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Investigation of Life Cycle Assessment of Hazelnut Production in Guilan Province of I.R. Iran Based on Orchards size Levels

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ABSTRACT: Focus of this study is on the identifying the main environmental burdens and suggesting some environmental improvement potentials by applying life cycle assessment (LCA) method for hazelnut production in Guilan province of I. R. Iran. Furthermore, this work provides comprehensive data for a hazelnut production related to different orchards size that can be used in subsequent LCA studies. The study was developed following the methodological guidelines of ISO 14040. Ten impact categories based on CML method and three impact categories using USEtox method were assessed. Large orchards (LOs) and small orchards (SOs) had the highest value in the CML impact categories. Results shows that expected in eutrophication (EP) which pesticide was the main hotspot, machinery was the main hotspot in all of the impact categories. Moreover, LOs and medium orchards (MOs) had the largest and lowest value in the USEtox impact categories, respectively. Eventually, MOs are known as the lowest contributor to environment by both of method. As well, reduction or substitution of machinery, pesticide and diesel fuel in consequent studies should be investigated.

Keywords: Life cycle assessment; Environmental hotspots; Hazelnut; Orchards size levels; CML method; USEtox method

INTRODUCTION

A hazelnut is the nut of the hazel and is also known as cobnut or filbert nut according to species. A cob is roughly spherical to oval, about 15–25 mm long and 10–15 mm in diameter, with an outer fibrous husk surrounding a smooth shell. A filbert is more elongated, being about twice as long as it is round (Nabavi-Pelesaraei *et al.,* 2013). Iran country with 23535 hectares orchard is eighth largest producer of hazelnut in the world (FAO, 2015). Moreover, one of the major poles of hazelnut production belongs to Guilan province in Iran (Anon, 2013). The intensification of agricultural practices has substantially increased water and fertilizer consumption. Fertilizer production significantly contributes to the Global Warming Potential (GWP), essentially from CO_2, CH_4, and N_2O emissions. Fertilizer use causes nitrogen emissions (as NH_3 and N_2O), nitrate leaching, and potassium and phosphorus losses to water (Beccali *et al.,* 2010).

Emissions from agriculture, 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 in Iranian agriculture (Mohammadi *et al.,* 2013). Production, formulation, storage, and distribution of these inputs and utilization with engine based equipment result in combustion of fossil fuels, and also emissions of GHGs like CO_2, N_2O and CH4 into the atmosphere that these emissions are responsible for global warming (Mohammadi *et al.,* 2013). Energy balance of crop production was much debated in the early 1970s when the world energy crisis made people aware that the supply of fossil energy is limited (Khoshnevisan *et al.,* 2013).

LCA is a comprehensive assessment and considers all attributes or aspects of natural environment, human health, and resources (Finnveden *et al.,* 2009). Life cycle assessment (LCA) is a method used to assess several environmental impacts (*e.g.* global warming, eutrophication, etc.) along the life cycle of a product. LCA has become an internationally accepted method also in agriculture for assessing environmental impacts and for identifying hotspots where the environmental burden for a product in a life cycle is particularly large (Knudsen *et al.,* 2011).

Many researchers have focused to LCA for determination of environmental impact assessment in agricultural activities. For example, Knudsen *et al.* (2011) calculated the environmental assessment of organic juice imported to Denmark. Khoshnevisan *et al.* (2013a) was investigated on LCA of potato production. In another study, Sahle and Potting (2013) examined the environmental LCA of Ethiopian rose cultivation. The aim of the present study is to determine the environmental impacts of hazelnut production in Guilan province of Iran to find the main contributor of production process.

MATERIALS AND METHODS

A. Data collection and processing

This study follows our previous study which was conducted on modeling of energy use and greenhouse gas emissions of hazelnut production using linear regression (Nabavi-Pelesaraei *et al.,* 2013). Accordingly, data used in this study were obtained from 120 hazelnut orchards from 12 villages in Guilan province of Iran in 2012–2013 crop years. The location of the studied area is shown in Fig. 1.

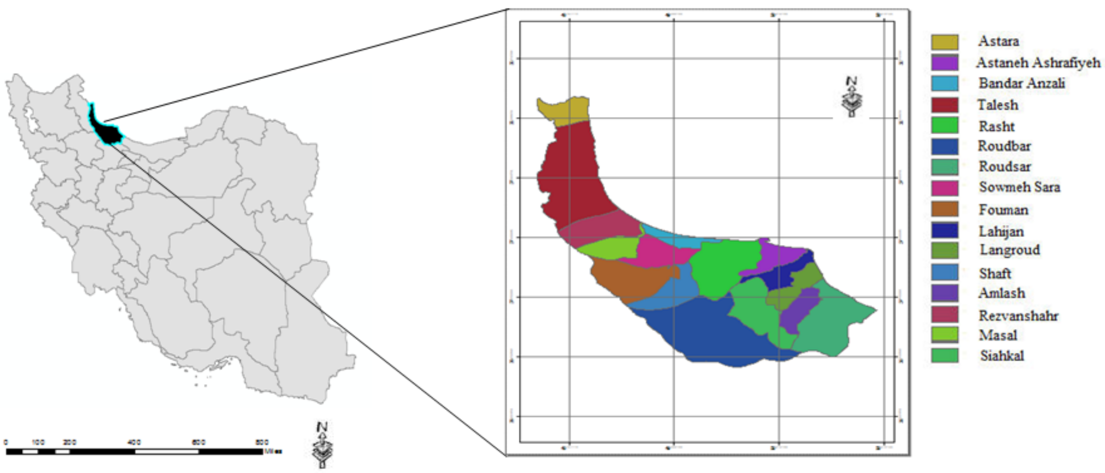

Fig. 1. Location of the studied area in the north of Iran (Nabavi-Pelesaraei *et al.,* 2014).

According to the International Organization for Standards, LCA is a method used to assess environmental aspects and impacts of products (ISO, 2006). One divides LCA into four distinct though interdependent phases: Goal and scope definition, Life cycle inventory analysis, Life cycle impact assessment and Life cycle interpretation.

B. Goal and scope definition

Goal and scope definition attempts to set the extent of the inquiry as well as specify the methods used to conduct it in later phases. One selects a product system, functional units, boundaries, allocation methods, and impact categories during this defining phase (Reap *et al.*, 2008). The goal and scope definition of an LCA provides a description of the product system in terms of the system boundaries and a functional unit.

The functional unit is the important basis that enables alternative goods, or services, to be compared and analyzed (Rebitzera *et al.,* 2004) that for an easier comparison with other works, the functional unit adopted was 1 ton of hazelnut, which was produced during considered production period. The study was a cradle to gate analysis of hazelnut production and the system boundaries were defined as shown in Fig. 2.

C. Life cycle inventory analysis

Life cycle inventory (LCI) analysis defines and quantifies the flow of material and energy into, through and from a product system (ISO, 2006). As a quantitative method, LCA has high requirements for data quality and is sensitive to uncertainties In LCA, data are collected and stored at the LCI stage. Firstly, regarding the data source, collecting site-specific data (with respect to a specific geographic location) or general data (the average data covering a larger geographical area), should be defined clearly (Chang *et al.* 2014). A detailed of LCI data for hazelnut production tabulated in Table 1 in result and discussion section.

Inventory data for the background system were obtained from databases. Data for the emissions related to the diesel consumption, adapted from Nemecek and Kagi (2007) and Nielsen *et al.* (2005). Inventory data for utilization of machinery as well as production of nitrogen, phosphate, farmyard manure, biocides and diesel consumption were taken from the Ecoinvent database (Nemecek and Kagi 2007).

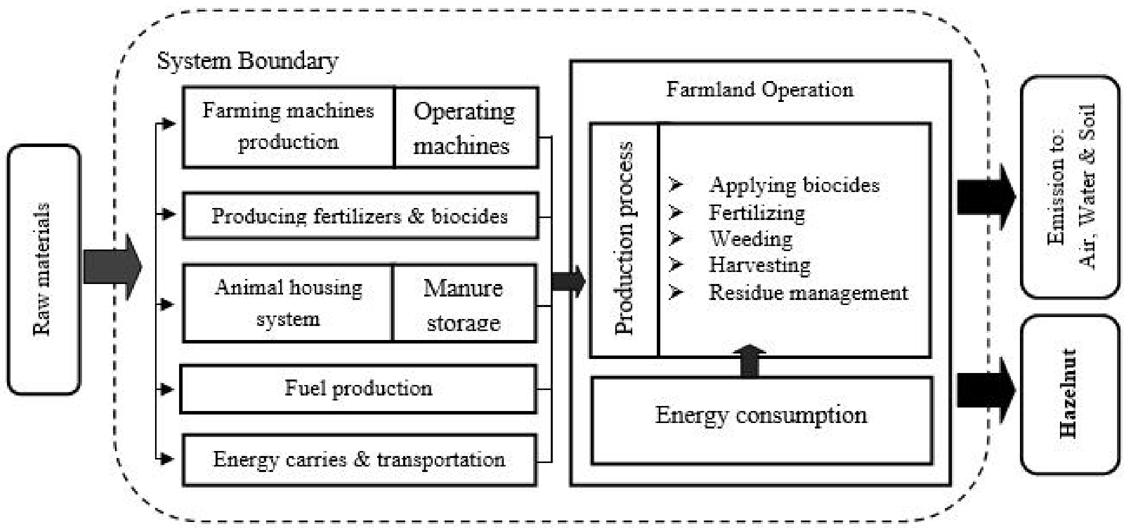

Fig. 2. System boundary of hazelnut production process in Iran.

D. Life cycle impact assessment

Life cycle impact assessment (LCIA) converts inventory data into environmental impact estimates using a two-step process of classification and characterization (Reap *et al.,* 2008). The impact categories analyzed based on CML 2 baseline (Guinée *et al.,* 2002) method in this study were: Abiotic depletion (AD), Acidification (AC), Eutrophication (EP), Global warming (GW), Ozone layer depletion (OLD), Human toxicity (HT), Fresh water aquatic ecotoxicity (FE), Marine aquatic ecotoxicity (ME), Terrestrial ecotoxicity (TE) and Photochemical oxidation (PO).

GW was exercised to express the contribution that gaseous emission from the arable farm production systems makes to the environmental problem of climate change. The upshot of indicator is articulated as kg of the reference substance, CO_2. HT covers the impacts of present toxic substances exciting in the environment on human health. TE refers to the impacts of toxic substances on terrestrial ecosystems. HT and TE are expressed in kg 1,4-dichlorobenzene equivalent. EP covers all potential impacts of excessively high environmental levels of macronutrients; the most important of which are nitrogen (N) and phosphorus (P). EP is demonstrated by kg PO_4^{-3} equivalent. PO is the formation of reactive chemical compounds such as ozone by the action of sunlight on certain primary air pollutants. These reactive compounds may be injurious to human health and ecosystems and may also damage crops. The result of this indicator is illustrated by kg of the reference substance, ethylene. AC has a wide variety of impacts on soil, groundwater, surface waters, biological organisms, ecosystems and materials. AC is expressed in kg SO_2 equivalents. ME for each emission of a toxic substance to air, water and/or soil express in kg 1, 4- dichlorobenzene equivalent per kg emission. FE for each emission of a toxic substance to air, water and/or soil express in kg 1, 4-dichlorobenzene equivalents per kg emission. Ozone layer depletion in the steady state for each emission to the air express in kg CFC-11 equivalent per kg emission (Guinée *et al.,* 2002; Khoshnevisan *et al.,* 2013). AD is related to extraction of minerals and fossil fuels due to inputs in the system under study; it is expressed as kilogram of antimony-equivalent/kilogram of extraction (González-García *et al.,* 2009).

The USEtox model is an environmental model for characterization of human and eco-toxicological impacts in LCIA and Comparative Risk Assessment. USEtox is designed to describe the fate, exposure and effects of chemicals (Huijbregts *et al.,* 2010).The impact categories analyzed based on USEtox method were: Human toxicity cancer, Human toxicity non-cancer and Ecotoxicity. The unit of the characterization factor for freshwater aquatic ecotoxicity is PAF.m^3.day/$kg_{emission}$ and for human toxicity cases/$kg_{emission}$ both summarized as Comparative Toxic Unit (CTU) to stress the comparative nature of the characterization factors (Rosenbaum *et al.,* 2011).

E. Life cycle interpretation

Life cycle interpretation marks the point in an LCA when one draws conclusions and formulates recommendations based upon inventory and impact assessment data. Iteration between life cycle interpretation and the other LCA phases often occurs (Guinée *et al.,* 2002; Reap *et al.,* 2008).

Basic information on LCI of hazelnut production was entered into Excel 2013 spreadsheets, Matlab R2014a and SimaPro 8.0.3 software package.

RESULTS AND DISCUSSION

In order to assess environmental impacts, LCA methodology was selected. Four steps are defined for an LCA study including goal and scope definition, the inventory analysis, the impact assessment and the interpretation (ISO, 2006). The goal of this study was the comparative environmental assessment of hazelnut production in three different orchard sizes (<1 ha, 1-3 ha, >3 ha) using the LCA methodology. The scope of the present study consisted of agricultural practices, materials and energy inputs employed during the farming season. The inventory data of 1 ton hazelnut production are presented in Table 1.

Table 1: Life cycle inventory data of 1 ton hazelnut production in small, medium and large orchards.

Inputs	Units	Small orchards	Medium orchards	Large orchards
A. Inputs				
1. Machinery	kg	102.26	92.79	105.60
2. Diesel fuel	L	20.12	21.18	22.27
3. Chemical fertilizers				
(a) Nitrogen	kg	31.66	32.83	34.43
(b) Phosphate (P_2O_5)	kg	40.53	42.03	44.08
(c) Potassium	kg	55.50	57.55	60.35
4. Manure	kg	739.64	888.17	858.52
5. Pesticides	kg	1.33	1.35	1.27

Table 2: Values of the potential environmental impact of the hazelnut production.

Impact categories	Measurement units	Small orchards	Medium orchards	Large orchards
AD	kg Sb_{eq}	0.01	0.01	0.01
AC	kg $SO_{2\ eq}$	3.90	3.35	3.77
EP	kg $PO^{-3}{}_{4\ eq}$	16.29	14.77	16.74
GW	kg CO_{2eq}	775.23	665.99	750.46
OLD	kg CFC11 $_{eq}$	0.000053	0.000051	0.000053
HT	kg 1,4-DB $_{eq}$	1223.82	1112.66	1260.99
FE	kg 1,4-DB $_{eq}$	359.74	326.85	371.16
ME	kg 1,4-DB $_{eq}$	788273.00	716346.54	812443.56
TE	kg 1,4-DB $_{eq}$	1.29	1.17	1.33
PO	kg C_2H_4	0.51	0.46	0.52

Table 3: Environmental hotspots of hazelnut production in each impact category.

Impact categories	Hotspots
AD	Machinery, pesticide and diesel fuel
AC	Machinery
EP	Pesticide, machinery
GW	Machinery
OLD	Machinery
HT	Machinery
FE	Machinery
ME	Machinery
TE	Machinery
PO	Machinery

Furthermore, Table 2 shows the relative contribution of impact categories in three different orchards sizes. As can be seen, LOs had the highest value in most of the impacts. The value of AD was equal in all of them. SOs had the largest value in AC and GW. It should be mentioned, OLD was equal in both of SOs and LOs. SOs after the large orchards s responsible for the highest contribution in all impact categories.

The main hotspots illustrated in each impact category in Table 3. Regarding to majority of impact categories in different orchard size, applying of machinery was the main hotspot in the production process. With regard to EP, pesticide was the main hotspot and machinery was the second main hotspot. Furthermore, pesticide and diesel fuel were the other main hotspots in the AD. Fig. 3 shows a comparative assessment of different orchard size in each impact categories using CML method. As can be seen, MOs in all of the impacts had the lowest contribution.

In terms of pollution, MOs are known as the best form of orchard size for hazelnut production. As well as, Fig. 4 illustrate the share of each orchard size in three impact categories using USEtox method. LOs and MOs had the largest and lowest value in impact categories, respectively. Hence, this method also demonstrated the MOs as the best orchards. The mean value of Human toxicity cancer, Human toxicity non-cancer and Ecotoxicity were obtained 3.4E-08CTUh, 1.2E-07 CTUh and 5.8 CTUe, respectively.

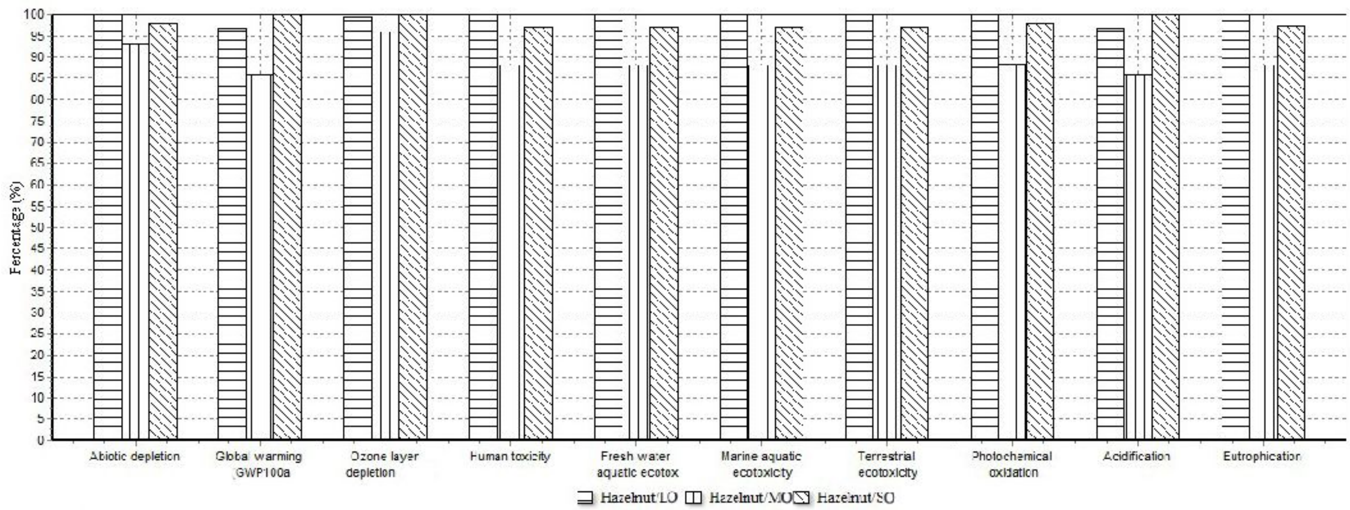

Fig. 3. Comparative assessment of different orchard size in each impact categories using CML method.

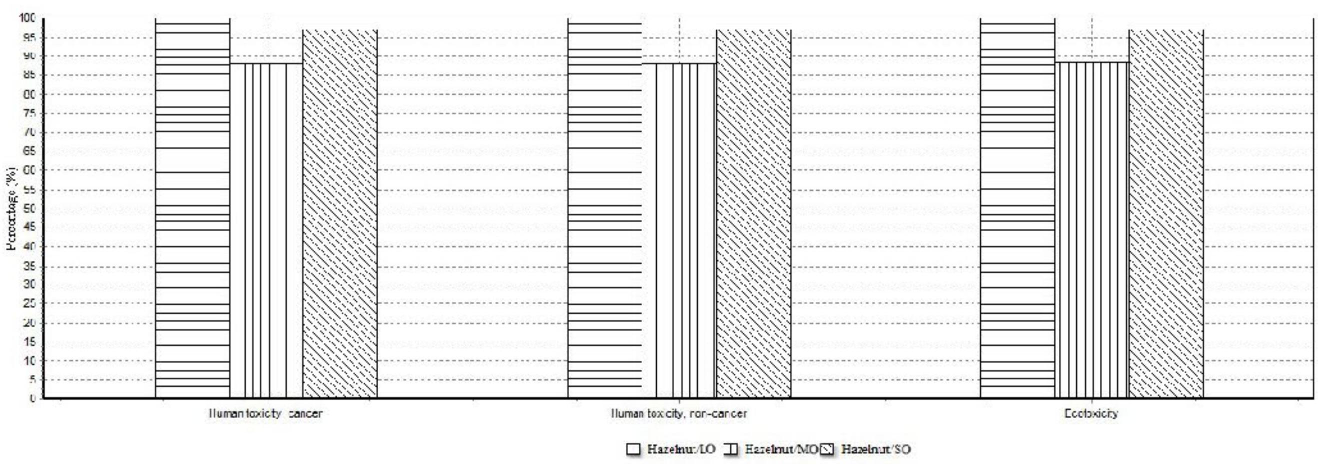

Fig. 4. Comparative assessment of different orchard size in each impact categories using USEtox method.

CONCLUSION

This study provides comprehensive data for a hazelnut production related to different orchards size in the Guilan province of I. R. Iran that can be used in subsequent LCA-studies. Environmental impact was assessed in order to identify and compare of three orchards level. Ten impact categories (AD, AC, EP, GW, OLD, FE, ME, HT, TE, and PO) using CML method and three impact categories (Human toxicity cancer, Human toxicity non-cancer and Ecotoxicity) using USEtox method were assessed to identify the main hotspots in the hazelnut orchards and consequently assist to the hazelnut orchardists to improve their environmental performance.

LOs and SOs had the highest value in the CML impact categories. Expected in EP that pesticide was the main hotspot, machinery was the main hotspot in all of the impact categories. Moreover, LOs and MOs had the largest and lowest value in the USEtox impact categories, respectively. Consequently, in the standpoint of choosing the best level of orchards by both of method, MOs are known as the lowest contributor to environment for hazelnut production. Hence, it's intelligible which reduction or substitution of machinery, pesticide and diesel fuel in hazelnut orchards should be considered. Therefore, improvements might possibly be achieved by increasing energy efficiency, enjoying the full advantage of using of machinery and reducing pesticide, diesel fuel and generally inputs consumption.

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