A computer-based Expert system to support the selection and implementation of systems for sustainable livestock waste management in South-East Asia

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Dissemination and knowledge transfer remain a challenge in many fields of research. This is especially the case for the application of livestock waste management in developing countries where there an overwhelming volume of material is already available to the farm advisor and the real need is often the transfer of such knowledge to the local level. The object of this project is to package up suitable techniques as an EXPERT and design system that can be applied directly to farm situations across South East Asia. A crucial aspect of the approach is to enable local people to make decisions based on the best available information – hence the descriptive title, as a "Decision Support Tool" or DST. The specific objectives of the package are to (i) serve as planning tool for the design of the selected manure management strategy (including cost calculations); (ii) to specify designs of the most appropriate manure management strategy including treatment options and/ or recycling; (iii) to predict the amount and the composition of the resulting manure and manure products; (iv) to provide a planning tool for the distribution of manure and manure products to crops and (v) to support the analysis of the environmental impact of livestock farms for any given proposed scenario. The software will comprise both calculation models (e.g. nutrient excretion of animals, nutrient balance, design and costs of manure treatment facilities), and decision tree elements (e.g. providing a structured analysis of the present situation at a given farm). Outputs will include summary reports providing specific recommendations, specifications, case study examples and supporting multimedia background information.

Introduction

In many developing countries and especially in the growing industrial economies of South-east Asia, livestock production is currently expanding at unprecedented rates. This process is driven by the increasing demand for animal products that is a consequence of population growth, urbanisation and income growth (De Haan, 1998). Delgado *et al.* (1999) give the annual growth rate for meat production as 8.4% in China and 5.7% in S.E. Asia between 1982 and 1994. Between 1997 and 2020 the average annual growth of consumption is predicted to be 3.0% in China and 3.3% in South-east Asia (Delgado et al. 2002). The main consequences of this trend are (i) a rising concentration of livestock farms located near large industrial cities, (ii) an intensification and specialization within animal production leading to an increase of the average farm size and (iii) a shift from ruminant livestock to dedicated meat production animals, especially pigs and poultry. Such developments have already lead to the disruption of local nutrient cycles in which manure was recycled locally on crops. A proper structured use or disposal of the livestock excreta and the large quantities of waste water is no longer readily possible: increasingly, the wastes are simply lost to the environment. This is leading to serious environmental impacts (Menzi and Gerber 2005), such as eutrophication of surface waters, the leaching of nitrate (and sometimes pathogens) to surface waters, the accumulation of nutrients and heavy metals in the soil and increased emissions to the atmosphere (especially ammonia and methane). In South East Asia the extent of these impacts is becoming very apparent and it is recognized that urgent measures are necessary both at the technical and the policy level.

The LWMEA project

Since 2000 the Food and Agriculture Organisation through the LEAD initiative (Livestock Environment and Development Initiative) has developed projects in South-East Asia based on the current ecological impact from intensive livestock production and potential measures to improve the situation. A review of developing agriculture was carried out in the initial phase for Thailand (Rattanarajcharkul *et al.* 2000), Vietnam (Dan *et al*. 2005; Hoa *et al*. 2005) and the Jiangshu Province in eastern China (Fang *et al*. 2000). In 2006, the World Bank project Livestock Waste Management in East Asia (LWMEA) was launched with the objective of implementing and evaluating abatement technologies in a series of study areas across the region. Supported by the Global Environment Facility (GEF) and the FAO, the objective of the project is the dissemination of effective waste management technologies to reduce the negative environmental impacts of livestock, both by demonstration and by facilitation of technology transfer. In Thailand, Vietnam and China national projects have been set up to put into place demonstrations of good manure management and treatment practices on selected farms. In parallel, the process of developing appropriate policies along with monitoring programs to evaluate the impact of the measures introduced is being supported. In a regional component (managed by FAO) crucial supporting measures are being developed including the exchange of experiences amongst the project countries and other countries in the region. A central objective is the preparation of a series of Decision Support Tools (DSTs) to support manure handling, policy development and regional planning activities. One of these will specifically address the technical need to evaluate the situation at a given farm and to provide a detailed design of the selected most appropriate treatment and management system: described here, the DST software is identified by its interim name MAUREEN (MAnure Utilisation for REcovery of Energy and Nutrients).

Objectives of the MAUREEN software

The planned DST software on livestock manure management and treatment is intended to be a user-friendly aid to those involved in extension services including government specialists on agriculture, farmers' associations, farm advisors, companies involved in agriculture, researchers and local technical support groups. It is not expected that farmers themselves would directly use the service but they would not be precluded. The package will seek to:

- provide details on the design and construction of the chosen manure treatment facilities and give appropriate advice and instructions for their proper use, including general measures in livestock production;
- evaluate different manure management strategies taking into account the farm specific conditions, the achievement of ecological aims and legal restrictions, costs, technical feasibility and the priorities of the stakeholders concerned;
- provide guidance for good practices on animal waste management, from livestock production and manure collection to recycling and discharge;
- analyze the present strengths and weaknesses of intensive livestock production with special focus on environmental impacts (water and soil pollution, emissions etc);
- develop manure and nutrient management plans for the correct distribution of the manure that shall be recycled and provide corresponding recommendations..

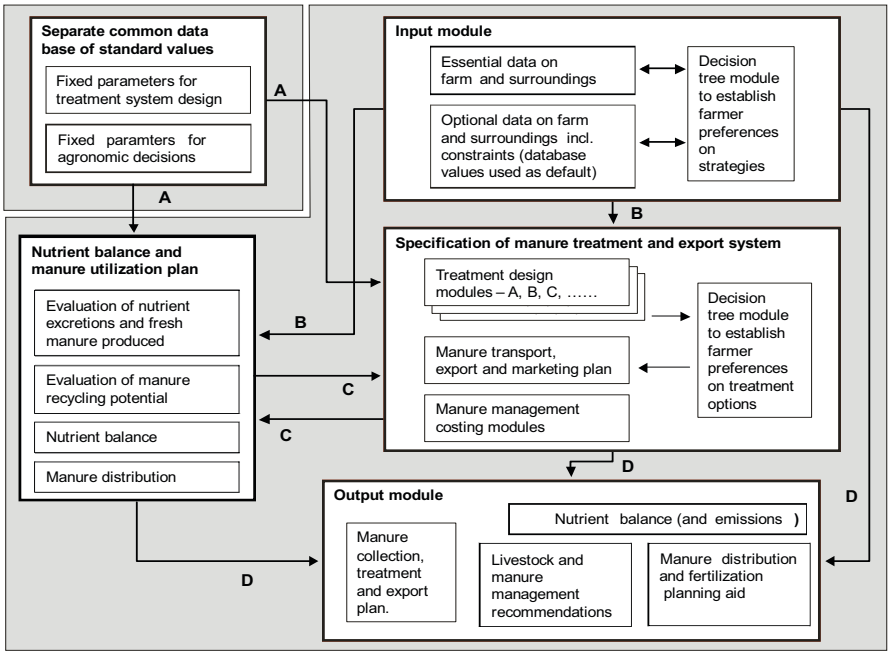
The software package will focus on intensive production systems for pigs, poultry and (where they exist) dairy and beef cattle as well. While the manure treatment parts will mainly address pig manure, the environmental impact and manure recycling modules will

also address poultry and dairy cattle manure. All current options for treatment and recycling will be included. Farm specific calculations will take into account livestock management and feeding, housing and manure handling systems, different manure treatment options, and manure use on crops and in fish production. The design criteria will reflect the key environmental parameters (in decreasing order of importance): (i) main water pollutants – nitrogen, phosphorous, organic matter and pathogens; (ii) gas emissions – methane, nitrous oxide and ammonia; (iii) other pollutants – pathogens, heavy metals and offensive odours.

General structure of the proposed package

The structure of the software will be divided between the principal programme (including input and output modules and the principle calculation routines) and an extensive database that will provide a source of all data needed in the programme (Figure 1). The core program will include both the calculation routines and decision making elements.

Figure 1: Schematic structure of the different modules of the MAUREEN software. The complete package is the operation of two distinct programmes together: a core programme and a separate comprehensive data file. The later is customised for each country and thus enables a wide spread use. By updating the software data base, the package can be kept up to date and relevant as the industry develops.



The full set of data will be provided by (a) specific descriptive data of the farm that defines the local situation, (b) preferences given by the operator in the event of choices to be made, (c) answers by the operator to specific questions from the system and (d), data drawn from the database including default values in the event of any data not being supplied. Of special note is that the core programme will include not any data itself: it is thus independent of features that describe a local scenario or the specific application of technology. As such, it is expected to be relatively generic and therefore able to adapt

to the inevitable future development of the industry. Furthermore, its adaptation to other countries or regions will be enabled by the preparation of the appropriate database to effectively customise the package for that region. Hence, adding a data-base populated with data describing livestock agriculture in Thailand in 2008 (for example) will make the package relevant to that country for a few years around that time period. The package will include numerous checks against poor or illogical data especially that supplied by the user – warnings will be included and in crucial places, selection may be constrained by a drop-down menu to ensure that realistic or existing options are chosen such as pump size or pipe diameter. The DST will also contain relevant background information files to provide the user with supplementary information if requested. The output will be both via the interactive operation of the programme (data and values supplied at each stage) and in the form of a report providing either the summary or details of the final system recommended.

Software Design and Programming

The MAUREEN package will be a user-friendly tool that will facilitate genuine improvements in the practical decision-making capacity of users. The software development will incorporate the following key design features:

- an interface design process that will be interactive, incorporating feedback from user groups to ensure that the operation of the software is as intuitive as possible;
- the initial inclusion of a data file for each of the three target countries. These datasets will be readily upgradeable (via an internet download). There will be the option to modify existing datasets or the addition of new ones for other countries or regions;
- the software itself can be updated (again via internet download) to allow the distribution of bug-fixes or improvements to both the user interface and model components.

General structure of the proposed package

Programming of the user interface and core model is being carried out in CodeGear Delphi™ and the model components described above will be implemented in an object-oriented fashion. An object-oriented approach ensures that data and functionality in the elements of the core model are tightly bound together. This should lead to more effective control of coding and semantic errors in the model as well as greater flexibility in the use of model components for different purposes. Internet awareness, to support the updating of software and data, is provided via a Simple Object Access Protocol (SOAP) connection to an online maintenance database implemented on a MySQL™ server platform.

The common database

The common database will include all general assumptions (e.g. technical, agronomic and ecological) along with fixed parameters, both for the manure treatment (e.g. equipment costs and availability) and livestock production (e.g. excretion volume from different livestock categories, distribution of excreta to liquid and solid manure in different housing systems, nutrient requirements of different crops). It will contain all default values for livestock production (feeding practice, production parameters, water use) and background information (*e.g.* national legislation, scientific articles and possible multimedia elements). In later versions of the package, a language database will be included to enable the replacement of labels and some text with Chinese characters or written language used in other Asian countries participating.

Input module

The input module comprises three data collecting components:

1. The collection of all the essential descriptive information about a specific livestock farm (or group of farms) and its surroundings which is needed for case specific calculations – livestock numbers and type, current livestock and manure management practices, cropland and fish production activity on the farm (or in the neighborhood) that is available to receive manure.
2. The collection of management parameters for which default values for standard practice could be used where the farm-specific information is not available or not reliable (e.g. production intensity, feeding practice, water use).
3. Information acquired by decision tree elements where initial preferences must be made by the operator such as an option to collect solid dung for separate bagging up and sale.

Nutrient balance and manure utilization plan

The application of a nutrient balance and manure utilization plan will calculate the nutrient and dry matter fluxes resulting from livestock production. This will start from the excreta from the animals, move to the collection of different types of manure, and proceed to the requirements of local crop or fish production. These nutrient fluxes are also used as input for the manure treatment calculations. The programming will draw from the existing model NuFlux which was developed in a previous project, but which did not include manure treatment (Menzi et al. 2002). It will establish and interpret the nutrient balance between livestock production and the local recycling potential (Menzi and Gerber 2006). Furthermore it will be used to establish fertilizer plans, manure distribution plans and other guidance for manure recycling.

Specification of manure treatment and export system

Based on the difference between the effective capacity of the local environment and the predicted amount of manure and other wastes being produced, the imbalance (if it is the case) is addressed by one of a series of treatment options. These will be grouped around options based on export (of manure or of manure products), treatment to eliminate excess unwanted components or treatment that will enable an improved quality (especially in terms of hygiene) that will enable other local fields to be included in a revised calculation. Treatments themselves will fall under one of a series of categories including separation (with and without composting of the solids removed), decantation, aeration, anaerobic digestion (with or without electricity production), drying options, lagooning and filtration systems (for dilute effluents).

Output module

The output module will present the results of the various calculations, decision trees and recommendations derived from them. It will also provide the opportunity to access background information and case study examples. Thus on receiving the final output, the operator will be able to make supplementary enquiries to enable an understanding of the process that has concluded with the proposed system.

Perspectives

In order to make this model a user friendly tool that is widely used, it is essential to find a good compromise between the extent of comprehensiveness) and its simplicity in

use. This implies that the wishes of and feedback from the national project teams and other stakeholders should be consulted throughout the model development process. During the preliminary consultation process completed in 2007, the enthusiasm and the expectations were high: the proposed software was seen as potentially valuable both as a planning aid and for awareness raising. However, for a complete impact there must also be additional dissemination via farmer-friendly summary leaflets, demonstration schemes and multimedia material (that are derived from the model) for the dissemination of the information to the farmers themselves. Validation of some parts of the model using experimental measurements may be necessary to add to credibility – this task is beyond the scope of this current project – however, current relevant experimental results from the systems monitoring within the framework of the parent LWMEA project will be utilised. Such work has for example already been started at the Asian Institute of Technology (AIT). The MAUREEN software package will be launched in the Spring of 2009.

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