Evaluating ecosystem services in the life cycle assessment of grassland-based dairy systems

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Abstract

The integration of ecosystem services (ESS) in life cycle assessment (LCA) poses two main challenges: (1) how to integrate ESS within LCA, and (2) how to quantify the delivery of ESS. Several approaches have been proposed to integrate ESS in LCA: using multiple functional units, allocation to ESS, system expansion and introducing additional indicators. Some ESS are already directly or indirectly covered in LCA impact categories, while others remain to be added. The methods SALCA-biodiversity, SALCA-soil quality and the newly developed SALCA-landscape aesthetics will be applied to assess the environmental impacts and ESS from three grassland-based dairy production systems in Switzerland.

Keywords: life cycle assessment, ecosystem services, biodiversity, soil quality, landscape aesthetics

Introduction

Grassland-based farming systems provide multiple ecosystem services (ESS). The Millennium Ecosystem Assessment (2005) report defined ESS as the 'benefits people obtain from ecosystems' and distinguished provisioning, regulating, cultural and supporting services. Later CICES (2016) proposed a classification into (1) provisioning services, (2) regulation and maintenance as well as (3) cultural services. The delivery of high-quality feed for animals and subsequently animal products belongs to the most important provisioning services of grassland. The regulation and maintenance services of grassland are manifold, e.g. through biodiversity (habitat, species and genetic diversity), functional biodiversity and pest regulation, soil quality and fertility, symbiotic nitrogen fixation, prevention of soil erosion, of nutrient leaching and run-off, feeding sources for pollinators, recycling of animal manure, and the potential for carbon sequestration in the soil. Among the cultural services, the aesthetic value of the landscape is of primary interest. Häyhä and Franzese (2014) describe the challenges of ecosystem service assessment and conclude that using one single approach – like e.g. economic valuation – is not capable to capture all relevant aspect of ESS. Instead, they advocate approaches combining different perspectives and metrics. Combining ecosystem service assessment with life cycle assessment (LCA) is such an approach. However, this approach poses two main challenges which are discussed in this paper: (1) how to integrate ESS within LCA, and (2) how to quantify the delivery of ESS.

Integrating ecosystem service assessment within life cycle assessment

LCA provides a framework for the analysis of impacts on the environment. It can cover some ESS directly and indirectly, but for many ESS additional methods and indicators are needed (Zhang *et al.*, 2010). Koellner *et al.* (2013) proposed an 'ecosystem services depletion potential' including the biotic production potential, climate regulation potential, freshwater regulation potential, erosion regulation potential, and water purification potential. Since the systems provide multiple functions and services, they need to be considered as multifunctional. Several options are available in LCA to address the multifunctionality of agricultural systems:

1. Using multiple functional units to account for the various functions of the agricultural system (Nemecek *et al.*, 2011): area*time, agricultural products, income related indicator.
2. Using allocation, by dividing the environmental impacts between the products and ESS. For instance, Ripoll-Bosch *et al.* (2013) have analysed the greenhouse gas (GHG) emissions from different lamb production systems in the Mediterranean region. Extensive production systems tend to have high GHG emissions per kg of meat. Economic allocation was used to allocate the environmental impacts between meat production and the provision of ESS, thus considering the delivery of ESS as a co-product. The economic value of ESS was estimated by the agri-environmental payments to the farmers, considered as a proxy for the willingness of the society to pay for the ESS. Without considering ESS, the intensive system performed best; after the allocation the extensive system had lower impacts. Kiefer *et al.* (2015) used economic allocation including ESS to allocate environmental impacts between milk, meat and the provision of ESS. The value of the latter was hereby estimated by the subsidies paid to the farmers for the provision of ESS. Allocating part of the emissions to ESS reduced the environmental impact per kg of milk.
3. Using system expansion, where an alternative provision of ESS is subtracted (avoided impacts). An example would be mowing grass on Alpine pastures instead of grazing by animals, in order to maintain a grass cover.
4. Including ESS as additional indicators.

Using an area-related functional unit (option 1 above) can reflect some aspects of ESS delivery; however, the area used by agricultural production is only a poor indicator, not allowing a differentiation of various levels of ESS, and therefore this solution is not satisfactory. Allocating a part of the environmental impacts to ESS (option 2) requires an economic valuation of the latter, which can be approximated by subsidies or estimated by other economic valuation methods (e.g. Häyhä and Franzese, 2014). However, subsidies are defined in political processes and do not necessarily represent the true value of ESS. Furthermore, this approach means that the provision of ESS is associated with environmental impacts such as climate change or eutrophication. The system expansion approach (option 3) requires the definition of an alternative system for ESS provision, which is often difficult to determine and also debatable. Including ESS as additional indicators (option 4) allows for a detailed and differentiated assessment. This will be explained in the next section.

Quantifying ecosystem services within life cycle assessment

The environmental impacts of grassland-based production systems can be assessed by the LCA method, e.g. as implemented by the Swiss Agricultural Life Cycle Assessment SALCA (Nemecek *et al.*, 2010). Hereby, some ESS can be assessed within the LCA framework, either directly, like C sequestration, prevention of water pollution or prevention of soil erosion or indirectly, like symbiotic N fixation leading to less need for N fertilisers and to mitigation of related environmental impacts. For other aspects, additional indicators are needed.

Biodiversity is a basis for the provision of multiple ESS, and a higher diversity increases the chance to provide the required ESS, although there is not a simple relationship. The potential impacts of agricultural management on biodiversity are assessed by the SALCA-biodiversity method (Jeanneret *et al.*, 2014), using eleven indicator-species groups, namely flora of crops and grasslands, birds, mammals, amphibians, snails, spiders, carabids, butterflies, wild bees, and grasshoppers. The method distinguishes between several level of management intensity of grassland, as well as grazing and cutting grass.

Soil quality is assessed by the method SALCA-soil quality (Oberholzer *et al.*, 2012), which characterizes impacts of land management practices on the quality of arable soils by means of nine indicators covering soil physical, chemical and biological aspects: rooting depth of soil, macropore volume, aggregate stability, organic carbon content, heavy metal content, organic pollutants, earthworm biomass, microbial biomass and microbial activity. The model has been recently extended to better take into account the effects of grazing animals.

Landscape diversity and aesthetics will be assessed by the newly developed method SALCA-landscape (Roesch *et al.*, 2016). It is based on preference values for the aesthetical quality of different landscape elements. The diversity and seasonality of the landscape is considered (Schüpbach *et al.*, 2016).

Outlook

ESS provided by grassland systems can be quantified by biophysical indicators and integrated in the LCA approach. The challenges hereby are to assess the effect of the production systems on ESS on farm, to cover the multitude of ESS and also to include ESS of upstream stages, such as production of concentrate feeds. The presented method will be applied to analyse three dairy production systems, implemented in a trial is being carried out at the Hohenrain demonstration farm in Central Switzerland (Hofstetter *et al.*, 2014) and on 38 pilot farms in three regions of the Swiss lowlands.

References

CICES (2016). Common classification of ecosystem services. Available at: http://cices.eu/.

Häyhä T. and Franzese P.P. (2014). Ecosystem services assessment: A review under an ecological-economic and systems perspective. *Ecological Modelling*, 289, 124-132.

Hofstetter P., Akert F., Kneubühler L., Kunz P., Frey H.-J., Estermann J., Gut1 W., Höltschi M., Menzi H., Petermann R., Schmid H. and Reidy B. (2014). Optimierung von Milchproduktionssystemen mit Eingrasen Systemvergleich Hohenrain II. *Mitteilungen der Arbeitsgemeinschaft Grünland und Futterbau*, 16, 27-31.

Jeanneret P., Baumgartner D.U., Knuchel R.F., Koch B. and Gaillard G. (2014). An expert system for integrating biodiversity into agricultural life-cycle assessment. *Ecological Indicators*, 46, 224-231.

Kiefer L.R., Menzel F. and Bahrs E. (2015). Integration of ecosystem services into the carbon footprint of milk of South German dairy farms. *Journal of Environmental Management*, 152, 11-18.

Koellner T., De Baan L., Beck T., Brandão M., Civit B., Margni M., L.M I.C., Saad R., De Souza D.M. and Müller-Wenk R. (2013). UNEP-SETAC guideline on global land use impact assessment on biodiversity and ecosystem services in LCA. *International Journal of Life Cycle Assessment*, 18, 1188-1202.

Millennium Ecosystem Assessment (2005) *Ecosystems and Human Well-being: Synthesis*. Island Press, Washington, DC, USA.

Nemecek T., Dubois D., Huguenin-Elie O. and Gaillard G. (2011). Life cycle assessment of Swiss farming systems: I. Integrated and organic farming. *Agricultural Systems*, 104, 217-232.

Nemecek T., Freiermuth Knuchel R., Alig M. and Gaillard G. (2010). *The advantages of generic LCA tools for agriculture: examples SALCAcrop and SALCAfarm*. In: 7th Int. Conf. on LCA in the Agri-Food Sector, Notarnicola, B. (eds.). Bari, Italy. pp. 433-438.

Oberholzer H.-R., Knuchel R.F., Weisskopf P. and Gaillard G. (2012). A novel method for soil quality in life cycle assessment using several soil indicators. *Agronomy for Sustainable Development*, 32, 639-649.

Ripoll-Bosch R., de Boer I.J.M., Bernués A. and Vellinga T.V. (2013). Accounting for multi-functionality of sheep farming in the carbon footprint of lamb: A comparison of three contrasting Mediterranean systems. *Agricultural Systems*, 116: 60-68.

Roesch A., Gaillard G., Isenring J., Jurt C., Keil N., Nemecek T., Rufener C., Schüpbach B., Umstätter C., Waldvogel T., Walter T. and Zorn A. (2016). *Umfassende Beurteilung der Nachhaltigkeit von Landwirtschaftsbetrieben*. Agroscope, Institute for Sustainability Sciences, Zürich, Agroscope Science.

Schüpbach B., Junge X., Lindemann-Matthies P. and Walter T. (2016). Seasonality, diversity and aesthetic valuation of landscape plots: An integrative approach to assess landscape quality on different scales. *Land Use Policy*, in press.

Zhang Y.I., Singh S. and Bakshi B.R. (2010). Accounting for ecosystem services in life cycle assessment part I: A critical review. *Environmental Science and Technology*, 44, 2232-2242.