D1.3: NARRATIVES FOR IMPLEMENTATION IN IMPACT ASSESSMENTS

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Executive summary

Changes with respect to the DoA

No changes with respect to the DoA. A draft of this deliverable served as input into the workshop organised on 5th March 2019.

Dissemination and uptake

The deliverable is publicly available.

Short Summary of results (<250 words) (word count:250)

This deliverable presents the narratives of the impact analyses in SUPREMA and serves as input for the scenarios to be run with the SUPREMA models. We envisage three narratives, respectively related to the baseline and scenarios: (a) Baseline, (b) EU common agricultural policy (CAP) and (c) climate change policy. Note that the feedback of the stakeholder workshops, respectively, on needs and narratives has been taken into account in the narratives. Applying a participatory approach involving stakeholders and their first-hand information ensures that insights from the "real world" are taken up into the SUPREMA modelling.

The CAP narrative focuses on CAP measures related to climate and the environment. These are new fundamental obligation on EU member states, being an important priority within their CAP strategic plans. We elaborate on the economic elements, primary agricultural production, supply chain and consumer preferences, including sustainability considerations of the CAP. For climate policy, the modelling undertaken within SUPREMA aims at assessing the potential contribution of the EU agricultural sector to climate change mitigation efforts, by considering mitigation targets (e.g. various levels of ambitions for methane reduction), specific sectors (e.g. relating to different types of manure management) and regions (EU versus other countries). In the narratives, we include life style changes, which are linked to consumer preference that are part of the CAP narrative. Sustainability is explicitly captured by carbon sequestration and growth in the supply of bioenergy, both representing new economic opportunities and linking the SUPREMA narrative on climate policy to the sustainable development goals.

Evidence of accomplishment

The deliverable itself can act as the evidence of accomplishment.

Glossary / Acronyms

AEC	AGRICULTURE-ENVIRONMENT-CLIMATE
AECM	AGRICULTURE-ENVIRONMENT-CLIMATE MEASURES
AFOLU	AGRICULTURE, FORESTRY AND OTHER LAND USE
AGLINK	AGLINK MODEL
AGMEMOD	AGRICULTURAL MEMBER STATE MODELLING FOR THE EU AND EASTERN EUROPEAN COUNTRIES
AGMIP	AGRICULTURAL MODEL INTERCOMPARISON AND IMPROVEMENT PROJECT
CAP	EU COMMON AGRICULTRAL POLICY
CAPRI	COMMON AGRICULTURAL POLICY REGIONALISED IMPACT MODELLING SYSTEM
CO_2 e	CARBON DIOXIDE EQUIVALENT
CGE	COMPUTABLE GENERAL EQUILIBRIUM
DG AGRI	DIRECTORATE GENERAL FOR AGRICULTURE OF THE EUOPEAN COMISSION
DG AGRI MTO	DG AGRI'S MID-TERM OUTLOOKS
DG ECFIN	DIRECTORATE GENERAL FOR ECONOMIC AND FINANCIAL AFFAIRS
EC	EUROPEAN COMMISSION
EU	EUROPEAN UNION
EUROCARE	EUROPEAN CENTRE FOR AGRICULTURAL, REGIONAL AND ENVIRONMENTAL POLICY L RESEARCH
EJ	EXAJOULE (10^{18} joules)
ES	ECO-SCHEMES
FAO	FOOD AND AGRICULTURE ORGANISATION
FAST	FARM SUSTAINABILITY TOOL FOR NUTRIENTS FOR THE EU CAP
GAEC	GOOD AGRICULTURAL AND ENVIRONMENTAL CONDITIONS
GDP	GROSS DOMESTIC PRODUCT
GLOBIOM	GLOBAL BIOSPHERE MANAGEMENT MODEL
GHG	GREENHOUSE GASES
GEM-E3	RECURSIVE DYNAMIC COMPUTABLE GENERAL EQUILIBRIUM MODEL OF THE EC THAT COVERS THE INTERACTIONS BETWEEN THE ECONOMY, THE ENERGY SYSTEM AND THE ENVIRONMENT
Gt	GIGATONNE (10^9 TONNES)

ha	HECTARE (10,000 m^2)
ICT	INFORMATION AND COMMUNICATION TECHNOLOGY
IIASA	INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
JRC	JOINT RESEARCH CENTRE OF THE EUROPEAN COMMISSION
KACL	KILOCALORIE
MAGNET	MODULAR APPLIED GENERAL EQUILIBRIUM TOOL
MACC	MARGINAL ABATEMENT COST CURVE
MITERRA	MODEL WHICH CALCULATES NITRATE AND PHOSPHORUS BALANCES, EMISSIONS OF NH_3, N_2O, NOX AND METHANE TO THE ATMOSPHERE, LEACHING OF NITRATE TO GROUND WATER AND SURFACE WATERS.
MS	EU MEMEBR STATE
N	NITRATE
NECP	NATIONAL ENERGY AND CLIMATE PLAN
NGO	NON-GOVERNMENTAL ORGANISATION
NTM	NON-TARIFF MEASURE
RDP	RURAL DEVELOPMENT
ROW	REST OF THE WORLD
SDG	SUSTAINABLE DEVELOPMENT GOAL
SMR	STATUTORY MANAGEMENT REQUIREMENT
SSP	SHARED SOCIO-ECONOMIC PATHWAY
SUPREMA	SUPPORT FOR POLICY RELEVANT MODELLING OF AGRICULTURE
t	TONNES
TFP	TECHNOLOGY FACTOR PRODUCTIVITY
TRQ	TARIFF RATE QUOTA
USDA	UNITED STATES DEPARTMENT OF AGRICULTURE
OECD	ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPEMENT
PBL	NETHERLANDS ENVIRONMENTAL ASSESSEMENT AGENCY
VCS	VOLUNTARY COUPLED SUPPORT
WP	WORKPACKAGE
WR	WAGENINGEN RESEARCH

1 Introduction

This deliverable contains details of the narratives of the impact analyses to be conducted in SUPREMA and serves as input for the scenarios and their application of the SUPREMA models under workpackage WP3.

In SUPREMA, we envisage three different respective narratives related to the scenarios: (a) baseline, (b) EU common agricultural policy (CAP) and (c) climate policy. Bilateral trade issues are covered under the CAP scenario while constraints in land and water, sustainable development goals (SDGs) are considered under the climate change scenario. In principle, supply chain issues are related to all scenarios, but due to the frequencies of upcoming adjustments they will be followed up only in relation with the CAP scenario In so far supply chain issues related to our scenarios and are not amenable to formal modelling they are captured via stakeholder involvement.

1.1 Approach of using narratives for deriving scenarios to be modelled

For deriving narratives, we will apply a participatory approach involving stakeholders and experts that will provide first-hand input and insights from the "real world" into the modelling undertaking in SUPREMA. That approach will lead to more realistic and hence better results capturing the expectation and needs of stakeholders in a more detailed and concise way. The stakeholder workshops will allow deciding on first-hand information by people taking actual decisions how potentially realistic scenarios may look like as well as an indication about the size of shocks to be modelled in respective scenarios.

We also ensure that results of the SUPREMA models are well understood and better accepted as reliable and realistic by elaborating mechanisms that drive model outcomes. A common agreement on assumptions necessary to conduct policy analysis will be crucial for the acceptance of outcomes as well as for understanding final model results. With the Workshop we also aim to add transparency, rather than adding a black-box, by emphasising the link between assumptions, drivers and explanatory variables, on one hand and on the other model results as well as by pointing out the limitations of the modelling exercise.

Involving stakeholders' knowledge and transform it into narratives and subsequently into assumptions to quantify scenarios also will help to effectively communicate the model outcomes to different groups of stakeholders. Additionally discussion on the taken assumptions will be kept in limits as stakeholders will have been already involved in the beginning. In that manner, different specific aspects in modelling relevant to stakeholders will be directly considered in the scenarios and results can be conveyed accordingly.

1.2 Structure of the deliverable

The deliverable is structured as follows:

First, the insights from the stakeholder workshop on needs is summarised and presented in relation to the narratives of the baseline, CAP and climate policy modelling. After that, three chapters respectively elaborate on the narratives baseline, CAP and climate policy modelling, thereby bringing together the work presented in the following milestones: MS7 "Baseline construction documentation", MS8 "Description and assumptions of the policy scenario", MS9 "Description and assumptions of the scenario under climate change", and the needs identified in the stakeholder workshop (see deliverable D1.1). The chapters incorporate the insights obtained at the stakeholder workshop about narratives which took place on 5th March 2019 in Brussels. The minutes of the stakeholder workshop are presented in Deliverable D1.4.that can be considered as being complementary to the present

deliverable. The insights from the stakeholder workshop is thus taken into account for developing the narratives.
The deliverable closes with a summary and overview of the conclusions for the narratives.

2 Link to the needs and challenges of modelling aspects as identified by stakeholders

The SUPREMA stakeholder workshop "Needs – Scope to address new challenges in modelling" was held in Brussels on 1st March 2018. The stakeholders participating consisted of several groups of stakeholders: policy-makers, administration, farmers, industries, market experts, non-governmental organisations (NGOs), and the scientific community. The stakeholders provided first-hand information on the challenges and needs relevant with respect to the future development of models and model based support for policy actions. The focus was on agri-food systems and policies influencing the agri-food system locally, nationally and on a global scale. Only limited challenges and needs raised by the stakeholders can be covered within the duration of the project; others have clearly a scope reaching beyond possible efforts within the project because some will require considerable investments in time and resources. Those needs will be covered in the road map for future developments which will be outlined in Deliverable 1.10 to explore future directions for agricultural modelling in the EU. While details of the challenges and needs are presented in deliverable D1.1, the main aspects will be shortly summarised below with a first attempt to separate 'Challenges and Needs' which might be covered during the duration of the project from those going beyond the scope of the project.

2.1 Challenges that might be covered during the duration of the SUPREMA project

2.1.1 Time horizon and spatial dimensions

Already before the workshop on needs it was anticipated that different time horizon would be relevant for stakeholders in their decision making process so that part of the discussion took place for different time-frames:

- medium-term perspective up to 2030;
- long-term perspective up to 2050;

In principle, those time-frames were confirmed in the workshop on needs whereas often similar topics were associated under both time-frames with some different foci. Hence, a number of stakeholders also mentioned that especially for climate related scenarios longer time spaces (up to 2070) might be desirable to capture full-fledged impacts.

It was emphasised that the spatial dimension would need to be well defined in relation to the analysis planned. SDGs would require a global dimension but a number of indicators would be more meaningful if they would allow for example to differentiate between rural and urban.

2.1.2 Policies

Discussion on policies

- Policy and governance
  - o EU leading science and policy globally is on the way
  - o CAP in general
  - o CAP after 2020 and multidimensional indication
  - o Global governance
  - o SDGs leading towards policy coherence
  - o Account for cross-sectoral effects of policies

2.1.3 Topics to be covered in 'Narratives'

In preparing the Workshop, a stock-taking among modellers with respect to topics led to structure the discussion with the stakeholders under three main themes which were

- Global perspective on addressing climate change and low carbon economy, sustainable development goals (SDGs) and resource constraints like land and water;
- Market and value chain perspective depicting international integration of agri-food sectors, its integration with up- and downstream sectors as well as societal concerns and ethical issues;
- Farming and supply adaptation comprising with new mitigation technologies and adoption of new technologies as well as restrictions farms related to environmental regulation.

Discussion and prioritising of topics followed according to the structure into the aforementioned broad themes. So the stakeholder workshop, Immediate 'needs' were seen to cover global aspects with respect to future food demand. In this regard, **trade and the feedback effects of European trade on the global situation of trade** were mentioned as being considered in the scenarios planned in the SUPREMA project. The discussion also included issues like **income generation and its distribution across different income groups in and outside European countries** affecting the well-being of all humans as growth and distribution as well as avoiding inequalities provide means overcome existing problems. A strongly linked was seen by stakeholders to future food demand developments and their implication for trade.

Also highly ranked by stakeholders were challenges with respect to environmental degradation of soil, water and bio-diversity and the feedback in the economy by expected cost increases on one hand but due to induced adaptation and mitigation strategies or adoption of new technologies. Water was also mentioned as a separate topic covering quantity (shortages and sudden surplus) and quality. A further very important issue mentioned refers to data that is elaborated further below. To present an example, the definition of SDG indicators was mentioned. Indicators need to be operational: e.g. the descriptions of SDGs are often relative vague in relation to what is required for model simulations.

While emphasis was on **modelling the reduction of greenhouse gases (GHG) and the mitigation and adaptation towards climate change especially with focus on the long-term perspective** it was also stated that a set of models would need to be linked and somehow coupled so as to model the complexities associated with these topic. Issues raised also dealt with strategy and their impact on SDGs (i.e. complete decarbonisation versus security in supply of food, energy, eco-system services).

Another challenge identified refers to modelling **changes in consumer preferences and behaviour**. Dietary changes towards lower content of animal protein might be driven by changes in consumer preferences and, that way, may have important impacts on GHG emissions. To what extent changes might materialize will depend on circumstances like e.g. availabilities, labelling, and income situation. Although demand shifts in society are evolving quite smoothly disruptive changes may occur quite sudden, often in combination with quality, hygienic, diseases or animal welfare problems. Nevertheless, demand shifts should be taken into account in models. Similarly, changes in the political agenda for example due to **strategies towards a more bio-based economy** were identified as being very important. Here a strong relation exists to low carbon and circular economy discussed under the global perspective. From the modelling perspective, both challenges would call for a more integrated approach of different models applied in a harmonized way.

Furthermore, **market structure and market power**, and the ongoing structural change in the food value chain, should be captured by the SUPREMA models. This was considered as being important since market structure and market power is known to determine the income at farm level. Hence, also distributional aspects directly related to food access and to hunger are seen as a future requirement for modelling. By stakeholders some considerations were given to the fact that private entities fulfil the role of public entities e.g. by defining and controlling standards. A growing gap is observed between increasing international supply and societal preferred regional provision of food which is seen to be engraved by structural change reducing the number of actors along the supply chain and increase asymmetries between different levels in the chain. Short supply chains are mentioned as a separate challenge as well.

With respect to social concerns, analysing the impact of productivity gains on development of employments was given quite some significance. A number of other perceived challenges were directly linked to SDGs and climate change, especially emphasised were sustainability, (im)migration, migrant labour (in food chains) and job availabilities under climate change, rural versus urban relationships, differentiate income groups, GHG reduction and employment transition. Hence, the focus was more on markets and supply chain with an emphasis on processing. Participants also attribute priorities to health and nutrition concerns in general, antibiotics use in husbandry related to animal welfare but also to health issues.

Modelling needs with respect to farming and supply adaptation comprise new mitigation technologies related to climate change, adoption of new technologies, including remote sensing, robotics as well as constraints in farming related to environmental regulation. Challenges were attributed to two areas one was how to face market and behaviour adjustments of actors and the other by farming risks. The first challenges can be characterized by the behaviour of consumers and processing industries. Consumers' behaviour is perceived as disruptive and difficult to anticipate because as citizens they express a willingness to pay for organic, animal welfare and low emission products while, at the point of sale, consumers choose differently. Also high priority by stakeholders received the adoption new innovations which will require a better representation in models Additionally, monitoring markets is seen as an important need which form a challenge for farmers and probably policy makers.

Priorities concerning farming risks were discussed with highest ranks allocated to water constraints and, equally important, whether to concentrate on adaptation or mitigation of climate change. Also yields, productivity gains in yields and variables contributing were perceived as important to cover whereas efficiencies in crops are placed in livestock (feed efficiency). Also feedbacks from breeding activities and climate change needs to be covered, technologies and innovation (see also SDGs and climate change) received high perception. Further challenges are seen in development of infrastructure and related cost and in the role of farm structure and education prioritised under SDGs. Existing knowledge on GHG effects are also considered as a challenge.

2.2 Additional aspects relevant to the modelling

In the discussion at the stakeholder workshop, the **availability of data of high quality** especially for the value chain has been regarded as one of the most relevant issue which should be considered as a permanent need. Although the use is relevant for all modelling activities it cannot be tackled within the SUPREMA project. Clearly new channels of data acquirement with a focus on the supply chain have to be formed, property right and privacy issues with respect to data require to be solved and transparency along the chain for all actors has to be established.

Furthermore, the **communication of result** and **explaining modelling methods** and outcome has been identified as a main need and challenge. Keeping the outcome of the models **understandable and transparent** was mentioned as an important aspect to address. Especially when analysing complex issues like sustainability or climate change, there is a need to better explain the results, including the modelling approaches and their influences on the results. The stakeholders for example indicated that the discussion and explanation of model results should also encompass what sustainability means with regard to model ecologic, economic and social aspects. The time horizon of the modelling has been identified as being important to modellers. For stakeholders, the differentiation between the medium-term and long-term appears not to be as straightforward and relevant when it comes to model-based impact assessments from the other stakeholder groups beyond scientists.

2.3 Needs that go beyond the SUPREMA project

The stakeholder workshop also identified challenges and needs for model-based analyses which are relevant but which go beyond the current scope of SUPREMA, as follows:

- Rural versus urban development,
- Land abandonment and rural exodus as a social element of structural changes across different regions
- Loss of agricultural land to non-agriculture production purposes, like infrastructure, houses and building etc., which is the contrasting effect of land abandonment, which indicates a surplus of land
- Immigration, migrant labour in food chain
- Degradation of resources and adaption technology to fight this development
- Internalization of positive and negative externalities
- Calibration and modelling of shocks such as natural disasters and diseases
- Modelling endogenous technical change, the coverage of artificial intelligence as well as the spread of innovation and new production, digitalisation approaches, including information and communication technology (ICT)
- Full coverage of the supply chains issue, only some limited application in a case study in SUPREMA

3 Narratives for the SUPREMA baseline

3.1 External drivers used in the baseline

This section provides an overview of the external drivers that are used in the baseline construction for the different models in the SUPREMA project. As shown in Table 1 there is quite variety in the exogenous variables that models take into account when constructing the baseline

Table 1: Exogenous variables taken into account by each of the models of the SUPREMA family - baseline

Drivers	AGMEMOD	CAPRI	GLOBIOM	IFM-CAP	MAGNET	MITERRA
Gross domestic product	x	x	x		x	
Population	x	x	x		x	
Output prices	x	x		x		
Oil price	x	*			possible	
Inflation	x	x			possible	
Technological change	x**	x	x	x	x	
Exchange rates	x	x	x		x	

* In CAPRI the oil price in the baseline is not explicit (but may have been incorporated in the results of AGLINK/GLOBIOM). ** In AGMEMOD, technological change is covered by the trend in yields or by cost saving which will need to be specified.

Moreover, some models implicitly take into account drivers from other models when constructing their baseline. Such is the case for IFM-CAP which embeds population and GDP growth assumptions from the CAPRI baseline via yield and output price developments or MITERRA that does the same when assuming the outcome projections of AGMEMOD. CAPRI takes output price information both from AGLINK and GLOBIOM which is one reason why the final baseline prices in CAPRI are aligned with but not equal to these model inputs. For MAGNET, the standard baseline has GDP, population, land productivity and livestock feed efficiency as the standard external drivers. Other variables could also be drivers, depending on the specific application of a study. Hence, the baseline chosen according to the purpose of the study and the research question to be answered crucially determine which variables are the external drivers. For example, the oil price could be endogenous.

3.1.1 Growth of the gross domestic product (GDP)

There are two mains sources of data when assuming GDP developments on the baseline (Table 2). AGMEMOD and CAPRI relate to DG AGRI's Mid-Term Outlooks (MTO) and underlying regional projections provided by the EC which are updated every year. These data cover up to 2030 (or ten years ahead whatever is longest). Currently, AGMEMOD uses the 2018 macroeconomic projections while CAPRI uses the 2017 ones. AGMEMOD is updated annually, while CAPRI is regularly updated but not necessarily annually. When the model baseline supersedes 2030 CAPRI and AGMEMOD rely on GLOBIOM, with the GLOBIOM weight increasing the more, the more we move beyond 2030. MAGNET allows for considerable flexibility, with several data sources and baseline assumptions that could be run depending on the purpose of the study and research questions to be answered; hence, it has implications for the technical change.. In a standard baseline for MAGNET one of the SSP baselines[1] are used.

Table 2: Sources of GDP growth assumptions for baseline in the SUPREMA family

Model	Source	Coverage	Latest update
AGMEMOD	DG AGRI MTO	2030	2018
	(as) GLOBIOM	2030-2050	To be developed
CAPRI	DG AGRI MTO	2030	2017
	(as) GLOBIOM	2030-2050	2016
GLOBIOM	DG ECFIN GEM-E3 (EU) SSP Database (ROW)	2050	2016
MAGNET	SSP Database	2020-2050/2100	2011

Note: MITERRA and IFM-CAP implicitly relate to DG AGRI's forecasts via links with AGMEMOD and CAPRI respectively. The GEM-E3 model is a recursive dynamic computable general equilibrium model that provides information about the interactions between the economy, the energy system and the environment. Note that GEM-E3 is not part of the SUPREMA models.

For the baseline construction, a decision has to be made regarding whether alignment of assumptions is needed or not. When deciding this it has to be noted that for CAPRI and AGMEMOD using DG AGRI up to the projection period of the Agricultural Outlook is key for reflecting the baseline in the SUPREMA models to be applied for policy assessment for policy support. When discussing divergences between projections and model results, the impact of GDP growth assumptions could be used to compare and explain modelling results.

3.1.2 Population

The same pattern as for GDP is found for population projections. AGMEMOD and CAPRI align to the figures used by the Mid-term outlook of DG AGRI and underlying regional projections provided by the EC up to 2030; CAPRI shifts to GLOBIOM from 2030 to 2050 and GLOBIOM uses data from GEM-E3 and

[1] The SSP baselines comprise five pathways are defined by the Intergovernmental Panel on Climate Change (IPCC): a world of sustainability-focused growth and equality (SSP1); a “middle of the road” world where trends broadly follow their historical patterns (SSP2); a fragmented world of “resurgent nationalism” (SSP3); a world of ever-increasing inequality (SSP4); and a world of rapid and unconstrained growth in economic output and energy use (SSP5). For details see Riahi et al. (2017).

the SSP database for the EU and the rest of the world (ROW) respectively. As stated before, MAGNET is rather flexible with regard to data used, with a standard application of SSP baselines. Again the latest updates are different across models (see Table 3).

Table 3: Sources of population growth assumptions for baseline in the SUPREMA family

Model	Source	Coverage	Latest update
AGMEMOD	DG AGRI MTO	2030	2018
	(as GLOBIOM)	2030-2050	To be developed
CAPRI	DG AGRI MTO	2030	2017
	(as) GLOBIOM	2030-2050	2016
GLOBIOM	DG ECFIN GEM-E3 (EU) SSP Database (ROW)	2050	2016
MAGNET	SSP Database	2030-2050/2100	2011

Note: MITERRA and IFM-CAP implicitly relate to DG AGRI's forecasts via links with AGMEMOD and CAPRI respectively. The GEM-E3 model is a recursive dynamic computable general equilibrium model that provides information about the interactions between the economy, the energy system and the environment. Note that GEM-E3 is not part of the SUPREMA models.

3.1.3 Output prices

Two of the models in the SUPREMA family take output prices as given when generating their baselines. CAPRI takes these prices from the DG AGRI Mid-term Outlook and AGMEMOD is calibrated to the world market price projections. By contrast, in CAPRI the merging process with GLOBIOM information, but also the alignment of price projections with price linkage equations in the baseline process at the (disaggregate) CAPRI level means that CAPRI prices can deviate from the original values in the DG AGRI Mid-term Outlook. If the purpose and context of the CAPRI application is policy support for DG AGRI the weight of GLOBIOM prices is typically set lower than in climate related applications. Due to the different nature of the two baselines, it is likely that different CAPRI versions for the medium and for the long run simulations will be used, the decision on the relative weight of both sources of data are still to be made.

3.1.4 Input prices

Another important external driver is the development of input prices. In particular the models include assumptions regarding the development of prices for fertilizers (CAPRI); Oil (CAPRI, AGMEMOD); gas, oil and coal prices (MAGNET) and overall inflation rates. Unless input prices are in the focus of attention CAPRI uses in general quite simple assumptions: Non-agricultural input prices are constant in real terms, thus increasing only with inflation. The oil price is not explicit and therefore implicitly increasing as in the main external sources for CAPRI (which are AGLINK and GLOBIOM). AGMEMOD applies a similar approach: Unless input prices are considered in more detail, generally it is assumed that input prices are constant in real terms, thus increasing only with inflation. Otherwise additional assumptions are required or input from other models (e.g. MAGNET) are applied.

3.1.5 Technological change

Another factor influencing baseline results are the assumptions made regarding technological change. In these models technological change is included as yield trend increases. Here all models except AGMEMOD align to the Mid-term Outlook projections of DG AGRI for the EU (albeit to different editions of the MTO including 2016, 2017 and 2018) with GLOBIOM using its own estimates for the rest of the world and CAPRI again merging information both from the Mid-term Outlook as well as GLOBIOM. AGMEMOD specifies for each commodity and each region a separate yield function including a trend variable. Crop yields are not explicit inputs into the CAPRI baseline. Instead it uses information both on production as well as areas which together define yields.

Other representations of technological change in the baseline can be included such as an improvement of nitrogen efficiency use (CAPRI) and feed use efficiency (CAPRI), production factors productivity and GHG emissions parameters (MAGNET, CAPRI). In MAGNET applications, the technological change can be implemented to any input-industry combination if such data are available. In the standard approach such a tech-change is calculated in the reference run (see below).

On top of the "yield trend" approach, new technologies are explicitly implemented in AGMEMOD. For example, the current 'animal welfare' driven technology leading to change towards the use of slower-growing chickens in Dutch poultry farming is explicitly accounted for in the model equations. Hence, this approach will require specific assumptions or input from other models.

Moreover some models include endogenous technology adoption (GLOBIOM for a shift in management practices, or spatially explicit reallocation of production within and across regions; CAPRI for mitigation technologies for non-CO_2 GHG) the parametrization of which can also be changed to reflect technological change. In MAGNET, there is an economy-wide technological change (productivity) factor calibrated in the reference run so as to meet the overall target for GDP growth given assumed labour and capital developments. The "technology matrix" is used to distribute technological change within the economy. The matrix applies a scaling factor for each input-industry combination. In the MAGNET baseline, GDP is endogenous while economy-wide technological change calculated in reference run is exogenous.

3.1.6 Diet and consumer behaviour

CAPRI and GLOBIOM also incorporate diets as external drivers in the baseline. Developments in future dietary preferences can be captured by income elasticity values which are calibrated in GLOBIOM to FAO data "World Agriculture Towards 2030/2050" (Alexandratos and Bruinsma, 2012). MAGNET is also capable of doing this via project specific exogenous assumptions based on literature.

The CAPRI baselines since project "AgClim50-II" monitor explicitly the intake of calories and other nutrients to prevent "unreasonable" developments. However, the calorie intake is not an exogenous input but a target variable such that deviations are traded off against other targets.

Other important information in the CAPRI baseline is consumer margins that determine the responsiveness of consumers to producer prices in scenarios. As explicit consumer prices are compiled based on hard data only for Europe in CAPRI, the European margins are linked to GDP per capita in the cross-section dimension and then projected over time and to other regions.

3.1.7 Policy representation in the baseline

Climate policy representation is covered via bioenergy assumptions and mitigation targets (either as hard constraints or as equivalent CO_2 prices). GLOBIOM represents mitigation targets for the land use sector via carbon prices and biomass demand. European Bioenergy targets are taken from PRIMES (2016) for CAPRI and GLOBIOM. GLOBIOM has an explicit carbon price of CO_2, N_2O and CH_4 emissions from agriculture, forestry and other land use (AFOLU) from energy models. CAPRI can set emission targets for the EU based on activities and carbon prices both for the EU and for the rest of the world. In a typical CAPRI baseline however, the carbon price has been assumed to be zero however. Thus any emission ceilings or carbon prices would be "top-ups" that are introduced as part of scenarios. MAGNET has a module for emission trading, renewable energy targets, biofuels mandates as well as carbon prices. These can be modified for each specific baseline application.

The SUPREMA model family provides a representation of agricultural policy in the ROW that is not as detailed as for the EU. CAPRI and IFM-CAP have no explicit agricultural policy representation for other world regions, however CAPRI does cover the trade policy instruments globally. However, while trade policy instruments (such as TRQs) affecting the trade of the EU with non-European regions are covered with specific efforts, trade instruments between non-European regions, say between the US and Japan, are only covered based on standard sources. International biofuel policies are relying in CAPRI on information from the AGLINK model that is underlying the mid-term Outlook. Land use policies are not considered explicitly. Implicitly they might be picked up indirectly through the model inputs from GLOBIOM. AGMEMOD has agricultural and trade policies covered for Turkey, Macedonia , Russia and Ukraine; and also fisheries policy for Iceland and Norway. In addition it also has agricultural and trade policies for selected African country models[2], however they run independently from the EU module.

GLOBIOM represents land use, biofuel and trade policy for the AGMIP regional aggregates. MAGNET is flexible in the modelling of policies in other countries. Depending on the aim of the study and the analysis conducted, countries and relevant policies can be included. The implementation depends on the study and data availability concerning the respective policies. In a standard MAGNET application, the baseline for non-EU countries comprises biofuel mandates.

3.2 Time horizon

From the feedback received the following models will be run for baselines in 2030 and beyond:
2030 Baseline:

- CAPRI
- AGMEMOD
- IFM-CAP
- MAGNET

2050 (and optionally 2070) Baseline:

- CAPRI
- GLOBIOM
- AGMEMOD
- MAGNET

4 Narratives for the Common Agriculture Policy (CAP) – focus on climate and environment

In the narrative, we propose to focus on CAP measures with respect to climate and environment because the new fundamental obligation on the EU member states is an important priority, showing greater ambition with regard to care for the environment and climate, within their CAP strategic plans, in comparison to what they have tried to achieve through the CAP in these areas in the current period of 2014-2020. When analysing the EU member states' draft plans for approval, the Commission will assess whether the plans meet this fundamental obligation. That assessment will be based on various kinds of information – including the targets which the EU member states set for themselves, i.e. the contents of the related interventions, the contents of standards of Good Agricultural and Environmental Condition (GAEC) within the conditionality system etc.

Moreover, a comprehensive analysis of the overall situation, problems and resultant needs will be required to support the intervention strategy included in each CAP plan. Intervention strategies will have to be underpinned by quantitative targets and milestones reflecting what is needed to achieve

[2] Kenya, Ghana, Tanzania, Ethiopia, Rwanda and Uganda.

the environment and climate objectives. The logic justifying the intervention strategy and the design of the plans will have to be established in full transparency, including through a public consultation. These elements will help the European Commission in its task of scrutinising and approving the plans.

The CAP's future environment and climate objectives have clear thematic links to the objectives and targets set out in, or arising from, various items of EU legislation. The EU member states will be obliged to explain in their CAP strategic plans how, in addressing the CAP's environment and climate objectives; they also intend to make a contribution to achieving the related objectives in non-CAP legislation. The items of legislation to be referred to in this way will be listed in the CAP rules.

<u>The CAP and climate change: a story line</u>
Agriculture covers almost half the land surface area of the EU, and on that territory it works in a very close relationship with the environment. On the one hand, it depends on various natural resources – i.e. soil, water, air and biodiversity – and is heavily influenced by the climate. On the other hand, agriculture shapes the environment in which it operates – not only through its use of natural resources but also by creating and maintaining landscapes greatly appreciated by the public (which often provide essential wildlife habitats). In addition, it is an emitter of greenhouse gases - though it also provides significant carbon sinks.

Managing this complex relationship in the interests of long-term sustainability has costs attached. The CAP has long played a role in helping to cover some of these costs, so that farmers can run viable businesses while also caring for the environment and climate – thus providing essential public goods that society expects. The CAP has also offered support in some cases to rural-based non-agricultural businesses which can influence the environment – e.g. in the forestry sector and other parts of the bio-economy. Three out of nine of the CAP's proposed key objectives for the future concern the environment and climate. They reflect the various aspects of the close relationship between the environment and climate, farming and rural areas as a whole. According to these objectives, the CAP will:

- contribute to climate change mitigation and adaptation, as well as sustainable energy;
- foster sustainable development and efficient management of natural resources such water, soil and air;
- contribute to the protection of biodiversity, enhance ecosystem services and preserve habitats and landscapes.

4.1 The proposed new CAP and its 3 layer-approach

The new green architecture will operate within the framework of the CAP's "new delivery model", according to which basic rules are set at EU level and substantial flexibility is left to the member states with regard to how to implement them. For each element of the future green architecture, member states will set out in their draft CAP strategic plans what they intend to do, and the Commission will assess these proposals.

At a base of the architecture will be a new system of "**conditionality**". This will link all farmers' income support (and other area-/animal- based payments) to the application of environment- and climate-friendly farming practices. It will take some features and content from the current systems of cross-compliance and "greening", which it replaces. The rules governing this new system will in some respects be less prescriptive at EU level than the rules for the current approach (especially in comparison with the current greening scheme), but the standards/requirements laid down will nevertheless imply higher environmental ambition.

The next or second layer consists of "**eco-schemes**" funded by the CAP's Pillar I budget. The EU member states will be obliged to make provision for these, but there will be no EU-level rules on what the content must be: what is essential is that the schemes contribute to achieving the CAP's environment and climate objectives. The member states will design them according to their targets and needs, within the framework of their CAP strategic plans, in such a way that they complement the other elements of environmental architecture. Participation in Pillar I eco-schemes will be voluntary for farmers.

The third main layer of the architecture consists of **payments within support for rural development – CAP Pillar II – for various kinds of management commitments (especially agriculture-environment-climate (AEC)commitments**). The EU member states will have to offer agriculture-environment-climate (AEC) payments in their CAP plans, but uptake will be voluntary for farmers, as at present. Like Pillar I eco-schemes, agriculture-environment-climate (AEC) payments can be used to cover a potentially wide range of agricultural practices: as under the current approach, no restrictions will be laid down in EU rules.

In addition to these three main layers, the EU member states will continue to be able to use their rural development (RDP) budgets to fund a range of other types of support which could be relevant for the environment and climate - such as funding for knowledge transfer, eco-friendly investments, innovation and co-operation. Such support could concern farmers, forest managers and other interested parties in rural areas.

Overall, then, the future CAP will address environment- and climate-related objectives in various ways. On the territory of a given the member state, a range of tools might be addressing a given environmental issue (e.g. biodiversity) in complementary ways, but under a general principle governing spending from the EU budget, "double funding" (i.e. paying twice in respect of a given cost) will remain prohibited.

4.1.1 Conditionality

The new system of conditionality is a link between, on the one hand, a set of standards/ requirements which farmers must meet and, on the other hand, CAP area- and animal-based payments (especially income support) received by farmers. In case of infringement, a farmer may face reductions of the CAP payments received. Conditionality will draw on the current systems of cross-compliance and greening, making significant improvements.

As in cross-compliance, some of the obligations to be met by farmers under conditionality, i.e. standards of Good Agricultural and Environmental Condition ((GAEC) are created by the CAP regulations, whereas others like Statutory Management Requirements (SMRs) have their basis in non-CAP legislation. Overall, the GAEC standards and the SMRs will cover issues related to: climate change; water; soil; biodiversity and landscapes; animal welfare; and various aspects of public health, animal health and plant health.

There will be several differences in the system compared to cross-compliance and greening.
First, although the requirements of the greening system will be absorbed into various GAEC standards, the level of detail of the standards as laid down in EU-level CAP rules will follow the existing GAEC approach and therefore be lower than for the current "greening" requirements (which included various numerical thresholds, exceptions etc.).

Second, the level of environmental ambition inherent in conditionality will be higher than that of cross-compliance and greening in the current period. This is partly because some existing standards will become more demanding (e.g. farmers will need to apply crop rotations instead of simply cultivating a certain number of crops at any one time), and partly because new standards and requirements will be included (e.g. appropriate protection of wetland and peatland, and the use of a Farm Sustainability Tool for Nutrients, as well as provisions related to legislation on water and pesticides).

Third, the EU member states' proposals concerning how to apply the GAEC standards in detail on their territory will for the first time be subject to approval by the EC in their CAP strategic plan.

4.1.2 Eco-Schemes

Pillar I eco-schemes are payment schemes concerning the environment and climate which will be funded from the Pillar I budget. The EU member states will have to make them available to farmers, but farmers will participate only if they wish to do so.

The EU member states will propose the content of their eco-schemes within their CAP strategic plans. There will be no particular EU-level rules on this content, but whatever an EU member state proposes must clearly help to achieve the environment and climate objectives of the CAP in a way which is consistent with the operation of other CAP tools, especially Pillar II support for agriculture-environment-climate (AEC) commitments. That content must also go beyond the requirements of conditionality.

The principle behind Pillar I eco-schemes is that some of the resources of CAP Pillar I should be targeted directly at environment and climate objectives through dedicated payments. Key differences between Pillar I eco-schemes and Pillar II support for agriculture-environment-climate (AEC) commitments will be as follows:

- Pillar I eco-schemes will be paid for entirely by the EU budget: there will be no co-financing by the EU member states.
- Because of the administrative mechanisms of Pillar I, eco-schemes are more suited to supporting annual commitments than multi-annual commitments (under which farmers sign contracts to apply certain practices for several years at a time).
- Whereas Pillar II payments for agriculture-environment-climate (AEC) commitments will always be explicit "compensation" payments (whose value will be based on the income losses and extra costs arising from the farming practices concerned), the EU member states will be able to treat Pillar I eco-schemes either as compensation payments (using the calculation method outlined above) or as "additional payments"/"top-ups" to direct payments (in which case payment values will not depend on a calculation of costs and losses).

4.1.3 Supporting agri-environment and climate actions (under the 2nd pillar)

The CAP's second Pillar – support for rural development – will continue to offer a wide range of tools which are either explicitly designed primarily to serve environment- and climate-related objectives, or can be adapted to do so. Essentially, all of the current possibilities will remain available but will be regrouped in the CAP rules into fewer, broader "types of intervention".

One of the most important tools will remain support for agriculture-environment-climate (AEC) commitments – as part of a broader type of intervention offering support for various kinds of management commitment.

As at present, the EU member states will be obliged to offer payments for agriculture-environment-climate (AEC) commitments within their CAP strategic plans (though the payments will remain voluntary for farmers). These compensate farmers for the extra costs and the loss of income which result from applying farming practices beneficial to the environment and climate. Agriculture-environment-climate (AEC) commitments can potentially cover a very wide range of content –

provided that they make a clear contribution to achieving the CAP's environment and climate objectives. They are more suitable than Pillar I eco-schemes for addressing multi-annual commitments which build up environmental benefits over time – and this will be their use. Their content must go beyond that of conditionality.

Other types of management commitment which CAP Pillar II may fund include support for particularly environment- and climate-friendly forest management practices.
Aside from multi-annual year-to-year management commitments, through CAP Pillar II, the EU member states will still be able to offer various kinds of support which can be relevant to the environment and climate, such as support for:

- knowledge transfer (e.g. for one-to-one advice on limiting greenhouse gas emissions);
- investments (e.g. in more efficient irrigation equipment);
- innovation (e.g. projects to adapt precision agriculture techniques to areas where they are not currently applied);
- co-operation (e.g. in organising the sustainable supply of farm waste from groups of farms for energy production);
- areas facing natural constraints, and areas facing particular disadvantages as a result of certain legislation (the Water Framework Directive , the Habitats Directive and the Birds Directive).

4.1.4 Nutrient management plans/farm sustainability tool

Under the proposed new CAP, the Farm Sustainability Tool for Nutrients (FaST) will need to be developed and each farmer needs to have this, as part of the enhanced conditionality requirement. This tool will help farmers to optimise their use of nutrients, and therefore their income, while protecting water quality and cutting greenhouse gas emissions. The tool will be effective only if farmers see a clear overall advantage in it. Therefore, the only related obligation on farmers (laid down in the system of conditionality) will be to use it, i.e. activate it and input the necessary data for the tool to be operational – i.e. the FaST will not be a tool for authorities to check on farmers and their input levels. The idea is that decision-making support provided through the tool will be clearly beneficial to the farm, ensuring buy-in beyond the traditional 'compliance' model. In order to provide a level playing field among farmers EU-wide, the member states should establish a system for making the tool available to farmers and including at least a certain minimum of functionality and features. The FaST has the potential to form part of packages of supported activities that are relatively easy to manage, with the help of technology and (as needed) of advisory systems. The tool with minimum functionality should also serve as a core-basis for additional on-farm digital technology, thereby boosting digital innovation in the sector.

4.2 Implementation and challenges of modelling the CAP

4.2.1 Summary of the insights obtained from the stakeholder workshop

In March 2019, a SUPREMA stakeholder workshop was held in which the narratives for the intermediate run CAP and long run climate change scenario were discussed. A first summary of the results from this workshop is presented in Table 4. As shown, the table provides a provisional overview of key issues that were raised, categorized according to some broad topic themes and with a status indication added to each item, indicating our estimate with respect to the possibilities to include or address these items in the modelling efforts foreseen in the SUPREMA project, or whether the item will be allocated to the roadmap and be prioritized as work for future research.

Table 4: Summary of items, key issues and challenges raised during the stakeholder workshop, with additional comments from the Suprema team

Broad topic	Item	Key issues/challenges	Status	Additional comments
Economic elements	GDP growth	No specific challenge is identified	S	For baseline, in line with SSP2: Middle of the Road. For scenarios: maybe include different growth paths for the global economy or certain countries
	Energy prices	Important item: changes in energy prices affect consumers and producers. Their effects spread through the whole economic system	S	Choose from: prices linked to GDP, energy projections with AGLINK, baseline from EU Energy Strategy
	Population	No specific challenge is identified	S/R	Demographics are very important if scenarios/models are demand driven. Consumer preferences are also linked to population/demographics: different paths for changing diets, different behaviour with respect to waste and recycling, etc.
	Labour market trends	Multidimensional element: it is related to sectoral/ farm concentration, location of the activity, land abandonment, productivity/innovation and eventually profitability of the sector	S	Alignment of all models could be difficult since the level of detail of the coverage of the labour market is very different across models. Maybe the focus can be on productivity - if so, clear definitions of labour productivity and its correspondence in the different models will be needed.
	Geographical/political elements	Brexit will impose a challenge with a lot of uncertainty around	S/R	Maybe we can incorporate its impact through sensitivity analysis and not in the main scenario

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Broad topic	Item	Key issues/challenges	Status	Additional comments
Primary agriculture	Greenhouse gases	Key question is 'what to assume with regard to climate change?' Another important aspect is the interaction EU agriculture versus ROW agriculture. 'Punishing' EU agriculture to reduce production can be controversial if less 'emission efficient' production is imported	S	It could be challenging to make assumptions regarding agricultural emission targets. Additional interaction with MS authorities for selected major producers could deliver some clarity on this. Another important issue is pricing emissions.
	Extreme weather events	Reality shows that they are more frequent	S	It could be very difficult to make assumptions about their frequency/impact. There is a risk that making very specific/strong assumptions on that regard leads to results that are somehow detached from a more general development path. Maybe this could be explored in sensitivity analysis and excluded in the main scenario
	Subsidies/taxes to alter innovation/mitigation strategies	"Polluter pays" or "Provider gets"?	S	Potential controversy: It can be seen as 'we finance pollution'? If so, how much we want to finance?
	Water used/availability	To which extend water availability will cause a displacement of production?	R	Additional research at MS level will be needed
	Representation of the new CAP	Key question is to define which measures (and targets) are we going to incorporate	S	Maybe more detail at MS is needed. An option could be to focus on key players at EU level
	Land use: competition agricultural use versus non-agricultural use (urban, forestry, infrastructure, etc.)	Urbanisation and deforestation can impose challenges to the agri sector in terms of expansion of farm size/increase production	R	This might require more detailed modelling of land use and a much more detailed representation of urban dynamics in the current modelling framework

Broad topic	Item	Key issues/challenges	Status	Additional comments
Primary agriculture (cont.)	Waste and nutrient recycling	Both topics are under addressed with the new CAP	S	Additional data at MS level would be needed. Treatment of this in the modelling would be basic since uncertainty around the topic is huge
	Biomass production	Is it sensible to assume that couple support could be used to expand biomass production? Is it possible to make robust assumptions about the competition between food/energy in the case of biomass crops?	R	Additional data/insights at MS level would be needed
	Payments for ecosystems	Huge uncertainty and lack of data to carry out robust modelling	R	No further comment
	Biodiversity	What is the meaning of biodiversity in the project? What are the key dimensions within CAP?	S/R	Additional data/insights at MS level would be needed
	Finance	is the availability of finance going to speed up (or curb) the adoption path of new technology and innovation?	R	In SUPREMA, we can incorporate the role of finance indirectly through innovation assumptions. In the future might be interesting to look at the role of finance in the adoption of innovation and mitigation technology
	Other policies	Synergies of CAP with other policies might reinforce its effect without imposing additional pressure on costs	S	Ignoring this could lead us to overestimate the cost
	Productivity	Important issues are: evolution of yields, CO_2 fertilisation, feed efficiency, adoption of new technology, etc.	S	Needs to be differentiated by MS or maybe by broad regions in Europe
	Expansion of precision farming	Needs to be differentiated by region	R	We might encounter important data issues to model this
	ICT	Which are the trends that are expected in the agricultural sector? What is the uptake of new technologies that we are expecting?	S/R	Additional research might be need. Maybe assume that no disruptive technological change will happen

Broad topic	Item	Key issues/challenges	Status	Additional comments
Primary agriculture (cont.)	Sustainability	Key issue is how to define sustainability? Probably it should be define in a broader sense, covering both technical aspects and financial aspects. If economic activities are not viable without public support are they really sustainable in the long run?	R	Additional data might be needed at MS level. An activity might be sustainable in a certain area and not in another without public support. Natural endowments could also change over time and require additional public intervention to maintain activities or require stop production or change activity.
	Nitrogen use efficiency	Impact of N	S	Different paths should be assumed by MS
Supply chain	Reducing waste through the supply chain	Which is the level of cooperation between actors that we could assume? Are there any joint interventions that we could assume? Would their impact on demand strong enough to affect production?	R	Better representation of households/producers/retailers will be needed.
	Product and price differentiation	How is agricultural production is addressing (new) consumers' preferences?	R	Better representation of price transmission mechanisms, price formation and consumer's preferences would be needed
	Transport costs	Is production consume locally? Would the CAP favour that to reduce emissions related to transport? To which extend is feasible?	R	Better modelling of price transmission mechanisms (and its components) would be needed.
	Distributional impacts	Should organic products be subsidised for not excluding low-income classes? What are the specific challenges of small famers?	R	Better treatment of households and producers representation would be needed
	New food processing techniques	Identification of realistic patterns for adoption of new technology	R	Not directly related with CAP
	Resource base and degradation: soil situation, emissions, weather, etc.	Which is the behaviour of the different actors of the supply chain to reduce the negative impact?	S	Additional data will be needed and better representation of individual choices might be needed?
	Trade wars	What are the implications of current trade agreements?	S/R	See above for weather events - only focus on modelling existing trade agreements

Broad topic	Item	Key issues/challenges	Status	Additional comments
Consumer preferences	Preferences for organic products, animal welfare, etc.	Consumers demand can speed up the transition process and 'force' the adjustment of the agricultural sector	R	Better representation of households/individuals will be needed.
	Protein transition	Identification of the speed at which it is happening, as well as expected trends for the coming years.	S	Latest research by OECD provides an starting point for this
	Food and health impacts	In which sense is consumers' behaviour changing? How strong/fast is this change happening?	R	Better coverage of health aspects, including cost of health provision at MS would be needed
	Waste	They are the bottom of the supply change. Its contribution to circularity is untapped	R	Better representation of households/individuals will be needed. Additional research for making assumptions is required
	Social trends, e.g. it is trendy to become vegan	Once again, consumers demand can speed up the transition process and 'force' the adjustment of the agricultural sector	R	Better representation of households/individuals will be needed.
	Product standards	Producers always adjust and deliver what consumers demands. This goes back to organic farming and animal welfare	R	Further development of individual preferences/choice would be needed
	Increasing demand for fruit and vegetables	Only if consumers' preferences change substantially agricultural production will adjust.	S/R	This is related to health impacts. Additional research and tailoring of the models would be required.

Note: Status: S=to be incorporated/modelled in SUPREMA; R=to be included in the roadmap; S/R = very basic treatment within SUPREMA and mainly to be covered by future research.

4.2.2 Agmemod improvements needed for assessing policy scenarios

In AGMEMOD, improvements are need for representing the new CAP policy measures. The model can handle the most important aspects of the CAP that are affecting markets, i.e. greening (ecological focus areas) and voluntary coupled support (VCS). Now, new instruments are introduced: enhanced conditionality (capturing the old greening, but potentially at some different rates), eco-schemes (ES) and agriculture-environment-climate measures (AECMs). The enhanced conditionality can be implemented but needs some implementation coefficient. Furthermore, ESs, like AECMs, have two components: they need to be offered and MSs can make own choices in this, and, when available, they need to be taken up by farmers (voluntary adoption). The model currently cannot explain this voluntary adoption. Moreover, the uptake of ES and AECMs has two potential impacts: (i) market impacts (e.g. reduction in productivity, constraints imposed on land use), and (ii) environmental and sustainability benefit. The latter are mainly an aspect for MITERRA, the first need to be taken into account in AGMEMOD . The market impacts basically depend on two factors: (1) the degree of measure adoption, and (2) the impacts on land productivity. Measure adoption will generally depend on the regulatory environment and market related costs and benefits. Another factor are policy-related remuneration rates for green services and the available budget. For the measures that we would like to simulate in a CAP scenario these aspects have to be integrated into the Agmemod model.

4.2.3 CAP scenario assessment

Conditional on adequate model improvements can be made with respect of presenting the ongoing CAP policy reforms, three CAP scenarios will be developed:

i) Strong sustainability and climate focus (a strict enhanced conditionality, and intensive use of ES and AECMs, limited use of VCS; reallocation of EU budget from direct payments to environmental program payments)

ii) Balanced sustainability and profitability approach (less strict conditionality, small role of ES and limited extension of AECMs, maximum use of VCS)

iii) As (ii), but with a consumer demand adjustment due to a diet/preference shift

Since the proposed new CAP will be based on another delivery model, which puts the EU member states in a prominent and more responsible role with respect to the targeting on policy objectives and the tailoring of policy measures to these objectives (subsidiarity). This may lead to more heterogeneous policies at member state level in the EU. Also the commitments that the member states have with respect to environmental objectives and how agriculture has to contribute to achieving these objectives differ. For this reason it will be considered whether in the simulations some more in depth-assessments at some member states can be made, provided sufficient information is available and synergy with other work could be generated (cross-financing will be needed because the budget of Suprema does not allow for detailed CAP scenario analyses at the EU member states level).

The scenarios will involve different assumptions with respect to the modelled policy measures (ES, AECM, VCS, including enhanced conditionality) and associated productivity impacts (modelled via adjustments in productivity). In case of specific analyses for the EU member states, the detail with respect to measures and regulatory constraints may require further refinements with respect to policy measures implementation.

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The scenario results will be describes with respect to their impacts on agricultural markets, EU trade, farm income, as well as with respect to a set of environmental indicators (e.g. leakages to the environment, GHG emissions).

5 Narratives for the climate and policies

Agriculture is the biggest source of anthropogenic non-CO_2 emissions. Over the past decades agricultural non-CO_2 emission have increased. This growth is mainly related to increased emissions from synthetic fertilizer and manure application and enteric fermentation from ruminants. However, even though emissions increased by around one third, agricultural production over the same period increased by around 70% according to the FAOSTAT gross production index. Hence agriculture still continues to improve its GHG efficiency at the global scale.

SUPREMA will assess the potential contribution of the EU's agricultural sector to climate change mitigation efforts. We will quantify the impact of various levels of ambition for methane (enteric fermentation, manure management, rice cultivation) and nitrous oxide emission reduction (synthetic fertilizer, manure applied to soils, manure left on pasture, manure management, cultivation of organic soils) by implementing a harmonized baseline scenario without mitigation efforts across models and contrast baseline results to a range of climate change mitigation scenarios. Several climate change mitigation dimensions will be implemented to assess the impact of mitigation efforts in the agricultural sector.

5.1 Modelling climate change mitigation in agriculture

5.1.1 Mitigation target

We will test different mitigation targets for agriculture in line with a 2°C and 1.5°C target across sector to assess the implications for the sector and related sustainability indicators. Particular attention will be however paid to the 1.5°C target, which h is perceived by our stakeholder as the most relevant. To emulate the mitigation potentials a carbon price on non-CO_2 emissions will be implemented in the models. Table 5 displays the average carbon price trajectory across IAMs for a 1.5°C ("RCP1p9") and 2°C ("RCP2p6") scenario that was extracted from the SSP database (https://tntcat.iiasa.ac.at/SspDb/). The carbon price will be implemented in the objective function of the models as a tax on agricultural non-CO_2 emissions to incentivize the uptake of emission reduction technologies as well as to guide model solution in terms of level and composition of different production activities.

Table 5: Carbon price trajectory in USD2005/t CO_2 for agricultural non-CO_2 emissions across climate change mitigation scenarios.

	2020	2030	2040	2050	2060	2070
2°C SCENARIO	7	3	118	192	353	469
1.5°C SCENARIO	10	181	476	678	1070	1417

5.1.2 Mitigation region

Agricultural markets are connected through international trade and consequently regional mitigation policies may impact other regions. Since the EU agricultural sector is amongst the most GHG efficient ones worldwide, the level of mitigation action taken outside the EU is key to assess the impact of domestic mitigation efforts on EU farmers. For example, if ambitious action is taken also in the rest of the world, EU farmers could benefit from increasing exports to regions that produce currently with high GHG intensity. On the other hand, if other regions do not participate in the mitigation efforts, the leakage effect could substantially lessen the global effect of EU action, or could even lead to global increase in GHG emissions albeit EU efforts. Hence, we will explore the effect of a unilateral mitigation policy in the EU on the sector. In this set-up we will apply the mitigation policy only inside the EU while the rest of the world is assumed not to take up any, or limited, mitigation efforts ("EU"). In a second variant we assume that the whole world takes coordinated efforts to achieve the climate target and the mitigation policies are implemented across all regions ("World"). In reality, some of the non-EU countries took already substantial commitments towards carbon neutrality, and these commitments will be taken into account in the final definition of the differentiated regional efforts.

5.1.3 Mitigation sector

Land based mitigation policies may affect agricultural markets either directly, e.g. through production changes and increased afforestation or dedicated energy plantations (Kreidenweis et al., 2016), or indirectly through increased costs for energy and GHG intensive inputs such as synthetic fertilizers. To limit climate change below 1.5 °C, total biomass demand for energy is projected to increase up to 300 EJ by 2050 (Rogelj et al., 2018) which may trigger environmental and social trade-offs such as increased deforestation and emissions, nitrogen losses, and food prices without accompanying measures (Humpenöder et al., 2018). Hence, we will assess in our analysis how increased competition for land related to land based mitigation policies will affect the potential for agricultural non-CO_2 mitigation and whether synergies or trade-offs would occur.

In a first set of mitigation scenarios we will test a mitigation policy implemented only via carbon price on agricultural non-CO_2 emissions ("agriculture") while in a second scenario variant, we will test if considering increased biomass use for energy sourced from agricultural land i.e. through the establishment of dedicated energy plantations, and afforestation delivers any synergies or trade-offs with non-CO_2 emission reductions ("AFOLU + BE"). Table 6 and Table 7 display the average biomass demand sourced from dedicated energy crops and afforestation requirements across the integrated assessment models (IAMs) for a 1.5°C and 2°C scenario.

Table 6: Primary biomass in exajoule (EJ) sourced from dedicated energy plantations across climate change mitigation scenarios.

	2020	2030	2040	2050	2060	2070
2°C SCENARIO	8	17	36	57	94	118
1.5°C SCENARIO	6	15	73	123	139	151

Source: Globiom simulation results.

Table 7: Additional afforestation compared to 2020 across climate change mitigation scenarios (million ha)

	2020	2030	2040	2050	2060	2070
2°C SCENARIO	0	10	113	206	260	317
1.5°C SCENARIO	0	17	161	276	370	420

Source: Globiom simulation results.

5.1.4 Life style change as a complementary mitigation measure

Demand side options through reduced consumption of livestock products may contribute to GHG savings with potential co-benefits for health and food security (Stehfest et al., 2009; Popp et al., 2010; Bajzelj et al., 2014; Herrero et al., 2016; Springmann et al., 2016; van Vuuren et al., 2018). For example, Springmann et al. (2016) showed that a global carbon tax of 50 USD/t CO_2e resulted in 107,000 avoided deaths globally and reduced agricultural non-CO_2 emissions by 1 Gt CO_2e in 2020. By mid-century, non-CO_2 mitigation potential through dietary changes could even be as high as 3.3-4.4 Gt CO_2e (Popp et al., 2010; Bajzelj et al., 2014; van Vuuren et al., 2018). Likewise the EC recognized in their recently published long term strategy, that consumers will have to contribute through lifestyle changes such as reduction in ruminant meat and dairy milk consumption, to emission reduction efforts (EC, 2018).

To test the effect of a shift in dietary preferences, we will quantify different scenarios with respect evolvement in dietary preferences and food waste. One scenario assuming business-as-usual SSP2 diet projections ("None") and one where we assume a diet shift of total livestock calorie consumption levels to recommended levels and a 50% reduction in food waste ("Diet+Waste"). We assume animal product consumption is cut in all countries that consume more animal product calories than 430 kcal/capita/day based on recommendations by the United States Department of Agriculture (USDA) (www.cnpp.usda.gov/USDAFoodPatterns). The calories target (excluding waste) is achieved gradually by 2070 such that calorie consumption will linearly decrease from 2020 level to 430 kcal/capita/day in 2070. For models explaining calories available for consumption including waste, calories per capita per day will be corrected for household waste based on FAO (2011). The threshold will be then equal to 430/(1-waste%/100) where the waste% is 11% for Europe, Russia, North America and Oceania, 8% for Industrialized Asia and North Africa, West and Central Asia, 2% Sub-Saharan Africa, 4% for South and Southeast Asia, and 6% for Latin America.

5.1.5 Other sustainability considerations

Climate change mitigation in the agricultural sector and the need for land for afforestation and energy plantations will potentially lead to further intensification of agricultural production with potential negative effects on biodiversity, air and water pollution, and water availability. Carbon pricing would have substantial implications for farm incomes, as well as on food security.

Finally, carbon sequestration and growth in the bioenergy supply will represent new economic opportunities. The suit of models available in SUPREMA is very complementary in terms of regional and SDG coverage, and thus suitable for assessment of climate mitigation implications on other sustainability dimensions within the EU and across the world. These will be systematically explored for the retained scenario narratives.

5.2 Implementation and challenges of modelling climate policies

Mitigation policies modelling in the long-term do not lack challenges. In this section, we will outline three of them, as follows: Parameter uncertainties, realistic mitigation policies and consumer behaviour.

Calibration of the uptake of mitigation technologies represents a challenge even for the present. Most of the technologies were either not widely adopted so far or data about the extent of their adoption is missing in the statistics, which makes application of standard econometric approaches challenging. Bottom-up engineering approaches represent a viable alternative. However, they often produce results which are not directly implementable in large scale economic models. The first issue is that bottom-up marginal abatement cost curves regularly show a large potential for mitigation technologies adoption at negative cost. If we assume rational farmers, this means that there are unknown hidden barriers or "forgotten" cost, and typically it is left to modellers to find a way to reconcile such a cost structure with the economic principals of their models. The second issue is that, while the data often provides only an average value across the farm population, and the modellers need to represent the cost distribution within the farm population to avoid unrealistic corner solutions, the distribution typically relies on expert knowledge. With widespread implementation of the mitigation technologies, their cost is likely to substantially decrease while their effectiveness would increase, this represents an additional source of uncertainty in the long-term projections.

Long-term climate change mitigation assessments often relied on a carbon tax trajectory representing the level of mitigation efforts needed and allowed to obtain the cost efficient solution in terms of effort distribution across regions, sectors, and mitigation measures. While carbon tax implementation is potentially feasible in sectors such as energy or heavy industry, its acceptability within the agricultural sector seems currently limited. It is more likely that mitigation policies in the agricultural sector will rather support adoption of GHG efficient activities and emission reducing measures through more or less targeted subsidies, extension services, and support to research and innovation. These real world policies may lead to substantially different distribution of mitigation efforts within the agricultural sector with direct implications for other SDGs.

Finally, it appears that the ambitious mitigation targets will be impossible to attain without life style change, in particular in our context without a dietary change. The models present in the SUPREMA toolbox are well equipped to simulate the outcomes of alternative assumptions about food consumption, however, they cannot take into account endogenously the consumer response to information campaigns, dietary guidelines, social pressure, etc. which are supposed to play a role in influencing the food choice. Furthermore, even the response to monetary instruments, such as fat taxes, is likely to lie out of the comfort zone of currently used demand elasticities.

Acknowledging these limitations, one has to see also the tremendous progress in representation of the entire food system in large scale sectorial models over the past few years, which gives reason to believe that with more and more attention being paid to the role of food system in the climate mitigation challenges, the modelling teams will find ways to deal also with the above mentioned current limitations.

6 Concluding remarks

For the narratives for the baseline, the CAP and climate policies, conclusions are drawn by explicitly taking into account the stakeholders' feedback provided at the two workshops, as explained. Specifically, narratives have been developed based on a participatory approach involving stakeholders and experts, an assessment of the policy debate (e.g. CAP after 2020) and expected policy challenges (e.g. climate change). The narratives form the basis for a baseline, CAP scenarios, and a set of climate policy scenarios. The CAP narrative refer to a medium term, with the time period of the CAP budget spanning from 2021-2027. The climate policy are consider the long run. The baseline presents business as usual (BAU) but is surrounded with a set of assumptions that have been discussed with a broad group of experts, yielding a balanced view on what a business as usual evolution could imply. All the tools used in SUPREMA will be aligned as much as possible to the baseline narrative (with SSP2, as developed by IASSA).

The two stakeholder workshops contributed to the selection of themes for further assessment, which include addressing global and EU aspects of long term climate change challenges, future food demand, trade, income generation and its distribution across different income groups in and outside European countries, environmental degradation of soil, water and biodiversity and water. With respect to the CAP its contribution to a wider set of objectives was emphasized, while at the same time the priority was put on increased sustainability and biodiversity preservation.

For the climate policies, the stakeholders expressed the need for taking the global perspective on climate change and low carbon economy, sustainable development goals (SDGs) and resource constraints like land and water, in sufficiently long time horizon (2070), taking into account aspects such as global governance, change in consumer preferences, or development of bio-based economy. In response to these needs, long-term climate change mitigation narratives considering different climate mitigation targets, lower level of ambition in non-EU regions, shift towards healthy diets, competition for land between afforestation and bioenergy development on one side, and agriculture and ecosystems services on the other side, were developed and presented to stakeholders at the Narratives workshop. This allowed to further refine the narratives, which now focus on the ambitious 1.5°C target and base the differentiated involvement of non-EU regions on expressed commitments of the individual countries. Scenarios derived from these narratives will allow to assess potential opportunities for the EU agricultural sector, as well as risks of leakage effects, through international trade in the global context.

The wish-list of policy simulation options was broad, as identified in the SUPREMA stakeholder workshops, and beyond the scope of the SUPREMA project. At the same time, the stakeholder clearly expressed the need for (ex-ante) policy assessment to support policy makers and stakeholders (including consumers) in the context of future decisions that have to be made and that can, in various respects, have far reaching consequences. As such, this emphasize the importance of SUPREMA, not only for the narrative and corresponding scenarios that will be analysed, but as least as much for the contribution of the project to the future policy research and the insights into future requirements that SUPREMA will generate with respect to model functionalities and the themes that need to be covered. For example, the stakeholders also raised the need to model adoption of new technologies, including digitalization and robotization. Although we recognize that these revolutionary technologies may play critical role in the climate change stabilization and in achieving related SDGs, parameterization of the models to explicitly include such technologies into SUPREMA models is beyond the scope of the project. However, these new trends would represent a relevant topic to be followed up and will be elaborated and discussed in the SUPREMA roadmap for future research for agricultural modelling in the EU and beyond.

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