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Sustainability assessment of animal production systems in the (sub)tropics : review and prospects on combining Life Cycle Assessment (LCA) with other environmental impact assessment methods

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Key words : animal nutrition , grazing , intensification , silvopastoral systems

Introduction In developing countries , the demand for animal products is increasing . However , intensified animal production can cause serious environmental problems , especially in sensitive areas , e .g . mountain ecosystems and (sub) tropical forests . Research concerning tropical and subtropical animal nutrition has focussed so far mainly on the optimisation of the nutritional properties of animal diets . However , especially in tropical and subtropical regions , where many developing countries are located , sustainability issues , such as soil , water and biodiversity conservation , should be considered thoroughly in order to maintain both the alimentary basis of the local population and the possibility to produce for the market . Life Cycle Assessment (LCA) is the internationally most accepted method to assess potential impacts to human health and the environment associated with a product , process or activity by evaluating resource consumption and emissions . In temperate zones , LCA has been applied for the assessment of the sustainability of different animal agriculture systems in several case studies , e .g . comparisons of conventional and organic dairy systems . In many cases , in order to achieve an increase of milk and meat production , specialists recommend to shift from (extensive) grazing systems to intensified animal production systems , which implies among others reduction of forest area in order to increase the percentage of open pastures and thus the productivity of herbaceous plant species , conversion of native pasture to 'improved' pasture , introduction of artificial fertiliser in order to enhance biomass production , supplementation with crop-residues and agro-industrial by-products , zero-grazing systems , etc . With the help of LCA , environmental implications of intensified production systems (including the above mentioned measures) can be compared with traditional grazing systems .

Material and methods In order to be able to differentiate between extensive grazing systems and intensified animal production systems , consensus on how to include biodiversity and other additional impact categories in LCA is essential . This paper i) describes the steps involved in a LCA , ii) gives an overview on existing publications concerning the use of LCA in tropical and subtropical countries , iii) points out which factors have to be specifically taken into account when applying LCA in tropical and subtropical animal nutrition , iv) and highlights the importance of including additional impact categories in LCA studies .

Results In tropical and subtropical countries , so far , only few LCA studies concerning the sustainability of different animal feeding alternatives have been conducted . However , LCA studies in temperate regions and related LCA studies in subtropical and tropical areas provide a good basis for the application of LCA in subtropical and tropical livestock nutrition . For example , 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 , which are important supplements for livestock in subtropical and tropical areas . Furthermore , LCA studies concerning irrigation-based fruit production and toxicological impacts of greenhouse farming include recommendations concerning the application of LCA in (sub) tropical environments . In several (sub)tropical countries , LCA is gaining importance both in industry and in research , and several groups started to adapt the methodology to (sub)tropical environments and to collect additional region-specific data .

Conclusions For some environmental impact categories , the LCA databases developed in Europe can be used directly , e .g . energy use . However , for other impact categories , data , models and methodology developed for the temperate zone need to be adapted to (sub)tropical environments . 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 . In this context , the combination of LCA with other environmental impact assessment methods and conventional field study techniques and experiments might be useful . 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 . Life Cycle Assessment of different resource use alternatives can help to improve the ecological sustainability of agricultural production in the tropics and subtropics , both by improving the marketability of more sustainably produced goods and by guiding research , consultancy and policy .