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Energy use efficiency and greenhouse gas emissions of farming systems in north Iran

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ABSTRACT

Efficient use of energy resources in crop production is an important goal in sustainable agriculture. This study compares the energy flow in farming systems across farm size with their corresponding greenhouse gas (GHG) emissions - presented in terms of carbon dioxide equivalent (CO_2 eq.) - in the north of Iran. To reach this aim, primary data were collected by survey with farmers whose main activity was major crops production in the region that included wheat, barley, canola, soybean, paddy and corn silage. The results showed that total energy input for corn silage (52.1 GJ ha^{-1}) is greater than other systems. The results also revealed that yield and output energy of crops were not significantly affected by field size, whereas energy use efficiency of systems increased significantly as field size increased. Study shows that the cultivation of paddy emits the highest CO_2 eq. emission (6094 kg CO_2 eq. ha^{-1}) among crops, in which around 60% is contributed by methane (CH_4). The efficient use of fertilizers, optimized pumping facilities for irrigation, stopping of crop residue burning in the field and use them for energy supply could be among the options to improve energy use efficiency and mitigate GHG emissions.

Contents

1. Introduction

Energy is one of the principal requirements for the economic growth and social development of a country or region. Scientific forecasts and analysis of energy consumption will be of great importance for the planning of energy strategies and policies [1]. The enhancement of energy efficiency not only helps in improving competitiveness through cost reduction but also results in minimized greenhouse gas (GHG) emissions and environmental

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impacts [2]. About 14% of the global net CO_2 emissions originating the agricultural systems [3], but this share in Iranian agriculture is smaller and estimated to be ~4% [4]. Emissions from this sector in Iran, however, shows an increasing trend during the last two decades due to a high application of synthetic nitrogen, direct energy inputs and intensive use of farm machinery [5].

In Iran, in recent years, the energy efficiency of the agricultural sector has been questioned because of increasing of energy use and the costs due to more mechanized agricultural production [5]. As energy costs rise and fossil fuel reserves decline, energy use efficiency of agricultural systems becomes increasingly important. Many factors contribute to energy productivity but the size of the farm can play major role in adding to its productivity, especially in developing countries like Iran, where the average farm size is relatively small and the majority of farmers own less than five hectare of farm land [6].

The relationship between farm size and energy productivity can be differed per regions by rapid mechanization. The level of mechanization, amount of arable land and type of crop are the important factors that energy use in the agriculture sector depends on them [7]. On the other hand, the amount of energy resources are different in each farming region and on the field, there is a competition among crops into consumption of large energy inputs such as machinery, fertilizers, and irrigation. Studies comparing crop production systems have examined relationship between energy indices and farm size which is reported the different findings. Mandal et al. [8] analyzed the cropping systems in terms of energy use and the economics in different categories of farm size. They concluded that the energy productivity decreases towards larger size of farms, except for pigeon pea mono cropping, where the trend is reverse. A survey in Turkey was performed on energy consumption patterns in different sizes of farms for canola production. According to the results of this study the energy productivity increases with farm size [9].

In the literature there are several techniques for agricultural systems analysis in the view of energy, economic and environmental dimensions. Soni et al. [10] considered the energy use index and CO_2 emissions in rainfed agricultural production systems of Northeast Thailand. In this study, system efficiency, total energy input and corresponding CO_2 eq. emissions were estimated and compared for different crops. In another study by Koga and Tajima [11] energy efficiency and GHG emissions under bioethanol-oriented paddy rice production in northern Japan was investigated. They concluded that there are opportunities for further improvement in energy efficiency and reductions in GHG emissions under whole rice plant-based bioethanol production systems. In other works, the parametric and non-parametric approaches have been used to analyze the efficiency of farmers in agricultural productions [12]. Data Envelopment Analysis (DEA) is a non-parametric model based frontier estimation technique for measuring the relative efficiencies of a homogenous set of Decision Making Units (DMUs) having multiple inputs and outputs [13]. Recently, DEA method has been utilized to estimate the economic and energy efficiency of agricultural products [14,15]. For the environmental costs of food production, Life Cycle Assessment (LCA) is one of the best methodologies for the GHG emissions of agri-food systems, by recognizing energy and inputs used as well as direct and indirect GHG emissions [16]. Pergola et al. [17] reported that he combined use of LCA and energy analysis could be useful to provide information for policy makers and producers in choosing sustainable management systems or products. The joint application of LCA and DEA has also proven to be a suitable method for quantifying operational and environmental targets. Mohammadi et al. [18] applied LCA+DEA methodologies for a total of 94 soybean farms in Iran to benchmark the level of operational input efficiency of each farmer. They concluded that 46% of the farms studied operated efficient and greenhouse gas (GHG) emissions can be mitigated ~11% if inefficient farms turn efficient.

In this regard, there are several studies on energy analysis in production of single crops and fruits like potato [19], wheat [20], canola [12] and tangerine [21], for Iranian agriculture, whereas there is no study on analysis of farming systems from both energy and environmental points of view. The purpose of this study is to examine and compare energy use efficiency and GHG emissions of six crops across size land holdings. Energy analysis in the crop production systems enables to identify the effective farming system in different farm size with respect to energy parameters.

2. Materials and methods

2.1. Site description and data collection

The study was carried out in Golestan province located in North of Iran. The climate is Mediterranean. In the last decade, the mean annual rainfall and mean annual air temperature were 442 mm and 18 °C, respectively. The soil is silt loam derived from alluvial plains and classified as *Typic Xerorthents* based on USDA soil taxonomy, with pH of 7.1–7.9 [22]

The data used in the study were obtained using a face-to-face interview method. A questionnaire form was designed to collect the required information related to various inputs use (electricity, biocides, fertilizer, etc.), the possessed lands by the farmers, their cropping pattern, crops yield, operations time, economical information, etc. The structure of this questionnaire form is similar with ones that had been applied for previous studies [12,19,23]. The selection of producers was based on the cropping patterns and that the farmers should be representative of the selected crops. In addition, secondary data was obtained from similar studies and statistics by various individuals and organizations related to this subject like Agricultural Ministry of Iran. Finally data of 72 farmers were used for computation of energy consumption and its various ratios in crop production systems. These systems were compared in relation to the energy balance with different size land holdings: small (<2 ha), medium (2–5 ha) and large (>5 ha) systems for two cycles of six crop rotation that included wheat (*Triticumaestivum*), barley (*Hordeumvulgare* L.), canola (*Brassica napus* L.), soybean (*Glycine max* (*L.*) *Merrill*), corn silage (*Zea mays*) and paddy (*Oryza sativa* Linnaeus). These are the major crops grown in this region and all of them are cultivated under irrigated farming. Two growing cycles are possible. From the month of December up to mid-June they plant wheat, barley and canola; and from July up to November they cultivate soybean, corn silage and paddy. Depending on the field size, the farmers may plant one to three crops per cycle.

2.2. Energy and CO_2 emission analyses

The energy efficiency of the agricultural system was evaluated by the energy ratio between output and inputs. The flow diagram illustrating the energy inputs, GHG emissions and products including main products and residues during crop cultivation and transportation

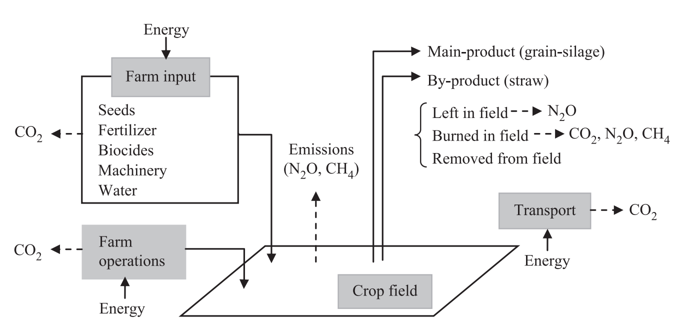

Fig. 1. The diagram of the energy inputs, greenhouse gas emissions and products during crop cultivation.