

Agricultural biomass as a raw material: the case of sustainable particle boards production

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Introduction: The global economy is recognised as being excessively resource-intensive, utilising nearly twice the amount of resources that Earth is capable of regenerating annually (Mata et al., 2023). Two heavily resource-dependent sectors are considered both the agricultural and the construction industry. Although these sectors are integral to societal well-being and play a vital role in driving economic growth (European Commission, 2022; FAO, 2021), they consume substantial amounts of natural resources resulting in considerable environmental impacts that adversely affect ecosystems (Duque-Acevedo et al., 2022). One of the key issues within these sectors is the generation and inadequate management of waste, which contributes to the environmental degradation. In fact, it is estimated that over 3,300 megatons of waste biomass are produced from major crops (European Commission, 2018), while the construction sector alone accounts for 35% of total waste generation within the European Union (EU) (European Commission, 2022). In many countries, the management and disposal of waste from these sectors poses significant challenges, particularly from environmental and social perspectives (Duque-Acevedo et al., 2022; Jannat et al., 2020). Considering these challenges, waste valorisation has emerged as a central strategy, in the context of circular economy (CE) (Mata et al., 2023). CE offers a viable solution ensuring a sustainable future, by emphasising on the reduction of emissions and the conversion of waste into valuable resources, thereby extending the life cycle of products and materials (Missiatto Gavioli et al., 2025). In this context, researchers have investigated the use of agricultural waste biomass as an alternative raw material to respond to the increased demand for sustainable and cost-effective building materials (Duque-Acevedo et al., 2020; Okeke et al., n.d.) and to highlight its potential application as sustainable alternatives to virgin wood in traditional wood-based materials in the particleboard industry (Lee et al., 2022). The present study seeks to explore the potential of agricultural residual waste and by-products as alternative raw materials for the manufacture of particleboards and composite panels, and their role in promoting sustainable construction practices.

Material and methods: Agro-particle boards could provide an optimal scheme for recycling and reusing agricultural residues and by-products, as well as economize on wood resources and reduce the impacts on forestry activity (Lee et al., 2022; Okeke et al., n.d.; Silva et al., 2014). This study compares the environmental performance of conventional particleboards made from forested wood (reference scenario) with the particle boards made from residual straw (bio-based scenario). Concerning the system boundaries, the system is analyzed under a “cradle-to-gate” approach and the functional unit (FU) is 1.0 m³ of finished uncoated particleboard. The SimaPro v10.2, and Ecoinvent database (v3.10) were used to perform the environmental assessment, while the Environmental Footprint 3.1 (adapted) V1.01 / EF 3.1 impact method was applied. Inventory data for the bio-base scenario investigated were based on primary data collected from a particleboard production facility via direct communication and site-specific documentation, while for modeling the reference scenario data obtained from available peer-reviewed literature as well as directly from the Ecoinvent database.

Results and Discussion: Figure 1 illustrates the normalised assessment results of the original and reference scenarios. Results indicate that using agricultural residues as a feedstock to produce construction materials offers a mixed sustainability profile compared to conventional feedstocks such as wood. More specifically, the bio-based scenario demonstrates significant benefits in human toxicity-related categories (32% - 64%), freshwater ecotoxicity from organics (-50%) and photochemical ozone formation (-8%). Also, particulate matter emissions of the bio-based scenario are reduced (-96%), reflecting the advantages of avoiding open burning agricultural residues. At the same time, the analysis reveals trade-offs, including a 47% increase in total climate change impacts and a 47% rise in fossil resource use, mainly due to energy-intensive processing and material treatment, indicating process emissions that should be addressed in future development. Therefore, it is highlighted that biogenic and land-use-change-related carbon emissions are lower for the bio-based scenario, reflecting the fact that straw, as an agricultural residue, does not contribute to deforestation. Moreover, the bio-based scenario performed worse in impact categories such as freshwater, terrestrial and marine eutrophication, where higher values indicate potential environmental concerns. These could stem from upstream emissions linked to agricultural practices, fertilizer runoff, or transportation impacts.

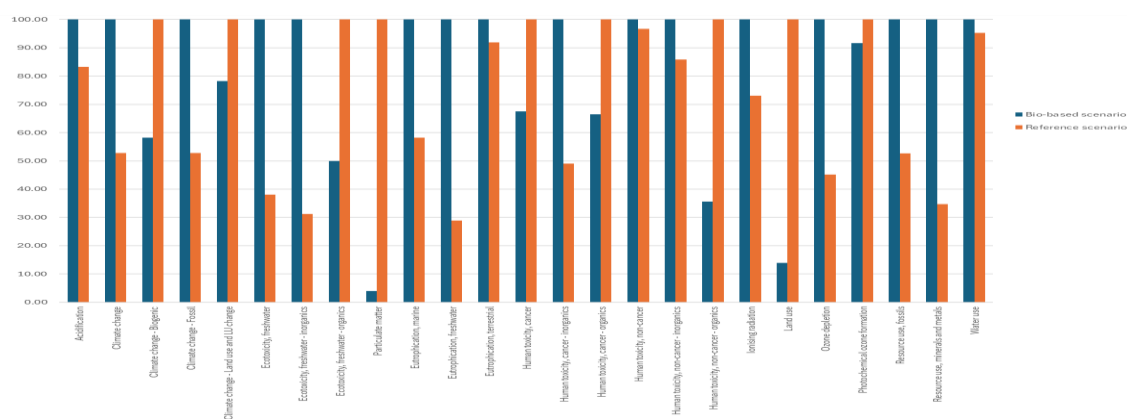


Figure 1: Normalized results of the bio-based and reference systems with Environmental Footprint method

Conclusions: The current study evaluates the impact of the use of residual straw for particleboard production using the EF method. Despite the drawback identified due to bio-based systems' trade-offs, the overall life cycle results suggest that straw particleboard could offer an environmentally preferable alternative to conventional wood-based products, promoting the principles of CE and the establishment of bioeconomy. However, constraints such as process energy demands as well as straw transportation distance should be optimized to enhance the viability of straw-based particleboards as a sustainable material pathway in the building and construction sector.

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