Interim Report on Modelling Technology

The CAPRI Model

European Consortium for Modelling of Air Pollution and Climate Strategies - EC4MACS

Task 7: Agricultural Scenarios

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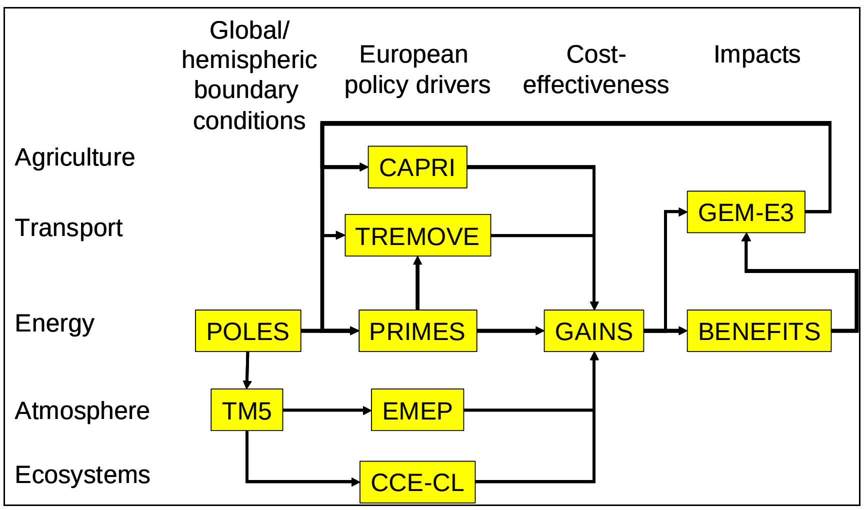
1. CAPRI model: current status

The documentation BRITZ, W., HECKELEI, T. and M. KEMPEN (Bonn, 2007) has been updated to reflect the status in Spring 2008. It is an annex to this interim report.

2. Envisaged model interfaces including the CAPRI model

Within the EC4MACS project several interfaces between involved environmental and economic models are intended. Figure 1 displays the preliminary model network of EC4MACS.

Figure 1: Model network of EC4MACS



Source: EC4MACS homepage 22.04.2008, http://www.ec4macs.eu/home/modelsystem.html?sb=3

2.1. EUFASOM data interface

2.1.1. Review of general model characteristics of EUFASOM

The European Forest and Agricultural Sector Optimization Model (EUFASOM) is a partial equilibrium model of the European agricultural and forestry sector (SCHNEIDER, U.A. AND D.E. SCHWAB, 2006). EUFASOM can be characterized as a bottom-up, optimization, fully dynamic, multi-national, agricultural and forestry sector model. In addition, the model portrays detailed environmental relationships and global agricultural and forestry commodity trade. EUFASOM has been developed as an integrated scientific tool for the comprehensive economic and environmental analysis of land use and land use change. The traditional agricultural and forest sector is represented across the EU through representative production technologies for 15 major traditional crops, 10 energy crops, 20 tree species, and 10 livestock categories. The model is regionalised according to the question investigated. EU-25 countries and 27 non-EU international regions are explicitly represented geographically. Within each political region in the EU, the model can be further resolved with respect to farming and natural conditions, i.e. different farm sizes and farm types. Natural conditions are based on more than 1 000 Homogenous Response Units (HRUs) and can be grouped according to soil textures and stone content, altitude levels, and slopes. For farming and natural conditions, only the shares of area within basic political regions are modelled. The model runs in 5-year steps from 2005 to a selected terminal period.

EUFASOM is a mathematical programming model including a welfare-maximising objective function with technological, resource, and market restrictions. EUFASOM's objective function maximises total agricultural and forestry sector surplus subject to a set of constraining equations, which define a feasible convex region for all variables. Feasible variable levels for all depicted activities range from zero to an upper boundary, which is determined by resource limits, supply and demand balances or trade balances. Calibrating the model involves restrictions that force the solution to form a convex combination of historically-observed or expert-estimated states. Solving EUFASOM involves the task of finding the 'optimal' level for all endogenous variables subject to compliance with all constraining equations. By means of EUFASOM's objective function, optimal levels of all endogenous variables are those levels which maximise agricultural and forest sector surplus, which are computed as the sum of total consumer surplus, producer surplus, and governmental net payments minus the total cost of production, transportation, and processing (cp. SCHNEIDER, U. ET AL., 2008).

2.1.2. Purpose of a model interface

Combining several models with coverage of agriculture in one project may serve two purposes:

- Cross-checking results or data that should be the same or differ in a particular way could increase confidence in both models or help to identify problems
- Exchanging data, results, or even model components could be a way to exploit complementarities between models.

The brief review above suggest that there are complementarities in the following areas:

EUFASOM has clear advantages in the modelling of **non food energy crops**: traditional forestry, new woody plants for bio-energy (coppice etc.) and new crops such as switchgrass where considerable technical knowledge has been collected in the ENFA project. In CAPRI these are absent or merged into certain 'other' categories ('other industrial crops', 'other crops') if there are statistical observations at all.

Error! Reference source not found. displays selected variables included in EUFASOM, in particular crops, trees and perennials which can be used for energy purpose and thus could be promising for a data or information delivery to CAPRI.

Table 1: Selected indexes included in EUFASOM

Crops	c(s)	Soft wheat, hard wheat, barley, oats, rye, rice, corn, soybeans, sugar beet, potatoes, rapeseed, sunflower, cotton, flax, hemp, pulse
Trees	f(s)	Spruce, larch, douglas fir, fir, scottish pine, pinus pinaster, poplar, oak, beech, birch, maple, hornbeam, alnus, ash, chestnut, cedar, eucalyptus, ilex locust, 4 mixed forest types
Perennials	b(s)	Miscanthus, Switchgrass, Reed Canary Grass, Poplar, Willow, Arundo, Cardoon, Eucalyptus
Livestock	l(s)	Dairy, beef cattle, hogs, goats, sheep, poultry
Wildlife	w(s)	43 Birds, 9 mammals, 16 amphibians, 4 reptiles

Products	y	17 crop, 8 forest industry, 5 bioenergy, 10 livestock

Source: SCHNEIDER, U.A. ET AL. (2008)

A second are where EUFASOM may have achieved a more detailed and sophisticated representation is **bioethanol and biodiesel** production , given that these have been introduced into CAPRI only recently. Demand for these fuels and the composition of corresponding feedstocks is currently exogenous in CAPRI and based on shaky data. It is planned to render the substitution of various feedstocks endogenous using a CES approach. Depending on the current status of modelling the biofuel processing industry in EU FASOM, these components might inform the specification choices in CAPRI.

Complementarities motivating a delivery of data and information to EUFASOM root in the key differences in modelling approach. Whereas both CAPRI and EUFASOM are programming models CAPRI presumably has a stronger focus to represent statistically observed behaviour. This results from the fact that the modified PMP approach is designed to reproduce both the level of observed variables as well as a given set of assumed supply side elasticities. However it may be an open issue to what extent the convex combination approach of Mc Carl achieves a similar empirical content.

However there are two areas where the stronger empirical focus of CAPRI is beyond doubt. The CAPRI **baseline** is essentially relying on a combination of ‘intelligent’ trends with a priori information on future market outlooks borrowed from other agencies. Both types of information (trends and external forecasts) have no role in a classical programming model such as EUFASOM. The projections from EUFASOM are technically developed as any other scenario and ‘just’ require an appropriate projection of technical coefficients into the future. If one is prepared to make the necessary assumptions (or specify the coefficients relying on some other methodology) EUFASOM may be applied to future points in time as well, even to very long time horizons. Given these differences in approach it may be interesting at least to compare the results.

Finally the stronger empirical focus of CAPRI is reflected in its approach to **trade modelling**. This is based on the Armington assumption which permits to represent two way trade between the regions involved, just as observed in statistics. In EUFASOM, on the contrary, models non EU regions as EU regions based on the same programming approach (welfare maximisation with transport cost for trade) which will not be able to represent observed trade. Furthermore the CAPRI market model offers a quite detailed representation of trade instruments including tariffs, bilateral and global TRQs, variable levies, the EU entry price system, export subsidies and WTO limits which are probably not included in EUFASOM..

2.1.3. Technical implementation

Regarding the first area of communication, **non food crops** and forestry, it would be desirable to calculate aggregate behavioural functions for a few land use categories, perhaps traditional forestry, woody energy crops and other non food energy crops, as a function of their aggregate revenue. To calculate this a yield and a price are also needed. These functions might be generated in auxiliary EUFASOM simulations where the prices of all activities in a group are increased by some percentage to obtain a series of observations (at least 2) to infer the area elasticity of these new land using activities in CAPRI. The details may be tricky to work out because the land use definitions do not necessarily match. Furthermore the responses in EUFASOM may be quite discrete when looking at smaller regional units such that an aggregation to countries or even country groups may be useful for CAPRI. Finally EUFASOM applies a long term dynamic approach as appropriate for forestry modelling. The impacts after a mediums horizon of, say, 10 years would probably reflect an incomplete adjustment if replanting and growing of trees takes time. On the other hand the analysis needs to incorporate the yield which may materialise only after 20 years or more, depending on the trees.The next steps would involve some more detailed communication about these open issues.

More communication is certainly also needed regarding the information need of CAPRI on conventional processing of **biofuels** (biodiesel and bioethanol). From a CAPRI demand perspective the following open issues need to be clarified:

- Which feedstocks are included in EUFASOM?
- What is the underlying database?
- Is ist possible to undertake auxiliary simulations to elicit behavioural response parameters from EUFASOM?
- What drives demand for biofuels in EUFASOM?

Communication on **baseline** results is not limited to a particular set of variables. Instead it could be interesting to compare and possibly to exchange data and results on all kinds of variables but it may be useful to focus in the interface work on key variables

- Activity levels,
- Market balances of products
- Price information

For all of these it will be necessary to clarify open questions. After a brief look at Schneider et al. 2008 (EAERE paper) it is unclear for example, how non grass fodder crops are covered (silage maize and others). The same applies to tobacco and other industrial crops. These questions may be easy to sort out after an exchange of the models database (gdx files) and some GAMS programs (sets…) to read and display those in a meaningful way.

Regarding **trade modelling** the precise shape has to be designed and discussed yet. A first step is an improved mutual understanding which may benefit on the CAPRI side from the updated documentation annexed to this interim report.

2.2. PRIMES data interface

2.2.1. Review of general model characteristics of PRIMES

PRIMES is a modelling system for energy markets which is similar, in terms of structure and approach, to POLES. However, PRIMES is more detailed and focuses in more detail on European countries. The model itself describes a non-forward looking market equilibrium over time, including dynamic relationships through learning curves and a vintage approach for technology description, i.e. technologies depend on the time they were built and on their age. PRIMES was developed at the National Technical University of Athens (starting in 1993-94) and is maintained at the 'E3M lab' where its documentation is offered for download (http://www.e3mlab.ntua.gr/).

The long run horizon of PRIMES is supported by a detailed description of technology choices in energy demand and energy production. The model explicitly considers the existing stock of equipment, its normal decommissioning and the possibility for premature replacement. At any given point in time, the consumers or producers select the technology of the energy equipment based on economic criteria which is potentially influenced by policy (taxes, subsidies, regulation, tariffs, etc.) and given technological options (including endogenous learning and progressive maturity on new technologies). Producers also decide on the use of existing capacity and on capacity expansion. Inertia exists in the penetration of new technologies, an adaptive expectations mechanism and consumer habits, respectively. Markets clear at different levels, similar to the procedure followed in POLES, depending on the type of energy (electricity: national, with EU-wide electricity grid; natural gas: multinational; refinery sector: national, etc.).

Related to the core PRIMES model of energy processing, transformation, and demand a 'biomass module' has been developed which supplements the core PRIMES model with a a supply module for biomass based fuels (E3Mlab – ICCS/NTUA, 2008b).

2.2.2. Purpose of a model interface

Being an energy model which covers bio-energy PRIMES is evidently perfectly equipped to model the demand for , say, biodiesel, as a function of biodiesel prices and prices of competing fuels and European energy and environmental policies. This core PRIMES model is currently supplemented with a biomass component describing supply of biomass to the energy sector, more precisely the marginal costs of biomass production of various forms. Conceptually this biomass component competes with agricultural and forestry models like EUFASOM and CAPRI, which also deliver, among other information, prices and hence marginal costs of biomass products. The question arises what is covered in the currently evolving biomass component which is unclear form the website information (E3Mlab – ICCS/NTUA, 2008b):

Is there competition for scarce land of biomass plants with food, feed, fibre production?

Are linkages to the animal sector included, which could be relevant, for example, if the current milk quota regime of the EU is abandoned?

Which parts of the CAP are included? Set aside? Energy crop premium? Decoupling?

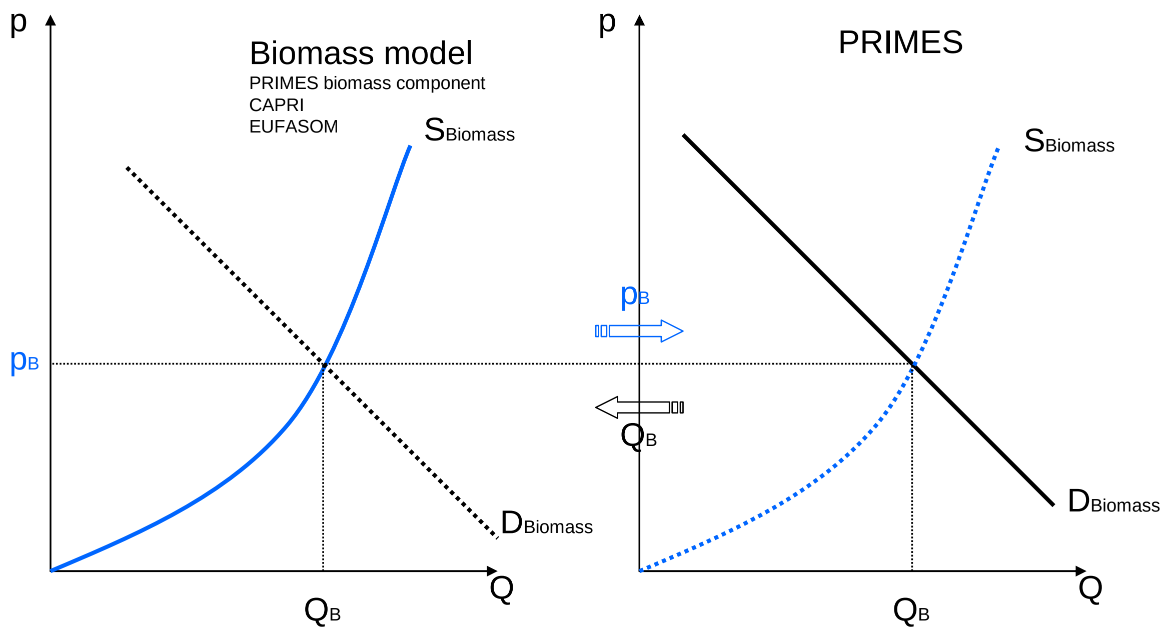
What about international trade in biomass products which is strongly affected by complex border measures which are likely to be liberalised if the ongoing WTO round leads to an agreement?

Without more complete information about the scope of the PRIMES biomass component it is impossible to assess which information from EUFASOM or CAPRI might be useful to improve the structure, accuracy, parameterisation or other aspects of the current biomass component.

The purpose of the reverse flow of information is far clearer: CAPRI needs a demand function for biofuels or at least projections of biofuel demand under a specified set of conditions including the biofuel prices. Conceptully this can be delivered by PRIMES but a practical problem might be the time needed to carry out a number of auxiliary simulations to derive such a simplified "response surface" from PRIMES which is essentially a simplified demand function.

The exchange of the biomass component, CAPRI model or EUFASOM with PRIMES could proceed quite similarly (Figure 2).

Figure 2: Biomass model - - PRIMES interaction



Source: Own illustration

Rather than interacting over biomass prices and quantities it is also conceivable to exchange biofuel prices and quantities. This gives a greater role to the biomass model which should include the processing activity therefore.

2.2.3. Technical implementation

The next step would be to increase the mutual understanding of each model's needs and capabilites which requires more information between the parties concerned.

2.3. RAINS/GAINS data interface

2.3.1. General model characteristics

"The RAINS" (Regional Air Pollution Information and Simulation) model developed by the International Institute for Applied Systems Analysis (IIASA) combines information on economic and energy development, emission control potentials and costs, atmospheric dispersion characteristics and environmental sensitivities towards air pollution (SCHÖPP ET AL., 1999). The model addresses threats to human health posed by fine particulates and ground-level ozone as well as risk of ecosystems damage from acidification, excess nitrogen deposition (eutrophication) and exposure to elevated ambient levels of ozone. These air pollution related problems are considered in a multi-pollutant context, quantifying the contributions of sulphur dioxide (SO2), nitrogen oxides (NOx), ammonia (NH3), non-methane volatile organic compounds (VOC), and primary emissions of fine (PM2.5) and coarse (PM10-PM2.5) particles. The RAINS model also includes estimates of emissions of relevant greenhouse gases such as carbon dioxide (CO2) and nitrous oxide (N2O). Work is progressing to include methane (CH4) as another direct greenhouse gas as well as carbon monoxide (CO) and black carbon (BC) into the model framework(AMANN, M. ET AL., 2004).

The GAINS model is an extension of the RAINS model developed to integrate an estimation module for greenhouse gases. New insights into the linkages between air pollution and greenhouse gases has stimulated an extension of the multi-pollutant/multi-effect approach that RAINS presently uses for the analysis of air pollution to include emissions of greenhouse gases. This could potentially offer a practical tool for designing national and regional strategies that respond to global and long-term climate objectives (expressed in terms of greenhouse gas emissions) while maximizing the local and short- to medium-term environmental benefits of air pollution. The emphasis of this tool is on identifying synergistic effects between the control of air pollution and the emissions of greenhouse gases (c.f. KLAASSEN, G. ET AL., 2004).

2.3.2. Existing model interface

A data interface between RAINS/GAINS and CAPRI has already been implemented among other occasions within the Ammonia[1] project, coordinated by ALTERRA at Wageningen University (http://www.scammonia.wur.nl/UK/), issued by the European Commission, Directorate-General Environment (Contract 070501/2005/422822/MAR/C1). The general objective of this service contract was to define the most appropriate, integrated and consistent actions to reduce nitrogen (N) emissions from agriculture to atmosphere, groundwater and surface waters. In the first task of the project a methodology was developed to assess and quantify the effects of various policies and measures to reduce the N losses from agriculture. This led to the development of the tool MITERRA-EUROPE, which has been heavily drawing on previous work with RAINS/GAINS at IASSA (Oenema, O. et al., 2007). Indeed it has been considered a success that (GAMS based) MITERRA-Europe was able to reproduce with high accuracy the calculations of RAINS because this was considered a precondition for successful communication between MITERRA-Europe and GAINS.

The relationship of CAPRI to both MITERRA-Europe and GAINS was somewhat more loose. Whereas MITERRA-EUROPE was a newly developed tool that could be allinge with GAINS to a large degree CAPRI was a model with its own history and agenda at the time of the Ammonia project. Hence it was neither feasible nor useful to copy the GAINS calculations completely or to a high degree as in MITERRA-Europe. Nonetheless there was an exchange of information:

- CAPRI delivered regionalised information on activity levels and other variables to MITERRA-Europe and GAINS (here only in national form, but including projections)
- CAPRI included most of the updated emission coefficients and ‘control strategies’ from GAINS.
- For particular scenarios CAPRI also included cost data for abatement options from GAINS and shared an assumption on the costs of ‘balanced fertilisation’ ith GAINS.

A special From a CAPRI point of view one additional outcome of this cooperation within the SCAMMONIA project was a CAPRI model improvement which has been integrated in a “branch version”: the ‘NH3 Version’ of CAPRI. In this version a part of the MITERRA code if necessary with minimal modifications has been included. A full integration of the complete MITERRA code was not desirable because this would have required fundamental changes in the CAPRI nutrient cycle description.

[1] Service contract “Integrated measures in agriculture to reduce ammonia emissions” Contract number 070501/2005/422822/MAR/C1. More information on the project homepage: http://www.scammonia.wur.nl/UK/)

2.3.3. Technical status of interface development

2.3.3.1. Dataflow from CAPRI to GAINS

The CAPRI to GAINS dataflow has included data about animal activities (animal herd size / region) for a cross-check with RAINS/GAINS data assumptions. A detailed description of this data comparison can be found in EUROCARE, 2007, section 1.1. The main challenge of this data exchange is the fact that there are a few differences in definitions which have been investigated in detail based on the 2006 data set. The main differences are:

- GAINS uses a more aggregate list of animal types (cows, other cattle, pigs, hens, other poultry, sheep, horses, fur animals) than CAPRI (8 types of 'other cattle', sows and pigs for fattening, ewes and sheep for fattening).
- GAINS explicitly distinguishes between manure technologies for cattle and pigs (DL, DS, OL, OS, PL, PS).
- All animal numbers are for animal places (animal countings on a particular day) whereas CAPRI gives production data which have to be converted to stock data using the process length in days.
- CAPRI gives "other animal production" in aggregate monetary terms which is not usable for GAINS.

These differences imply that there is clearly a need for a data interface handling the appropriate conversions. There are essentially two conceivable options which have been explored in parallel so far to avoid premature decisions:

- Conversion to stock form and aggregation in CAPRI before data export from CAPRI to GAINS.
- Conversion to stock form and aggregation in GAINS after data export from CAPRI to GAINS.

Option 1 appears to be more attractive in terms of convenience for the IASSA team and in terms of familiarity with the disaggregate CAPRI database on the part of CAPRI operators.

Option 2 may permit some additional checking in the IASSA team if data comparable to the CAPRI level are available. Such a comparison has been carried out at a certain point by Willem Asman which increased the mutual insight into the differences in definitions.

2.3.3.2. Data flow from GAINS to CAPRI

CAPRI relies on GAINS data in particular for:

- Shares of particular manure management options (DS, DL etc.)
- Penetration rates for abatement options
- Time of grazing animals on grassland
- Share of IPPC farms
- Share of urea in total N fertiliser
- Emission factors for particular abatement options
- Cost information related to abatement measures

These data have been updated within the Ammonia project but they are originally from IASSA. The data import into CAPRI relies on Excel files and this is likely to be the easiest solution for a quick update, if needed. This holds in particular if ongoing relationship to Alterra may be used to obtain the set of Excel files in the same format as before.

For more efficient communication in EC4MACS over a longer horizon run a more standardised procedure, perhaps relying on one larger input file, is currently being explored.

2.4. DNDC data interface

2.4.1. General model characteristics

DNDC (Denitrification and Decomposition) has been developed in 1992 and since then improved continuously. DNDC is a biogeochemistry model for agro-ecosystems that can be applied both at the plot-scale and at the regional scale. It consists of two components, the first calculating the state of the soil-plant system such as soil chemical and physical status, vegetation growth and organic carbon mineralization, based on environmental and anthropogenic drivers (daily weather, soil properties, farm management). The second component uses the information on the soil environment to calculate the major processes involved in the exchange of greenhouse gases with the atmosphere, i.e. nitrification, denitrification, and fermentation. The model thus is able to track production, consumption and emission of carbon and nitrogen oxides, ammonia, and methane. In general process-based models like DNDC are applicable to analyse impacts of changing farming practise, as they are able to cope with the complex interplay of environment and anthropogenic activities (LI, C. ET AL., 2007)

2.4.2. Existing model interface

Interactions between CAPRI and DNDC have already been provided within the CAPRI - DynaSpat project (Common Agricultural Policy - The Dynamic and Spatial Dimension). Details about this project can be found at http://www.ilr1.uni-bonn.de/Agpo/rsrch/dynaspat/dynaspat_e.htm. Within this project the model interface between CAPRI and DNDC has been established to estimate GHG fluxes from agricultural soils. Main model output for the DynaSpat purpose was a prediction of NO, N2O, N2, CH4 and NH3 fluxes as well as nitrogen uptake by the plants and nitrogen losses by nitrate leaching.

2.4.3. Technical implementation

Within EC4MACS no current interaction is required, as it has already been done within the CAPRI - DynaSpat project. The existing data interface and model adjustment, described in detail in the current CAPRI model documentation (see ANNEX: 8.2. Linkage to process-based modelling (DNDC)) can also be used for the EC4MACS purpose.

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ANNEX

Annex 1: CAPRI documentation 2008: Version 1