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Environmental impacts of peanut production system using life cycle assessment methodology

Amin Nikkhah [a], Mehdi Khojastehpour [a, *], Bagher Emadi [a], Alireza Taheri-Rad [a], Surur Khorramdel [b]

[a] Department of Biosystems Engineering, Ferdowsi University of Mashhad, Mashhad, Iran
[b] Department of Agronomy, Faculty of Agriculture, Ferdowsi University of Mashhad, Mashhad, Iran

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ABSTRACT

Agricultural activities emit the greenhouse gases and the other environmental contaminants to the atmosphere. Thus, the environmental impacts of agricultural activities have to be examined for identification, assessment and mitigation. In this study, life cycle assessment (LCA) methodology was used to determine the environmental impacts of peanut production system in Guilan province of Iran. These environmental impacts were classified into six impact categories including global warming, acidification, terrestrial eutrophication, depletion of fossil resources, depletion of phosphate and potash resources. Results indicated that the final indices for these six impact categories were calculated as 0.040, 0.216, 0.360, 3.98, 0.291 and 0.026 for one ton peanut production in this region, respectively. The depletion of fossil resources had wider negative effects on the environment. Farms of 0.1–0.5 ha showed the highest amount of global warming potential as well as the depletion of fossil resources. The environmental index and resource depletion index for one ton production of peanut were 0.62 and 4.30, respectively. Also, the final indices of global warming, acidification, terrestrial eutrophication, fossil, phosphate and potash resource depletion were revealed to be 0.0017, 0.0091, 0.0152, 0.168, 0.012 and 0.001 for generating 1000 MJ energy, respectively.

1. Introduction

In recent years, due to the population growth and increasing demand for food, it has been tried to rectify this demand by increasing both under cultivation lands and production yield. This means more consumption of agricultural resources and inputs that resulted in detrimental impacts on the environment. The agricultural sector as a main consumer of energy in Iran emits around 36.5% of total N_2O emission and 2% of two other gases including CO_2 and CH_4 (MOE, 2012). N_2O which is emitted by agricultural activities has a potential of 310 times more than CO_2 in global warming (Snyder et al., 2009). According to the International Energy Agency (IEA), Iran is among the ten countries that had the highest amount of CO_2 emission during 2010, and Iran's share is the highest among the Middle East countries (IEA, 2012). Therefore, it is required to pay more attention to the activities and useable inputs of agricultural sector.

Cultivation of peanut (*Arachis hypogaea* L.) as an agricultural crop requires different inputs which potentiality may pollute the environment. Peanut seed with more than 40% oil is the second important oilseed after soybean in tropical and semi-tropical regions. There are more than 3000 ha lands cultivated with peanut in Iran, which 2500 ha of that is in Guilan province (Hosseinzadeh-Gashti et al., 2009).

The life cycle assessment (LCA) is a suitable method for evaluating the environmental impacts of agricultural production which has been used in several studies including wheat production in Switzerland (Charles et al., 2006), wheat and maize in China (Wang et al., 2007), sugar cane in Australia, corn in US, sugar beet in UK (Renouf et al., 2008) and sunflower and rapeseed in Chile (Iriarte et al., 2010). In a study conducted by Liu et al. (2010) LCA of pear production was performed and concluded that a list of choices are available to reduce environmental impact in the pear production, namely the conversion from the conventional farming to organic

* Corresponding author. Department of Biosystems Engineering, Ferdowsi University of Mashhad, Azadi Square, Mashhad, Iran. Fax: +98 51 38796843.
E-mail addresses: mkhpour@um.ac.ir, mkhpour@yahoo.com (M. Khojastehpour).

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farming and using manure for biogas production. In another study, conducted by Abeliotis et al. (2013) LCA methodology was used to investigate bean cultivation and the authors reported that organic production of beans leads to protection of the global abiotic resources.

In Iran, a study based on life cycle assessment was conducted to determine the environmental impacts of wheat production in Gorgan (Soltani et al., 2010). It showed that the production has brought about huge environmental effects in terms of the depletion of non-renewable energy, eutrophication, photochemical oxidation and acidification. Khoshnevisan et al. (2013a) explored LCA of cucumber and tomato production systems under greenhouse in Iran. They showed that greenhouse cucumber production had a higher environmental impact than that of tomato due to major total energy input and correspondingly higher environmental burdens in all impact categories. In another study, carried out by Khoshnevisan et al. (2013b) the environmental impacts for strawberry production was examined under Guilan climatic conditions using LCA methodology. Several other investigations to determine the environmental impacts of agricultural production using life cycle assessment method has been carried out in Iran (Mirhaji et al., 2011, 2012; Mohammadi et al., 2013). Due to high cultivated lands with peanut and lack of any published document about its environmental effect, this study examined the environmental impacts for peanut production under Guilan climatic conditions using LCA methodology.

2. Material and methods

2.1. Selection of case study area and data collection

The study region was Astaneye Ashrafiyeh in the east of Guilan province (Iran) with 37° and 16 min latitude and 49° and 56 min longitude which is 3 m above mean sea level. Guilan has a population of approximately 2.5 million people (Statistical Centre of Iran, 2014). This province shares a border with the country of Azerbaijan. The annual average rainfall in Guilan province is more than 1000 mm (Rice Research Institute of Iran, 2013). Cochran's formula was used to determine the sample size and 75 farmers were selected (Snedecor and Cochran, 1980).

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

$$d = \frac{t \times s}{\sqrt{n}} \tag{2}$$

where n is the required sample size; s, the standard deviation; t, the value at 95% confidence limit (1.96); N, the number of holding in target population and d, 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. Data were collected from the peanut producers by using a face to face survey during growing season of 2011–2012.

Life cycle assessment consists of four stages including the goal and scope definition, life cycle inventory (LCI), life cycle impact assessment (LCIA) and interpretation (Iriarte et al., 2010).

2.2. Goal and scope definition

In the method of life cycle assessment, the goal and the functional unit (FU) must be first determined. It is being discovered recently that rice paddy cultivation is not economical in Guilan province of Iran (Pishgar-Komleh et al., 2011) and some farmers are diverting their paddy fields to cultivating peanut. Sustainable development of the peanut production in north of Iran requires the consideration of environmental impacts in the production system. Therefore, the goal of this survey was to study the environmental consequence of impact categories including the global warming, acidification, and terrestrial eutrophication, depletion of fossil resources, depletion of phosphate resources, and depletion of potash on the production and drying the peanut. The role of functional unit is to connect inputs and outputs as well as providing necessary conditions for comparison. The functional units in this study were the production of 1000 kg peanuts and 1000 MJ energy.

2.3. Life cycle inventory analysis

In this section, all the required inputs, sources and values to produce the considered product and also all the pollution emitted by using various inputs in the environment were calculated on the basis of functional unit.

2.3.1. Inputs of system

In this study, the amount of diesel fuel consumption for producing and drying peanut as well as nitrogen, phosphorus and potash fertilizers consumption were considered as input variables. The amount of diesel fuel consumption to produce peanut and also the drying process are shown in Table 1 according to divided operations. In this region, peanut is established preferably in the month of April and May and it is harvested once a year in the month of September and October. The average production of peanut in this area is shown in Table 2. The hull of peanut was considered about 25% of the total weight of peanut (Fasina, 2008). The nitrogen consumption in the form of urea is also mentioned in Table 3. The amount of nitrogen was considered around 46% of usable urea (Erdal et al., 2007). It should be mentioned that due to the desirable conditions of raining, the water was ignored in the calculation.

In this study two functional unit were chosen: mass-based (one ton of produced peanut) and energy-based (1000 MJ energy production). One ton of mass production was selected as functional unit in many studies (Liu et al., 2010; Khoshnevisan et al., 2014; Bojacá et al., 2014: Meier et al., 2015). On the other hand, there is a growing interest for biodiesel production in Iran. Moreover, there is a high potential for biodiesel production from oil seeds in Iran (Ghobadian, 2012; Safieddin-Ardebili et al., 2011). Peanut is an edible oil seed which is potentially a feedstock for biodiesel fuel production (Jaruwongwittaya and Chen, 2010). Sustainable development of the energy production from peanut in this region requires consideration of environmental management in the production system. Therefore, 1000 MJ energy production was chosen as the other functional unit. Table 3 shows the consumption values of four inputs including diesel fuel, nitrogen, phosphorus and potash fertilizers to produce 1000 kg of peanut and 1000 MJ of energy.

2.3.2. Outputs of system

The degree of emission is different based on the soil type, climatic conditions, and farm management system. Then, instead of measurements, organized methods were used to estimate the average degree of emission that is used in this study (Brentrup et al., 2004a). According to the study was done by Tzilivakis et al. (2005) the emissions of the main greenhouse gases including N_2O, CO_2 and CH_4, for the combustion of each liter of diesel fuel are 2.73 kg carbon dioxide, 18.1×10^{-6} kg nitrous oxide and 173×10^{-6} kg CH_4. Moreover, the amount of emission of SO_2 and NO_x pollutants for the combustion of each liter of diesel fuel were 22.2×10^{-3} kg and 4×10^{-3} kg, respectively (Dehghani, 2007).

The emission degree of various urea and nitrogen combinations is about 90% degree of global ammoniac emission which is caused