CROSS-COMPLIANCE ASSESSMENT TOOL

Policy-oriented research:
Scientific support to policies SSP

Specific Targeted Research Project (STREP)

Deliverable 5.1: Technical Design of Prototype 1

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Authors of this report and contact details
Name: *Partner acronym*

Arno Krause   *Alterra*
Wim de Winter   *Alterra*
Onno Rosenschoon   *Alterra*
Diti Oudendag   *Alterra*
Berien Elbersen   *Alterra*
Janneke Roos-Klein Lankhorst   *Alterra*

Contact details of first authors/editors:

Name: Arno Krause
Address: Droevendaalsesteeg 3, 6700 AA Wageningen
Email: arno.krause@wur.nl

Name: Wim de Winter
Address: Droevendaalsesteeg 3, 6700 AA Wageningen
Email: Wim.dewinter@wur.nl

Name: Diti Oudendag
Address: Droevendaalsesteeg 4, 6700 AA Wageningen
Email: diti.oudendag@wur.nl

Name: Onno Roosenschon
Address: Droevendaalsesteeg 3, 6700 AA Wageningen
Email: onno.roosenschoon@wur.nl

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I.   Acronyms and Definitions

	Abbreviation	**Full term**
A	ANSI	American National Standards Institute
C	CC	Cross Compliance
	CCAT	Cross compliance Assessment Tool
D	DOW	Description of Work (of CCAT)
E	EU	European Union
G	GAMS	General Algebraic Modelling System
	GDX	GAMS data exchange (format)
	GIS	Geographical Information System
	GSE	GAMS Simulation Environment
	GUI	Graphical User Interface
H	HSMU	Homogeneous Spatial Mapping Unit
I	IEEE	Institute of Electrical and Electronics Engineers
N	NUTS	Nomenclature of Territorial Units for Statistics
O	OpenMI	Open Model Integration Environment
R	RDBMS	Relational Database Management System
P	PMaP	Parameter Modification and Provision
S	STU	Soil Typological Unit (Unit in European Soil Map)
W	WP	Work Package

1 General

The analytical tool finally to be developed enables the assessment of impacts of Cross Compliance (CC) given different implementation pathways and specific national and regional conditions. Due to the challenges outlined in the description of work (DOW) of the project prototype 1 will build as much as possible on relevant existing projects.

With special regard to the final users requirements prototype 1 will be implemented as a standalone desktop application that the user has to install on his or her computer. The installation package of the software tools is intended to be self contained, meaning that all required elements for the successful operation will be included.

This report aims to describe the technical design of the first CCAT prototype based on the overall approach and selection of available models as described in other CCAT deliverables:

- Deliverables 2.1 and 2.2 : General approach to the assessment of the impacts of CC in the EU and list of indicators

- Deliverable 2.3: Report describing the operationalisation of the first selection of indicators into impact indicators for the implementation of these in the first prototype of the analytical tool.

- Deliverable 2.4: Report describing the data and information requirements to be provided by WP3

- Deliverable 2.5: Report describing the design of the analytical tool (prototype 1) specifying the types of output to be produced and the functionalities required to produce the final impacts

2 Objective of the CC assessment tool prototype 1

One of the main objectives of the CCAT project is to make an interactive computer application to estimate the effects of a variety of Cross Compliance (CC) measures in terms of agricultural markets, producer's income, consumer's welfare, land use, soil, water, air, climate, biodiversity and landscapes, as well as food safety, animal welfare and health. The application should seek to integrate existing knowledge and models as far as feasible.

To start the prototype-creation a first test case should be worked out. This test case will handle the effects of the Nitrate Directive and will include the CAPRI-MITTERA model chain (see for further specifications D4.1.1 and D4.2.1).

The prototype will serve the following aims:

   a) Verification of the collection use-cases as provided by the various project participants

   b) Verification and testing of a real system integration between the models

   c) Performance tests & validation

The intended user is a non-computationally trained domain specialist. The prototype 1 will be limited by including environmental aspects.

3 Components and Environment

Due to the given premise seeking to integrate existing knowledge and models as far as feasible, two main components were short listed being able to act as basis for extension. These two options consist in the models Integrator and MITERRA which have been described in more detail in CCAT Deliverables 2.1/2.2.

In the beginning of the project Integrator has been considered as a serious candidate to the core model of the CCAT-application. Although there is a conspicuous overlap in the objectives of CCAT and Integrator, it has nonetheless been deemed not suitable for this purpose.

The first reason for this is that where CCAT aims at a steady-state evaluation, Integrator is a dynamic model system that would require substantial effort to make it fit in. The difference between dynamic models and state models is, that dynamic models work their way through time series, where any stat at $t + 1$ is based on the previous state at time t. Conversely, "steady-State" models evaluate an altered state in a one-step calculation from primary data that are time-independent in a mathematical sense, even though in a practical sense aimed at making assessments for an historical or future period. Secondly, there is a compatibility issue regarding the spatial resolution of the primary data. Thus the approach is to extend the MITERRA Europe model. The extension will be based on knowledge of other models (such as INITIATOR2, INTEGRATOR CAPRI, DNDC, and EPIC). This will be done according to deliverable 2.1/2.2., (chap. 5.4.2 table 5.2) where an overview is given that explains which extensions for Miterra have to be taken into account (Metal balance, Phosphorous leaching all from Integrator). In the same deliverable, in chapter 5.2.1 the role of DNDC and EPIC is defined.

Using MITERRA as core component of CCAT has the advantage that it already covers most of the required functionalities as specified by the users and described in Deliverable 2.3. MITERRA has been developed in the GAMS-environment which is open to extensions.

The consequent choice for MITERRA as core component makes the usage of OpenMI[1] as modelling standard in the CCAT project less obvious. Here too, there'd be a mismatch between MITERRA as a steady-state model and OpenMI as a modelling standard for dynamic models.

After analysis of the system environment it appeared that using OpenMI would result in a high programming effort which will exceed the project budget whereas the functional benefits would not justify this.

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[1] OpenMI (short for Open Model Integration Environment) is a data and model integration framework and was developed by HaromIT, which consists of a number European environmental software companies and university researchers. The primary objective is to take otherwise independent data and computing systems, and provide a standard means for describing how time series are communicated between the systems.For more information see: http://www.crwr.utexas.edu/gis/gishydro06/GISandHIS/GISHydro06_Goodall.htm

4 Architectural design of the CCAT - prototype 1

There is a considerable amount of publications available concerning software- or system architecture. A profound compilation of literature can be found in the internet[2].

In principal the architecture of a software-system serves as fundamental description to understand or design a system. Thus rather the collaboration or interaction in terms of data and control-flows, constraints of conditions is necessary to be described than the understanding of the system parts it selves. Moreover the software architecture discipline is centred on the idea of reducing complexity through abstraction and separation of concerns.

According to the ANSI/IEEE Std 1471-2000 the term architecture is defined as the fundamental organization of a system, embodied in its components, their relationships to each other and the environment, and the principles governing its design and evolution[3].

The concept of coupling is usually related to the concept of cohesion (whereas cohesion here is defined as a measure of how well the lines of source code within a module work together to provide a specific piece of functionality): low coupling facilitates high cohesion, and vice versa[4]. For example, one approach to increasing cohesion is functional design, which seeks to limit the responsibilities of modules along functionally-related boundaries. Modules with single responsibilities tend to communicate less with other modules, which typically causes the side-effect of reduced coupling.

Systems Low coupling refers to a relationship in which one module interacts with another module through a stable interface and does not need to be concerned with the other module's internal implementation ("information hiding").

Very loosely coupled systems have the added advantage that they tend to build more quickly and also can be maintained, reused and scaled more easy[5]. This is due to the low amounts of inter-module dependency[6]. To be more precise: with low coupling, a change in one module will not require a change in the implementation of another module.

Low coupling can be regarded as a sign of a well-structured computer system, and when combined with high cohesion, supports the general goals of high readability and maintainability.[7]

Starting point of the CCAT prototype 1 architecture is the existing GAMS-environment that includes Miterra and CAPRI. It is realized as a 3-tier client-server architecture consisting of

- a front-end or "client-application",

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[2] http://www.sei.cmu.edu/architecture/published_definitions.html#Modern (last access on Monday, 5th of Nov.2007)
[3] ISO/IEC 42010:2007
[4] Dustdar et al. 2003
[5] Krause 2006
[6] Dunkel & Holitschke 2003
[7] Cp Krause 2006

- a component framework triggered by the front end including a number of cooperating components and
- a persistence layer (database).

The components are free to define their own database requirements. For CCAT the application framework has to be extended with a component to link the measures to model parameters (PMaP, Parameter Modification and Provision) and the user interface with a screen to select and quantify the measures. Figure 1 provides an overview of the software architecture of the prototype 1:
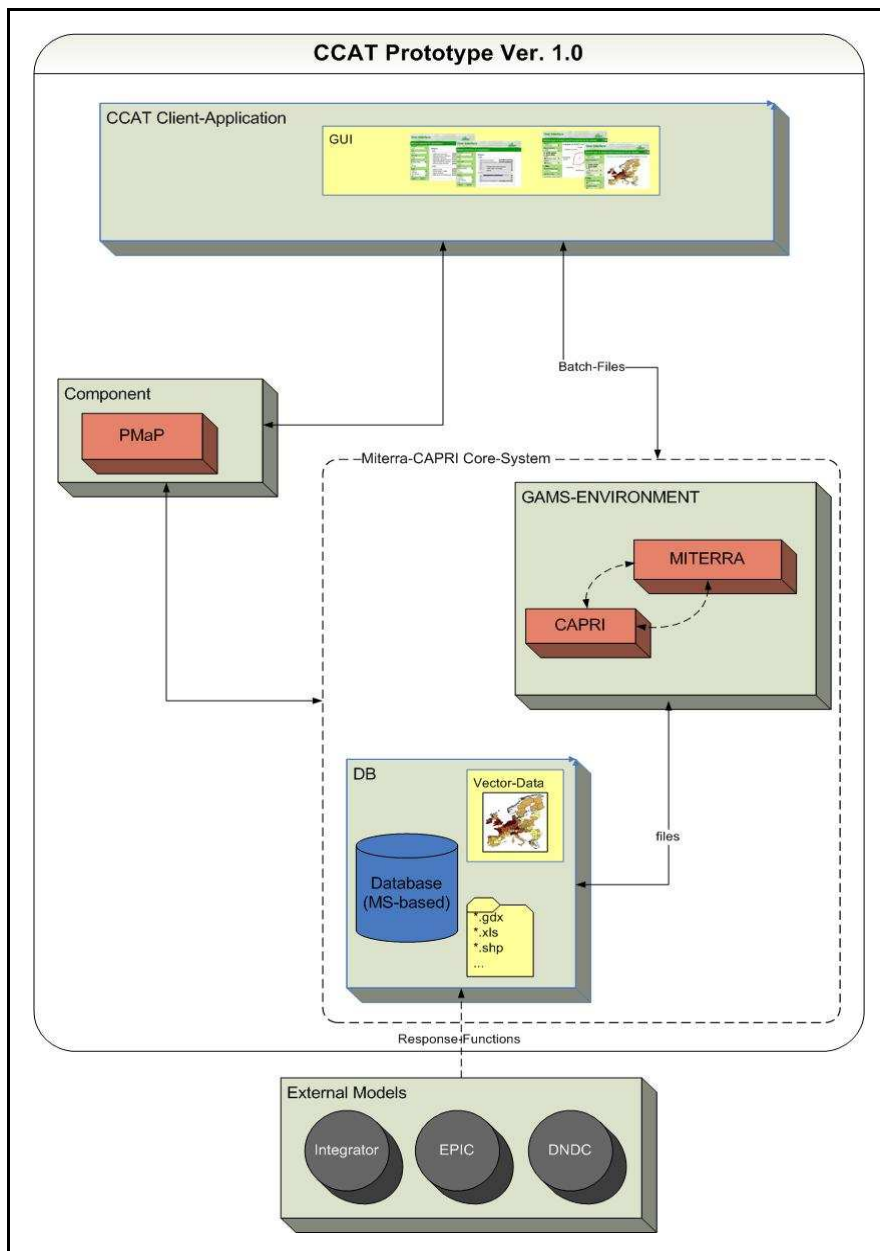

Figure 1: Overview of the CCAT prototype 1

As shown in Figure 1 the CCAT-prototype 1 is composed by loosely coupled coherent components.[8]

In the following chapters the different components of prototype 1 will be discussed separately more detailed.

4.1 The CCAT-Client Application

The graphical user interface (GUI) that will be used in CCAT should be a model independent GUI. This is a very important feature which makes the model builder totally independent of the GUI (builder).

At this moment Miterra can run without GUI (for builders only) and with a GUI named GSE (GAMS Simulation Environment). This GUI is model independent. The GUI also takes care of model version control. This implies that it can handle various versions of the model (or set of models) without additional costs on adapting the GUI to new versions. The GUI was especially built for GAMS models but can now also handle all kind of other models and data transformations. The interfaces between the GUI and the model(s) are controlled by meta-information files and batch files (to process the run-off of the model) the GUI can run on top of any (set of) model(s).

Beside model version control the GUI takes care of model scenario control. It allows defining new scenarios, running those scenarios, presenting results in a multidimensional data viewer and exporting results towards a variety of formats like Word, Excel, Graphs, etc. And also the possibility to present results by means of GIS (e.g. Nuts2-polygons) is incorporated. A largely appreciated feature is scenario comparison. The GUI allows direct comparison of scenarios (even across version boundaries) in all presentation forms.

The built-in model version and scenario control (with additional documentation possibilities) guarantees a full reproducibility of work done with the model in the past.

Currently Miterra uses GSE as a GUI (written in Delphi) which has been developed at LEI (Agricultural Economic Institute).

In principal the technical implementation of the GSE can be realized in two alternatives:

- Alternative 1: Delphi version based on extending the existing GUI programmed in Delphi (already in a generic way connected to Miterra) or another conventional client

- Alternative 2: A Web based version based on Visual Studio.net which has to be built from scratch.

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[8] Cp. Balzert 2000

Alternative 1 can be based on an existing GUI-version and will be at least available for PC's with Windows operating systems. There are conceptual investigations going on that look for possibilities to make this version available for other operating systems as well. The advantage of this alternative is, that implementation efforts can benefit of existing software. However it is also possible to implement a conventional client in any other modern programming language from scratch.

The GUI alt1 will work as follows. When starting the client a screen pops up where measures can be selected and values can be added (parameterisation) to variables. When the definition of a scenario is finished and after pressing the "run" button a batch-file is performed in which all actions (data selecting, model selecting etc) are being defined. When the user starts the model run by pressing a button start (or other) the batch-file will be executed. All output to be seen on the screen should be defined in a *.gdx file. All kinds of maps are possible to produce if there's a shape-file available. The formulating/generating of the batch-file is the responsibility of the CCAT-group. In the batch-file all kind of actions and operations can be defined. Scenario and version management is guaranteed.

For Alternative 2 (web based version) a server is necessary for all models and data to be stored. The principle of web based GSE is more versatile than the GSE in Delphi.

The GUI alt2 will work as follows. It starts with someone sitting behind his/her PC (notebook) starting the program from the web. When starting the model a screen pops up where measures can be selected and values can be added (parameterisation) to variables. When the definition of the scenario has finished a batch-file is generated in which all actions (data selecting, model selecting etc) should be defined. When the user starts the model run by pressing a button start (or other) a task engine on the server will take care of starting the batch-file to be run. All output to be seen on the screen, should be defined in a *.gdx file.

As well as in alternative 1 all kind of maps are possible to produce as far as a shape-file is available. The formulating/generating of the batch-file is the responsibility of the CCAT-group. In the batch-file all kind of actions and operations can be defined. Scenario and version management is guaranteed.

No license will have to be bought but there will be a payment for advice, support and use of the server.

In both alternatives a GIS component will be available which makes it possible to present some results in maps. For Miterra a combination of Nuts2 and Nuts1 shape-file was made. But also other shape-files can be included so maps for different scales can be made in case output is desired at another region level. The following chapters depict both alternatives in more detail.

4.2 The Miterra-Capri-Core System

The Miterra-Capri-Core system represents the middle tier of the client-server system and contains the main part of the CCAT business logic. The components of this tier will be explained in detail in the following chapters 4.2.1 - 4.2.4.

4.2.1 The GAMS-Environment

In the GAMS-Environment two models are running: CAPRI and Miterra. CAPRI calculates the effect of policy measures on economic and structural effects in agriculture. Miterra calculates with the redefined agriculture (from CAPRI) the environmental impacts of the assessment of policy measures.

CAPRI and Miterra are selected as the agricultural environmental core module in the prototype of the CCAT-project, This implicates the use of GAMS in the prototype. Communication with other models and data will have to be tuned with the language GAMS.

4.2.2 The GAMS language

GAMS stands for "General Algebraic Modelling System" and is specifically designed for modelling linear, nonlinear and mixed integer optimization problems which may require many revisions to establish an accurate model. The system is especially useful for solving large, complex problems.

GAMS is available for use on personal computers, workstations, mainframes and supercomputers. In this paragraph a short overview of GAMS advantages and other information is given[9]

Some of the most important advantages of modelling in GAMS are[10] :

- The GAMS model representation is in a form that can easily be read by people and computers. This means that the GAMS program itself is the documentation of the model. The separate description required in the past is no longer needed. A great help in direct documentation in GAMS is that GAMS allows the user to include explanatory text as part of the definition of any symbol or equation.

- The system models problems in a highly compact and natural way. The user can change the formulation quickly and easily, can change from one solver to another, and can even

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[9] On www.gams.com more information can be found as well as the users guide (also available on the mentioned website).
[10] Internet: www.gams.com and Rosenthal, 2006.

convert from linear to nonlinear programming with little trouble. In other words, GAMS lets the user concentrate on modelling by eliminating the need to think about programming.

- GAMS offers a full range of interfacing capabilities like
    - Data Import/Export from Standard Applications (MS Office, Databases, Text Files etc.)
    - Execute programs from within GAMS (including another GAMS job itself)
    - Call GAMS from complex applications
    - Visualization tools

A schematic overview about the GAMS interface capabilities for importing and exporting dsata is represented below in Figure 2:
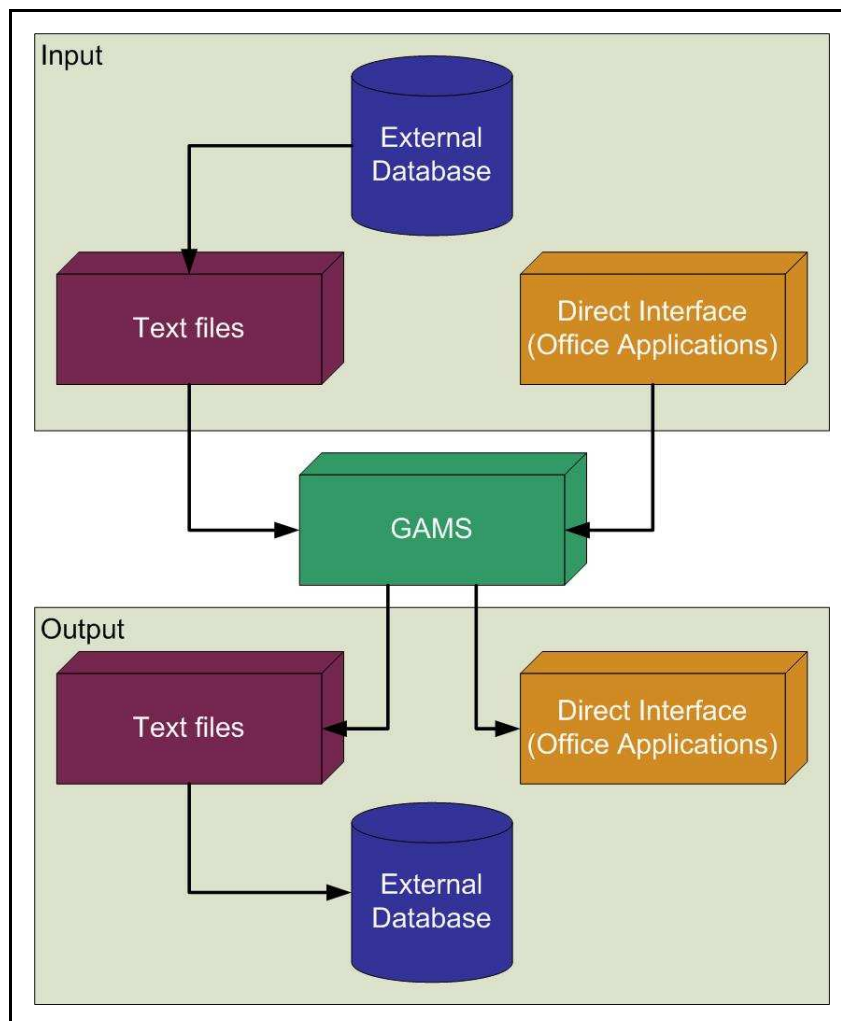

Figure 2: Generic GAMS Interfaces

- GAMS can communicate with all kind of other programs. For example data stored in txt-files, Excel, Access, Oracle, DB2, MySQL etc. can be used by GAMS.

Following Figure 3 provides a conceptual overview of program-intercommunication:
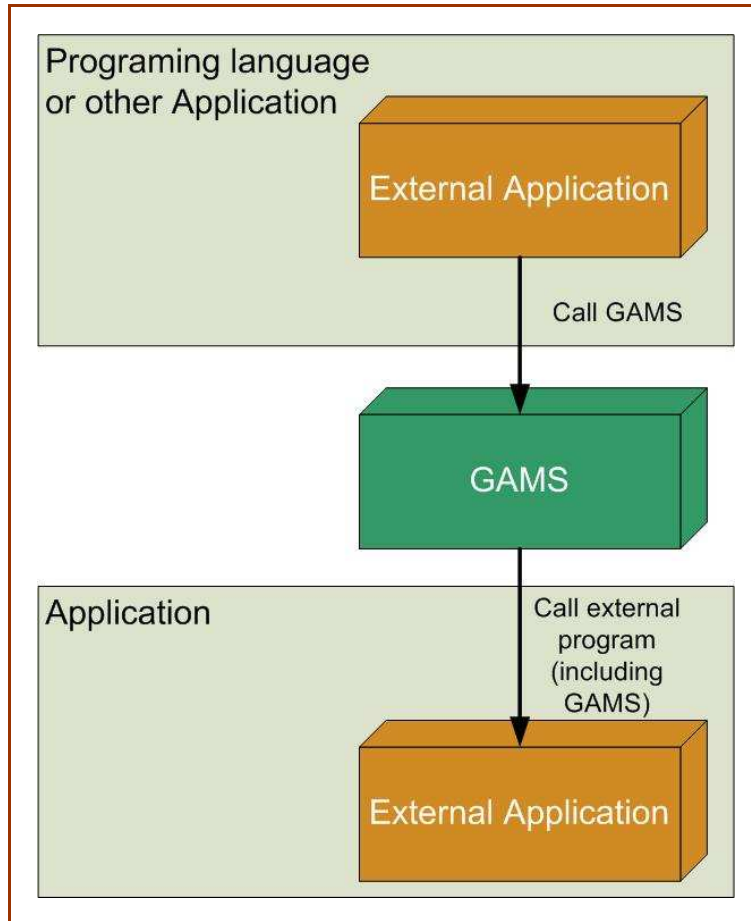

Figure 3: GAMS generic Application interfaces

More information about GAMS with links to other programs and Controlling GAMS from other External Programs can be found in McCarl GAMS User Guide (200x).

4.2.3 Miterra as central core application

Miterra (-Europe) has been developed by Alterra in Task 1 of the Service contract 'Integrated measures in agriculture to reduce ammonia emissions' [11]

Miterra is a model consisting of:

- an input module with activity data, emission factors and a set of (packages of) measures to mitigate NH3 emission and N leaching;

- a calculation module,

- an output module.

The input data used in Miterra is on regional (NUTS 2) level or country level and includes data of N inputs, N outputs, N surplus, land use, crop types, soil type, topography, livestock numbers etc., emission factors for NH3, N2O, NOX and CH4, and leaching factors for N. Behind the leaching factors (on Nuts2) is a database[12] with information about soil type, temperature, rainfall e.g. In prototype 1 all calculations will be done at the Nuts 2 level, although input data are available at smaller spatial level than Nuts 2. In prototype 2 calculations will be done at smaller spatial levels and will not follow the administrative boundaries but much more the natural boundaries relevant to the environmental assessments (see also D 2.3 and D4.2.1).

Miterra uses information (calculation methods and/or model results) from CAPRI (Eurocare/University of Bonn, mainly on Nuts2 level), the RAINS (GAINS) model of IIASA (on country level) and other sources like FAO (See D4.2.1).

More information about the use of data can be found in Appendix A1. Appendix A2 mentions the measures already available in Miterra at the end of November 2007.

The following Figure 4 provides a schematic presentation of Miterra. All arrows in the figure are calculated within Miterra

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[11] www.scammonia.wur.nl

[12] There are in fact two databases behind, one with HSMU/STU data for EU-15 countries and one with HSMU/STU data for EU-10. There are two reasons to have them separated. The first is that limits of Access are reached (2 MB), second is HSMU-numbers of EU-15 start at 1 as well as the HSMU-numbers of EU-10. The relevant data is transformed to excel-input files. It would be better in the future to have these data in gdx-format so it will be more easily to use the HSMU-data and transform it to nuts2 regions.
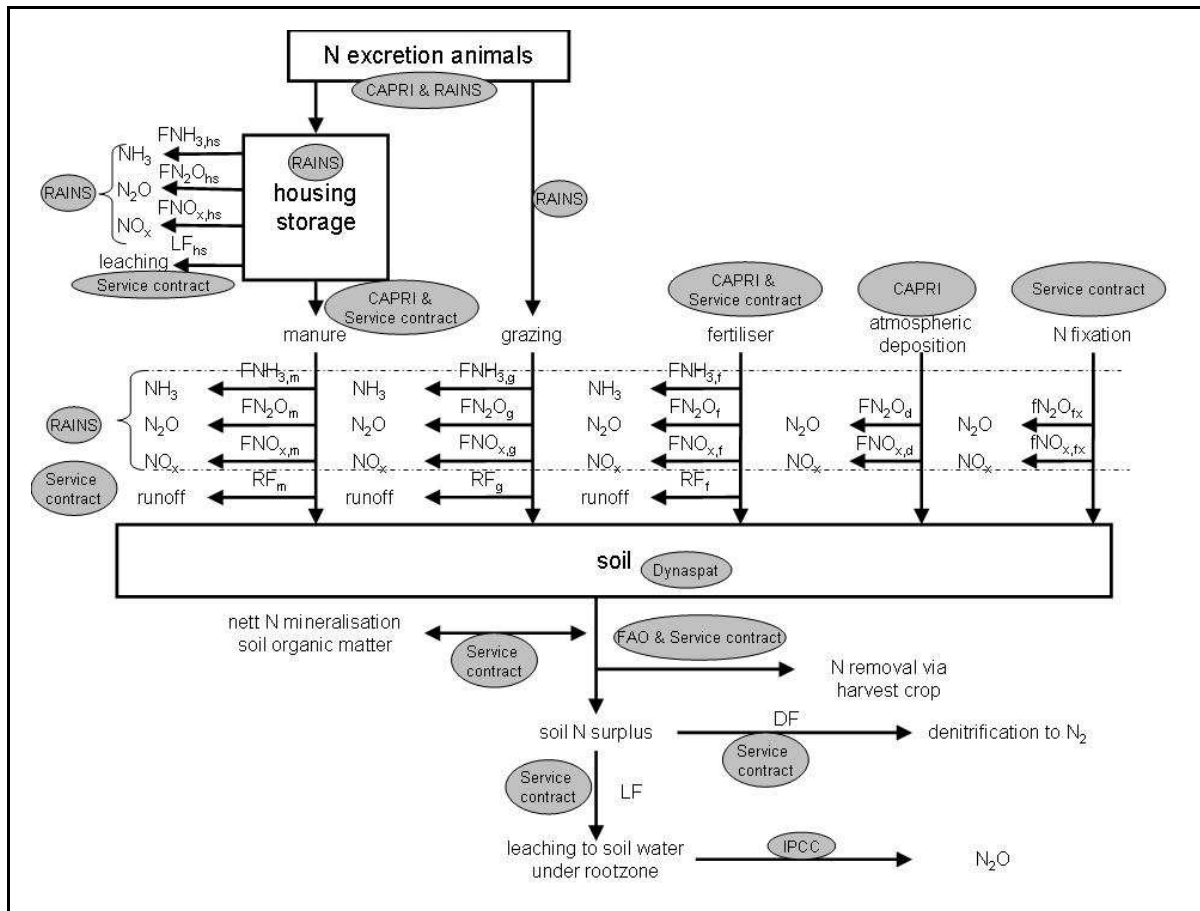
Figure 4: Schematic presentation of Miterra

Looking at Figure 4 the sources of used information are presented in grey. The sources are RAINS, CAPRI, FAO, IPCC, and Dynaspat. Service contract means that the data/calculation is obtained in the current project. F indicates emission factor for gaseous emission, L leaching fraction, D denitrification fraction, and R means runoff fraction.

Although some input data are available at below Nuts 2 level, the assessment of the environmental impacts are now available at Nuts 2 level, using average input figures per Nuts region. However assessments at other resolution levels will be possible in further versions and can be done using region transformation codes and vector-maps of Nuts2 combined with grid-maps[13] or other. The amount of effort to make this possible depends on whether only output will have to be transformed to other scale-levels or also input. But both options are technically possible with not an enormous amount of effort.

The model can easily be included in the GUI called GSE which creates the possibility of version and scenario management.

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[13] For the project Eururalis Miterra a procedure is formulated to transform output at nuts2-level (from Miterra) to grid-level of 1 by 1 km^2.

Additionally Miterra respectively the GAMS-environment provides generic methods to include a role and right specific user management. As a role and right specific user management is not foreseen for prototype 1 although the discussion on this has not been finalised.

4.2.4 Integration of CAPRI and Miterra

Miterra and CAPRI are both programmed in the language GAMS. The advantage of using the same language is that databases and equations can be easily exchanged between Miterra and CAPRI.

The integration of Miterra and CAPRI is basically formed by a GDX-output file from CAPRI being an input file for Miterra. Besides that, Miterra uses for the data used from CAPRI the same variable names as in CAPRI. In other words the integration follows the principle of a file-based data-exchange whereas Capri provides a binary *.gdx-file that is stored at a specific location in the file-based system of the operating system and afterwards picked up by Miterra for further processing.

The final integration depends on how the simulations will be handled in CAPRI.

- If the market price is not affected by the cost effect of CC the model CAPRI can be part of the GAMS-Environment. In this case CAPRI and Miterra can run in a batch. The GUI GSE (and also the one from CAPRI) can handle batch files.

- If the market price is affected, CAPRI will make simulation runs. This will be stored in the Miterra/Capri database? Miterra will select the data from this database.

At this moment no concrete choice was made but both alternatives are technically possible.

4.3 The Parameter Modification and Provision (PMaP) component

The component "Parameter Modification and Provision (PMaP) represents a component that was will be specifically designed for the CCAT project and so which will have to be implemented for it. The purpose of this component is to translate the measures used in CCAT to parameters used by the models. Knowledge about model parameters affected by the measures is included in PMaP, as well as knowledge of the way these parameters are to be modified (multiplication, addition, linear shift, etc.).

With this regard it

- provides the front end with a list of measures to be selected
- includes the knowledge to modify Miterra's parameters according to the measures that have been selected.

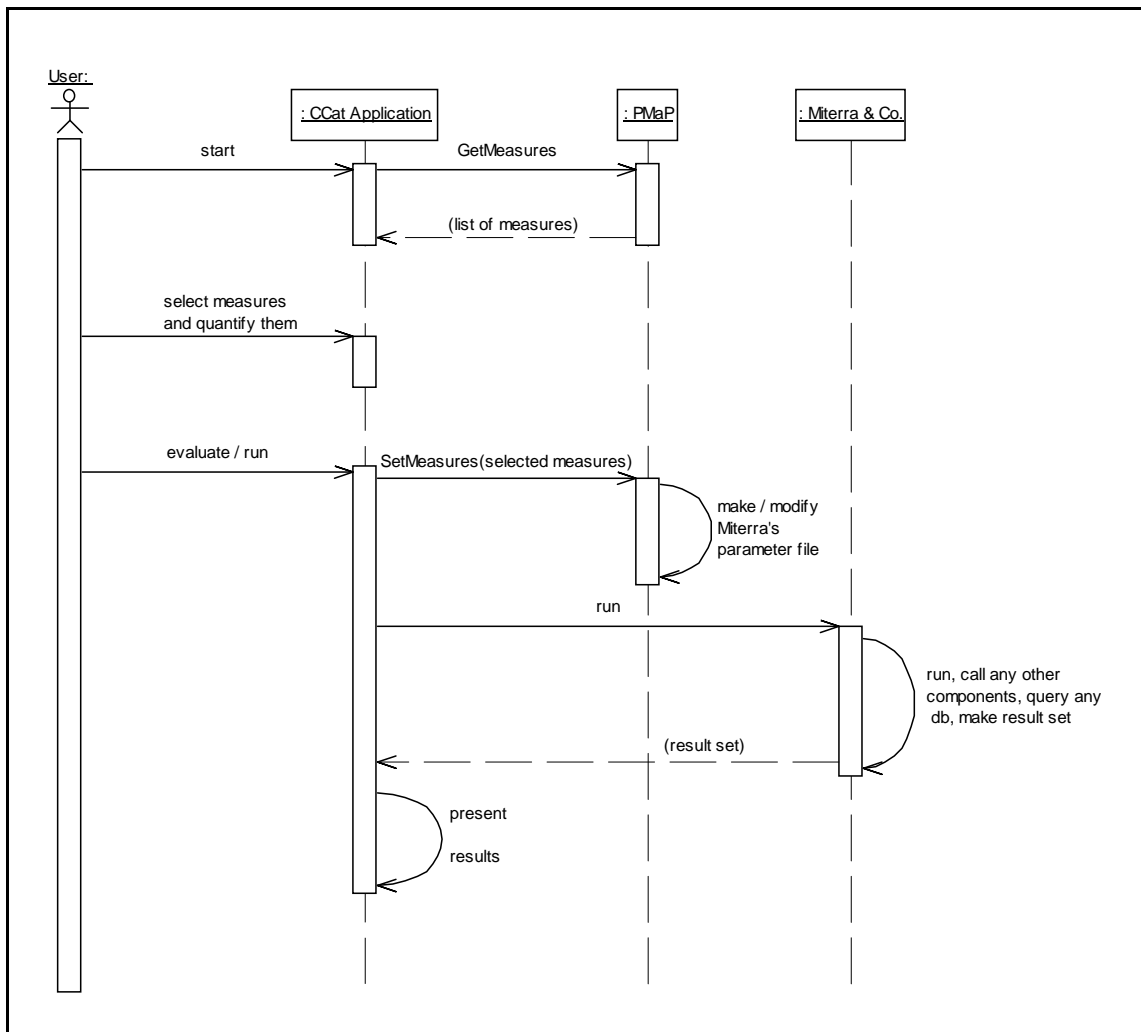Its role is schematised below in Figure 5:

Figure 5: Sequence diagram of the Parameter mapping process

Measures can either be simple or include more complex options, such as extend, regional selection, sector options, or other quantifications. In the latter case, PMaP is to provide the front-end with a definition of each measure and the translation of this into input data for Miterra to assess the environmental impacts.

4.4 Data management and access

Miterra is programmed in GAMS. A GAMS-model can communicate with the outside world by txt-files, CSV-files, Excel-files, Access, Oracle, GDX-files and other. GDX-files are internal GAMS-files.

All input data which Miterra uses, are in Excel-files (three files) in several sheets except the communication with CAPRI. This communication is made with GDX-files.

For improving the performance of Miterra first all excel files are read and written to a GDX-file. After that when there are no changes in the data anymore, Miterra uses the GDX to shorten the runtime of the model. Output in Miterra is in Excel and GDX.

Miterra can be connected with the GUI named GSE. This user interface makes it possible to export also results in Excel, Word, Access, SPSS, ASCII, CSV, GDX, GAMS-data file and HTML (see also chapter 4.1).

The following Figure 6 provides a generic overview of the communication in terms of data retrieve via *.txt – files:
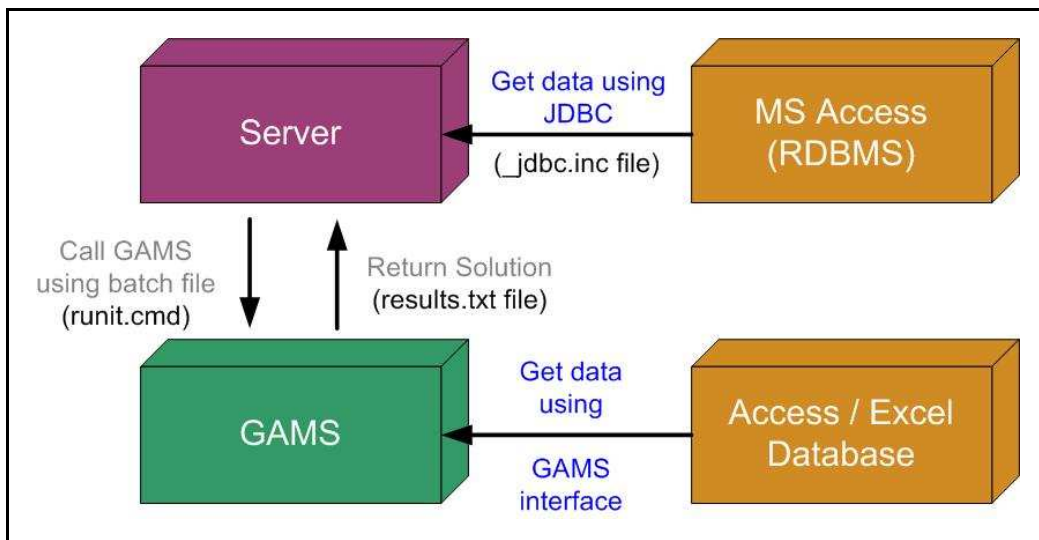

Figure 6: Communication via .txt files

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Appendices

Appendix A

A.1 Input data

Variable	National	Nuts2-distribution	Other
Crops	CAPRI	CAPRI	
Number of animals	RAINS	CAPRI	
Fertilizer N	FAO	Crop demand and other calculations	
Fertilizer P	CAPRI	CAPRI	
Deposition	CAPRI and MNP	Country-level	
Biological fixation	Fixed factors per ha per crop type		
Use of animal manure			All manure produced in a nuts2 is assumed to be applied in the same nuts2.
Use of fertilizer per fertilizer type	RAINS	Country-level RAINS	
Housing-/grazing days	RAINS	Country-level RAINS	
Excretion N	RAINS	Country-level RAINS	
Excretion P	N/P ratios based on OECD, Dutch statistics, and Sheldrick et al. (2003).	Country –level	
Yield	FAO statistics and calculations	Country-level data	
Use of ammonia abatement techniques	RAINS	Country-level RAINS	
Leaching and runoff fractions		Average of HSMU's	Calculation based on HSMU/STU-information
Emission factors for NH3, CH4, N2O, NOx e.a.	RAINS	Country-level RAINS	

A.2 Implemented measures

In this paragraph the measures in Miterra are listed. New and/or other measures in this project (CCAT) will have to be implemented.

In MITERRA-EUROPE, the ammonia measures (and parameters) of RAINS (as listed above) are included:

- Low N Fodder (dietary changes)
- Stable Adaptation
- Covered Manure Storage (low efficiency and high efficiency options
- Biofiltration (air purification);
- Low Ammonia Application of manure (high efficiency and low efficiency techniques)
- urea substitution, substitution of urea with ammonium nitrate
- incineration of poultry manure

In MITERRA-EUROPE a list of measures to decrease N leaching is set up. It is assumed that packages of measures are implemented to decrease N leaching and to fulfil to the constraints of the Nitrates Directive. The following are included;

- balanced N fertilizer application;
- maximum manure N application standard of 170 kg N per ha (except where a derogation applies).
- no fertilizer and manure application in winter and wet periods
- limitation to fertilizer application on steeply sloping grounds
- manure storage with minimum risk on runoff and seepage
- appropriate fertilizer and manure application techniques, including split application of N
- prevention of leaching to water courses riparian zones buffer zones
- growing winter crops

For implementation of the Water Framework Directive (WFD) it is assumed that the following measures are taken:

- Full implementation of measures of the Nitrate Directive in Nitrate Vulnerable Zone;
- Decrease in input of P fertilizer and manure to decrease the risk on phosphorus leaching to surface water are included.