Recycling of manure and organic wastes - a whole-farm perspective

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Abstract
As worldwide agricultural production increases, it tends to become concentrated on increasingly larger units. Livestock produce large volumes of manure which, like imported waste materials and crop residues, are a source of valuable plant nutrients and renewable energy, but also a potential threat to the environment and human health. This article discusses briefly the need to assess recycling of organic wastes and manure using a whole-farm approach to avoid a situation where the introduction of new technology and management to regulate one source of pollution will aggravate other environmental impacts downstream in the manure management chain on farms. Some examples of manure N and C turnover are discussed as examples of on-farm interactions.

Introduction
Worldwide agricultural production is increasing dramatically, and it tends to become concentrated on larger production units in order to increase the profitability of the enterprise. Agriculture manages large volumes of animal manure, as well as crop residues and imported wastes. This biomass is both a source of valuable plant nutrients and a threat to the environment.

The whole-farm perspective of agricultural waste treatment and management has been selected as a central theme for the 12th Ramiran conference. The ultimate goal of the work presented in the many contributions is to ensure a rational recycling of nutrients while controlling environmental hazards such as odour, ammonia (NH_3) and greenhouse gas (GHG) emissions, nutrient leaching, and dissemination of pathogens, heavy metals or organic micro-pollutants in the environment.

Research activities typically focus on an individual production factor or environmental effect, e.g., reducing the N surplus of pig diets or increasing the energy yield from organic waste materials in digesters. But with a strong focus on one factor there is a potential that important side-effects or interactions are overlooked or disregarded because they occur "downstream" in the manure management chain.

The best evaluation of a change in practice is obtained using a holistic approach linking feeding, housing, treatment processes, storage conditions and field application practices. Finding practical methods or models to address the whole-farm perspective, however, is a great challenge. Firstly, agricultural production systems are extremely diverse, and secondly the various indicators of sustainability are not always easy to compare.

Manure and waste management in agriculture

Nutrient and organic matter flows on livestock farms are intimately connected with nutrient cycling associated with crop production (Fig. 1), and this connection of course also applies to pollutants and pathogens.

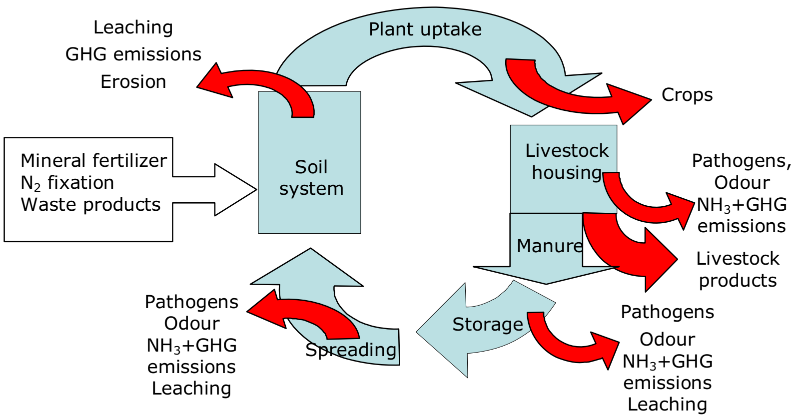

Figure 1. A simplified illustration of carbon and nutrient flows and environmental impacts on a livestock farm.

However, manure and waste management practices vary greatly between different parts of the world. The diversity is illustrated below, but without consideration of economics, nutrient use efficiency, environmental issues or hygienic risks.

In Southeast Asia (i.e., Vietnam) 85% of the livestock is produced by small holders (Tran Thi Dan et al., 2003). Pigs are kept in houses with solid floors, and farmers separate excreta into a liquid and a solid fraction by scraping the solid fraction off the floor by hand. The solid fraction is a commodity sold to farmers producing high value crops like coffee, vegetables, fruits etc. The liquid fraction is channelled to fish ponds, where carp grow on vegetation taking up the added manure nutrients. Sedimented organic matter is emptied from the ponds and used as a fertilizer.

European agriculture handles more than 65% of livestock manure as slurry, that is, a liquid mixture of urine, faeces, water and bedding material (Menzi, 2002). In Scandinavia slurry is typically collected in stores, which are designed to allow for extended storage so that spreading can take place before or during the growing season where a crop can utilize the nutrients. In other countries the slurry storage time is typically shorter and spreading times are often defined by existing storage capacity rather than considerations about nutrient use efficiency. Nutrients are recycled in so far as crops are used for animal feed, or when nutrients are returned to farmland in sewage sludge or other waste products.

The ten new member states of the European Union (EU) face a particular challenge, because subventions and the opening of markets have lead to a rapid intensification of livestock production, with frequent surpluses of nutrients spread on agricultural land. Also, NH_3 and GHG losses, as well as soil pollution with heavy metals, have increased due to the need to comply with the EU legislation banning the land-filling of sewage sludge.

In North America, confined animal production systems (mainly pig production) typically use pit storage of the manure underneath slatted floors. From the pit, excreta are flushed to lagoons where solids are settled and the retention time of the liquid fraction can be several years. The liquid may be discharged via "constructed wetland" treatment systems with intense denitrification, or the liquid may be applied on small spray fields.

Evidently the manure management strategies, pollution risks and needs for import of nutrients in wastes or mineral fertilizers of these systems are extremely different. Still, a set of basic *sustainability indicators* for a common model framework could perhaps be identified which are defined and quantifiable in all systems.

Side effects envisaged through whole-farm analysis

The importance of considering interactions between different parts of a management chain, or between different elements, can be illustrated by previous studies of manure N flows and links with C turnover.

Ammonia emissions from livestock production contribute to soil acidification, threaten N-limited ecosystems, and NH_4^+-based particles in the air represent a health risk for humans. Hutchings et al. (1996) assessed the effect of different mitigation strategies on total emissions from cattle farms with a whole-farm NH_3 model. An interesting conclusion from this study was that establishing a roof on a slurry tank to reduce NH_3 emissions during storage could increase total NH_3 emissions, if no precautions are taken to reduce NH_3 volatilization from the cattle slurry applied in the field. This was due to higher emissions after field application as a result of a higher slurry dry matter content, which in turn resulted from the exclusion of rain water during storage that would otherwise dilute the slurry and facilitate infiltration into the soil.

Ammonia volatilization during manure management and application, as well as N leaching from manure stores, are among the environmental problems which are being addressed in EU member states. National emission ceilings for NH_3 emissions are set in the NEC directive (Directive 2001/81/EC); storage capacity and timing of application are addressed in the Nitrate directive (Directive 91/676/EEC). It is essential that reductions in gaseous and point-source N losses are accompanied by compliance with reduced total N applications rates at manure spreading (such as those specified in Nitrate Vulnerable Zones) otherwise increased N loss from agricultural soil may exacerbate water pollution problems.

It is well known that emissions of methane (CH_4) and nitrous oxide (N_2O) during manure management are influenced by temperature, organic matter composition, nitrogen content and storage time. A recent model therefore linked C and N turnover in a dynamic prediction of CH_4 and N_2O

emissions during handling and use of livestock slurry. The model results indicated that anaerobic digestion, producing CH_4 at the expense of volatile solids, would cause a 90% reduction of CH_4 emissions during the subsequent storage. Also, a >50% reduction of N_2O emissions after spring application of digested as opposed to untreated slurry was predicted (Sommer et al. 2004). The calculations further suggested that daily flushing of slurry from the warmer environment in cattle houses to an outside store would reduce GHG emission by 35% compared to a situation where slurry channels were emptied once a month. Hence, residence time is also an important factor to define.

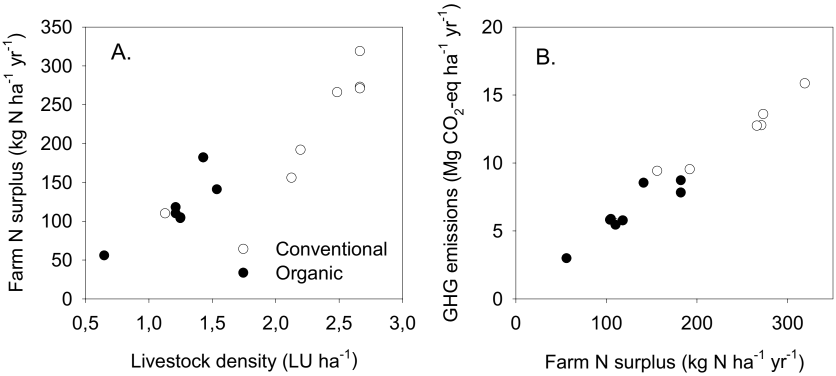

Fig. 2. A strong relationship between livestock density and N surplus (A), and a strong apparent relationship between N surplus and total greenhouse gas emissions (B) has been observed for organic and conventional dairy production (Olesen et al., 2006).

The last example considers a whole-farm model of C and N flows that was used to analyze dairy production under organic and conventional conditions in different parts of Europe (Olesen et al., 2006) and to evaluate GHG mitigation strategies (Weiske et al., 2006). The model quantified internal flows, as well as imports and exports, and it estimated GHG emissions, crop yields and milk production levels. Whereas the strong relationship between livestock density and N surplus (Fig. 2A) was not unexpected, it was interesting that the relationship appeared to be the same for extensive (organic) and intensive production systems. Even more surprising was the apparent relationship between N surplus and total GHG emissions (Fig. 2B), a relationship that was also observed by Schils et al. (2005) using a different model.

Conclusion

The examples of the previous section indicate that the consequences of introducing new technology or changing management may be difficult to predict without the support of a whole-farm model with quantitative descriptions of nutrient transformations and emissions at the different stages of a production cycle.

A model framework containing a set of basic, inter-linked sustainability indicators could be used to evaluate overall effects of new technology or management at an early stage. Ideally, this could ensure that research and development of one particular aspect of manure and waste management does not increase health risks or environmental problems elsewhere on the farm.

The many contributions for the conference have been allocated to one of seven main themes (see below). We hope that, by bringing together topics such as feeding strategies, manure and waste treatment and handling, energy production, hygienization, monitoring of nutrient flows and modelling, and with the participation of researchers representing a wide range of agricultural systems, we can strengthen the whole-farm perspective and practical relevance of the discussions.

Main themes of the 12th Ramiran conference

Energy production - biofuel & biogas, incineration
Livestock production, ammonia and greenhouse gases
Treatment technologies for organic effluents
Measuring and monitoring nutrient flows and emissions
Merging models for predicting emissions and nutrient leachings
Feeding of livestock - manure composition
Technology needs in the developing world

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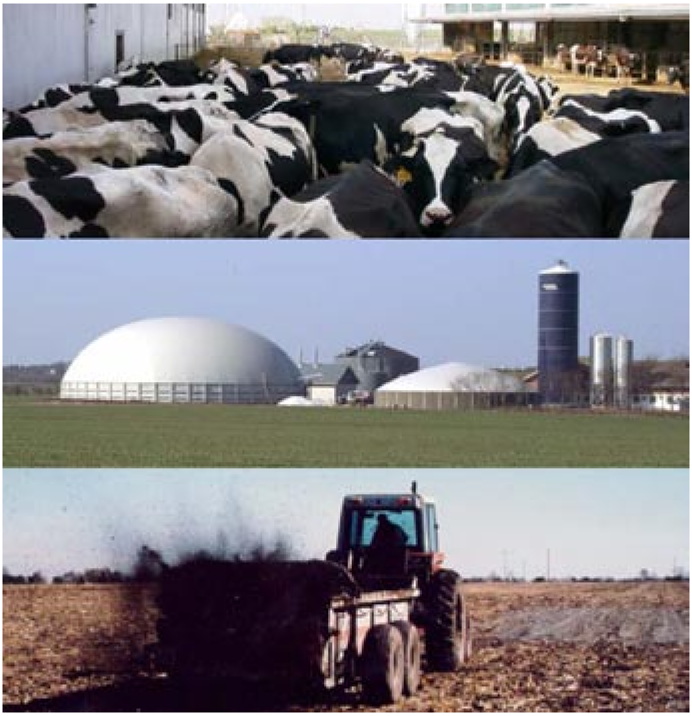

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