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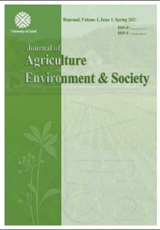

Assessment of environment impacts of forage corn production using LCA: case study in Khorramabad, Iran

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ABSTRACT

Forage corn is an important crop with characteristics that make it attractive for livestock industry. In the west of Iran and the margin of the Zagros mountains, due to the flourishing of animal husbandry, production of forage corn is quite vital. However, such crop production may affect environmental phenomena including global warming, ozone depletion, eutrophication, acidification potential and human toxicity potential. In the present study, the life cycle assessment methodology has been applied to study contaminants production due to forage corn cultivation. Therefore, different environmental impacts, along with the production processes, have been evaluated. The potential environmental impacts are calculated according to the production unit equivalents considered by the global databases. The amount of greenhouse gases emissions due to the production of one ton of forage corn is 118.46 units, as CO_2 equivalent. To consider the impact as ozone depletion, this amount was calculated to be one ton of forage corn equal to 0.0000147 units per kilogram of CEC_{11} production. Eutrophication potential in the production of one ton of forage corn was estimated to be 0.4618 units, equivalent to kilograms of PO_4 production. Improvements in corn production efficiency may result in less contaminants production and lower environment degradation.

Highlights

- The study examines the environmental impacts of forage corn production in western Iran using LCA method.
- The study evaluates the greenhouse gas emissions, ozone depletion, eutrophication, acidification, and toxicity for humans and terrestrial ecosystems as environmental indicators.
- The study shows that the production of one ton of forage corn generates 118.46 units of greenhouse gas emissions equivalent to CO_2.
- The study suggests that improving the efficiency of forage corn production can reduce pollution and environmental degradation.

1. Introduction

Rising global population and their requirement for food, and energy is a challenge which is compounded by increased pressure on natural resources. Decision on how and to what extent humans need to consume resources require precise and sophisticated scientific research and analysis. In this study, Life Cycle Assessment (LCA) methodology has been used. According to this method, it is possible to measure any performance of any given farm on the basis of the amount of inputs that the farmer will provide to the plant and the outputs of it (Brentrup et al., 2004). To evaluate the effects of a production process, a goal and scope of the study should be explained, then it can be used to assess a life cycle inventory and to carry out an impact assessment (Mcgregor, 2002).

Determining a functional unit in the life cycle analysis can be very effective in analysis process. A functional unit is a reference that interconnects the inputs and output of a produced crop. With such unit, the researcher can compare different systems with different structure based on a common basis (Sonesson et al., 2010). The amount of inputs (including fossil fuels and chemical fertilizers),

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production and transfer of agricultural inputs (such as fertilizer application) and field operations (such as plowing and harvesting) can be determined for a functional unit (Khorramdel, 2011). By carefully applying agricultural inputs, the probability of approaching sustainability standards will always increase. One of the methods to preserve natural resources and achieve sustainable development, especially sustainable agriculture, is environmental assessment of the production process of agricultural crops. The life cycle assessment methodology is an accepted method for assessing environmental impacts throughout a product lifecycle (Mir Haji et al., 2012). Many studies have argued that LCA is an appropriate way of quantifying the environmental impact of crops production. In this model, inputs will be collected based on observed data of application of chemical fertilizers, machinery, fossil fuel consumption and other inputs for the production of various crops (Esmaielpoor et al., 2015).

Given the inputs of production and how they can be consumed by plants during their growth, it may be possible to find the proper management production of crops with the least pollutant emissions. It should not be ignored that natural resources will be degraded, and every step towards preserving and sustainable consumption of these resources, helps to sustain resources for human survival on the earth. The purpose of this research is to study a LCA model to assess the environmental impacts of producing one ton of forage corn. It is our aim to evaluate the contaminants emitted by forage corn in Khorramabad, western Iran.

2. Materials and Methods

2.1. Study area

This study targeted Khorramabad location in Lorestan province of Iran (33.46N, 48.33E, 1117 asl). The average annual precipitation of this location is 524 mm and the average annual temperature is 17.07 ° C. Khorramabad is located in a valley between two mountains of the Zagros mountain range. Animal husbandry is also prevalent in this study location, and the production of forage corn is abundant in the region.

2.2. LCA methodology

The review of the life cycle assessment should be included the definition of the goal and scope, the analysis of the inventory, the impact assessment and the interpretation of the results. The data are divided into questionnaire, laboratory, computational and library categories.

2.2.1. Goal and scope

2.2.1.1. Study goal

The results of this research may help to enhance the production of this crop and reduce any hazardous environmental impacts. The scope of this study includes six stages of corn production, in which the inputs and outputs of each stage, including the emissions of each stage into the environment, form the life cycle inventory. Different stages are: tillage, planting, irrigation, fertilization, plant protection and harvesting.

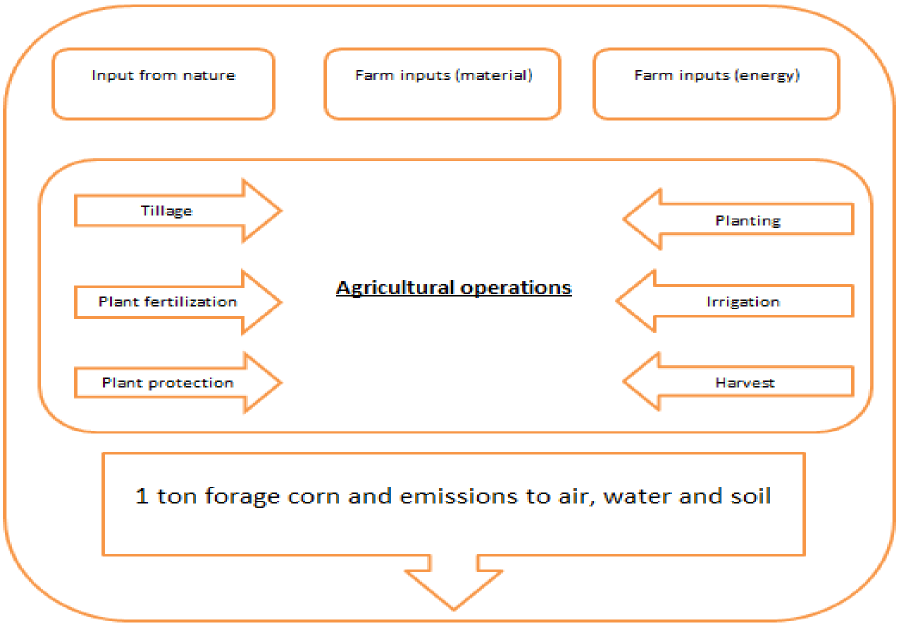

Figure 1. The framework defined for the boundary of the study system of the forage corn field

2.2.1.2. The boundary of the investigated system

The boundary intended for this research was the farm framework. Inputs and outputs data of the study were collected at the defined boundary (Figure 1).

2.2.2. Life cycle inventory

In the second stage, all the necessary resources in the production system for the production of forage corn should be entered exactly in the inventory. All outputs and emissions of the triple-environments would be calculated. According to the Ecoinvent reports, all data are not of a high quality, and in the present study, data has been collected at the L_4 level. This data level has the highest acceptability in the global database.

Collection of data consisted of several steps. At first, information from a questionnaire directly filled up by farmers and some of the relevant authorities. In the next step, the supplementary information of the questionnaire (fossil fuel consumption, electrical energy, etc.) was recorded by the researcher after the evaluation. Final step related to computational information (emissions to air, soil, water, calculation of carbon dioxide consumption from air, etc.) that are calculated using standard Ecoinvent models and to determine the values of the data considered in the functional unit scale.

2.2.3. Functional unit

After classifying information and data, it is essential to consider a functional unit. Functional unit is a scale to understand the connection of a product with another product. Functional unit as a reference can compare different systems based on the common structure (Wiedemann and Mcgahan 2011). It should be noted that life cycle calculations are measured at all stages based on the functional unit (Nemecek et al., 2011b). In this study, the information was collected at scale of one hectare of forage corn farm. Therefore, in order to better understand the results of the life cycle assessment, a functional unit for production of one ton of forage corn is considered.

2.2.4. Life cycle impact assessment

The selection of impact assessment groups should reflect the complete set of environmental issues associated with the cropping system under study, taking into consider the goal and scope of application. In the present research, the main goal is appraisal of environment destruction caused by the production system. Therefore, the impact assessment groups are related to the environmental disturbance with the research objective and it has the best display in the selection of category consequences indexes.

After determining the system boundary according to the goal and scope of the study, the evaluation method would be chosen. The study method of this research has been selected in the SimaPro software from a series of European recipes. The CML-IA recipe instruction evaluates the 11 impacts assessment according to the investigator inputs. Environmental impact assessment has an abbreviation and an equivalent unit that is presented in Table 1 (Goedkoop et al., 2008; Pre consultants, 2003).

Table 1. Impact Squares - Equivalent Units and Specifications

Impact assessment	Unit	Specifications
Natural resources depletion, abiotic (AD)	kg Sb equivalent.	This potential consist of consumption of renewable and non-renewable resources
Abiotic depletion, fossil fuels (ADF)	MJ	The exploitation of fossil fuels, mineral resource and also the potential of fossil resource depletion
Global warming potential (GWP)	Kg CO2 equivalent	The potential share of one material in greenhouse emissions impact
Ozone layer depletion (ODP)	kg CFC-11 equivalent	The value of ozone layer destruction which is its major created by hydrocarbons including Carbon, Chlorine and fluorine
Human toxicity potential (HTP)	kg 1,4-DB equivalent	Damage potential of one unit of released chemical material to environment base on toxicity of a combination and its potential of consumption dose
Terrestrial eco-toxicity (TE)	kg 1,4-DB equivalent	Emissions of toxic substances to soil
fresh-water aquatic eco-toxicity (FEW)	kg 1,4-DB equivalent	Emissions of toxic substances to fresh water
marine eco-toxicity (ME)	kg 1,4-DB equivalent	Refers to impacts of toxic substances on marine ecosystems
Photochemical oxidation (PO)	Kg C_2H_4	The potential has showed the creation of the 1 capacity of ozone of volatile organic material for ozone production
Acidification (AC)	kg SO_2 equivalent	The potential shows the acidification impact of SO2 Another material which has recognized as acidification, are nitrogen oxide and ammonium. Also the impact of SOx is similar to SO2
Eutrophication (EU)	kg PO_4^{-2} equivalent	The potential was used based on PO_4^{-2} , another emission of eutrophication were nitrogen oxidation N_2O and ammonium NH^{4+}

2.2.5. Characteristic coefficient

In the evaluation section, the effect of the phrase "characteristic coefficient" is also applicable to those effects expressed equally. For example, carbon dioxide, methane and nitrous oxide emissions all affect global warming. However, the potential of these gases is different from climate change. For carbon dioxide, it is considered to be 1, and for methane is 21, and for nitrous oxide is 310. Therefore, if one kilogram of nitrous oxide is released into the production process of a product, it is equivalent to releasing 310 units, and expressed as 310 kilograms of carbon dioxide. In this section, the number of 310 is called the coefficient of determination or characteristic coefficient (Bare et al., 2003). Therefore, to express the environmental impact of global warming, it is not necessary to express all the effects of greenhouse gases and can all be expressed in terms of production in carbon dioxide.

2.2.6. Interpretation of the results

There are several basic elements in life-cycle interpretation. These elements can be categorized as follows:

• Identify important issues based on the results from the life cycle inventory process and assessing the life cycle inventory in the overall assessment of the life cycle,

•An assessment that considers completeness, sensitivity and consistency

•Finally, make conclusions, limitations and recommendations.

Use the World Wide Web to set defaults: The World Wide Web used in this research is called the Ecoinvent database. This database is reviewed and updated over time, the latest version (version 3) was used at the time of the current research. The Ecoinvent 3 has more different models and methods than the Ecoinvent 2.

2.3. Investigating uncertainty of data

The Monte Carlo statistical method is used to prevent the exponential growth of data. The application of the Monte Carlo method in mathematics and statistics is very extensive. It is tried to use this method, by random selection, one or a limited number of responses were attempted from the existing answers to arrive at an acceptable solution. This issue becomes valuable when a set of alternatives is available to answer a very large problem and the virtually impossible to test all of them. To access the Monte Carlo method, the square of the standard geometric deviation must be estimated and indicated by the GSD2 abbreviation in the above method. Therefore, the following relationships can be calculated (Roux, 2014):

$$GSD = \exp\left(\sqrt{\frac{\sum_{i=1}^{n}\left(ln\frac{A_i}{\mu_g}\right)^2}{n}}\right) \qquad (1)$$

A: Range of numbers and the frequency of alternatives are in the range of i to n, μ_g. It will be obtained from the following equation:

$$\mu_g = \sqrt[n]{A_1 A_2 \dots A_n}$$

After the Monte Carlo method has been introduced for quality as "life cycle inventory entries", trial data were introduced into SimaPro.

Number of test questionnaires (n): The following formula is used to determine the number of sample individuals and can be calculated according to the following equations (Snedecor and Cochran, 1989):

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

$$d = \frac{S\times t}{\sqrt{n}} \qquad (3)$$

t: 1.96 (at 95% probability level), s: advances the standard deviation of society, d: desirable accuracy probability, N: size of society and n: sample size.

It should be noted that performing uncertainties in research data manually is a complex task. The SimaPro software has an uncertainty analysis evaluation file. Among four methods of estimating the uncertainty of SimaPro, Monte Carlo method was chosen in this study. In the evaluation columns, lognormal values were entered. The software, by entering the value of variance, according to the coefficient of variation, evaluates uncertainty in all of the environmental effects separately. It should be noted that the longest evaluation of SimaPro software is the assessment of uncertainty and this process requires a long time.

2.4. SimaPro software

The software used for the Life Cycle Assessment Methodology is called SimaPro. SimaPro version: 8.3.0, report version V_3, language: English. The side software that is used during the process of collecting and performing the steps of the article are; Excel, Grapher v12.7.855, Math type v6.8, and Edraw max v8.4.

2.5. The source of emissions data

The crop production emissions in the triple environments, were calculated using equations and references in the Ecoinvent (Table 2).

Table 2. Resources used to calculate emissions.

Environment	Emissions	Data sources
Air	NH_3, CO_2, NO_X, N_2O, CH_4, SO_2 & CO & etc	Bengona et al., 2015; Nemecek, 2007; Nemecek, 2011; Agrommon, 2009
Water	Phosphate, Nitrate, cadmium, lead, zinc & etc	Bengona et al., 2015; Nemecek, 2007; Nemecek 2011; The emission model SALCA-P and SALCA-NO_3, 2006
Soil	Cadmium, lead, zinc & etc	Nemecek 2007; Nemecek 2011; Robert and stauffer, 1996

3. Results and Discussion

3.1. Life cycle inventory (LCI)

Field inputs and outputs were collected as detailed as possible. The results were calculated in terms of functional unit. Results are presented (Table 3) after the statistical evaluations and data uncertainty analysis.

3.2. Cut off the important paths of inputs

According to the employed method for planting forage corn in the studied area, at first materials and operations of agriculture should be evaluated. Then at each production stage different materials will be also used that should be considered and thus emissions related to different production stage will be examined separately. A separate calculation of emissions at the interpretative stage will be very beneficial. In setting up the inventory, the materials used were listed with all the details on the L_4 level. Default data was extracted from the Ecoinvent database for setting energy consumption inventories.

The data for all farm input was evaluated by default values extracted from reports of Ecoinvent. After setting and choosing the default, each data was verified based on conditions of Iran. Emissions to the environment, given the laboratory data and licensed models of the Ecoinvent were calculated. Based on the study conducted on use of electricity energy for irrigation water pumping in the agricultural process, it has been observed that the environmental release of the process is equal to 230-830 units per kilogram of CO_2 production across different regions. Therefore, irrigation water management and the use of more efficient processes, such as sprinkler irrigation and drip irrigation, are highly recommended (Schlesinger, 1999; Ghasempour, 2016).

Table 3. The part of life cycle inventory.

Inputs	Unit	Amount	Comment
Inputs from nature			
Water, in ground	m^3	139.308	Ecoinvent report and This study
Carbon dioxide, in air	kg	467.233	Nemecek and schntzer, 2012
Land occupation, annual crop	ha	0.0205	Nemecek and schntzer, 2012
Inputs from technosphere (material)			
Seed	kg	0.735	This study
N fertilizer, urea	kg	8.95	This study
P fertilizer, triple superphosphate	kg	3.61	This study
Pesticide, unspecified	kg	0.0895	This study
Agricultural machinery	h	0.167	This study
Chopper harvesting	ha	0.0205	65hp, 1250kg
Inputs from technosphere (energy)			
Labor	h	1.962	This study
Electricity	kwh	52.112	Ecoinvent report and This study
Diesel, burned in agricultural machinery	MJ	147.1898	Ecoinvent report and This study

3.2. Life cycle assessment of production stages

According to results obtained by the life cycle assessment, the amount of greenhouse gas emissions to exacerbate global warming threats to produce one ton of forage corn is 118.46 the unit equivalent of producing kilograms of CO_2. Disposal of abiotic depletion resources related to fossil fuels has been fulfilled in the production of one ton of corn equal to 1726.38 MJ. Eutrophication potential of the product unit in Khoramabad is estimated to be 0.4618 kg equivalent to PO_4 production. In a similar experiment in 2013, on corn fodder plant, the amount of autoclaving potential was 0.41 kg equivalent to PO_4 production (Bacentti et al., 2013). The contribution of each of the stages of production to the impact assessment is represented in Figure 2.

It is noteworthy that in the same experiment, by using two tons of organic fertilizers per hectare, they have succeeded in achieving global warming potential of 29.75 unit, equivalent of producing kilograms of CO_2 (Bacentti et al., 2013). Therefore, depending on the type of cropping system and the type of farm inputs, farmers are generally exposed to the amount of publications in the environment. Numeric values of the environmental impact for one ton of forage corn is given in Table 4..

Table 4. The amounts of different environmental impacts for production one ton of forage corn. CML-IA recipe

Impacts assessment	Value calculated without uncertainty assessment	Median	Mean	SD (Standard deviation)	CV (Coefficient of Variation)
AD	0.000633	0.000599	0.000637	0.000196	30.72108
ADF	1726.383	1301.889	1751.615	2829.887	161.5587
GWP	118.463	91.22857	120.1522	177.1907	147.4718
ODP	1.47E-5	1.16E-5	1.48E-5	1.87E-5	126.4954
HTP	51.38039	46.66575	51.72478	32.93569	63.67488
FEW	23.04889	20.70289	23.20639	14.88244	64.13079
ME	151730.5	146095.9	151610.4	41575.27	27.42244
TE	0.26878	0.236646	0.271491	0.250925	92.42493
PO	0.033666	0.02731	0.034044	0.042638	125.2436
AC	0.735621	0.587642	0.743328	0.970134	130.5123
EU	0.461843	0.449245	0.462899	0.086714	18.73279

With regard to the column diagram, the effect of chemical fertilizers was significant in most cases but this evaluation is not at the data level of the L4, because there were not adequate details. Even the expression of the category of fertilizer also makes statements on the level of L3 for example, represent phosphorous fertilizer or nitrogen fertilizer. In the impact assessment of abiotic depletion (fossil fuels), the use of chemical fertilizers is important. It is noteworthy that each chemical fertilizer has different effects on the impacts assessment in the life cycle inventory.

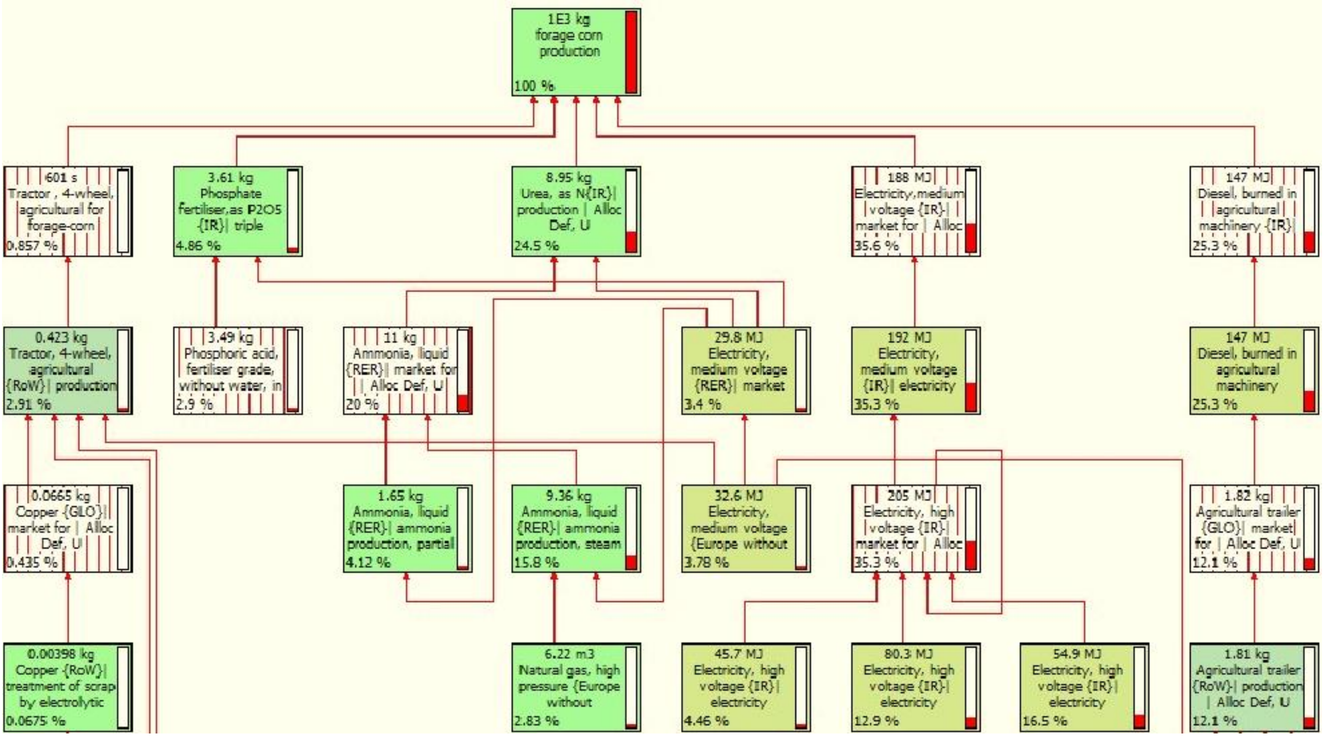

Figure 2. Paths of the important inputs to produce a ton of forage corn.

3.3. Impact assessment of production inputs

In order to clarify the subject and understand better the production processes in the present experiment, various inputs of production were individually examined. After defining a life cycle for each input separately, the results became more appealing. The mesh was in the impact category of abiotic depletion and phosphorus fertilizer impact was significant. More details of the thread, as fallow:

- In the abiotic depletion effect class, triple superphosphate fertilizer plays the dominant role in the life cycle inventory defined for the life cycle assessment.
- In the abiotic depletion (fossil fuels) effect class, nitrogen fertilizer impact was also significant. Further details indicated that urea fertilizer application in the fertilization stage had an impact on the environmental damage of this category.

In Figure 4, the effect of field inputs on the impacts assessment has been shown to be effective. As described above, in addition to defining a flowchart, generating life cycle assessment is useful for each inventory inputs. According to Figure 2, irrigation of forage corn cultivation has a greater effect on the use of chemical fertilizers. Forage corn irrigation is done using electric energy and well water extraction. According to experimental results, the use of electricity has the greatest impact on greenhouse gases emission in irrigation process. This step increases the entry of nitrate and phosphate into groundwater and results subsequently in a more powerful formation of other environmental impacts. Increasing the concentration of other substances in the surrounding ecosystems causes the collapse of ecosystems balance. The presence of nitrate and phosphate is essential for plant growth, but increasing its concentration in water causes excessive growth of algae in freshwater. Further, this will reduce the amount of oxygen in the water and ultimately lead to the deterioration of the ecosystem (Guinee, 2002).

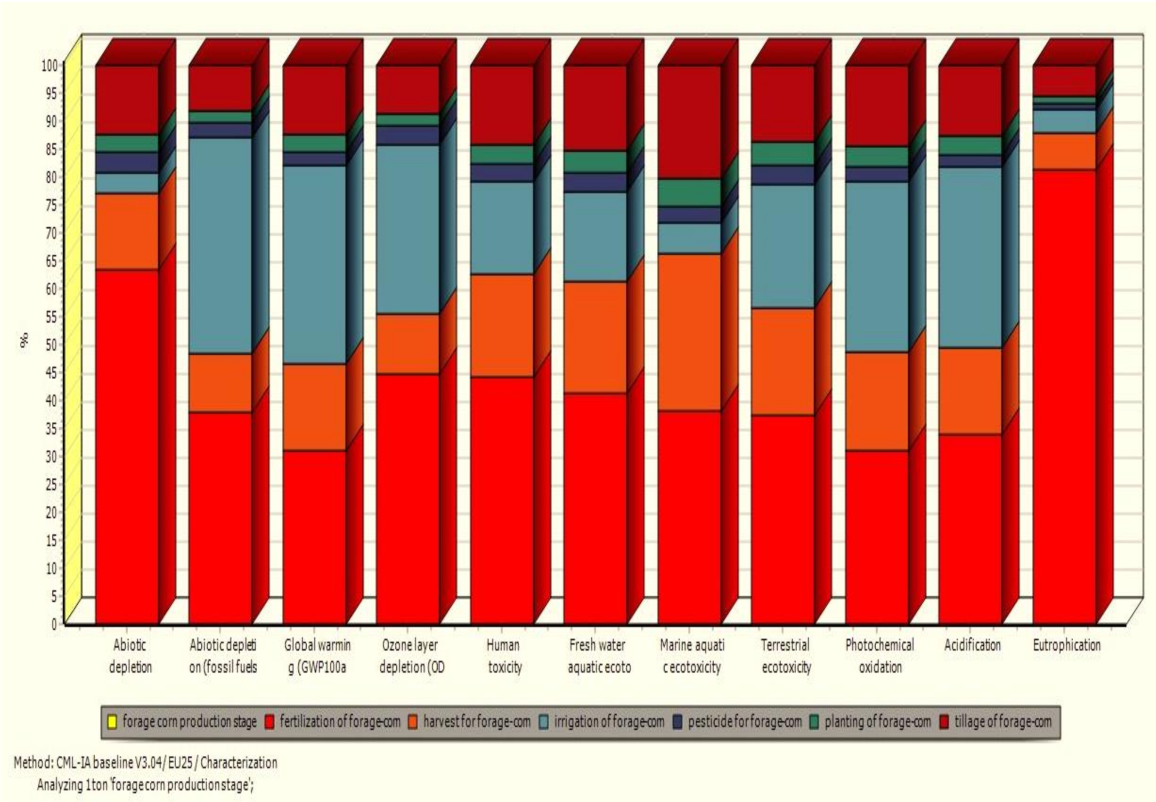

Figure 3. Column chart impacts assessment for production stages of one-ton forage corn. CML-IA recipe.

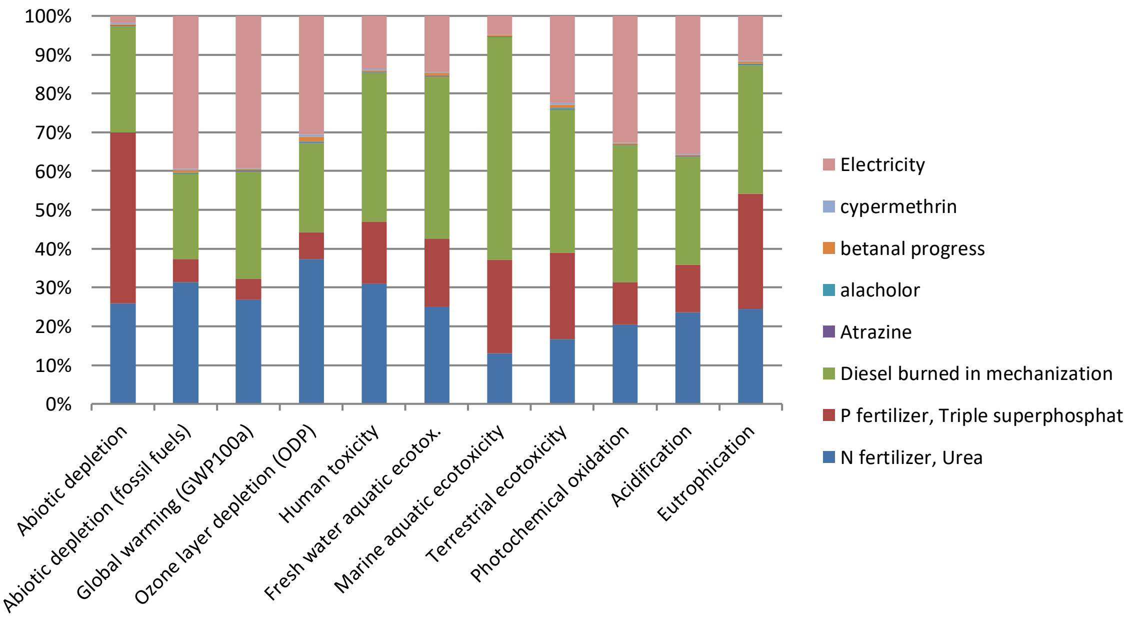

Figure 4. Column chart effect of farm inputs on impacts assessment. CML-IA Recipe.

The ozone layer depletion by chlorine and bromine adds to the amount of harmful ultraviolet light that causes the surface to warm up. The ozone depletion potential is represented by the reference unit of kilogram of CEC_{11} production. After evaluating the data, this potential for one ton of forage corn equal was 0.0000147 units per kilogram of CEC_{11} production. A large amount of emission factors associated with this environmental impact due to the use of pesticides and herbicides during the agricultural process. Carbon, chlorine and fluorine are the most important substances that have the property of ozone depletion (Guinee, 2002).

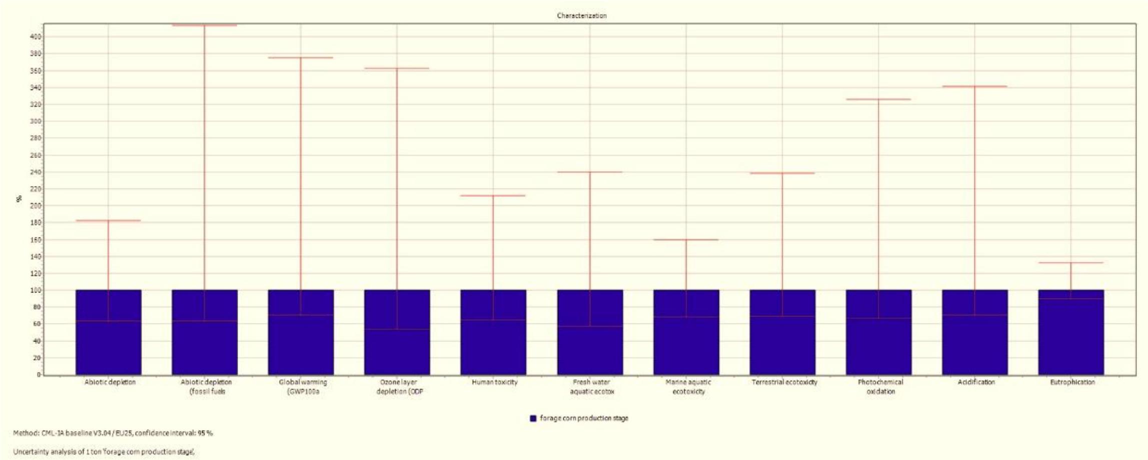

Figure 5. Results of uncertainty assessment for one ton forage corn production.

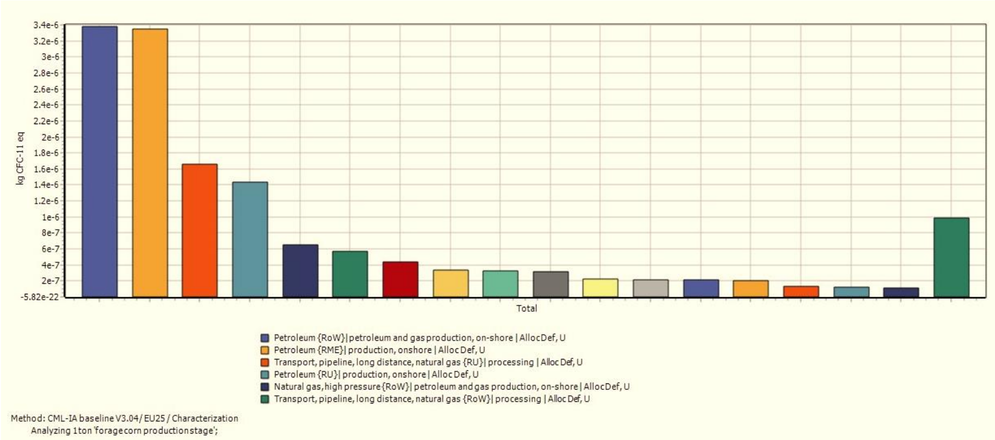

Figure 6. The most effective inventory entries in the environmental impact of the ozone layer depletion.

3.4. Uncertainty analysis of research data

The results obtained from the average data may not be the same for all research farms. Given the average value, the data in the fields is higher or lower than this value. Therefore, considering the difference in the data, the environmental impact values would be certainly different. By analyzing data, an uncertainty range is defined for each environmental impact. This range starts from the values before the average and continues up to values above the average. The graph of the uncertainty analysis of one ton of forage corn is presented in Figure 5.

The most uncertainties in the data are seen in the environmental impact of ozone depletion (ODP). It is necessary to mention, there are farms in the studied area that can impose more than the average ozone depletion. The potential of this environmental impact may be a range of 40 percent less or about 400 percent higher than the average (Fig 4). Subsequently, the effects of global warming and abiotic depletion fossil fuel are in the next category.

The results indicated that photochemical oxidation and acidification of picks were approximately at the same level. The rest of the environmental impacts are shown in Figure 5. According to the life cycle inventory evaluation information, it can be interpreted that which inputs had the most effect on the environmental impact of ozone depletion and what are the uncertainties of the inputs.

According to Figure 6, the greatest impact is seen for fossil fuel inputs and transportation. These materials can be referred to fossil fuels and natural gas. Highest consumption of natural gas in the life cycle inventory is the urea fertilizer production. The uncertainties in this environmental effect are probably due to infrastructure differences (distance to the main road and distance with the manufacturer), topography (land slope) and machinery (power of machinery, used equipment). The green column on the right side of the graph shows the effect of other things in the inventory.

4. Conclusion

4.1. Life cycle assessment conclusion

Considering the global issue of food security and food shortage with current production situation, many people around the world are challenging to provide food. Therefore, it seems reasonable to enhance production management than reducing inputs. Reforming the infrastructure for production is very necessary and should be reconsidered through government institutions. Revision of cropping pattern can be beneficial with respect to the conditions of region and natural resources. Considering climatic conditions, topography, natural resources and mechanization of each region are appropriate steps in choosing the suitable crops (Hassani et al., 2016).

Another issue in the study area was about those instruments which were not developed and historically improved. For example, a tractor with a plow was used for sloping lands and flat lands. Therefore, due to the increased duration of agricultural operations and increased fuel consumption, one ton of forage corn in steep lands will be more polluting. The adaptation of the equipment and the power required for their use in tillage may help to reduce environmental emissions.

When a tractor is over-powered, fuel consumption and greenhouse gas emissions increases. In this way, this stage will result in more environmental damage. Therefore, any improvement in developing the proper mechanization infrastructure are very beneficial. Most farmers may not be able to purchase the right equipment and the farmer only considers the financial situation at the time of purchase. In this situation, government agencies can help the farmers and reducing environmental damage through the purchase of appropriate equipment and facilating the availability of advanced equipment in the area. It is very important to pay attention to financial situation of farmers as the first production level in terms of agricultural infrastructure reform (Hassani and Ramroudi, 2017).

Therefore, according to this study, environment friendly production of forage corn is possible only by modifying the pattern of its production. An improved management can be able to progress towards the least-polluting production, along with the consideration of manufacturing infrastructure and more precise programs for application of chemical fertilizers, chemical pesticides, fossil fuels and other required inputs.

4.2. Long-term emissions conclusion

It should be noted that environmental pollutants will increase through accumulation in nature during their production process across many years however the values quoted in this study are based only on the study year. The SimaPro software has the ability to calculate historical environmental impacts. Considering farm inputs and environmental impact indicators, a long-term scenario can be developed. Aquatic and atmospheric environments due to fluidity may not be appropriate in this scenario. Providing a scenario for continuation of the current production process is necessary. To forecast the future and to provide a scenario based on the results, several separate environmental impacts of inputs can be considered for production one ton of forage corn.

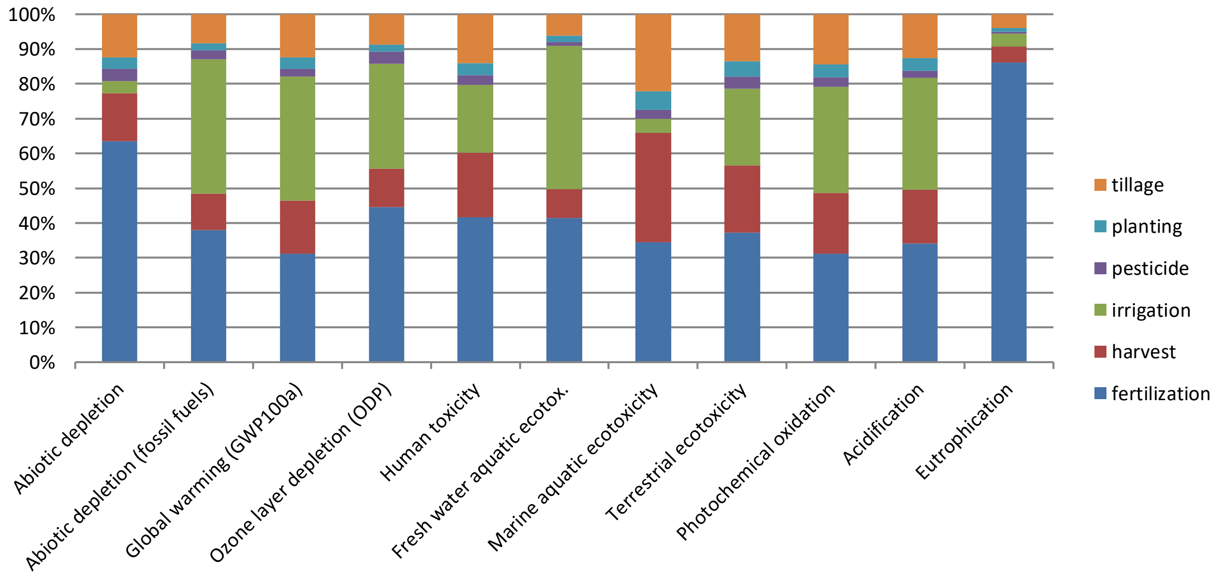

Figure 7. Long term environmental impact assessment based on current production inputs. CML-IA Recipe.

Considering the assumptions of the whole column in Figure 7 and comparing it with Figure 3, most changes are in the effects of eutrophication, fresh water aquatic toxicity, human toxicity and ozone layer depletion. Environmental impacts of chemical pesticides will not be exceeded annually, and their accumulation in the biological environment will have adverse effects. There is a general belief among farmers that more application of chemical fertilizers and more irrigation leads to higher yield and consequently higher profits from the agricultural process. Over time, chemical fertilizers appear to be a powerful factor for eutrophication. The use of chemical fertilizers also increases the impact assessment of human toxicity in long term and leads to a higher pollution. Therefore, modifying the management of inputs and production of forage corn can directly affect the improvement of the production scenario. This increase in the percentage of chemical fertilizers used in the impact assessment of ozone layer depletion and fresh water aquatic ecotoxicity is also clearly visible. In addition to fertilizer use, the application of chemical pesticides, and the processes of tillage and planting in long-term have more effects on aquatic ecosystems. Looking at the long-term scenario graph, other percentages can also be deduced. It should be noted that the values in the long-term scenario are predicted by the percentage of stages and avoided by providing numerical values in prediction.

4.3. Uncertainty analysis conclusion

In uncertainty analysis, the results indicate the uncertainty distance of the data from the mean. This distance included values both beyond and above mean value. It may be possible to set precise plans for the management measures to reduce environmental impacts. Considering the uncertainty results of this study, there are many differences in inputs, energy consumption, publications, mechanization, and many others. One reason for these differences can be the field topography. On steep slopes, machinery and tools, in addition to increasing the operating time, use more fossil fuels. The lack of tools and methods of instrumentation can be the next factor. In many cases, in the studied area, the actual level of the farm is different from the farmer estimate. As a solution farmer can measure the area with a GPS device and is quite helpful and effective in applying the inputs, more accurately. Regarding the use of chemical pesticides, it should be noted that determining economic loss level and accurate calibration of spraying equipment can be effective in correctly applying this input. Using water pumps according to the needs of the fields and adjusting the duration of irrigation can be effective in reducing electric energy and water consumption.

Recommendations and suggestions:

- Knowing farms with less environmental impacts and management of other fields can be recommended as an environmental strategy.
- Factors that reduce environmental impacts can be investigated. If these factors are identified, it may be possible to further reduce the hazard impacts on environment.
- The results of the studies can be used to land use planning and prevent the cultivation of inappropriate land.

5. Acknowledgment

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