Overview of LCA studies on agricultural waste management

Overview of Life Cycle Assessment studies on agricultural waste management

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Introduction

Agricultural waste management involves a wide range of residual materials, both bio-based and of other kinds, such as containers polluted by pesticides and fertilizers, and plastic foils/metals/glass from greenhouses. From the point of view of agricultural activities, bio-based waste can be outflows (e.g., agricultural products, manure, etc.), or inflows (e.g., waste materials deriving from different activities – as food/food-processing waste and sewer sludge digestate, etc.). Agricultural waste management practices coherent with the concept of circular economy allow the conversion of the above-mentioned materials into biofuels, biomaterials, and bioenergy (Yrjälä et al., 2022; Vasco-Correa et al., 2018). This study is aimed at the analysis of the environmental impacts of agricultural waste management through an overview of the Life Cycle Assessment (LCA) studies available in the state-of-the-art literature (among the others, De Luca et al., 2017; Lee et al., 2020; Montemayor et al., 2022; Zhu et al. 2022).

Methodology

The literature review was developed into three main phases: 1. Survey of Scopus database adopting the keywords "Agricultural waste", "management" and "LCA" and the period 2014-2023. This provided 312 references. 2. The pre-screened references have been examined based on title and abstract, obtaining 178 references. 3. The selected references were categorized based on the environmental assessment methodology applied, involved waste material, applied technologies, and obtained products.

Results and discussions

158 scientific articles and 20 reviews have been published from January 2014 to February 2023, with 12-23 articles and about 2 reviews in each year. Considering the environmental assessment tool applied, our specific interest was focused on understanding if LCA was the only approach, or if it was supported by others. Among the selected references, LCA was mostly (89 %) the only adopted approach (Figure 1), but in few references also Technical and Economic Analysis (TEA) (8%) and Life Cycle Costing (LCC) (3%) have been applied. About system boundaries, the "cradle to gate" approach was the most applied (123 references), followed by "cradle to grave" (46 references). The selected studies involved a single farm or plant in 64 % of references, considering as geographical context – when specified - Italy, China, Spain, and Brazil with 10-20 studies for each of the mentioned countries. Within the selected LCA studies, a wide variety of functional units have been identified, such as electricity/heat produced, mass unit of agricultural waste/manure, mass unit of cultivated product, etc.

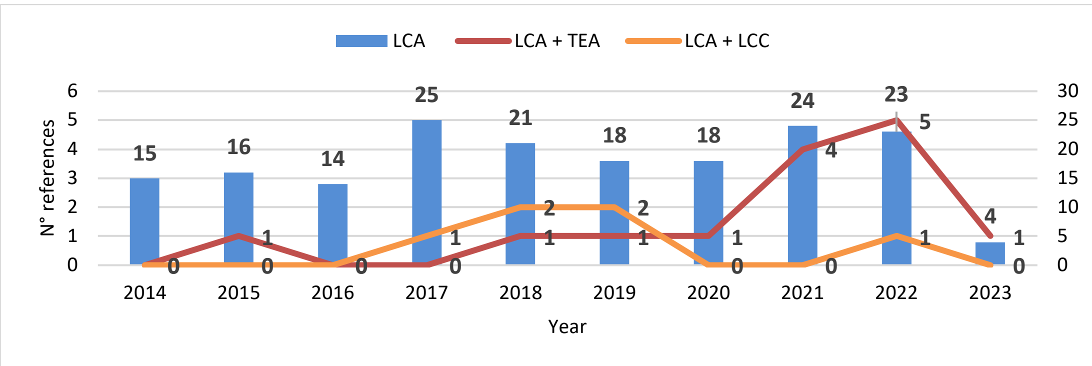

Figure 1. Overview of the literature survey: (a) type of selected references and (b) life-cycle analysis tools applied.

The waste materials considered in the selected references have been categorized into agricultural products, agricultural waste, manure, animal feed and digestate, fertilizers and pesticides, and other non-agricultural waste. Agricultural waste was the most studied (42 % of the selected references), followed by agricultural products (19

%) and manure (14 %). In terms of applied technologies, anaerobic digestion and thermochemical treatments were predominant, and the selected studies mainly (87 %) described pilot and full-scale installations. Thermochemical treatments were identified in gasification, pyrolysis, and combustion, where gasification and pyrolysis were the most applied. On the other hand, within the LCA studies focusing on anaerobic digestion processes, the mesophilic temperature range and wet conditions were the most used, and maize/rice/corn wastes and cow/pig manure were the most common feedstock. About the products, biofuels and bioenergy and various biomaterials (as fertilizers, animal feed and biochar) were predominant within the selected references.

Considering the results of the selected LCA studies, when different types of agricultural residues and manure were involved, the reported impact categories were as follows: Global warming potential, Ozone depletion potential, Aquatic and Terrestrial Eutrophication, Terrestrial acidification, Terrestrial and Aquatic ecotoxicity, Human health, and Land occupation. About the applied technologies for agricultural waste management, anaerobic digestion impacted mainly Global warming power, Ozone depletion potential, Eutrophication and Acidification categories. On the other hand, thermochemical process generated impacts in Global warming power, Acidification and Eutrophication. The same impact categories have been identified within the conversion of agricultural waste into animal feed through Black Soldier flies (Beyers et al., 2023), while in this case further efforts are needed to improve the sustainability of the process.

Conclusions

In overall, based on the performed literature survey, actual agricultural waste management operations have a very good level of technological development, and allow to obtain bioenergy, biofuels, and biomaterials. LCA was the prominent environmental assessment tool, only rarely supported by others. In the wide spectrum of waste materials, applied technologies and resulting products described by the selected references, the results of the selected LCA studies showed that the involved impact categories where numerous (usually Global warming potential, Ozone depletion potential, Aquatic and Terrestrial Eutrophication, Terrestrial acidification, Terrestrial and Aquatic ecotoxicity, Human health, and Land occupation). In conclusion, the adoption of practices based on the conversion of agricultural waste into high-value products and bioenergy is crucial in the Circular Economy. However, the choice of the proper technology for agricultural waste management should account not only the related environmental impacts, but also the socio-economic features of the specific local context (e.g., amount of feedstock, technology development level, demand for product, infrastructures, and catchment area).

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