0.14 kg in ZT systems. In addition, energy profitability was determined to be the lowest in the CT system (Table 7).

When the net energy values of the systems are examined; It was observed that the highest value was obtained with 64,333.66 MJha^{-1} in CT treatment while the lowest was obtained with 61,912.43 MJ ha^{-1} in the ZT system. According to multiple comparison test results; There were no statistically significant difference between PT and RT systems in energy parameters other than net energy gain. In terms of net energy gain, PT and RT systems were in the same group statistically. Considering the net energy gain, Conservational Tillage should be preferred in wheat agriculture in the region. However, considering the other energy parameters, the statistical results in the study area, in terms of energy use in rainfed agricultural conditions instead of conventional tillage, protective tillage or reduced tillage systems should be used. Chappell *et al.* (2011) in their study by considering the energy ratio of the recommendations and wheat and chickpea production has the highest energy rate recommended direct herbicide + planting application. Studies on the determination of energy efficiency in wheat agriculture (Tabatabaeefar *et al*., 2009; Ghorbani *et al*., 2011; Sial, 2005; Chappell *et al*., 2011; Marakoglu and Carman, 2010) energy parameters change according to factors such as climate, soil properties and applied methods. These results demonstrate the importance of identifying suitable management for crop production in different geographical areas and climatic zones for sustainable agricultural production.

Economic analysis

The experimental results of economic analysis of wheat production were presented in Table 8. The higher costs in wheat production were paid for Agricultural machinery and diesel fuel consumed, maximum in PT (40.40% of total cost), while the cost under wheat cultivation for fertilizer + manure (ranged 19.73-29.22% of total cost of production). Wheat production profitability with ZT, RT, PT and CT systems were 0.95, 0.69, 0.52 and 0.32 respectively. This indicated that more beneficial per unit cost in wheat production ZT system. Previous studies were reported profitability calculated as 1.10 in soyabean, 1,98 in mustard, 2.03 in wheat and 2.30 in chickpea, while 2.13 and 2.14 were obtained in apricot production under organic and inorganic treatments (Gundogmus, 2006). Similarly, wheat production with ZT, RT and PT systems were more profitable ratio to CT system (Muhammadi and Omid, 2010; Esengun *et al*., 2007; Ghiyasi *et al*., 2008), in ZT system was obtained 1.24, which was comparatively more beneficial than that of CT system. High cost of the tillage was the main reason in these tillage systems rather to NT system (Rafiee *et al*., 2010; Samavatean *et al*., 2010).

The cost spent for unit energy for different farming treatments of wheat production were calculated 0.002 $/MJ for ZT and RT systems while maximum was 0.004 $/MJ which revealed that optimal cost of 1 MJ of net energy in CT treatment compared to other treatments. Increasing crop yield and diminishing production cost will lead to enhance the wheat production. So, the production ration in all treatments is higher as compared to CT treatment. In this way we can maintain the crop productivity at a desired stage and remain sustainable by optimizing the energy consumption level.

Conclusions and Recommendations

This study evaluated four tillage treatments in wheat production under rainfed conditions to develop a sustainable wheat production practice. For this purpose; wheat yield, fuel consumption, energy and economic analysis were determined for each tillage system. The energy budget revealed Conventional tillage as expensive treatment while lowest input and output values were obtained from direct sowing system. Fertilizer, seed and fuel + oil had the highest share in total input energy. Energy ratio, specific energy, energy ratio and energy profitability according to the values of reduced soil tillage has been the best results. Besides; Since sowing, conservational/ protective tillage and reduced tillage treatments showed no significant difference. It is concluded that these methods should be used in terms of efficient energy use instead of traditional method in wheat agriculture in the region.

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Novelty Statement

In this research study, we studied the impact of four soil tillage methods on wheat yield, fuel usage and energy use efficiency under rainfed agriculture systems. This study performed complete energy and economic budget in order to recommend a sustainable and economical practice for wheat sowing in rainfed agriculture system.

Author's Contributions

Rana Shahzad Noor conceived the conceptualization of research study, design and development of the experiment, data collection, formal analysis, investigation, methodology, visualization, writing an original draft, reviewed, supervised and write-up editing. Fiaz Hussain contributed in data collection, formal analysis, investigation, methodology, visualization and writing an original draft. Irfan Abbas, Muhammad Umar Farooq and Abu Saad contributed in data collection and data formal analysis. Muhammad Umair contributed to perform formal analysis of this manuscript. Yong Sun supervised the entire research work. Prof. Dr. Yong Sun contributed as internal reviewer for the manuscript.

Conflict of interest

The authors have declared no conflict of Interest.

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