Agrammon: A new internet based model for the differentiated estimation of ammonia emissions from individual farms or at the area-wide scale

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Abstract

A new model ("Agrammon") for the calculation of ammonia emissions from farms is being developed in Switzerland. Agrammon is a model based on the simulation of the nitrogen flow and allows to consider the complex interactions between different stages of the manure management chain. For animal houses and slurry storage, the emission rate also depends on the size of the d emitting surface. The model considers all structural and management parameters that influence emissions and that are known to the farmer without special investigations. It allows for scenario calculations and the comparison of results with baseline scenarios. Apart from the use for emission inventory calculations based on farm and management data from a representative survey, the model will be made available to a wider public via the internet.

Based on expert consultations and new literature the algorithms from the predecessor model DYNAMO were reviewed, revised and transformed into standardised formal process descriptions. These descriptions can be automatically converted into executable model code by a parser implemented in the Perl programming language. The parser also generates a user interface for input of model parameters. For making the inventory, an interface to a relational database is provided. The database serves as archive for consolidated data from farm surveys or as storage of individual input data of registered users as well as for plausibility testing and statistical analysis of the data.

Introduction

As ammonia emissions from agriculture are increasingly recognized as a serious impact to the environment and a loss of resources for farms, international agreements, new national policies and extension service campaigns aiming at the reduction of emissions have gained in importance during the past years. They all depend on reliable estimates of emissions which are able to take into account relevant farm management and structural parameters that influence emissions. The same is true for the reporting obligations on the development of emissions under the Gothenburg Protocol.

In most countries of North-western Europe modern inventories on ammonia emissions from agriculture use empirical models based on the nitrogen (N) flow and that take into account important aspects of farm and manure management as influencing factors for the calculation of emissions. An overview of such models in the UK, Germany, Denmark, Netherlands and Switzerland is given by Reidy et al. (2007a) who compared these models in the framework of the European Agricultural Gaseous Emissions Inventory Researchers Network (EAGER).

One of the first N-flow models to estimate ammonia emissions from agriculture was described by Menzi and Katz (1997) who developed it to generate a new Swiss inventory of agricultural ammonia emissions. The model was later revised and extended to consider a much wider range of influencing factors (Menzi and Reidy 2005), because the inventory for 2000 did no longer rely on expert judgement for farm and manure management but

on a detailed representative survey which allowed a much more detailed and reliable consideration of such "activity data" (Reidy et al. 2007b). The emission calculations were therefore no longer performed on a national or level but rather for 1950 individual farms. The results were then compiled to average values for 36 farm classes differentiating between three geographical areas, three altitude levels and four farm types. From the beginning it was an important goal that the new model DYNAMO (DYNamic Ammonia MOdel) should not only be used for inventory calculations but should also be implemented as a user-friendly tool that farmers and extensionists could use to evaluate the emission status of individual farms and to perform scenario calculations. Such scenario calculations could be a powerful tool for awareness raising and for evaluating emission abatement options. However, DYNAMO was never released publicly because disagreements between the trends of emission inventory data and immisson measurements lead to an extensive review. Although this review did not reveal major weaknesses of the model it was decided to develop a new model, both for the inventory calculations and for public use. The aims of the model revision were:

1. To revise and up-data all the emission factors and calculation algorithms in view of new scientific data, the results of the review and the conclusions from the EAGER network (Reidy et al. 2007a).
2. To include mineralization, immobilization and denitrification processes in more detail.
3. To put the model on a new programming basis which will make it more transparent, more flexible for later modifications and extensions and to make it accessible via the internet.
4. To produce a detailed and transparent documentation of the model.

Form the beginning it was the aim that the new model should - like DYNAMO - be suitable both for the emission inventory calculations and as publicly available internet tool for scenario calculations by farmers and extensionists.

An interdisciplinary team of experts in agronomy and emissions, air monitoring, data handling and programming was mandated with the development of the new model. The project is supported by the Swiss Federal Office for the Environment (FOEN).

Model design

The new model with the provisional name "Agrammon" basically follows the same N flow approach as its predecessor to allow the consideration of the complex interactions between different stages of the manure management chain. Following the requirements of the new draft Corinair guidebook for tier 3 emission calculations emission factors in percent of the soluble N (total ammoniacal N – TAN) are used. This partly differs from DYNAMO where emissions for animal houses, grazing and generally for poultry manure had been expressed relative to the total N flow (N_{tot}). Separate flows are considered for liquid and solid manure. The model does not calculate the N excretion of the animals but uses the regularly revised official national guide-values (Walther et al. 2001), which are also the basis of the nutrient balance regulations. However, the influence of milk yield level and special feed rations (e.g. maize silage during summer feeding) on N excretions is considered. For pigs, N excretions and the proportion of TAN are adjusted if feed with reduced protein content is used.

During grazing, emissions in animal houses are reduced less than proportional to the time that the animals are outside, because it is assumed that the emitting surface remains (except for 24 h grazing). As an exception to the general approach, emission factors for slurry storage are not given in percent of the TAN flow but rather per m^2 of storage surface,

because the emitting surface remains the same even if the N flow through the storage is reduced due to grazing (except for 24 h grazing for all animals). Higher emissions are considered for animal housing systems in animal welfare label programs to account for the higher surface per animal and especially the mandatory exercise yard.

The major farm and manure management variables considered by the model are the housing system, special feed components or feed with reduced protein content for pigs, the duration the animals spend outside the house (grazing and exercise yard), the floor type of exercise yards, the slurry storage system and the existence and type of a cover, the slurry storage surface area, the slurry spreading technique, incorporation of solid manure, the proportion of manure that is spread during summer months (June to August), the consideration of climatic factors and daytime of application when choosing the slurry application time, and the amount and type of mineral N fertilizer used. The basic philosophy for choosing these influencing factors was that variables have to be relevant for the emissions and that the information is readily available on the farm without any special measurements, records or investigations.

Development procedure for the new model

The development of the new model included the following major steps:

- Review of emission factors and underlying assumptions behind the model.
- Revision and structured documentation of the model algorithms.
- Model design and implementation (programming).
- Design of the relational database used for the management of activity data and results.
- Extensive model testing.

Revision and structured documentation of the model algorithms

All the processes considered in DYNAMO were reviewed and revised on the basis of a review of new literature, the results of workshops with experts from different fields and experience gained during the past years (e.g. in the framework of the EAGER network). The more detailed consideration of immobilisation, mineralization and denitrification processes was based on the German emission model GAS-EM (Dämmgen et al 2006). Wherever possible the algorithms were simplified. The product of this task was a detailed standardized description of all the processes to be considered.

Model design

The following considerations were used as guide lines for the implementation of the Agrammon modeling environment:

- The model algorithms must be documented in a form understandable to scientists without special training in software engineering or programming.
- The documentation should be closely coupled to the actual implementation for ease of maintenance and accuracy (especially during modifications).
- The implementation of model improvements must be possible with minimal programming effort.
- Changes to the model algorithms must be tracked so that model results can be attributed to the actual model code or algorithms they were produced with.

Overall, for the whole life-time of the model the interpretation of simulation results must be reproducible and interpretable based on the underlying scientific process descriptions.

The first three goals described above can be reached by automated code generation from the standardized process descriptions. These process descriptions contain both a scientific documentation and the mathematical formulation of processes covered by the Agrammon model. While the scientific documentation is almost "free form", the mathematical formulas must follow a more strict "machine-readable" syntax. Each model process is described in a separate (ASCII-coded) file, following a defined syntax. This description consists of the following sections:

- Section "general" (required): lists some information about the document ownership and history, followed by a short and a more detailed process description. For formatting purposes syntax elements of the LaTeX text processing system can be used, thus allowing complex layouts as well as aesthetically pleasing mathematical formulations.
- Section "technical" (optional): lists all model intrinsic (technical) input parameters including their values, units and textual description. These parameters can be considered to be part of the actual model version and are not specific to a specific farm.
- Section "input" (optional): lists in a similar manner all user-definable input variables, e.g. parameters specific to the individual farm.
- Section "external" (optional): specifies all sub-processes on which the current process depends. The output parameters (see next section) of these sub-processes are used in the mathematical formulas describing the current process and thus "link" the various sub-processes together.
- Section "output" (required): describes the actual calculations done for the process covered by the model descriptions, using technical and input parameters described in the sections above as well as output parameters from other ("external") process descriptions. The syntax used for the mathematical formulas is based on the Perl programming language, slightly simplified for referencing external processes (i.e., some "magic" is applied during code generation to hide syntactical details from the more scientifically interested users).

Figure 1 shows a block diagram of the Agrammon software environment. The textual process description (on the left) are read by the Agrammon parser and after a check for syntactical correctness translated into:

- executable model code,
- an input parser capable of reading and verifying model input (both for technical model parameters and user input),
- and printable documentation (in PDF-format).

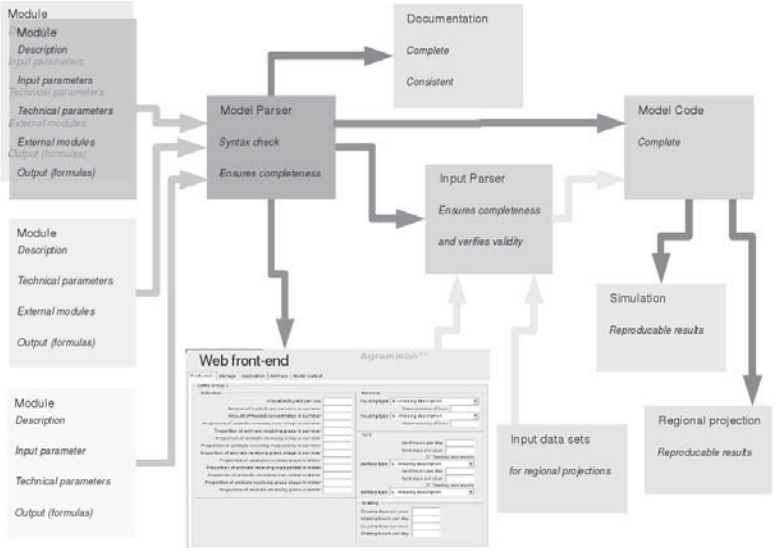
While these components are sufficient for running Agrammon simulations (especially for batch processing of large amounts of input data sets), in addition, code for a "single-user" (web-based) graphical user interface can be automatically generated directly from the process description files.

With this set-up the process description files can be maintained and extended easily with relatively little experience in software development and without any changes to the core of the modeling environment. Model developers therefore can concentrate on improvements of the scientific aspects of the model.

The model parser is implemented in the Perl programming language (version 5.x), using the Config::Grammar Perl module for parsing the process description and input files. The web interface generated by the parser is a Web 2.0 application based on the Qooxdoo

Ajax framework (http://qooxdoo.org/). The server component is running on a Linux-based server under the Apache web server. Both model code and process descriptions are stored in a Subversion revision control system, providing facilities for concurrent software and model development by various users as well as easily traceable documentation of the model development history.

Figure 1. Block diagram of the various elements of the Agrammon software environment.



Being a web application Agrammon can be used without software installation on the local client computer. Maintenance and updates are limited to the server thus ensuring instantaneous access to the latest published model version for all users. The Agrammon system can be used either anonymously or by authenticated users who can store input parameter sets of their farm for later use, for example for repeating a simulation with partially changed input parameters (development over time, scenario calculations) or with updated model versions. A separate interface allows batch processing of input parameter sets used for inventory calculations and regional projections and is accessible to authorized users.

Relational database

To make use of the survey data for inventory calculations the collected data is stored in a relational database which has the following purposes:

- archive for input data (from survey or registered individual input) and corresponding results.
- plausibility checks and documentation for input data.
- transformation of survey data to the format required by the model.
- statistical analysis of the results of the survey on farm and manure management technique.
- generation of emission factor data sets for up-scaling of emission inventory.
- generation of specific datasets (e.g. group of specific farms) for special analysis.

Model testing

Before being released for routine use the model will have to be extensively tested. In a first round of testing simple datasets for a standard farm will be used to check the general plausibility of the results. Calculations with DYNAMO using the same datasets will facilitate this task. Further testing will be done with datasets that contain a wide range of combinations of different input data. In a follow-up project is also planned to conduct a detailed sensitivity analysis.

Outlook

The first application of the new model will be the calculation of a new Swiss emission inventory using the results of a survey on farm and manure management conducted in winter 2007/08. This stratified survey in which about 3000 farms participated provides representative data for 45 classes of farms (3 geographical regions, 3 altitude zones, 5 farm types).

Parallel to the inventory calculations the interface for the public internet version for farm-specific calculations will be developed. It is planned that this public version should be available sometime during summer 2008. In the initial version the user interface will be switchable between German and French. Additional language can be included easily depending on the requirements.

The public version will be equipped with different sets of standard data for farm and manure management which are derived from the survey. Thus it will be possible to compare the results for a specific farm with average results of comparable farms. It will also be possible to define a baseline scenario for a farm to allow subsequent scenario calculations.

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