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Design requirements for the development of an LCA Engine

KOIDIS C.[1*], VLACHOKOSTAS C.[2], ACHILLAS C.[3], MICHAILIDOU A.[2], AIDONIS D.[1] BANTSOS A.[1], MAKRIS D.[2], MERTZANAKIS C.[2], SAVVA.[2]

[1] Engineering for Business
[2] Dept. of Mechanical Engineering, Aristotle University of Thessaloniki, Thessaloniki, Greece
[3] Dept. of Supply Chain Management, International Hellenic University, Katerini, Greece

*corresponding author
e-mail: ck741@efb.gr

Abstract

The work focuses on the development of a web-based tool to promote life cycle thinking and assessment of agricultural production. The computational tool is based on a sophisticated LCA Engine which provides personalized, real-time results, with the exploitation of real data from sensors. This comes in contrary to the standard practice of software using data sourcing solely from life cycle inventory databases available in the market (e.g. Ecoinvent, Agribalyse). The tool is designed to simulate all levels of the supply chain (production, processing, packaging, transportation, etc.) and perform an accurate calculation of the production's carbon footprint, as well as other environmental impacts that are required for environmental certification processes. In the present study, we present the design requirements of the web-based tool, as those resulted from a large-scale survey conducted in different types of potential end-users, such as farmers, farmers' associations, agri-food companies and agri-consultants. The work is funded within the framework of the Operational Programme "Central Macedonia" of the PA 2014-2020, Innovative Investment Plans, and co-financed by the Greek State and the European Union and, in particular, by the European Regional Development Fund (ERDF) (project code: KMP6-0078501).

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1. Introduction

Life cycle assessment (LCA) is the most widely used methodology for the evaluation of the environmental impacts of the life cycle (LC) of a product or service. LC of a product or a service includes the phases of production, distribution, use, and end of life (EOL). LCA can be used to identify hotspots and opportunities to improve the environmental performance of a product or service at different stages of their LC, to inform decision-makers, to help with the selection of relevant indicators of environmental performance, and finally for marketing reasons. An LCA study consists of four phases: the goal and scope definition, the life cycle inventory (LCI) analysis, the life cycle impact assessment (LCIA) phase, and the interpretation phase (ISO, 2006).

To carry out an LCA study, a software is typically used due to the large amount of data and coefficients that are required as well as the large number of calculations needed. However, all available LCA computational tools that are currently available in the market, rely on static data and LCI databases with average and outdated data for the calculations of impacts for any given process. Therefore, LCA results are characterized by significant uncertainties (De Vries et al., 2012). In this light, there is a potential to improve the performance of LCA engine tools, if those tools as well as the LCI are developed specifically for different products and locations (Levasseur et al., 2010). To that end, in the framework of the "Real-time environmental assessment of agricultural and agrifood production for the support of certification schemes" project, a real-time, online LCA Engine is being developed, focusing exclusively on the agrifood sector, where certification is highly demanded.

The LCA Engine tool is envisaged to be utilizing real-world data in real-time, sourcing from sensors apart from exploiting data from available LCI databases and literature data (Ecoinvent, 2021). The tool is designed to assess environmental impacts caused by all phases of the product supply chain and to perform an accurate calculation of the production's carbon footprint, as well as other environmental impacts that are required for environmental certification processes (Yang and Chen, 2014).

In order to maximize the user-friendliness and extend of the applicability, user requirements and needs is a prerequisite and should be defined. On this basis, a user-requirements survey was conducted and sent to potential end-users, in order to mine their vies and preferences. The key outcomes of the user requirements survey will be used in order to effectively design the functions of the LCA engine. In the material to follow, the methodology adopted to conduct the survey as well as the conducted survey are being synoptically presented.

2. Methodology

The survey is based on a flexible and robust questionnaire. Main characteristic of the developed survey is to be deployed with ease in order to be understandable to the potential users. Moreover, it was developed to cover all possible needs and requirements that a user of an LCA engine tool may possibly demand. The analysis was carried out by using Google Forms, to be as easy to disseminate to different types of potential end users, such as farmers, associations, agri-food companies, agri-consultants and in general stakeholders related to the agrifood chain.

The survey was developed into five different group categories questionnaire. The first group of questions was introductive questions about the user's domain of expertise, possible experience with software, and opinion about real-time LCA opportunities and difficulty. More specially the interviewees where asked:

- What is your domain of expertise?
- Where is your place of business?
- How familiarized are you with the use of software in agri-food sector?
- How willing would you be to register in real time, every process of the production, in the software?
- What is the degree of difficulty, in your opinion, of registering the stages of production, in real time, into the software?

The first two questions were formed as open-ended questions whereas the next three were given a 5 set of qualitative multiple-choice answers (dichotomous choice).

The second group of questions was about the scope and reasons for which the users intend to use the LCA engine tool and LCA results. More specifically:

- To what extent do the following apply to why you intend to use the Life Cycle Analysis tool?

  a) Improving the environmental performance of the product

  b) The competitiveness of the product

  c) Compliance with environmental legislation

  d) To obtain environmental certification

  e) Participation in funding programs

  f) Knowledge of the environmental burdens of the production process

Questions a-f were given a 5 set of qualitative multiple-choice answers.

The third group of questions aims to identify the potential end user's requirements regarding the technical characteristics of the engine tool. More specifically:

- Rate the following technical characteristics based on their importance to you

  a) User authentication

  b) Search bar

  c) Navigation menu for quick and easy access to other functions

  d) Tutorial function to guide you with step-by-step instructions

  e) Using the application via a mobile device (smartphone, tablet, etc.)

  f) Data entry by several users

  g) Suggestions for alternative processes (e.g., watering at a different time) that lead to resource savings

- In what format would you prefer the manual?

  a) Text

  b) Multimedia

The fourth group of questions aims to identify users' preferences about data logging into the LCA engine tool. In this light the interviewees where asked:

- In what units would it be convenient for you to register the area of the plot?

  a) Acres

  b) Hectares

  c) Square meters

- Rate the following technical characteristics based on their importance to you

  a) Import data from an Excel file or other software

  b) Monitor data recorded by sensors

  c) Export/edit data from Excel file or other software

  d) Reading/editing the already registered data

  e) Register Real-time data entry

Last but not least, the fifth group of questions is related to the environmental impacts of the product. It aims to identify in which manner/form the potential end-users prefer the results to be presented. In addition, the users define whether they would prefer the engine tool to include features such as the comparison between their product impact and the maximum impact that can be caused to claim environmental product certification and which of the most commonly used impact categories they would prefer to be assessed. More specifically:

- Rate the following technical characteristics based on their importance to you

  a) Comparison of environmental impacts with the necessary limits for environmental certification

  b) Recording of environmental impacts for each individual stage of production

  c) Recording of the environmental impact of the entire production

d) Comparison of consumption of energy, materials, and water resources for different time periods

- In what units do you want the environmental impact to be calculated?

  a) Per unit of arable area

  b) Per unit volume of product

  c) Per unit mass of product

- Which environmental impact categories would you be interested in being calculated?

  a) Climate change

  b) Ozone layer depletion

  c) Soil and water acidification

  d) Eutrophication

  e) Depletion of mineral resources

  f) Effect on human health

  g) Consumption of water resources

  h) PM formation

For all the above questions a 5 set of qualitative multiple choice answers (Likert scale) was defined

3. Results

The first results depict that the stakeholders are very willing to register in real time, every process of the production, in the software (average level 4,18 out of 5). This important considering the important trend towards smart and precision farming. However, the degree of difficulty related to the registering of the stages of production, in real time, into the software is an issue (average level 3,2 out of 5). For all important features of the LCA engine i.e., User authentication, Search bar, Navigation menu, Tutorial function, Using a smart application (smartphone, tablet, etc.), Data entry by several users the average level of necessity is over 4 out of 5 in the Likert scale.

It should be noted that important features such as suggestions for alternative processes (e.g., watering at a different time) that can lead to resource savings presents and average level of necessity 4,54 out of 5. This is an important result considering that agrifood industry is strongly related to resources such as water and energy. This is also the case for the comparative analysis that relates the environmental impacts with the necessary limits for environmental certification.

Among other results, the environmental impacts that are preferred to be estimated promotes climate change as the most important impact. This is followed by the consumption of water resources and the effect on human health. This result is quite rational considering the importance of climate change and the impacts of climate crisis to the agricultural sector (Vlachokostas et al., 2021). In addition, it goes without saying that the consumption of water resources is a critical environmental impact and presents interactions with climate change for the agrifood sector. Last but not least the effect on human health and biosphere (e.g., soil and water acidification), puts forward the need for eco-friendly and climate neutral agricultural production processes.

Conclusions

Assessment of the effects of agricultural production and agrifood on the environment and on the climate is an area of the interface of science and policy where quantitative Life Cycle Assessment / Information Communication Technologies methods should be developed, adopted and used. However, in most real life cases, relevant decision making is characterized by the lack of reliable and real time information related to the different life cycle stages of the agrifood supply chain. Clarity in defining important real time parameters is a prerequisite for proper interpretation of the results (Vlachokostas, 2022). Undoubtedly, the current state of knowledge has still gaps and uncertainties. The purpose of ongoing research is to reduce gaps and in addition refine the agrifood LCA related methodology to reduce uncertainties. It is the authors strong belief that this study puts a little stepping stone towards this direction.

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