Methodology underlying the CAPRI model

Last update: 21 September 2021

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1 Introduction

The Common Agricultural Policy Regional Impact (CAPRI) model is an agricultural sector model with a focus on Europe (disaggregation into 276 NUTS2 regions, detailed activity data and coverage of Common Agricultural policies), but embedded in a global market model to represent bilateral trade between 45 trade regions (countries or country aggregates).

It is the outcome of a series of projects supported by European Commission research funds, the first one 1996-1999. Operational since more than two decades (1999), it supports decision making related to the Common Agricultural Policy (CAP) and, due to the development of environmental indicators, also environmental policies related to agriculture. In the following we will focus on the elements most relevant to the EUCLIMIT (Development and application of EU economy-wide climate change mitigation modelling capacity) project whereas the full documentation is online at (https://www.capri-model.org/dokuwiki_help/doku.php).

The CAPRI outlook systematically merges the information in historical time series with external projections from other models or independent expert knowledge while imposing technical consistency. In this application key external information came from the models PRIMES, GLOBIOM and AGLINK, together with national expert information on specific items. The key outputs (to GAINS) were the activity data in the livestock sector plus mineral fertilizer and manure use in the crop sector.

CAPRI and GLOBIOM are both modelling the agricultural sector of EU countries and estimate the supply and demand of agricultural products as well as emissions from production and soil. There is thus an overlap of the models in terms of coverage but both have a quite different orientation and structure. Therefore they complement each other and give the user additional information when they are applied to the same scenarios.

The methodology report on CAPRI is structured in the following way. Section 2 briefly presents the general modelling suite as far as it is related to agriculture. Section 3 gives some details on the database where significant improvements have been achieved under EUCLIMIT. Section 4 explains the methodology to produce the CAPRI outlook and the improvements implemented under EUCLIMIT. Section 5 is devoted to “scenario mode” of CAPRI which has been used under EUCLIMIT to distinguish the “reference run” (with additional measures) from the “baseline” (only adopted measures). Two annexes complete this report. The first is a listing of the items available. Annex 2 gives some technical details on the animal sector of CAPRI that is most important for the role of CAPRI in the EUCLIMIT modelling chain.

2 Position in the agriculture related modeling suite of EUCLIMIT

To respond to the project tasks regarding emission projections, the models communicate as shown in Figure 1 below. The macro-economic outlook as well as economic activities and energy use by sector is captured by GEM-E3 and PRIMES. The biomass component of PRIMES provides bioenergy related information both to CAPRI and GLOBIOM, ensuring consistency in bioenergy related assumptions. However, due to the differences between CAPRI and GLOBIOM, different pieces of information are used as model inputs:

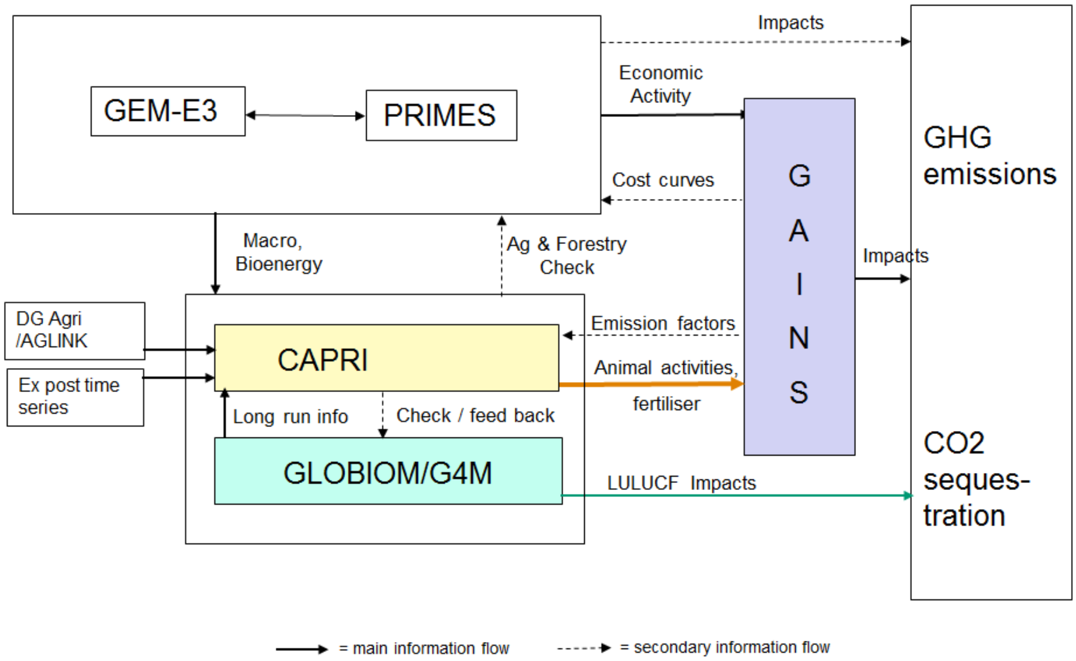
- GLOBIOM uses information on various types of bioenergy demand (heat, power, cooking, transport fuels of first and second generation) and biomass production of energy purposes (from crops, forestry, waste items) as lower bounds for the market equilibrium.
- CAPRI uses supply and demand of biofuels and the shares of first and second generation production. Furthermore the broad split of first generation agricultural feedstocks (cereals, oilseeds, sugar crop) as well as the areas for lignocellulosic crops are inputs from the PRIMES biomass component.

These differences reflect the endogenous coverage of forestry and lignocellulosic crops in GLOBIOM. Both models yield results on the complete area allocation and feed back to the PRIMES biomass components in case of questionable results, for example if a very high expansion of lignocellulosic crops would have dubious implications for the whole area allocation in a country.

GLOBIOM projects a long run market equilibrium for key agricultural (and forestry) products from basic drivers such as GDP, population, food consumption trends, productivity growth. It is interacting with the G4M model for supply side details on forestry. The CAPRI model uses these GLOBIOM projections as prior information for its own baseline. This means that they provide target values for the CAPRI baseline. At the same time CAPRI uses prior information from the AGLINK baseline, but due to the relative strength of these models the weight of AGLINK decreases relative to GLOBIOM along a longer-term projection horizon (2030-2070). The preliminary baseline results of CAPRI and GLOBIOM are compared and in case of surprising differences a feedback loop of information is initiated.

Relying on a considerable level of technical detail, the forestry and agriculture models may also supply projections of emissions and removals of GHGs. However, in the EUCLIMIT modelling suite it is only the LULUCF results from GLOBIOM on carbon releases and sequestration that enter the final reporting. Non-CO_2 emissions from agriculture (and other sectors) are calculated in GAINS, considering technical abatement options and their cost and using the agricultural activity information from CAPRI (animal herds, fertilizer use). The energy related emissions of CO_2 are directly provided by PRIMES.

Figure 1: Overview of EUCLIMIT model interactions.



Important model characteristics may be summarized as follows, highlighting the differences and complementarities.

2.1 CAPRI

CAPRI (for Common Agricultural Policy Regional Impacts) is a global agricultural sector model developed at Bonn University with a clear focus on Europe. The main characteristics are:

- Global multi commodity model covering about 60 agricultural and processed products and 80 world regions, aggregated to 45 trade regions.
- Supply modelling in Europe occurs in more detail (276 NUTS2 regions, potentially disaggregated into 2000 Farm Types) in nonlinear programming models. Both the behavioral function of the global market model as well as the nonlinearities in the European programming models ensure smooth responses to changes in economic incentives.
- Partial equilibrium, meaning that non-agricultural sectors are excluded but there are options and experience to link the CAPRI core model to CGEs.
- European agricultural land use is represented completely (including fruits, vegetables, wine etc.), but some globally relevant crops (e.g. peanuts) are not modelled. Land use classes other than agricultural are taken into account in land use balances, not least to simulate carbon effects.

- The livestock sector is represented in great detail including feed requirements (energy, protein, fibre etc.) and young animal herd constraints (Annex 2).
- CAPRI has a detailed coverage of CAP and further environmental as well as agricultural trade policies (including TRQs), relying on the Armington approach for two way international trade.
- The model is not designed for stand alone outlook work but incorporates external prior information combined with a statistical analysis of its time series database
- It is comparative static in its core (dynamics being limited to land use change (LUC) accounting) and parameters are not specified for very long scenario runs (>2070).

2.2 GLOBIOM

The Global Biosphere Management Model (GLOBIOM) has been developed and is used at the International Institute for Applied Systems Analysis (IIASA). The main characteristics are:

- Global land use model covers 53 world regions, including all EU MS. The regional break down can be altered if needed.
- A maximization of a social welfare function in a linear program simulates the market equilibrium. Breakdowns into small simulation units tend to specialize, which to a certain extent smooth out during aggregation.
- It is a partial equilibrium model with bottom-up design, not only in a strong regional disaggregation (simulation units) but also in the technological detail.
- Substantive experience with linkages to other biophysical and economic models (EPIC, G4M, RUMINANT, PRIMES, POLES etc.)
- It covers the major global land-based production sectors (agriculture, forestry, bioenergy, other natural land) and different bioenergy transformation pathways.
- Compared to CAPRI less details on agricultural policies as the focus is on global land use issues. Bilateral trade is modelled, but two way trade and TRQs are not explicitly represented.
- GLOBIOM is recursive dynamic as e.g. land use changes are transmitted from one period to the other and subject to certain inertia constraints.
- Suitable for long-term scenarios up to the year 2100 driven by long-term macro-economic drivers, while short to medium run projections may not capture recent trends, as GLOBIOM calibrate its baseline to an average around the base year (2000).

2.3 G4M

For the forestry sector, biomass supply is projected by IIASA's Global Forestry Model (G4M):

- Geographically explicit forestry model
- Estimates afforestation, deforestation and forest management area and associated emissions and removals per EU Member State

- Is calibrated to historic data reported by Member States (MS) on afforestation and deforestation and therefore includes policies on these activities. Explicit future targets of forest area development can be included.
- Informs GLOBIOM about potential wood supply and initial land prices
- Receives information from GLOBIOM on the development of wood demand, wood prices and land prices

3 CAPRI database

The main characteristics of the CAPRI data base are:

- Wherever possible link to harmonized, well documented, official and generally available data sources to ensure acceptance of the data and the possibility of annual updates.
- Completeness over time and space. As far as official data sources comprise gaps, suitable algorithms were developed and applied to fill these.
- Consistency between the different data (closed market balances, perfect aggregation from lower to higher regional level etc., match of physical and monetary data)

Data are collected at various levels from the global, to the national, and finally regional (NUTS2) level. A further layer consists of geo-referenced information at the level of clusters of 1x1 km grid cells which serves as input in the spatial down-scaling part of CAPRI (not used in EUCLIMIT). As it would be impossible to ensure consistency across all regional layers simultaneously, the process of building up the data base is split in several parts:

- Building up the *global data base*, which includes areas and market balances for the non-European regions in the market model (mostly from FAO) and bilateral trade flows.
- Building up the *European data base at national or Member State level* (not only EU but also United Kingdom, Norway, Turkey, Western Balkan). It integrates the Economic Accounts data (valued output and input use) with market and farm data, with areas and animal herds (that are currently not covered for non-European countries).
- Building up the data base at *regional or NUTS 2 level*, which takes the national data basically as given (for purposes of data consistency), and includes the allocation of inputs across activities and regions as well as consistent areas, herd sizes and yields at regional level.
- Given the extent of public intervention in the agricultural sector, policy data complete the database. They are partly CAP instruments like premiums and quotas and partly data on trade policies (Most Favorite Nation Tariffs, Preferential Agreements, Tariff Rate quotas, export subsidies) plus data on domestic market support instruments (market interventions, subsidies to consumption) and rural development policies.

- Starting with the nitrogen cycle, which was recorded in CAPRI from the start, more and more environmental data are incorporated into the model. Agricultural greenhouse gas (GHG) emissions, which are mainly based on data coefficients derived from the GAINS model, are complemented by GHG effects from land use, land use change and forestry (LULUCF), which are mainly based on UNFCCC data. Environmental approaches in CAPRI are in line with IPCC 2006 guidelines.

The following table shows the elements of the CAPRI data base as they have been arranged in the tables of the data base.

Table 1: Main elements of the CAPRI data base

	Activities	**Farm- and market balances**	**Prices**	**Positions from the EAA**	**Environment**
Outputs	Output coefficients	Production, seed and feed use, other internal use, losses, stock changes, exports and imports, human consumption, processing	Unit value prices from the EAA with and without subsidies and taxes	Value of outputs with or without subsidies and taxes linked to production	Emission/ removal of Green House Gases (GHG)
Inputs	Input coefficients	Purchases, internal deliveries	Unit value prices from the EAA with and without subsidies and taxes	Value of inputs with or without subsidies and taxes link to input use	Input coefficients and parameters concerning GHG according IPCC
Income indicators	Revenues, costs, Gross Value Added, premiums			Total revenues, costs, gross value added, subsidies, taxes	
Activity levels	Hectares, slaughterings (flow data) and herd sizes (stock data)				
Secondary products		Marketable production, losses, stock	Consumer prices		

		changes, exports and imports, human consumption, processing, biofuel use			

In 2012-13 there has been a thorough revision of the CAPRI **global database** which was motivated and financed from other projects, mainly to adjust to a different organization and data availability from FAOSTAT.

More important for EUCLIMIT are the European data which mostly rely on EUROSTAT and are compiled in two major modules, "COCO" (for complete and consistent at the national level) and "CAPREG" for the CAPRI (NUTS2) regions. The first one, the COCO module for the **national database**, is itself composed of two submodules:

- COCO1 submodule: This is the major step preparing the bulk of the national database for European countries, one country after the other. It involves three steps:
  - A data import step that collects a large set of very heterogeneous input files
  - Including and combining these partly overlapping input data according to a set of hierarchical overlay criteria, and
  - Calculating complete and consistent time series while remaining close to the raw data in an optimization program.

  The data import and overlay steps form a bridge between raw data and their final consolidation step to impose completeness and consistency. The overlay step tries to tackle gaps in the data in a quite conventional way: If data in the first best source (say a particular EUROSTAT table from some domain) are unavailable, look for a second best source and fill the gaps using a conversion factor to take account of potential differences in definitions. To process the amount of data needed in a reasonable time this search to second, third or even fourth best solutions is handled as far as possible in a generic way where it is checked whether certain data are given and reasonable.

  Since the herd output of CAPRI is an input for the GAINS model in the EUCLIMIT project, the development of flow data (levels) to herds in the CAPRI model is briefly described in the next paragraph.

  Before 2011, CAPRI largely disregarded the statistical information on animal herd sizes defined as animals stocks counted at certain survey dates, in favour of the flow data, the slaughterings per year which were more closely related to meat market balances. Nonetheless the conceptual differences caused mapping problems to other modelling systems that use these animal stock data rather than the flow data, in particular GAINS and GLOBIOM operated at IIASA. To improve the fit of the databases, CAPRI has included the herd size data as well, and where they were inconsistent with the flow data also reported by EUROSTAT, has implemented a compromise data set that meets the technical constraints linking animal herd size, slaughterings per year, process length, daily growth and final weight. Under EUCLIMIT this integration was fully integrated in all CAPRI modules from the feed requirement functions, the regionalisation step and the baseline modules to fully exploit the potential for additional consistency checks.

- COCO2 submodule: The second COCO module estimates consumer prices and some supplementary data for the feed sector (by-products used as feedstuffs, animal requirements at the MS level, contents and yields of roughage).

  In addition, the biomass-carbon allocations of forests calculated in precedent CAPRI task "COCO1" are adjusted to the UNFCCC data for the Mediterranean and some other MS regions. The correction of the forest emission factors for these regions was mandatory to overcome the difference between CAPRI and UNFCCC biomass carbon allocations in relation to forest.

  Both COCO tasks run simultaneously for all countries. COCO2 builds on intermediate results from the COCO1 submodule.

CAPRI is a policy information system regionalised at **NUTS 2 level** with an emphasis on the impact of the CAP. The CAPREG module consists of a regionalized agricultural sector model using an activity based approach. It is thus necessary to define for each region in the model, at least for the basis year, the matrix of I/O-coefficients for the different production activities together with prices for these outputs and inputs. Moreover, for calibration and validation purposes information concerning land use and livestock numbers is necessary. The key data are coming from various tables of EUROSTAT's statistics on land use, crop and animal production, and cow milk collection. For some data the Farm Structure Survey (FSS) provides important data to regionalize the national data even though these data are not available on an annual basis.

3.1 Standard database updates in CAPRI

A large scale modelling system such as CAPRI requires an extensive database that needs to be up to date and cleaned from data errors or gaps. Erroneous data are partly cleaned by automated routines in this context but frequently are also detected only in the process of analysing results. They are listed in detail in the log of the CAPRI versioning system SVN (e.g. for revision number 8728, 29.06.2020:"Ensuring that second generation information from Aglink (biofuels from forest and agricultural residues) is picked up and passed on in coco." to make sure that the data are available in the COCO module). This maintenance of the database may not be directly related to EUCLIMIT but it is essential for the functionality of the system (activating the behavioural function for processing of rice will give an error if there is no input into processing). Updates that have been directly related to EUCLIMIT include the biofuel data (bioethanol from https://www.epure.org , biodiesel from https://ebb-eu.org/).

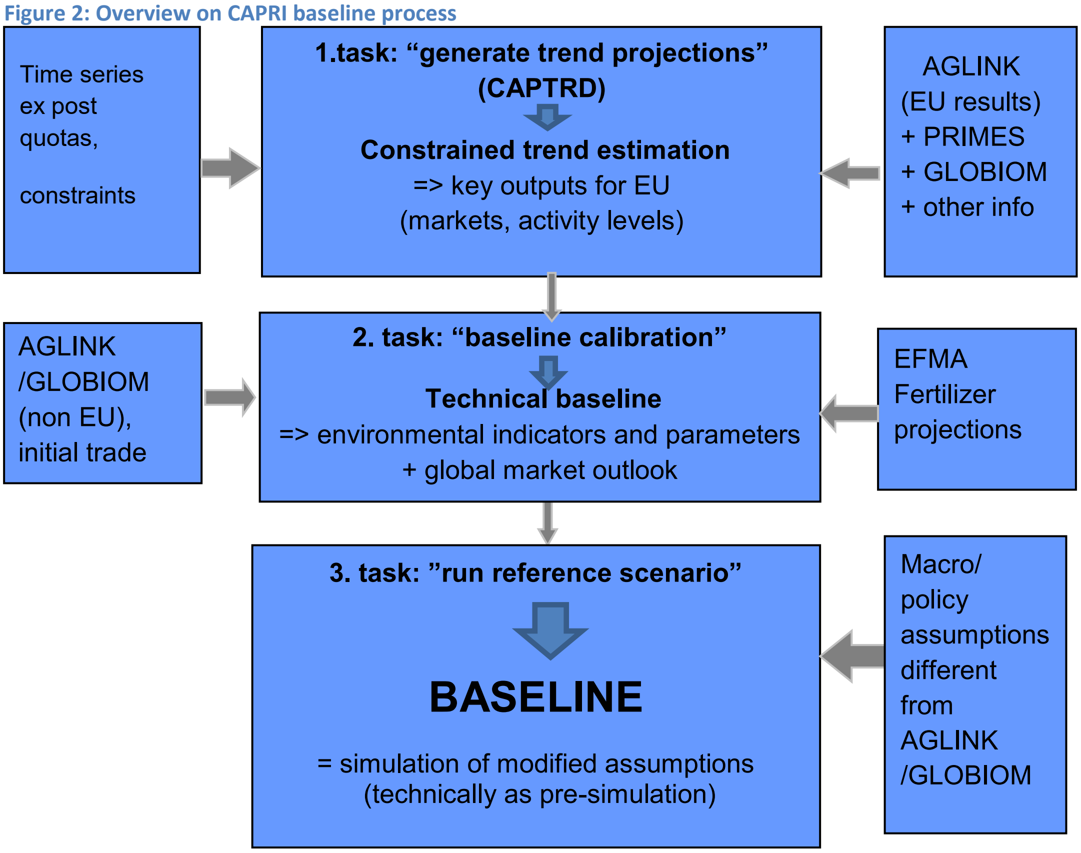
4 Baseline Generation

The purpose of a baseline is to serve as a comparison point or comparison time series for counterfactual analysis. The baseline may be interpreted as a projection in time covering the most probable future development or the European agricultural sector under the status-quo policy and including all future changes already foreseen in the current legislation.

Conceptually, the baseline should capture the complex interrelations between technological, structural and preference changes for agricultural products world-wide in combination with changes in policies, population and non-agricultural markets. Given the complexity of these highly interrelated developments, baselines are in most cases not a straight outcome from a model but developed in conjunction of trend analysis, model runs and expert consultations. In this process, model parameters (e.g. elasticities) and exogenous assumptions (e.g. technological progress captured in yield growth) are adjusted in order to achieve plausible results. Plausibility, in this sense, is to some degree determined by experts' judgements (as given by, for example, European Commission's own projections).

Figure 2 presents the three main tasks of baseline generation and their inputs in each of the task.

Figure 2: Overview on CAPRI baseline process



The **first task**, "generate trend projections", merges the information in the ex post time series with external information (AGLINK, PRIMES, GLOBIOM, national expert information) and results in **constraint trend estimations**.

The CAPRI module providing projections for European regions (CAPTRD) operates in three steps:

- Step 1 involves *independent trends* on all series, providing initial forecasts and statistics on the goodness of fit, or on the variability of the series.
- Step 2 imposes *constraints* like identities (e.g. production = area * yield) or technical bounds (like non-negativity or maximum yields) and introduces specific *expert information* given at the MS level or for specific sectors (like data from PRIMES for bioenergy).
- Step 3 includes expert information on aggregate EU markets, generally from the AGLINK and GLOBIOM models. It is treated in a step distinct from step 2 because it requires some disaggregation to single MS but also because it often is the key information steering the outcome.
- Depending on the aggregation level chosen, the MS result may be disaggregated in subsequent steps to the regional level (NUTS2) or even to the level of farm types.

The result of this task is a first projection for the key variables in the agricultural sector (activity levels and market balances) in Europe.

The constrained trends stemming from CAPTRD task are subject to further consistency restrictions in its second and third tasks. Hence, they are not independent forecasts for each time series and the resulting estimator is a system estimator under constraints (e.g. balanced areas and markets). However, also the constrained trends approach is a rather technical solution. On one hand, it is taking technological relationships into account, but on the other hand, does not consider behavioural functions or policy developments.[1]

The **second task,** "baseline calibration of the market and supply modules", creates a "**technical baseline**". The output includes a market data set that is consistent with the regional trends and with calibrated parameters to steer behavioral functions, and it adds producer prices to be used by the supply models. The baseline calibration of the supply module calibrates various technical and behavioral economic parameters of the supply models, so that the projected regional production is the optimal production at the producer prices coming from the market model calibration.

The **last task** comprises the final reference run which generates the **baseline**. Here, some of the assumptions that were made in tasks one and two need to be revised to obtain the desired starting point for further analysis. For some studies it turned out useful to modify the macro-economic assumptions stemming from external expert sources (AGLINK, GLOBIOM), for example. However, for the EUCLIMIT project the macro-economic assumptions are in line with external sources.

4.1 Specific features and improvements under EUCLIMIT 5

4.1.1 Specific features

Actual information from external models linked to CAPRI are applied in EUCLIMIT 5. GLOBIOM and PRIMES data from October and November 2020, respectively, an actual AGLINK version (aglink2020dgagri) from December 2020 and actual EFMA fertilizer forecasts (Forecast_2019.pdf) are involved in CAPRI for the EUCLIMIT 5 project.

The constraint trends are based on ex-post data from COCO and the global database, updated to 2017, as well as information from the external models mentioned above. AGLINK (Aglink2020dgagri) and GLOBIOM data from 2020 are used for the macro assumptions. The

[1] The only exception are the quota regime on the milk and sugar markets which are recognised in the trend projections.

macro data of GLOBIOM included already the Covid19 effects for 2020. This effect was included into CAPRI via the baseline.

4.1.2 Update of MS level expert information

Representatives of the Member States (MS) were able to express their views on the CAPRI projections for their countries. EUROCARE received these remarks through the European Commission. Often the MS' comments and criticism relate to differences in projections with their own national modelling results or different expectations.

The MS's comments and EUROCARE's response on how and to what extent adjustments have been made in CARPRI are listed below by country.

Table 2: MS comments and CAPRI adjustements

	MS comment	**CAPRI adjustment**
AUSTRIA		
Milk yield of dairy cows	Fast increase; adjust to Austrian WEM numbers; check 2020 as well	The long run increase in milk yields has been dampened and the medium run evolution revised in view of recent EUROSTAT data.
Dairy cow herd	Adjust the number of dairy cows to reflect milk yield development	The earlier strong Covid19 effect on dairy cows is revised and together with the consideration of the latest EUROSTAT data on dairy cow numbers, the 2020 decrease compared to 2015 is almost eliminated. Beyond 2020 the downward trend is strongly moderated, together with downward adjustments to milk yield growth. However, a complete alignment to the WEM numbers is not plausible. This would render AT a strong net exporter.
Non-dairy cattle herd	Check	The strong drop in CAPRI non-dairy herd in 2020 is moderated, but not the general decline. Austrian projections of an increase in the non-dairy herd contradict recent EUROSTAT data.
Pigs herd	Adjust 2020 number to reflect more closely the 2019 number provided; not clear why pig numbers go up after 2040	The marked decline of pig numbers in 2020 disappeared after considering the latest EUROSTAT data, also the recovery after 2040 (in line with a downward correction of GLOBIOM projections for pork production). Hence the decline is monotonic, going down to about 2.3 Million pigs in 2050.
Sheep and goat herd	Check 2020 number; looks too high compared to historical data and projections	Current EUROSTAT data for sheep is increasing between 2015 and 2019, confirming the high value in 2020. But CAPRI also sees this as a more temporary peak, followed by a moderate decline (in line with the GLOBIOM outlook).

Mineral fertilizer	Looks like Austrian projection ignores corona crisis 2020 or lower demand comes indeed from larger cattle population and higher amount of animal manure.	Austrian fertilizer projections are much higher than 2018 statistics, in spite of Covid19. But after 2020 updated CAPRI projections imply a largely stagnating mineral fertilizer use.
BELGIUM		
Milk yield of dairy cows	Check milk yield	The milk yield calculated from the milk production and the dairy herd in the current EUROSTAT data shows an increase in milk yield that is comparable to the increase in CRF yields over the recent years, such that updated EUROSTAT data have also narrowed the gap between CRF and CAPRI in terms of development
Dairy cow herd	Dairy cow herd	Considering recent EUROSTAT data increases the numbers of dairy cows from 2015 to 2020, similar to CRF and EUROSTAT. However, beyond 2020 CAPRI expects a decline in the dairy cow herd. Furthermore CAPRI cannot adjust to the level of the CRF data as CAPRI has to rely on EUROSTAT in general (giving higher cow numbers than CRF) in Belgium.
CZECH REPUBLIC		
Dairy cow herd	Check with national projections	The earlier strong increase in milk yields has been moderated giving an evolution similar to those of Czech experts. This indirectly also moderates the decline in cow numbers that stabilize around 325000 heads, which is lower than the national projections but markedly higher than earlier CAPRI projections.
Non-dairy cattle herd	Check with national projections	CAPRI maintains a certain decline in the non-dairy herd which is in line with the GLOBIOM outlook on beef production. The projections on the sheep herd have been revised downward to reflect the expectation of a declining sheep meat production, in line with GLOBIOM.
Pigs herd	Check with national projections	The assumption of a declining pigs herd has been maintained, contrary to national expectations. This is in line both with recent EUROSTAT data that do not show signs of a recovery and also with the long run GLOBIOM

		outlook on pork production.
Mineral fertilizer	Consumption of mineral fertilizer: check, explain and correct data; do not match EUROSTAT nor GHG inventory.	It seems that two EUROSTAT sources (fertilizer use and the sales based on EFMA) agree with CRF on the strong increase up to 2017 but also show a reversal in 2018 and 2019. The immediate outlook is an expansion in line with EFMA while long run efficiency gains dominate only after 2040.
DENMARK		
Milk yield of dairy cows	Check with DCE projections	The DCE forecast for 2020 is close to the EUROSTAT milk production of 2019. Hence, more recent EUROSTAT data will improve the short-term forecast in CAPRI.
Dairy cow herd	Check with DCE projections	More recent data from EUROSTAT have informed the projection. The strong Covid19 effect has been removed and the number of dairy cows is increasing now from 2015 to 2020.
Non-dairy cattle herd	Check with DCE projections	Projections of non-dairy herds match EUROSTAT and CRF data. Here specific action does not appear necessary, except perhaps clarification why the Danish DCE data are markedly higher. The long run outlook is slightly corrected downwards in line with beef projections in GLOBIOM.
Pigs herd	Check with DCE projections	Consideration of recent EUROSTAT data slightly increases the forecasted pigs herd over the next years and thus reduces the deviation from the DCE forecasts. In the long run it has been understood that the Danish legislation operates against a further growth of the pigs herd beyond 2020 which was entered as a priori information, slowing down the growth of the Danish pig population that exceeds 13 million only after 2040.
FINLAND		
Milk yield of dairy cows	Correct milk yields downwards	The milk yields calculated from recent EUROSTAT data are still higher in 2019 than in Luke's statistics. Nonetheless, using the latest EUROSTAT data has slightly reduced the milk yield forecasts over the years up to 2030.

Dairy cow herd	Correct number of dairy cows upwards	Using more recent data from EUROSTAT increases the number of dairy cows in 2020. In addition, the treatment of the Covid19 effect has been changed, also resulting in a higher projection of the dairy herd in 2020.
Non-dairy cattle herd	Correct number of non-dairy cattle (too sharp drop)	Recent data from EUROSTAT have moderated the short run decline in 2020, so that the non-monotonous development between 2015 and 2025 is avoided. However the long run trend of a moderate decline has been maintained, decreasing the non-dairy herd to about 525000 animals in 2070.
Mineral fertilizer	Check	The long run decline for fertilizer use has been maintained while considering recent EUROSTAT data for the short run (2020).
GERMANY		
Pigs herd	Check	Consideration of the new German fertilizer regulation has curbed the growth of the pigs herd.
Sheep and goat herd	Check	Aggregated sheep and goat numbers of CRF (UNFCCC) are in line with ex post data of CAPRI. Differences in levels are often due to CRF using the June counting and CAPRI taking an average of June and December. The outlook has been corrected slightly downward in line with GLOBIOM projections on sheep meat production.
Mineral fertilizer	Check	For fertilizers a strong reduction from 2015 to 2020 is already visible in the available statistical data. Compared to this reduced level the further expected decline to 2050 is only 16% (and 2% to 2030).
IRELAND		
Milk yield of dairy cows Dairy cow herd	The milk yield for the future (2030) may be overestimated somewhat. Could be adjusted downward to reflect the Irish comments, which would increase the number of dairy cows (total production seems ok).	There are no big differences between FAPRI and CAPRI milk yields per dairy cow. Current EUROSTAT data suggest an upward correction for 2020 (so in the direction of FAPRI) that reduces the projected growth in milk yields and increases the dairy cow herd over the medium run

Animal herds	Check with national projections	FAPRI projections for the pigs herd, dairy cows, and in particular non-dairy cow exceed 2019 ex post data of EUROSTAT, while CAPRI projections are somewhat below. The strong Covid19 effect for dairy cows in 2020 has been modified, correcting CAPRI animal herds for 2020 upwards. For pigs revised recent GLOBIOM projections would suggest a strong decline, contrary to the FAPRI Ireland outlook from 2018. Given the uncertainties, CAPRI has maintained a rather stagnating outlook for this sector.
Mineral fertilizer	Check with national projections	The level effect for fertilizer has been revised, increasing the 2020 fertilizer consumption to about 370 kt. Concerning the trend, the Irish projections imply an increase in fertilizer use that is in contrast to medium run projections by EFMA. The increase is also at odds with developments and ambition throughout of Europe to increase fertilizer use efficiency. Therefore the downward sloping fertilizer projections are basically maintained in terms of direction.
ITALY		
Milk yield of dairy cows	Check with national projections	Based on the most recent EUROSTAT data, milk yield rose to 6660 l per dairy cow in 2019, such that the 8000 l per dairy cow assumed by ISTAT would deviate strongly from the dairy cow numbers and yield data of EUROSTAT.
Dairy cow herd	Check with national projections	ISTAT's dairy cow numbers (1600 in 2020) are much lower than EUROSTAT's (1876 in 2019), although the EUROSTAT data have currently been revised downwards somewhat. In the long run, from 2040 onwards, the updated CAPRI projections show a more moderate decline in the herd size.
Poultry herd	Check with national projections	Poultry heads have been slightly revised downward. For hens this is in line with reduced GLOBIOM projections on eggs production.
Rice level	Change upwards	The rice level in CAPRI follows external supports. Both AGLINK (DG AGri) and GLOBIOM (IIASA) see a stagnating development of cereal production in Italy. In the very long run (after 2050), GLOBIOM even expects that the rice area will decrease markedly.

Mineral fertilizer	IIASA assumes a greater emission reduction that is probably due to a greater reduction in the use of synthetic fertilizers.	The decline in mineral fertilizer consumption has weakened in the last revision, but in fact, gradually reduced quantities can be observed due to increased efficiency.
LITHUANIA		
LATVIA		
Milk yield of dairy cows	Correct milk yield and milk production data for 2020 (and adjust as a result projections)	Use of recent EUROSTAT data increases the projected milk yields in short run ex ante years. This also eliminates the short run decline in milk production in 2020.
Mineral fertilizer	Check and correct the source of mineral fertilizer consumption data	We agree that the strong drop in fertilizer use after 2015 was not convincing and have revised the projections. The latest projections show a decline only after 2060.
MALTA		
Milk yield of dairy cows	Check with national projections	Latest EUROSTAT data slow down the increase in milk yield per dairy cow and influence future forecasts. Upon reconsideration the growth in milk yields has been constrained. This also acts to stabilize the dairy cow population, may be not like in the WEM projections of Malta but certainly to a more moderate path of decline.
Dairy cow herd	Check with national projections	More current EUROSTAT data show only a slight decrease in the number of dairy cows and have slowed down the decrease in the projections, so that they are come closer to the development in the WEM model.
Mineral fertilizer	Check	The projections of mineral fertilizers were checked against those in other regions and other variables. While the improvement in the nitrogen surplus in Malta is not extraordinary compared to other countries, the reduction in mineral fertilizer was indeed very strong and has been moderated as well.
NETHERLANDS		
Dairy cow herd	Check with national projections	The decrease in the number of dairy cows in 2020 was unrealistic and has been corrected considering the most recent EUROSTAT data.
Pigs herd	Check with national projections	The pigs herd in GAINS (and EUROSTAT) is twice as high as in KEV. The KEV data may not relate to all types of pigs, which includes piglets and sows.

Mineral fertilizer	Check	Indeed we have anticipated further efficiency gains and savings in mineral fertilizer use. Considering national comments these have been revisited and moderated, in particular after 2050.
POLAND	Check with national projections	
Milk yield of dairy cows	Check with national projections	The milk yield per dairy cow appears to be reasonable against developments in other countries and has been basically maintained.
Animal herds	Check with national projections	Dairy, non-dairy and pigs herd projections fit well to the most recent EUROSTAT data. NECP projected higher herds until 2040. Checking the CAPRI projections and recent EUROSTAT data did not provide strong arguments for fundamental revisions. However, there have been moderate upward revisions in the cattle sector, downward revisions in the poultry population after 2050, and downward revisions in sheep and goats, taking into account recent data and a downward revised outlook from GLOBIOM.
Mineral fertilizer	Check	Fertilizer related efficiency gains have been reconsidered and reduced in magnitude.
SWEDEN		
Dairy cow herd	Check	The decline in the number of dairy cows in the past and the increase in the future were mainly driven by milk production and demand. The future production and demand are aligned with GLOBIOM assumptions. The earlier projected recovery has been reconsidered and removed. A different specification has eliminated the exaggeration of the Covid19 effect on the dairy cow herd in 2020.
SLOVAKIA		
Milk yield of dairy cows	We need a downward correction on milk yield per cow and an increase in the number of dairy cows as a result in the future.	The high increase in ex-ante milk yield growth is related to a reduced dairy herd. The slower decline in the dairy herd has also slowed down the rise in milk yields per cow, such that the final projections are closer to expectations by NEIS.
Dairy cow herd	We need a downward correction on milk yield per cow and an increase in the number of dairy	Considering more recent EUROSTAT data for dairy cow herds (which correspond exactly to the NEIS data) have led to an earlier stabilization of the herd projections.

	cows as a result in the future.	
Non-dairy cattle herd	Check	The decline in the non-dairy herd corresponds to GLOBIOM outlook for beef production and has been basically maintained.
SLOVENIA		
Milk yield of dairy cows	Check historical values for milk yield dairy cows (5% too low); projected milk yield: lower the increase in milk yield up to 2050 (too sharp increase)	The decline in dairy cow numbers and increase of milk yields has been slowed down to pick up features from the national scenarios.
Dairy cow herd	Change in milk yields include possible effect on number of dairy cows if milk demand remains the same.	The decline in dairy cow numbers and increase of milk yields has been slowed down to pick up features from the national scenarios.
Pigs herd	Adjust pig numbers upward	As pig fattening has markedly declined in the past, an increase in the herd of pigs, as in the national projections, seems unrealistic without political support measures in place. The latest EUROSTAT data also shows a further decrease. Finally the GLOBIOM projections on pork production also point to a further decline.
Sheep and goat herd	Change number of small ruminants (sheep and goats): demand low and in addition bears and wolves keep stock low	The increase in the sheep and goat herd has been slowed down after reconsideration of recent statistical data and a downward correction in the GLOBIOM expectations for sheep meat production.
Mineral fertilizer	Check if N fertilizer consumption is not too low	The decline in fertilizer consumption has been slightly reduced. However, gradual nitrogen use efficiency gains are just as plausible and desirable for Slovenia as for other countries such that the expected increase in the national projections is not really convincing.

Representatives of the MS naturally look at the latest statistical data and, in the case of projections, the results of their national models, if available.

In terms of historical data, a model as comprehensive as CAPRI usually cannot be as current as newly published data. Updating data is time consuming and always a few years behind. If the actual data differ significantly from the past, this information is often not yet taken into account in CAPRI.

As part of the EUCLIMIT 5 project, actual data on animal herd sizes from EUROSTAT were introduced in a bypass via the task of “generate trend projections” (CAPTRD). The above list shows that this has already invalidated a considerable number of critical objections to the short-term forecast.

With regard to the projections, national model approaches can differ greatly from the CAPRI model. CAPRI is a consistent approach with interactions between activities, production and prices at different regional aggregation levels. Consequently, changing one influencing factor leads to a chain of other changes. For example, dairy cow herds are affected by the entire cattle breeding chain (see Annex 2) and milk and meat production restrictions. All influencing factors must fit together in order to satisfy the equations in the supply model and the equilibrium challenge in the market model.

In order to meet the requirements of the MS, adjusting screws such as the external information from other models or experts have been turned. In some cases, these adjustments tended to improve the results and came closer to the results of the national model.

4.1.3 Update of EFMA information of fertilizer outlook

Fertilizer projections from EFMA are used in CAPRI for the medium term horizon. Fertilizer information published in EFMA reporting has become more complete in terms of single country information such that it was feasible to update the EFMA forecasts for basically all EU MS without lengthy communication processes.

However it should be mentioned that beyond 2020, an increasing weight has been given to the CAPRI internal projection mechanisms as opposed to the EFMA projections (running to 2022 only). These internal mechanisms rely on a stable evolution of parameters describing farmer’s behaviour, including their habit to apply a certain over-fertilisation above crop needs, even when acknowledging that a part of organic nutrients are considered not “plant available” (and thus expected to be lost to the environment).

4.1.4 Deepening of linkages to IIASA models

The transfer of GLOBIOM products that are assigned to CAPRI products is continuously expanded and adapted. In EUCLIMIT 5, the list is expanded to include vegetable oils.

It is also worth mentioning that some technical details to deal with the transition from the medium run (up to 2020) to the long run (2030 and beyond) have been changed in the CAPTRD module. Now, it is possible phase in the GLOBIOM information already before 2020 if this is useful for common applications. In the end it turned out that for EUCLIMIT it is not useful to increase the weight for GLOBIOM a lot up to 2020, but the initial discussion suggested that more flexibility might be needed.

In previous EUCLIMIT versions the CAPRI land use data was extended for non-agricultural land uses. A total area balance has been added to the set of CAPRI constraints used in the initial trend estimations (CAPTRD step in Figure 2) with benefits for the projections.

Furthermore the consistent "double" accounting in the animal sector in terms of flow data (slaughterings) and stock data (animal herds counted at some point in time) has also been extended from the database routines to the projection routines with a few additional equations under previous EUCLIMIT projects.

In terms of the linkages to GAINS there have been no changes such that the outputs to gains continue to be

- animal herd data (dairy cows, other cattle, pigs fattened, piglets, sows, sheep, hens, other poultry)
- dairy cow milk yields including milk directly fed to calves
- nitrogen fertilizer and manure use quantities

5 Simulation mode

The CAPRI **global market module** breaks down the world into 45 country aggregates or trading partners, each one (and sometimes regional components within these) featuring systems of supply, human consumption, feed and processing functions. The parameters of these functions are derived from elasticities borrowed from other studies and modelling systems and calibrated to projected quantities and prices in the simulation year. Regularity is ensured through the choice of the functional form (a normalised quadratic function for feed and supply and a generalised Leontief expenditure function for human consumption) and some further restrictions (homogeneity of degree zero in prices, symmetry and correct curvature). Accordingly, the demand system allows for the calculation of welfare changes for consumers, processing industry and public sector. Policy instruments in the market module include bilateral tariffs and tariff rate quotas (TRQs). Intervention purchases and subsidised exports under the World Trade Organisation (WTO) commitment restrictions are explicitly modelled for the EU 14.

In the market module, special attention is given to the processing of dairy products in the EU. First, balancing equations for milk fat and protein ensure that these exactly exhaust the amount of fat and protein contained in the raw milk. The production of processed dairy products is based on a normalised quadratic function driven by the regional differences between the market price and the value of its fat and protein content. Then, for consistency, prices of raw milk are also derived from their fat and protein content valued with fat and protein prices.

The market module treats bilateral world trade based on the Armington assumption (Armington, 1969). According to Armington's theory, the composition of demand from domestic sales and different import origins responds smoothly to price relatives among various bilateral trade flows. This allows the model to reflect trade preferences for certain regions (e.g. Parma or Manchego cheese) and to explain the common feature of trade statistics that a country may export to another country and in the same period also import from this trading partner. As many trade policy instruments like TRQs are specific for certain trading partners, bilateral trade modeling is a precondition for accurate representation of trade policies.

For **European regions** the supply side behavioural function in the global market module approximate the behaviour of country aggregates of regional **nonlinear programming models**. In these models regional agricultural supply of annual crops and animal outputs are given as solutions to a profit maximisation under a limited number of constraints: the land supply curve, policy restrictions such as sales quotas and set aside obligations and feeding restrictions based on requirement functions.

The underlying methodology assumes a *two stage decision process*. In the *first stage*, producers determine *optimal variable input coefficients* per hectare or head (nutrient needs for crops and animals, seed, plant protection, energy, pharmaceutical inputs, etc.) for given yields, which are determined exogenously by trend analysis (data from EUROSTAT) and updated depending on price changes against the baseline. Nutrient requirements enter the supply models as constraints and all other variable inputs, together with their prices, define the accounting cost matrix. In the *second stage*, the *profit maximising mix of crop and animal activities* is determined simultaneously with cost minimising feed and fertiliser in the supply models. Availability of grass and arable land and the presence of quotas impose a restriction on acreage or production possibilities. Moreover, crop production is influenced by set aside obligations. Animal requirements (e.g. feed energy and crude protein) are covered by a cost minimising feeding combination. Fertiliser needs of crops have to be met by either organic nutrients found in manure (output from animals) or in purchased fertiliser (traded good). A nonlinear cost function covering the effect of all factors not explicitly handled by restrictions or the accounting costs – such as additional binding resources or risk - ensures calibration of activity levels and feeding habits in the base year and plausible reactions of the system. These cost function terms are estimated from ex-post data or calibrated to exogenous elasticities. Fodder (grass, straw, fodder maize, root crops, silage, milk from suckler cows or mother goat and sheep) is assumed to be non-tradable, and hence links animal processes to the crops and regional land availability. All other outputs and inputs can be sold and purchased at fixed prices. The use of a mathematical programming approach has the advantage to directly embed compensation payments, set-aside obligations, voluntary set-aside as well as to capture important relations between agricultural production activities. Not at least, environmental indicators as NPK balances and output of gases linked to global warming are easily represented in the system.

The equilibrium in CAPRI is obtained by letting the *regional supply and global market modules* iterate with each other. In the first iteration, the regional aggregate programming models (one for each Nuts 2 region) are solved with prices taken from the baseline. After being solved, the regional results of these models (crop areas, herd sizes, input/output coefficients, etc.) are aggregated to the country level, leading to a certain deviation from the baseline solution, depending on the kind of scenario. Subsequently the supply side behavioural functions of the market module (for supply and feed demand) are recalibrated to pass at the given prices through the quantity results from the supply models. The market module is then solved, yielding new equilibrium producer prices for all regions, including European countries. These prices are then passed back to the supply models for the following iteration. At the same time, in between iterations, premiums for activities are adjusted if ceilings defined in the Common Market Organisations (CMOs) are overshot.

Annex 1 Activities and items in CAPRI

List of activities in the supply model

Group	Activity	Code
Cereals	Soft wheat Durum wheat Rye and Meslin Barley Oats Paddy rice Maize Other cereals	SWHE DWHE RYEM BARL OATS PARI MAIZ OCER
Oilseeds	Rape Sunflower Soya Olives for oil Other oilseeds	RAPE SUNF SOYA OLIV OOIL

Group	Activity	Code
Other annual crops	Pulses Potatoes Sugar beet Flax and hemp Tobacco Other industrial crops New energy crops	PULS POTA SUGB TEXT TOBA OIND NECR
Vegetables Fruits Other perennials	Tomatoes Other vegetables Apples, pear & peaches Citrus fruits Other fruits Table grapes Table olives Table wine Nurseries Flowers Other marketable crops	TOMA OVEG APPL CITR OFRU TAGR TABO TWIN NURS FLOW OCRO
Fodder production	Fodder maize Fodder root crops Other fodder on arable land Gras and grazing	MAIF ROOF OFAR GRAS
Fallow land and set-aside	Set aside obligatory idling Set aside obligatory used as grass land Set aside obligatory fast growing trees Set aside voluntary Idling of former GRAS for histosol protection Idling of former CROP for histosol protection Fallow land	ISET GSET TSET VSET IHISGR IHISCR FALL

Group	Activity	Code
Cattle	Dairy cows Sucker cows Male adult cattle fattening Heifers fattening Heifers raising Fattening of male calves Fattening of female calves Raising of male calves Raising of female calves	DCOW SCOW BULF HEIF HEIR CAMF CAFF CAMR CAFR
Pigs, poultry and other animals	Pig fattening Pig breeding Poultry fattening Laying hens Sheep and goat fattening Sheep and goat for milk Other animals	PIGF SOWS POUF HENS SHGF SHGM OANI

Land use classes in CAPRI

ARTO	total area - total land and inland waters
FORE	Forest area
CROP	crop area - arable and permanent
GRSLND	Grassland includes pastures and meadows (GRAS) but also unmanaged land covered with non-forest vegetation and some gras (UNFCCC type)
WETLND	Wetlands include inland waters and some wet vegetation (UNFCCC type)
RESLND	Residual land with sparse grass but potentially other vegetation (UNFCCC type)
ARTIF	artificial - buildings or roads
OART	artificial

ARAO	(other) arable crops - all arable crops excluding rice and fallow (see also definition of ARAC below)
TGRS	temporary meadows and pastures (~ OFAR) plus fallow from FAO
TCRP	temporary crops (=ARAC-FALL-OFAR) from FAO
FODBAL	fodder (permanent grassland or fodder on cropland) or fallow (incl. set aside land)
PARI	paddy rice (already defined)
GRAT	temporary grassland (alternative code used for CORINE data, definition identical to TGRA)
FRCT	fruit and citrus
OLIVGR	Olive Groves
VINY	vineyard (already defined)
NUPC	nursery and permanent crops (Note: the aggregate PERM also includes flowers and other vegetables
BLWO	board leaved wood
COWO	coniferous wood
MIWO	mixed wood
POEU	plantations (wood) and eucalyptus
SHRUNTC	shrub land - no tree cover
SHRUTC	shrub land - tree cover
GRANTC	Grassland - no tree cover
GRATC	Grassland - tree cover
FALL	fallow land (already defined)

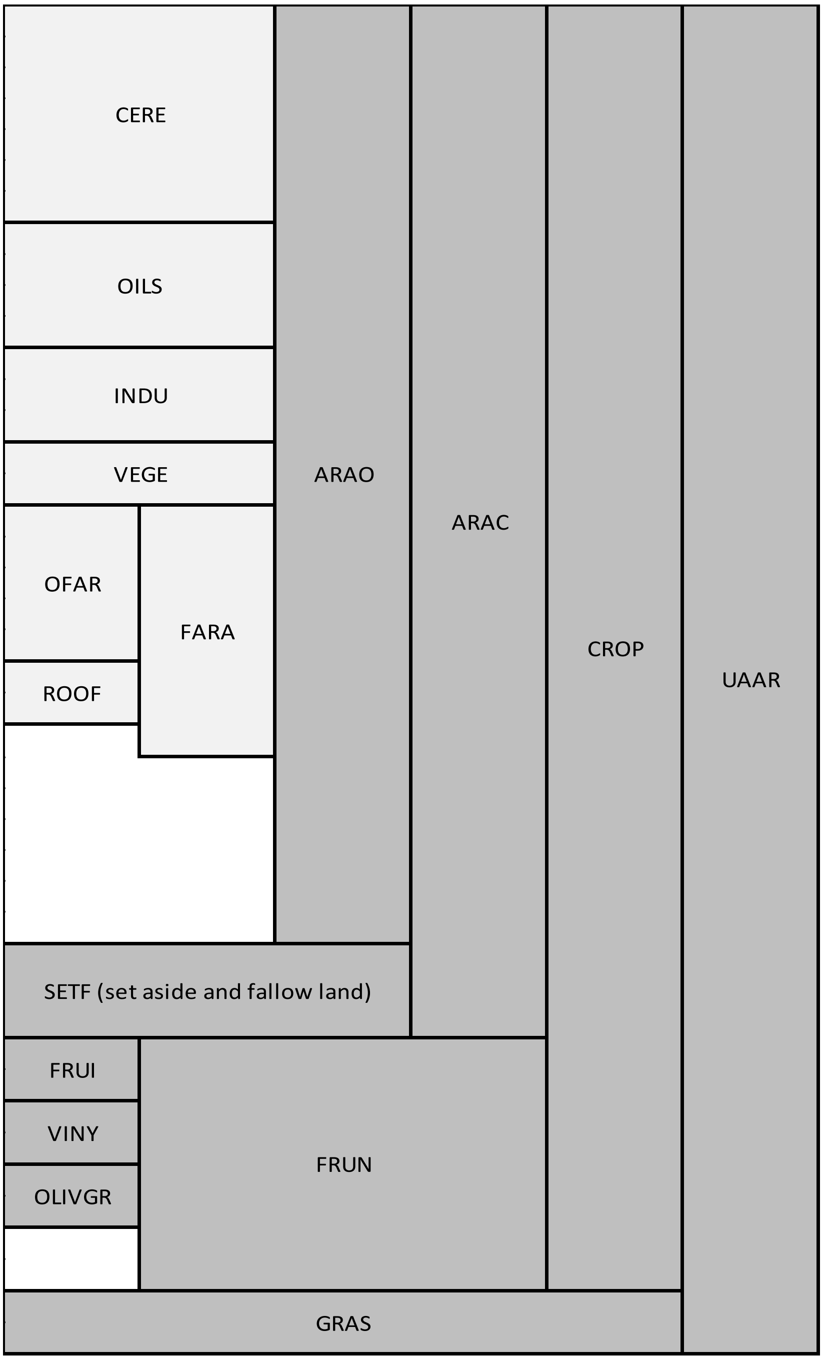
OSPA	other sparsely vegetated or bare
INLW	inland waters
MARW	marine waters
KITC	kitchen garden
FARA	fodder production activity on arable land

Land use aggregates in CAPRI

OLND	other land - shrub, sparsely vegetated or bare
SVBA	sparsely vegetated or bare
OLNDARTIF	other land + artificial
ARAC	arable crops
FRUN	fruits, nursery and (other) permanent crops
WATER	inland or marine waters
ARTIF	artificial - buildings or roads (already defined)
OWL	other wooded land - shrub or grassland with tree cover (definition to be discussed)
TWL	total wooded land - forest + other wooded land
SHRU	shrub land
FORE	forest area (already defined)
GRAS	gras and grazings production activity
UAAR	utilizable agricultural area (already defined)
ARTO	total area - total land and inland waters (already defined)
ARTM	total area including marine waters

CROP	crop area - arable and permanent (already defined)

Mapping primary agricultural activities to groups and land use in CAPRI



Mapping land use classes to aggregates in CAPRI

<table>
<tr><td>PARI</td><td rowspan="4">ARAC
(TGRS+TCRP)</td><td rowspan="8">CROP</td><td rowspan="10">UAAR</td><td rowspan="19">ARTO</td><td rowspan="20">ARTM</td></tr>
<tr><td>FALL</td></tr>
<tr><td>ARAO</td></tr>
<tr><td>GRAT</td></tr>
<tr><td>FRCT</td><td rowspan="4">FRUN</td></tr>
<tr><td>OLIVGR</td></tr>
<tr><td>NUPC</td></tr>
<tr><td>VINY</td></tr>
<tr><td>GRANTC</td><td rowspan="2">GRAS</td><td rowspan="3"></td></tr>
<tr><td>GRATC</td></tr>
<tr><td>OART</td><td>ARTIF</td><td rowspan="10"></td></tr>
<tr><td>BLWO</td><td rowspan="4">FORE</td><td rowspan="5">TWL</td></tr>
<tr><td>COWO</td></tr>
<tr><td>MIWO</td></tr>
<tr><td>POEU</td></tr>
<tr><td>SHRUTC=OWL</td><td rowspan="3">OLND</td></tr>
<tr><td>OSPA</td><td rowspan="4"></td></tr>
<tr><td>SHRUNTC</td></tr>
<tr><td>INLW</td><td rowspan="2">WATER</td></tr>
<tr><td>MARW</td><td></td></tr>
</table>

Output, inputs, income indicators, policy variables and processed products in the data base

Group	Item	Code
Outputs		
Cereals	Soft wheat Durum wheat Rye and Meslin Barley Oats Paddy rice Maize Other cereals	SWHE DWHE RYEM BARL OATS PARI MAIZ OCER
Oilseeds	Rape Sunflower Soya Olives for oil Other oilseeds	RAPE SUNF SOYA OLIV OOIL
Other annual crops	Pulses Potatoes Sugar beet Flax and hemp Tobacco Other industrial crops New energy crops Agricultural residuals usable for biofuels	PULS POTA SUGB TEXT TOBA OIND NECR ARES
Vegetables Fruits Other perennials	Tomatoes Other vegetables Apples, pear & peaches Citrus fruits Other fruits Table grapes Table olives	TOMA OVEG APPL CITR OFRU TAGR TABO

Group	Item	Code
	Table wine Nurseries Flowers Other marketable crops	TWIN NURS FLOW OCRO
Fodder	Gras Fodder maize Other fodder from arable land Fodder root crops Straw	GRAS MAIF OFAR ROOF STRA
Marketable products from animal product	Milk from cows Sheep and goat milk Beef Pork meat Sheep and goat meat Poultry meat Eggs Other marketable animal products Livestock residues usable for biofuels	COMI SGMI BEEF PORK SGMT POUM EGGS OANI LRES
Intermediate products from animal production	Milk from cows for feeding Milk from sheep and goat cows for feeding Young cows Young bulls Young heifers Young male calves Young female calves Piglets Lambs Chicken Nitrogen from manure Phosphate from manure Potassium from manure	COMF SGMF YCO WYBUL YHEI YCAM YCAF YPIG YLAM YCHI MANN MANP MANK
Other Output from	Renting of milk quota	RQUO

Group	Item	Code
EAA	Agricultural services Non Agricultural Secondary Activities Service output from GHG mitigation [Quantity measure in constant prices of 2005]	SERO NASA mitiO
Inputs		
Mineral and organic fertiliser Seed and plant protection	Nitrogen fertiliser Phosphate fertiliser Potassium fertiliser Calcium in fertiliser Seed Plant protection	NITF PHOF POTF CAOF SEED PLAP
Feedings tuff	Feed cereals Feed rich protein Feed rich energy Feed based on milk products Gras Fodder maize Fodder other on arable land Fodder root crops Cow Milk for feeding Sheep and Goat Milk for feeding Feed other Straw	FCER FPRO FENE FMIL FGRA FMAI FOFA FROO FCOM FSGM FOTH FSTRA
Young animal Other animal specific inputs	Young cow Young bull Young heifer Young male calf Young female calf Piglet Lamb Chicken	ICOW IBUL IHEI ICAM ICAF IPIG ILAM ICHI

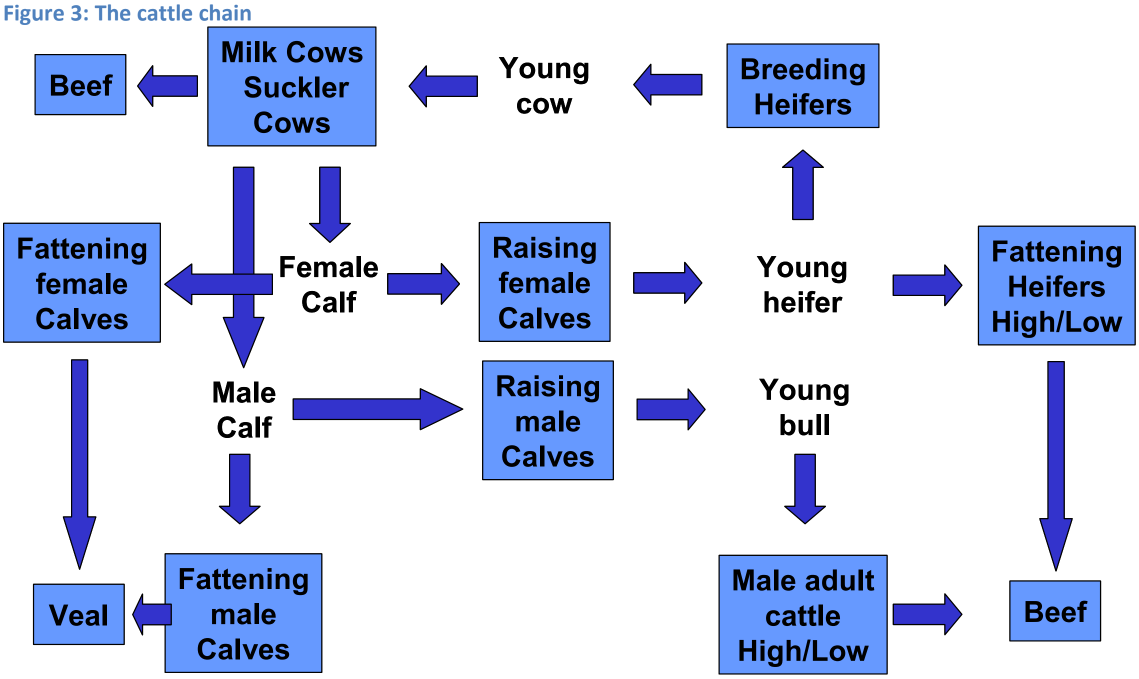
Group	Item	Code
	Pharmaceutical inputs	IPHA
General inputs	Maintenance materials	REPM
	Maintenance buildings	REPB
	Electricity	ELEC
	Heating gas and oil	EGAS
	Fuels	EFUL
	Lubricants	ELUB
	Water balance or deficit	WATR
	Agricultural services input	SERI
	Other inputs	INPO
	Efforts for GHG mitigation may be negative in case of benefits [Quantity measure in constant prices of 2005]	mitil
Other indicators		
Income indicators	Production value	TOOU
	Total input costs	TOIN
	Gross value added at producer prices	GVAP
	Gross value added at basic prices	GVAB
	Gross value added at market prices plus CAP premiums	MGVA
Activity level	Cropped area, slaughtered heads or herd size	LEVL
Policy variables Relating to activities	Premium ceiling	PRMC
	Historic yield	HSTY
	CAP premium per ton	PRMT
	Set-aside rate	SETR
	Premium declared below base area/herd	PRMD
	Premium effectively paid	PRME
	Premium amount in regulation	PRMR
	Type of premium application	APPTYPE
	Factor converting PRMR into PRMD	APPFACT
	Ceiling cut factor	CEILCUT

Group	Item	Code
Processed products	Rice milled	RICE
	Molasse	MOLA
	Starch	STAR
	Sugar	SUGA
	Rape seed oil	RAPO
	Sunflower seed oil	SUNO
	Soya oil	SOYO
	Olive oil	OLIO
	Palm oil	PLMO
	Other oil	OTHO
	Rape seed cake	RAPC
	Sunflower seed cake	SUNC
	Soya cake	SOYC
	Olive cakes	OLIC
	Other cakes	OTHC
	Biodiesel	BIOD
	Bioethanol	BIOE
	Butter	BUTT
	Skimmed milk powder	SMIP
	Cheese	CHES
	Fresh milk products	FRMI
	Cream	CREM
	Concentrated milk	COCM
	Whole milk powder	WMIO
	Whey powder	WHEP
	Casein and caseinates	CASE
	Feed rich protein imports or byproducts	FPRI
	Feed rich energy imports or byproducts	FENI
	Destilled dried grains (byproduct from ethanol production)	DDGS
	Glycerine (byproduct from Biodiesel production)	GLYC
	Raw milk at dairy	MILK

Annex 2 Animal sector details in CAPRI

Without doubt the animal sector is the most complex topic in the CAPRI regional programming models because it includes various internal relationships as well as inter-linkages with the crop sector. Among the former are the various input-output relationships related to **young animals**. Figure 3 shows the different cattle activities and the related young animal products used in the model. Milk cows and suckler cows produce male and female calves. The relation between male and female calves is estimated ex-post in the “COCO module” that handles the data consolidation. These calves are assumed to weigh 50 kg at birth and to be born on the 1st of January. They enter immediately the raising processes for male and female calves which produce young heifers (300 kg live weight at the end) and young bulls (335 kg). These raising processing are assumed to take one year, so that calves born in t enter the processes for male adult fattening, heifers fattening or heifers raising on the 1st January of the next year t+1. The heifers raising process produces then the young cows which can be used for replacement or herd size increases in year t+2.

Figure 3: The cattle chain



Source: CAPRI Modelling System

Accordingly, each raising and fattening process takes exactly one young animal on the input side. The raising processes produce exactly one animal on the output side which is one year older. The output of calves per cow, piglets per sow, lambs per mother sheep or mother goat is derived ex post, e.g. simultaneously from the number of cows in t-1, the number of slaughtered bulls and heifers and replaced in t+1 which determine the level of the raising processes in t and number of slaughtered calves in t. The herd flow models for pig, sheep and goat and poultry are similar, but less complex, as all interactions happen in the same year, and no specific raising processes are introduced.

In most cases, all input and output coefficients relating to young animals are estimated in the database identical at regional and national level, projected by constrained trends and maintained in the simulations. For **slaughter weights** a certain regional variation is allowed in line with stocking densities. In reality farmers may react with changes in final weights to relative changes in output prices (meat) in relation to input prices (feed, young animals). A higher price for young animals will tend to increase final weights, as feed has become comparatively cheaper and vice-versa. In order to introduce more flexibility in the system, the dairy cow, heifer and bull fattening processes are split up each in two versions that may substitute against each other in scenarios as shown in the following table.

Table 3: Split up of cattle chain processes in different intensities

	Low intensity/final weight	High intensity/final weight
Dairy cows (DCOW)	DCOL: 75% milk yield of average, variable inputs besides feed and young animals at 75% of average	DCOH: 125% milk yield of average, variable inputs besides feed and young animals at 125% of average
Bull fattening (BULF)	BULL: 20% lower meat output, variable inputs besides feed and young animals at 80% of average	BULH: 20% higher meat output, variable inputs besides feed and young animals at 120% of average
Heifers fattening (HEIF)	HEIL: 20% lower meat output, variable inputs besides feed and young animals at 80% of average	HEIH: 20% higher meat output, variable inputs besides feed and young animals at 120% of average

For all regions it is assumed that ex post and in the baseline the shares for the high and low yielding variant (e.g. DCOL, DCOH) are 50% for each. As so far no statistical information on the distribution of intensities has been used, the category “intensive” has been *defined* to represent the upper 50% of the historical and baseline distribution. In scenarios however, these shares may change in response to incentives.

For fattening activities the process length DAYS, net of any empty days (EDAYS, relevant for seasonal sheep fattening in Ireland, for example) times the daily growth DAILY should give the final weight after conversion into live weight with the carcass share *carcassSh* and consideration of any starting weight *startWgt*.

- $$X_{r,yield,t}^{maact,Trend} / carcassSh_{maact} = startWgt_{maact} + X_{r,DAILY,t}^{maact,Trend} \cdot \left(X_{r,DAYS,t}^{maact,Trend} - X_{r,EDAYS,BAS}^{maact,data} \right)$$

The process length permits to convert between the CAPRI activity levels for fattening activities (activity level LEVL = one finished animal per year, flow data) and the animal herds (HERD) that may be observed in animal countings at some point in time (stock data, used in GLOBIOM and GAINS).

- $$X_{r,HERD,t}^{maact,Trend} = X_{r,LEVL,t}^{maact,Trend} \cdot X_{r,DAYS,t}^{maact,Trend} / 365$$

The process length is fixed to 365 days for female breeding animals (activities DCOL, DCOH, SCOW, SOWS, SHGM, HENS) such that the activity level is equal to the herd size there.

The **input allocation for feed** describes which quantities of certain feed aggregates (cereals, rich protein, rich energy, processed dairy feed, other feed) or single fodder items (fodder maize, grass, fodder from arable land, straw, raw milk for feeding) are used per animal activity level.

This input allocation for feed takes into account nutrient requirements of animals, building upon requirement functions from the animal nutrition literature. In the case of cattle they have been taken from the IPCC (2006) manual on emissions accounting according to a "tier 2" methodology. For other animals the requirement functions are using other sources and are typically simpler. The crude protein needs are not only used to steer feed demand but they also determine the N content of excretions and therefore the fertiliser value of manure, but also the risk of emissions.

The feed allocation and hence input coefficients for feeding stuff are determined in the solution of the supply models to ensure that energy and protein requirements cover the nutrient needs of the animals while respecting maximum and minimum bounds for lysine, dry matter and fibre intake. Furthermore, ex-post, they also have to be in line with regional fodder production and total feed demand statistics at the national level, the latter stemming from market balances. And last but not least, the input coefficients together with feed prices should lead ex post to reasonable feed cost for the activities.

Historical data do not always meet these consistency relationships. In fact a frequent problem is that nutrient intake is implausibly exceeding the requirements from the literature. A certain luxury consumption is perfectly plausible, just reflecting that observed data usually do not meet the high efficiency laboratory situations in the literature. Nonetheless without further corrections the measured excess would often attain 50% or more, at least for protein. A number of remedies have been introduced therefore in CAPRI to reduce the number of odd cases:

I. Grass and other fodder yields have been estimated (in COCO already) as a compromise of statistical and expert information (from Alterra, O. Oenema, G. Velthof)
II. Losses of straw have been permitted to vary according to the surplus situation in the region
III. A luxury consumption embedded in the sectoral data on feed input and animal products has been steered mainly towards the less intensive (sheep, cattle) activities as opposed to more intensive production chains (pigs, poultry).

This excess „luxury“ consumption is treated as a parameter characterizing farmer's behavior, just like the "over-fertilization parameters" related to fertilizer use. The requirements from the literature are therefore adjusted (upwards) to permit a balance of feed use and requirements in the historical period. Subsequently they are maintained in simulations apart from some moderate gains in feed efficiency over time.

Organic fertilizer is another link to the crop sector. Given the feed allocation, the nutrient contents of manure may be calculated. In the historical period the mineral fertilizer use is also known and allows to calculate the above mentioned parameters characterizing nutrient availability in organic fertilizers and the over-fertilization on the part of farmers. In the baseline, prior information for mineral fertilizer use may be available from external projections (EFMA) or trend extrapolations. This prior information as well as the behavioral parameters are adjusted to yield consistency in nutrient availability from organic and mineral fertilizers on the one hand, and nutrient use in the crop sector on the other (acknowledging gaseous losses).

By contrast in scenarios the behavioral parameters are fixed. Nutrient supply has to be adjusted to nutrient need that follows from crop yields. Animal activities therefore have manure as a secondary output, valued at a shadow value that is related to the mineral fertilizer price. However, in scenarios that constrain emissions directly in the regional supply models, this value might also become negative.