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

Andrea Corinna Mayer[1] and Imke Johanna Maria de Boer[2]

[1] ETH Zurich, Institute of Animal Sciences, Switzerland
[2] Animal Production Systems Group, Wageningen University, The Netherlands

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 tracebility 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

(Halberg et al., 2005; Berlin, 2002; de Boer, 2003; Casey and Holden, 2006b; Thomassen at al., 2007). In addition, meat production has been compared with plant based protein production based on LCA (e.g. Helms and Aiking, 2003, Aiking et al., 2006, Baroni et al., 2007, Duchin, 2005). As an example for the results of LCA studies concerning animal production, Cederberg and Stadig (2003) emphasise that beef production in combination with milk production (surplus calves) can be carried out with fewer animals than in sole beef production systems, thus reducing the environmental burdens per product unit. In line with this; Casey and Holden (2006) state that a continued increase in specialisation of the dairy and the beef sectors would make it difficult to reduce GHG emissions. The advantages of less intensive and combined systems should be kept in mind when dealing with (sub)tropical animal production systems, where a combination of milk and beef production is very frequent and livestock needs to be seen in the context of larger livelihood systems (Sumberg, 2002). De Boer (2003) concluded that results of these different LCA studies can not be compared directly, because of differences in system boundaries, allocation procedures or normative values used with respect to CH_4 and N_2O emission. This shows that even in northern countries, where LCA in agriculture is already established, further harmonization of the LCA methodology is needed in order to increase the comparability of different studies. Currently, LCA studies of animal products are expanded to the full food chain by including the life cycle stages of product processing (Berlin et al., 2007), packaging and transportation of products to the households (Sonesson and Berlin, 2003). The inclusion of additional life cycle stages again emphasises the importance of harmonisation of the LCA methodology.

Agriculture-related LCA studies in (sub-)tropical environments

As mentioned above, in (sub)tropical countries, there does not exist any LCA study concerning animal production, but LCA studies in temperate regions and related LCA studies in (sub)tropical areas provide a good basis for the application of LCA in (sub)tropical livestock nutrition. Sanjuán et al. (2005) analysing orange production in Spain, point out that there is a lack of environmental information for agricultural LCA in subtropical regions and a need to adapt some aspects of impact methodology to the subtropical soil and climate characteristics. In the following, we review the inclusion of certain impact categories in LCA studies related to our subject, which could provide a good basis for the application of LCA in (sub)tropical animal production.

Energy consumption

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

AIKING, H., DE BOER, JOOP, VEREIJKEN, J. (2006): Sustainable protein production and consumption: Pigs or peas? Series Environment and Policy 45, Springer, Netherlands, 226 pp.

BARONI, L., CENCI, L., TETTAMANTI, M. AND BERATI, M. (2008): Evaluating the environmental impact of varous dietary patterns combined with different food production systems. European Journal of Clinical Nutrition 61: 279-286.

BERLIN, J. (2002): Environmental life cycle assessment (LCA) of Swedish semi-hard cheese. International Dairy Journal 12 (11): 939-953.

BERLIN, J., SONESSON, U. AND TILLMAN, A.-M. (2007): A life cycle based method to minimise environmental impact of dairy production through product sequencing. Journal of Cleaner Production 15: 347-356.

Blottnitz, H. And Curran, M.A. (2007): A review of assessments conducted on bio-ethanol as a transportation fuel from a net energy, greenhouse gas, and environmental life cycle perspective. Journal of Cleaner Production 15(7) : 607-619.

CASEY, J.W. AND HOLDEN, N.M. (2006): Quantification of GHG emissions from suckler-beef production in Ireland. Agricultural Systems 90:79-98.

CEDERBERG, C. AND STADIG, M. (2003): System expansion and allocation in life cycle assessment of milk and beef production. International Journal of Life Cycle Assessment 8 (6): 350-356.

CEDERBERG, C., WIVSTAD, M., BERGKVIST, P., MATTSSON, B. AND IVARSSON, K. (2005): Environmental Assessment of Plant Protection Strategies Using Scenarios for Pig Feed Production. AMBIO: A Journal of the Human Environment: Vol. 34 (4): 408–413.

CIVIT, B. AND ARENA, P. (2006): Consideraciones sobre el impacto del uso del suelo en estudios de Análisis de Ciclo de Vida conducentes a la definición de indicadores. Encuentro de Investigadores y Docentes de Ingeniería 2006, Mendoza, Argentina.

CHAPAGAIN, A.K., HOEKSTRA, A.Y., SAVENIJE, H.H.G. AND GAUTAM, R. (2006): The water footprint of cotton consumption: An assessment of the impact of worldwide consumption of cotton products on the water resources in the cotton producing countries. Ecological Economics 60 (1): 186-203.

COLTRO, L., MOURAD, A.L., OLIVEIRA, P.A.P., BADDINI, J.P.O. AND KLETECKE, R.M. (2006): Environmental profile of Brazilian green coffee. International Journal of Life Cycle Assessment 11 (1): 16-21.

DE BOER, I.J.M. (2003): Environmental impact assessment of conventional and organic milk production Livestock Production Science 80 (1-2): 69-77.

DUCHIN, F. (2005): Sustainable consumption of food. Journal of Industrial Ecology 9 (1-2): 99-113.

ecoinvent 2006, Swiss Centre for Life Cycle Inventories, http://ecoinvent.ch/.

FRISCHKNECHT, R, STEINER, R AND BRAUNSCHWEIG, A. (2006): Swiss Ecological Scarcity Method: the new version 2006, Presentation at the 7th International Conference on EcoBalance, Tsukuba, Japan, November 14, 2006.

HALBERG N., VAN DER WERF H. M. G., BASSET-MENS C., DALGAARD R. AND DE BOER I. J. M. (2005): Environmental Assessment Tools for the Evaluation and Improvement of European Livestock Production Systems. Livestock Production Science, 96: 33-50.

HELMS, M AND AIKING, H. (2003): Food and the environment: towards sustainability indicators for protein production. Ecosystems and Sustainable Development 4 (1, 2): 1047-1056; Book Series Anvances in Ecological Sciences 18 and 19 (Proceedings of the 4theInternational Conference on Ecosystems and Sustainable Development, 4-6 June 2003).

HEUVELMANS, G., MUYS, B. AND FEYEN, J. (2005): Extending the Life Cycle Methodology to cover impacts of land use systems on the water balance. Journal of Life Cycle Assessment 10 (2): 113-119.

HUMBERT, S., MARGNI, M., CHARLES, R., TORRES SALAZAR, O.M., QUIROS, A.L. AND JOLLIET, O. (2007): Toxicity assessment of the main pesticides used in Costa Rica. Agriculture, Ecosystems and Environment 118: 183-190.

JUNGBLUTH, N. AND FRISCHKNECHT, R. (2007): LCA of imported agricultural products – impacts due to deforestation and burning of residues. Proceedings of the Third International Conference on Life Cycle Management, August 27-29 2007, Zurich, Switzerland.

KINJO, M. OHUCHI, T., KII, H. AND MURASE, Y. (2005): Studies on Life Cycle Assessment of sugi lumber. J. Fac. Agr., Kyushu Univ. 50(2): 343-351.

KOELLNER, T. AND SCHOLZ, R. (2007): Assessment of land use impacts on the natural environment. Part 1: An analytical framework for pure land occupation and land use change. International Journal of Life Cycle Assessment 12: 16-23.

LEÓN, W.E. AND ANTÓN, A. (2007): Eficiencia del uso del agua en la producción agrícola en Guatemala. Poster at the 3rd International Conference on Life Cycle Management "From analysis to implementation" in Zurich, 27-29 August 2007.

LINDEIJER, E., (2000): Biodiversity and life support impacts of land use in LCA. Journal of Cleaner Production 8: 313–319.

MILA I CANALS, L., BURNIP, G. M., COWELL, S. J. (2006): Evaluation of the environmental impacts of apple production using Life Cycle Assessment (LCA): Case study in New Zealand. Agriculture Ecosystems and Environment 114 (2-4): 226-238.

MILA I CANALS, L., ROMANYA, J. AND COWELL, S.J. (2007): Method for assessing impacts on life support functions (LSF) related to the use of 'fertile land' in Life Cycle Assessment (LCA). Journal of Cleaner Production 15: 1426-1440.

OWENS JW. (2002): Water resources in life-cycle impact assessment: Considerations in choosing category indicators, Journal of Industrial Ecology 5 (2): 37-54.

PENNINGTON, D.W., POTTING, J. FINNVEDEN, G. LINDEIJER, E., JOLLIET, O., RYDBERG, T. AND REBITZER, G. (2004): Life cycle assessment Part 2: Current impact assessment practice. Environment International 30: 721-739.

REBITZER, G. EKVALL, T. FRISCHKNECHT, R., HUNKELER, D., NORRIS, G., RYDBERG, T., SCHMNIDT, W.-P., SUH, S., WEIDEMA, B.P AND PENNINGTON, D.W. (2004): Review: Life cycle assessment. Part 1: Framework, goal and scope definition, inventory analysis and applications. Environment International 30: 701-720.

SANJUAN, N., ÚBEDA, L. CLEMENTE, G., MULET, A. AND GIRONA, F. (2005): LCA of integrated orange production in the Comunidad Valnciana (Spain). International Journal of Agricultural Resources Governance and Ecology 4 (2): 163-177.

SONESSON, U. AND BERLIN, J. (2003): Environmental impact of future milk supply chains in Sweden: a scenario study. Journal of Cleaner Production 11: 253-266.

SUMBERG, J. (2002): Livestock nutrition and foodstuff research in Africa: when is a nutritional constraint not a priority research problem? Animal Science 75: 332-338.

TAN, R.R., CULABA, A.B. AND PURVIS, M.R.I. (2004): Carbon balance implications of coconut biodiesel utilization in the Philippine automotive transport sector. Biomass and Bioenergy 26 (6): 579-585.

THOMASSEN, M.A. AND DE BOER, I.J.M. (2005): Evaluation of indicators to assess the environmental impact of dairy production systems. Agriculture Ecosystems and Environment 111 (1-4): 185-199.

VON BLOTTNITZ, H. AND CURRAN, M.A. (2007): A review of assessments conducted on bio-ethanol as a transportation fuel from a net energy, greenhouse gas, and environmental life cycle perspective. Journal of Cleaner Production 15: 607-619.

WEISS, M., PATEL, M. HEILMEIER, H. AND BRINGEZU, S. (2007): Applying distance-to-target weighing methodology to evaluate the environmental performance of bio-based energy, fuels, and materials. Resources, Conservation and Recycling 50: 260-281.

YUSOFF, S. AND HANSEN, S.B. (2007): Feasibility study of performing a Life Cycle Analysis on crude palm oil production in Malaysia. International Journal of Life Cycle Assessment 12 (1): 50-58.