Methodological framework to evaluate circularity in livestock systems

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1 INTRODUCTION & OBJECTIVES

The specialization of modern agricultural systems has increased land productivity to meet the demand for food but has led to a greater dependence on external inputs based on fossil fuels (fertilizers, concentrates). In addition, the disconnection between the components of the agri-food system has led to significant imbalances that end up as emissions, generating impacts on a local and global scale. The transition towards circular food systems is therefore imperative, and livestock can play an important role in it by i) promoting efficient use of biomass resources unsuitable for humans (grasslands, crop residues, food by-products), and ii) by implementing strategies and technologies that allow reducing inputs and recycling outputs within the system.

Jointly assessing circularity and environmental impact in such complex systems is not easy though. While life cycle assessment (LCA) methodology has been applied to this purpose, impact categories and process units of LCAs do not always capture the actual implications for resource flows in agri-food systems (AFS), and specific approaches to assess circularity are needed.

2 METHODS

Evaluating whether agricultural strategies currently promoted for livestock sustainability involve circularity, depends on what is considered as circular. Considering the context and goal of the project, a definition of circularity especially adapted for livestock production systems was proposed, aligned with the general principles of circular economy (CE) (**Table 1**). Previous research initiatives, guidelines, and scientific literature were gathered and reviewed. The applicability of different metrics and approaches identified to assess circularity in agri-food systems (AFS) was explored. A specific framework was also developed to identify and categorise the resource flows involved in this type of system.

3 RESULTS

A **selection of indicators and methods** that can be applied when assessing the circularity of livestock systems was proposed (**Table 2**). They were organized according to their suitability considering the type of circular strategy explored and the main resources involved.

A framework was developed to identify and categorise the resource flows involved in AFS systems (**Figure 1**). The two types of cycles (biological and technical cycles) in the model of circular economy (Ellen MacArthur Foundation, 2019) are associated with the concepts of *ecosphere* and *technosphere* in LCA methodology, integrating both approaches for circularity and environmental impact assessment within the same framework. According to this view, systems in the Technosphere can produce either primary and/or secondary products, while resources extracted from natural systems (Ecosphere), can be categorized as renewable or non-renewable inputs (as parallelism between primary vs secondary products from systems in the Technosphere).

Table 1. Circular economy principles according to Ellen MacArthur Foundation (2019) and its connection with the framework developed in CircAgricGHG for livestock systems.

Ellen MacArthur Foundation, 2019	CircAgricGHG framework
Design out waste and pollution	Reduce losses along the food chain, such as food waste or emissions
Keep products and materials in use	Increase resource recovery to reuse it as food, feed, fertilizer, or other valuable biomaterials.
Regenerate natural systems	Minimize the use of finite and limited resources, such as arable lands or phosphorus.

Through the **CircAgricGHG project**, we are adapting and testing a selection of LCA and circularity indicators to be applied in agri-food systems within a consistent methodological framework. The **objective** of this work is i) to share the main concepts and advances proposed by this framework and ii) to discuss their strengths and challenges when tested on some case studies of livestock systems applying circular strategies.

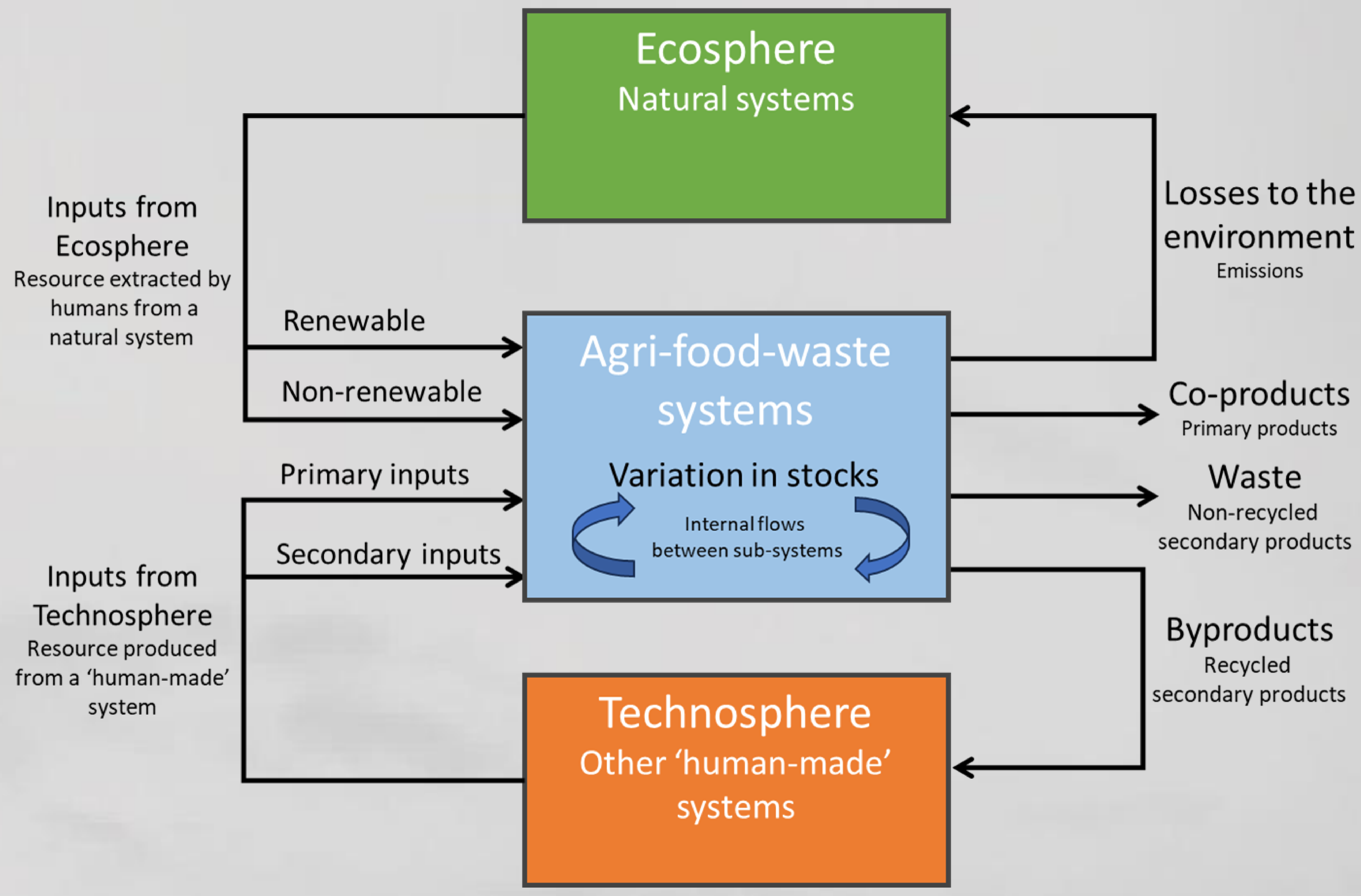

Figure 1. Resource flows to consider in circularity assessments of agri-food-waste systems (AFWS).

Table 2. Selection of indicators for assessing circularity of livestock systems.

Resource	Circular Strategy	Indicator
Nutrients	Reduce losses	*PNB - Partial Nutrient Balance*
Nutrients	Reduce losses	*NUE – Nutrient Use Efficiency*
Nutrients	Increase recovery	*NRI – Nutrient Recycling Index*
Nutrients	Minimize resource use	*ICirc – Circularity of input flows*
Nutrients	Increase recovery	*OCirc – Circularity of output flows*
Biomass/Nutrients	Minimize resource use	*ePCR – Edible Protein Conversion Ratio*
Biomass/Nutrients	Minimize resource use	*Secondary-to-total input (%)*
Biomass/Nutrients	Reduce losses	*Losses (%)*
Biomass/Nutrients	Increase recovery	*Finn's Cyling Index*
Land	Minimize resource use	*Land competition*
Land	Minimize resource use	*Land Use Ratio*
Non-renewable Energy	Minimize resource use	*CED – Cumulative Energy Demand*
Water	Minimize resource use	*Water footprint (Blue)*
Water	Minimize resource use	*AWARE / Water Scarcity*
Non-renewable resources	Minimize resource use	*Abiotic depletion*
Non-renewable resources	Minimize resource use	*Consumption of fossil-P fertilizers*

4 CONCLUSIONS

An approach is proposed integrating LCA methodology concepts and circularity indicators with the aim to be applied in agri-food systems within a consistent methodological framework. Next steps involve to explore their strengths and challenges when tested on some case studies of livestock systems applying circular strategies.

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