

FarmLCA: a LCA tool for capturing the complexity of agro-ecological farm systems

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1. Introduction

While producing sufficient food is vital for an increasing world population, our current food systems contribute substantially to environmental problems, such as climate change, pollution and eutrophication. Agro-ecological innovations are seen as potential solutions to achieve more sustainable food systems. At farm scale, agro-ecological practices include recycling of nutrients and biomass, reduced external inputs, enhanced soil health, improved animal welfare and increasing biodiversity through the use of synergies (e.g. between animals, crops, trees, soil and water) and economic diversification (Wezel et al. 2020). While agro-ecological systems typically show lower environmental impacts on a field or farm scale, they tend to produce less food per hectare. To analyse such trade-offs, models are needed that can capture the complex on-farm environmental interactions of crops, livestock, trees and soils as well as environmental impacts related to off-farm activities. Here, we present such a model, the FarmLCA, which comprises two parts: 1) a farm system model for interactions of crops, livestock, trees and soils and 2) a coupled LCA of on- and off-farm environmental impacts. To demonstrate the model we assess a typical mixed farm in Scotland, UK, producing arable crops and beef, and show the effect of agro-ecological innovations introduced on that farm.

2. Methods

The farm system model enables assessment of impacts for crop management as well as animal husbandry (Figure 1). Emissions from fields, changes to soil organic carbon, as well as emissions from manure management and enteric fermentation of livestock are calculated in different submodels (Table 1). Interlinkages between crops and livestock can be assessed by specifying the share of crops or straw sold or used internally for feed, grazing or bedding, as well as the share of crop residues not harvested and integrate into soils. The nutrient content of on-farm manure used for crop fertilization is calculated based on the herd structure and feeding of the herd. Plausibility checks on available manure and on-farm feed, rationing requirements

of the herd as well as fertilization requirements of crops are implemented. The second part of the model links the on-farm impacts to impacts of imported feed, fuel, fertilizer as well as standard life cycle inventory databases to assess impacts of machinery, irrigation etc. Impacts are finally assessed through IMPACT WORLD+ (Bulle, et al. 2019).

3. Results and discussion

Applying the model to a mixed farm in Scotland (530 ha of arable crops, temporary and permanent grassland, 220 cows and 211 calves) showed hotspots regarding climate impacts of beef (enteric methane) as well as crop production (field emissions from fertilization). Introducing innovations (no-till, cover crops) on the crop side affected both impacts of crops as well as of beef. Trade-offs and synergies with other environmental impacts will be shown.

4. Conclusions

The FarmLCA model is an operational tool to overcome the shortcomings of typical LCA software when dealing with complex interactions at farm-scale to assess the environmental performance of agro-ecological innovations. It has been widely applied in many case studies on mixed farms, agro-forestry systems, but also both conventional and organically managed specialised arable or livestock farms. Future developments should focus on implementing more detailed indicators for example to capture potential impacts of agro-ecological practices on biodiversity. The FarmLCA provides pragmatic and time-efficient solutions to assess the environmental impacts of farms, farming practices or food products and can be combined with an economic assessment to support farmers decision-making.

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6. References

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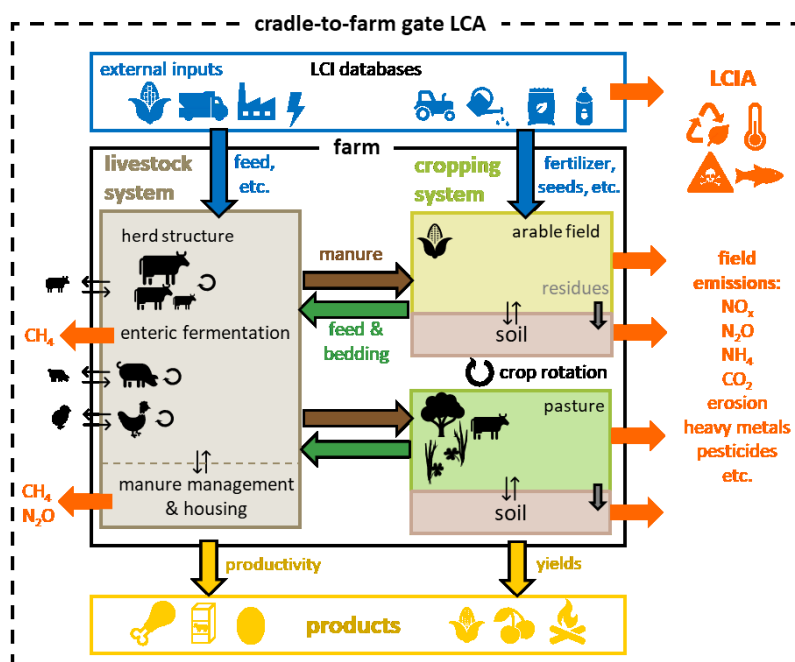


Figure 1. Elements of the FarmLCA model. For arrows with black contours, plausibility checks are conducted regarding nutrient in- and outputs.

Table 1. Submodels implemented to calculate emissions of livestock and crops

Production	Emission	Method
Crop field emissions	N_2O	IPCC 2019 (Tier 1 & 2)
	CO_2	IPCC 2019 (Tier 2)
	NO_x	EMEP/EEA 2023 (Tier 1)
	NH_3	EMEP/EEA 2023 (Tier 2)
	NO_3	SQCB- NO_3
	PO_4, P	SALCA-Phosphorus
Manure management	CH_4	IPCC 2019 (Tier 2 & 3)
	N_2O , direct & indirect	IPCC 2019 (Tier 3)
	NH_3	EMEP/EEA 2023 (Tier 2)
Enteric fermentation	CH_4	IPCC 2019 (Tier 2 & 3)