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Review

Integrating Multi-Criteria Techniques in Life-Cycle Tools for the Circular Bioeconomy Transition of Agri-Food Waste Biomass: A Systematic Review

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Supplementary material

Table S1. Search equation applied to the Scopus and Web of Science databases to consolidate the reviewed literature.

Search query	References
("multi-criteria decision making" OR "MCDM" OR "multi-criteria decision analysis" OR "MCDA" OR "multicriteria" OR "multiple criteria" OR "multi-criteria" OR "multi-criteria decision" OR "multicriteria evaluation" OR "multi-criteria evaluation" OR "multi-criteria decision" OR "multi-criteria analysis" OR "multicriteria analysis" OR "multi-attribute decision" OR "multiobjective decision" OR "multiobjective analysis") AND ("life cycle assessment*" OR "life-cycle assessment*" OR "life cycle analys*" OR "life-cycle analys*" OR "life cycle sustainability assessment*" OR "life-cycle sustainability assessment*" OR "life cycle sustainability analys*" OR "life-cycle sustainability analys*" OR "lca" OR "life cycle thinking" OR "life-cycle thinking" OR "life cycle costing" OR "life-cycle costing" OR "life cycle impact assessment*" OR "life-cycle impact assess-ment*" OR "life cycle inventory" OR "life-cycle inventory" OR "life cycle impact analys*" OR "life-cycle impact analys*") AND (agr* OR food) AND (waste OR residue* OR "sub-product" OR feedstock OR biomass OR "biomass-based waste" OR "organic waste" OR "organic-based waste" OR "biowaste" OR "bio-based waste" OR "crop residue*" OR "crop waste" OR "residual biomass" OR "vegeta* crop* residu*")	[23,40,50]

Table S2. Description of aspects and categories scrutinized in the publications.

Aspects	Research question	Categories
Agri-food waste biomass	What types of agri-food waste biomass have been investigated?	Rice (straw and husk); silage; rye; wheat straw; oat straw; barley straw; soybean stover; peanut shell; sunflower stalk; sugarcane (top and leaves); cassava steams; mustard crop residue; maize (cobs and stalk); coconut (shell and husk); Pineapple (peels and leaves); among others
Recovery technologies	What are the recovery technologies used or assessed?	Biological approaches (composting, anaerobic digestion, fermentation, microbial fuel cell, transesterification); termochemical approaches (pyrolysis, gasification, combustion or incineration, hydrothermal carbonization); physical approach (squeezing); among others
Applications	What is the application developed using the AWB?	Biochemicals (sugars, aromatic chemicals, polyphenols, enzymes, biocomposite, biohydrogen); biopolymers (bioplastics, building materials, nanofibrils); biofuels for transportation (biodiesel, biogas); bioenergy (bioelectricity and bioheating); biofertilizers (soil stabilizer); constructions biomaterials; among others
Spatial scales	What are the territorial dimensions of the sustainability assessment?	Micro scale (i.e., resources, processes, products); meso scale (i.e., supply chain and farm-based); macro scale (i.e., city, nation, world regions, global)
Typology of stakeholders involved	What types of stakeholders are involved in the study?	Researchers, supply chain actor, neighboring communities, consumers, workers, consumers, farmers, legislators, no stakeholder, not specificied
Specific stakeholder role in LCA phases	What specific stakeholder actions occur during the LCA phases?	Goal and scope definition phase (identify the problem, establish scope, define alternatives, formulate the goal); inventory analysis phase (interpret aspects from in-ventory, select impact criteria, define measurement methodologies, assist data collection and processing); impact assessment phase (group the indicators, normalize indicators, weigh/rank indicators); interpretation phase (address uncertainties, infer insights, framework for decision towards the goal, recommendations to future works).

Stakeholder participation method	What method of participation do stakeholders use?	MCDA, interviews, Focus group, delphi, survey, conceptual content cognitive, not specified
LCA tools	What LCA tools have been used?	E-LCA; S-LCA; LCC; LCSA; TM-LCA
MCDA techniques	What MCDA techniques are applied?	AHP; ANP; OWA; SMART; MAVT; MAUT; WSM; PROMETHEE; MULTIMOORA; ELECTRE; TOPSIS; NAIDE; VIKOR; CEPI; MACBETH; MCM; PMCA
Criteria	What criteria are evaluated in the LCA/MCDA framework?	Economic (initial costs, operation costs, cost of loss invesments); social (health and safety risks, stakeholders aceptability); environmental (resource use, surface water quality, protection of ground water, protection of land stability, acidification, eutrophication, global warming, ecotoxicology, non-renewable energy use); technical (performance, durability, flexibility, adaptability, resources available); business strategy indicators (fit with strategy, fit with brand Image, fit with company expertise); government indicators (contribution to GDP; policy adaptability; achieving national targets); among others

Table S3. Indicators found by dimension in the publication set.

Dimensions	Indicators	Percentage of use
Environmental	Global Warming Potential, Land use, Carbon footprint, Fossil depletion, Metal depletion, Acidification, Eutrophication, Photochemical oxidation, Ecotoxicity Potential, Energy consumption, Abiotic Depletion, Raw Material Consumption, Residual Waste, Macronutrient (N, P, and K) content recovery, Recycled contents, Water use, Particulate matter, Ionising Radiation, Undesirable substances, Ozone Layer Depletion, Stratospheric ozone depletion, Tropospheric ozone formation	39%
Economics	Transport cost, Average wage, Production cost, Raw Material Cost, Capital Costs, Labor cost, End-of-Life costs, Revenue generated, Import substitution	18%
Social	Human well-being, Human health, Share of workforce in sector, Job creation, Occupational accidents level, Age of Farmer, Education Level, Skiller labor, Safety, Social acceptance, Stakeholder Involvement, Participation in Associations, Stakeholder support, Accessibility to waste management system, Odors generation, Noise creation	26%
Technical	Renewability of resources, Demand Readiness Level, Integration Readiness Level, Technology Readiness Level	7%
Business strategy	Fit with Strategy, Fit with Brand Image, Fit with Company Expertise	5%
Governmental	Contribution to GDP, Policy adaptability, Achieving national targets	5%