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Evaluation of greenhouse gases emission based on energy consumption in wheat Agroecosystems

Farzad Mondani *, Sepide Aleagha, Mahmud Khoramivafa, Rozhin Ghobadi

Department of Agronomy and Plant Breeding, Razi University, Kermanshah, Iran

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ABSTRACT

In order to have sustainable development, it is necessary to manage energy use and greenhouse gases (GHG) emission in all production processes. The aim of this study was to compare wheat production in dryland and irrigated agroecosystems in terms of greenhouse gases (GHG) emission based on energy consumption under different climatic regions. Data were collected from growers using a face-to-face questionnaire during 2013. The results showed that total energy consumption in irrigated and dryland wheat agroecosystems was 53082.9 and 15603.3 MJ ha^{-1}, respectively. Energy use efficiency was 22.1% higher in dryland wheat agroecosystem than irrigated wheat agroecosystem. Total GHG emission for irrigated wheat agroecosystem was 3184.4 kg CO_{2-eq} ha^{-1} and 680.36 kg CO_{2-eq} t^{-1} while it was 553.1 kg CO_{2-eq} ha^{-1} and 381.3 kg CO_{2-eq} t^{-1} in dryland wheat agroecosystem. In irrigated wheat agroecosystem the highest GHG emission was 3561.8 kg CO_{2-eq} $ha^{-1}$for arid–warm region and the lowest was 2832.6 kg CO_{2-eq} ha^{-1} for wet–moderate region. In dryland wheat agroecosystem the highest GHG emission was 584.2 kg CO_{2-eq} ha^{-1} for wet–cold region and the lowest was 523.01 kg CO_{2-eq} ha^{-1} for semiarid–warm region. In irrigated wheat agroecosystem diesel fuel had the highest emission (46.9%), followed by electricity (36.2%) and farmyard manure (7.5%). In dryland wheat agroecosystem the highest share of GHG emissions belonged to diesel fuels (75.8%), machinery (14.2%) and chemical fertilizers (8.5%), respectively.

1. Introduction

The enormous greenhouse gases (GHG) emission, especially carbon dioxide (CO_2), produced by human activities and their influence on climate conditions became a major ecological and political challenge. Concentration of GHG in atmosphere increased quickly over the past decades. For example, CO_2 concentration had risen to 380 ppm in 2006 compared to 280 ppm in 1700 (IPCC, 2007). If the increasing trend of GHG emission continues, there is the possibility of huge climate changes in the future (Timmermann et al., 1999). Although, details of predictions are a subject for argue, due to uncertainty in climate projections, most scientific societies agree that increasing of temperature has considerable negative impacts on human developments and natural and agricultural ecosystems (Fischlin and Midgeley, 2007). Nevertheless, it is believed that these occurrences can be avoided with significant decreases in GHG emission (Meinshausen et al., 2009). It is therefore important to realize GHG emissions from various actions and resources in production systems to recognize potential areas for emissions reductions.

Climate change and air pollution are major environmental concerns related to use of fossil fuel energy. Furthermore, considering that fossil fuel energy is a limited resource, it has to be conserved for future generations by efficient use in energy. Agricultural production systems and energy consumption have very closed relation. Agriculture is an energy user and energy supplier (Alam et al., 2005). Energy use in agricultural production systems has elevated in response to increasing human population, limited supply of arable land and desire in improving standards of living (Banaeian et al., 2011). Agriculture practices are a considerable contributor to rising GHG level (Jones et al., 2012). The role of these practices is about 20% of total anthropogenic GHG emission (IPCC, 2001). However, a pretty low percentage of agricultural emissions (13%) are as CO_2 while it contributed to about 60% of global anthropogenic nitrous oxide (N_2O) emissions and 50% of global anthropogenic methane (CH_4) emissions (Smith et al., 2007). Production, formulation, storage, distribution of agricultural inputs and application with tractorized equipment lead to consumption different source of energy such as diesel fuel, which emits GHG into atmosphere. Therefore, a reasonable first step for GHG emission reductions

* Corresponding author. Fax: +98 8318321083.
E-mail address: f.mondani@razi.ac.ir (F. Mondani).

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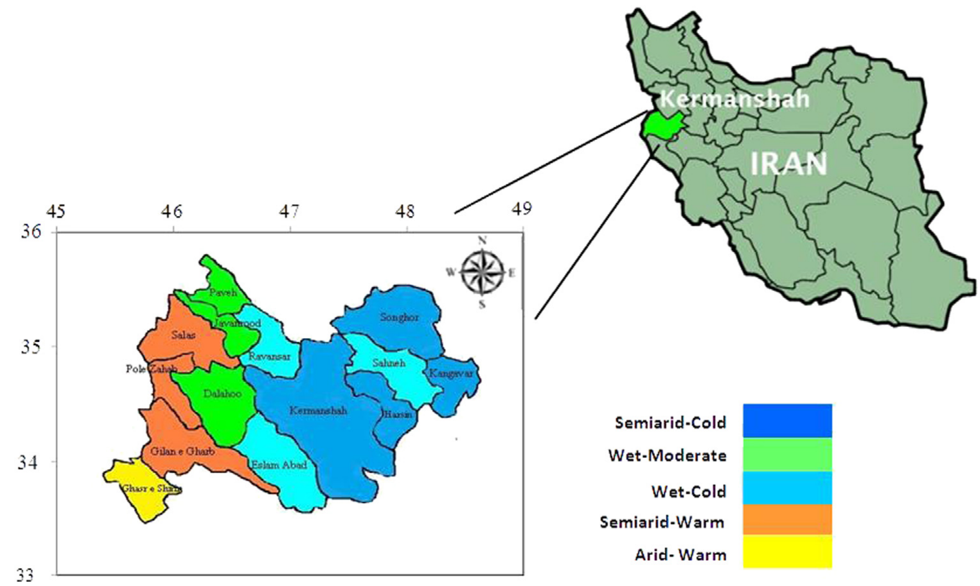

Fig. 1. Classification of different climatic regions for Kermanshah province (latitudes 33°42′ N and 35°17′ N and the longitudes 45°25′ E and 48°60′ E) based on De Martonne method.

in agroecosystems is quantify amount of emissions from specific sources in production processes and identify the most economically sensible options for reduction of GHG emission (Jones et al., 2012). To achieve these purposes, creation of available information related to energy use in operations farm, and their exchange to GHG equivalents and finally expressing energy use in terms of GHG emission as kg carbon equivalent is very essential (Lal, 2004).

In Iran, the energy consumption in agricultural sector has been recently questioned due to raise energy demand, costs and more mechanized in various agricultural operations (Mohammadi et al., 2014). Although, many studies have been conducted on the energy consumption in different crops including wheat (Ghorbani et al., 2011), sugar beet (Asgharipour et al., 2012), cotton and grain corn (Zahedi et al., 2014, 2015), tomato (Rezvani-Moghaddam et al., 2011), been, lintel, and chickpea (Koocheki et al., 2011) but, few numbers of them have focused on GHG emission (e.g. sugar beet Yousefi et al., 2014 and wheat Khoshnevisan et al., 2013b). Whereas, the agricultural sector of Iran was done in various climatic regions and soil environments, hence, it is very essential to quantify energy consumption and GHG emission for each climatic region.

One of the most crop in Iran is wheat which produced approximately 12.4 million tons from a total area of 6.4 million ha (about 3.9 million ha of dryland wheat agroecosystem and 2.5 million ha of irrigated wheat agroecosystem) in 2013 (MAJ, 2013). The wheat production system is a major income source and an important source of employment for many rural families. Therefore, the objectives of present study were (i) to assess the total energy consumed and the share of each energy sources, (ii) to evaluate energy use efficiency and energy productivity, and finally (iii) to quantify GHG emission according to energy inputs for irrigated and dryland wheat agroecosystems in different climatic regions.

2. Materials and methods

2.1. Study location

The present study was conducted in Kermanshah province, in the west of Iran, is located between the latitudes 33°42′ N and 35°17′ N and the longitudes 45°25′ E and 48°60′ E. The average annual temperature and precipitation were 16.5 °C and 403 mm, respectively. In 2013, the wheat cultivating area in Kermanshah province was almost 547 000 ha, including about 340 000 and 207 000 ha dryland and irrigated farms, respectively. In this province, wheat production occurs with a range of different growing conditions. Therefore, based on information collected from central meteorological station, different locations of Kermanshah province were classified in five climatic regions based on De Martonne method (Fig. 1).

The details of the cultivated area for irrigated and dryland wheat agroecosystems in each climatic region were collected from Ministry of Jihad-E-Agriculture of Iran (MAJ, 2013). After data collection, all agricultural activities such as land preparation, seeding rate, irrigation water, chemical fertilizers, pesticides and human labour needed in irrigated and dryland wheat farms were separately determined.

2.2. Energy input and output

To quantify the relationship between irrigated and dryland wheat yields and there energy consumptions and GHG emission, data were collected from growers in each climatic region using a face-to-face questionnaire during 2013. The sample size was calculated according to Neyman method (Eq. (1)) (Yamane, 1967):

$$n = \frac{N \times S^2}{(N-1)S_X^2 + S^2} \quad (1)$$

where n is the required sample size, N is the population volume, S is the standard deviation, S_X S_h^2 is the standard deviation of the sample mean ($S_X = d/z$), d is the permissible error in the sample size, was defined to be 10% of the mean for a 95% confidence interval, and z is the reliability coefficient (1.96, which represents a 95% reliability). Based on above calculations, the sample size was 386 (186 and 200 for irrigated and dryland wheat agroecosystems, respectively).

The data obtained from the questionnaires averaged and generalized to 1 ha. In order to estimate the energy inputs consumed in wheat farms, human labour, machinery, diesel fuel, seeds, farmyard manure (FYM), chemical fertilizers (nitrogen, phosphate, potassium and micro fertilizers), pesticides and herbicides (kg or liter) amounts were multiplied by their energy equivalents (Table 1).