Energetic examination of dry farming system in chickpea production of Paveh county, Iran

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Abstract— **The aim of this study is to determine energy consumption of input and output used in chickpea production under dry farming system in Paveh county, Iran. For this purpose, the data were collected from 125 chickpea producers under dry farming system. The results indicated that total energy inputs were 5856.59 MJ ha^{-1}. About 67% of this was generated by diesel fuel, 11% from pesticides and 10% from seed. Energy indices results revealed that energy use efficiency, energy productivity, specific energy, and net energy were computed as 1.28, 0.09 kg MJ^{-1}, 11.48 MJ kg^{-1}, and 1642.17 MJ ha^{-1}, respectively. Energy forms analysis illustrated that 71% of total energy use was belonged to direct energy. So, the share of indirect energy is about 29%. On the other hand, renewable energy covered 14% of total energy consumption. Obviously, 86% is related to non-renewable energy. Finally, it can be concluded management of diesel fuel, pesticides and seed application can be improved the chickpea production under dry farming system in the studied area, significantly.**

Keywords: Chickpea, Direct energy, Dry farming, Energy use efficiency, Renewable energy

1. Introduction

Chickpea (*Cicer arietinum L.*) is an annual grain legume that originated in the west of Asia and is used extensively for human consumption. Chickpea is one of the most important grain legumes which are traditionally cultivated in marginal areas and saline soils [1]. The agronomic importance of chickpea is based on its high protein content (25- 29%) in human as well as livestock diet. Major world chickpea producers include India, Turkey, Pakistan, Russia, Myanmar, and Pakistan [2]. Fossil fuels, which are nonrenewable resources, are indispensable to modern agriculture, contributing to impressive yields in crop production. They are primarily consumed in the manufacture and operation of agricultural machinery and the production and application of chemical fertilizer. Although agriculture's share of world energy use is small, it is noteworthy that the development of energy-intensive agriculture has increased fossil fuel consumption [3].

Efficient energy use in agriculture sector is one of the conditions of sustainable agriculture, because it allows financial savings, fossil resources preservation and decreasing air pollution [4]. The amount of energy use is one of the key indicators for developing more sustainable agricultural practices. Wider use of renewable energy sources increases the energy supply and efficient use can make a valuable contribution to meeting sustainable energy development targets [5]. Using energy in agricultural production has been studied for different crops [6-9], however, no study has been yet conducted regarding energy analysis of dry farming system in chickpea production. Energy input-output analysis is usually used to evaluate the efficiency and/or environmental effects of production systems. The aim of this study was to determine input-output energy flow in dry farming system of chickpea production in Paveh county of Iran to investigate the efficiency of energy consumption.

2. Material and methods

This study was carried out in 125 chickpea producer in Paveh county of Iran. This province is located in the west of Iran, within 33° 04′and 35° 17′ north latitude and 45° 25′ and 48° 06′ east longitude [10]. Data were collected from the growers by using a face-to-face questionnaire performed in August-September 2021. Farms were randomly chosen from the villages in the area of study. The size of each sample was determined using a simple random sampling method. This method was described by Cochran [11]:

$$n = \frac{N(s \times t)^2}{(N-1)d^2 + (s \times t)^2} \quad (1)$$

where n is the required sample size; s is the standard deviation; t is the value at 95% confidence limit (1.96); N is the number of holding in target population and d is the acceptable error (permissible error 5%). For the calculation of sample size, criteria of 5% deviation from population mean and 95% confidence level were used. Sample size is calculated as 118. However, in this study, 125 units were considered for more reassurance.

The energetic efficiency of the agricultural system has been evaluated by the energy ratio between output and input. Human labor, machinery, diesel fuel, lubricating oil, pesticides, herbicides, and seed amounts and output yield values of chickpea crops have been used to estimate the energy ratio. Energy equivalents shown in Table 1 were used for estimation. The sources of mechanical energy used on the selected farms included tractors and diesel oil. The mechanical energy was computed on the basis of total fuel consumption (L ha^{-1}) in different operations. Therefore, the energy consumed was calculated using conversion factors (1 L diesel = 56.31 MJ) and expressed in MJ ha^{-1} [12].

Table 1. Standard energy coefficients of inputs and output in agricultural production

Item	Unit	Energy coefficient (MJ unit^{-1})	Reference
A. Inputs			
1. Human labor	h	1.96	[13]
2. Machinery	kg	142.7	[14]
3. Diesel fuel	L	56.31	[15]
4. Pesticides	kg	199	[16]
5. Herbicides	kg	85	[17]
6. Seed	kg	14.7	[18]
B. Output			
1. Chickpea	kg	14.7	[18]

Based on the energy equivalents of the inputs and output (Table 1), the energy indices including energy use efficiency, energy productivity, specific energy, and net energy were calculated [19] as the following:

$$\text{Energy use efficiency} = \frac{\text{Output energy (MJ ha}^{-1}\text{)}}{\text{Input energy (MJ ha}^{-1}\text{)}} \quad (2)$$

$$\text{Energy productivity (kg MJ}^{-1}\text{)} = \frac{\text{Chickpea yield (kg ha}^{-1}\text{)}}{\text{Input energy (MJ ha}^{-1}\text{)}} \quad (3)$$

$$\text{Specific energy (MJ kg}^{-1}\text{)} = \frac{\text{Input energy (MJ ha}^{-1}\text{)}}{\text{Chickpea yield (kg ha}^{-1}\text{)}} \quad (4)$$

$$\text{Net energy (MJ ha}^{-1}) = \text{Output energy (MJ ha}^{-1}) - \text{Input energy (MJ ha}^{-1}) \quad (5)$$

In the last part of the research, energy consumption has been divided into two category with four condition including the first category: direct and indirect energy and the second category: renewable and non-renewable energies. Direct energy included energy embodied in human labor and diesel fuel while indirect energy covered machinery, pesticides, herbicides, and seed. Furthermore, renewable energy consisted of human labor and seed; while non-renewable energy covered machinery, diesel fuel, pesticides, and herbicides.

3. Results and discussion

Table 2 showed the input-output energy analysis of chickpea production under dry farming system in Paveh county of Iran. Total energy used in various farm operations during chickpea production under dry farming system was 5856.59 MJ ha^{-1}. While Average annual yield of farms investigated was 510.12 kg ha^{-1} and calculated total output energy was 7498.76 MJ ha^{-1}.

Table 2. Physical amounts and input-outputs energies of chickpea production under dry farming system

Item (unit)	Quantity per ha	Energy equivalent (MJ ha^{-1})
A. Inputs		
1. Human labor (h)	118.77	232.79
2. Machinery (kg)	2.32	331.06
3. Diesel fuel (L)	69.85	3933.25
4. Pesticides (kg)	3.12	620.88
5. Herbicides (kg)	1.63	138.55
6. Seed (kg)	40.82	600.05
The total energy input (MJ)	-	5856.59
B. Output		
1. Chickpea (kg)	510.12	7498.76
Total energy output (MJ)	-	7498.76

Figure 1 also disclosed the share of each input in chickpea production under dry farming system in Paveh county of Iran. Diesel fuel consumed more than 67% of total energy inputs, followed by pesticides 15.80% during production period.

Diesel energy was mainly consumed for land preparation, cultural practices, and transportation. From Table 2 it is shown that human labor was the least demanding energy input for chickpea production under dry farming system with 138.55 MJ ha^{-1} (only about 2% of the total sequestered energy), followed by human labor by 232.79 MJ ha^{-1} (4%). In another study, Salami and Ahmadi [20] evaluated that the total energy consumption and produced energy by chickpea production in Kurdistan, Iran about 5880 and 6130 MJ ha^{-1}, respectively. Moreover, they reported that diesel fuel with more than 37% had the highest share in total energy use in this crop.

Energy indices results including energy use efficiency, specific energy, energy productivity and net energy of chickpea production under dry farming system in the Paveh county of Iran are tabulated in Table 3.

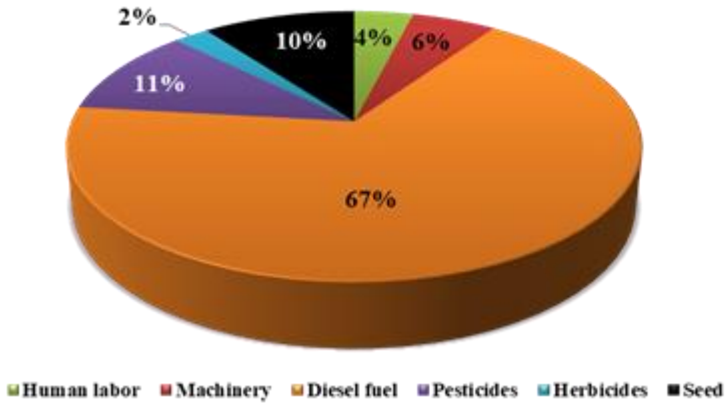

Figure (1). Share of each input in total energy consumption of chickpea production under dry farming system

Based on the results, energy use efficiency as the most important index is 1.28 in the chickpea production under dry farming system that illustrated the low efficiency of energy consumption in the mentioned crop.

Table 3. Results of energy indices in chickpea production under dry farming system

Energy index (unit)	Unit	Quantity
1. Energy use efficiency	-	1.28
2. Energy productivity	kg MJ^{-1}	0.09
3. Specific energy	MJ kg^{-1}	11.48
4. Net energy	MJ ha^{-1}	1642.17

In a similar study, Salami and Ahmadi [20] revealed that the energy use efficiency of chickpea in the Kurdistan region is about 1.04.

Table 4 showed the quantity of energy forms as direct, indirect, renewable and non-renewable categories. Based on the results, direct emissions consumed about 2475 MJ ha^{-1} more than indirect energy and the rate of renewable energy is less than non-renewable energy about 4191 MJ ha^{-1}.

Table 4. Results of energy forms in chickpea production under dry farming system

Energy form	Unit	Amount
1. Direct energy	MJ ha^{-1}	4166.04
2. Indirect energy	MJ ha^{-1}	1690.55
3. Renewable energy	MJ ha^{-1}	832.84
4. Non-renewable energy	MJ ha^{-1}	5023.75

The contribution of energy forms for chickpea production under dry farming system is demonstrated in Fig 1. The percentages of direct, indirect, renewable and non-renewable energies were computed at 71.13%, 28.87%, 14.22% and 85.78%, respectively. The high rate of non-renewable source is high risk for our environment. Conservation agriculture and optimized energy-supply systems can affect the primary energy inputs, as well as the ratio of primary energy to carbon dioxide emissions.

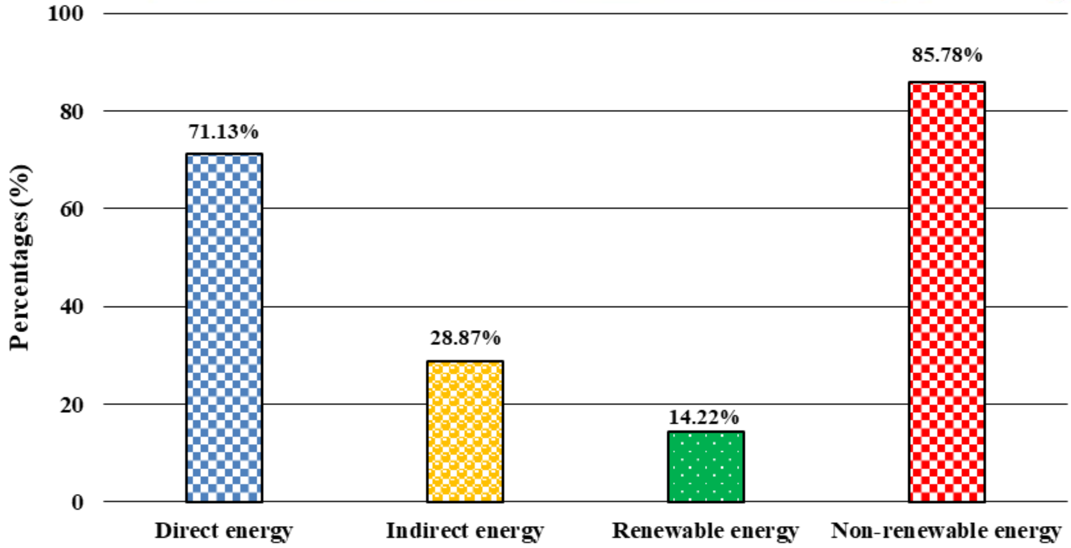

Figure (2). Distribution of energy forms of chickpea production under dry farming system

4. Conclusions

Evaluating CO_2 emissions in chickpea production under dry farming system in Kermanshah province of Iran and in the next step, finding relation between CO_2 emitter inputs and chickpea yield with applying Cobb-Douglas production function were the main objective of this research. Initial data were collected by completing questionnaire among 125 chickpea producers. After that, CO_2 emitter inputs with their standard emissions coefficients were determined. Results revealed that total CO_2 emissions in chickpea production under dry farming system in Kermanshah province, Iran were about 242 kg $CO_{2\ eq.}$ ha^{-1}. Diesel fuel with 192.79 kg CO_2 eq. covered about 79% of total CO_2 emissions in chickpea production under dry farming system. Moreover, CO_2 ratio was calculated as 0.48 kg CO_2 eq. per kg of harvested chickpea. According to econometric model evaluated, results revealed that diesel fuel was the most significant CO_2 emitter input that influences on the production with 1.38 elasticity. The second important input was found as water for irrigation with 0.12 elasticity.

Acknowledgements

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