MIND STEP

MODELLING INDIVIDUAL DECISIONS TO SUPPORT THE EUROPEAN POLICIES RELATED TO AGRICULTURE

Deliverable D1.3: Report on the conceptual framework of the MIND STEP project

AUTHORS	Silvia Coderoni (UCSC) John Helming (WECR) Marc Muller (WECR) Marta Pérez-Soba (JRC) Paolo Sckokai (UCSC) Hugo Storm (UBO) Alessandro Varacca (UCSC)
APPROVED BY WP MANAGER:	Paolo Sckokai (UCSC)
DATE OF APPROVAL:	02-08-2021
APPROVED BY PROJECT COORDINATOR:	Hans van Meijl (WR)
DATE OF APPROVAL:	04-08-2021
CALL H2020-RUR-2018-2	Rural Renaissance
WORK PROGRAMME Topic RUR-04-2018	Analytical tools and models to support policies related to agriculture and food - RIA Research and Innovation action
PROJECT WEB SITE:	https://mind-step.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 817566.

This project has received funding from the European Union's Horizon 2020
research and innovation programme under grant agreement N° 817566.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 817566.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 817566.

ACRONYMS

ABM - Agent-based Model

AES - Agri-Environmental Schemes

CAP - Common Agricultural Policy

EU - European Union

GHG – greenhouse gases

IDM - Individual Decision Making

MS – Member States

SDGs - Sustainability Development Goals

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 817566.

EXECUTIVE SUMMARY

The overall objective of MIND STEP is to support public decision making in agricultural, rural, environmental and climate policies, taking into account the behaviour of individual decision-making units (IDM) in agriculture and the rural society. In this respect, WP1 has identified the future needs in the research and policy agenda and explored the feasibility of potential modelling exercises by using the MIND STEP toolbox, consisting of already existing models at farm, regional, national and worldwide levels and newly proposed individual decision-making (IDM) models and Agent Based Models (ABM).

This report synthesizes the work done for Task 1.3 that has reviewed the above-mentioned MIND STEP models and modelling approaches with a specific focus on their policy and farm, regional, national, EU and global driver coverage, in order to identify whether they could properly address the benchmark scenarios identified in Task 1.1.

The Task has been carried out through: (i) desk research; (ii) stakeholders' engagements; iii) interactions with partners of the MIND STEP Consortium that are developing/have developed and/or are maintaining the models in the MIND STEP toolbox.

This assessment has pointed out model gaps and eventual needs of model extensions and development of new tools. At the same time, it has also revealed the potential of model integration and collaboration to supplement the outcomes of individual models e.g., improved micro-economic underpinning of aggregated models.

Overall, all proposed scenarios of the "climate change" group could indeed be modelled. Six out of eight scenarios of the "preserve biodiversity, ecosystem services and environmental care" group can be modelled, while the remaining two can be potentially modelled by modifying the current model set-up. The "increase competitiveness" group of scenarios seemed to emerge as the most difficult to model. In fact, only four out of seven scenarios have been judged to be modellable, while three out of seven are potentially modellable, as long as the models in the MIND STEP toolbox can be properly modified.

Closely related to the work of Task 1.3, Task 1.2 has reviewed the models' ability to produce appropriate indicators for monitoring and measuring the impact of the same policies and drivers (i.e., the list of indicators identified in Task 1.2). Together, Task 1.1, Task 1.2 and Task 1.3 constitute the "conceptual framework" of the whole MIND STEP project, in the sense that the whole modelling and policy analysis work will refer to the identified set of policy questions, indicators and model gaps. This analysis will be used as input for the data framework in WP2, the modelling work in WP3, WP4 and WP5 and for the policy evaluation in WP6.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 817566.

This project has received funding from the European Union's Horizon 2020
research and innovation programme under grant agreement N° 817566.

1. INTRODUCTION

MIND STEP project is aimed at supporting public decision making in agricultural, rural, environmental and climate policies. This objective is very relevant in the light of the deep policy changes that are foreseen for the European agricultural and rural sector (European Commission, 2018; 2019; 2020). The main novelty of the approach proposed is in explicitly considering the behaviour of individual decision-making (IDM) units in agriculture and the rural society.

The overall objective of WP1, in this respect, was to characterize the future policy objectives and questions that will be relevant in the European context, and consequently, in the project's research agenda and investigate the viability of modelling exercises by using the tools of the MIND STEP toolbox (see Section 6.2 for an overview of the MIND STEP toolbox).

This report does not give a detailed literature review of strengths and weaknesses of all possible modelling approaches and methodologies, including the ones outside the MIND step toolbox. Instead, this report synthesizes the work done for Task 1.3 that has reviewed the MIND STEP models and modelling approaches with respect to their capability to properly simulate selected aspects of the benchmark scenarios identified, via stakeholders' involvement, in Task 1.1.

This assessment has pointed out model gaps and eventual need of model extensions and development of new tools. At the same time, it has also revealed the potential of model integration and collaboration to supplement the outcomes of individual models.

The Task has been carried out through: (i) desk research; (ii) stakeholders' engagements; iii) interactions with partners of the MIND STEP Consortium that have developed and/or are maintaining the models in the MIND STEP toolbox.

In order to complete the MIND STEP "conceptual framework", Task 1.2 has proposed a list of indicators and reviewed the models' ability to produce appropriate indicators for monitoring and measuring the impact of the same policies and drivers.

Together, Task 1.1, Task 1.2 and Task 1.3 constitute the "conceptual framework" of the whole MIND STEP project, in the sense that the whole modelling and policy analysis work will refer to the identified set of policy questions, indicators and model gaps. This analysis will be used as input for the data framework in WP2, the modelling work in WP3, WP4 and WP5 and for the policy evaluation in WP6.

This Deliverable is organized as follows: Section 2 presents the synthesis of the work done in Task 1.1; Section 3 the scenario grouping according to the post-2020 Common Agricultural Policy (CAP) objectives; Section 4 discusses the MIND STEP potential to model the proposed scenarios, by presenting which scenarios can be modelled or potentially modelled, meaning contribute to selected aspects, as well as the most relevant model gaps; Section 5 presents the synthesis of the Task 1.2; Section 6 the conceptual framework of the MIND STEP project by illustrating a synthesis of Tasks 1.1 and 1.2 and how the MIND STEP toolbox will implement the selected policy scenarios; finally, Section 7 provides brief concluding remarks.

2. SYNTHESIS OF TASK 1.1

Task 1.1. was aimed at identifying the relevant policy questions and related benchmark scenarios that could be modelled in the MIND STEP project to address the IDM response of EU farmers to potential policy changes.

In particular, this study wanted to answer the following research questions: Q1: *What agricultural policy objectives are relevant and worth of investigation today?; Q2*: *Which benchmark scenarios*

This project has received funding from the European Union's Horizon 2020
research and innovation programme under grant agreement N° 817566.

should be investigated in order to capture the most relevant impacts of these policy objectives on EU agriculture and rural areas?

These questions have been addressed using a set of qualitative tools. Among them, stakeholders' engagement via interviews, the use of policy expert team and the use of a focus group (including members of the core stakeholder group and the policy expert team) played a crucial role.

The MIND STEP core stakeholder group (see ANNEX 1 for the complete list), was carefully chosen to cover a broad range of interests from different groups, including both public and private sector representatives, giving particular attention to the inclusion of policy makers at a strategic level. Through a 5-step qualitative research approach, the proposed post-2020 Common Agricultural Policy (CAP) objectives were ranked based on the stakeholders' answers and the corresponding key policy questions for each post-2020 CAP objective, as defined by the policy expert team. Finally, for each policy question we associated a list of relevant benchmark scenarios as identified by the stakeholders.

A clear focus on environmental policy objectives emerged from the MIND STEP core stakeholder group views and the importance of the environmental issues coherently emerged also for the proposed scenarios, where stakeholders indicated more frequently environmental and low carbon setups. As regards modelling issues, the importance to analyse the trade-offs between economic and environmental objectives, and among environmental objectives, also clearly emerged.

3. THE SCENARIO GROUPING ACCORDING TO POST-2020 CAP OBJECTIVES

The first step of the analysis was the classification of the 24 scenarios derived from Task 1.1. These scenarios have been classified in three main groups, each with a particular ambition stemming from the 9 post-2020 Common Agricultural Policy (CAP) objectives. Table 1 summarise the scenario grouping and their respective ambitions.

The "Climate Change" scenario group has the overall ambition to reduce or prevent the emissions of greenhouse gases (GHG) from primary agricultural production by reducing the sources or enhancing the sinks. The "preserve biodiversity, ecosystem services and environmental care" scenario group aims at accelerating the transition to a sustainable farm system that should have a neutral or positive environmental impact. Finally, the "increase competitiveness" group of scenarios has the goal of modelling changes in CAP payments, supply chain management tool and innovation, and assess their impacts on economic and environmental sustainability.

For each scenario, we have further indicated whether it was a supply-side scenario (i.e., if it was aimed at modelling changes from the producers' side), or a demand-side one (i.e., if it was aimed at modelling changes of the consumers' side). Besides, in the supply-side class of scenarios we have distinguished whether it was a policy-driven or a market-driven scenario, i.e., if it was aimed at modelling changes introduced by some new policy settings or by some market mechanisms. Finally, for each scenario, it has been indicated to which post-2020 CAP objective it was primarily intended to contribute. This indication has been done through the expert judgement of the research team which relying on the official document of the EU Commission about the future CAP objectives (European Commission, 2018). Of course, the same scenario can contribute to more than one objective, but the research team has tried to indicate the objective to which each scenario gave its primary contribution.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 817566.

Table 1 The scenario grouping and their respective ambitions.

SCENARIO GROUP	AMBITION
• **CLIMATE CHANGE ACTION**	• To reduce or prevent the emissions of greenhouse gases from primary agricultural production by reducing the sources or enhancing the sinks
• **PRESERVE BIODIVERSITY, ECOSYSTEM SERVICES AND ENVIRONMENTAL CARE**	• To accelerate the transition to a sustainable farm system that should have a neutral or positive environmental impact
• **INCREASE COMPETITIVENESS**	• To model changes in CAP payments, supply chain management tool and innovation, and assess impacts on sustainability

Table 2, Table 3 and 4, show in detail the scenario group description for each of the three groups by also detailing the type of scenario and the post-2020 CAP objective it is related to.

Most of the scenarios proposed by the stakeholders are supply-side driven, while only one is demand-side, namely: “Simulate the impact on the agricultural sector of changes in diets (e.g., reduction of meat consumption)”. Among the supply-side scenarios, 20 are policy-driven and the remaining three are market-driven scenarios, i.e., “Simulate the adoption of emission trading systems between farms”; “Creating markets for ecosystem services (carbon sequestration)” and “Creating markets for ecosystem services (water)”.

Looking at which post-2020 CAP objective each scenario is related to, it emerges that all the scenarios are supposed to contribute to some extent to the rural development and modernisation objectives, while 17 are supposed to contribute to Environmental care, 10 to biodiversity, 9 to Climate change, 8 to Competitiveness and Fair income and 2 to Societal demands.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N° 817566.

Table 2 Climate change scenario group description.

CLIMATE CHANGE ACTION	Type of scenarios: Supply-side: policy-driven	Supply-side: market-driven	Demand-side driven	Post 2020 CAP policy objectives*: Biodiversity	Environmental care	Climate change	Competitiveness	Fair income	Societal demands	Rural development	Modernisation
Simulate the adoption of carbon taxes on agricultural production	■				■	■				■	■
Simulate the adoption of a carbon border tax adjustment together with previous instruments	■				■	■				■	■
Simulate the adoption of subsidies targeted to climate change mitigation	■				■	■				■	■
Impact of different GHG mitigation measures (i.e., constraints on livestock numbers and/or on nutrient disposal).	■				■	■				■	■
Create incentives to increase carbon sinks by farmers (and measure the impact of different land use options)	■				■	■				■	■
Create incentives for energy transition in agriculture (e.g., renewables)	■			■	■	■				■	■
Simulate the adoption of emission trading systems between farms		■			■	■				■	■
Creating markets for ecosystem services (carbon sequestration)		■			■	■				■	■
Simulate the impact on the agricultural sector of changes in diets (e.g., reduction of meat consumption)			■	■	■	■				■	■

*Definitions of the post 2020 CAP Objectives:
Biodiversity: Contribute to the protection of biodiversity, enhance ecosystem services and preserve habitats and landscapes
Environmental care: Environmental care (efficient management of natural resources such as water, soil and air)
Climate change: Contribute to climate change mitigation and adaptation, as well as sustainable energy.
Competitiveness: Increase competitiveness and agricultural productivity in a sustainable way to meet the challenges of higher demand in a resource-constrained and climate uncertain world
Fair income: Ensure a fair income to farmers.
Societal demands: Improve the response of EU agriculture to societal demands on food and health (antimicrobial resistance), including safe, nutritious and sustainable food, reducing food waste, and animal welfare.
Rural development: Promote employment, growth, social inclusion and local development in rural areas, including bio economy and sustainable forestry.
Modernisation: Modernise the agricultural sector by attracting young people and improving their business development

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 817566.

Table 3 Preserve Biodiversity, Ecosystem Services and Environmental Care scenario group description.

	Type of scenarios			Post 2020 CAP policy objectives*							
PRESERVE BIODIVERSITY, ECOSYSTEM SERVICES AND ENVIRONMENTAL CARE	Supply-side: policy-driven	Supply-side: market-driven	Demand-side driven	Biodiversity	Environmental care	Climate change	Competitiveness	Fair income	Societal demands	Rural development	Modernisation
Mandatory reduction of input use (e.g., -20% fertilizers, etc.)											
Mandatory 25% UAA cultivated with organic farming methods											
Adoption of collective payments to farmers (territorial approach to environmental care) (e.g.: new approaches to nutrient policies or agri-environmental payments)											
Create incentives linked to the environmental footprint of agricultural activities											
Increased use of EU subsidies for various types of agri-environmental measures											
Simulate land use changes derived from different livestock management options (e.g., more grazing, constraints on feed, constraints on livestock numbers, etc.)											
Creating markets for ecosystem services (water)											
Introduction of measures to deal with animal welfare issues (antimicrobial regulations)?											

*Definitions of the post 2020 CAP Objectives:
Biodiversity: Contribute to the protection of biodiversity, enhance ecosystem services and preserve habitats and landscapes
Environmental care: Environmental care (efficient management of natural resources such as water, soil and air)
Climate change: Contribute to climate change mitigation and adaptation, as well as sustainable energy.
Competitiveness: Increase competitiveness and agricultural productivity in a sustainable way to meet the challenges of higher demand in a resource-constrained and climate uncertain world
Fair income: Ensure a fair income to farmers.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 817566.

Societal demands: Improve the response of EU agriculture to societal demands on food and health (antimicrobial resistance), including safe, nutritious and sustainable food, reducing food waste, and animal welfare.
Rural development: Promote employment, growth, social inclusion and local development in rural areas, including bio economy and sustainable forestry.
Modernisation: Modernise the agricultural sector by attracting young people and improving their business development

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 817566.

Table 4 Increase competitiveness scenario group description.

	Type of scenarios			Post 2020 CAP policy objectives*							
INCREASE COMPETITIVENESS	Supply-side: policy-driven	Supply-side: market-driven	Demand-side driven	Biodiversity	Environmental care	Climate change	Competitiveness	Fair income	Societal demands	Rural development	Modernisation
Model the removal of first pillar direct payments											
Model a further full decoupling of first pillar payments											
Model a fundamental change in the distribution of direct payments (i.e., linkage of payment to farm labour rather than to farm area or other parameters, etc.…);											
Model a re-coupling of the First Pillar Payments to public goods and ecosystem services											
Model the adoption of publicly supported risk management tools (i.e., subsidies for income stabilization tools)											
Simulate the adoption of supply chain management tools such as contracting and producers' organizations											
Model an increased use of subsidies for innovation adoption (precision agriculture, conservation agriculture, 5g, robotics, Artificial Intelligence, Blockchain, etc.)											

*Definitions of the post 2020 CAP Objectives:
Biodiversity: Contribute to the protection of biodiversity, enhance ecosystem services and preserve habitats and landscapes
Environmental care: Environmental care (efficient management of natural resources such as water, soil and air)
Climate change: Contribute to climate change mitigation and adaptation, as well as sustainable energy.
Competitiveness: Increase competitiveness and agricultural productivity in a sustainable way to meet the challenges of higher demand in a resource-constrained and climate uncertain world
Fair income: Ensure a fair income to farmers.
Societal demands: Improve the response of EU agriculture to societal demands on food and health (antimicrobial resistance), including safe, nutritious and sustainable food, reducing food waste, and animal welfare.
Rural development: Promote employment, growth, social inclusion and local development in rural areas, including bio economy and sustainable forestry.
Modernisation: Modernise the agricultural sector by attracting young people and improving their business development

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 817566.

4. THE MIND STEP POTENTIAL TO MODEL THE SCENARIOS

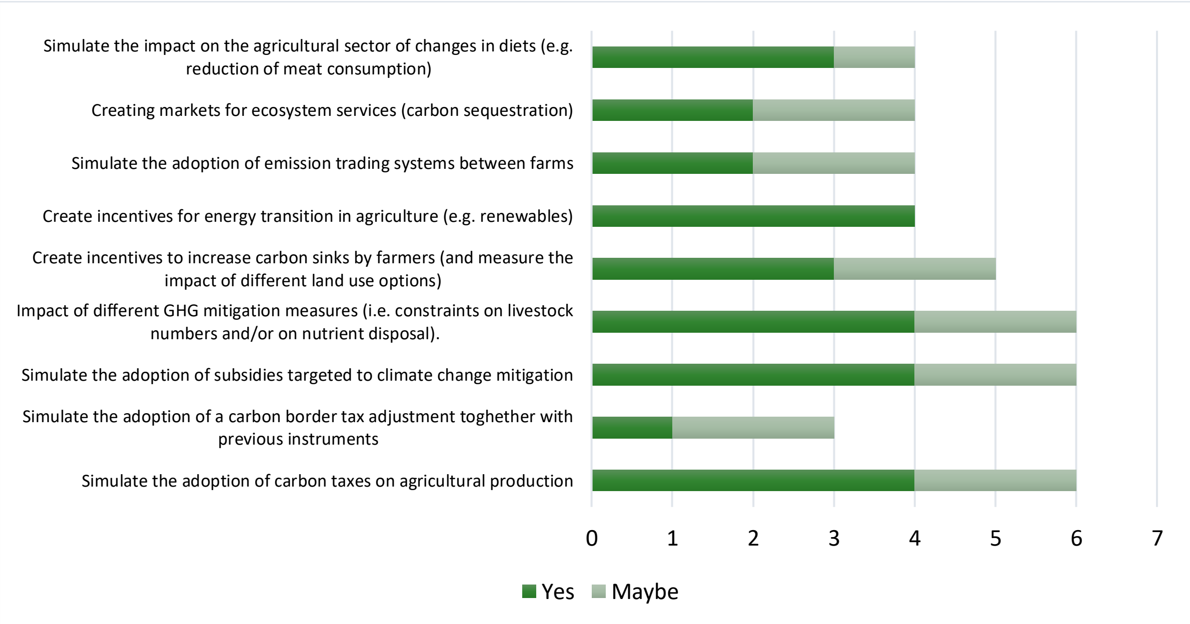
4.1. Which scenarios can be actually or potentially modelled?

The next step of the analysis has involved all the seven MIND STEP consortium members in charge of the modelling work (Thuenen, IIASA, INRA, RURALIS, UBO, UCSC, WR, WU) to whom we asked which of the suggested policy scenario could be already modelled with the models of the MIND STEP toolbox or which ones could be potentially modelled by providing some modification or improvements to the actual toolbox. The analyses highlighted which scenarios were the easiest to be modelled by the consortium and which ones will need additional efforts.

Figures 1 to 3 show the replies to this question by the MIND STEP consortium members that are involved in modelling exercises. The numbers in the figures may however overestimate the number of models (or modelling systems) in the MIND STEP toolbox that are fit for simulating the scenarios proposed. Indeed, since different partners contributing within the same modelling system may have separately replied to the question whether they could model the scenario or not, the bar plot in Figure 1 may be slightly biased. To the project's purposes, however, what really matters is whether a scenario can be actually or potentially modellable, regardless the number of times it is indicated. In the following paragraphs, we discuss the policy team's replies for each scenario bloc presented in Table 1.

As regards the "climate change" scenario group (Figure 1), it emerged that all the scenarios proposed could indeed be modelled, both actually and potentially.

Figure 1 Climate change scenarios that can be modelled.

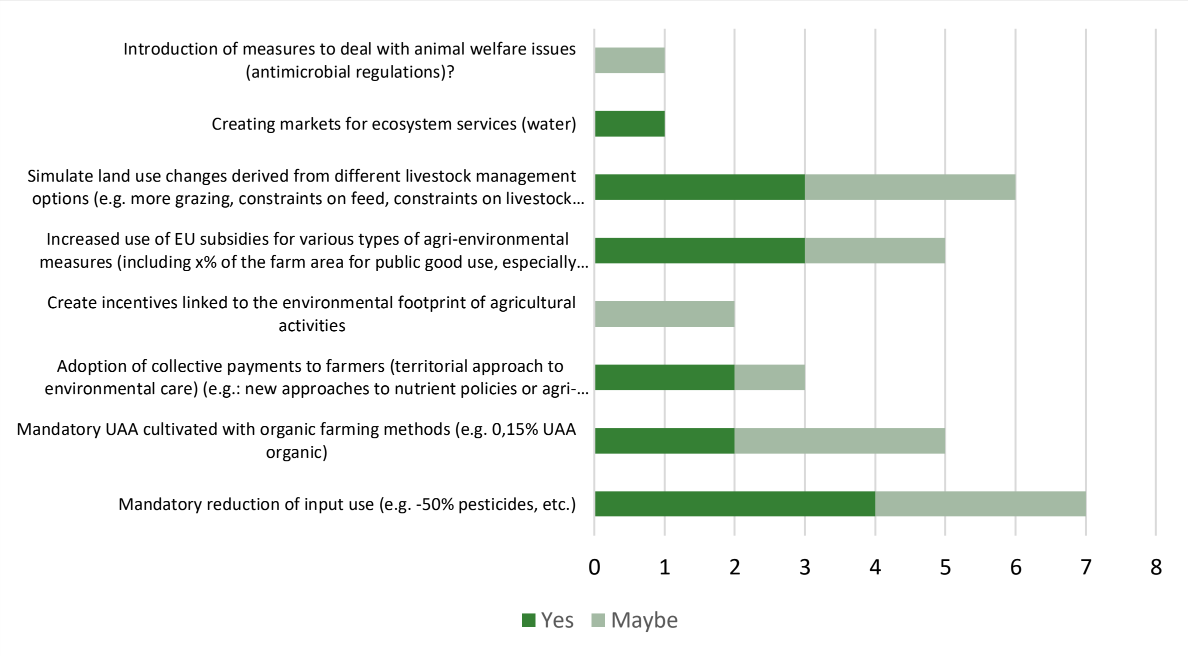


When it comes to the "preserve biodiversity, ecosystem services and environmental care" scenario group (Figure 2), six out of eight scenarios can be actually modelled, while the remaining two can be potentially modelled by modifying the current model set-up. These are the "Create incentives linked

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 817566.

to the environmental footprint of agricultural activities" and the "Introduction of measures to deal with animal welfare issues (antimicrobial regulations)?" scenarios.

Figure 2 Preserve Biodiversity, Ecosystem Services and Environmental Care scenarios that can be modelled.



Finally, the "increase competitiveness" group of scenarios (Figure 3) seemed to emerge as the most difficult to model. In fact, only four out of seven scenarios have been judged to be actually modellable, while three out of seven are potentially modellable, as long as the models in the MIND STEP toolbox can be properly modified. These are: "Model the adoption of publicly supported risk management tools (i.e., subsidised income stabilisation tools)"; "Simulate the adoption of supply chain management tools such as contracting and producers' organisations, etc."; "Model an increased use of subsidies for innovation adoption (precision agriculture, conservation agriculture, 5g, robotics, Artificial Intelligence, Blockchain, etc.)". After a discussion with the modellers, the sometimes rather general descriptions of the scenarios make it more difficult to assess if the scenarios can be modelled or not.

Figure 3 Increase competitiveness scenarios that can be modelled.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 817566.

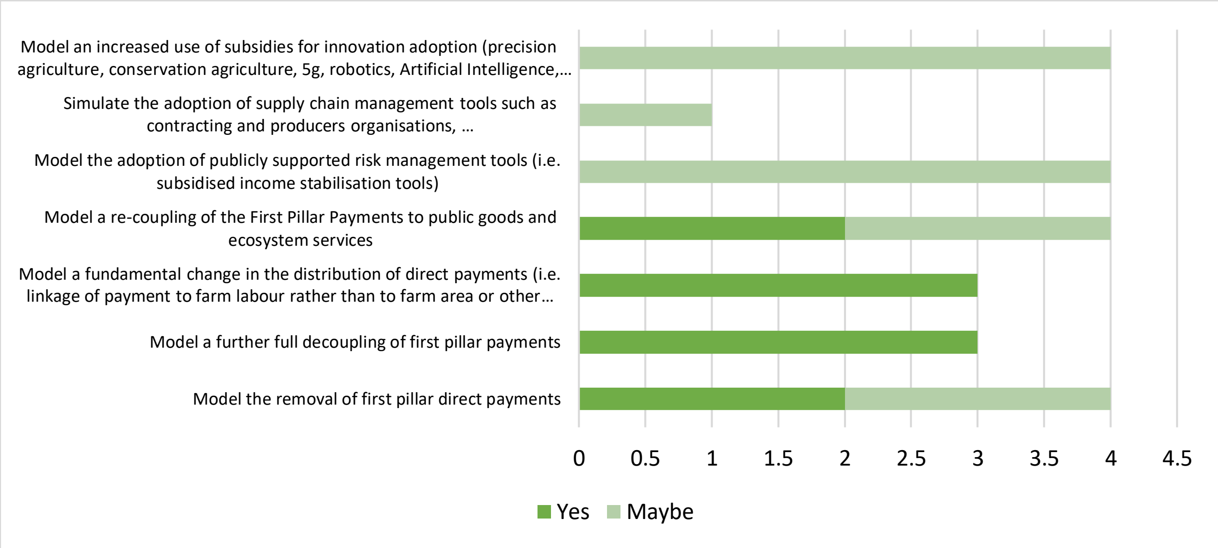
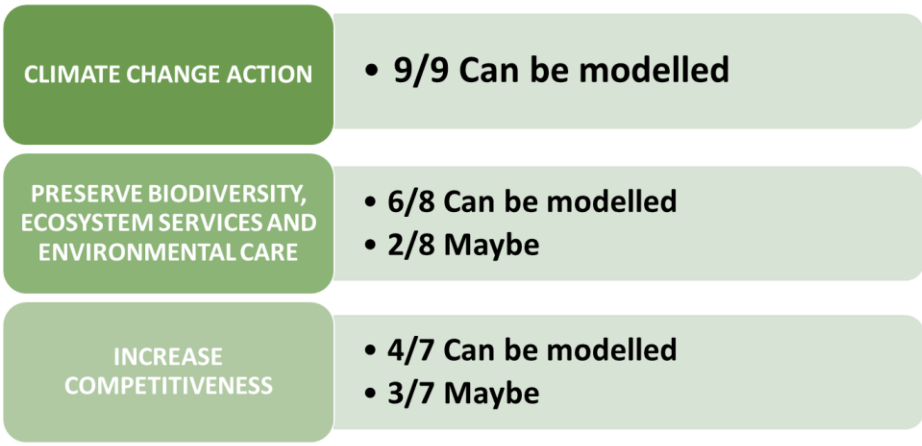


Figure 4 summarizes the number of scenarios that can be modelled according to each group.

Notice that there is a very important caveat with respect to the capabilities of the MIND STEP toolbox to simulate the indicated scenarios: at present, the spatial scale at which these modelling exercises may be developed has not been specified yet (see Section 4.2). This means that the same scenario could be developed at different spatial scales (e.g., national, NUTS2; IDM, etc…), thus the issue of spatial scale remains, at this stage of the project, still open, and depends mainly on the type of model that will be used. However, as the focus of the project is the IDM, this scale of analysis will be the preferred one whenever possible.

Figure 4 Group of scenarios that can be modelled.



4.2. The most relevant model gaps

When indicating whether the scenarios proposed by stakeholders could be modelled, partners have been also asked to comment about the specific difficulties in modelling each scenario by identifying the model gaps with respect to the current MIND STEP modelling toolbox. When available, the partners have also indicated what solutions (if any) could potentially be deployed to fill these gaps. Of

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 817566.

course, not all the scenarios could be modelled by all models in the MIND STEP toolbox. Therefore, for completeness, this section discusses the most relevant comments received for each scenario, focussing on the current issues and on the aspects that were deemed potentially modellable (see figures 1-3), thus drawing attention to the most relevant gaps in the toolbox. We proceed by addressing scenarios individually, while leaving some common remarks at the end. To facilitate the reading, we structure the discussion such that each review follows the order of tables 2 through 4. Finally, notice that we only report the reactions from the MIND STEP consortium, hence not all scenarios might be mentioned in the upcoming paragraphs.

4.2.1. Climate change action scenarios

For the scenario named "Creating markets for ecosystem services (carbon sequestration)", the difficulties are mainly related to each specific ecosystem service and its translation into an operational indicator. For example, for biodiversity, partners have indicated that the scenario can be modelled if biodiversity is intended as crop mix (e.g., via a Shannon index), or as species rich grassland or as intensity metrics (e.g., Nitrogen-intensity). The wider interpretation of biodiversity (also related to management practices beyond crop choice) has been judged as being too difficult to model at this stage. However, more sophisticated biodiversity indicators should become available for reporting in the GLOBIOM model, thanks to the model development activities planned during the MIND STEP project, mostly related to land use/cover rather than management.

If markets for ecosystem services (carbon sequestration) between individual farms is meant, another difficulty is that market interaction regarding ecosystem services between individual farms is lacking in the existing and EU-wide individual farm model IFM-CAP. Interaction between individual farms is also not foreseen in the new IDM models in the MIND STEP toolbox. If appropriate indicators for ecosystem services are available, the farm models can however be used to analyse income foregone and shadow prices per sector and region. This gives an indication of competitiveness. Results can also be used for improved parameterisation of the aggregate models in the MIND STEP toolbox.

This would also solve the cross-cutting challenge concerning the spatial resolution of the economic analysis, for which the commonly available NUTS2 level can be far too coarse, if data is not built from individual underlying farms.

Finally, in certain models, indicators of agricultural land use, such as the Shannon index for crop mix, the share of certain key crops (e.g., legumes) or the changes in livestock density, can be exogenously modelled and interpreted as measurements of ecosystem services. However, in these models, the development of a market for services with endogenous demand cannot be foreseen as outcome of the project modelling activities.

4.2.2. Preserve Biodiversity, Ecosystem Services and Environmental Care scenarios

We start our discussion with the "Adoption of collective payments to farmers", i.e., implementing a landscape/territorial approach to environmental care. Partners have stressed that optimization models could in principle be used to address the choice of accepting the payment or not. However, the overall trade-offs at country level would require connecting farm adoption to ecological impact. In particular, the application of FarmAgriPolis in Task 4.3 could focus on participation of farmers in collective payments and results could be used in other models. In addition, surveys may help to set up

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 817566.

scenario runs for large farm samples by incorporating, for example, the willingness to participate in a program if neighbouring farms participate.

Turning to the “Mandatory reduction of input use” scenario, modelling largely depends on which input one aims to focus on. Whereas it is relatively straightforward to model the use of nitrogen and water, the exercise seems a lot more difficult for pesticides. Thus, in principle, the model will be able to run these scenarios but would have to be carefully checked and possibly adjusted to make behavioural (and yield) response realistic. Namely, if yield reductions and increased/decreased costs for mechanical/chemical treatments were known (i.e., derived from FADN data or expert surveys), then income change at the farm level could in principle be calculated. Including these results in aggregated models would allow assessment of potential price increases due to lower supply and import and export flow changes.

Looking at the “Mandatory 25% UAA cultivated with organic farming methods”, the policy team pointed out that organic production systems, as an alternative technology, need either to be checked and further developed in some models (e.g., FARMDYN), or fully represented in others (e.g., GLOBIOM). If the share of UAA cultivated with organic methods is set exogenously, all models can, in principle, evaluate the impact of the adoption of organic farming on economic performances, environmental indicators and factor use. However, the main issue here is modelling farmers’ willingness to adopt organic production practices, which also depends on unobserved economic and non-economic drivers. Moreover, so far, no EU regional model explicitly models organic farming. If one simply approximates the adoption of organic farming by simply creating a farm group characterised by lower average yields and costs, this will ignore many key aspects of organic farming, such as the closed fodder and nutrient balances. The use of individual farm models where a farm is either organic or non-organic, would require e.g., a market for land to analyse the adoption of organic farming and related structural changes. The farm models could be used to assess shadow prices to assess what farmers might potentially convert from conventional to organic farming from economic perspective. The main challenge is certainly data availability, as organic farms are not representative in the FADN dataset and non-economic behavioural aspects also play a role. These aspects are not included in FADN.

“Create incentives linked to the environmental footprint of agricultural activities” comes with the challenge of defining the “environmental footprint”. If footprints could be translated into e.g., levies, quotas, restrictions on use and production of specific farm inputs and outputs, models could accommodate them more easily. Some partners have highlighted the importance of setting different system boundaries for the definition of footprint that, in turn, would translates into further data availability issues.

The scenario “Create incentives for energy transition in agriculture (e.g., renewables)” can already be implemented in some available models such as the biogas module in FARMDYN. However, other technology options (e.g., solar and wind energy) still need to be incorporated in the current analytical tools, and this is certainly not a straightforward task.

For the “Increased use of EU subsidies for various types of agri-environmental measures” scenario, the MIND STEP partners highlighted that, as with any scenario, the quality of the analysis strictly depends on how well the adoption is modelled. Indeed, previous empirical analyses show that non-monetary factors play an important role which, unfortunately, is not easy to capture.

For measuring the “Impact of different GHG mitigation measures (i.e., constraints on livestock numbers and/or on nutrient disposal)”, targeted simulations are already planned. Furthermore, improvements through a more realistic modelling of farmers’ behaviour based on behavioural economic theories are also in the MIND STEP agenda.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N° 817566.

When it comes to "Simulate the adoption of emission trading systems (ETS) between farms", simulations' settings depend on whether the trading is meant between farms, which is obviously only possible for the IDM models. The bottom-up aggregation of single farm outcomes to regions and/or farm groups may thus allow the creation of market models by deriving aggregate demand and supply responses for the emission rights. This approach can also be used to model the markets for ecosystem services, conditional on the operationalisation of the ecosystem services themselves. At the same time, such aggregated results can also be linked to existing market models in the MIND STEP toolbox. To model the emission market, for example, one could think of imposing a quantity restriction on emissions, rather than a tax, and then calculate how this will get allocated across farms, sectors and regions. As for individual decision making, the Agrispace model can feature individual farms and farm groups to study structural change in agriculture, but it needs further development to properly simulate the ETS scenario. One of the key problems is to find a proper way to measure farm-level emissions (i.e., the certification system) and hence the permits. Until now bottom-up aggregation of the newly developed technology-rich IDM models to the EU is not foreseen, while the existing farm level model that covers all farms in the FADN, IFM-CAP does not include all necessary technologies.

The scenario "Simulate the adoption of a carbon border tax adjustment together with previous instruments" can be done using market models, drawing on elasticities derived from the farm models.

Since the MIND STEP toolbox does not comprise demand side/consumers' models, "Simulate the impact on the agricultural sector of changes in diets (e.g., reduction of meat consumption)" is challenging. However, the existing literature on the market impacts of changes in diets can be translated into alternative farm gate prices, thus allowing simulating this policy indirectly.

Reactions to the scenario "Create incentives to increase carbon sinks by farmers (and measure the impact of different land use options)" were mixed. If the carbon sinks can be formulated as production activities, then the scenario should be quite easy to implement. On the other hand, if the interest lies in the capability of production activities to sequester carbon, then soil's potential storing is critical and requires dynamic modelling. In some very specific case, such as an increase in grassland acreage, this scenario has previously been modelled using CAPRI in combination with CENTURY, a specific model for carbon sequestration dynamics.

The scenario to "Simulate land use changes derived from different livestock management options (e.g., more grazing, constraints on feed, constraints on livestock numbers, etc.)" can be modelled by FARMDYN that already includes different feeding regimes related to grazing and grassland management options. Also, the INRA model includes substitution between crop land and grassland.

Finally, the scenario on the "Introduction of measures to deal with animal welfare issues (regulations)" is very challenging as the project did not foresee any package or task on this issue. In general, if animal welfare indicators and the corresponding extra costs for farmers are known, modelling such policy changes might be feasible. Most of the animal welfare measures will indeed come with additional costs also in form of investment costs (stable extension) and a higher labour cost. This issue is particularly relevant for monogastrics systems. However, the representation of pig and poultry fattening systems in agricultural statistics is not very good. Knowing the costs, the impact of an animal welfare policy on the sector's competitiveness could be carried out, along with the leakage effects on import and export. However, farm level models like FARMDYN do not have this problem and can be thus used to estimate investment decisions, triggered by different animal health measures. The same problems can be identified for animal welfare labelling as price mark-up can be analysed with market models if impact on demand and extra costs of labelling are known.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 817566.

4.2.3. Increase competitiveness scenarios

The first scenario in this group, “Model an increased use of subsidies for innovation adoption (e.g., precision agriculture, conservation agriculture, 5g, robotics, Artificial Intelligence, Blockchain, etc.)” is also rather challenging. Partners of the MIND STEP consortium clarified that, in some cases, it is possible to formally model innovation adoption through economic choices, as long as the production activities with the new technologies can be formulated, and costs are known. Unfortunately, behavioural factors are important too, and they are not part of the core MIND STEP models.

In general, this scenario could be easily modelled if investment requirements, willingness to adopt, time frame of adoption and productivity enhancing potential of new technologies were known. However, in such circumstances, IDM models would not even be necessary. Some of the technologies proposed might be already represented in the toolbox portfolio of mitigation options (e.g., conservation agriculture). Another issue to be confronted with is that the productivity and ecological consequences of using new technologies are not fully known; a possible solution could be an aggregate analysis to assess consequences on agricultural production in the EU if "robotics" increases capital costs and saves labour to a certain extent (based on literature and expert consultation).

The scenario concerning “Simulate the adoption of supply chain management tools such as contracting and producers’ organisations, etc.”, is very challenging as some models (e.g., GLOBIOM) lack an explicit representation of some key supply chain actors. However, one possible fix would consist in adopting a top-down approach, as developed in Task 4.4: (a) change the equations in a market model (i.e. CAPRI/MAGNET); (b) obtain different changes in farm level prices under different assumptions about market structure (including the presence of contracts/producer organisations);(c) use the different price levels to simulate the impact on farm income (and potentially on other target variables, such as environmental indicators) in the IDM models.

The possibility to “Model the removal of first pillar direct payments” is also quite complex, as it requires modelling investment decisions, farmers’ financial positions, willingness to continue farming and thus the design of a structural change module representing farmers’ exit from the market when a large part of their income is removed. Although nontrivial, these extensions could be tackled by combining different selected models, such as through Agripolis in combination with an IDM for selected regions. The FARMDYN model could also be used to see how the removal of first pillar direct payments would influence farm income. Task 4.2 provides an exit model estimation – as long as income changes can be approximated to some extent.

The MIND STEP team also deems “Model a fundamental change in the distribution of direct payments (i.e., linkage of payment to farm labour rather than to farm area or other parameters, etc.)” rather challenging, mainly due to difficulties in modelling behaviour (which might not be robust enough for this kind of exercise). The scenario could in principle be simulated if the payments were linked to selected inputs (e.g., fertiliser, pesticides, feed concentrates) or agro-environmental indicators (e.g., carbon stock or N-surplus). If linked to labour, however, substitution between labour and other inputs (capital, land, purchased inputs) is currently not properly modelled in farm level models. Or at best only partly e.g., endogenous choice of stable size FARMDYN. Nevertheless, FADN and FSS can be helpful to understand the first order effects of a different distribution of direct payments on income, without a specific modelling. Such results may be then analysed among different regions, farm groups or other characteristics.

To “Model a re-coupling of the First Pillar Payments to public goods and ecosystem services”, it is key to understand how to link production activities to public goods and ecosystem services, an issue that needs to be addressed together with policy makers.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N° 817566.

Finally, the scenario providing "Model the adoption of publicly supported risk management tools (i.e., subsidised income stabilisation tools)" is feasible if and only if risk is explicitly incorporated in IDM models. This seems feasible with IFM-CAP and FARMDYN that already include risk parameters. Task 5.2.4 will also improve risk representation in GLOBIOM for instruments addressing extreme weather/yield volatility, so there are potential synergies to exploit with other models. The only difficulties are related to the fact that the focus of the project is on modelling farmers decision making to use/not-use of risk management instruments. Adoption is dependent also on the level of risk aversion, and behavioural factors, some of which will be analysed in Task 3.5.

4.2.4. Cross-cutting issues

Among the potential cross-cutting issue in modelling the proposed scenario through the MIND STEP toolbox, the possibility to assess the trade-off between economic and environmental performances will heavily depend on the available indicators. The trade-off in terms of income forgone as a result of the adoption of environmentally friendly behaviour is straightforward, but the ecological impact is likely more difficult to obtain and would depend on the specific environmental objective.

Concerning the opportunity of modelling different responses heterogeneously among MS/regions (e.g., different type of incentives and regulations in Europe), partners have indicated that most models are set up in a way that such differences can be accommodated. The major possible limitation, however, lies in the data: the lack of specific information will likely hamper modelling heterogeneity. In principle, such country specific data can be collected via surveys to national/regional policy makers to fill model gaps.

Modelling synergies and trade-offs between different environmental policy objectives (e.g., adaptation to climate change vs. mitigation; biodiversity vs. mitigation, etc.) will, again, depend on indicators that are currently used in the models or that will be built in as a result of modelling activities. The trade-offs between mitigation measures and farm productivity, for instance, is going to be assessed.

The possibility to analyse the different scenarios dynamically is provided by both the FARMDYN model, which allows for the dynamic implementation of (selected) policies, and Agripolis, through the dynamic version of the IDM model.

To sum up, Table 5 summarizes the most relevant model gaps for the scenarios that the MIND STEP partners deemed potentially modellable within the MIND STEP toolbox, plus some possible solutions.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 817566.

Table 5 Most relevant model gaps according to each scenario and possible solution foreseen.

Scenario	Model Gaps	Possible solutions
Model the adoption of publicly supported risk management tools (i.e., subsidised income stabilisation tools)	Difficulties arise if the focus is on modelling farmers decision making to use/not-use of risk management instruments. Adoption is dependent also on the level of risk aversion, and behavioural factors.	Task 5.2.4 will improve risk representation in GLOBIOM for instruments addressing extreme weather/yield volatility, so there are potential synergies to exploit with other models. Risk aversion and behavioural factors will be analysed in T3.5.
Simulate the adoption of supply chain management tools such as contracting and producers' organisations, etc.	In the bulk of the models supply chain actors are not represented (e.g., GLOBIOM).	In Task 4.4 that is about modelling price transmissions in the supply chain, the role of contracts and producer organisations could perhaps be included.
Model an increased use of subsidies for innovation adoption (precision agriculture, conservation agriculture, 5g, robotics, Artificial Intelligence, Blockchain, etc.)	Non-economic behavioural factors are important for adoption. Data are included in FADN and they are also not part of the core MIND STEP models. The productivity and ecological consequences of using new technologies are not fully known.	The scenario could be modelled if investment requirements, willingness to adopt, time frame of adoption and productivity enhancing potential of new technologies are known. Some of those technologies might be already represented in the toolbox portfolio of mitigation options (e.g., conservation agriculture). A possible solution at farm level could be to evaluate productivity and efficiency gains and ecological consequences (based on expert guesses and literature).and assess what farm might possibly adopt and what not based on these rather limited number of behavioral aspects.
Introduction of measures to deal with animal welfare issues (antimicrobial regulations)?	The project did not foresee any package or task on this issue. Gaps are linked to knowledge of animal welfare indicators and extra costs. The relevance of this issue is maybe mainly for the monogastric who's in agricultural statistics and hence in the models is not very good.	If animal welfare indicators and extra costs on farm are known, it could be feasible. The farm level model like FarmDyn can be used to estimate investment decisions, triggered by different animal health measures.
Create incentives linked to the environmental footprint of agricultural activities.	The main difficulty is the definition of the "environmental footprint", as one general requirement is that footprints also come from interaction between different activities (e.g., rotations) so one might have to look at this at the farm system level. Is very important to understand where system boundaries are set for the definition of the footprint as this, in turn, translates on the data availability.	The footprint could be translated into e.g., levies, quotas, restrictions on use and production of specific farm inputs and outputs.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 817566.

5. SYNTHESIS OF TASK 1.2

In Task 1.2. the analysis has concerned the identification of the proper indicators to assess the impact of the policy scenarios proposed in the first stakeholder workshop. To derive the consolidated indicators framework, a three-step approach was followed. First, The MIND STEP research team has reviewed relevant indicator datasets and selected indicators meaningful to answer the policy questions. A draft list was structured around relevant themes covering both the economic, environmental and social dimensions of sustainability, and the MIND STEP policy questions. The draft indicator list consistently combined: i) indicators used to assess the impact of EU agricultural policy, including the Common agricultural policy Context, Result and Impact indicators from the 2014-2020 period (by DG AGRI)[1]; ii) Agri-environmental indicators (by EUROSTAT)[2]; iii) indicators used in the MIND STEP models. This consolidated list included 83 indicators grouped by themes, covering climate, environmental and socio-economic issues relevant for the scenarios.

Second, the draft list was validated with the MIND STEP core group of stakeholders, via a questionnaire and an online stakeholder workshop, where the list and the results of the questionnaire were discussed, in order to gather the stakeholders' opinion on the completeness of the indicator list, the relevance of the indicators, and the number of indicators needed to convey meaningfully outcomes of one scenario. Then, the second stakeholder workshop has been organized to get feedback on the completeness and relevance of the indicator framework and to illustrate the use of the MIND STEP toolbox for selected policy scenarios. Among major stakeholders' contribution that are relevant for the framework definition: i) the environmental dimension was the most selected sustainability dimension. It was the only dimension selected for Climate change and Biodiversity scenarios, while the economic dimension was the most selected among the other two for the Competitiveness scenario; (ii) the minimum number of indicators to describe the policy impacts in each scenario depends on the level of ambition, but 9-15 may be enough to analyse the key impacts. We also observed a strong coincidence in the indicator themes relevant for each scenario group: the largest agreement was in the Climate change scenario where all were environmental impact indicators. From the most relevant 10 indicators, 6 indicators belong to the theme GHG emissions, 2 to energy, 1 to land use/land cover and 1 to soil quality and fertility (i.e.: soil organic carbon in agricultural land).

Third, a systematic literature review has been done, using the Web of Science and Scopus, targeted to identify additional indicators, cited (in research or practice) to assess agricultural policy impacts.

Thus, the consolidated indicator list not only includes indicators currently used in agricultural policy, but also new indicators available from the models, proposed by the stakeholders or emerging from the systematic literature review. This MIND STEP indicator framework will be used as input for the data framework in WP2, the modelling work in WP3, WP4 and WP5 and for the policy evaluation in WP6. In this way, the indicator framework can ensure a harmonized and consistent use of indicators across the MIND STEP project. At the end of the project, we will review the real use of the indicators by the models and revise the current version accordingly.

[1] https://agridata.ec.europa.eu/extensions/DataPortal/cmef_indicators.html

[2] https://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicators

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 817566.

6. THE CONCEPTUAL FRAMEWORK OF THE MIND STEP PROJECT

6.1. MIND STEP framework

The analysis of the most relevant policy objectives (task 1.1), of the corresponding indicators (task 1.2) and of the current model gaps (task 1.3), constitutes the "conceptual framework" for the whole MIND STEP project, in the sense that the whole modelling and policy analysis work will refer to the identified set of policy questions, indicators and model gaps.

As an example, Table 6 reports, for each climate change scenario, the 9 to 15 indicators that have been most selected by the modellers as those that they could already model with the current model settings.

All the scenarios' simulations should be able to appraise the indicator for land use change, cropping patterns, livestock density and the shadow price of land (9 out of 9); while almost all the scenarios' simulations should be able to appraise the indicator for farming intensity, GHG emissions from agriculture, share of livestock units under support to reduce GHG emissions and/or ammonia, gross nutrient balance – nitrogen, tillage practices and soil organic carbon in agricultural land (7 out of 9); specialisation and farm income by type of farming (7 out of 9).

Interestingly, the indicators that have been selected as most important indicators for Climate change scenarios group, i.e., GHG emissions from agriculture and Soil organic carbon in agricultural land, are among those most likely to be assessed by the modelling exercise.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 817566.

Table 6 Climate change modellable scenarios and pertinent indicators.

Indicator name/ Scenario	Simulate the adoption of carbon taxes on agricultural production	Simulate the adoption of carbon taxes on agricultural production	Simulate the adoption of subsidies targeted to climate change mitigation	Impact of different GHG mitigation measures.	Create incentives to increase carbon sinks by farmers	Simulate the adoption of a carbon border tax adjustment	Create incentives for energy transition in agriculture (e.g. renewables)	Creating markets for ecosystem services (carbon sequestration)	Simulate the adoption of emission trading systems between farms
Land use change	X	X	X	X	X	X	X	X	X
Cropping patterns	X	X	X	X	X	X	X	X	X
Farming intensity	X	X	X		X	X	X	X	
Specialisation	X	X	X	X	X		X		X
Risk of land abandonment							X		
Greenhouse gas emissions from agriculture	X	X	X	X	X	X		X	X
Share of agricultural land under commitments to improve climate adaptation	X	X							
Share of livestock units under support to reduce GHG emissions and/or ammonia, including manure management	X	X	X	X	X	X		X	X
Share of agricultural land under commitments to reducing emissions, maintaining and/or enhancing carbon storage				X	X	X		X	
Share of farms benefitting from CAP investment support contributing to climate change, mitigation and adaptation, and to renewable energy or biomaterials production	X	X		X					
Carbon price						X			
Ammonia emissions	X	X							
Mineral fertiliser consumption	X	X							
Livestock density	X	X	X	X	X	X	X	X	X

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 817566.

Indicator name/ Scenario	Simulate the adoption of carbon taxes on agricultural production	Simulate the adoption of carbon taxes on agricultural production	Simulate the adoption of subsidies targeted to climate change mitigation	Impact of different GHG mitigation measures.	Create incentives to increase carbon sinks by farmers	Simulate the adoption of a carbon border tax adjustment	Create incentives for energy transition in agriculture (e.g. renewables)	Creating markets for ecosystem services (carbon sequestration)	Simulate the adoption of emission trading systems between farms
Gross nutrient balance – nitrogen	X	X	X	X	X	X		X	
Tillage practices	X	X	X	X	X	X		X	
Soil organic carbon in agricultural land carbon storage potential/compost balance	X	X	X	X	X	X		X	X
Share of agricultural land under management commitments beneficial for soil management	X	X				X		X	
Area supported for afforestation and creation of woodland, including agroforestry	X	X				X		X	
Farm labour force							X		
farm income by type of farming	X	X	X	X	X		X		X
farm income by region							X		
Total factor productivity in agriculture							X		
Labour productivity in agriculture							X		
Shadow price of land	X	X	X	X	X	X	X	X	X

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 817566.

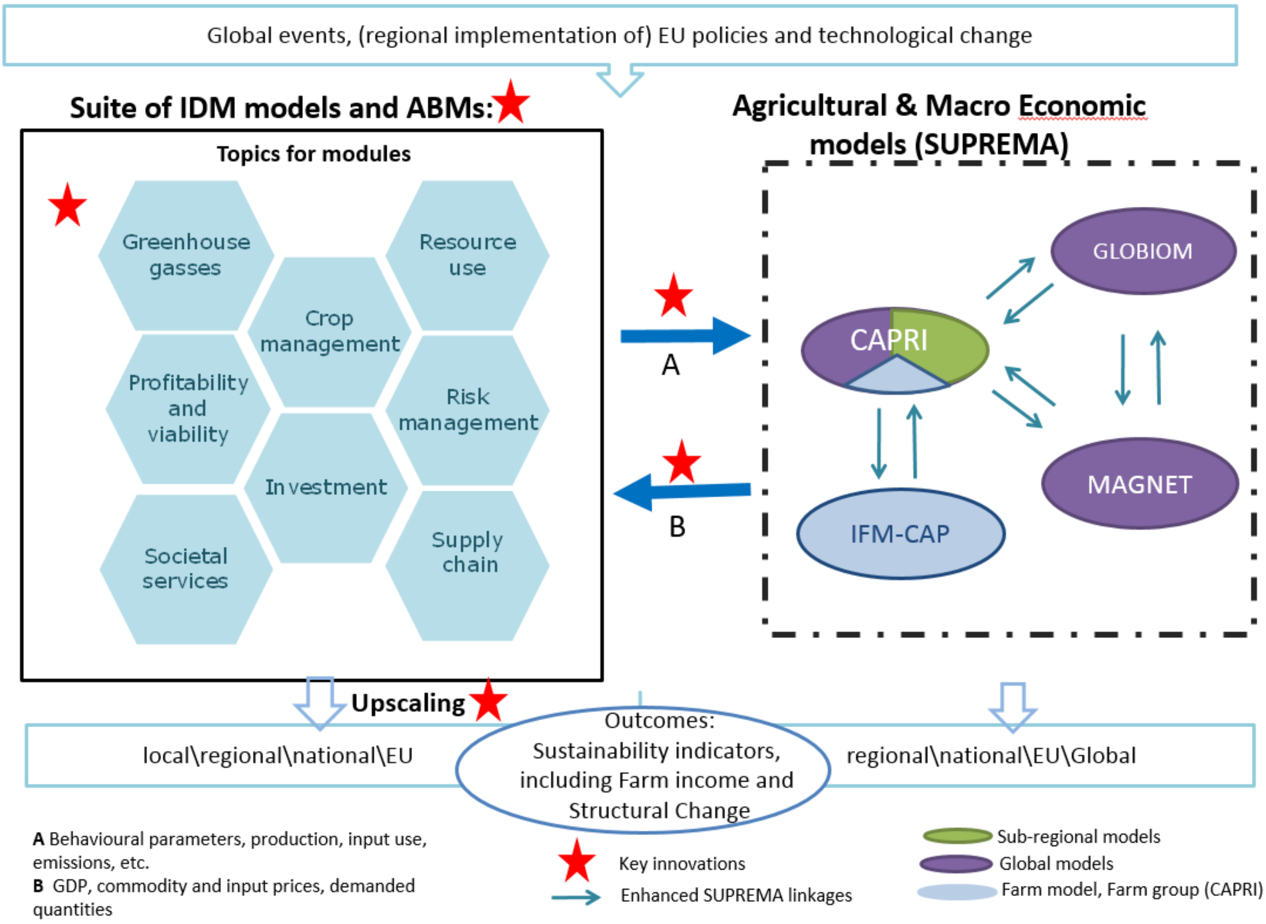
6.2. Illustration on how MINDSTEP toolbox will model the selected policy scenarios.

Given the need to "develop modelling at various geographic scales – from regional to global", and the wider scope of EU policies related to agriculture to also contribute for example to the Paris climate agreement, the Sustainability Development Goals (SDGs) and the Farm to Fork strategy, the Individual Decision Making (IDM) models are linked with current EU-wide and global models. This collection of stand-alone and interlinked models constitutes the MINDSTEP toolbox, see Figure 5.

The EU-wide and global models provide a spatially comprehensive set of sustainability indicators, such as food security (availability, access, utilization, stability), employment, national income (GDP), biodiversity, greenhouse gas emissions, and land and water use, beyond the regions/countries and sectors covered by IDM unit approaches. This approach allows also to take into account the indirect effects of global events and EU policies, mediated through European and international markets. The IDM models in the MINDSTEP toolbox, correspond to the roadmap for agricultural modelling in the EU building on the outcomes of the SUPREMA (Support for Policy Relevant Modelling of Agriculture) project (Jongeneel et al., 2020). The IDM models contribute to improved micro-economic underpinning of primary production in the EU-wide and global models. In general, they allow a more detailed representation of technologies, sectors and regions which is needed e.g., for modelling adoption of technologies and realistic upscaling of results. This is an important step forward, but as mentioned in the report, a drawback of the newly developed IDM models and tools is that they will not cover all agricultural sectors and regions in the EU.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 817566.

Figure 5 MIND STEP model toolbox: Integration of Individual Decision Making (IDM) models and current models.

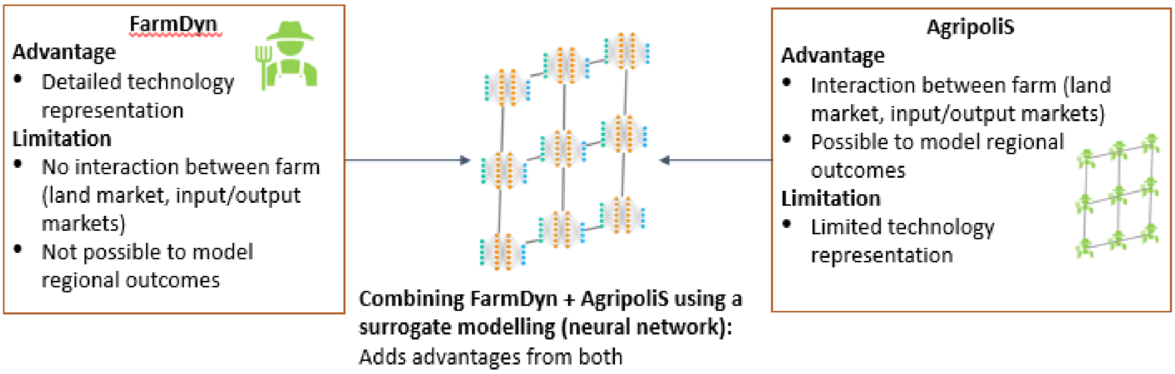


The Mind Step toolbox contributes to improving our capabilities to model the scenario “Mandatory reduction of input use”.

One example are the activities in WP4.5. Here we aim to combine the single farm model FarmDyn with the Agent-based Model (ABM) Agripolis by the help of surrogate models. Used individually, each model has specific advantages and limitations in term of modeling the scenario. FarmDyn has a detailed representation of farm technology which is required to fully capture a mandatory reduction in input use, however, as a single farm level model, it is not capable to capture interaction between farms or market effects. Agripolis on the other hand, is well placed capturing those interaction effects but is limited in terms of the representation for farm technology. Ideally, we would combine both model by using FarmDyn as the IDM within Agripolis. However, such a direct combination is hardly feasible due to computational demands. To overcome those limitations, we aim to build a surrogate model of FarmDyn using deep neural networks. Those surrogate models are intended to approximate, as close as possible, the behavior of FarmDyn but can be run more sufficiently computationally and more easily used within AgripoliS. Combining both models in this way aims to leverage the individual advantages of each model while overcoming their limitations.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N° 817566.

Figure 6 Combination of the model FarmDyn with the ABM Agripolis model



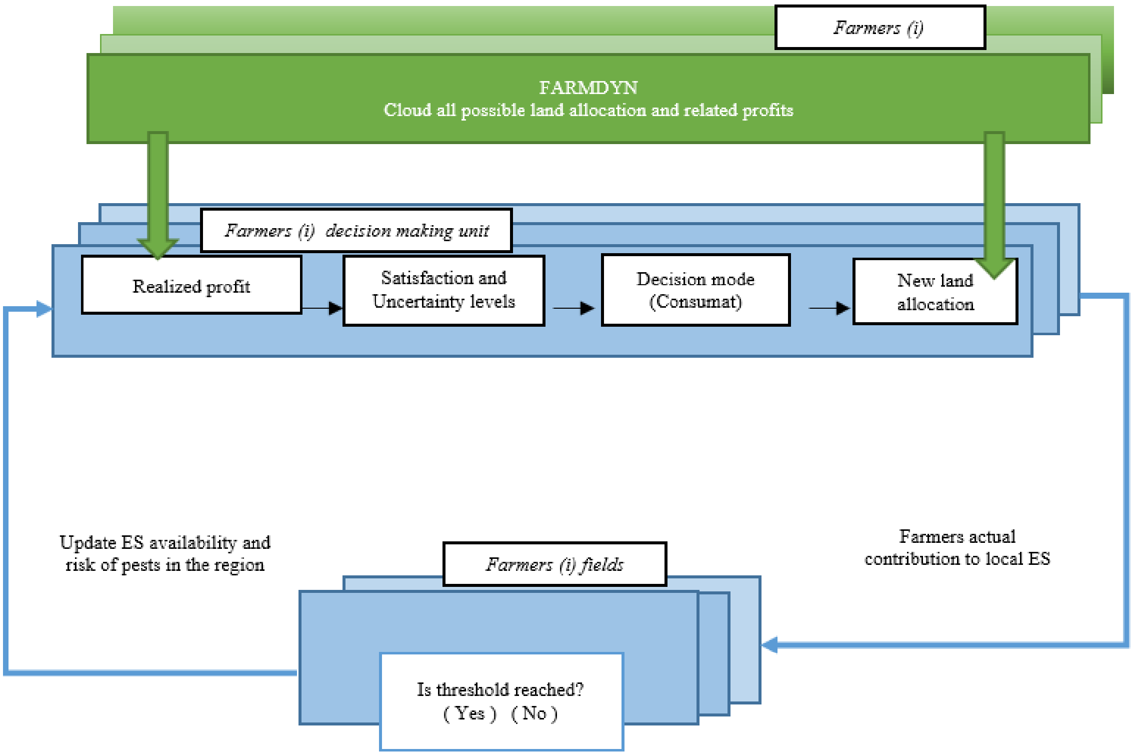
Another example of more realistic upscaling including non-economic behavioral aspects, the following steps describe the use of an ABM to simulate farmers decisions: "Adoption of Agri-Environmental Schemes (AES) (i.e., flower strips) on arable farms in an arable region in the Netherlands":

- We start by running different scenarios for arable farms in the Dutch FADN, located in the province of Flevoland with the bio-economic farm model FarmDyn.
- We use Netlogo to model an ABM of farmers deciding whether to invest or not in the provision of AES by converting arable land into natural elements (such as flower strips).
- We model decision making of different farmer types towards the implementation of AES at the farm level. Some farmers might be more prone to invest in AES than others with more intensive agricultural practices.
- Using the Consumat approach (Jager et al. 2001; Janssen and Jager 2001), farmers display different decision strategies based on income satisfaction and uncertainty.
- We define farmers' strategies as their plan of action that the farmers will take given the set of personal circumstances (combination of income satisfaction and uncertainty) that might arise in the decision-making process.
- Farmer's strategies are deliberation, imitation, repetition and social comparison.
- Every strategy state the individual cognitive process of a farmer that either makes decisions in isolation (i.e. individual maximisers) or looks up and learns from others peers in the landscape (i.e. heuristic-based agents) (van Duinen et al. 2016).
- Services from ecosystems provide essential inputs (e.g., pollination, water quantity and water quality) providing benefits for all farmers in the area.
- Once farmers decide on their individual level of AES the model assess the regional level of ecosystem services provided by the collective pool of AES.
- Collective benefits will only realise when reaching a threshold of enough farmers choosing to contribute to the provision of these ecosystem services. Scale matters in terms of the benefits of ecosystem services.
- Benefits from investing in ecosystem services at the farm-level are also perceived by other farmers in the landscape independently from their investment in flower strips or hedgerows.
- The additional benefits perceived by all farmers in the landscape are primary, reducing the probability of being exposed to pests' threat.
- Then the model update availability of ecosystem services and risk of pests in the region to model decision making in the next period.
- The figure below provides an overview of ABM.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 817566.

- The model will be validated during a presentation of preliminary results with farmers.

Figure 7 ABM overview: the farmer decision making model and its integration with the ecosystem service representation.



ABM overview: the farmer decision making model and its integration with the ecosystem services representation.
Source: adapted from Malawska and Topping (2016)

7. CONCLUSIONS

This report has synthesized the work done for Task 1.3 that has reviewed the models in the MIND STEP toolbox with a specific focus on their policy and farm, regional, national, EU and global driver coverage, in order to identify whether they could properly address selected aspects of the benchmark scenarios identified in Task 1.1.

This assessment has pointed out model gaps and needs of model extensions and development of new tools. At the same time, it has also revealed the potential of model integration and collaboration as a way to supplement the outcomes of individual models (see paragraph 6.2).

Overall, all the proposed scenarios in the "climate change" scenario group could indeed be modelled. Six out of eight scenarios of the "preserve biodiversity, ecosystem services and environmental care" scenario's group can be modelled, while the remaining two can be potentially modelled by modifying the current model set-up. The "increase competitiveness" group of scenarios seemed to emerge as the most difficult to model. In fact, only four out of seven scenarios have been judged to be modellable, while three out of seven are potentially modellable, as long as the models in the MIND STEP toolbox can be properly modified.

Closely related to this work, Task 1.2 has reviewed the models' ability to produce appropriate indicators for monitoring and measuring the impact of the same policies and drivers (i.e., the list of

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 817566.

indicators identified in Task 1.2). The synthesis of the work has resulted into a detailed list of key policy questions and related benchmark scenarios that should be modelled together with an indicator framework that not only includes indicators currently used in agricultural policy, but also new indicators available from the models, proposed by the stakeholders or emerging from the systematic literature review.

Together, Task 1.2 and Task 1.3 constitute the “conceptual framework” of the whole MIND STEP project, in the sense that the whole modelling and policy analysis work will refer to the identified set of policy questions, indicators and model gaps. This analysis will be used as input for the data framework in WP2, the modelling work in WP3, WP4 and WP5 and for the policy evaluation in WP6. At the same time, it is clear that not all the identified model gaps cannot be solved in MIND STEP, in a manner that is consistent with the initial MIND STEP proposal. To solve this problem, the subsequent modelling work will have to focus first on the scenarios that can be analysed with the readily available data and models in the MIND STEP toolbox.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N° 817566.

8. ACKNOWLEDGEMENTS

The Deliverable 1.3 is developed as part of the H2020 MIND STEP project which received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 817566.

9. REFERENCES

European Commission (2018). Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing rules on support for strategic plans to be drawn up by Member States under the Common agricultural policy (CAP Strategic Plans) and financed by the European Agricultural Guarantee Fund (EAGF) and by the European Agricultural Fund for Rural Development (EAFRD) and repealing Regulation (EU) No 1305/2013 of the European Parliament and of the Council and Regulation (EU) No 1307/2013 of the European Parliament and of the Council, {SEC(2018) 305 final} - {SWD(2018) 301 final}, COM(2018) 392 final, Brussels, 1.6.2018.

European Commission (2019). Communication from The Commission To The European Parliament, The European Council, The Council, The European Economic And Social Committee And The Committee Of The Regions, The European Green Deal, COM(2019) 640 final, Brussels, 11.12.2019

European Commission (2020). Communication from The Commission To The European Parliament, The European Council, The Council, The European Economic And Social Committee And The Committee Of The Regions, A Farm to Fork Strategy. For a fair, healthy and environmentally-friendly food system, COM(2020) 381 final, Brussels, 20.05.2020.

Jager, W., M.A. Janssen, and C. Viek. (2001). Experimentation with household dynamics: the Consumat approach. International Journal of Sustainable Development 4(1):90–100.Malawska and Topping, 2016

Janssen MA, Jager W (2001). Adoption of new products in a market of changing preferences and social networks. Journal of Economic Psychology 22: 745–772

Jongeneel et al. (2020). The Suprema Roadmap Exploring Future Directions For Agricultural Modelling In The Eu, D.1.10 of the project: "Support for Policy Relevant Modelling of Agriculture (SUPREMA)", Project Number 773499.

Malawska, A., and Topping C.J. (2016). Evaluating the role of behavioral factors and practical constraints in the performance of an agent-based model of farmer decision making. Agricultural Systems. 143: 136-146, https://doi.org/10.1016/j.agsy.2015.12.014

van Duinen, R., T. Filatova, W. Jager, and A. van der Veen. (2016). "Going beyond perfect rationality: drought risk, economic choices and the influence of social networks." Annals of Regional Science 57(2–3):335–369.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 817566.

APPENDIX 1

Table A1 List of the core stakeholder group members of the MIND STEP project

	Name	Organisation
1	David Baldock	IEEP
2	Robert Finger	ETH
3	Christopher Genillard	Genillard & Co Consultant Company
4	Reina Groen	Province of Flevoland (NL)
5	Eva Iglesias Martínez	CEIGRAM
6	Simon Kay	EC DG CLIMA
7	Jussi Lankoski	OECD
8	Simon Schlüter	German farmer association in Brussels
9	Ben Van Doorslaer	EC DG AGRI
10	Stefan Van Merrienboer	Rabobank

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 817566.