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**Life Cycle Inventory data for the Italian olive oil supply chain: how to ensure representativeness**

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**Abstract**. Life Cycle Assessment (LCA) is increasingly used to assess the potential environmental impacts of agri-food products, but practitioners face many problems in identifying and solving various methodological and data availability issues. One of the main critical issues is linked to the lack of reliable site-specific data representing the specificities of the Italian agri-food production processes. These reliable data are still missing in commercial databases, which generally use approximate data or data related to other countries. To reduce this lack, the project "Promoting Agri-Food Sustainability: Development of an Italian Life Cycle Inventory Database of Agri-Food Products (ILCIDAF)" aims to develop a database of Life Cycle Inventory (LCI) for some Italian agri-food products. This paper reports preliminary results related to the Italian olive oil supply chain showing two different LCI data collection approaches: 1) combining statistical and secondary data and 2) using primary data collected through surveys. Although differences in data among the proposed approaches exist, the datasets result in a high level of details that could be used for representing, from macro (country) to micro (organization) levels, the specificities of the Italian olive oil production, showing a higher quality of data compared to existing commercial LCI databases.

**Keywords.** olive oil, Life Cycle Assessment (LCA), agri-food, Life Cycle Inventory (LCI)

# Introduction

The evaluation of the environmental impacts of agri-food products using the Life Cycle Assessment (LCA) method has experienced a growing interest in recent years due to the need to develop a carbon-neutral economy, looking for sustainable strategies to reduce resources and increase production performances (Notarnicola et al., 2017). However, reliable site-specific Life Cycle Inventories (LCIs) representing the specificities of the Italian agri-food production processes are still missing in commercial databases (Notarnicola et al., 2022). To reduce this lack, the project (PRIN – Progetti di Ricerca di Interesse Nazionale 2017- Prot. 2017EC9WF2, sector ERC SH2, Linea C – financed by the Ministry of University and Research) "Promoting Agrifood Sustainability: Development of an Italian Life Cycle Inventory Database of Agri-Food Products (ILCIDAF)" aims to develop a database of LCI for four Italian agri-food products: olive oil, citrus, wine, and grain products. However, it is essential to highlight that building reliable inventory data for the assessed products is challenging because data used at the flow level need to be characterized with a high level of representativeness, which is influenced by temporal, geographic, and technological aspects (Samarghandian et al., 2016).

In this paper, preliminary results related to modelling the Italian olive oil supply chain are reported to highlight how data representativeness could be ensured. In particular, this is done by showing the methods and materials used to develop LCI datasets for the Italian context and calculating the data quality scores through the pedigree matrix (Samarghandian et al., 2016). Then, these results are compared to the data quality calculated for the only dataset available on Ecoinvent for Italian olive production (Notarnicola et al., 2022). This preliminary study aims to provide critical qualitative analysis of data reliability and representativeness for the specific Italian context.

# Material and method

The European Union (EU) accounts for more than 67% of the world's olive oil produced (European Commission, 2020). Italy is one of the largest producers of olive oil in the EU after Spain, producing about 20% of EU olive oil in 2021 (European Commission, 2021). The Italian regions contributing to about 80% of this production are Pulia, Sicily, Calabria, Lazio and Campania (ISTAT, 2021). The olive oil supply chain consists of 5 main phases: i) agricultural phase, ii) olive oil production phase, iii) packaging phase, iv) distribution and consumption phase, and v) waste management phase (Espadas-Aldana et al., 2019; Salomone et al., 2015). For this preliminary study, only the data quality reached by the agricultural phase is presented, referring to the Sicilian context in 2021. To compare the datasets, the pedigree matrix data quality assessment method is applied at the flow level following the framework reported in Thomas Nemecek et al. (2019) and Samarghandian et al. (2016).

A detailed description of two data gathering approaches is reported in the following sections. Instead, the common calculations of both approaches are detailed in section 1.2.3.

## First approach: primary data for LCI

For the first approach, the datasets are developed using primary data from surveys to represent specific areas of Sicilian cultivated land for producing olives used for extra virgin olive oil production. A questionnaire for each phase was developed and shared with farm owners to gather information on: e.g., the variety of cultivars, the cultivation practices, the substances used for fertilization and/or pest control and techniques used for wastes or by-products management. The data collected refer to the seasonal period 2020-2021.

## Second approach: statistical and secondary data for LCI

For this approach, the datasets representing Sicilian regional processes of olive production are elaborated by combining statistical and secondary data provided by: i) the Italian statistical database (ISTAT, 2021), ii) Integrated Production Regulations (IPR) (Regione Siciliana, 2021), and iii) a technical handbook of agriculture (Ribaudo, 2017). The inputs acquired from the national statistical databases are related to cultivated land and quantity of produced olive, considering a time interval between 2015 and 2020. The consumption of fuel, lubricating oil, electricity and water used in irrigation practices and soil management are estimated based on the data reported in Ribaudo (2017). Instead, the Sicilian IPR recommendations are used to estimate the amounts of fertilizers and pesticides usable per hectare.

## Emissions calculations for LCI

The inputs relating to olive production are used for calculating the emissions in the field deriving from the application of fertilizers, the distribution of pesticides and the combustion of fuels; these are calculated according to the suggestions provided by Notarnicola et al. (2022). In particular: i) the emissions linked to fertilization processes are estimated using the methodology described by Zampori & Pant (2019) and Prasuhn (2006); ii) emissions linked to pesticides are calculated according to the assumptions reported in Zampori & Pant (2019); iii) emissions from fuel combustion are estimated by Nemecek & Kägi (2007); iv) the emissions linked to natural phenomena, such as erosion and leaching, are calculated using the Swiss Agricultural Life Cycle Assessment (SALCA) model (Freiermuth, 2006), adequately customized for the Italian regions.

# Results and discussion

Table 1 shows the data quality scores estimated for the two proposed approaches, compared with the "olive production IT" process available in the Ecoinvent database (Wernet et al., 2016). The indicators are calculated at the flow level using a 1-5 scoring system, where 1 is the best and 5 is the poorest or unavailable data (Edelen & Ingwersen, 2018).

Table 1. Data quality indicators (DQI) of Reliability (R), Completeness (C), Time-related (TiR), Geographical (GR), and Technological Representativeness (TeR) aspects at the flow level



Among the three datasets, the first approach is characterized by the best data quality scores, as it is supposed to be. The datasets developed in the context of the ILCIDAF project are characterized by "Very good quality" (<2) for representing the Sicilian context in 2021, while the Ecoinvent dataset has a "Good quality" score (among 2 and 3). Looking at flow levels, not all the data gathered for the two approaches are better than the data in Ecoinvent. In fact, with the first approach, not all data were available to build the dataset, and missing data had to be covered using secondary data or entering the number 5 as scores. Generally, farm owners cannot provide information on direct emissions linked to processes or split contributions to energy and water consumed by plants, providing only a highly detailed overview of global consumption of energy, materials, water, and fuel for transport but always site-specific. On the contrary, in the second approach, detailed information on energy and materials contributions to the type of operation is estimated considering geographic representativeness within one level of resolution or less if data is specific to a particular region.

Although the first two indicators (R and C) are based on the way data are validated or completed varying from 1 and 2 except for rare cases, representativeness scores depend on the goal and scope of the LCI dataset. This means that while the technological and geographic representativeness is "1" in almost all flows of the Ecoinvent dataset, the scores, if used for specific regions (meso) or farms (micro) case studies, could become 2 and 3, respectively, affecting the uncertainty of environmental results. In addition, among 70 inputs and outputs in the Ecoinvent dataset, only 6% of them refer to Italian boundaries, while the remaining are related to the global or rest of the world context (Notarnicola et al., 2022). Also, the calculated inputs and outputs included are approximate data or data related to other countries, such as the case of emission of heavy metals, calculated with a Swiss data model. On the contrary, in the ILCIDAF database (for both the proposed approaches), the SALCA model is adapted to the Italian context, using the concentration values of heavy metals within one level of geographic resolution and data estimated by less than three years. These methodological choices make the proposed database more representative of the Italian agri-food situation.

Furthermore, concerning the temporal aspect, high discrepancies exist among the ILCIDAF datasets and Ecoinvent due to the data collection period. It is crucial to notice that in the second approach, contrary to the first, the data on productivity considers medium-long term values for reducing the influence (negative or positive) caused by the yearly fluctuation of perennial trees in data estimation but without specifying the relative productivity for ages of the orchard. Concerning the time-related representativeness of flows, the following observation can be made: 1) in the first case, the differences between the data collected and the reference period time of study are less than three years; 2) for the second one, the data on the management of soil and technology operation is estimated from a handbook published more than three years ago; and 3) finally, in the case of Ecoinvent, data are older than ten years. For that reason, almost all data are characterized by a very low temporal representativeness.

Finally, although the first approach provides data only for one year of production, it is characterized by high data quality scores for specific situations in terms of geographic, temporal, and technological aspects. Therefore, considering the site-specific operations, cultivar, climatic condition, and soil characteristics that affect regions in Italy, only one dataset for representing Italian agri-food production is insufficient.

# Conclusions

This study shows preliminary results reached into the context of the ILCIDAF project for the olive oil supply chain. It aims to identify how to ensure representativeness in LCI for Italian agri-food products. The first evidence is that more site-specific LCI datasets for agri-food products are needed, and flow data have to ensure high data quality scores. Comparing the two proposed approaches – one based on primary data and the second on technical and statistical data – with the only one existing in commercial databases for Italy, high discrepancies are highlighted among data and their quality, especially for geographical and temporal representativeness. Then, in commercial databases, except for olive production, all life cycle phases and representative processes of the olive supply chain are still missing. Finally, this study confirms the high need for having LCI datasets for more geographical resolution degrees from micro to macro levels to reduce the uncertainty in LCA models and to represent the goal and scopes established by LCA practitioners.

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