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Applying Cobb–Douglas production function to model CO_2 emissions of chickpea production under dry farming system in Paveh county, Iran

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Abstract— **This study examines CO_2 emissions of inputs in chickpea production under dry farming system, and to find relationship between CO_2 emitter inputs and yield in Paveh county, Iran. For this purpose, 125 chickpea producers under dry farming system has been investigated for data collecting. Standard coefficients were used to calculate the CO_2 emissions and Cobb-Douglas production function was applied to model CO_2 emitter inputs and chickpea yield. Based on the results, total CO_2 emissions during production process of chickpea under dry farming system was 242.47 kg CO_2 eq. per ha and diesel fuel with 79% was the most significant CO_2 emitter inputs among all. After that, pesticides with 11% has the second rank. Moreover, CO_2 ratio was also about 0.48 that showed per kg of chickpea yield about 0.48 kg $CO_{2\ eq.}$ was emitted. Econometric results revealed that diesel fuel with elasticity 1.38 in 1% and machinery with elasticity 0.91 in 5% were the most effective CO_2 emitter inputs. In model analysis can be said R^2 about 0.94 indicated the acceptable accuracy of model and also, Durbin-Watson test with 1.96 illustrated that there are not any autocorrelation between variables.**

Keywords: Chickpea, CO_2 emission, Cobb-Douglas, Dry farming, Modeling

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1. Introduction

Chickpea (*Cicer arietinum L.*) is the most grown plant after lentils and dry beans with edible grain legumes cultivated in Turkey due to its resistance to heat and drought. Chickpea is relatively high in the content of crude protein (16.4-31.12%) and carbohydrate (50-74%), compared to the some other legume grains and it is commonly used as food and feed materials [1]. It was previously reported that the average protein content of chickpea as feed material is around 21.7% [2]. Chickpea has an average composition of 16-21% protein, 3% ash, 3-7% lipids, 5-13% crude fiber and 59-67% carbohydrates [3].

Production, formulation, storage, distribution of these inputs and application with tractorized equipment lead to combustion of fossil fuel, and use of energy from alternate sources, which also emits CO_2 and other greenhouse gases (GHGs) into the atmosphere. Thus, an understanding of the emissions expressed in kilograms of carbon equivalent (kg CE) for different tillage operations, fertilizers and pesticides use, supplemental irrigation practices, harvesting and residue management is essential to identify C-efficient alternatives such as biofuels and renewable energy sources for seedbed preparation, soil fertility management, pest control and other farm operations [4]. Intensifying global focus on the environmental responsibility has forced industries and policy makers to develop strategies to decrease the production of harmful emissions [5]. The contribution of global agriculture to air pollution accounts for about 5-13.5% of annual GHG emissions [6]. So, the survey of GHG emissions (especially CO_2 emissions) is very important for agriculture activity. Models are the only practical way to quantify the net effect of farm practices on GHG emissions or to assess climate change mitigation measures [7]. There are many methods for modeling and one of the most famous of them is Cobb-Douglas production function that has been widely used in energy-environment-economic theories for decades. The Cobb-Douglas production function was first investigated by CW. Cobb and PH. Douglas and published in the journal American Economic Review in 1928 [8]. The Cobb-Douglas function is a function or equation involving two or more variables, in which one variable is called a dependent variable and the other is called an independent variable [9]. Accordingly, the main aim of this study is finding relation between CO_2 emissions of different inputs with chickpea yield under dry farming system. So, the Cobb-Douglas production function was fitted for this purpose.

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]:

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

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 coefficient standard of emissions was used for estimation of CO_2 emissions for each input (Table 1). In this study, machinery, diesel fuel, pesticides, and herbicides were found as manufacturer CO_2 emissions in chickpea production under dry farming system. The CO_2 coefficient of machinery input consists of manufacturing and applying the machinery on the farms and is based on energy units. For calculation of CO_2 emissions, the first step was to determine the input quantity based on units of each input.

Table 1. Standard CO_2 emissions coefficients of inputs in agricultural production

Input	Unit	CO_2 emissions coefficient (kg $CO_{2\,eq.}$ unit^{-1})	Reference
1. Machinery	kg	10.13	Calculated from [12]
2. Diesel fuel	L	2.76	[13]
3. Pesticides	kg	5.1	[14]
4. Herbicides	kg	6.3	[15]

The efficiency of CO_2 emissions was determined by CO_2 ratio index that was show the emissions rate per kg of harvested chickpea under dry farming system:

$$CO_2\ ratio = \frac{Total\ CO_2\ emissions\ (kg\ CO_2\ eq.\ ha^{-1})}{Chickpea\ yield\ (kg\ ha^{-1})} \qquad (2)$$

The different mathematical functions such as linear, linear logarithmic, logarithmic-linear and second degree polynomial were tested to find and analyze the relationship between CO_2 emitter inputs and yield. Cobb-Douglas function yielded better estimates in terms of statistical significance and expected signs of parameters among other functions.

Cobb–Douglas function is expressed as follows [16]:

$$Y = f(x)\exp(u) \qquad (3)$$

This can be further written as:

$$\ln Y_i = a + \sum_{j=1}^{n} \alpha_j \ln(X_{ij}) + e_i \qquad i = 1,2, \ldots, n \qquad (4)$$

Eq. (4) can be expressed in the following form:

$$\ln Y_i = a_0 + \alpha_1 \ln X_1 + \alpha_2 \ln X_2 + \alpha_3 \ln X_3 + \alpha_4 \ln X_4 + e_i \qquad (5)$$

Where Xi stands for corresponding CO_2 emitter inputs as X_1 is machinery; X_2 is diesel fuel; X_3 is pesticides; and X_4 is herbicides. Moreover, Y_i is chickpea yield, a_0 is intercept and e_i is experimental error.

In this research, Excel 2019 spreadsheet is applied for analysing the CO_2 emissions and SPSS 25 is used for modeling among outputs and inputs to describe the objective function.

3. Results and discussion

The quantity of each inputs related to chickpea production under dry farming system in Paveh county of Iran and their CO_2 emissions are tabulated in Table 2. Based on the results, the total CO_2 emissions was calculated about 242 kg $CO_{2\ eq.}$ per ha of chickpea production. As can be seen in Table 2, Diesel fuel with about 193 kg $CO_{2\ eq.}$ and herbicides with about 10 kg $CO_{2\ eq.}$ were the most significant and insignificant inputs from CO_2 emissions point of view. The CO_2 ratio rate also was computed as 0.48 kg $CO_{2\ eq.}$ per kg of harvested chickpea.

Table 2. Physical amounts and CO_2 emissions of inputs for chickpea production under dry farming system

Item (unit)	Quantity per ha	CO_2 emissions equivalent (kg $CO_{2\ eq.}$)
1. Machinery (kg)	2.32	23.50
2. Diesel fuel (L)	69.85	192.79
3. Pesticides (kg)	3.12	15.91
4. Herbicides (kg)	1.63	10.27
Total CO_2 emissions (kg $CO_{2\ eq.}$)	-	242.47

The distribution of CO_2 emissions for chickpea production under dry farming system in Paveh county of Iran were demonstrated in Figure 1. Results revealed the highest share of total CO_2 emissions was belonged to diesel fuel with 79%, followed by machinery with 10% during chickpea production under dry farming system process.

In a similar study, Nabavi-Pelesaraei et al. [17] reported the total CO_2 emissions of rice production was calculated about 1847 kg $CO_{2\ eq.}$ and diesel fuel with 60% had the highest share among all CO_2 emitter inputs.

In the last part of this study, for estimation of the CO_2 emitter inputs and chickpea yield relationship was used Cobb–Douglas production function on different categories of farms. Therefore, chickpea yield (endogenous variable) was assumed to be a function of machinery, diesel fuel, pesticides, and herbicides (exogenous variables). For data used in this research, autocorrelation was tested by using Durbin–Watson test [18]. This test result revealed that Durbin–Watson value is as 1.96 for Eq. (5).

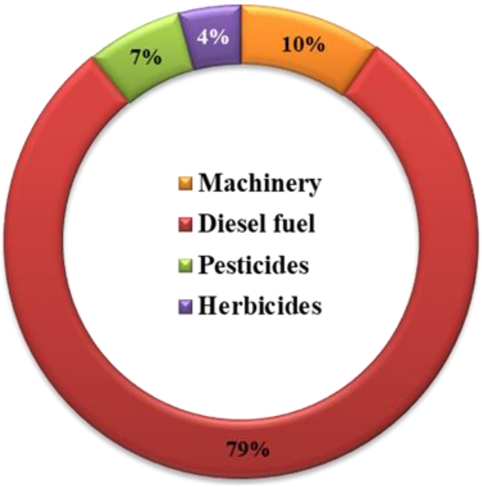

Figure (1). Contribution of each CO_2 emitter inputs in total emissions

This means that there is no autocorrelation at the 5% significance level in the estimated model. The R^2 value was as 0.94. Regression results for Eq. (4) are shown in Table 3. With respect to the results of assessment of Cobb-Douglas function on each one of the inputs in chickpea production, it could be seen that the impacts of each one of the inputs differ in constitution production level. The results revealed that the impact of CO_2 emitter inputs could be assessed positive on yield (except herbicides). Diesel fuel had the highest impact (1.38) among the other CO_2 emitter inputs in chickpea production. This indicates that by increase in the CO_2 emissions obtained from diesel fuel input, the amount of output level increase in present condition. This impact was significant at 1% level, with respect to the assessed results, a 1% increase in the CO_2 emissions of diesel fuel input led to 1.38% increase in yield. The second important input was found as machinery with 0.91.

Table 3-Econometric estimation results of inputs

Item	Coefficient	*t*-ratio
Model: $\ln Y_i = a_0 + \alpha_1 \ln X_1 + \alpha_2 \ln X_2 + \alpha_3 \ln X_3 + \alpha_4 \ln X_4 + e_i$		
1. Machinery	0.91	2.72 **
2. Diesel fuel	1.38	3.44 *
3. Pesticides	0.57	1.18
4. Herbicides	-0.37	-0.64
Durbin-Watson	1.96	
R^2	0.94	
Return to scale ($\sum_{i=1}^{n} \alpha_i$)	2.49	

*, ** Indicates significance at 1% and 5% level, respectively.

4. Conclusions

Evaluating CO_2 emissions in chickpea production under dry farming system in Paveh county 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 Paveh county, 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.

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