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Energy use and economic analysis for wheat production by conservation tillage along with sprinkler irrigation

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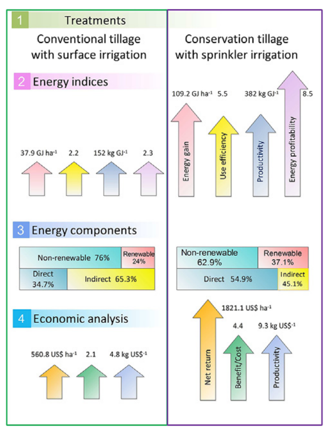
HIGHLIGHTS

- A combination systems of tillage and irrigation was suggested for wheat farms.
- Conservation tillage with sprinkler irrigation system had higher energy indices.
- The highest energy use efficiency and productivity were 5.53 and 382 kg GJ^{-1}.
- Diesel, nitrogen and seeds were prime energy consuming inputs in wheat production.
- Conservation tillage with sprinkler irrigation had higher economic productivity.

GRAPHICAL ABSTRACT



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ABSTRACT

This study was conducted to investigate the combination of both sprinkler irrigation and conservation tillage in sustainable agriculture for wheat production. To exploit the advantages of the two systems, conventional tillage along with surface irrigation (T_1) and conservation tillage along with sprinkler irrigation (T_2) were compared based on energy indices and economic analysis. The study was carried out for two years of 2012–2013 and 2013–2014 in a semi-arid environment located at the northwest of Iran. Results revealed that the total average energy consumed was 16.36 and 14.07 GJ ha^{-1} for T_1 and T_2, respectively. The total energy input components of indirect and non-renewable were 65.3% (54.9%) and 76.0% (62.9%) for T_1 (and T_2). Energy inputs of diesel, nitrogen fertilizer and seeds were prime energy consuming components. In T_2, the sprinkler irrigation was another energy consumption input. The highest net energy gain (109.25 GJ ha^{-1}), energy use efficiency (5.53), energy productivity (382.00 kg GJ^{-1}) and energy profitability (8.50) and the lowest specific energy (3.36 MJ kg^{-1}) were found in T_2. As well as the highest net return (1821.08 US\$ ha^{-1}), a benefit-cost ratio (4.4) and productivity (9.33 kg US\$$^{-1}$) was obtained in T_2. Therefore, application of conservation tillage along with sprinkler irrigation could be suggested as a promising combination for wheat production in a semi-arid environment.

1. Introduction

Agricultural production has a considerable and significant correlation with energy input (Tabatabaeefar et al., 2009). Consequently,

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applications of conventional agricultural systems with high energy input will generate certain environmental challenges such as global warming and air pollution (Pahlavan et al., 2012; Ghorbani et al., 2011; Karkacier et al., 2006). On the other hand, agricultural section produces a considerable energy which is used to promote food security and economic productivity (Zangeneh et al., 2010). Therefore, energy input-output analysis can be used to estimate energy indices which in turn are required for sustainability and environmental effects assessments of agricultural productions (Taghavifar and Mardani, 2015; Barut et al., 2011; Rathke et al., 2007).

Wheat (*Triticum aestivum* L.) is a vital cereal crop, a source of proteins and calories with an annual production about 730 million tons globally (FAOSTAT, 2017; Mondal et al., 2016). Wheat production is an energy intensive process. Previous research studies have confirmed that for wheat production, energy input ranges from 9.3 to 53.1 GJ ha^{-1} under various treatments and production conditions (Houshyar and Grundmann, 2017; Mondani et al., 2017; Sahabi et al., 2016). All the findings confirmed that the type of management, soil characteristics and climate conditions in wheat production caused variable energy output from 31.7 to 148.4 GJ ha^{-1}, net energy gain from 20.0 to 142.7 GJ ha^{-1}, energy use efficiency from 1.4 to 13.0, specific energy from 1.99 to 15.8 MJ kg^{-1}, energy productivity from 60 to 400 g MJ^{-1}, energy profitability between 0.44 and 12.6 (Sahabi et al., 2016; Taghavifar and Mardani, 2015; Rahman and Hasan, 2014; Alhajj Ali et al., 2013). Selecting optimum practices in agricultural productions depend on economical components of the production process (Komleh et al., 2011; Mousavi-Avval et al., 2011; Zangeneh et al., 2010). In wheat farming, the cost of production was reported to be between 200.8 and 630.3 US$ ha^{-1}, net return was between 312.6 and 975.4 US$ ha^{-1} and the benefit-cost ratio ranged from 1.7 to 2.6 (Sahabi et al., 2016; Kumar et al., 2013; Ghorbani et al., 2011).

Conservation tillage system is an eco-friendly technology for sustainable agricultural productions. Research findings indicate that soil and water conservation indices, crop production, energy saving, and economic benefit of conservation tillage system were more than those obtained from a conventional tillage system (Lalani et al., 2017; Santín-Montanyá et al., 2017; Lampurlanés et al., 2016; Parihar et al., 2016). While, some results show that conservation tillage system did not increase crop production as compared to conventional tillage (Huang et al., 2015; Pittelkow et al., 2015; Sime et al., 2015; Paudel et al., 2014). On the other hand, recent studies on the comparison of irrigation systems showed that irrigation efficiency, water use efficiency and economic returns of the sprinkler irrigation were higher than that of the surface irrigation system in crop production (Darouich et al., 2017; Andrés and Cuchí, 2014; Ze-Qiang et al., 2010). However, energy use of the sprinkler system is higher than surface irrigation methods under the similar water resource conditions (Tarjuelo et al., 2015; Ritschard, 2011; Lal, 2004).

To the best of our knowledge any study on the combination conservation tillage system and sprinkler irrigation system in crop production in terms of energy saving, crop yields and economic aspects have not yet been reported. This collaboration in terms of energy indices and economical components for wheat production is being reported for the first time in this study. The aim of this study was to determine the energy input-output, energy indices (such as net energy gain, energy use efficiency, specific energy, energy productivity and energy profitability) and economic analysis (net return, benefit-cost ratio and productivity) of a wheat production under the combination of conservation tillage and sprinkler irrigation system.

2. Materials and methods

2.1. Experimental site

The experiments were carried out in the northwest of Iran, located in East Azarbaijan province; 47° 7′ N, 38° 15′ E for a duration of two cropping years. The experimental site is 1900 m above sea level with semi-arid climate with an average rainfall of 380 mm yr^{-1}, more than 85% of which is distributed during wheat growth season (November to mid-July). The average of air temperature, relative humidity, wind velocity, pan evaporation, monthly sunshine at the site were 10 °C, 57%, 10 km hr^{-1}, 1450 mm yr^{-1} and 243 h, respectively. The monthly distribution of air temperature and rainfall for two growing years of wheat and annual mean of these factors for 8 years (from 2007 to 2014) is depicted in Fig. 1, for which the data was obtained from a meteorological station located near the experimental site.

The experimental treatments were designed based on the tillage system with four replications. The treatments were designed as:

T_1: conventional tillage system (including moldboard ploughing with 15 cm working depth, disk, field leveling and seeder) with a surface irrigation system.

T_2: conservation tillage system (including no-tillage with direct sowing in the previous crop residue) with a sprinkler irrigation system.

The soil in the field was identified as sandy loam in texture. In farm soil of conventional tillage system, bulk density, field capacity, permanent wilting point, electrical conductivity, PH, Organic C and total N were respectively 1.46 g cm^{-3}, 17%, 10%, 1.2 dS m^{-1}, 8.0, 0.52% and 0.05%, while in farm soil of conservation tillage system, properties were 1.40 g cm^{-3}, 28%, 11%, 1.3 dS m^{-1}, 7.9, 1.11% and 0.12%, respectively. The experiments comprised of 8 plots each with a plot area of 600 m^2 (15 × 40 m). The wheat (variety Alvand) was sowed in the first week of November during two cropping years (2012–2013 and 2013–2014) with a seed rate with an average of 208 kg ha^{-1}.

Note that, wheat is the principal cereal crop in this country that cultivated about 7 million ha for grain and straw production (Golizadeh et al., 2014). In T_1 plots, the amount of fertilizers were 130 kg ha^{-1} N, 100 kg ha^{-1} P_2O_5 for both cropping years. While, in T_2 plots, the amounts were 140 kg ha^{-1} N, 80 kg ha^{-1} P_2O_5 and 65 kg ha^{-1} K_2O for the first cropping year. Based on soil analysis, in the second year fertilizers were not used. In T_1 and T_2 plots, as the seeds were sowed, one-third of N and full doses of P and K were used. The remaining amount of N was applied in two equal batches viz. before the first and

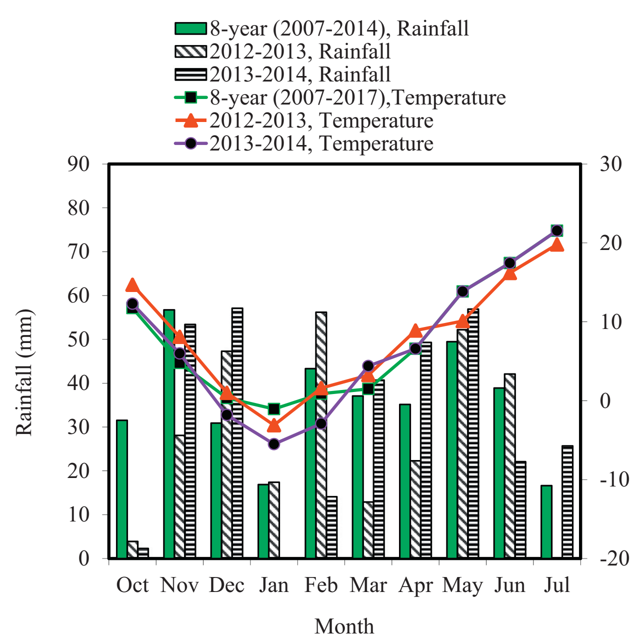

Fig. 1. Monthly distribution of rainfall (bar) and air temperature (line) over the years of 2012–2013 and 2013–2014; and 8-year (2007–2014).