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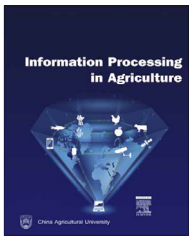

Life Cycle Assessment modeling of milk production in Iran

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ABSTRACT

Livestock units are known as one of the most influential sectors in the environment pollution. Therefore, the aim of this study was to investigate the environmental impacts of milk production in Guilan province of Iran through Life Cycle Assessment (LCA) methodology. The primary data were collected from 45 units of milk production through a field survey with the help of a structured questionnaire. The reliability was assessed using Cronbach's alpha coefficient and was estimated an acceptable value of 0.91. The consumption of resources and emissions were allocated to a functional unit (FU) of one ton of milk. Impacts of emissions in five impact categories of global warming, acidification, eutrophication, photochemical oxidation and depletion of resources were investigated. The results showed that the characterization index for these impact categories were 1831 kg CO_2 eq, 7.97 kg SO_2 eq, 3.42 kg PO_4^{-3} eq, 0.21 kg C_2H_4 eq and 838.39 MJ, respectively. Final indices for these impact categories were calculated as 0.24, 0.28, 0.076, 0.017 and 0.046, respectively. Environmental index (EcoX) and resources depletion index (RDI) were obtained 0.61 and 0.04, respectively. In this study, the highest potential for environmental impacts of production revealed for acidification and followed by global warming impact category.

1. Introduction

Besides securing food for the rising population, according to predictions will be more than 9 billion in 2075, the environment preservation is one of the most important challenges facing humanities [1]. Agriculture is one of the main sources of greenhouse gas (GHG) emissions such as CO_2, CH_4 and N_2O [2,3]. It is necessary to evaluate environmental impacts of different sectors of agriculture particularly dairy cow breeding units that are one of the main resources of GHG emissions [4]. The FAO report "Livestock long shadow: environmental issues and options" claims that livestock units constitute about 18% of the entire GHG emissions of which 3–5.1% are from dairy cow breeding units [5,6].

Although there are different methods for assessing the environmental impacts associated with food systems, but the appropriate one is the Life Cycle Assessment (LCA),

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because this method is suitable for determination of inputs, outputs and environmental consequence in a production process [7,8]. A Literature review disclosed that many researchers have reported the valuable application of LCA model in environmental management of agricultural production [9–14].

Some studies have been conducted in terms of environmental impacts assessment during dairy farm activities, for example Van der Werf et al. [15] evaluated the environmental impact of dairy cow breeding in terms of traditional and organic systems. They investigated the impact categories of global warming, acidification, eutrophication, land occupation and fossil resources depletion. They claimed that the impact of land occupation in the organic system was higher in comparison to a traditional system, while the other impact categories had not many differences in the two systems. Castanheira et al. [16] studied environmental impacts of dairy cow breeding units in Portugal. The biggest sources of N_2O, NH_3 and CH_4 were reported to be diesel fuel, manure management and enteric fermentation.

McGeough et al. [17] performed a study on LCA in dairy units of Canada and reported that the amount of GHG emission per one liter of milk was 0.92 kg CO_2 eq. O'Brien et al. [18] studied environmental impacts of milk production in Ireland. The results indicated that the effective environmental impacts were global warming, acidification, eutrophication, land occupation and fossil resources depletion for each functional unit of milk production. LCA model was also applied to evaluate environmental impacts resulted from global warming potential in milk production units in the United States. The total GHG per liter of milk was equal to 0.20 kg CO_2 eq [19].

Guerci et al. [20] analyzed the environmental impacts of dairy farms activities in Denmark, Germany and Italy through LCA and found that the average annual production of milk per cow was between 6275 and 10,964 L. Effective environmental impact categories were acidification, eutrophication, depletion of fossil sources and global warming. The impacts of all of the effective environmental groups in dairy units of Denmark were less than Germany and Italy. In another study, carried out by Zhang et al. [21] they examined the environmental impacts for dairy cow breeding units in Canada using LCA methodology based on an integrated system. The integrated system in the study was for applying an aerobically digested for production of biogas energy and digested slurry. The results indicated that usage of an integrated system in livestock units can decrease fossil recourses and global warming up to 80% and eutrophication and respiratory effects up to 50%. Some other studies which were conducted on environmental impacts through LCA in dairy cow breeding units are also available [14,22,7,23–26].

The sustainable production of milk in Guilan province of Iran requires the consideration of environmental management in the production systems. However, to the best of knowledge of authors, no previous analytical work has been reported on the environmental impacts of milk production in Iran. Therefore, the aim of present study was the environmental impacts assessment of milk production in dairy cow breeding industrial units in Guilan province, Iran based on LCA methodology.

2. Materials and methods

2.1. Site of study and sample selection

The study was carried out in industrial units of dairy cow breeding of Guilan province in northern Iran during agricultural year of 2012–2013. Guilan province is located in the north of Iran on the south of Caspian Sea, within 36°34′ and 38°27′ north latitude and 48°53′ and 50°34′ east longitude. Guilan has a population of approximately 2.5 million people [27]. From 180 industrial units of cow growing in Guilan at the time of the study, 129 of which were dairy cow breeding units [28]. The average numbers of cow in the studied area were ranged 20–200 cows that average was equal to 54.5 head. The most using of machinery were for the process of milking equipment, processing of animal feed, and followed by allocated milk cooling. In addition, many activities such as animal feeding operation were done by human labor. Based on the Cochran formula, 45 active units were selected for this study [29].

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

$$d = \frac{t \times s}{\sqrt{n}} \quad (2)$$

where, n = sample size, N = number of holdings in the target population, t = the reliability coefficient (1.96), s = the variance, and d = precision.

Data were obtained from 45 units of milk production using a face to face questionnaire method during 2012–2013. The instrument used in this research was a questionnaire whose validity was confirmed by university faculty members and agricultural experts. The estimated reliability, using Cronbach's alpha, was 0.91, which was an acceptable reliability. Each producer was asked to detail activity as inputs to milk production recorded as diesel fuel (lit), electricity (kWh), natural gas (m^3), animal feed (kg) and manure (kg), and as the output yield (kg).

2.2. Life Cycle Assessment

This method comprises four sections as: goal and scope definition, life cycle inventory (LCI), life cycle impact assessment (LCIA) and finally interpretation [8,30,31].

2.2.1. Goal and scope definition

The purpose of this study was to assess the environmental performance of milk production in dairy farming industries in Guilan province, Iran. The functional unit (FU) is connected to the inputs and outputs and provides a condition for comparison, which is usually equivalent to one ton of milk [16,32]. In the current study, the functional unit was chosen as one ton produced milk.

2.2.2. System boundary

In first, inputs including fuel, electricity, animal feed and other activities such as animal manure management (transport and accumulation) and enteric fermentation that