Towards Ecological Sustainability in (sub)tropical Animal Nutrition – Life Cycle Assessment as a Tool to Identify Environmentally Sound Feeding Options

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Introduction

The increasing demand for animal products in developing countries presents opportunities, but also serious challenges to the socio-economic and environmental sustainability of animal production systems. Research concerning (sub)tropical animal nutrition has focussed mainly on the optimisation of the nutritional properties of animal diets. Especially in (sub)tropical regions, where many developing countries are located, sustainability issues, such as soil conservation and biodiversity, should be considered thoroughly in order to maintain the alimentary basis of the local population in the long run.

In recent years Life Cycle Assessment (LCA) has proved to be a useful tool to assess the integral environmental impact of agricultural production systems. The LCA methodology has been standardised internationally (ISO 14040:2006, ISO 14044:2006) and the UNEP/SETAC Life Cycle Initiative is pressing towards defining worldwide recommended practice and guidelines for LCA application. In temperate zones, LCA has been applied to assess the environmental impact of different animal production systems, e.g. comparison of conventional and organic dairy systems or different animal diets. In (sub)tropical countries, LCA studies concerning animal production do not exist. LCA studies in temperate regions and related LCA studies in (sub)tropical areas, however, provide a good basis for the application of LCA in (sub)tropical animal production. For example, LCAs on soy bean production in Brazil are included in LCAs of European animal products, because soy bean meal is used as animal feed. In addition, LCA studies on bioethanol production in Mediterranean and tropical regions can provide useful data concerning the environmental burdens of crop cultivation, e.g. wheat and corn. These crops or their by-products are important supplements for livestock in (sub)tropical areas. Quantification of the integral environmental impact of (sub)tropical feed ingredients is of importance for sustainable development of (sub)tropical countries, and to increase quality and traceability of LCAs of European food chains. Yet, current LCAs neglect several environmental problems specific to emerging and developing countries, such as soil erosion, soil fertility and biodiversity.

This paper i) describes the steps involved in an LCA, ii) gives an overview on existing publications concerning the use of LCA in (sub-)tropical agricultural production, iii) points out which aspects have to be specifically taken into account when assessing the integral environmental impact of (sub-)tropical feed ingredients.

Structure and components of an LCA

An LCA practitioner tabulates emissions to the environment and resource consumption at each stage in the life cycle of a product, including raw material extractions, energy acquisition, materials production, manufacturing, use, recycling and ultimate disposal (Rebitzer et al., 2004). The goal and scope definition implies a description of the product system in terms of the system boundaries and the functional unit (e.g. weight or volume of product), which allows to compare and analyse alternative goods or services (Rebitzer et al., 2004). Subsequently, the life cycle inventory (LCI) includes compilation and tabulation all environmental emissions and resource use. Finally, in the life cycle impact assessment (LCIA) stage, the potential environmental impact of a product is computed and interpreted. Impact categories include e.g. climate change, stratospheric ozone depletion, photooxidant formation (smog), eutrophication, acidification (Pennington et al., 2004). According to ISO 14042, the LCIA standard, there are three broad groups of impact categories that should be taken into account when defining the scope of an LCA study: human health, natural environment (resources and life support functions, climate regulation, soil fertility), and man-made environment (e.g. forest plantations).

Status of LCA studies on animal production in temperate regions

Initially developed to assess environmental impact of industrial processes, LCAs in agriculture have been carried out mainly for single crops or production of artificial fertiliser. Since 2000, LCA has been applied to assess the environmental impact of different animal production systems in several case studies – however, only in temperate regions. In Northern Europe, ‘cradle to farm-gate’ LCA studies have been performed for a variety of animal products
Concerning bio-ethanol reviewed by Blottnitz and Curran (2007) included soil health in the impact category land computing the eutrophication potential, by including the NP balance (e.g. Kinjo et al., 2005). Only one of the papers and Arena (2006) from Argentina emphasise that desertification should be taken into account in LCA by including 2003). Especially in (semi)arid regions, there is a high risk of desertification due to unsustainable agriculture. Civit leguminous plants (the main N-source e.g. in organic dairy production) should also be taken into account (De Boer, 2003). Energy consumption should be included in (sub)tropical LCAs, as there exist large differences between more extensive animal production systems without pesticides and fertiliser application and based on animal traction, compared to intensive animal production systems that import concentrate feed from other countries. As energy consumption is comparatively easy to assess, it is included in most of the LCAs, e.g. in LCA papers concerning bio-ethanol (Blottnitz and Curran, 2007; Tan et al., 2004; Weiss et al., 2007), coffee production (Coltro et al., 2006) and apple production (Mila i Canals et al., 2006).

Ecotoxicity and human toxicity

Ecotoxicity and human toxicity were considered in one and three of the LCA papers concerning bio-ethanol, respectively, reviewed by Blottnitz and Curran (2007). Cederberg et al. (2005) point out that pesticide use could be a major environmental problem in (sub)tropical soy production for pig supplementation. Mila i Canals et al. (2006) found that human toxicity related impacts in apple production in New Zealand were dominated by emissions of the synthetic pesticides used in IFP. Humbert et al. (2007), who evaluated the impacts of the 30 active substances most used in Costa Rica using two models originally developed to support comparative assertions in the context of LCA, emphasise that it would be possible to achieve a 90% reduction of human toxicity and a 75% reduction of aquatic ecotoxicity due to pesticide used in Costa Rica, focussing on only six active substances of the 30 most commonly used.

Soil erosion and fertility (incl. desertification)

Soil parameters can be included in several impact categories of LCA. Up to now, soil parameters are mainly used for computing the eutrophication potential, by including the NP balance (e.g. Kinjo et al., 2005). Only one of the papers concerning bio-ethanol reviewed by Blottnitz and Curran (2007) included soil health in the impact category land use. The environmental impact of agricultural systems is usually assessed based on nutrient balance at farm level; however, nutrient losses during production of farm inputs (i.e. concentrates, artificial fertilisers), and N-fixation by leguminous plants (the main N-source e.g. in organic dairy production) should also be taken into account (De Boer, 2003). Especially in (semi)arid regions, there is a high risk of desertification due to unsustainable agriculture. Civit and Arena (2006) from Argentina emphasise that desertification should be taken into account in LCA by including e.g. (changes of the) vegetational cover as an indicator. Mila i Canals et al. (2007) recommend a consistent framework based on soil organic matter as a simple but robust approach for the LCIA of land use occupation and transformation impacts affecting life support functions; however, they recommend using this method always in combination with a proper assessment of the impacts on biodiversity.

Water consumption

In spite of the evident relevance of water and land use in terms of impact to human and ecosystem health, adequate methods for assessing water consumption in LCA are still missing. Water is listed as input parameter in the Life
Cycle Inventory phase (ecoinvent 2006), the phase in which resource uses and emissions are quantified, but only little differentiation is made into various types of water uses. Even less attention is given to water use in the Life-Cycle Impact Assessment (LCIA) phase, in which emissions and resource uses are grouped and compared according to their environmental impact. So far, water resources have mainly been described qualitatively (Owens 2002) and on the basis of politically defined environmental targets (Frischknecht et al. 2006). Chapagain et al. (2006) propose the inclusion of a water footprint. Heuvelmans et al. (2005) recommend to introduce a new impact category regional water balance in order to cover water quantity impacts; however, they fear that the increasing data requirement might hinder the feasibility of their method, and thus recommended developing a simpler numerical model that can calculate the indicator scores from more easily accessible data. There are promising first attempts to include water consumption in (sub)tropical LCA, e.g. León and Antón (2007) analysing the water consumption of corn, bean and potato in Guatemala, and Coltro et al. (2006) studying coffee production in Brazil. However, in most of the (sub)tropical LCA studies, water consumption is missing (e.g. Blottnitz and Curran, 2007). This gap in adequate methods to assess water use has been recognised by the UNEP/SETAC Life Cycle Initiative, which established an international working group on “Assessment of water use and consumption within LCA” recently.

Land use and biodiversity in LCA

So far, in most of the LCA studies, only land occupation in terms of area used for the production of a certain functional unit is included (e.g. Coltro et al., 2006). In order to be able to account for ecosystem services of agricultural and grazing land and to differentiate between extensive and intensive land use, consensus on how to include biodiversity in LCA is essential, especially in the (sub)tropics, where plant and animal species diversity is very high, thus resulting in substantial differences between e.g. virgin forest and intensive agriculture. Methods for assessing land occupation have been made operational within the framework of LCA. However, also these approaches need further development, as they are limited to the European continent only and therefore lack the ability to address the particular needs of emerging countries. In LCA, indicators were proposed for species diversity and ecological diversity, mainly focusing on vascular plant species (Lindeijer, 2000; Koellner and Scholz 2007), and they are not yet available for other regions of the world. Therefore, land conversion and effects on biodiversity are usually not included in (sub)tropical LCAs (e.g. Kinjo et al., 2005, Sanjuán et al., 2005, Yusoff and Hansen, 2007). None of the papers regarding bio-ethanol production reviewed by Blottnitz and Curran (2007) considered biodiversity.

Conclusions

Up to date, the application of LCA to agriculture has concentrated mainly on industrialised countries and temperate zones, and few LCA studies have been conducted in areas related to (sub)tropical agriculture. Data, models and methodology developed for the temperate zone need to be adapted to (sub)tropical systems. Pilot studies are necessary to investigate how LCAs of (sub)tropical animal production systems can be implemented and to what extent new developments in terms of methodology and data collection is needed. Therefore, publications concerning LCA in animal production, existing (sub)tropical LCA studies in related areas, and existing LCA databases should be reviewed. LCAs on (sub)tropical agriculture should specifically include soil erosion and fertility, water consumption and biodiversity, in addition to the impact categories usually included in LCA studies. Concerning the integration of biodiversity, there are already feasible existing methods at least for European conditions, while more efforts are needed to develop simpler models or indicator sets to include soil erosion and water consumption in (sub)tropical LCA. For other impact categories, the LCA databases developed in Europe can be adapted or used directly, e.g. energy use. LCA can help to improve the ecological – and thus also long-term economical – sustainability of animal production in the tropics and subtropics, both by improving the marketability of more sustainable produced animal products and by guiding research and policy in a more sustainable direction.

References


