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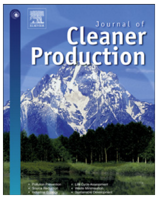

Analysis of cotton production by energy indicators in two different climatic regions

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A B S T R A C T

In this study, the energy pattern of cotton production was analyzed and compared by energy indicators in the Darab (with arid climate) and Gorgan (with sub-humid climate) regions, in Iran. For this purpose, different climatic conditions, agronomic managements, energy inputs and cotton varieties were considered. The data were collected from a survey of 30 cotton fields in each region during 2013–2014. All agricultural managements in the studied fields were monitored and recorded. Then, some energy related indicators, including renewable and non-renewable energies, energy use efficiency, direct and indirect energies, net energy, energy productivity and specific energy were calculated. On the base of obtained results, total energy consumption of cotton production was estimated as 36,189.03 in Darab and 31,860.6 MJ ha^{-1} in Gorgan. The factors relating to energy consumption were diesel fuel (Darab 39.09% and Gorgan 59.94%), and fertilizers (Darab 16.9% and Gorgan 15.25%). The cotton output energy was being as 34,076.04 MJ ha^{-1}for Darab and 35,231.26 MJ ha^{-1}for Gorgan. Also, energy use efficiency was calculated as 0.942 in Darab (as an arid climate) and 1.106 in Gorgan (as a sub-humid climate). The indirect energy and non-renewable energy were relatively high in Gorgan compared to Darab. It was concluded that energy productivity index implies that lower units of output was obtained per unit energy in Darab region. Also, the high ratio of non-renewable energy in total used energy inputs causes negative effects on the sustainability of cotton production systems.

1. Introduction

Global food security relies mainly on the productivity of agriculture section, environmental resources use efficiency, year-to-year stability, and long-term sustainability (Denison and McGuire, 2015). The indiscriminate use of environmental resources to achieve greater production, leads to depletion of environmental resources, increasing environmental pollution and the increasing concentration of (GHGs) emissions (Esengun et al., 2007).

Evidence suggests that excessive use of inputs (such as fossil fuels, agrochemicals, machinery and electricity) with the goal of a significant increase in food and fiber production and improving nutrition has led to agricultural intensification. However, greater use (more intensive energy use) of energy threatens human health and the environment, therefore, this makes more efficient use of energy to become a major issue in sustainable agriculture (Yilmaz et al., 2005). Efficient use of farming techniques and the intelligent use of inputs reduces adverse effects of external inputs on the environment and leads us to sustainable intensification (Erdal et al., 2007). To that end, today integrated systems of farming, conservation agriculture and practices, low-input agriculture, organic farming and etc. have been proposed as a solution (Dumanski et al., 2006). For example, Arunrat et al. (2016) investigated the five alternative crop rotations of ten alternative cropping systems in Phichit province of Thailand. Results showed that alternative cropping systems with selecting crop rotation not only reduce GHGs emissions of the rice fields, but also increase the benefits of farmers.

The energy analysis done with two objectives: evaluation of agroecosystems efficiency and assessment of related adverse effects on the environment. Many researchers have studied the energy balance of different crops and agroecosystems. All of these studies have focused on the energy use efficiency and impact on

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energy consumption of the production systems on the environment (Akpinar et al., 2009). In the study of Yilmaz et al. (2005) in cotton production systems in Turkey, 49.73 GJ ha^{-1} energy was consumed totally, while the energy input to energy output ratio was equal to 0.74. In this regard, fossil fuels, fertilizers and machinery were the most important components of energy consumption. In a study with the aim of optimizing the energy inputs in Punjab province, Pakistan, the energy input for cotton production systems was investigated (Singh et al., 2000). The results showed that 70% of the total energy consumed for seedbed preparation, irrigation operation and weeding. The researchers also concluded that with one to three percent more energy, especially for plowing, irrigation and spraying, cotton yield can be increased by as much as 6–8 percent (Singh et al., 2000). In a study in Turkey, the maximum energy required for cultivating and crops was reported as 45,596.5 MJ ha^{-1} for tomato and 34,891.2 MJ ha^{-1} for potato (Canakci et al., 2005). In another study, Ullah et al. (2016) investigated eco-efficiency of cotton cropping systems in Pakistan using life cycle assessment (LCA) and data envelopment analysis (DEA). Results showed that pesticides and fertilizer use, irrigation, field operations, and field emissions were the main sources of environmental impacts. They concluded that high economic performance and low environmental impacts cannot be combined in the most cotton farms of Pakistan. Yadav et al. (2017) identified sustainable and environmentally safer cropping systems with low global warming potential and low energy requirement for rainfed rice fallow lands in India. Their results showed that the relative amounts of energy input in all cropping systems involved 44–55% for chemical fertilizers, 13–17% for land preparation, 12–15% for diesel and 11–14% for labor. Also, the highest energy productivity was obtained from the rice –garden pea system.

Tsatsarelis (1991) reported that the total amount of sequestrated energy for cotton production in central Greece with the with the highest share for irrigation and synthetic fertilizers was about 82,600 MJ ha^{-1}. Yaldiz et al. (1993) showed that the highest share of energy consumption of cotton production systems of Turkey belongs to fertilizers and irrigation. In one study to compare sweet sorghum, cotton and maize in terms of energy productivity in China, the results showed that the energy input of sweet sorghum production systems was less than cotton and maize (Ren et al., 2012). The results of this study demonstrated a significantly positive impact of the diesel fuel and nitrogen fertilizer energy inputs on the sweet sorghum energy output.

Energy indicators have been investigated in different regions of Iran for different field crops, including wheat (Ghorbani et al., 2011), barley (Ghasemi-Mobtaker et al., 2010), potato (Rajabi-Hamedani and Shabani, 2011), canola (Sheikh-Davoodi and Houshyar, 2009), sugarcane (Karimi et al., 2008), rice (AghaAlikhani et al., 2013) and soybean (Alimagham et al., 2017). For example, Zahedi and Eshghizadeh (2014) reported that the total energy of cotton production systems in Isfahan, central province of Iran, is equal to 52,507.8 MJ ha^{-1}. Energy use efficiency, specific energy, energy productivity, energy intensiveness, and net energy indicator values were reported as 0.7, 19.2 MJ^{-1} kg, 0.10 kg MJ^{-1}, 27.2 MJ \$$^{-1}$, and −15,625.2 MJ ha^{-1}, respectively.

In the viewpoint of the energy analysis, the total input energy of a system can be separated into two forms: renewable/non-renewable and direct/indirect inputs (Singh et al., 1994). In general, in advanced cotton production systems, non-renewable energy resources accounted for the major share of the energy. In this regard, fertilizers, pesticides and fossil fuels are the largest share. Many researchers have pointed out a higher share of non-renewable sources of energy compared to other sources (Esengun et al., 2007). For instance, in Turkey, Erdal et al. (2009) reported that the share of direct, indirect, renewable and non-renewable energy of total energy input (19,558 MJ ha^{-1}) of cotton production systems was equal to 4384 MJ ha^{1} (28.87%), 10,800 MJ ha^{1} (71.13%), 1867 MJ ha^{-1} (12.30%) and 13,316 MJ ha^{-1} (87.70%), respectively.

Cotton is an important economic fiber crop, also it is considered as an important feed source (as an oil crop), and the cottonseed meal also is used for animal feed (Agarwal et al., 2003). Cotton is a high value crop in the world trade of agricultural products and can also play an important role in agricultural employment. International traders are China, India, the USA, the EU and central Asian and African states are the major producers and international traders of this crop all over the world (FAO, 2016). The area under cotton cultivation in Iran in 2015 was 72,000 ha (with total production of 175,000 t). In the same year the share of Golestan province was 13.39 percent and the share of the Fars province was 17.79 percent (Ministry of Jihad-e-Agriculture, 2015). Energy analysis for agroecosystems has been considered since the 1970s. In the process of energy analysis, agroecosystems are considered as user and producer of energies (Pimentel et al., 1973). Given the importance and role of cotton as a strategic crop in the world, determining the energy inputs and energy-related can help to optimize cotton production systems. Therefore, this study aimed to determine the energy related indicators and energy consumption patterns in cotton production systems in Iran. In this research, it compared cotton production by energy indicators in two important cotton production regions for the point of view different climatic conditions (sub-humid and arid), agronomic management, energy inputs and used cotton varieties. Also, for the first time, the state of electrical energy consumption was analyzed in cotton production systems in Iran.

2. Material and methods

2.1. Description of the regions

This study aimed to evaluate and compare the energy indicators in cotton production systemsof two different climates. For this, the study was performed in two different regions. Darab township is located almost in the south of Iran, between 28°46′ and 28°76′ north latitude and 54°32′ and 54°54′ east longitude with arid climate and an average annual rainfall of 270 mm. Darab is one of the major agricultural zones in Fars province, which it's arable lands are mostly irrigated by groundwater resources. In terms of topography, the agricultural areas of Darab, are located between the plains and mountains. One of the challenges in this area is the low chemical quality of the water along with the drop in groundwater levels. The chemical quality of groundwater in this flat is influenced by the salt domes, evaporation rate and the direction of groundwater, which are the main factors affecting the water quality of the plains.

Gorgan township (Golestan province), is located in the northern strip of Iran, has a sum-humid climate and average annual precipitation of 533.9 mm. The township is geographically located in 36°30.6′ and 36°58.8′ north latitude and 54°12.9′ and 54°44.9′ east longitude. Golestan province in Iran is an ancient land of cotton cultivation and over the years has been known as the land of white gold. That's why Golestan province is introduced as Iran's capital of cotton (Mehregan et al., 2013). Due to history of cotton cultivation in the province and favorable climatic conditions for cotton cultivation, National Cotton Research Center of Iran is located in this province. Some values of climate variables (such as temperature, evaporation, sunshine hours and relativity humidity) are presented in Table 1 for two townships in 2013.