Manure and nutrient management in a system of Area-Wide Integration (AWI) of intensive livestock and crop production in Jiangsu Province

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Background

Fast growing pig and poultry production around big urban centres in South East Asia is posing an increasing threat to the environment because the livestock production is largely concentrated on specialised farms with little or no land to use the animal excreta. In the framework of an international initiative coordinated by FAO, options for an area-wide integration of specialised livestock and crop production are developed. One of the four project regions is Jiangsu Province, West of Shanghai. The first phase of the project focused on a detailed assessment of pig production, nutrient fluxes and options to improve the pig waste management on a regional basis. The Swiss College of Agriculture (SCA) is supporting the Chinese national project team coordinated by the Research Centre for Rural Economy (RCRE) in questions concerning the manure and nutrient management. One contribution to the AWI project was the development of a calculation model to quantify nutrient fluxes and balances of intensive livestock production (NuFlux-AWI; see attachment).

Conclusions from the first phase of the project

Livestock production and its environmental impacts

Environmental impacts from pig production are already a serious problem and could be catastrophic if pig production continues its strong growth without improving the manure management. An improved manure management in which manure is recycled as fertiliser on crops is therefore a precondition for livestock growth.

Even though solid manure management could certainly also be improved, improvement should first focus on liquid manure and slurry. Discharge of animal wastes to water courses should not be tolerated. A change from the traditional system with in-house separation of solid and liquid manure to systems producing only slurry should be prevented. Sufficient storage capacity for liquid manure should be built and appropriate technologies for the transport and spreading of liquid manure should be studied. Farmers should give great care to reduce the dilution of their liquid manure by using less water in the animal houses and by preventing large amounts of rainwater to get into the liquid manure.

A regional equilibrium of the nutrient balance should be reached. Total nutrient input (manure and chemical fertiliser) to crop production should not surpass the nutrient demand of the crops. The P_2O_5 input in pig manure should be reduced by lowering the P-content of the feed.

Limits of implementing an area-wide integration of specialised livestock and crop production

Big livestock units are not possible without an area-wide collaboration between livestock and crop production. Nevertheless the implementation of such a concept will not be easy because it brings short-term disadvantages to both sides (compared to today's situation). For the livestock farmer, the construction of sufficient and appropriate manure storage capacity will be costly. For the crop

farmer costs for handling the manure (transport to the field and spreading) will in most cases be higher than today's costs for chemical fertilisers. Furthermore, an exact dosing of nutrients according to crop needs will be more difficult because of the unsure and variable composition of the manure as compared to chemical fertiliser. An improved manure and regional nutrient management will therefore only be possible if it is clearly demanded by an implemented policy, and if farmers are given appropriate recommendations and possibly financial support.

A sustainable manure and nutrient management will not be possible without additional costs. Costs can therefore not be the main argument for deciding what should be done. Nevertheless it will be very important to keep costs in mind when evaluating in more detail what manure storage, treatment, transport and spreading techniques would be most appropriate. From the viewpoint of the provincial or national economy, a support of the investment in the manure management on farms will most certainly be more economical than dealing with ecological problems later.

Apart from the costs, the reluctance of crop farmers to use liquid manure on their crops will probably be the biggest difficulty to overcome before an AWI concept can be implemented. It will not only be necessary to organise demonstration experiments showing the feasibility of such practice and to provide reliable recommendations on the optimal manure use but to also to find means how crop farmers can share in the profit of livestock operations.

The bigger a livestock farm, the more difficult the manure management will be. Costs can be assumed to be lowest for medium sized farms, because manure transport will become very costly for very big units.

Implementing a policy requiring a regional nutrient equilibrium will be further complicated by the fact that chemical fertiliser use is often already higher than recommended.

In view of the great complexity of the problem, a successful introduction of an AWI concept will only be possible with a wide and intensive collaboration of policy makers, scientist from different fields and representatives of livestock and crop farmers.

Nutrient flux model

NuFlux-AWI has already been a very helpful tool for the assessment of the nutrient fluxes and balances. Its results were an important input for GIS-maps on the present nutrient balance situation. Thanks to the competent inputs of different experts from Nanjing and the high flexibility of the model, the values on nutrient excretions of cattle and poultry can be considered to be reliable within ±20% or better. The values on amount and composition of manure are still less reliable because of lacking input data on relevant processes. Nevertheless the comparison with survey results is promising. Measurements from future project activities will allow a continuous validation and improvement of the model.

The results of the AWI project and our further assessment of livestock production systems were also an important input for livestock density and nutrient balance maps recently developed by FAO.

Outlook

The first phase of the AWI project can be considered highly successful in analysing the situation, building up the awareness about the sustainability problems caused by the present development and identifying options to guide the development into a more sustainable direction. The key to the success was the excellent collaboration between experts from different institutions in China as well as from Switzerland, Denmark and FAO. The next phase of the project and a possible extension of the activities across a wider part of South East Asia are in the planning phase. It can be hoped that the results and tools for the AWI project can also be utilised in other regions.

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NuFlux-AWI: A CALCULATION MODEL TO QUANTIFY NUTRIENT FLUXES AND BALANCES OF INTENSIVE LIVESTOCK PRODUCTION IN DEVELOPING COUNTRIES

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Abstract

NuFlux AWI is a user-friendly Excel-based calculation model to assess the nutrient fluxes of intensive livestock production and manure management. It was developed in the framework of a project on area-wide integration of specialised livestock and crop production currently running in Thailand, China, Vietnam and Mexico under the coordination of FAO. The model can be used for regional or farm-specific nutrient and heavy metal balance calculations and as a planning tool for manure management. It provides results on nutrient excretions, amount and composition of different types of manure from pig and poultry production and nutrient losses to the environment. It is possible to use the model with integrated region-specific default values on livestock and crop production or with more specific input data.

Key words: manure management, nutrient balances, pigs, poultry, environment, model

Introduction

A rapidly growing demand for livestock products has led to fast growing intensive pig and poultry production in various countries of South East Asia and Latin America, especially near metropolitan areas. The development is expected to continue in the coming years. The new specialised livestock operations are to a large extent on farms without or with little own cropland. Especially the liquid animal waste is therefore often not utilised, but discharged to the environment. This leads to a considerable pressure on the environment. In the framework of the International Livestock, Environment and Development Initiative (LEAD), FAO has launched a project to develop and implement new systems of Area-Wide Integration (AWI) of specialised livestock and crop activities. The project aims at developing ways to "remarry" livestock and crop production on a regional scale, to thus enable a sustainable manure management without loosing the economies of scale. National subprojects are currently under way in areas of Thailand, China, Vietnam and Mexico. To analyse the present situation, to evaluate development scenarios, to monitor the future development and to support farmers in the correct management of manure and fertilisation, tools are needed to quantify nutrient fluxes, manure quality and value and environmental effects. To satisfy this variable needs, NuFlux-AWI was developed. NuFlux-AWI is a user-friendly Excel-based calculation model that calculates all relevant fluxes of intensive livestock production and manure management.

Design of the calculation model

"Terms of reference" for the model

An analysis of the needs of the projects and the different project participants provided the following requirements for the nutrient flux and manure management model:

- Tool to provide a robust indicator of the livestock pressure on the environment at various scales (e.g. region, province, farm), on the basis of the sparse available information. It should adapted to various farming system and the conditions in different countries.

- Tool to support the improvement of fertilisation (e.g. amount and composition of manures); especially the proper substitution of part of the mineral fertiliser with manure.
- Planning aid for manure distribution to different crops on farm and regional level.
- A user-friendly and easy to update tool which can cope with different levels of detail and reliability of input data (e.g. regional calculations with standard values and farm-specific calculations where relevant management variables for pig, poultry and crop production.

General approach of the model

The model is designed to calculate fluxes for pig and poultry in more detail than for ruminants, because monogastrics contribute more than two thirds of the manure in most project regions and because detailed information on ruminant rations are difficult to get.

The model starts the calculations with the most reliable available information: production parameters for livestock (beginning and end weight, amount and composition of feed used), nutrient demand recommendations for different crops etc. As shown schematically in figure 1, the steps for the calculation are then (i) nutrient excretions, (ii) amount and composition of fresh manure, (iii) amount and composition of manure available for crops, (iv) nutrient demand of crops, (v) nutrient balance. A special module provides a tool for planning the distribution of the different types of manure to different crops.

For the nutrient balance, both a supply/demand balance and an import/export balance can be calculated. The supply/demand balance is recommended as standard, because it is easier to get the necessary input data and it is more robust to lacking or unreliable inputs.

The model is equipped with regional default values for all the relevant variables concerning livestock and crop production. These default values which characterise a standard or average management for each project region were put together with local experts. The whole set of default values can be replaced when introducing the model in a new region. If more specific information is available, each default value can be replaced in user-friendly input screens.

Input data livestock production

Detailed calculations of the nutrient fluxes and the manure quantity and quality are done for the following livestock categories: Breeding sows, piglets, fattening pigs, boars, laying hens, young hens, broilers. For each of these categories two production systems or intensities (e.g. high-yielding international breeds and native breeds) are differentiated. For other livestock categories default values for the available manure nutrients (excretions minus losses) are integrated. Such default values are currently built-in for dairy cattle, other cattle, Horses, donkeys/mules, sheep and goats. The list can be changed easily.

The list of relevant management variables that are taken into account for each pig and poultry category includes the following elements:

- Production parameters: e.g. beginning and end weight, duration of rotation, feed conversion ratio.
- Housing systems: systems that produce only liquid manure, systems with liquid and solid manure, systems with only solid manure.
- Feed ration: Choice between one feed and phase feeding; amount used per rotation and composition (crude protein, P, K, Mg, Cu, Zn) of each feed
- Bedding material: share of animals with bedding material and average amou
- nt used per animal per day; choice of three bedding materials.
- Cleaning water use (for pigs only): amount of water used per animal per day or amount used per day for the whole heard (with or without drinking water).

For the amount of fresh excreta per animal per day (fresh, dry and organic matter) assumptions had to be made on the basis of the experience from Switzerland and the project partners.

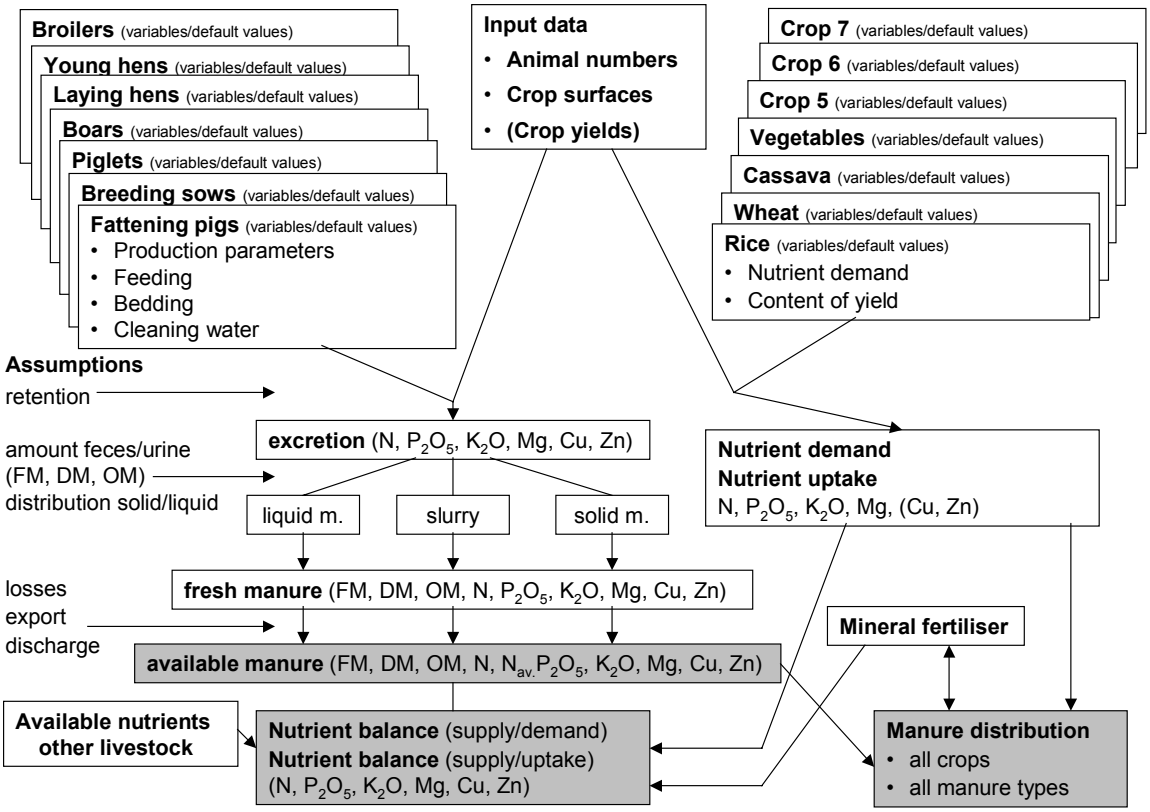

Figure 1: Schematic structure and path of calculation of the model.

Input data crop production

For each project region, all relevant crops are included. A list of maximum 49 crops is possible. For each crop the nutrient demand recommendations for N, P_2O_5, K_2O and Mg are included. To allow import/export balances, the nutrient and heavy metal uptake and the yield can also be entered. The nutrient demand is given per local surface unit.

The actual total amount of mineral fertiliser used (N, P_2O_5, K_2O, Mg, Cu, Zn) must be entered for balance calculations.

Other variables and assumptions

Assumptions were necessary for the distribution of the excreted fresh, dry and organic matter and each element to liquid and solid manure in the corresponding housing system as well as for the losses in houses and during storage. They were be made on the basis of the experience from Switzerland and the project partners. They are now continuously validated and improved with measurement results in the projects. They can easily be changed individually.

Outputs of the model

The output of the model includes the following parts, which can be jumped to individually:

- Nutrient and heavy metal balance: total balance in kg or tons and in percent of the crop nutrient demand and uptake (if chosen). For easy interpretation a colour code with 6 classes is used to show the balance in percent of the crop demand and uptake.
- Amount and composition of manure: For each of the three pig and poultry manures the total amount (fresh, dry and organic matter) and the composition (dry matter, N, P_2O_5, K_2O, Mg, Cu, Zn) in kg/ton is given.
- Summary of intermediate results, manure export and discharge etc.

- Summary of inputs: animal numbers, crop surfaces, nutrient demand of crops
- Summary of all default values

Languages and translation

To allow an easy translation of the whole model (not program code), all the text is referenced to a translation sheet (about 1000 lines). The whole model can be changed to any language included in this translation sheet with one mouse click. At present English, Thai and Chinese are integrated. Translations to Spanish, Vietnamese, German and French are under way.

Programming tools and user manual

The model is a Microsoft Excel file with Visual Basic applications. It can be run on any machine equipped with Microsoft Office 97 or higher. The model can be distributed in a compressed version on one floppy disk.

A detailed user manual is available in English.

Possible applications of the model

The model is equipped with three user modes:

- General user mode: For calculations with default values. Only animal numbers and crop surfaces must be entered. No practical background is necessary. This mode is useful for regional balances (e.g. for scenario calculations on the policy level).
- Advanced user mode: All the default values for livestock and crop production can be changed to more specific data. This approach is recommended for farm-specific calculations and for more detailed scenarios. An agricultural background is recommended.
- Expert user mode (password protected): Meant for the "national operator", who can change the default settings.

The main screens, the output and the calculation procedure are the same in all modes. This congruence is important to assure that compatible results and conclusions are arrived at.

In the AWI project, the model has so far been used to calculate regional nutrient balances and manure quantities and composition for individual project farms. The results on nutrient excretions were also extensively used in more detailed GIS-applications (nutrient balance maps, development of decision making tools for policy makers etc.).

Outlook

The accuracy of the model depends on the reliability of the available input data. While the results on nutrient excretions are probably already within an accuracy of $\pm$20% or better, the results on manure quantities and composition are not very reliable yet, because practically no information was available on the distribution of the excreta solid and liquid manure, losses from lagoons etc. for the project regions or comparable conditions. Measurement results from the projects will allow to continuously improve the reliability of the results. The iterative validation and up-dating of the model will therefore be continued.

The model was developed for countries in Asia and Latin America. Nevertheless, with the necessary adaptations, it might also be a valuable tool in Europe. The results can even be expected to be more reliable because of better input data and because better assumptions backed by research will be available. A beta version of the model can be downloaded on the LEAD Virtual Centre (http://lead.virtualcentre.org/selector.htm; R&D, AWI).