H2020 Project COASTAL - Deliverable D14 Operational SD Models for Coastal-Rural Interactions -Case Study Level

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COASTAL
Collaborative Land-Sea Integration Platform

Deliverable D14 Operational SD Models for Coastal-Rural Interactions - Case Study Level

Final Version

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CO	Confidential, restricted under conditions set out in Model Grant Agreement	
CI	Classified information as referred to in Commission Decision 2001/844/EC)	
Deliverable type		
R	Document, report	X
DEM	Demonstrator, pilot, prototype	
DEC	Web sites, patent fillings, videos, etc.	
OTHER	Software, technical diagram, etc.	

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Executive summary

Existing research and administration primarily addresses coastal and rural development from either a land- or sea-based perspective, making policy recommendations ill-adapted to fully benefit from opportunities which could otherwise foster synergistic economic development of coastal regions and the hinterland. The aim of the H2020 project COASTAL (https://h2020-coastal.eu), which started in May 2018, is to identify these opportunities by improved understanding of the social-ecological land-sea interactions. To this end, coastal and rural stakeholders interacted with local experts in six Multi-Actor Labs throughout the EU Territory. Causal Loop Diagrams, System Dynamics (SD) models, scenarios and other tools have been developed to support the design of **evidence-based** business road maps and policy guidelines.

This WP4 deliverable (D14) is a status report for the progress made with the design and implementation of the **operational** land-sea models by the Multi-Actor Labs (MALs) after 36 months. The report builds on the deliverable D13 describing the system architecture and database for the draft models (Viaene et al., 2020). These **operational** stock-flow models are now available for all MALs and can be used to analyse systemic land-sea interactions and evaluate different policy alternatives with examples described in this deliverable. Not surprisingly, the project and systems modelling were affected by the impacts of the covid-19 pandemic. Planned formal and informal meetings with partners to jointly discuss the progress of the modelling, technical and design problems, and work out solutions had to be organised as online events which turned out to be far less effective despite of the number of meetings. Nevertheless, all MALs were able to identify the key stock and flow variables and quantify the social-environmental interactions connecting these variables. In the final phase of the project, these models will be combined with quantified scenarios to address system uncertainties and used to visualize **business road maps** and policy actions. This will help make policy and business recommendations evidence-based and allow comparison of proposed strategies for coastal-rural development, including best practices and system tipping points. Topics range from fish farming, sustainable water management, eco farming and rural tourism to renewable energy, and are being examined in the context of **the EU Green Deal**.

System Dynamics (Sterman, 2000) was selected as integrative framework based on the graphical transparency of this type of modelling, the direct translation of problems into model structures, consideration of systemic limitations, appropriateness for including human and social aspects directly in the models, and the limited computational requirements – making these models particularly useful for interactive use by and with stakeholders. Systems Dynamics (SD) and more in particular stock-flow modelling is widely used since the 1950s for problem analysis in applications ranging from logistics, control management, engineering and financial management to public policy. By nature, stock-flow

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modelling is strongly problem-driven and an SD-based modelling approach is used to avoid modelling the system 'as a whole', if this can be avoided. Clients or 'problem owners' and business analysts interact to create mental models or 'mind maps' clarifying the problem at hand and defining the way the problem(s) are connected to specific policy or management indicators and potential solutions. It can be used, for example, to explain why certain start-up businesses fail, whereas other incentives do not under similar circumstances, or why the short-term and long-term impacts of strategic decisions can be quite different. Although the human brain is capable of providing part of the answer this becomes more difficult when multiple factors interact, and linear extrapolation of historic patterns is inadequate. This is certainly true for complex social-environmental systems which are densely used and rapidly developing, with economic activities competing for resources such as space, water, energy and skilled labour.

While causal loops and narrative scenarios, as developed in the first phase of the project, are useful for conceptual analysis of problems and solutions, the models have an added value for sensitivity testing of different policy actions. Typical strengths, as compared to other types of models, are the holistic perspective, consideration for systemic limits, tipping points and non-linearities, the graphical interface of models allowing interactive design and high computing speeds. Nevertheless, the design and calibration of SD models can be challenging, particularly when stakeholder engagements result in overly complex or ill-balanced causal loop diagrams or modellers are less familiar with SD modelling. The main challenges faced are: (1) to properly align qualitative and quantitative analyses, (2) to ensure coordination with existing and planned development strategies, and (3) to engage stakeholders directly throughout all phases of the project. The stakeholders, actor and research partners collaborated intensely to address these challenges and design, implement and test SD models for the prioritized issues identified in the causal loop diagrams. The current models capture the essential dynamics of the land-sea systems and can generate counter-intuitive response to alternative policy and business decisions. Stress testing these decisions with the models generates new information which can be used to design, fine tune or adjust business road maps and policy recommendations. The SD models are part of the COASTAL toolbox and their use for defining road maps should be understood as an indirect process. For example, an SD model for water resources management may reveal that awareness raising is a critical policy lever to intervene in the system and increase climate resilience. The practical implementation of awareness raising can then be defined in a policy road map once its significance has been confirmed with model simulations. The quality of the models is improved by engaging the stakeholders and actor partners in the process of **model confidence building** (Senge and Forrester, 1980), obtaining feedback on the model scope (boundaries and level of detail), model structure (land-sea interactions included in the model), the model dynamics (time-dependent patterns generated with the models) and the policy implications and relevance for decision making.

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For each MAL we provide an overview of the model structure, the variables and data used, examples of policy analyses and report on the model confidence process. The 2nd round of multi-actor workshops, one for each MAL, served as testing ground to obtain feedback from the coastal and rural stakeholders on the model purpose, structure, dynamics and usefulness for designing and improving synergistic business road maps and policy guidelines. To compare the progress for the six MALs, in terms of usefulness of the models, we used a qualitative model checklist with 25 criteria for the model scope, quantification, model behaviour, design and layout, and validation. To conclude, we provide a synthesis section in which the general status of the MAL models is summarised and in which we reflect on the progress made with the modelling and provide an outlook for remaining challenges in the modelling process. Annexes are used for this model checklist, a more detailed data inventory, and a complete description of the equations and functional relationships used by the models.

Important methodological lessons can be learned from the modelling exercise. Model complexity should be tuned to the purpose of holistic policy analysis with enough consideration for cross-thematic aspects. Stakeholders are best engaged in the co-creation process by focusing on the policy implications rather than the underlying modelling, even if their feedback on models is constructive and useful. A step-by-step design strategy supported with system archetypes and concrete examples is essential for facilitating the translation of causal loop diagrams into operational policy models. To conclude, we provide a synthesis section in which the general status of the MAL models is summarised and in which we reflect on the progress made with the modelling and provide an outlook for remaining challenges in the modelling process.

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Abbreviations and acronyms

CCWE	cross-catchment water export
CCWI	cross-catchment water inflow
CLD	Causal Loop Diagram
LSI	Land-Sea Interaction
MAL	Multi-Actor Lab
MWS	municipal water supply
REA	Research Executive Agency
RCP	Representative Concentration Pathways
SD	System Dynamics
SF	Stock-Flow
SSP	Shared Socioeconomic Pathways
SSW	subsurface water
SW	surface water
UCWW	unconnected coastal wastewater
USR	urban surface runoff
WWTP	wastewater treatment plant

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1 Introduction

1.1 Stock-flow modelling

The COASTAL sector workshops, organised in the second half of 2018 for the MALs, were aimed at developing mind maps for specific sectors (agricultural, environment, water management, fisheries, …). Processing and polishing of the mind maps resulted in more refined conceptual models, which were used to formulate graphical Causal Loop Diagrams (CLDs) showing the relevant feedback mechanisms explaining the problem qualitatively. Capturing the feedback mechanisms in terms of quantitative stocks and flows affecting the increase or decrease of the stocks is a core activity in System Dynamics modelling (Sterman, 2000). Converting the CLDs into stock-flow models allows quantifying policy and business alternatives under different scenarios in an evidence-based manner. This requires an effort in terms of defining the stock-flow architecture, collecting quantitative data for parameter setting, formulating equations, model calibration and model validation. Nevertheless, there are several advantages to quantitative modelling, the main ones being: (1) a model provides an objective structure allowing evidence-based analyses (2) the stock-flow models can handle the complexity of system transition, (3) pinpointing of tipping points and significant control levers, (4) a framework which can be used for multiple scenarios with adaptable parameter settings, (5) sensitivity analyses for policy alternatives can be carried out. Well-designed models and model structures can be polished, documented and exchanged between collaborative research teams and managed in a generic library of reusable model components (Task 4.4).

A common practice for modellers who are not or less experienced with stock-flow or System Dynamics (SD) modelling is to aim for a direct, one-on-one translation of their CLDs into a stock-flow model and add as much detail as possible and considered relevant from a single theme perspective (water resources management, agriculture, tourism development, …). This quickly results in model clutter and models which are difficult to design , maintain and use. Instead, the focus should be on the feedback structures, and in particular the cross-thematic interactions. One of the misunderstandings is that stock-flow models are always more complex than the CLDs in the preceding analysis phase (Sterman, 2000). In some cases, stock-flow structures can even have a more condensed graphical appearance due to the use of mathematical equations and non-linear functions. From the start, work task 4.2 – SD modelling of coastal-rural interactions - faced three challenges:

- to ensure proper alignment of the quantitative stock-flow modelling with the qualitative analyses resulting from the stakeholder engagements in the first project phase (problems, solutions and barriers, and land-sea interactions);
- to tune the design of the models to the purpose of analysing coastal-rural interactions, taking into account the availability of data and the role of system uncertainties (addressed with scenarios developed under Task 5.3);

- to assist the Multi-Actor Lab teams with their modelling in a systematic way, ensuring streamlining of results;
- Ensuring models are evidence-based, using available data and validated.

Differences in scope, modelling expertise and modelling preferences, and data availability are factors which can be expected to affect the design, reusability and quality of models, as well as the efficiency of the modelling process. The philosophy and main principles of SD modelling were outlined in the Problem Scope (deliverable D12) and a number of tutorial sessions, starting with the kick-off meeting in Methoni, Greece in May 2019. Understanding and addressing problems by identifying the underlying feedback mechanisms was explained in a step-wise manner, using examples for tourism development and groundwater use. These examples turned out to be useful for communicating the general principles of SD modelling, but more was needed to get all MAL teams started with modelling their own systems.

Several measures were taken to maximize the efficiency and harmonization of the modelling:

- Instead of modelling the complete system in a top-down manner, covering all interactions indicated in the Causal Loop Diagrams (see deliverable D4), the MALs were encouraged to identify the priorities for their modelling and first develop sub models, which only were to be integrated once these were running;
- The MAL teams were assisted through weekly exchanges with the WP coordinator to discuss the progress of the modelling, problems and develop solutions. Initially, these meetings were organised with all teams. Later, follow up was only for those teams that needed support ;
- Additional tutorials and guidelines were distributed to direct the modelling at a strategic level;
- Technical support for model documentation and online exchange of models through the project website and share point were provided. The exchange of models was facilitated by the use of VenSim® as common modelling platform;
- Modelling workshops were organised, during the General Assembly meeting in Methoni and in connection with the first Review meeting in Brussels, as these were occasions where everyone was already present.
- A structured template for deliverables including examples was provided.

The general modelling strategy communicated to the partners was based on three principles:

1. identify the key stock variables based on the causal loop diagrams;
2. follow a step-by-step design process with gradual increase of complexity of the models;
3. focus on the quantification by measurable variables, use of non-linear response functions, system limiting factors and correct units of measurement.

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1.2 How does the stock-flow modelling relate to the rest of the project?

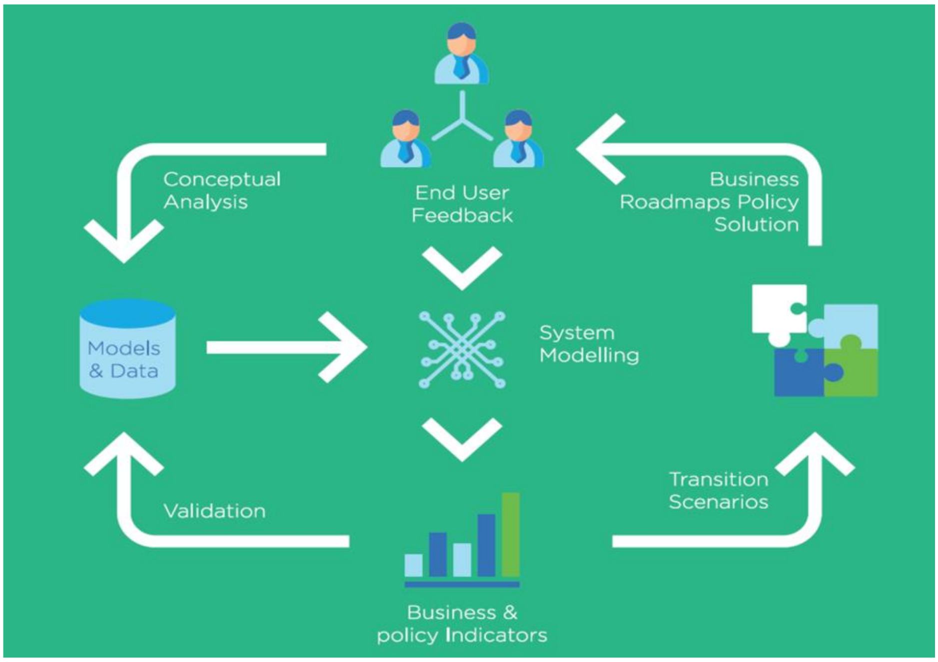

Figure 1: Pivotal role of the systems modelling in the COASTAL project.

In COASTAL the quantitative stock-flow modelling has a pivotal role with both contributing and depending work packages (Figure 1). WP1 (multi-actor analysis) and WP2 (Knowledge Transition) pave the way for the stock-flow modelling by identifying and prioritizing the land-sea interactions, capturing the system feedback structure and developing expert and local knowledge as well as data needed for the modelling. In addition, WP5 will interact with WP4 to develop consistent scenarios for driving the models and addressing the social-economic uncertainties in the models. Both WP3 (business & policy analysis) and WP5 (policy robustness) depend on the availability and quality of the models for developing evidence-based business road maps and policy actions. The stock-flow models will be used to formulate and support strategic business and policy analyses aimed at improving coastal-rural synergies. To achieve this, separate stock-flow models of the coastal-rural interactions were developed for each case study, starting from the qualitative understanding of these interactions developed in WP1. The qualitative analysis in WP1 resulted in a set of Mind Maps and Causal Loop Diagrams (CLD) describing the different interactions identified for each of the MAL.

1.3 Research versus policy modelling

SD models are excellent tools for integrating thematic models and expertise (Figure 2). A common misunderstanding is to confuse the type of modelling for the thematic 'silo models' and corresponding data needs with those of the SD model layer that integrates the 'silo models'. Ideally the collection of data should be driven by the model design rather than the other way around. As COASTAL

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demonstrates modelling and data development can take place in parallel, and an iterative approach is sometimes preferably. This could start from historic data for an observed problem, which is to be explained from the system feedback structure.

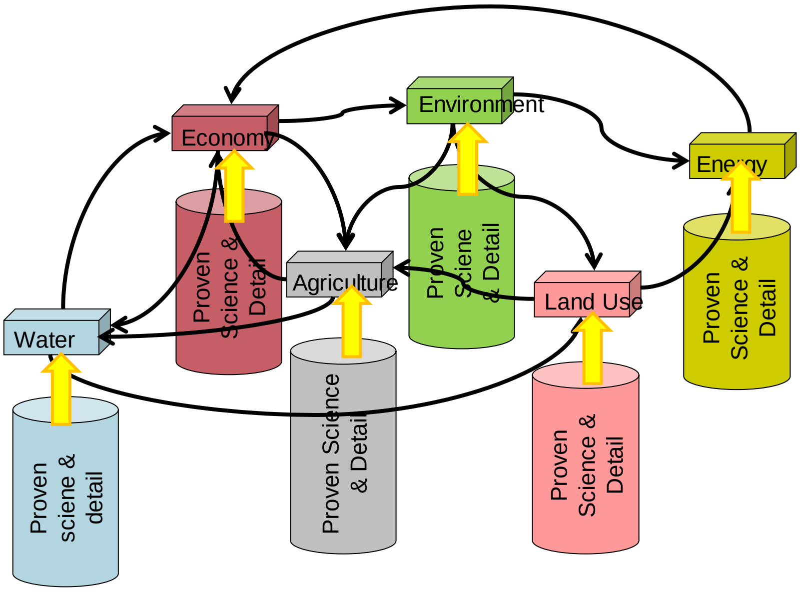

Figure 2: Thematic integration using a system dynamics framework (De Kok et al., 2015).

Some major differences in design, purpose and use of thematic and policy models are presented in Table 1 and it is important for model developers, in particular experienced modelers, to be aware of these differences when designing SD models to avoid the common pitfall of translating their silo models into stock-flow models.

Table 1: Differences between thematic 'silo' modelling and SD modelling.

Thematic Models (cylinders)	Policy Model (System Dynamics)
time horizon, temporal and spatial resolution are *process* centred	time horizon, temporal and spatial resolution are *policy problem* centred
accurate representation of processes	*adequate* representation of processes
model propels data collection	*data constrain* model development
in depth and sectorial	*sketchy but integral*
as complicated as necessary	*as simple as possible*
scientifically *innovative*	scientifically *proven*
raises more *questions* than answers	build to provide *'definite' answers*
interesting and worthwhile *in their own right*	interesting and worthwhile only *through their output*
numbers validatable	*outcomes* validatable
response time, interactive-use *not critical*	response time, interactive-use *critical*
transparency & user-friendliness not an issue	transparency and user-friendliness are critical
the developer is the user	end-user involvement during development is critical

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1.4 Purpose and structure of this deliverable

This deliverable describes for the different MALs the operational stock-flow models that were developed based on both the draft or 'pilot' model architectures as described in the preceding WP4 deliverable D13, exchanges with stakeholders and progressing understanding of how the models should be used. The pilot models (D13) were described based on the feedback structures, aligning the stock-flow structures to the causal loop diagrams resulting from the first round of multi-actor workshops. While some MALs produced operational models already with their pilot models for D13 this was not the case for all MALs. For this deliverable, D14 the aim is to produce operational models for all MALs. The very concept of "operationality", however, was not yet defined at the beginning of the project although it can be understood as operational usefulness, i.e. extending beyond technical completion. Even so, this usefulness will depend on the intended type of use (policy preparation, evaluation, analysis, research, …) and linked to the relevant model users. A list of predefined, qualitative criteria was prepared and distributed among the MALs as a 'model checklist'. By answering the questions, the modellers could evaluate and compare the progress made with their models and identify any issues requiring additional effort or attention. The checklist (see Annex 2) addresses:

- the scope of the model: to what extent addresses the model the problems and solutions raised by the stakeholders?
- model structure: state of completion in defining stock, flows, feedback, interactions, model drivers and systemic limitations. Is model detail balanced and are sub models integrated, if any?
- Model quantification: does the model run with real data, are all interactions quantified with equations and scenarios available for the model?
- Model behaviour: does the model run correctly without technical anomalies or unexplained policy anomalies?
- Documentation and visualization: is the model completely and well documented and the graphical design adequate for understanding the model design and use?
- Model validation: have stakeholders and/or experts examined the model structure and model behaviour and provided their feedback?

By the end of April 2021, the model checklist could be completed for all models, providing a general self-assessment of the modelling progress (Annex 2). This information was useful for identifying common or specific modelling problems for the MALs and comparing their progress.

The priority was to harmonize the modelling process across the MALs and provide an integrated framework for the interactions between the narrative and conceptual WPs (WP1, WP3 and WP5) and quantitative WPs (WP2 and WP4). In the next chapters we will therefore first present the general methodology that will be applied to translate the Causal Loop Diagram (CLD) and stakeholder/actor

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feedback established in WP1 into a stock-flow model design. Then for each MAL the sections sequentially describe:

a) The general problem scope for the MAL and land sea interactions considered;
b) The CLD capturing the outcomes of the multi-actor analysis and serving as guiding architecture for the stock-flow modelling (selection of variables and interactions);
c) The problem scope for the specific sub models (if applicable) or complete land-sea system model
d) The quantification (major equations and variables) for the sub model. A complete and detailed overview of the main variables, parameters, equations and functions is found in Annex 4;
e) An overview of the integrated land-sea system model (linking of the sub models);
f) Business and Policy Analysis: examples of model outcomes and an explanation of how the model can be used;
g) An overview of the data sources used (a detailed overview is found in Annex 5);
h) The outcomes of the confidence building process – the feedback provided by stakeholders and experts on the model structure, dynamics and potential usefulness for analysing land-sea interactions and developing evidence-based business road maps and policy recommendations.

Some important methodological lessons can be drawn from the modelling exercise. Model complexity should be tuned to the purpose of holistic policy analysis with enough consideration for cross-thematic aspects. Stakeholders are best engaged in the co-creation process by focusing on the policy implications rather than the underlying modelling, even if their feedback on models is constructive and useful. And a step-by-step design strategy, supported with system archetypes and concrete examples is essential for facilitating the translation of causal loop diagrams into operational policy models. To conclude, we provide a synthesis section in which the general status of the MAL models is summarised and in which we reflect on the progress made with the modelling and provide an outlook for remaining challenges in the modelling process.

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2 Methodology

2.1 Modelling strategy

Mind maps, narratives, transition pathways, causal loop diagrams and stock-flow models should be considered as complementary policy analysis tools with a different purpose and fit into the iterative workflow of the COASTAL project (Figure 3).

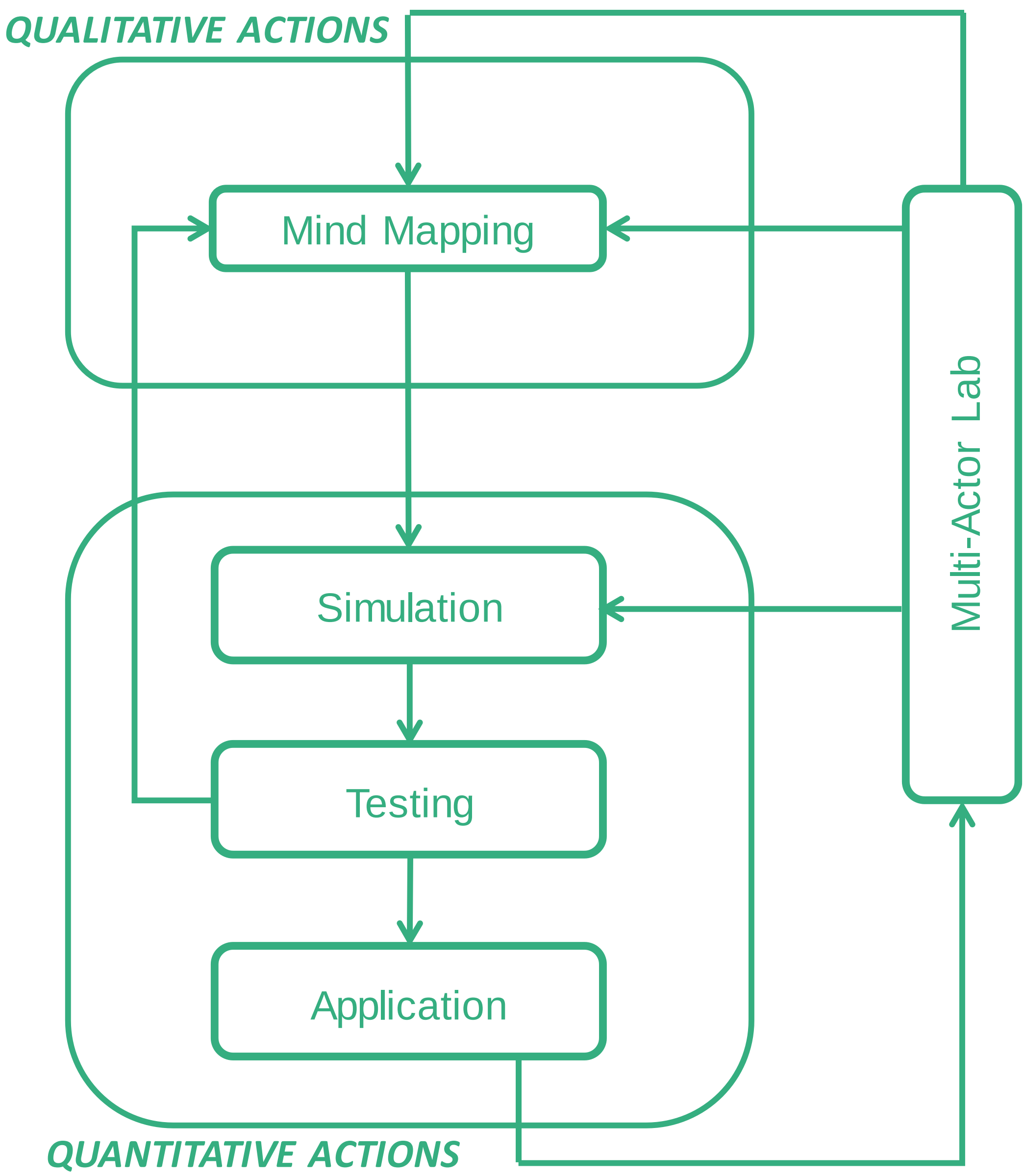

Figure 3: Iterative workflow for stock-flow modelling with integration of qualitative and quantitative work tasks (see deliverable D12).

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The general methodology adopted for the systems modelling is based on a pragmatic application of System Dynamics modelling, starting with the results of the causal loop diagrams resulting from the multi-actor workshops (deliverable D05). Preceding the multi-actor workshops, six sector workshops were organised for each of the MALs (Tiller et al., 2019). Typically, in each sector workshop, 10-20 participants from a key coastal or rural sector were invited to present their concerns and priorities with respect to land-sea interactions. The workshops resulted in graphical models or 'mind maps' collecting all the relevant aspects of the land-sea interactions identified during the discussion by the participants. The results from the individual sectors were afterwards condensed into Causal Loop Diagrams (CLDs) both at a sectoral level and as an overall CLD integrating the individual sectors. Besides the mind maps and CLDs, the requirements for the stock-flow models were also distilled from the problem scope or future narratives for the different MALs and further consultation with MAL actors or experts that were considered relevant by these MAL actors. In some cases, this process, starting at the initial CLDs and further consultation steps, led to a revision of the set of problems that were initially identified as relevant to the MAL and reconsidering the set of problems that should be addressed in the modelling. A detailed analysis of the causal loop diagrams was used in deliverable D13 to define the feedback structures and envisaged model functionalities for each MAL. This information was then used to guide the design of the pilot stock-flow models which are described in D13.

For practical and methodological reasons, most of the MALs designed and implemented their stock-flow models first at the thematic level (water management, agriculture, tourism, …) while identifying the cross-thematic interconnections. It is a common pitfall to attempt to model a system as a whole rather than the problems generated by its dynamics (Sterman, 2000). Even though the CLDs for the MALs are themselves a condensed representation of the land-sea interactions that were identified, these were often still too complex and unbalanced in terms of detail to serve as architecture for quantification into stock-flow models. The reason is that the CLDs do not represent one single problem but a whole set of intertwined problems. It was therefore that at the onset of the stock flow model development in M12 the MALs were recommended not to convert the whole CLD for the MAL directly into a single stock-flow model. Instead we chose to distinguish smaller subsets of problems in the MAL CLD that together combine to describe the relevant problems of the CLD. This implies that the stock-flow models consist of a set of smaller stock-flow models that each model parts of the problems defined by the MAL CLD. The advantage is that the development of these individual smaller models is easier to manage. Once completed sub models can then be integrated in a single VenSim implementation as model 'view', and then interconnected.

The model development was also organised in a 2-tiered approach. In a first step the MALs produced a set of pilot stock flow models. These are detailed in the deliverable D13. Based on these pilot model designs, in a second model development step, actual operational stock-flow models were implemented. These operational models are not necessarily the pilot models adorned with data and equations and an interface to suit operational use but should be seen as a further development taking

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into account additional feedback from the MAL actors/stakeholders during meetings including the second round of multi-actor workshops but also insight from applying the pilot models by the modelling teams

For COASTAL the general focus lies on land-sea interactions at a local-regional scale, but the problems of the Multi-Actor Labs (MALs) require a more detailed specification of the modelling process. Fortunately, the project is strongly problem-driven with a key role for the local partners and stakeholders in the definition of the issues to be analysed. To assist in this process, early in the project WP4 identified seven relevant questions to be answered (see deliverable D12), which were refined upon request of the reviewers:

a) **Problem definition**: which problem(s) are to be addressed with the model and why? If multiple problems occur, can these be prioritized or should separate models be developed? The model design depends on this problem definition.
b) Related to the previous question: who is the **problem owner** perceiving the existing or future situation as a problem, or who is affected by the problem and who or what is causing the problem? For example, an administration such as a water utility company may identify drought as a problem to be addressed (problem owner), while farming is the primary sector affected with multiple causes (climate change, competing users, mismanagement, ...) underlying the problem. The model design should reflect a problem which is relevant for the problem owner and include it's causes.
c) As implied by the word System Dynamics is a technique to analyse problems of the **structural dynamics** of the underlying system. stock-flow modellers are less interested in equilibrium states and the systems studied (and the corresponding models) can well be out of equilibrium. A good example is the "overshoot-and-collapse" behaviour generated by the corresponding system archetype (see deliverable D12). For the complete duration of the simulation the system is out of equilibrium. This makes stock-flow modelling different from other numerical and analytical exercises focusing on the correct representation of the (equilibrium) state of the system at a certain point in time (for example, a water or accounting balance). Stock-flow modelling is less appropriate or useful if the problem identified is not inherently dynamic. In such cases a different approach is needed. Nevertheless, hybrid model frameworks combining tools and expertise can be very useful. For example, a water balance can (and should be) used to calibrate a stock-flow model addressing water resource management.
d) Depending on the complexity, dynamics, need for quantified modelling and other factors modellers should always ask themselves if a quantified stock-flow model is the appropriate tool for understanding and analysing a problem. Stock-flow modelling can be used in COASTAL to make solutions **evidence-based**. There may be no need for modelling to develop solutions, or alternative approaches (stakeholder interviews, numerical modelling, literature research, field work, …) may be more appropriate.
e) **Model purpose** is equally important and highly relevant for the design of a stock-flow model. The purpose of the model can range from problem solving, introducing SD techniques,

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demonstration and educational training for awareness raising. It's important to emphasize that stock-flow models are technical instruments, generally not appropriate for interaction with persons not familiar with, or, interested in models as such. This is even true for well-polished stock-flow models. Therefore, the COASTAL consortium adopted an approach were modelled scenarios and solutions are used for interacting with stakeholders, rather than the model structures themselves. Nevertheless, the stakeholders have been directly involved in the conceptual modelling (WP1). Furthermore, several tutorial presentations were developed to take audiences through the process of stock-flow modelling step-by-step, in case the added value of SD-based policy analysis is to be demonstrated with a concrete example. Depending on the application of the model (research, policy or business analysis, training, …) one should decide on the focus, level of detail, layout and presentation of the model.

f) The level of detail or **granularity** of a model refers to the way it is composed of individual parts or variables. The complexity of stock-flow models should be in the feedback structure and interactions between variables rather than the total number of variables. The reason is that this feedback structure determines the dynamics of the model and hence the way the model responds to policy and business decisions. Excessive model granularity is to be avoided, certainly in the earlier phase of the modelling process. Instead the focus should be on understanding problems from the correct feedback structure. The challenge for COASTAL is that stakeholders often tend to add as many factors as they consider important. Although the potential role of system feedback is explained to the workshop participants it is not their first concern. This necessitates a careful translation of the mental models of the stakeholders into a model structure which captures the meaning of the discussions in stock and flow variables.

g) **Boundary adequacy** of stock-flow models refers to the degree the spatial, temporal, administrative boundaries of a model, and problem scope, have correctly been identified as related to the problem definition. For example, a stock-flow model addressing the impact of climate change related drought on agriculture can have climate scenarios as driving mechanism but there is no need to include or **internalize** the underlying mechanisms of climate change in the model unless there exists feedback from the model system.

In particular questions d-g are important for the design, implementation and use of stock-flow models. Together, the questions are also relevant for the process of **model confidence building** with stakeholders, external experts and decision makers. Model confidence building (Senge and Forrester, 1979) refers to the validation of the SD models, i.e. building trust in their usefulness **related to the intended purpose** of the models, and a variety of tests focusing on the model structure, behaviour and policy implications, are available for this purpose. Although the stakeholders and actor partners were directly engaged in identifying problems, opportunities and obstacles as a starting point for the modelling, the technical implementation of the models has been carried out by the research partners in the project. These stakeholders, however, have an equally important role in application of the models, in formulating business and policy recommendations and in dissemination of the project

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outcomes. Therefore, it is important to confront the stakeholders with the stock-flow models or with the policy implications and lessons to be drawn from model simulations. One of the important objectives of the second round of multi-actor workshops was a broad, interactive, model validation. While the stock-flow modelling was progressing the modelling, teams came to the realization that the design of most stock-flow models was less appropriate for communication to a general public without background knowledge of stock-flow modelling. In addition, end users can be expected to be more interested in the policy implications and solutions generated with the models rather than technical details. Instead, feedback of the stakeholders was organised by focusing the workshops (one for each MAL) on the potential of stock-flow modelling (using selected examples), narrative scenarios linked to the models and the formulation of concrete policy actions as a stepping stone to the business road maps. A more detailed accounted of how the stakeholder feedback is found in each MAL chapter of this deliverable. The principles and test found in the literature (Senge and Forrester, 1979) were translated into practical guidelines (Annex 3) and a presentation template which were distributed to the project partners to be applied and the workshops as seen fit.

Across the MALs variation could be noticed in thematic focus, the complexity of the problems scope (see deliverable D12), the extent to which land-sea interactions were already the subject of thematic modelling and also the modelling expertise in general. These differences are reflected in the way the modelling questions are addressed by the MALs, although the questions are relevant for all models. To coordinate and harmonize the modelling considerable emphasis was put on the problem-driven nature of SD modelling and need to identify the underlying feedback structures of problems and solutions, using typical examples such as the overshoot-and-collapse behaviour caused by rapid development of a tourism region (Figure 4). This tutorial example was well recognized by all partners and clarified the basic principles of SD modelling from the start of the project.

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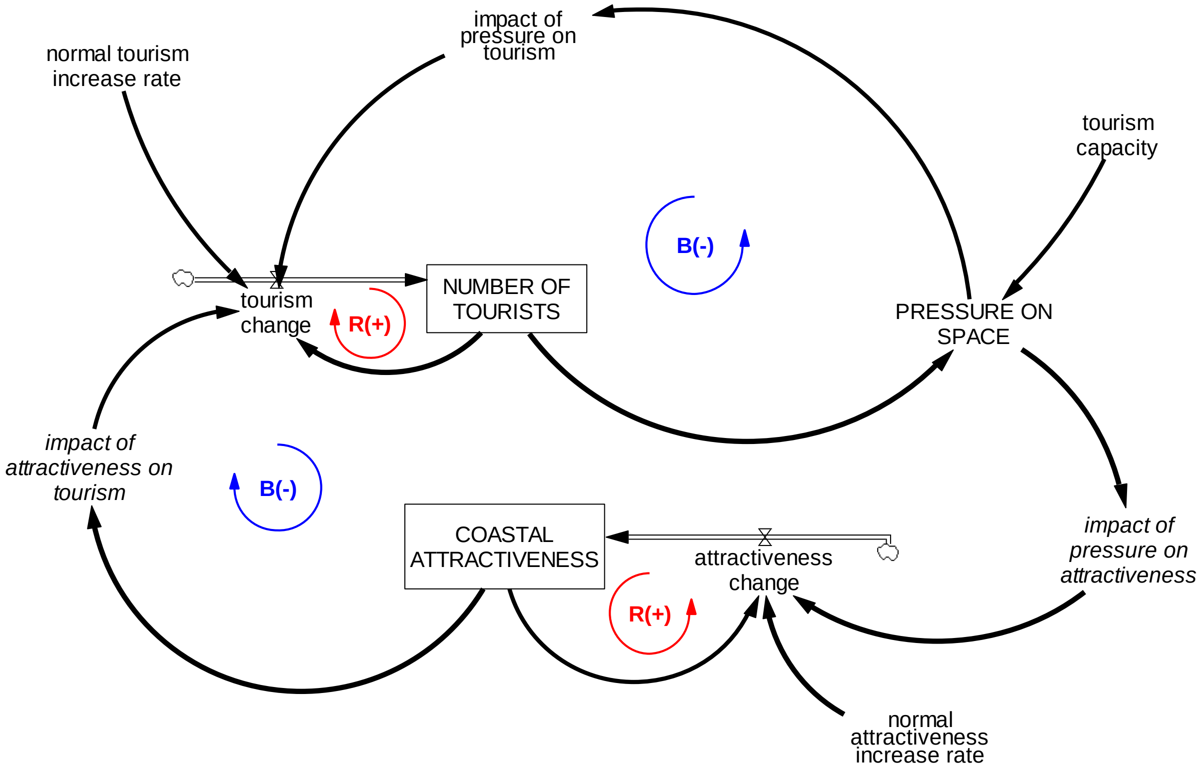

Figure 4: Tutorial example of a stock-flow model for tourism development.

However, a coherent **modelling strategy** was needed to standardize the models and ensure model constructs could be exchanged between the MALs and expertise shared, thereby increasing the efficiency of the modelling process. The importance of such a modelling strategy was discussed early in the project with the partners, starting with the purpose and focus of the systems modelling for the COASTAL project.

A common approach in System-Dynamics modelling is to start from a time horizon, extending back into the past to allow for historical calibration of the model and into the future to draw the time-dependent boundary of the model as related to the purpose. For example, sea level rise will be less relevant for models with a time horizon of a decade. From there so-called 'reference modes' (Sterman, 2000) are to be defined : time graphs and data showing the dynamics of the problem over time. This is then followed by the formulation of 'dynamic hypotheses', narratives explaining the problems observed. Once the dynamic hypotheses have been agreed upon these can be translated into graphical, qualitative feedback structures providing a conceptual model of the problem. Next, the conceptual model is quantified into a stock-flow model, tested and used to generate, analyse and compare different strategies to address the problem. The SD modelling cycle is iterative, building on the expertise of the modellers and feedback from the potential users and stakeholders, and allowing for growing insights in the problem. In view of the broad problem scope, number of partners and case studies COASTAL follows a more pragmatic approach, combining certain principles of SD modelling

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with multi-actor analysis. These principles include the consideration for system feedback for understanding problems, the use of qualitative, mental models as a basis for quantitative modelling, and a model architecture based on 'stock' and 'flow' variables (Sterman, 2001). This is very important for understanding both the purpose, methodological principles, and limitations of the systems modelling in COASTAL.

2.2 Modelling techniques

In terms of visualization and documentation the MAL teams were encouraged to polish and describe their models with a number of technical recommendations:

- Each stock-flow model was to be organised in separate but interconnected VenSim views and a "policy dashboard". The dashboard should provide access to key indicators and model controls without confronting users unnecessarily with the model details;
- All variables and parameters were to be defined in measurable, correct and consistent units, the consistency can be verified with the VenSim Unit Check tool;
- If possible, non-linear look-up functions, their use a common practice in SD modelling, were to be defined with normalized (dimensionless) input and output;

The MALs had to address some common model-technical issues which could be solved in different ways. To create a Good Modelling practice, it was considered more effective and efficient to provide pre-designed tools and examples to assist the modelling teams with their task, enabling them to focus their work on the content-related aspects of the structuring, implementation and testing of their SD models. In addition to the recommendations listed above, generic tools with examples were provided to address the following issues:

1) Use of model input data: in VenSim modellers can choose to internalize their data into the model (using the equation functionality) or collect and organize all their data in spreadsheets. The use of external files to collect and read all data was considered to be superior provided the data were well documented. In case data were internalized by the MALs the recommendation was to add a documentation of the source and preferably to add the parameters as separate model elements in the model interface. By the time the SD models became operational all MALs had adopted the practice of using external data files.
2) Adding seasonality to the models: seasonality is common in social-environmental modelling, phenomena such as precipitation, tourism expenditures, crop harvesting all of which are subject to seasonal fluctuations and call for an appropriate time resolution of the models. The MALs were provided with tools to introduce this seasonality in their models, usually based on a monthly time step, in case their models were working with a different time base.

3) Model structuring and connecting sub models: depending on the scope of the land-sea models it was necessary to organize the models. In VenSim this can be done by organizing the model in different views which can be linked by means of shadow (clone variables). General structure diagrams can be added to provide an overview of the total model structure.
4) Adding 'soft' variables: soft variables are human or environmental factors which are difficult to measure or quantify. Examples are public awareness, landscape quality and environmental pressure. Nevertheless, these factors can have an important role in closing feedback loops and the policy implications generated with a model. The recommendation is therefore to include these factors in the models (Sterman, 2001). The MALs were assisted with examples on how to include such 'soft' variables;
5) Use of table functions: in SD modelling table functions are useful for quantifying the interactions of variables which are difficult to capture in mathematical equations. For example, the impact of awareness on water use. For this SD software provides the option of using graphical table or 'look-up functions', preferably using normalized (dimensionless) input and output. Examples were used to clarify the use of these functions, generally appearing in the models as "impact of variable X on variable Y". The range of the functions was to be set. For the shape the MALs were provided examples such as S-shaped and growth/decline saturating functions as tables in Excel;
6) Determining growth rates: growth rates affect the model dynamics but turned out to be difficult to define or calibrate based on the literature and available data. For example, a transition from traditional to eco farming can be expected to occur at a certain rate of growth while slowing down when a maximum (saturation) level is attained. Both the MALs and stakeholders were challenged to reflect on the existence and role of these growth rates and saturation levels. A technical solution using the logistic growth model was developed to derive the growth rates in an indirect way from a critical threshold level, the initial condition for the variable, the saturation level and the time to reach the threshold (Annex 6). Defining a critical level as fraction of a saturation level and the time to reach this level is generally easier than the mathematical concept of a growth rate.
7) Linking up with scenarios: scenarios were not yet available at the time of completion of the models as their definition had to await the definition of model boundaries and driver variables. The challenge here is to link the narrative scenarios (WP5) to the numerical models. A tool based on generic, normalized functions was developed to facilitate the integration of the scenarios with the models and operation of the models for different scenarios. Modellers can use the tool by defining the final values for driver variables and time-dependent behaviour the variable (linear, saturating growth, S-shaped growth, …).

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SD models require data to be used, although these data demands are limited as compared to other type of models. The data include the initial conditions, time delays (if used in the model), scenarios, systemic limits and model-specific parameters such as the growth and decline rates governing the rate of change of the stocks. The source of these data can be diverse and may include field sampling, statistics, scientific reporting, or expert judgment. All of these were used in COASTAL. Nevertheless, some type of data is more difficult to obtain or may need to be generated from other data. An interesting example turned out to be the estimation of the tourism development rate in the tourism model for the Romanian MAL. This parameter was not available and had to be estimated in some other way. Fortunately, a saturation level and maximum capacity for tourism were known. A logistic growth model was used to derive the growth (development) rate from an estimate for the time needed to arrive at the saturation level. Parameters such as the capacity, saturation level (fraction of the capacity) and the time to arrive at this saturation level are easier to communicate and discuss than a mathematical concept such as the growth rate. Alternatively, scenarios could have been used to model the development of tourism, but this reduces the room for feedback in the model.

Fully quantified stock-flow models are essentially 1D models: the time-rather than location-dependency of policy indicators can be modelled. Most social-environmental problems call for spatial differentiation of models and data. In principle, the problems can be addressed by direct integration of SD models with spatially explicit models (Figure 2). The low cost VenSim® licenses used for COASTAL did not permit this type of model integration, nor was it desirable to focus the modelling effort on this type of application. This was discussed with the MAL modelling teams and a compromise was found in including spatially *relevant* indicators and variables in the models. For example, the ratio of the actual number of offshore wind turbines and the total area available for this activity (being constant in time or not) is an indicator for the spatial pressure.

2.3 Modelling support and collaboration between the MALs

To organize the modelling, Work Package 4 assisted the MALs with modelling guidelines, group and individual support sessions (both face-to-face and online exchanges), model templates, examples and step-by-step illustrations of the modelling. More specifically, to support the modelling process, the following support was provided to the MAL participants:

- A first workshop during the General Assembly at Methoni was used to introduce System Dynamics modelling to the participants and the Vensim Software in early May 2019. The presentations and generic Vensim model examples shown at the kick-off workshop were made available on the COASTAL participants portal. About half the workshop was organised as a hands-on session where participants used the Vensim freeware to set up a model for a topic they were well familiar with. For most modelling teams this was either a water flow or water quality model;

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- Bilateral Skype calls were regularly organised with the individual modelling teams of the MALs on a monthly basis. These were typically used to discuss specific modelling issues encountered for the MAL or when using Vensim. As time passed MALs also sent Vensim models that were then discussed in the Skype calls;
- To clarify problems identified during the Skype calls, small, generic models were used that were made available by both e-mail and the COASTAL partner area.
- Three group calls were organized to address common concerns or to present the next steps in the organisation of the model development;
- An additional workshop with those involved in the modelling in WP4 was organised in January 2020 in Brussels, back to back with the first project review meeting at the Research Executive Agency (REA) in Brussels. During this workshop the different problems with the SD-methodology observed during the Skype sessions and mentioned by the different modelling groups were discussed and possible solutions were clarified.
- In general, information was shared with the different MAL modelling teams through a share point. This not only allows MALs to share their models with the WP4 leader responsible for assisting the MALs in the modelling process but also for MALs to share their models amongst each other.

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3 Operational stock-flow models for coastal-rural interactions

3.1 Multi-Actor Lab 1 - Belgian Coastal Zone (Belgium)

3.1.1 General problem scope of the land sea system

The Belgian coast (67 km length) and hinterland face environmental and economic stresses from intensive multifunctional use of space. Land- and sea-based activities such as agriculture, fisheries, agro-food industry, transport, energy production and recreation are closely interwoven and competing for space (Figure 5). A new Maritime Spatial Plan for the Belgian Coastal Zone for the period 2020-2026 was recently approved[1]. Figure 5 shows the dense use of space and complexity of combining offshore environmental and economic functions.

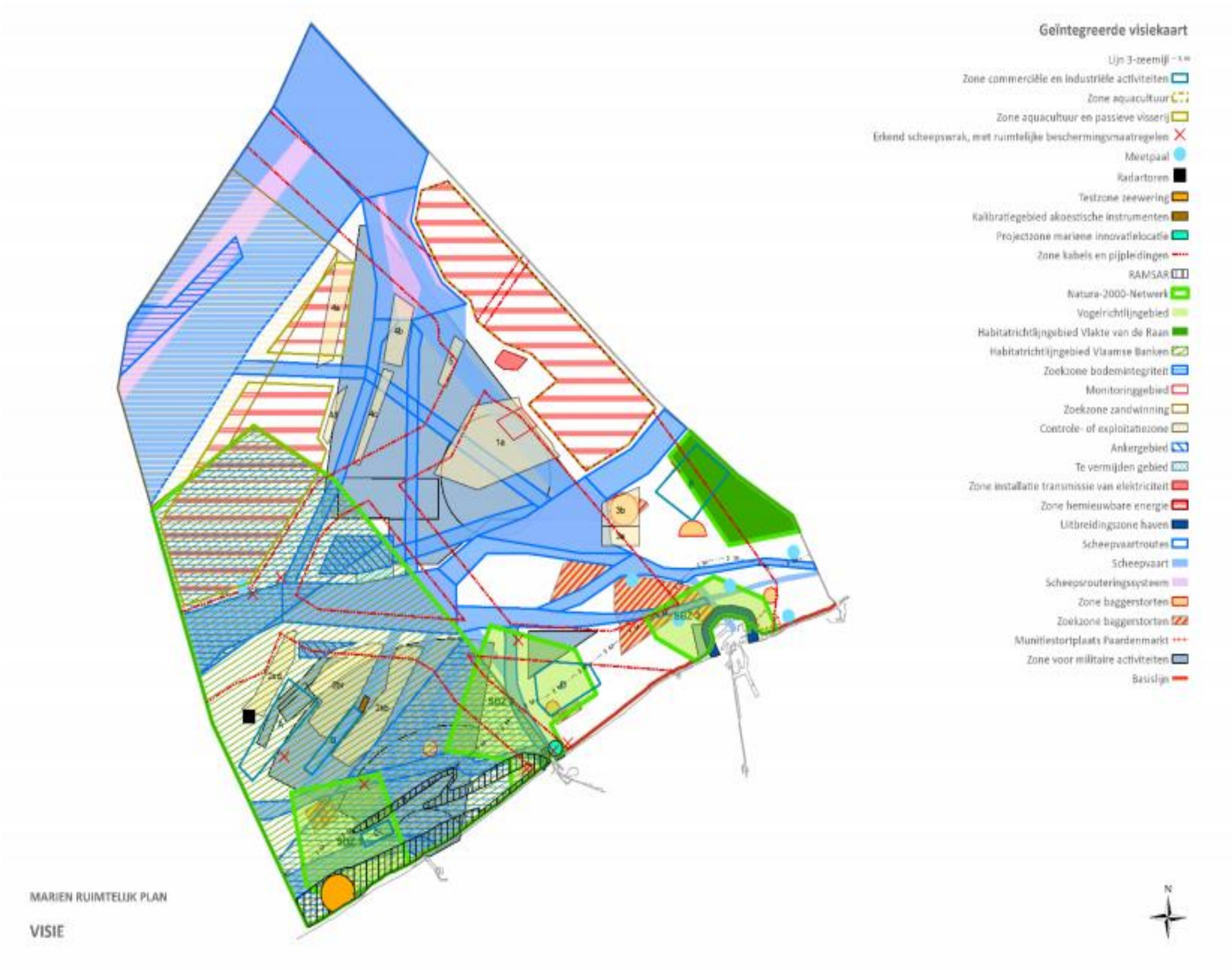

Figure 5: Integrated Map as part of the new Marine Spatial Plan 2020-2026 for the Belgian Coastal Zone (Belgian Federal Public Service Health, Food Chain Service and Environment, 2019)

[1] https://www.health.belgium.be/sites/default/files/uploads/fields/fpshealth_theme_file/msp-2020-englishtranslation.pdf

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Figure 6 and Figure 7 show the land use in the Belgian Coastal Zone with a 100 m resolution for respectively the year 2013 and 2050 (Growth-As-Usual scenario) as modelled with the VITO RuimteModel[2]. The densely populated coastal zone is in contrast with the hinterland with a primarily agricultural function.

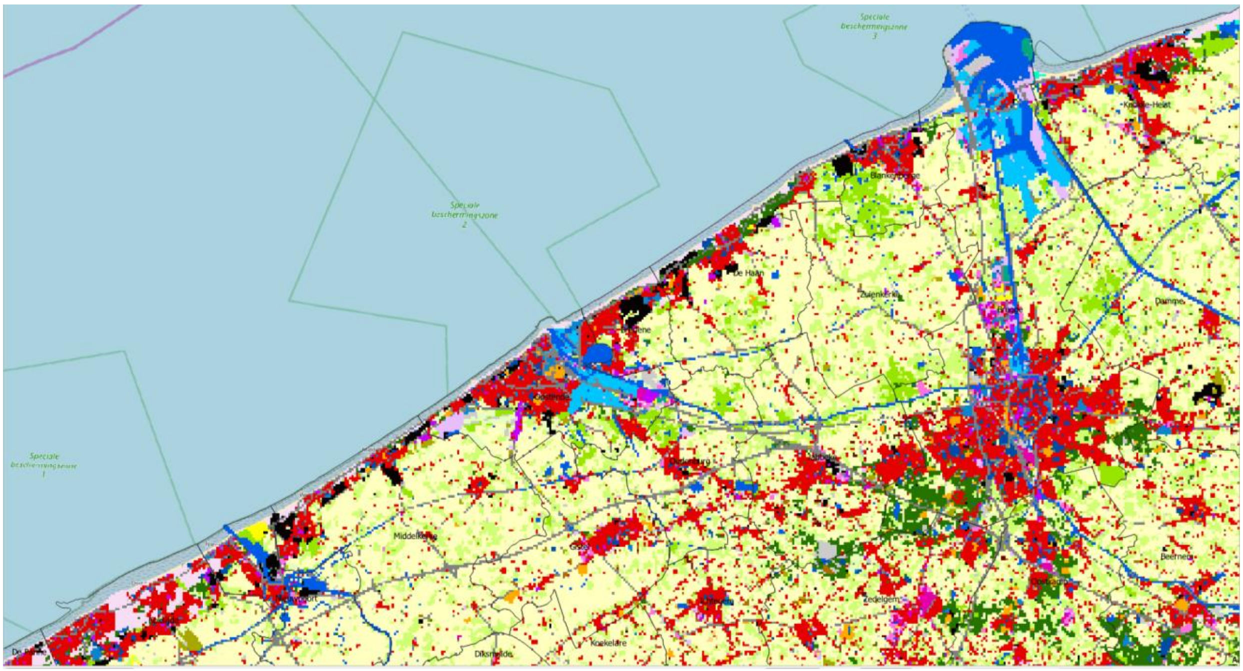

Figure 6: Land use in the Belgian coastal zone (situation 2013) showing the build-up area (red).

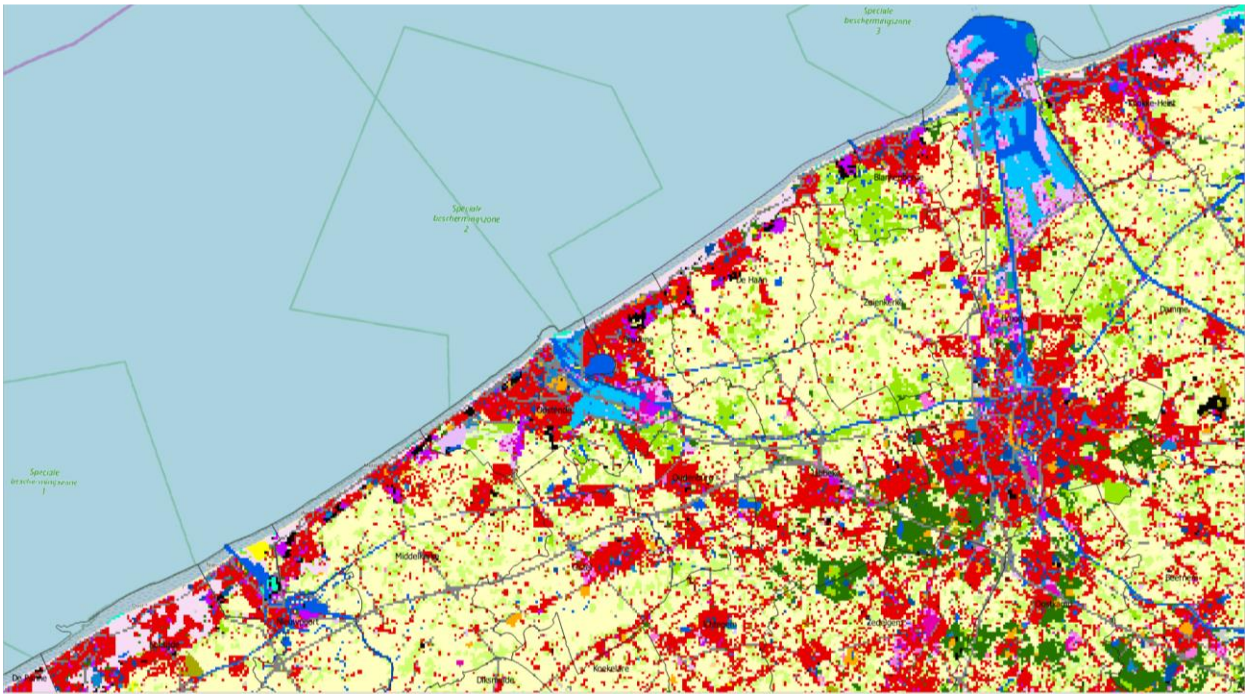

Figure 7: Land use in the Belgian coastal zone (situation 2050 – Growth-As-Usual scenario) showing the build-up area (red).

[2] https://ruimtemodel.vlaanderen

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New development opportunities for this densely populated region are created by blue growth, and especially on- and offshore energy production, creating opportunities for new jobs and strategic specialization of port activities. This includes innovative production methods using wave and tidal energy. Belgium is one of the leading countries in know-how related to deep offshore energy production and the first country to put in practice multi-purpose use of wind farms by combining these with shellfish aquaculture. Meanwhile, the quality of fresh water resources is under pressure, and land-based emissions of nutrients still exceed the EU-WFD target levels and contribute to coastal eutrophication. The quantities of fresh water are under pressure during extended periods of drought because of multiple demands from industry, tourism, population and agriculture. A major stressor is the increasing salinization of inland waters related to human waterworks, water management, and sea level rise. A main challenge for this case study is the fragmentation of policy and knowledge for coastal and rural development. A common administrative framework for coastal-rural integration is lacking and policy responsibilities are fragmented at the regional and national level.

Potential land sea interactions to be considered for the Belgian Coastal Zone include:

- The amount of the water that is exchanged between the farming area in the coastal zone and the sea will be determined by climate change (sea level, rainfall, evapotranspiration), land use (farming, residential, nature) and population dynamics.
- The potential for wind energy and other uses of marine space and its effect on job creation and availability of skilled labour force, infrastructure and activities in the coastal zone

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3.1.2 From multi-actor analysis to modelling

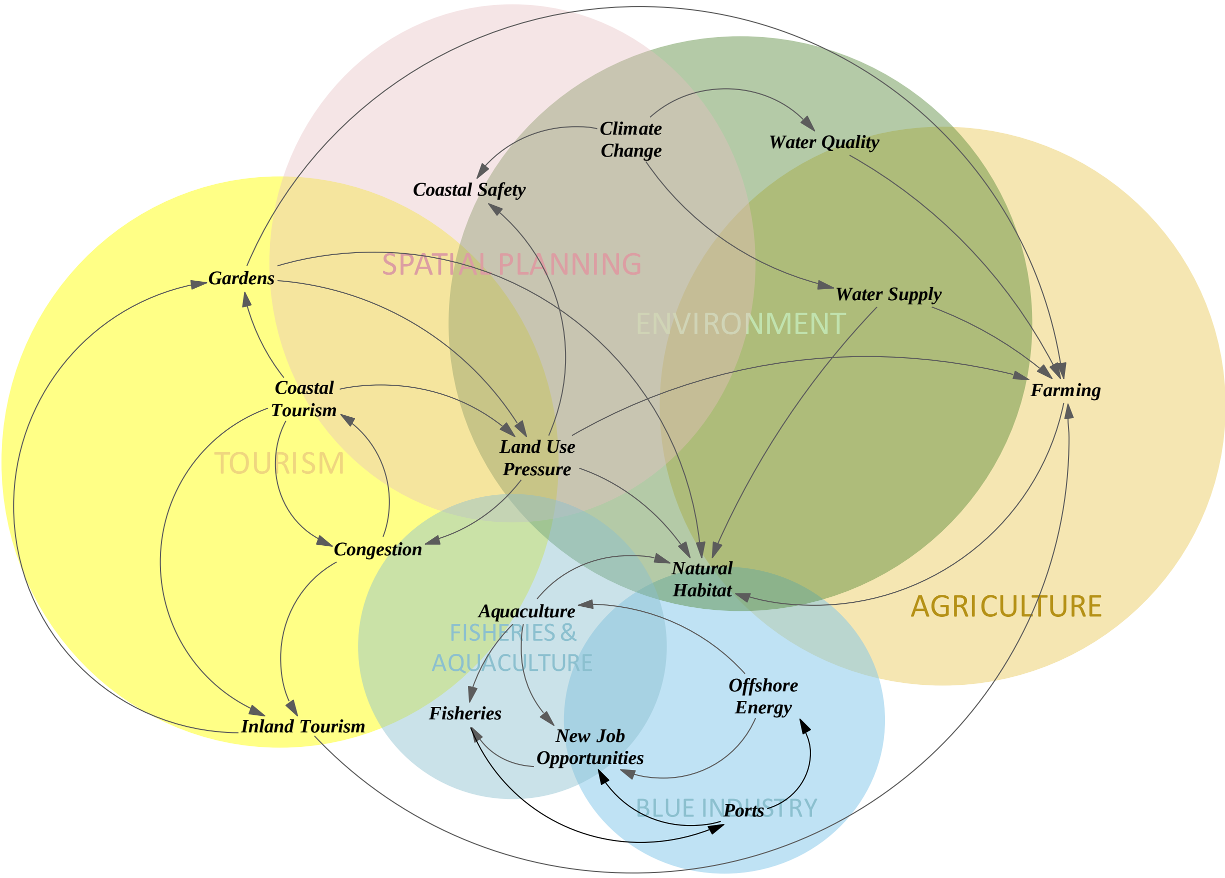

Figure 8: Overview mind map with the main issues and linkages for the Belgian Multi-Actor Lab (project team analysis), showing the themes for the six sector workshops and overlap in issues raised.

As COASTAL is a multi-actor project, the purpose of the stock-flow modelling was explained and discussed with the actor partners involved (Flemish Land Agency, Flanders Marine Institute, Greenbridge, the harbour of Ostend and West-Flanders Development Agency). Clearly, the stock-flow models should meet three requirements to meet their purpose: (1) addressing land-sea interactions in a synergistic manner, (2) alignment with existing or planned planning and administrative regulations, and (3) a focus on innovation and contribution to the formulation of practical business road maps and policy guidelines. Following the discussion, it was decided to center the modelling around two themes related to rural development and blue growth (Figure 9):

- Climate resilience of the Oudland Polder: Impact of climate change and water management on polder land used primarily for farming and nature;
- Decommissioning of offshore wind parks: offshore energy production, maintenance and decommissioning coupled to employment, port development and onshore infrastructure;

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It was not considered meaningful to integrate these two themes in a single land-sea system model as cross-thematic interactions were not identified earlier in the project. Instead, it was deemed more useful to analyse the land-sea interactions for the two themes individually and focus the modelling of the themes on the economic and environmental variables relevant for rural development and blue growth. The following chapters are devoted to providing a more detailed account on how this was done.

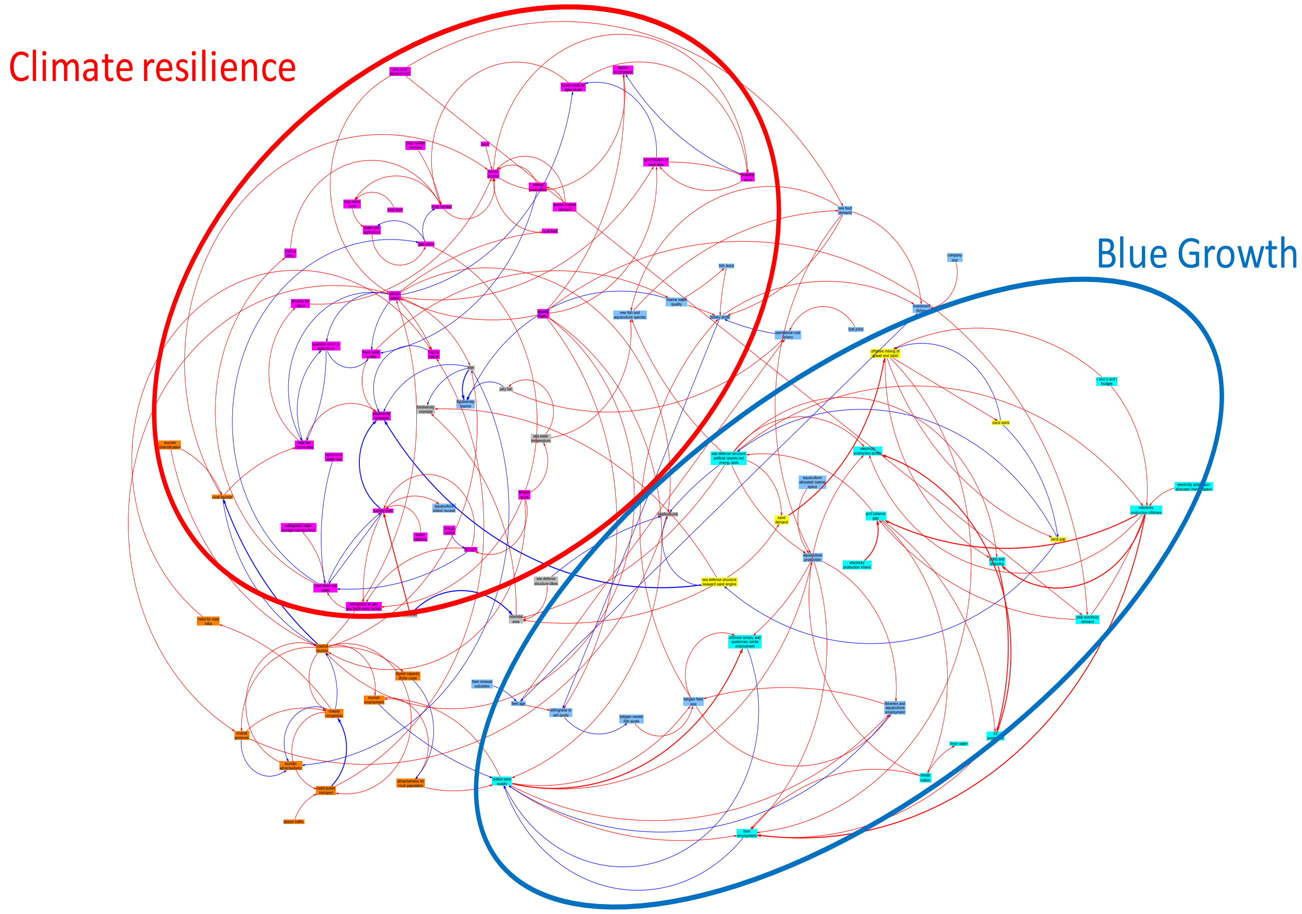

Figure 9: Positioning of the disjunct themes of climate resilience and blue growth within the CLD for the total land-sea system.

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3.1.3 Sub model 1: Climate resilience, spatial planning and water management for the Oudland polder

3.1.3.1 Problem scope of the Oudland polder model

The problem and related model scope was determined together with VLM, the actor involved in the agriculture and environment sectors. Referring to the part of the CLD produced in WP1 that is relevant to the model scope, the model investigates the interaction between the land use (agriculture, nature) in the polder which strongly depends on the groundwater level of the polder and the different drivers, such as climate change and demography in the coastal zone which have an effect on the amount of water available for the polder. Another problem mentioned by VLM is the decreasing number of active farmers in the polder. When farms are sold, these are often not bought by farmers but are converted to luxurious residences or used for other purposes, a process referred to as gentrification.

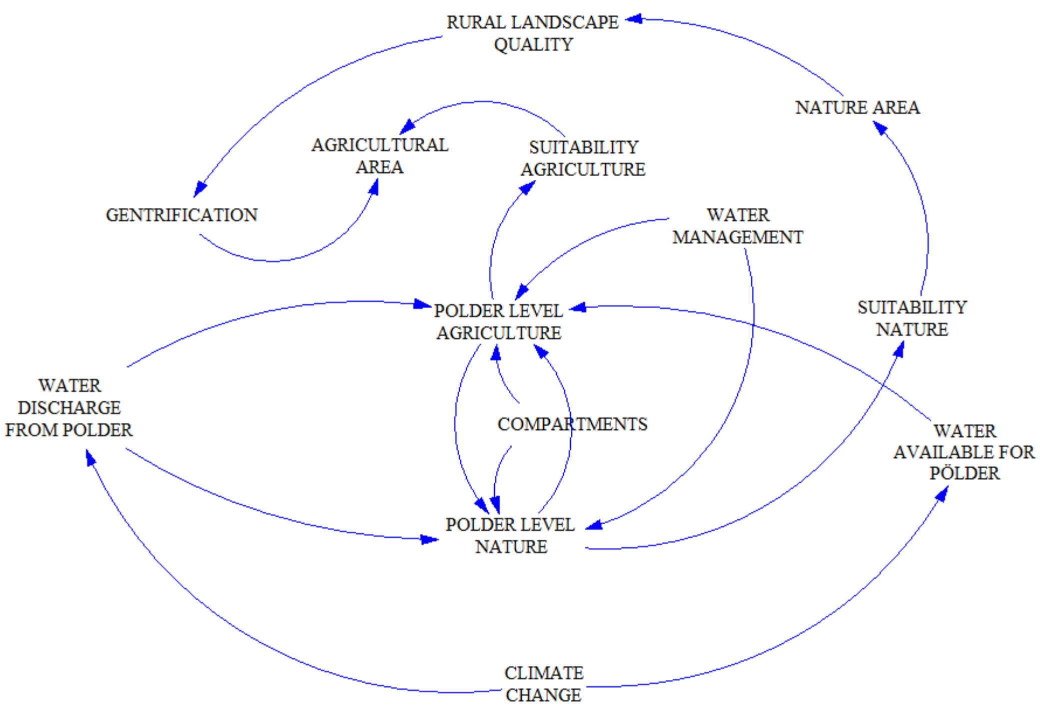

Figure 10: Part of the MAL1 CLD that relates to the model scope as defined during the second reporting period.

Aspects from the MAL1 CLD which are only indirectly related to the model scope, such as 'fisheries' and 'blue industry' are not considered in this model. Demography is an input in this CLD and as such assumed to be unaffected by the processes described by the CLD for the current model. Variables related to climate change are included as input to the model and assumed to be independent of the processes in the model.

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A CLD representing the general overview of the model structure, linking land use, water management and gentrification , is shown in Figure 10. In the next 2 chapters we'll describe the steps and decisions taken to setup stock-flow models for the water management for the polder and the gentrification. For these models the calculation period was taken to be from 2010 to 2050. 2010 to 2020 as an historic period can be used for validation. For the time step, a timestep of 1 month was taken to accommodate for the monthly changes in farm practice.

3.1.3.2 Quantification of the polder water level management

From the discussion with VLM, a model for water management in the polder should address the following considerations:

- Climate change is expected to result in rising sea levels and in changing precipitation and evapotranspiration patterns. This could result in salinification and/or water logging of the low-lying polder near the coast which is used for farming and nature.
- A polder is a strongly managed system in which the water level in the ditches is set by adding and removing water to increase or lower the groundwater level.
- For the coastal polders in Flanders, water is available from different sources, such as surface water discharge of inland water (e.g., rivers and canals), the effluent of the waste water treatment plant or water recovery from sealed areas, such as the abundant caravan areas along the coast. While this water could be used as recharge to the polder, it is also claimed for other uses, such as drinking water production or the need to maintain a certain discharge in the canals for shipping and for avoiding salinification.
- Water can be stored temporarily. An example is water buffering in creek ridges.
- To lower the groundwater level in the polder, the water manager will need to discharge water from the polder. While water is typically discharged gravitationally to the sea at low tides, rising sea levels could well mean that pumping will be needed in the future.
- According to the land use, potentially conflicting ground water management schemes are needed. For nature, a constant shallow groundwater depth is preferred while for farm land the groundwater level should be lowered in spring to promote trafficability and kept high during summer time to sustain the crop water demand. Therefore, depending on whether the water level management policy caters to the needs of the environment or the farming community, a different management strategy will be needed.
- Salinification is mainly a problem for animal breeding.

The main stock variables are the polder levels for the polder areas assigned to agriculture and nature. By adding and removing water from the polder the polder level can be varied. While not included explicitly in the CLD - assuming there is no human intervention - the polder level will rise due to precipitation. As a counterpart to precipitation, evapotranspiration (ET) will decrease the polder level. The CLD variables water needed for crops (crop water needed) and for nature (water needed nature)

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correspond to the ET. Depending on crop type (crop type) and relative area used for agriculture (land use agriculture) the total ET for the model area can be determined from the ET for crops and nature.

The possibility to increase the polder level depends on the water available and the amount needed. The latter is dependent on the difference between the polder level and the desired level where the desired level is set according to water level management. The desired level and the water needed are not shown in the CLD but are required in the stock-flow model to correctly model the dynamics of the system. Analogous to the recharge, the discharge is determined by the amount of discharge wanted and the discharge capacity of the system. The discharge to sea is dependent on the tides, which implies that an hourly time step is needed. To limit calculation time, it was however decided to not model the tidal effect explicitly but to use the fraction of time available for discharge to estimate the available discharge capacity.

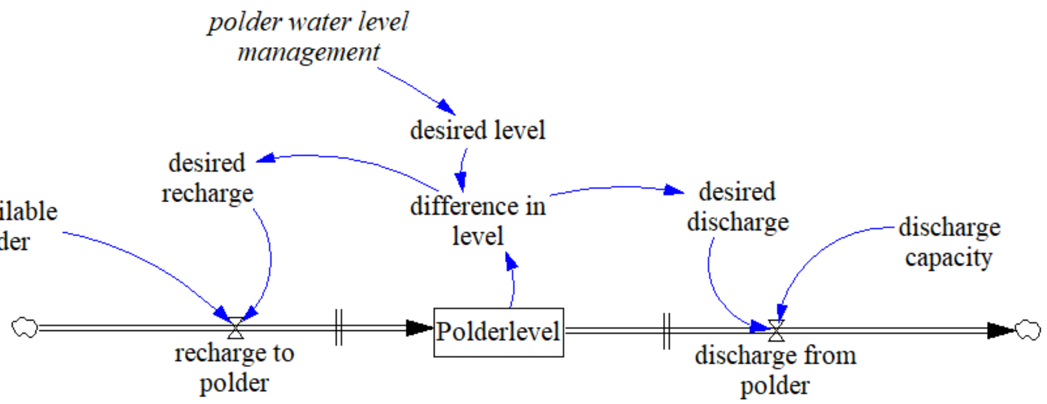

Figure 11: Basic stock-flow model structure for the polder water management.

While the structure in Figure 11 is essentially what is required if one neglects precipitation and evapotranspiration, the following considerations led to the final SD structure for the water management:

- In case the desired recharge is less than the water available for the polder, not all available water will be used. Water that is not used will be used for other purposes and/ or eventually discharged to the sea. This implies that the actual water discharge to the polder that is calculated from the available water will have a feedback on the water available itself. As long as we don't consider this feedback, we can ignore the circularity in this calculation. However, if that is not the case, we have to introduce a stock to the structure. This stock will correspond to a buffer that separates the water supply from its user (= the polder). While a buffer with zero capacity can be the solution to the circularity problem, for the polder water management, we can also put this buffer to good use as there are plans to buffer water in the creek mounds in the polder. In the stock-flow model structure, the water available is added to the buffer stock variable and removed by the recharge required by the polder. What is not removed can stay in the buffer up to buffer capacity. All above buffer capacity is added to the buffer loss, which feeds the rest back to the available water calculation.

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- In the final model, the precipitation and ET have also been added as can be expected. Notice though that they are also connected to the recharge and discharge rate calculation. This is done to avoid what is called the steady state error. This can be understood by considering the balance equation of the stock for the polder level:

$$Level_{new} = Level_{old} + (recharge - discharge + precipitation - ET) * TimestepLength$$

During steady state the level remains constant and $Level_{new}$ is equal to $level_{old}$. This implies that for steady state recharge-discharge = precipitation-ET should be true. From this we can further deduce that recharge = precipitation - ET and discharge = ET – precipitation should also be true. So, for a correct calculation and to ensure that the stock balance is always maintained , the precipitation and ET should be added to the recharge and discharge calculations.

- The area of the polder needed to convert between discharges as found in rivers and for pumps (volume/time) and discharges that relate to areas such as ET and groundwater level changes (length/time) and vice versa. Inside the polder, we consider the units of length/time, while water transfer from/to outside the polder will be in volume/time

- The specific yield which is used to calculate the amount of water that is released from a groundwater reservoir when the groundwater level changes. As groundwater is contained within a porous medium, a unit volume of a ground water reservoir does not only contain water and a drop of 1 m in groundwater level will not result in a release of 1 m of water from the reservoir.

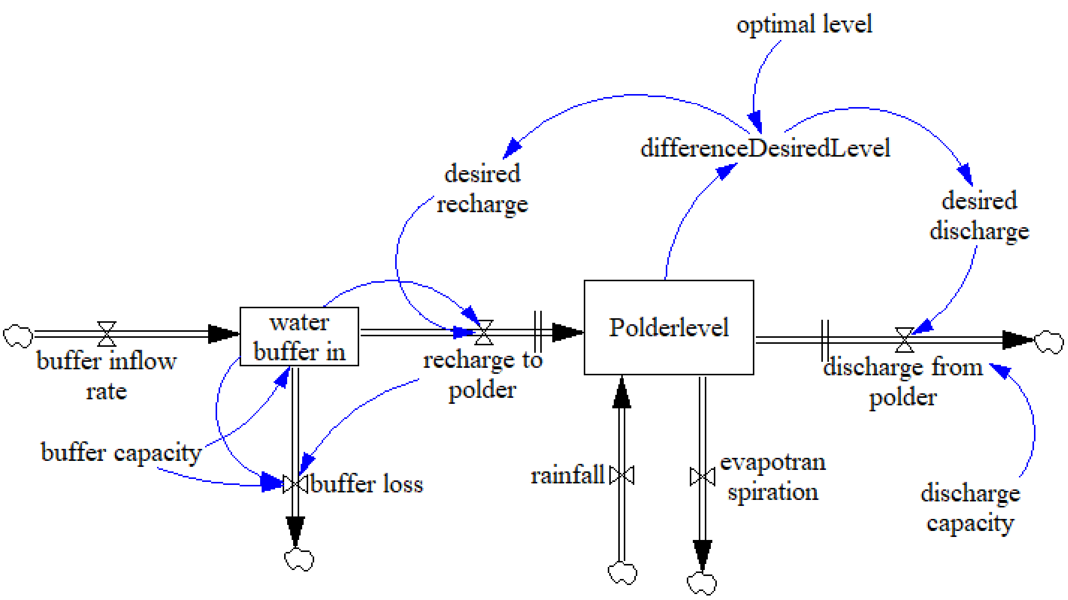

Figure 12: stock-flow model for the water management in the polder

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A final aspect that needs to be considered in the model is the different water management for nature and agriculture areas and the possibility to manage these as separate compartments . For the stock flow model this will result in replicating the water management model as presented in Figure 12. The resulting stock flow model is shown in .

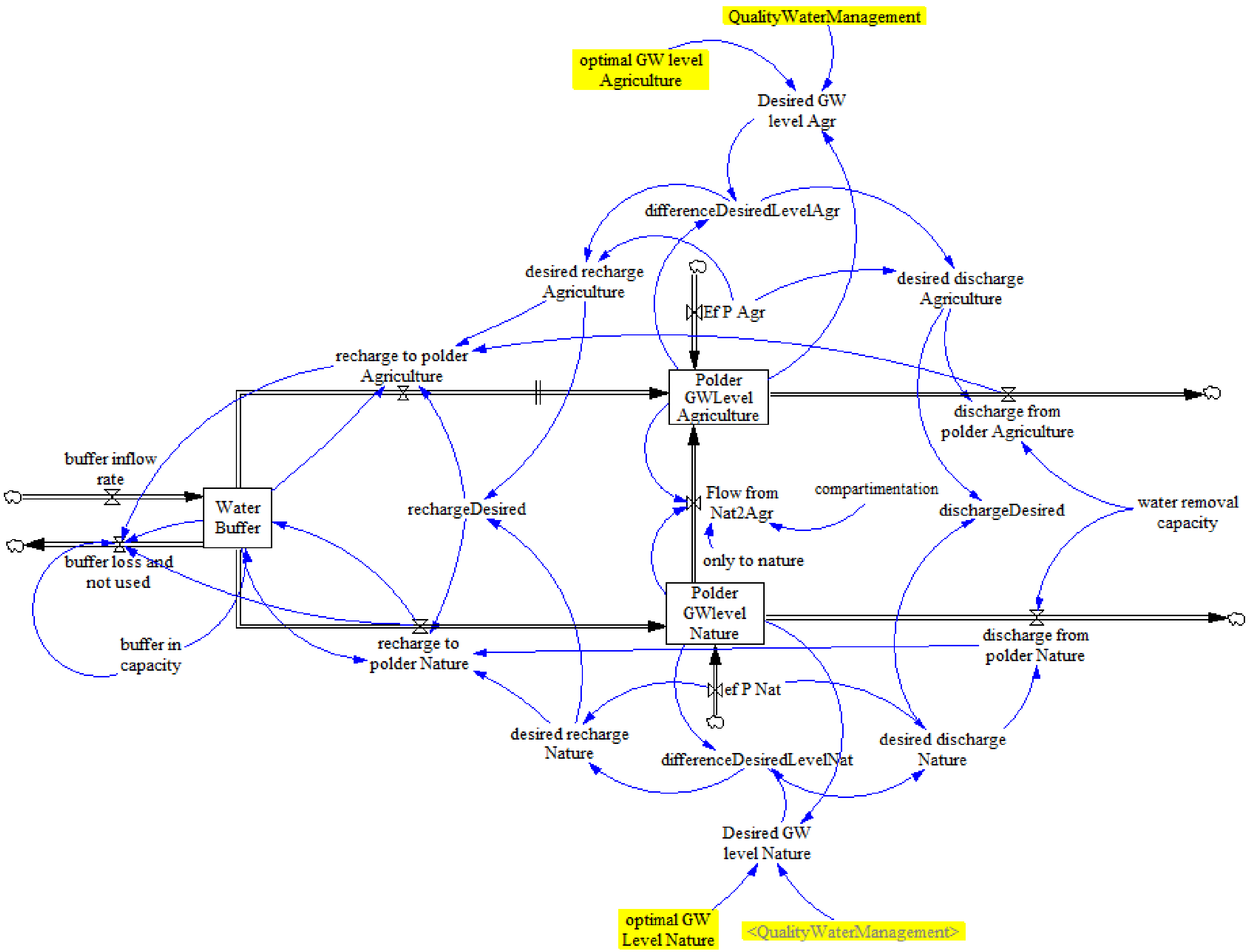

Figure 13: Stock flow model considering a separate water management regime in the agricultural and natural areas of the polder and allowing from considering separate compartments for each of these. The yellow variables are the inputs to the model.

3.1.3.3 *Quantification of the gentrification*

The land use fractions assigned to agriculture and nature in the polder water management model presented in 0 are input to the model and are obtained from the results of the 'Ruimtemodel

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Vlaanderen'[3]. The RuimteModel Vlaanderen is a Land Use simulation model developed to simulate integrated scenarios. The kernel of the model is an activity-based cellular automata (ACA) based Land Use model (White et al. 2012). In ACA-based Land Use models, Land Use change is explained by the current activity (i.e. population and employment) in a cell as well as by the changes of activity within its neighbouring cells. Results of the Ruimte model Vlaanderen are shown in Figure 7.

The gentrification process we model assumes that when farmers sell their farm to an existing or a new farmer or sell it to be used for residential purposes (gentrification). When selling to an existing farmer this results in the number of farms decreasing but farm size increasing. When gentrification occurs the number of farms decreases. The effect of farm land being lost with gentrification is assumed to be contained in the development modelled by the Ruimtemodel Vlaanderen and is therefore not considered in the current model to avoid double counting. Both the loss due to sale to another farmer as the gentrification are assumed to be irreversible. The resulting stock-flow model is shown in Figure 14.

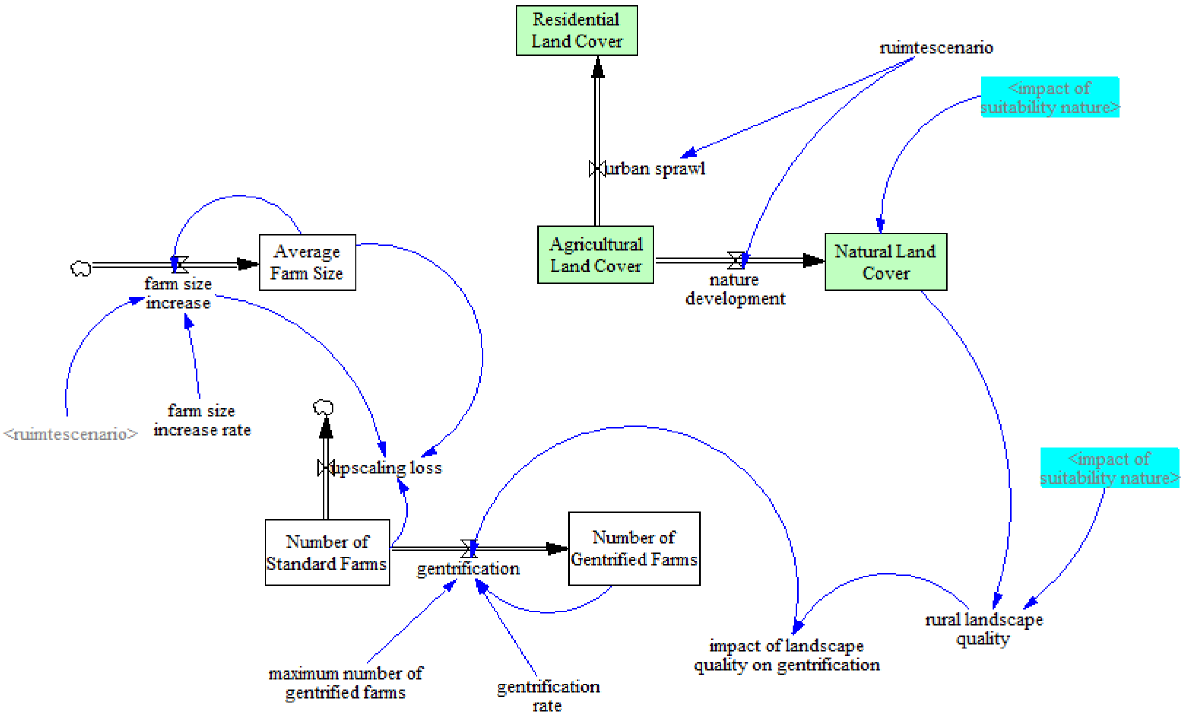

Figure 14: SD model for gentrification. The variables with a green back ground are based on Ruimtemodel Vlaanderen results. The variables with a blue back ground are interactions with the water management.

The following can be remarked about the SD model for the gentrification as presented above in Figure 14:

- The gentrification rate is input to the model
- Gentrification is limited by a maximum allowed number of gentrified farms.

[3] https://ruimtemodel.vlaanderen

- The land use is based on the Ruimtemodel Vlaanderen. The value for the natural area is modulated by considering the effect of the water management for nature. The same is true for the rural landscape quality which will decrease when nature is affected by poor water management. Deterioration of the environment will in turn affect the chances that rich people find it to buy the farms in the area and will this result in a slowdown in the gentrification process.

The calculation of the effect of the water management on the suitability for nature is further detailed in Figure 15.

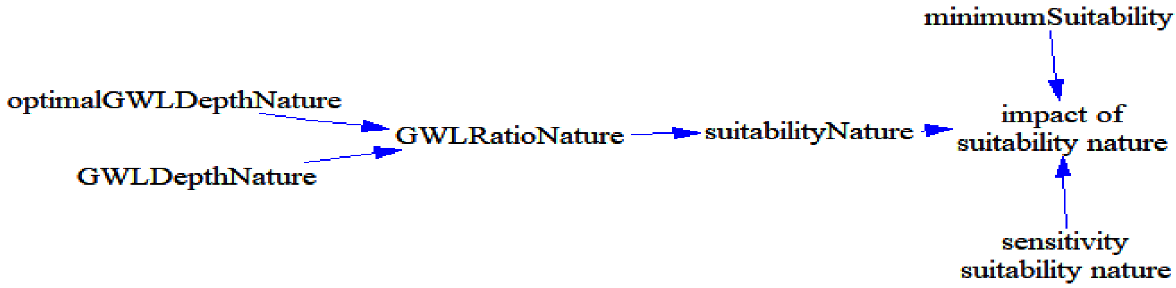

Figure 15: SD model structure used to calculate the effect of water management on suitability for nature.

The calculation is based on the ratio between the groundwater depth and the optimal groundwater depth for nature. This ratio is used with a lookup function (suitabilityNature) that takes on the shape of a parabola with a maximum value of 1 for a ratio of 1 and attains a minimum of zero depending on the sensitivity of the vegetation to deviations of the groundwater depth to the optimal depth. This 'suitabilityNature' value is then combined with a minimum suitability and a sensitivity value in the equation:

$$\text{impact of suitability nature} = MAX(\text{minimumSuitability}, \text{suitabilityNature})^{\,sensitivity\ suitability\ nature}$$

To calculate the rural landscape quality, an index defined between 0 and 100, the impact of suitability nature is then input into a lookup function (Figure 16).

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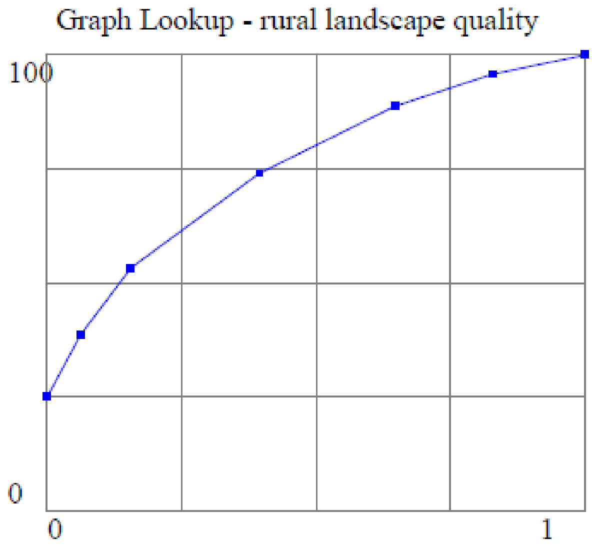

Figure 16: Vensim lookup function to calculate the rural landscape quality (Y) from the impact of suitability nature (X).

3.1.3.4 Problem scope of the decommissioning sub model

The problem scope for the decommissioning model was determined together with the Port of Ostend (AGHO) and the provincial West Flanders Development Agency (POMWVL), two key players in the development of offshore wind energy in Belgium. The Port of Ostend is the main hub for the installation and (de)commissioning of wind turbines and POMWVL has a coordinating role in supporting technological innovation. The Belgian Offshore Platform[4] is the central forum bringing together administrations, stakeholders, experts and industries developing offshore wind energy in a triple-helix collaboration. Other important platforms are Flanders Blue Cluster[5] and, at the European level, Wind Europe[6]. Together, these partnerships and platforms proved to be invaluable for collecting scientific and technological data needed and helped define the model scope. In general, the technological innovation related to the design of the turbines, power generation and maintenance are impressive and rapidly advancing.

Regardless of the limited marine space available in Belgium, Belgium has over little more than a decade managed to take on a significant role in the deployment of wind farms at sea and with 1,186MW installed capacity in 2018 has the 4th largest installed capacity in Europe after the UK, Germany and Denmark (Kruse et al., 2019). Initially, the model development for blue industry in COASTAL was focused on wind farms at sea and how offshore energy production could be used for hydrogen production, desalinisation and as a complement to electricity production onshore. One of the problems discussed with respect to the latter was the need for grid accommodation on the

[4] https://www.belgianoffshoreplatform.be/nl/

[5] https://www.blauwecluster.be/about

[6] https://windeurope.org/

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onshore electricity network of the electricity produced by an intermittent source such as wind energy (Dijkema et al., 2009, Crabtree et al. 2010). Further discussion with energy experts (oral communication Vingerhoets, P. and Meinke-Hubeny, F.) however led to the conclusion that in the future, scenarios where electricity surplus from wind-energy is a problem are not likely as enormous amounts of electricity will be needed to compensate for the decarbonisation of our society. The interconnectivity of the grid in Europe is also expected to improve significantly in the coming years (Wuppertal Institut,2020). Based on this insight and a discussion with the MAL actors for Blue Industry, it was then decided to focus this sub model on the following aspects:

1) A general life cycle analysis covering offshore wind turbine (de)commissioning and the development of onshore infrastructure and know how to support these activities;
2) The economic aspects of offshore wind farms (deployment, maintenance and decommissioning) as well as related activities such as hydrogen production, desalinisation or recycling of decommissioned turbines are seen as a business opportunity that favours innovation and attracts investments in research and development to the area;
3) The limiting conditions, in particular availability of a qualified labour force and the physical limits set by space that can be used for this purpose both offshore where the wind parks are and onshore where space for handling decommissioned wind turbines, port facilities and infrastructure are needed.

An obvious physical limitation to deploying an offshore wind park is available marine space. This is regulated by the marine space use map for which the most recent version for 2020-2026 is shown in Figure 5. For our purpose, as the focus is on wind farms, we will distinguish between areas assigned to wind farms and other areas. The sum of both these area types will be the total area of the Belgian territorial zone. In Belgium, marine spatial planning is a federal (national) responsibility while coastal development and flood defence are Flemish (regional) responsibilities. This makes land-sea interactions complex in administrative terms. While the Marine Spatial Plan 2020-2026[7] establishes the current area available for the different functions, future revisions might enlarge the area suitable for renewable energy and thereby decrease the area available for other uses or vice-versa. The Belgian Marine Spatial Plan is revised every 6 years.

Decommissioning wind turbines poses questions related to material waste and recycling, the required port infrastructure and the transport of turbine parts. While the current debate is often focusing on technology and contribution to renewable energy COASTAL will contribute to the debate by focusing the modelling on the dynamics of the decommissioning process. The number of wind turbines to be dismantled in a certain year depends on the varying number of wind turbines installed over previous year and the lifespan of the turbines. As wind park concessions are planned as part of the six-year Marine Spatial Plans and wind turbines are installed in larger numbers as wind farms at irregular

[7] https://www.health.belgium.be/en/environment/seas-oceans-and-antarctica/north-sea-and-oceans/marine-spatial-plan

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intervals, this decommissioning rate is characterized by peak years followed by years without decommissioning. The number of turbines to be decommissioned will determine the amount of port infrastructure and skilled labour required. Excessively low or high decommissioning rates are undesirable from a logistic, economic and engineering point of view. While it is more difficult to see how stock flow modelling can contribute to the technological aspects of turbine installation and decommissioning, assessing the consequences of choices in long-term planning is a problem for which SD modelling is very much suited.

The decision to focus the modelling on the decommissioning is based on an explicit request by the MAL actor partners. The term was not considered in the original CLD for the sector (Figure 17).

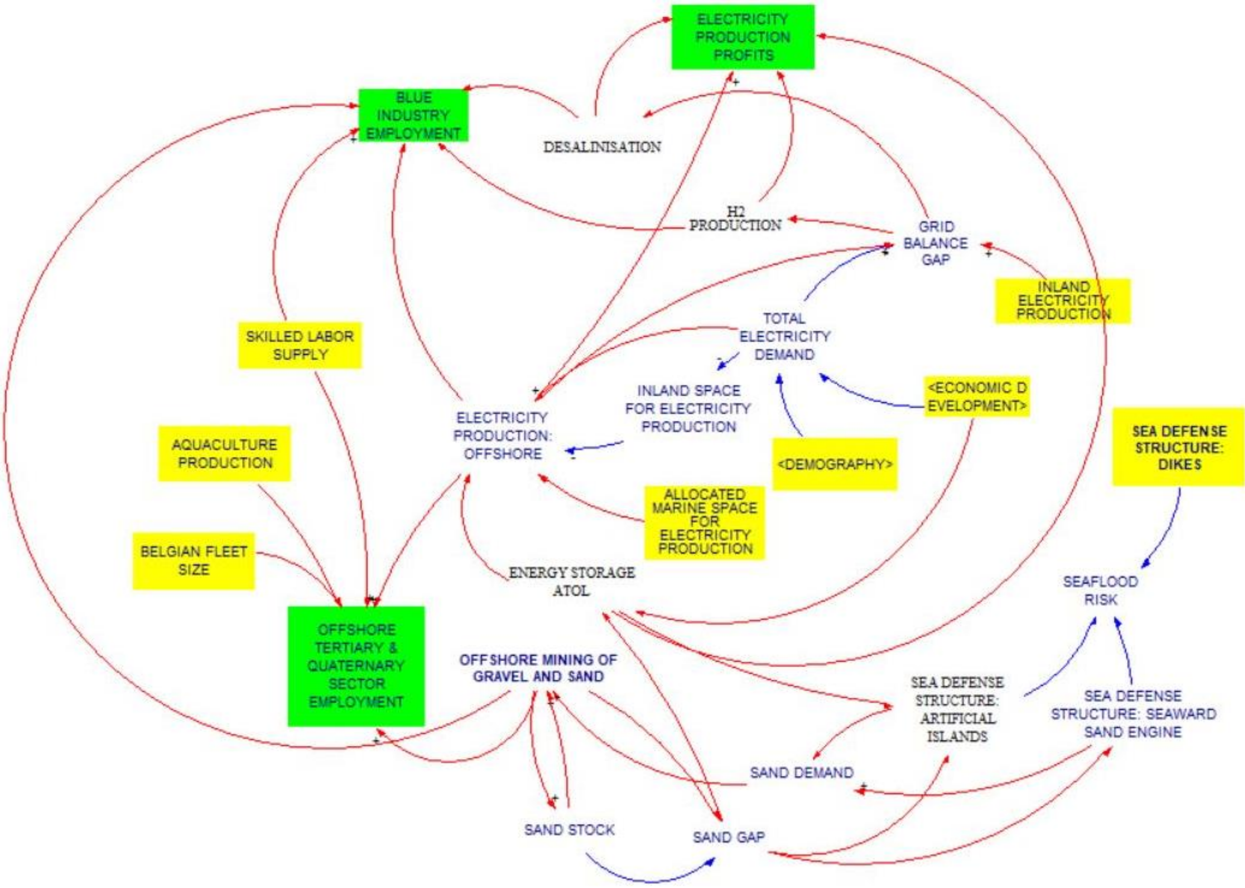

Figure 17: CLD for the Blue Industry established from the sectoral workshop. Inputs are highlighted in yellow. Outputs that are not used elsewhere in the CLD are in green.

First, the CLD was therefore adjusted to consider the potentially relevant processes related to the decommissioning. The following considerations were made:

- While only decommissioning is mentioned, this can also be extended to include other phases in the life cycle of the marine wind park. Once marine space is released, it again can be used for other purposes, of which the installation of a new wind park seems a likely option. This implies that marine space will be possibly occupied by a sequence of wind parks where the

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request for a new concession and plans for a new wind park (by possibly new candidates) will go hand in hand with plans for decommissioning by the owners of existing wind parks. In our CLD, we will distinguish planned, operational and end-of-life marine wind parks.

- In general, decommissioning is required by the end of the 20-year turbine service life. So far, in the offshore wind sector only a few wind turbines have been dismantled offshore in Europe and experience with the decommissioning is still limited but in the near future this will change because from 2020 to 2030, 1,800 offshore wind turbines in Europe will reach their end-of-life (Topham et al. 2019). Upon reaching their end-of-life, there are a number of options for the wind turbines: lifetime extension, repowering or decommissioning where decommissioning can be either a partial or a total removal of the offshore wind foundations. In the permit granted for the wind park, the site's restoration to its original condition is required. However, the permit also considers the need for consultation concerning the practical implementation of this requirement and how far this can go. While there is to date limited experience with the decommissioning of marine wind parks, experience with oil rigs indicates that biological production and biodiversity are enhanced due to the presence of the decommissioned structures (Frumkes, 2002; Sayer and Baine,2002). While partial removal is cheaper at time of decommissioning it also incurs extra costs due to the requirement for subsequent monitoring of the site.
- Repowering as defined here includes two types of actions. Full repowering refers to the complete dismantling and replacement of turbine equipment at an existing project site. Partial repowering is defined as installing a new drivetrain and rotor on an existing tower and foundation and allows extending the wind park lifetime to two generations (Sun et al., 2019). Partial repowering – for example by replacement of only the turbine drivetrain and rotor—allows existing wind power projects to be updated with equipment that increases energy production, reduces machine loads, increases grid service capabilities, and improves project reliability at lower cost and with reduced permitting barriers relative to full repowering and greenfield projects.

According to the German Federal Ministry for Economic Affairs and Energy (BMWI, 2015) offshore wind energy offers significant economic development potential. Whether during the construction of plant components, the assembly of a wind farm or its subsequent operation – generating energy from the sea requires products and expertise from numerous industries. The fledgling technology is also in need of specialised professionals. The BMWI report (2015) mentions following elements in the value creation chain in offshore wind energy:

- Project planning and development
- Financing and insurance
- Turbine construction
- Transport and assembly for turbines and wind parks
- Grid connection
- Operation and maintenance

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- Disassembly and/or repowering

Each of these elements requires specialised labour and facilities most of which will have to be stationed at or near the coast. In Belgium, the existing and rising economic relevance of the offshore wind energy business is expected to result in about 16,000 jobs between 2010 and 2030 being created (Belgian Offshore Platform 2019). The European Union anticipates 170,000 jobs in the industry by 2020 and around 300,000 just a decade later (BMWI, 2015). Profiles that will be needed range from technical profiles, such as engineers and skilled workers from the metal and electrical industries, surface engineering and mechatronics, meteorologists, geologists and marine biologists, skippers and machine operators industrial climbers and divers, but also commercial experts who can assess the economic viability of future wind farms and experts in financing and insurance and in the areas of approval and certification In Belgium, 39 percent of the interviewed stakeholders expect the labour market and access to qualified employees to become a problem in the future (Kruse et al., 2020).

When it comes to facilities, the mere size of many of the components involved poses logistical challenges (BMWI, 2015). For example, motorway bridges with a standard height of 4.5 metres are insufficient for the transportation of the six-metre-wide rotor blades. To support the offshore wind farm industry ports can provide facilities for (BMWI, 2015) preassembly during deployment or the import and export of the installation for both of which sufficient storage space, quay surfaces with heavy-duty capacity and loading capacities are essential. Ports can also be safe havens in bad weather, for the ships used in wind farm construction. For maintenance and operation (M&O) of the wind park, the port can take on a service function offering response, supply and research, development testing and training. For the decommissioning, one of the 4 main concerns of Belgian Stakeholders (Kruse et al., 2020) is the large storage space requirements to store the decommissioned parts of turbines before having them sent to other locations. Almost half of them (44%) believe new facilities will be required for waste management and recycling.

An adapted CLD, taking into consideration these aspects in more detail, is shown in Figure 18.

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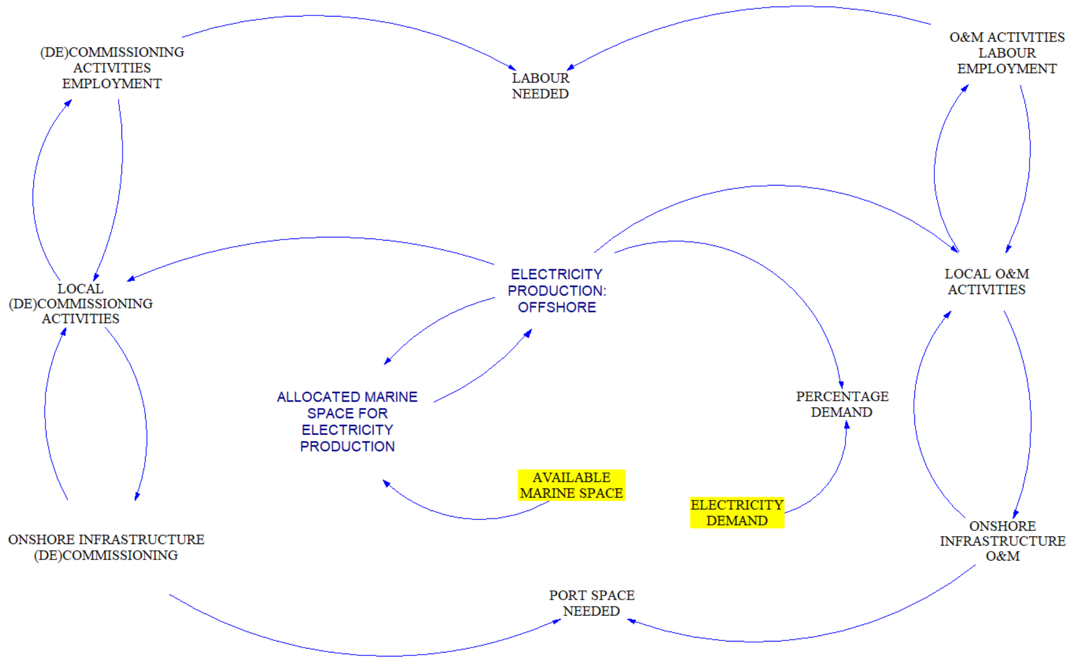

Figure 18: Adapted CLD with focus on the activities accompanying wind parks at sea, infrastructure and labour force requirements. (inputs are yellow)

The next step in the model design was to define a stock-flow model structure which could cover the principal processes in the CLD: the installation, ageing and removal of the turbines. Then, variables depending on the number, size and age of turbines (energy production, maintenance costs, labour needed,…) could be added easily. A general overview of the complete model structure for the port and energy (decommissioning) model is shown in Figure 19. An age-cohort model based on co-ageing (Sterman, 2001), similar as used in demographic models, is at the core of the stock-flow structure. The dynamics of the chained cohorts governs the installation of new offshore wind turbines, their ageing, and the decommissioning when the turbine life time is reached. All calculations are based on a yearly time step although parameters such as the time required for dismantling a turbine can be less than a year. The co-ageing model core is the basis for deriving the power capacity and power generated (based on the turbine power, power reduction due to ageing and operational hours), the maintenance costs (depending on the turbine age), employment for installation, maintenance and decommissioning, and final the spatial-environment aspects and infrastructure. Life time extension is automatically managed in the model with age cohorts up to a maximum age of 28 years (the actual life time being around 20 years). The installation of new wind parks, initial turbine power, turbine life time, use of offshore space and operational costs are introduced in the model as time series read from an external data file (spreadsheet). In addition to a business-as-usual scenario for the decommissioning rate and derived indicators, the model can be used to examine the impact of other planning scenarios or sensitivity for model-specific parameters, such as the decommissioning rate.

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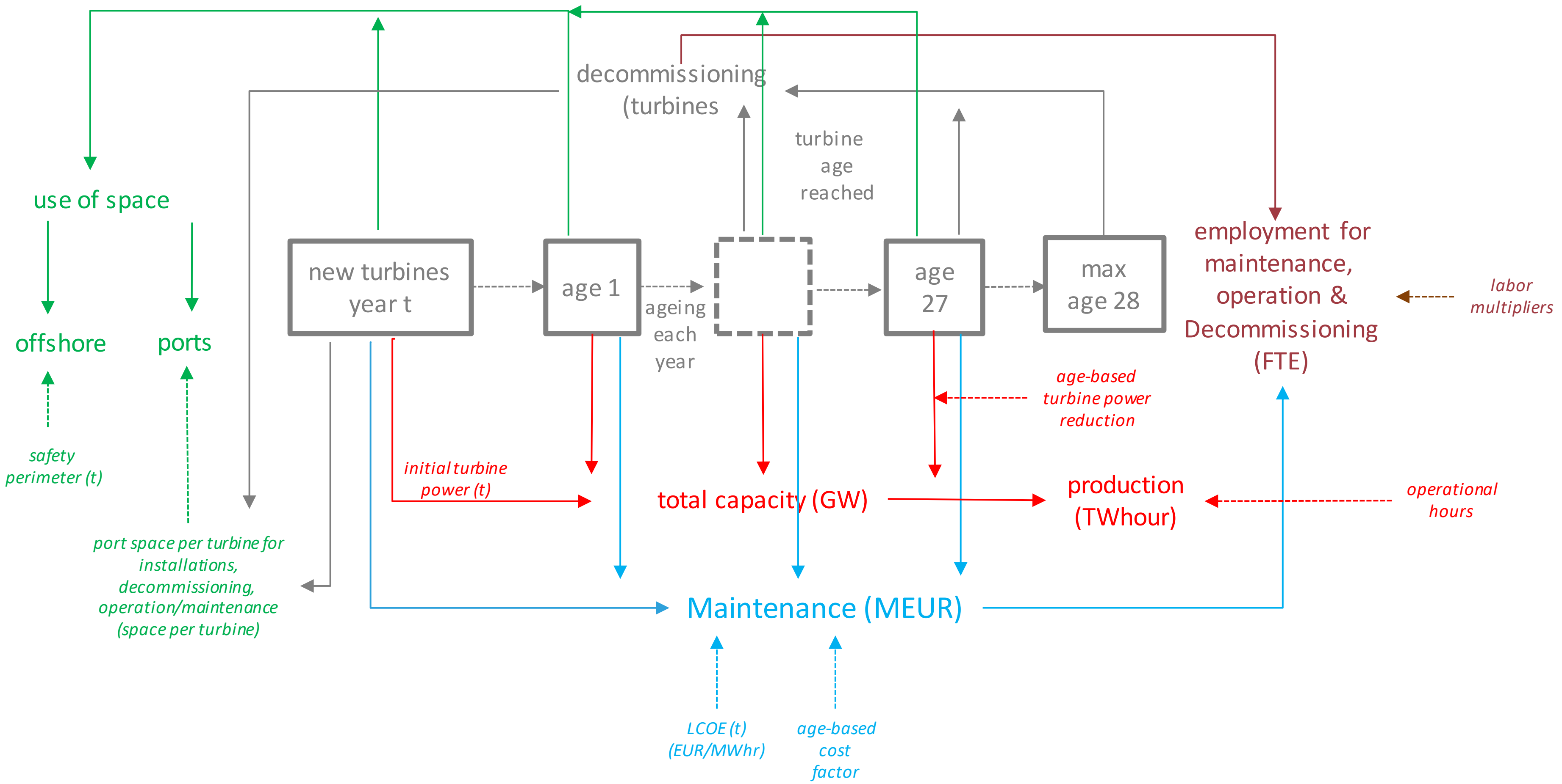

Figure 19: General model structure for the port and decommissioning model.

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3.1.3.5 *Quantification of the port and energy sub model*

The decommissioning model uses a yearly time step *dt* to calculate the time period 2008-2050. The year 2008 was selected as this is when the first turbines were installed. Quantification of the model structure (Figure 19) is based on the following elements:

1) A generic equation for the actual number of wind turbines *N(t,T)* in year *t* for age cohort with age *T (*Figure 20*):*

$$N(t,T) = N(t-dt,T) + N(t-dt,T-1) - N(t-dt,T) = N(t-dt,T-1)$$

   The number of ageing turbines are either added to the next age class or removed in case the age of the cohort matches the life span for the actual year minus the age of the cohort (by using the scenario for the life span).

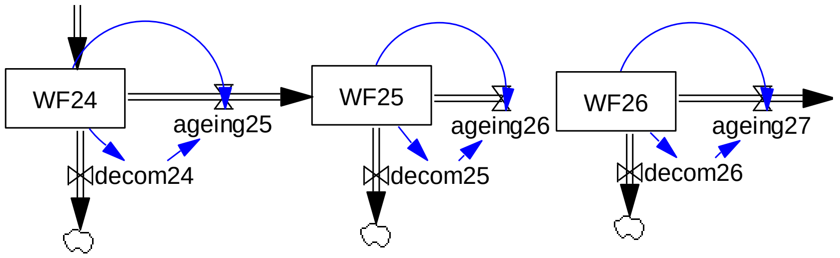

Figure 20: Age-cohort mechanism used for the wind turbined (graphical representation in VenSim).

2) Different time series corresponding to different scenarios where produced for the planned installation, known life span of the turbines, initial power capacity of the turbines, maintenance costs and demand of offshore and onshore space per turbine taking into account a safety perimeter. These are read from an external spreadsheet, which can be updated or corrected quickly if needed. As an example, Figure 21 shows the standard scenario for the maintenance costs, expressed in terms of the Levelised Costs of Operational Energy or LCOE in EUR/MWhr.

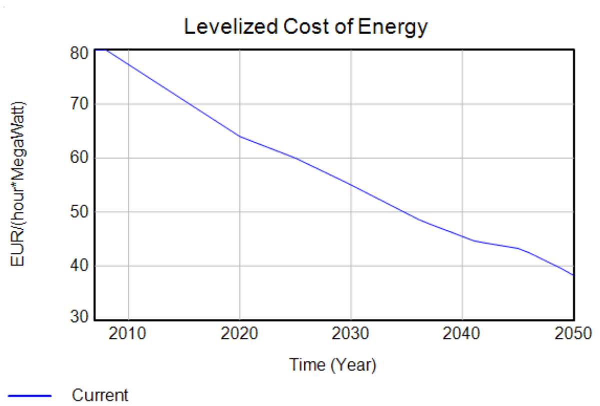

Figure 21: Scenario for the Levelized Cost Of Energy (LCOE) in EUR/MWhr.

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3) Parameters (aka fixed constants) to derive secondary variables, such as the employment demand or use of space. If necessary, any of these constants can be made time dependent and added to the scenarios. Examples are the number of yearly hours of operation, the yearly loss of power due to ageing, the number of persons employed per turbine (FTE) etc.
4) The use of non-linear response functions representing the dependency between variables. In the existing model, only one such response function was used for the impact of the turbine age on the maintenance costs. This function is then multiplied with the LCOE to calculate the maintenance cost.

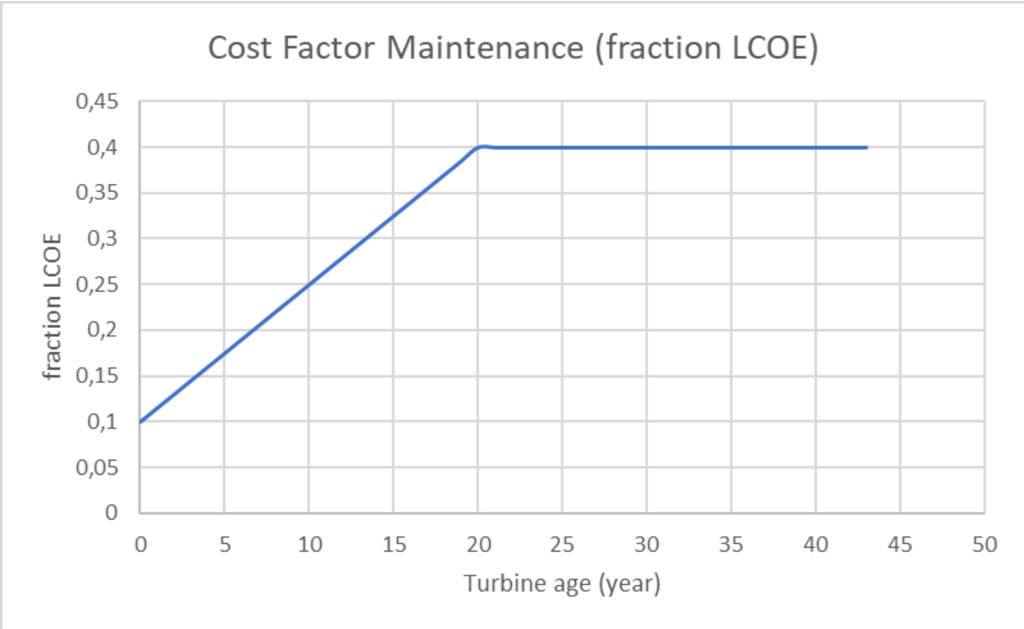

Figure 22: Impact of turbine age on the maintenance costs.

A complete and detailed overview of all variables, parameters and equations is found in Annex 4A.

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3.1.4 Overview of the stock-flow models and land- sea interactions

The two model subsystems are not strongly connected as the general Causal Loop Diagram (Figure 9) shows, and it is not considered meaningful to integrate the two models. Referring to model structures shown in Figure 13 and Figure 14(Oudland polder model) and Figure 19 (decommissioning model) we conclude both sub models provide support for systemic analysis:

- For the **Oudland polder model** the stock-flow model structure links land use planning with water management and gentrification in agriculture. The complexity of the model is in the equations and data rather than the feedback structure. The water management is different for areas intended for agriculture and nature. One of the questions raised by stakeholders was how introducing separate compartments for the land occupied by agriculture and by nature could affect the water balance for these areas. The water component of the stock flow model furthermore allows investigating the effect of changes in the different water sources and sinks including natural ones such as precipitation and evapotranspiration which will change with climate change but also water reuse from waste water treatment plants or rainwater collected from paved areas and the buffering of water in creek ridges. The latter all being forms of possibilities for human intervention in the polder water balance. A somewhat different topic covered by the stock flow model is the gentrification of farms in the polder region. While this is, as it is modelled now, mostly an autonomous process in the model, some feedback was introduced to account for effect of land use changes on gentrification. The gentrification model is also affected by the water management by considering the effect of water management on suitability for agriculture / nature. Land-sea interactions are included through the impact of sea level rise on water discharge for the polder. This is not an immediate concern for this region, but the problem was raised several times during the sector workshops and implies that the installation of pumps to remove water will be necessary in the future.

- For the **port and energy model**, now focusing on the decommissioning of offshore wind turbines, the systemic analysis covers the logistics, economic and energy aspects of offshore wind farming (Figure 19). With the decision to focus the model further around the **decommissioning rate** (the long-term pattern of the yearly number of decommissioned turbine), it was necessary to reconsider the definition of stock and flow variables and use the age-cohort system and age-based stocks (Figure 20) to build up the model. At a general level, this is not a complex model both in terms of the feedback structure and equations used. Some feedback is present in the age-cohort chains. In line with the reality of marine spatial planning in the Belgian coastal zone, the model is strongly exogenously driven by planning scenarios for installation of the turbines and technological factors, such as the turbine capacity and maintenance costs. Intrinsically, the final model is a graphically designed accounting model. The holistic value of the model could be increased by including the impacts of systemic limitations, for example a lack of skilled labour or port space could limit the capacity for

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decommissioning the wind turbines. Some tests were run to examine the potential usefulness, but this was considered to be of academic and educational value rather than practical value for the priorities indicated by the actor partners. Therefore, the priority is given to improving the data used by the model and discussing the usefulness of the model simulations for long-term planning with selected stakeholders. This will be done in conjunction with the EU-funded project DecomTools[8], which focuses more on the engineering and technological aspects, and short-term planning of decommissioning. In the future, the model could be elaborated in terms of material reuse and the impacts/demands on port infrastructure.

[8] https://northsearegion.eu/decomtools/

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3.1.5 Business and policy analysis

The user interaction with **the Oudland polder model** is through a policy dashboard that provides access to a selection of drivers and key policy indicators for the water management, land use and the gentrification (Figure 23). The model can be used for short and long-term planning related to the water and land use management in the polder as well as the gentrification. The model structure reflects a water balance for a polder area with two compartments, one for agriculture and one for nature coupled to land use information and a stock flow model for the gentrification. Using the stock-flow models for the Oudland polder, the following interventions and policy impacts can be addressed:

- Changes in the polder water balance due to land use (farmland or nature) but also climate change and vice versa the land use that is feasible given climate change;
- How much water is available for recharge to the polder considering that the available water could be needed for other uses such as drinking water production or maintaining a minimum discharge to the sea to avoid salinification of the canal?
- What is the effect of different polder water level management schemes? What would be the effect of changing the drain layout and thus how fast re/discharge affects the polder level?
- How will sea level rise affect the capacity for discharging water from the polder? How much pumping capacity is required to remove the water?
- How will changes in population and tourism affect the water management in the polder?
- Will it help to buffer water to bridge periods where there is not enough water and if we buffer how big does the buffer have to be?
- How can water management decisions affect the land use (agriculture/nature/residential)?
- How will farming in the polder evolve and to what extend will it still exist due to gentrification?

The Oudland polder model is relevant for short- and long-term strategic planning of water and land use management in the Oudland polder but can, with the necessary configuration changes, be adopted to any polder area. With respect to the EU regulatory frameworks and directives, the model is of relevance for the EU Green Deal due to its components for agriculture and environment.

The port and energy model has been fitted with a policy dashboard showing a broad selection of key policy indicators related to the actual size of the wind park, the decommissioning and installation of turbines, the energy production capacity, maintenance costs, use of space and employment (Figure 24). The model can be used for long-term planning related to the logistic, infrastructure and economic aspects of installing and decommissioning offshore wind turbines. The generic model core based on age-cohorts for turbines and modular design of the model using separating scenarios, policy indicators, engineering and economic aspects of the model, and input data is flexible and can easily be adapted or updated.

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Typical interventions and policy impacts that can be examined with the model include:

- New (spatial) planning scenarios for offshore wind parks;
- Different technological scenarios (power, size and life time of the turbines, maintenance costs);
- The implications on direct and indirect employment, both onshore and offshore;
- Examining the role of specific parameters, such as the time required for installing and decommissioning the turbines, the yearly operational hours and the power loss rate.

The port and energy model is relevant for mid- and long-term strategic planning of offshore wind energy production in the Belgian North Sea and other EU territories, the contribution to achieving carbon neutrality by 2050, and the port infrastructure planning. With respect to the EU regulatory frameworks and directives, the model is of relevance for the EU Green Deal, EU-MSFD, and the EU Blue Growth Strategy.

In all the above stock flow model models changes to scenarios, which match the time frame of the EU Green Deal, and parameter settings are easily implemented by adapting the input data which have been gathered in xls worksheets without requiring editing the model itself. Both models also combine a generic design and high degree of flexibility in data structure, enabling application to other regions and elaboration with additional scenarios or parameters without significant effort.

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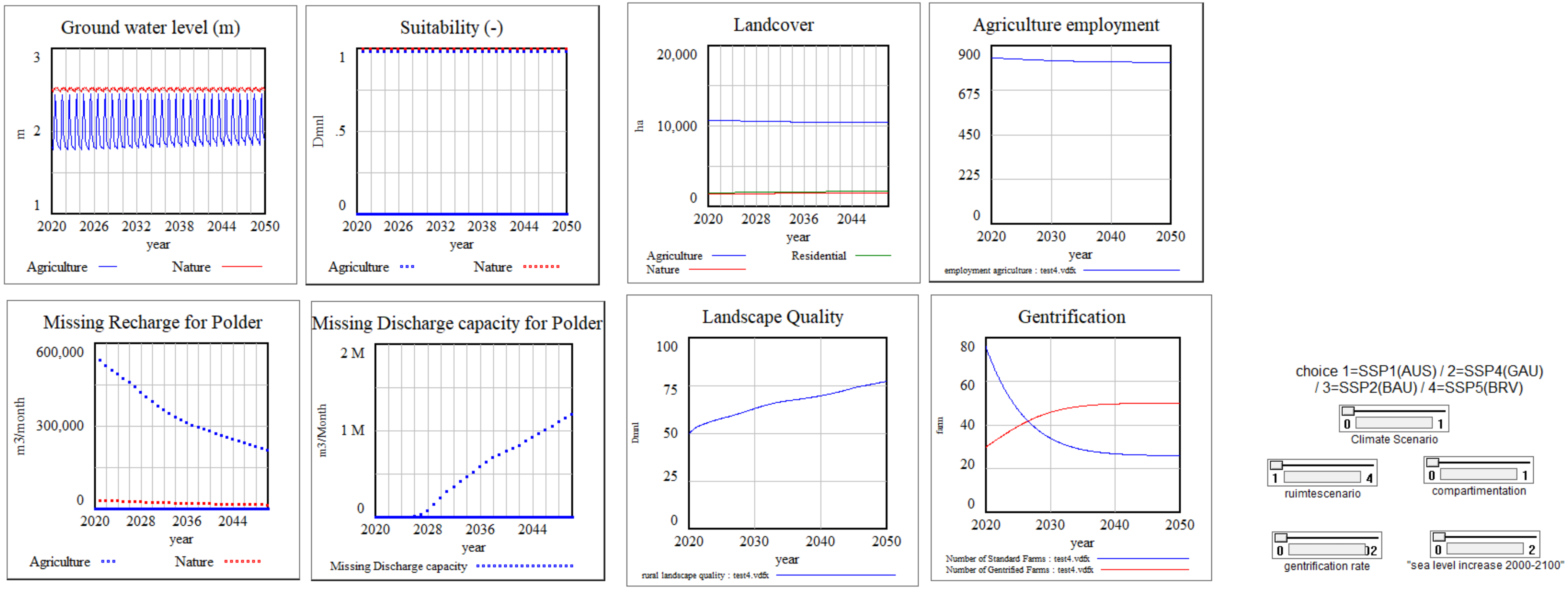

Figure 23: Selected indicators for the Oudland polder model as visualized in the model dashboard.

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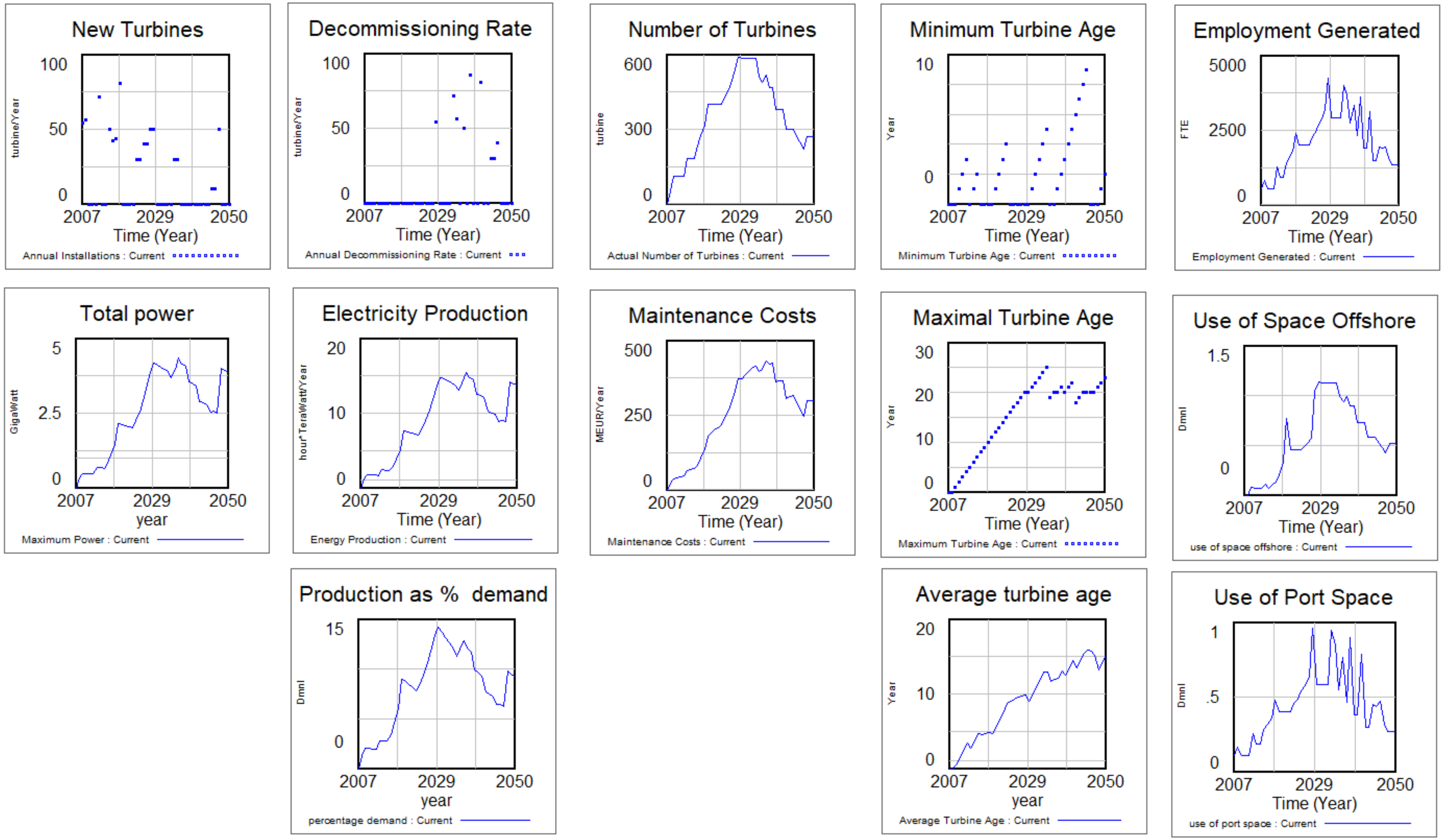

Figure 24: Overview of key indicators in the policy dashboard for the decommissioning model.

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3.1.6 Model confidence building

3.1.6.1 Oudland Polder Model

The development of the Oudland Polder model was based on feedback provided during regular meetings and the second multi-actor workshop with the VLM and other stakeholders that were considered relevant such as ILVO (Flanders Research Institute for Agriculture, Fisheries and Food) and INBO (Research Institute for Nature and Forest). During these meeting model focus shifted, partially also due to changes in the participants. Where during the first meeting with VLM the model scope was mainly on hydrology and the effect of introducing separate compartments for agriculture and nature water management, in subsequent meetings land use management and gentrification were considered more important. This shift in scope was mainly due to the realisation that spatially explicit numerical hydrological modelling results already exist or are planned in the near future. As stakeholders are used to such detailed model results they had difficulties seeing the added value of the stock flow water balance results which represent the polder water level with a single value. It was therefore decided to broaden the model scope and include land use change and gentrification as well as soft variables such as scarcity awareness which are not considered in numerical hydrological models. For gentrification several small models were constructed to present the concepts underlying the dynamics during the different meetings and a first model was also realised as part of the Oudland Polder model. As ILVO have a lot of knowledge regarding gentrification, a dedicated meeting was also held with them during which it was decided that the current model for gentrification will need to be revisited and improved in a later stage. This additional model development will not necessarily jeopardise the timing of the rest of the process as model implementation is straight forward in Vensim. Summarising, for the Oudland Polder model development will have to continue into the third reporting period but will go hand in hand with regular stakeholder consultation to assure model development is in line with the stakeholders needs.

3.1.6.2 Port and Energy Sub model

The original plan was to obtain stakeholder feedback on the Port and Energy sub model during the second multi-actor workshop. This workshop was organised as an online event on February 26, 2021. Around 40 stakeholders covering both rural and coastal sectors were invited. Unfortunately, there was little if no will from the blue industry sector to participate, except for the actor partners already participating in the project. Therefore, it was decided to let the model be cross-examined at a later stage, preferably in conjunction with an oncoming event for the EU-funded project DecomTools, which addresses the decommissioning of offshore wind turbines from a technological and engineering perspective. However, the model has been tested and proven to be correct in technical terms. Nevertheless, a "counterintuitive" drop in the total number of wind turbines is observed around the year 2030 (see Figure 24). This would imply under-exploitation of offshore space reserved for wind energy production, which is highly unlikely as it contradicts the anticipated development of renewable energy. Closer examination of the model and problem revealed this was caused by a lack of a timely replacement of decommissioned turbines in the planning scenarios read by the model. Therefore, the data used will be examined in more detail, improved prior from any direct engagement with stakeholders to discuss the model validity and usefulness for evidence-based long-term planning. Hence, a general lesson learned from the current model is that the long-term patterns for key indicators, such as the decommissioning rate and total size of the wind parks, are highly sensitive for the planning schedule of commissioning (or recommissioning) wind turbines. Other model aspects that need to be verified are the parameter settings for estimating employment related to decommissioning and the use of onshore space, which is a model proxy for the impact on port infrastructure

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demands. More detail will be needed to address this aspect in the model before a meaningful interaction with stakeholders can be organised. As explained in the synthesis section, the effort to adapt this type of model when necessary is limited due to the modular and graphical design.

3.2 Multi-Actor Lab 2 - South-West Messinia (Greece)

3.2.1 General problem scope of the land sea system

South West Messinia (SW Messinia) is a representative example of an interlinked coastal-inland area in the Eastern Mediterranean region well known for its unique beauty and long history (Figure 25).

Figure 25: A view of the SW Messinia case study from Palaiokastro (check view point in Figure 26).

It is a rural area with small towns and villages (Figure 25). The landscape is mainly dominated by olive-trees, which were planted during the 1970s replacing other types of crops (Maneas et al., 2019). Part of the case study is designated as an Integrated Tourist Development Area (ITDA), which is one of the biggest tourist investments in Greece, and a major driver for the economy for the area. At the core of the case study lies a coastal wetland, which is part of a wider Natura 2000 site that includes a variety of Mediterranean habitats and cultural sites (Birds directive 2009/147/EC; Habitats Directive 92/43/EEC).

Tourism is expanding and goes hand in hand with infrastructure development (hotels, roads and airports), the creation of new job opportunities and it can provide opportunities for diversified livelihoods but also increases the pressures on agricultural, water resources management and the environment (Tiller et al., 2019; Maneas et al., 2019; Klein et al., 2014). The area produces olive-oil of high standards, but the current conditions (land fragmentation, willingness to cooperate) add limitations to the sustainability and growth of the sector (Tiller et al., 2019). In addition, the production of olives is mainly based on conventional farming practices (e.g., tillage, use of pesticides, herbicides and synthetic fertilizers), which result in higher run-off from agriculture and subsequently environmental degradation of coastal and marine areas (Tiller et al., 2019; Berg et al., 2018). Meanwhile, the wetland is in a bad environmental state, and unless actions are taken towards the restoration of hydrological conditions and the enhancement of its ecosystem services, it is expected that it may soon collapse with implications to fishing and tourism.

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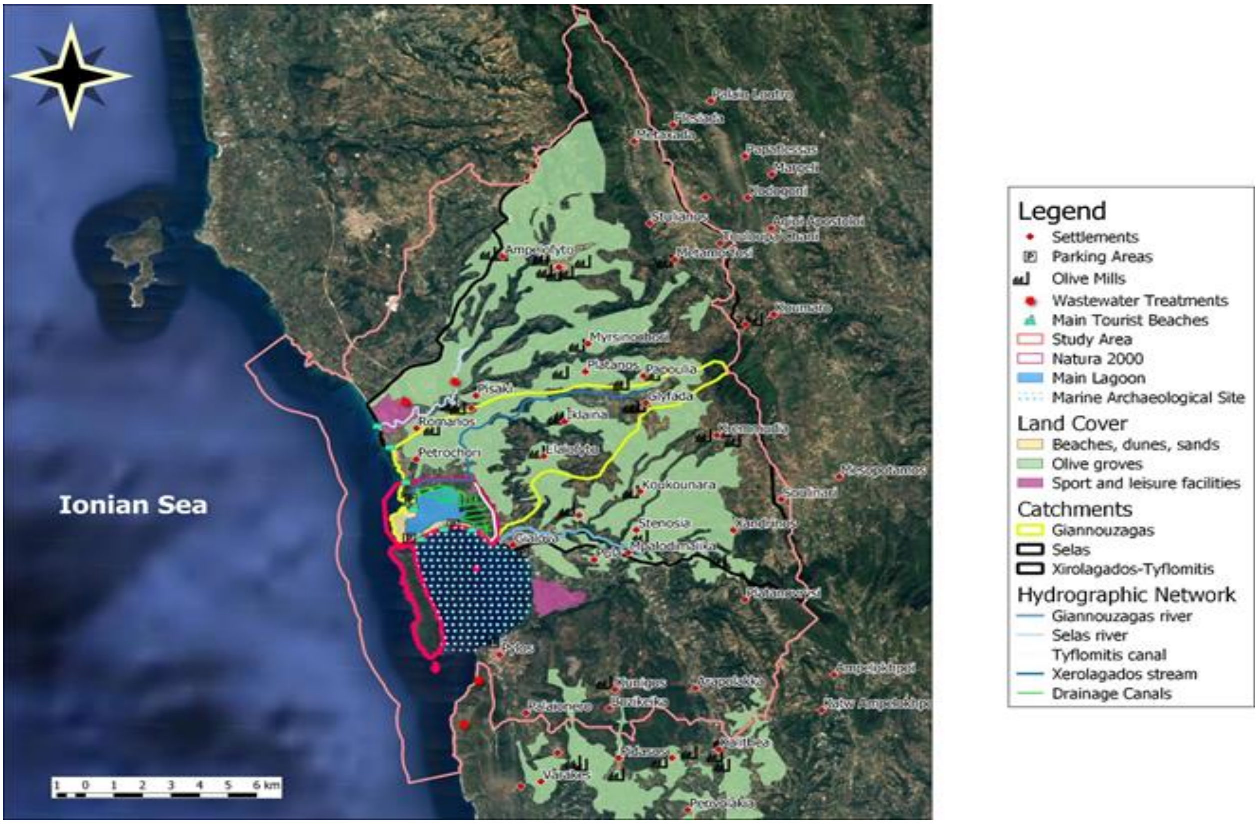

Figure 26: Land uses and pressures in the SW Messinia (Pantazis, 2020).

Potential land-sea interactions to be considered for the Greek case study include:

- How can an increase of freshwater inputs create better conditions in the wetland and the effects on wetland and coastal fishing as well as contribute to the diversification of tourism?
- The potential of integrated farming as a model for olive-oil farming and its effect on the sustainability of the sector, the cyclic economy, the impacts on the wetland, the coastal zone and the diversification of tourism.
- The potential for sustainable tourism including marine tourism activities (such as diving tourism, pescatourism etc) and land agro/eco-tourism activities that would reduce the negative effects of tourism for the local population and the environment.

3.2.2 From Multi-actor analysis to modelling

According to our stakeholders, the main constraints for the sustainable development of the area are the lack of trust and cooperation within and among the sectors of economy. The lack of marine and terrestrial spatial planning further implicates the challenges and limits the options for achieving better conditions (Tiller et al., 2019). These, combined with gaps in legislation and poor enforcement (Tiller et al., 2019) constrain the possibility of adopting and supporting a common vision about the area.
During the first MAL workshop, the common vision for the area was summarized as: “Join forces in creating the Brand Name of Sustainable Messinia that expands across all sectors, activities and

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products” (Tiller et al., 2019). Thus, the model scope was determined based on the outcomes and feedback from the first MAL workshop (Tiller et al., 2019), and our current understanding of the system (Androni & Eleyhteriadi, 2019; Faulwetter et al., 2019; Hatzianestis et al., 2019; Maneas et al., 2019; Manzoni et al., 2019; Berg et al., 2018; Klein et al., 2014; Bousbouras et al., 2011; Koutsoubas et al., 2000). Even in a small area like SW Messinia, the system is quite complex, and there are different levels of detail for each of the components (Figure 27).

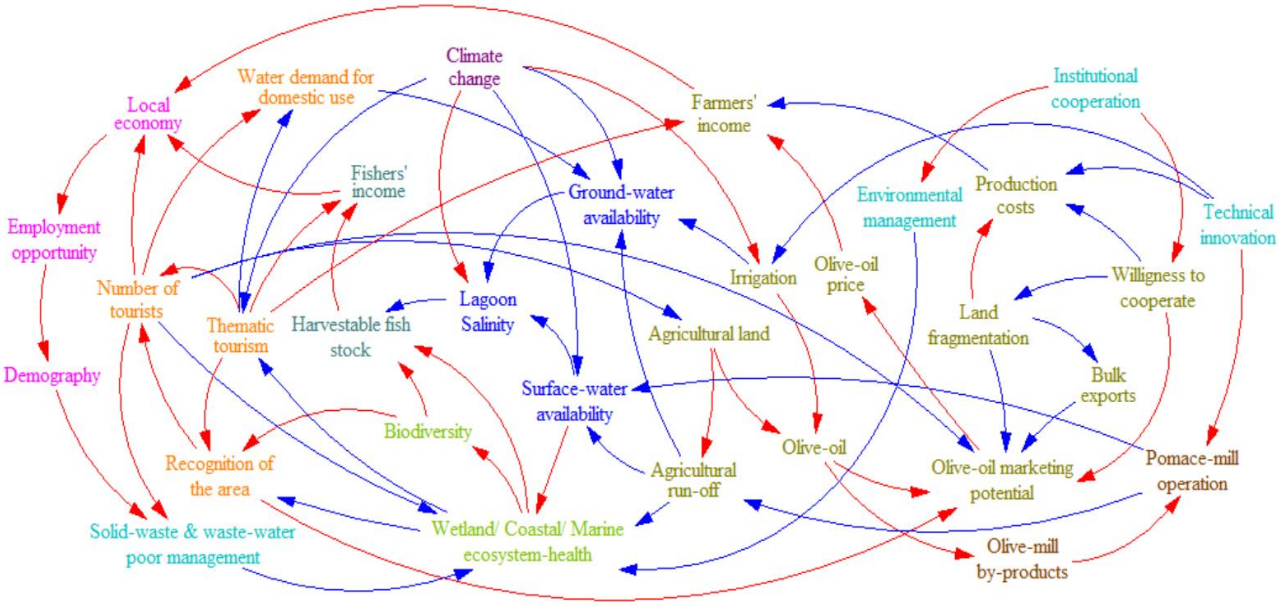

Figure 27: A simplified overview of land-sea interactions described in the combined CLD model (Tiller et al., 2019). Pink colour is used for components linked to population, orange for components linked to tourism, blue for components linked to water resources, light green for components linked to the environment, dark yellow for components linked to agriculture, brown for components linked to local industry, dark teal for components linked to fishing, teal for components linked to institutions and innovation, and purple for climate change.

Starting from current conditions, the aim of the operational model is to show how:

- the restoration and enhancement of ecosystem services in the Gialova Lagoon wetland;
- a shift to more integrated farming practices;
- the current trends of tourism development are putting pressures on land and water resources and the need and possibilities to diversify the tourism product towards thematic sustainable destination tourism

to create the baseline for achieving the common vision for the area (Tiller et al., 2019).

Thus, our approach is based on dividing the whole model into two sub models that when combined connect all the different land-sea interactions that are important for our case. One model focuses on the Gialova lagoon and the pressures on the most sensitive ecosystem of the area, which also supports a viable fishing community. The other sub model focuses on the land uses of tourism and farming, the interactions between them and their relation to the status of the lagoon and the marine environment. The second model is an outcome of the combination of the previously separated sub models of farming and tourism, which were decided to be included in a common view due to the increased links and connections between them.

Both sub models will consider possible effects of climate change (temperature changes, precipitation, desertification vulnerabilities etc.).

Increased monitoring and remote sensing in the farm could benefit both the agricultural and the public sector reducing the impact to the environment. New technologies in the farm could lead to optimized use of water/natural resources and prudent use of agrochemicals (reducing farmers' costs) and to a more effective management/follow-up of the whole production process (from farm to fork), generating more free-time for farmers (improving farmers' well-being). Such agriculture could be more attractive to young generations. Coupling new technologies with authenticity could boost the local/regional olive-oil production and create new high-quality products. Agri-, pesca- and eco-tourism activities have great potential in the area and offer opportunities to increase land-sea synergies, coastal-rural stakeholders' collaboration and the creation of more jobs. It can also create a new market for local products.

3.2.3 Sub model 1: Wetland salinity regulation and enhancement of ecosystem services

3.2.3.1 Model scope for the wetland

The problem and related model scope was determined based on the outcomes of the first MAL workshop (Tiller et al., 2019), and our current understanding of the system (Maneas et al. ,2020; Androni & Eleyhteriadi, 2019; Faulwetter et al., 2019; Hatzianestis et al., 2019; Maneas et al., 2019; Manzoni et al., 2019; Bousbouras et al., 2011; Koutsoubas et al., 2000).

The main challenge that needs to be addressed is the regulation of salinity inside the Gialova Lagoon wetland, where over the years, the combined effects of increased salinity and limitation in water circulation have led to extensive reed and cattail mortality, which are typical habitats for water birds (Maneas et al., 2019). The survival of commercially important fish species found in the lagoon is also affected by salinity. At present, the wetland is characterized as saline with hypersaline conditions for nearly 30% of the year, and unless freshwater inputs are enhanced by restoring hydrologic connectivity between the wetland and the surrounding freshwater bodies, salinity in the lagoon is expected to increase even more under future drier and warmer conditions (Manzoni et al., 2020).

The wetland has gradually reached to this status after the diversion of the local river (Xerolagados), and of the local upwelling groundwater resources (Tyflomitis aquifer) to the sea, which happened in the 1960s. Up to today, most of the fresh water resources are still diverted to flow at sea, and only a small fraction of Tyflomitis upwelling groundwater is feeding the wetland. Under these conditions, the wetland salinity continues to increase, but the reconnection of the wetland with more fresh water inputs could reverse the increasing trend. However, measurements taken during the COASTAL project (HCMR report, D33) showed that when these resources meet the wetland they are already impacted by nutrient loads, thus any attempt to restore connectivity could create other problems (e.g. eutrophication). In addition, the related river resources are polluted by olive-mill by-products, and the related groundwater resources are used for irrigation and drinking water supply and there is a need

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to balance between societal and conservation needs. The part of the CLD that it is relevant to the model scope is shown in Figure 28.

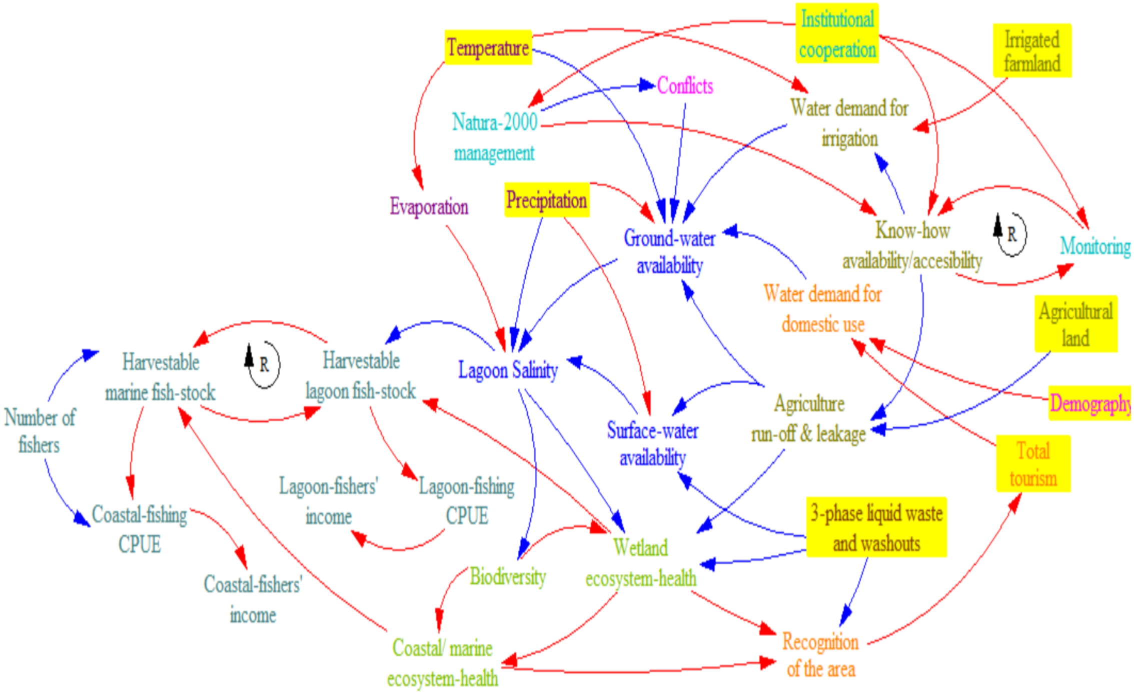

Figure 28: Part of the MAL2 CLD that relates to the model scope (yellow: inputs) (Tiller et al., 2019). Pink colour is used for components linked to population, orange for components linked to tourism, blue for components linked to water resources, light green for components linked to the environment, dark yellow for components linked to agriculture, brown for components linked to local industry, dark teal for components linked to fishing, teal for components linked to institutions and innovation, and purple for climate change.

3.2.3.2 Quantification of the wetland salinity regulation

From discussions with experts and local stakeholders a model for salinity regulation in the wetland should contain the following processes:

- Flora and fauna species have a specific tolerance to salinity that is critical to their survival, and when salinity exceeds certain limits, the ecosystem becomes toxic to organisms;
- Climate change is expected to result in higher temperatures, and in changing precipitation, evaporation and evapotranspiration patterns. This could result in reduced fresh water availability from the aquifer, increased salinity and prolonged hypersaline conditions;
- Groundwater availability is critical for lowering the salinity levels. However, irrigation and domestic supply are based on groundwater resources. For the case of Tyflomitis-Xerolagados catchment, an increased demand has an effect on the groundwater aquifer that supplies the wetland with fresh-water inputs;
- Surface water from the catchment is regularly polluted with liquid wastes from the operation of 3-phase olive-mills and cannot be used to enrich the wetland;
- Run-off and leakage from agriculture affect surface and groundwater quality increasing the impact of nutrient load to the wetland;

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- The lack of water management both for nature and for people can create conflicts that could result in decreased availability of fresh water inputs to the wetland.

The details for the quantification of the pilot Water – Wetland model are described in D13. Here we present an overview of the selected inputs and the final structure of the operational model (Figure 29).

The calculation period for the wetland operational model is from 2020 to 2100, and it is applied at the Tyflomitis-Xerolagados catchment area (part of the Greek case study). The physical characteristic of the groundwater aquifers (e.g. size, geology, discharge to adjacent aquifers) are imported as fix rates based on available information from previous studies in the area (ENVECO, 2008) and GIS analysis. The climatic conditions and their change in time are based on projections from XENIOS project from 2013, based on the A2B scenario of the IPCC.

The groundwater abstraction to cover the irrigation demand, is an input given as abstraction per well. The current value is based on available information from previous studies (ENVECO, 2008, Pantazis, 2018). The effect of climate change (CC) on irrigation demand is similar to the effect of CC on evapotranspiration ET. The groundwater abstraction for water supply (as drinking water) is an input which is based on population and tourism trends (calculated under sub model 2). The percentage of the water supply which is linked to the Tyflomitis aquifer is based on available information from previous studies (ENVECO, 2008), and it is validated in communication with the local water agency (during the second MAL in March 2020). The fractions for the fresh water inputs into the lagoon are estimated based on field observations by experts on site.

On an annual basis, the Mean Annual Salinity in the wetland is dependent on fresh-water inputs/outputs and saline-water inputs/outputs. For the scope of the model we will assume that the lagoon volume is not changing on an annual basis. The value of the current salt mass (at 2020) was estimated based on previous work (Manzoni et al., 2020) and current measurements (NEO stations). The hypersaline ratio is a ratio which compares the lagoon salinity with the sea salinity which is a constant. For the fish tolerance ratio, we used the salinity preferences of sea-bream, a species that prefers water bodies with relatively high salinity, and has an optimum between 30 and 40 g/L. For the aquatic vegetation ratio, we used the tolerance of reed (around 15 g/L).

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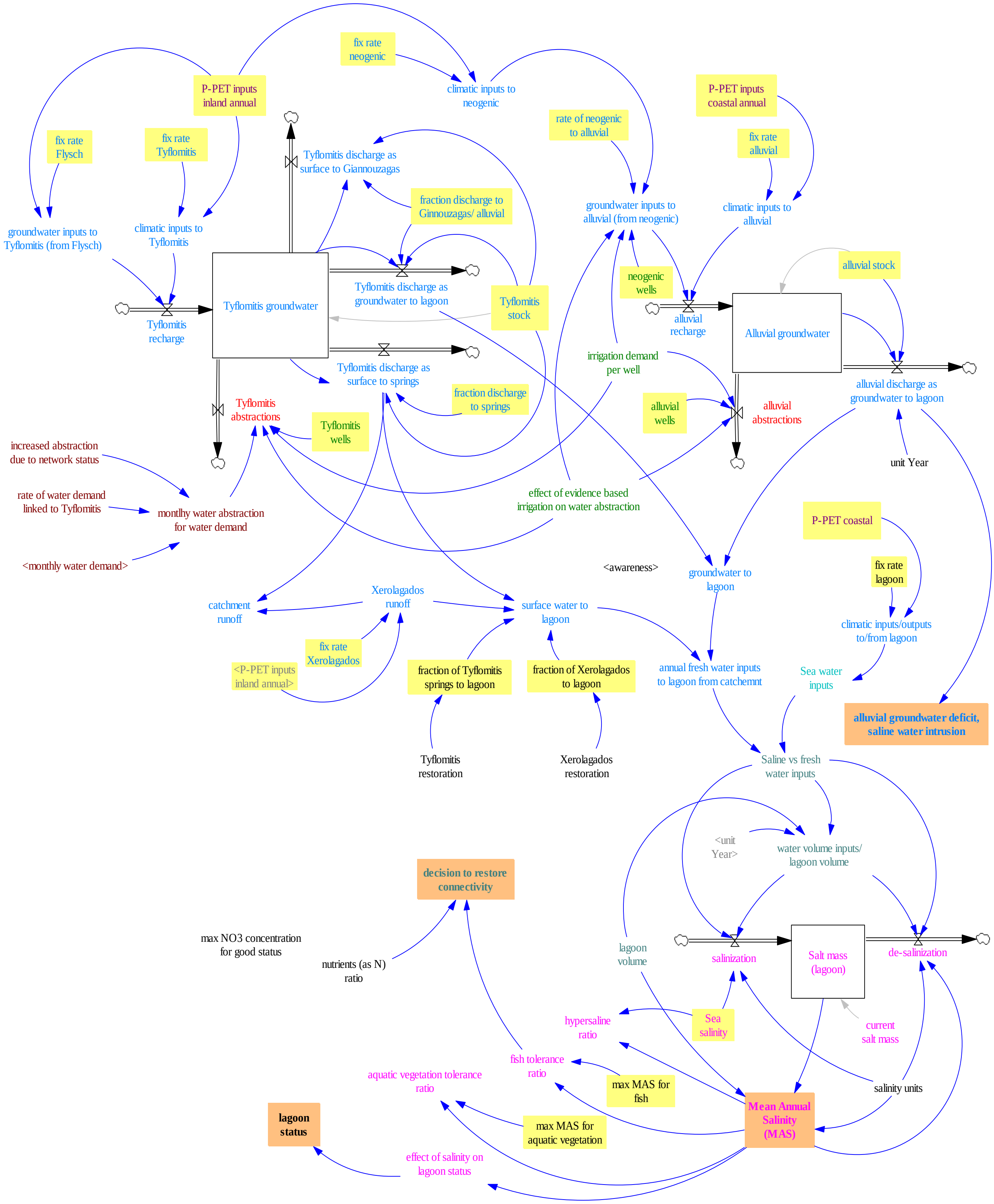

Figure 29: Wetland – Water operational sub model for the Greek case study. Blue for variables linked to groundwater and surface water. Light blue for variables linked with sea water. Teal for variables linked to wetland water. Pink for variables linked to wetland salinity. Green for variables linked with agriculture. Dark red for variables lined to water demand for municipal use. Purple for variables linked with climate (precipitation, evapotranspiration). Variables in a yellow box are inputs in the system. Variables in an orange box are KPIs.

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3.2.4 Sub model 2: Shift from conventional to integrated farming

3.2.4.1 Model scope for of the shift from conventional to integrated farming

The model scope was determined based on the outcomes of the first MAL workshop (Tiller et al., 2019), and our current understanding of the system (Holmering, 2020; Myers et al., 2019; Berg et al., 2018; Salguero Engstrom, 2018; Kjellström, 2014; Xenios, 2013).

The part of the CLD that it is relevant to the model scope is shown in Figure 30. Messinia is considered as one of the most important regions regarding the production of extra virgin olive oil in Greece. Some of the farms are irrigated, and most of them are cultivated based on conventional practices (e.g., tillage, use of pesticides, herbicides and synthetic fertilizers), which result in higher run-off from agriculture and subsequently environmental degradation of coastal and marine areas (Tiller et al., 2019; Berg et al., 2018). The quality of olive oil is also affected by the intensity of farming practices and make farms less competitive on the market by impacting their sustainability and product quality, and there is a need to improve the olive-growing sector's management practices by optimizing their resource use in a more effective and sustainable way.

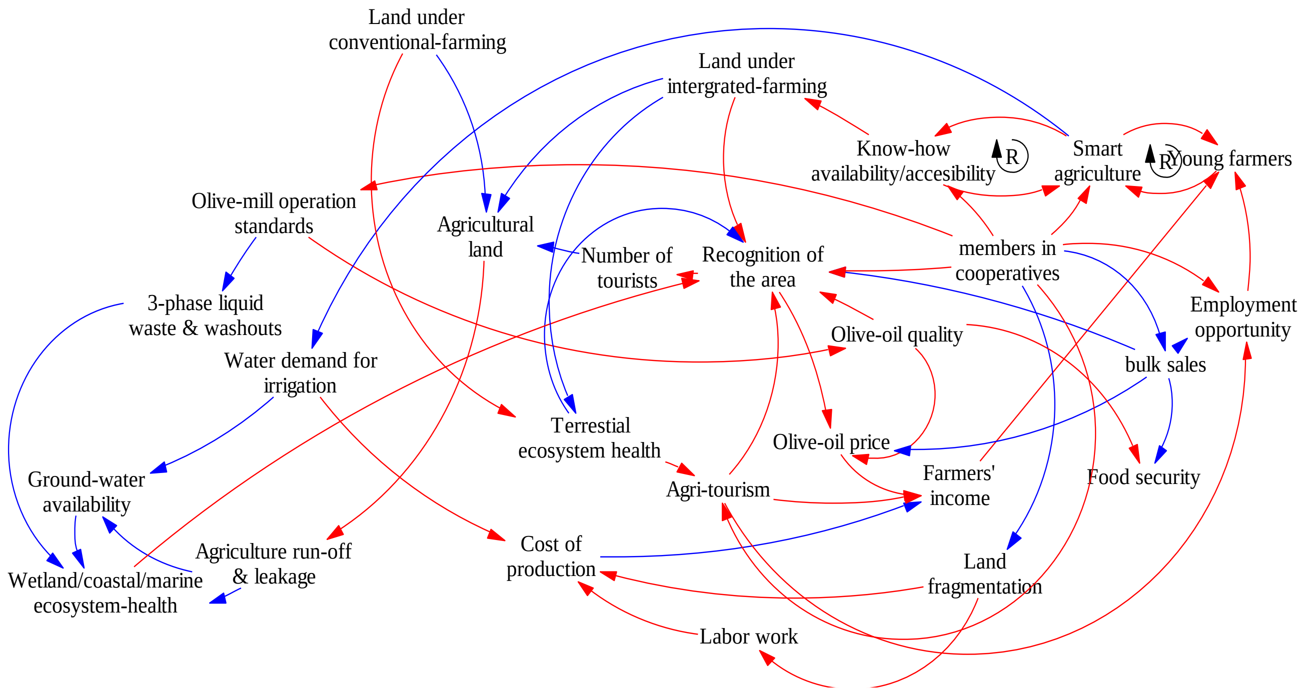

Figure 30: Simplified Version of the MAL2 CLD that relates to the pilot model 2 scope (adapted from Tiller et al., 2019).

The main challenge faced by this model is the willingness of the farmers to convert to integrated practices first and then gradually into organic practices. According to our stakeholders, a transition from conventional to organic farming is not a realistic goal (Tiller et al., 2019), at the moment. However, during the last MAL workshop, some of them agreed that it would be something that could be considered in 10 -20 years' time, and once the first step had been successful. Currently their vision

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includes a transition from conventional to integrated olive farming, and they argue that a more integrated olive farming model is the most proper way to sustain olive-oil production in the area up to specific standards (Tiller et al., 2019). However, still such a transition requires a change in practices and the exploitation of technological advances that is not straightforward given the small size of the average farms, and the average age of the farmers, in Greece (Pavlis, et al, 2016). Our stakeholders have suggested that by cooperating they could reduce the initial costs and hence increase the willingness to adopt more sustainable agricultural practices. However, at the same time farmers have identified a lack of information and knowledge, as well as a lack of trust and ability for cooperation. These issues have repeatedly been identified by previous researchers in the area and are recognised as barriers for transformation.

Integrated farming is perceived as a selection of farming practices able to combine the benefits of conventional and organic agriculture leading to a lesser environmental impact while sustaining a sufficient crop yield to ensure an economic profit. It uses a more planned and evidence-based approach for the application of pesticides, and similar to organic farms, uses fertilisers that are naturally-derived instead of synthetic ones (Pimentel et al., 2005; Papadopoulos 2015). At the same time tillage and herbicide use are replaced by mowing, reducing the risk of soil erosion (Berg et al., 2018). The practiced followed in integrated farming increase the natural value of the land, providing better support for biodiversity. Integrated olive-farming requires high standards of olive-mills for olive-oil extraction eliminating the contamination of surface waters by the operation of 3-phase olive-mills. This will increase food security and create a brand name for the olive-oil production, which should lead to reduced bulk exportations, increased marketing potential, and thus profit for the farmers.

3.2.4.2 Quantification of the shift from conventional to integrated farming

For developing the pilot stock-flow model for the shift from conventional to integrated farming, we will greatly depend on the variables and the connections described in the relevant CLD (Tiller, 2019). However, since the initial CLD refers to organic farming, when creating the Pilot SD model (Viaene, 2020) we proceeded with changing organic to integrated farming and have now included this as an intermediate step for the transition to organic farming, the model has been simplified and adapted from the pilot version presented in D13 following discussions with experts and stakeholders. However, the main concepts remain the same.

From discussions with experts and local stakeholders a model for the shift to integrated farming should contain the following processes:

- Factors affecting farmers choice to adopt integrated farming practices at an individual level, which relate to the perceptions, regarding costs and knowledge on what is needed (Figure 31)
- The transition factors that affect the rate of change at a social level which relate to policies, subsidies, the price of olive oil and the ability to use technological advances (Figure 31)
- The potential effect of these changes at the price of the olive oil (Figure 32)
- The effect of the changes on water quality (Figure 33)

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- The effect of the changes on land biodiversity and area attractiveness (Figure 34)

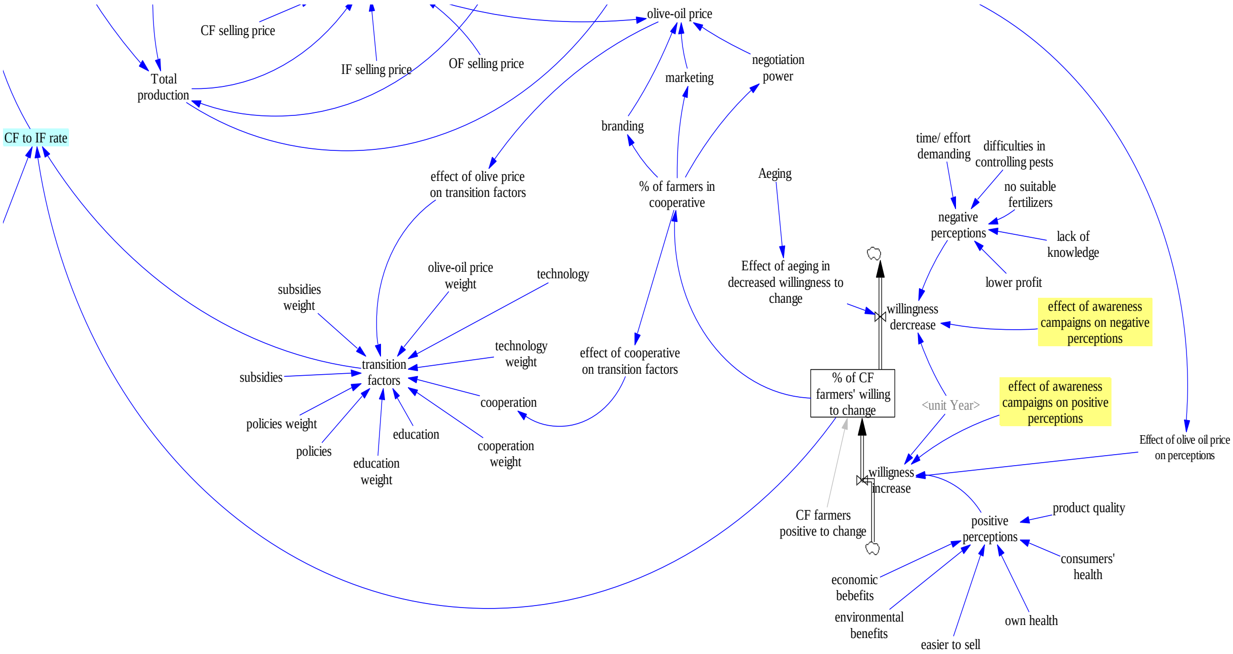

Figure 31: Part of Sub model 2 A shift from conventional (CF) to Integrated Farming (IF) showing the factors affecting the rate of change (CF to IF)

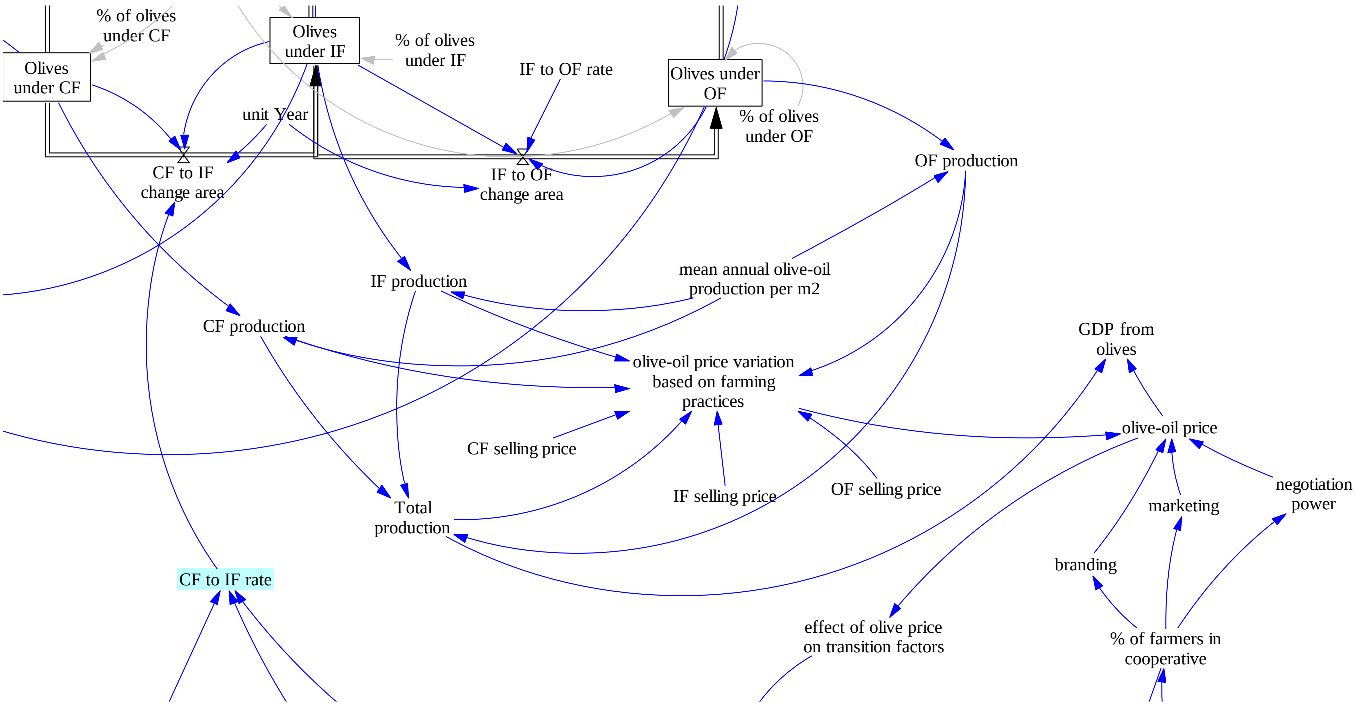

Figure 32: Part of Sub model 2 A shift from conventional to Integrated Farming showing the effect the shift can have to the price of olive oil

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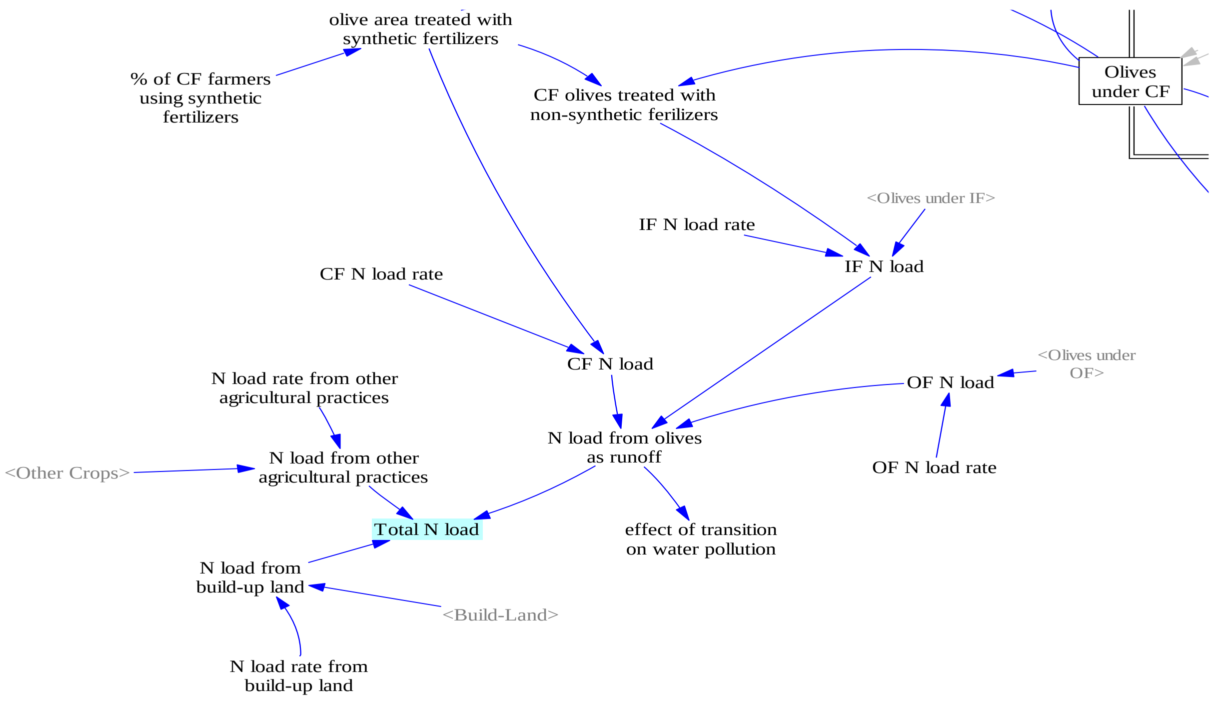

Figure 33: Part of Sub model 2 A shift from conventional to Integrated Farming showing the effect the shift can have to the total N load in rivers (The Value is then used in the Water Model to calculate Status)

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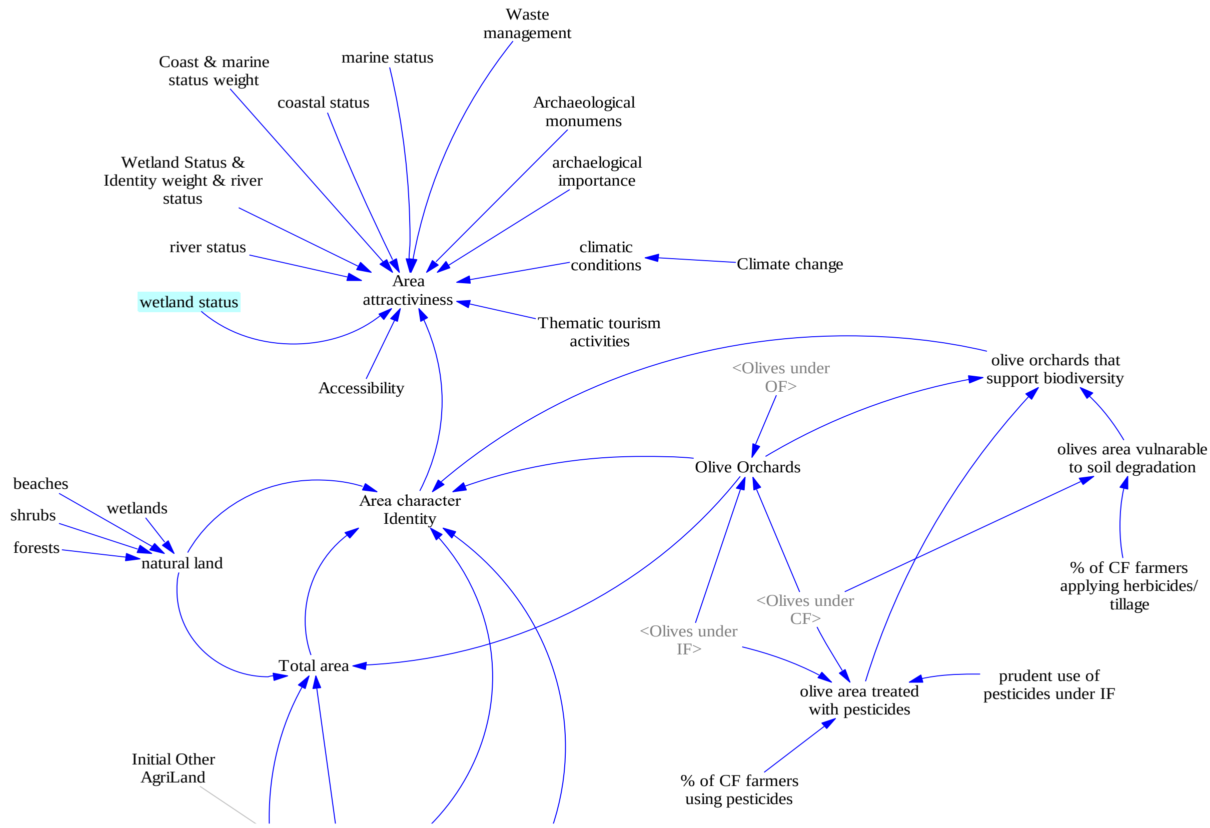

Figure 34: Part of Sub model 2 A shift from conventional to Integrated Farming showing the effects of a successful shift on the olive orchards biodiversity, the character of the landscape and the area attractiveness (The parameters are also used in the tourism sub model)

The calculation period for model is from 2020 to 2100, and the period has been chosen to follow the timeline of the water model, whose values are very much dependent on data availability, and include climatic parameters. However, the values used follow calculations of trends and changes that have happened in the area during the last 10 to 20 years. In our study area organic farms contain on average 185 (±55) trees/ha and produce on average 1090 lt of olive oil per hectare, while conventional farms contain about 210 (±75) trees/ha and produce on average 1140 lt/ha (Berg et al., 2018, extended information in Salguero Engstrom, 2018). Under integrated farming, we assume that the per hectare number of trees and olive-oil production will be optimized to values between those mentioned above. As already mentioned, given the small size of the farm the only viable option for the adoption of sustainable farming practices (integrated and organic) is through a co-operative. The values and weights assigned to the willingness of the farmers to change their practices are based on discussions with the stakeholders and on previously published research, which was conducted in the area using one to one interviews and questionnaires (Berg et al., 2018, extended information in Salguero Engstrom, 2018). We have decided to make the percentage of farmers willing to change into a stock as it is such an important parameter in the model, which is affected both by endogenous (olive oil price) and exogenous (policies) changes with regards to the system. Besides the factors that affect farmers decision the rate of change from Conventional to Integrated first and then to Organic is also

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affected by a number of transition factors (policy, education, available technology, cooperative effect). The importance of each value has been ranked according to stakeholders' preferences.

Cooperatives will also play a major role in providing know how and supporting agronomists for full time farming consultation to all members, support the application of smart agriculture and relevant data management with support from academic experts, take over the task of branding, marketing and promotion under the guidance of relevant expert, resulting in a better quality produce that could be place branded, in which case its price could be up to 5 times higher than it is now, as it was mentioned by local experts..

Under integrated farming, the use of tillage and herbicides is not allowed, thus the transformation should reduce the risk of soil erosion and eliminate the use of Glyphosate in the farms. With regards to pesticides, an evidence-based approach could reduce the amount of pesticides per hectare, also decreasing potential residues in olive-oil and improving its quality. Fertilising is based on naturally derived products instead of synthetic ones. The above combined could decrease agriculture run-off and leakage with benefits to the wetland ecosystem and increase the capacity of the farms to support biodiversity, like organic farms. However, the use of pesticides, even more prudent, will still pose a threat to biodiversity. Increased diversity in the farm could be branded to increase the marketing potential but also support agritourism. Water consumption for irrigation could be reduced to optimum since it will be based on data availability on soil and tree needs. To ensure the brand name of Sustainable Messinia and high-quality olive-oil, a strong cooperative, could increase the demand of high operation standards of olive-mills, excluding operations that still pollute the rivers. The operation of this type of olive-mill could be controlled by the relevant authorities.

As more land will be under integrated farming, this will pave the way for branding the area characteristics, adding to final selling price. This could increase food security in terms of a steady and sustainable olive-oil production, from farm to fork. Under the current situation with Covid-19, and possible similar threats in the future, increased food security may become a prerequisite for consuming and trading, and the sector runs the risk of being left outside the market if no actions are taken.

According to our stakeholders, bulk exports make up almost 90% of the total exports. Under integrated farming and strong cooperatives, this huge amount of olive-oil could be branded, marketed and promoted to meet the needs of the global market, with increased profit for the farmers. A steady supply of the market, a prerequisite in trading according to local experts, could be achieved via the operation of cooperatives who should also take the task of branding, marketing and promotion based on relevant experts. The olive-oil price is expected to continuously rise due to better branding, marketing, promotion and negotiation power and fewer bulk exports.

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3.2.5 Sub model 3: Shift from a seasonal Sun/Sea/Sand tourism destination to a sustainable destination with expansion of the tourism season

3.2.5.1 Model scope for the shift from Sun/Sea/Sand tourism to Sustainable Thematic Tourism

The model scope was determined based on the outcomes of the first MAL workshop (Tiller et al., 2019), and our current understanding of the system, including national and regional policy planning for the area, which identifies tourism as one of the major drivers of economy in the area.

The main challenges dealt with this sub model are

1) The Seasonal resource stresses of the current tourism development model;
2) The land use conflict and the pressures on the Messinian Landscape Identity;
3) The opportunities offered through differentiating the tourist product based on the cultural and geographical characteristics of the area.

Aspects of the MAL that are only indirectly related in this model, like the effects closed by the water demand to the groundwater levels and the lagoon salinity, as well as the changes of farming practices that are covered with the other two sub models, are not considered again as parts of tourism model presented.

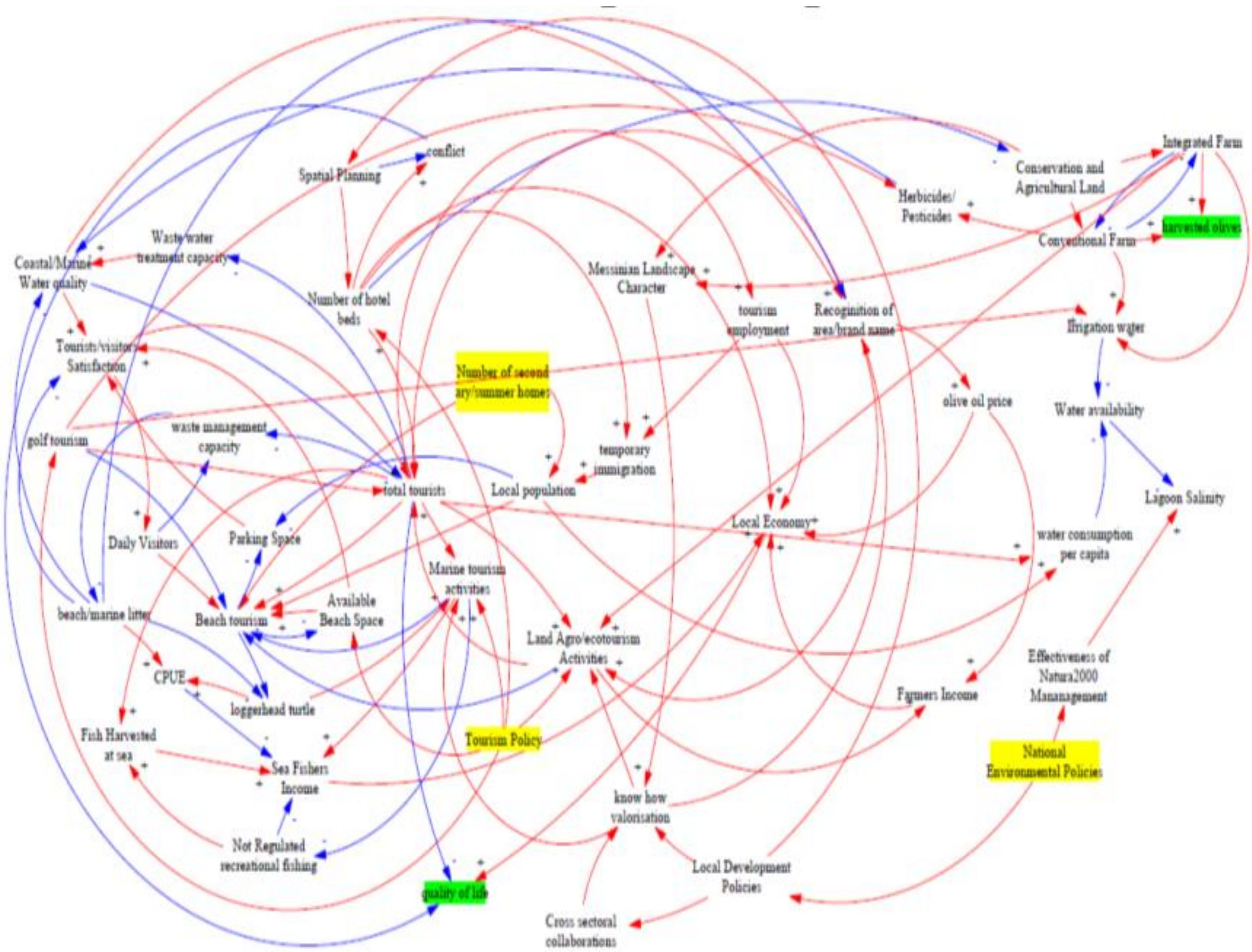

Figure 35: CLD on which the Tourism SD pilot model will be based (Inputs: Yellow, Outputs: Green) (Red arrows show positive feedback, Blue arrows show negative feedback.)

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3.2.5.2 Quantification of the shift from Sun/Sea/Sand tourism to Sustainable Thematic Tourism

In the last 20 years the area reserved for built land or sports facilities has increased by 3.8% (Figure 36). Not surprising the greater of the land use change is happening along the coastline and in areas with views to the sea, the lagoon and the famous beach of Voidokoilia. The expansion includes hotels, and secondary homes, along with accommodation to fit in the employees of the tourism industry.

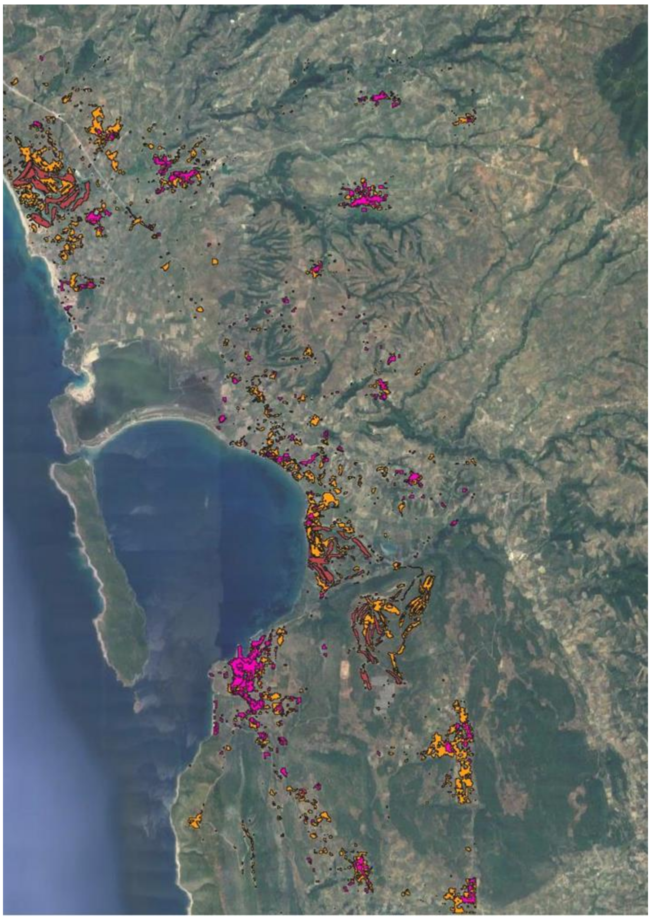

Figure 36: Aerial view of MAL II Case study area showing built up land in 2000 (pink areas) and in 2020 (Orange areas), as well as the site of the two golf courses that were creates in the same period.

In the analysis for the model we decided to maintain a high trend of urban expansion, with a slightly reduced rate however, at the suggestion of our stakeholders, who also include the largest developer in the area (TEMES). The model time horizon is 2020 to 2100 and follows a monthly time step to accommodate for the seasonal stresses on infrastructure, facilities, population and the environment.

Built land and expected tourists are the two STOCK variables in the model. The rate of change of built land is based on the comparison between the total land occupied by man-made buildings in 2000 and in 2020 and from that the new bed capacity is calculated according to the spatial planning legislation that allows for the creation of 100 beds per 20 hectares (which is also the minimum size of land for the development of a new hotel).

In addition to the hotel beds, about 36% of the houses in the municipality are characterised as summer homes or secondary homes. The effects of the increased water demand have been included in the analysis of Model 1, with reference to the protected area of Gialova Lagoon, thus they will not be analysed again with this model. The other problems caused by the temporal increase of population

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in the area are the increased waste load which for Greece is estimated to be around 1.2 kg per person per day. Similarly, the municipal wastewater facilities receive a load of approximately 150 lt per person per day, while the sewage treatment capacity is limited. With the expected increase in the tourism numbers, these pressures are expected to intensify. The intensification of tourism activities in the area also puts pressure on land use and the landscape identity of Messinia in the long term, which the tourism sector also wants to maintain and improve as a branding characteristic. An analysis of all the variables and equations used to calculate the interactions in the model follows in the Annexes 4b and 5b. This aspect of the Messinian Landscape Identity was also analysed in D13. The possible opportunities offered and their effect on seasonality have been proven difficult to quantify as they are very limited and innovative ideas by the stakeholders have so far been limited to alternative activities (fishing, diving, nature walking) that would be on offer during the same season, with the idea of attracting a different type of tourist and for offering a nature package.

3.2.6 Overview of the stock-flow models and land sea interactions

Two operational models have been created based on the three initial pilot sub models (described in detail in COASTAL deliverable D13).

The Water – Wetland sub model focuses on the restoration of the local wetland which is of high ecological and cultural importance and has an economic value due to fishery and potential development of eco-touristic activities. The land-sea interactions which are examined are:

- Groundwater availability for the restoration of salinity in the coastal wetland (Gialova Lagoon) in connection to groundwater use for irrigation and water supply (drinking water).
- Groundwater and river water availability in connection to nutrient loads from agriculture and local settlements (catchment inputs).
- Coastal lagoon quality in connection to nutrient loads from catchment.
- Fish health in connection to the Mean Annual Salinity of the lagoon.

The Land Uses sub model is used to analyse

- How the gradual transition from conventional to integrated and eventually to organic farming could benefit the sector and lead to improved water quality and benefit biodiversity;
- Tourist development pressures on land uses;
- Increased water demand;
- Area attractiveness in relation to landscape and nature characteristics.

3.2.7 Business and policy analysis

3.2.7.1 Sub model 1: water management in connection to wetland restoration

Using the above stock-flow models, the following problems can be addressed:

- How groundwater abstraction for irrigation and domestic use and related increase due to climate change will affect the local water resources.

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- How groundwater abstraction for irrigation and domestic use and related increase due to climate change will affect saline water intrusion.
- How climate change will affect the lagoon salinity if no actions are taken.
- How salinity affects fish and aquatic vegetation inside the wetland.
- How much fresh water is needed for the restoration of salinity to optimum values for fish health and other ecosystem services, and increased climate resilience.
- How each restoration strategy will affect the lagoon salinity and which can be the best selection to suggest to policy makers.
- How the nutrient status of the fresh water inputs close to their potential connection with the wetland, affects the decision for restoration of fresh water inputs and how is this connected to inland activities.
- How to improve water quality to allow the restoration of the fresh water inputs.
- How farming technology can reduce irrigation needs and inputs.
- Why a poor lagoon status is bad for tourism?

KPIs:

- Mean Annual Salinity (MAS)
- Mean Annual Abstraction for Irrigation (MAAI)
- Mean Annual Abstraction for Municipality Use (MAAMU)
- Mean Annual Alluvial Groundwater Deficit – Saline Water Intrusion (MAAGD - SWI)
- Lagoon-Wetland Status (LWS)

For the restoration of salinity in the Gialova Lagoon wetland, the Water-Wetland sub model suggests that under current and future climatic conditions the increase of freshwater inputs from the catchment is vital for regulating lagoon salinity. By saving water from Irrigation and Municipal Use (awareness, network improvement, smart agriculture) the model suggests that wetland salinity could be kept to current values for the next decade, but this is not enough to achieve salinity values optimum for fish or to reverse salinization after 2030 (Figure 40). Based on the model outputs, the de-salinization to optimum salinity values can be achieved only by restoring the natural flows with Xerolagados and Tyflomitis. The model gives the possibility to end users to check the effect of the additional fresh water inputs to the restoration of salinity values, by allowing the user to intervene with the system on both fresh water inputs (for example increase the inflow from Tyflomitis from 10% to 30%, and the inflow from Xerolagados from 0 to 10%). However, despite the increasing demand for restoration (from local fishers to improve fish health), the water quality of these fresh water bodies (at locations in proximity to the wetland, where the restoration work could be implemented) are not in a good trophic status and any restoration effort could cause other problems (e.g. eutrophication).

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To account for the above, the model contains a policy indicator variable with the title *decision to restore connectivity*, which is affected by the fish tolerance ratio (MAS/max tolerance of fish to MAS) and the nutrient status of the fresh water bodies. The model is designed to give a signal when the values of the ration exceed 1. For the nutrient status, the model is designed to show how changes in agriculture (from conventional to organic) will improve the nutrient status, and also to allow the restoration when the status is improved. The user can intervene with the system by applying technological or/and nature-based solutions which could reduce the nutrient concentrations in a shorter period.

Xerolagados river is also affected by waste-water from the local olive-mill industry. This problem is affected by the willingness and the capacity of the local Policy Makers to enforce the regulations. Under current conditions the parameter is set to 0 in the model, meaning that no restoration is allowed. The end user will need to change this policy indicator to 1 to allow inputs from Xerolagados (it can be done easily while running the model). For the status of the alluvial groundwater aquifer, the model suggests that due to Irrigation and climate change there is an increasing deficit of groundwater volume which increases the risk of saline water intrusion into the aquifer.

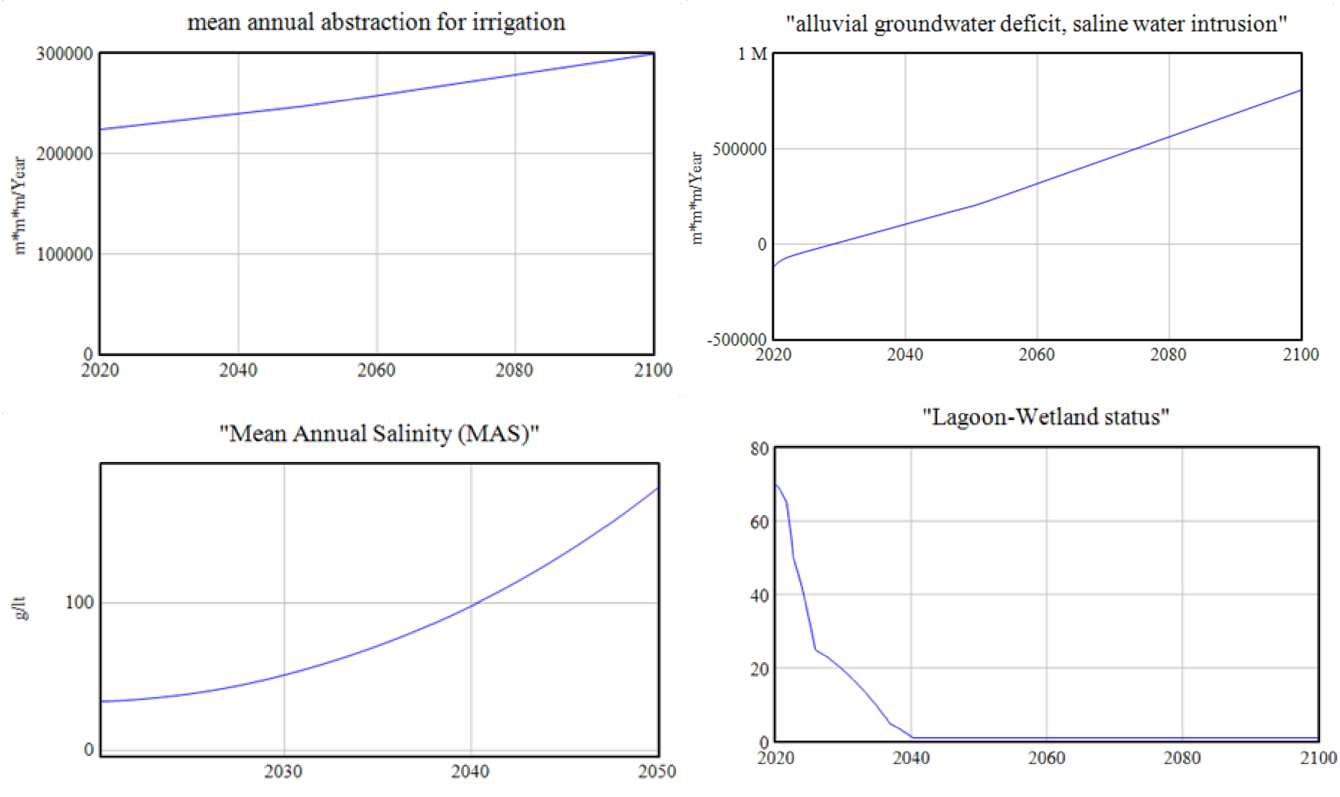

Figure 37: Mean annual abstraction for irrigation (m^3/year), Alluvial groundwater deficit, saline water intrusion (m^3/year), mean annual salinity (g/l) and lagoon -wetland status (-)

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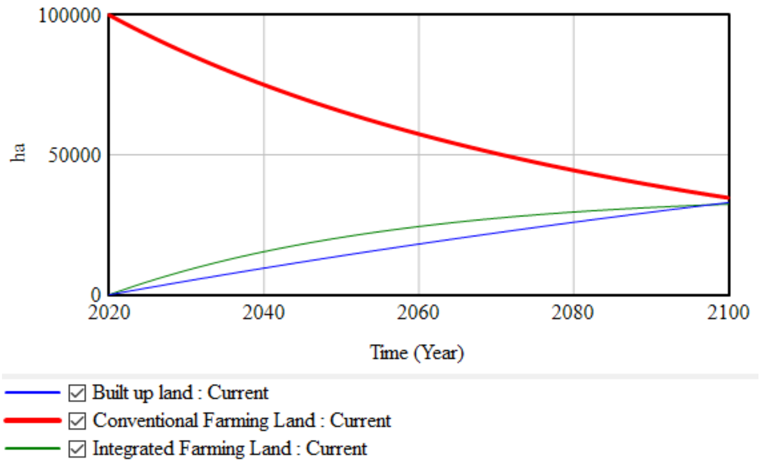
3.2.7.2 Sub model 2: Shift from conventional to integrated farming and finally to organic farming

Using the above stock-flow models, the following problems can be addressed:

- The land use changes;
- The issue of product quality as well as the issue of product competitiveness in the market due to the use of agrochemicals;
- The issue of bad management practices in agriculture such as the bad use of water and chemicals;
- The lack of cooperatives' modernization;
- The factors that affect willingness of farmers to adopt sustainable practices;
- Socioeconomic transition parameters that affect the adoption of sustainable practices.



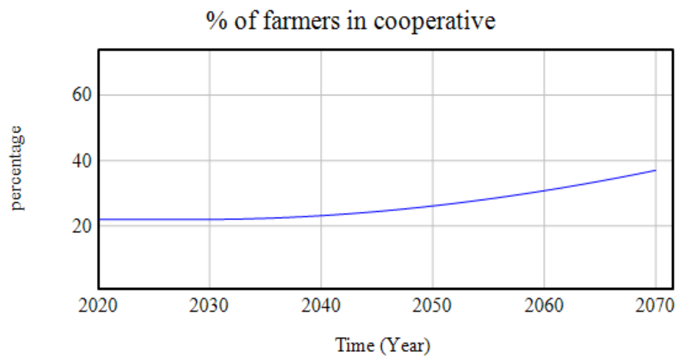


Figure 38: Land use development and % farmers in cooperatives from 2020 to 2100.

3.2.7.3 Sub-Model 3 Sustainable Thematic Tourism

Using the above stock-flow models, the following problems can be addressed:

- The issue of seasonal pressures on water resources, coastal space and marine environment;
- The issue of seasonal pressures to wastewater and solid waste management capabilities of the municipality;
- The issue of increasing hotel development;
- Assessment of the sustainability and possible impacts of these activities.

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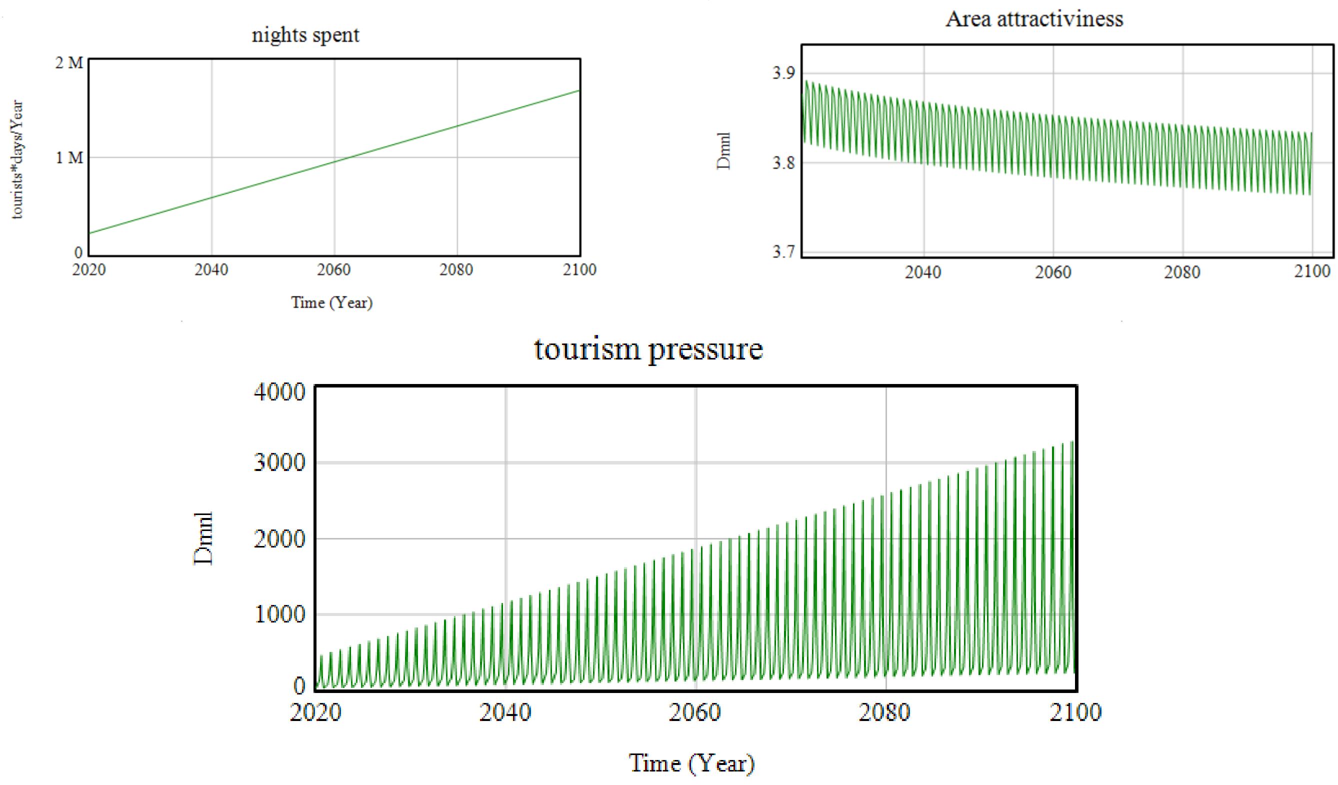

Figure 39: Development of nights spent (tourist days/year), the attractiveness of the area and the tourism pressure from 2020 – 2100.

3.2.8 Model confidence building

The confidence building of the model was built upon consultation with experts, available literature and discussions with our stakeholders during the 2nd Multi-Actor Laboratory which took place in March 2021.

During the 2nd MAL, the team described the purpose and the boundaries of all three sub models were presented and described to the stakeholders by presenting them step by step why and how each component is attached to the model. After the presentation and the discussions, the stakeholders were asked if the agree with what was described and their answers were collected by using online questionnaires.

Prior to showing an example of model behaviour (Figure 40), the team explained to the stakeholders what type of data are used as inputs in the model and the relevant sources, so they are aware. For discussing the model behaviour, we presented graphs, where possible showing how specific KPIs (MAS) change in time based on decision making, where as in others non-quantified at the time the presentations included historical trends.

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With respect to the water model that was fully quantified at the time all the stakeholders found the behaviour of the model reasonable, and in fact they could identify how such a model could become a useful tool for the water management of their wetland, and their local groundwater resources. With respect to the farming and tourism model, although they agreed with the overall presentation of the quantified parts, they identified several characteristics, such as the parameters that affect tourist's attractiveness to the area and/or the factors that affect their decision making when it comes to field management. These issues where put in a ranking order by our stakeholders and the outcomes of this exercise were used to quantify the weights of different aspects that are related to non-tangible parameters (attractiveness, willingness) in the model.

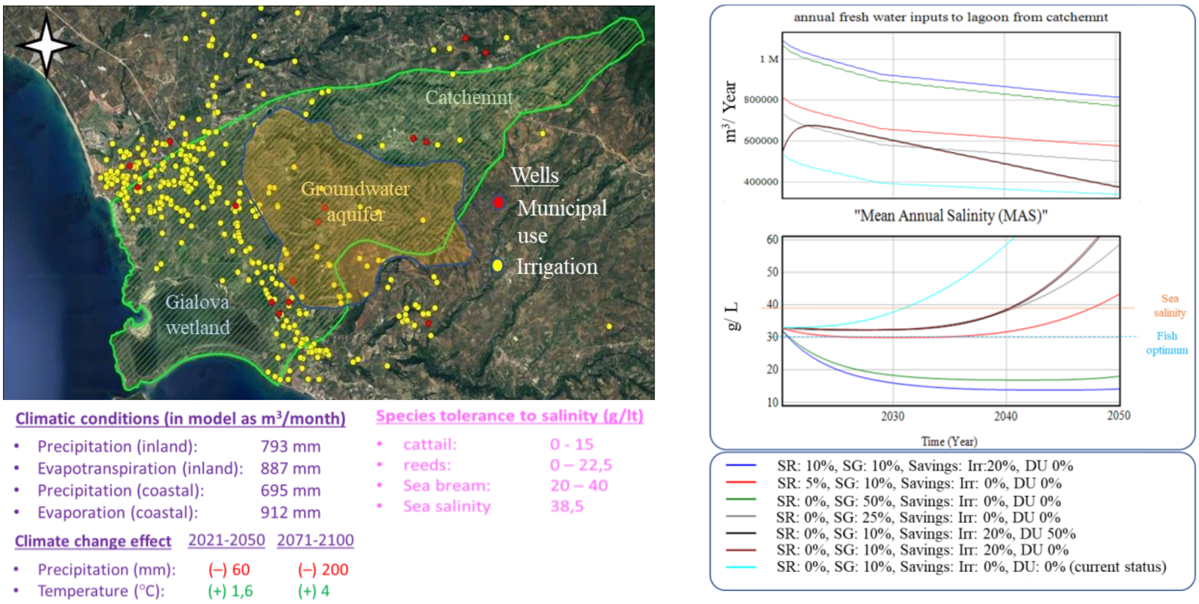

Figure 40: Map of the area, and example of Water-Wetland model behaviour based on the given climatic conditions and changes.

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3.3 Multi-Actor Lab 3 - Norrström and Baltic Sea (Sweden)

3.3.1 General problem scope of the land sea system

The Baltic Sea is one of the world's largest brackish water bodies, with a land catchment area about four times larger than the sea surface area (Figure 41). In the Swedish part of the Baltic catchment, the Norrström drainage basin (outlined in yellow in Figure 41) and its adjacent and surrounding coastal zones (all together constituting the local MAL3 in COASTAL, and corresponding to the total Swedish Northern Baltic Proper water management district) is a key area with a total population of 2.9 million people. It includes the Swedish capital of Stockholm as well as agricultural and industrial activities, and contributes considerable nutrient loading to the Baltic Sea. As a consequence of such loading, the MAL3 archipelago and coastal waters, as many other parts of the Baltic Sea and also many inland waters, suffer from eutrophication and harmful algae blooms (HELCOM, 2018).

Figure 41: The Baltic Sea and its cross-boundary catchment area (outlined in red) with the Swedish Norrström drainage basin (outlined in yellow). Source: HELCOM, 2018

Such water quality and ecosystem status problems, resulting from continuous excess nutrient (nitrogen and phosphorus) inputs to inland, coastal and marine waters in MAL3 (HELCOM, 2010), are recognized since decades but management results remain insufficient despite various international agreements and environmental regulations applied on local/national and regional/international levels (Destouni et al., 2017). Figure 42 shows the evolution of annual nutrient inputs to the Baltic Sea, with increasing trends mainly between the 1950s and the late 1980s for both nitrogen and phosphorus, and decreasing trends thereafter but with loads still remaining above environmental targets. The source attribution pie charts in Figure 42 include both point and diffuse (current and historical) anthropogenic sources (HELCOM, 2018). Policies and regulations to reduce nutrient loads from various

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sectoral activities by 50% were first developed at national and international level already by the 1988 HELCOM Ministerial Declaration (HELCOM, 2007).

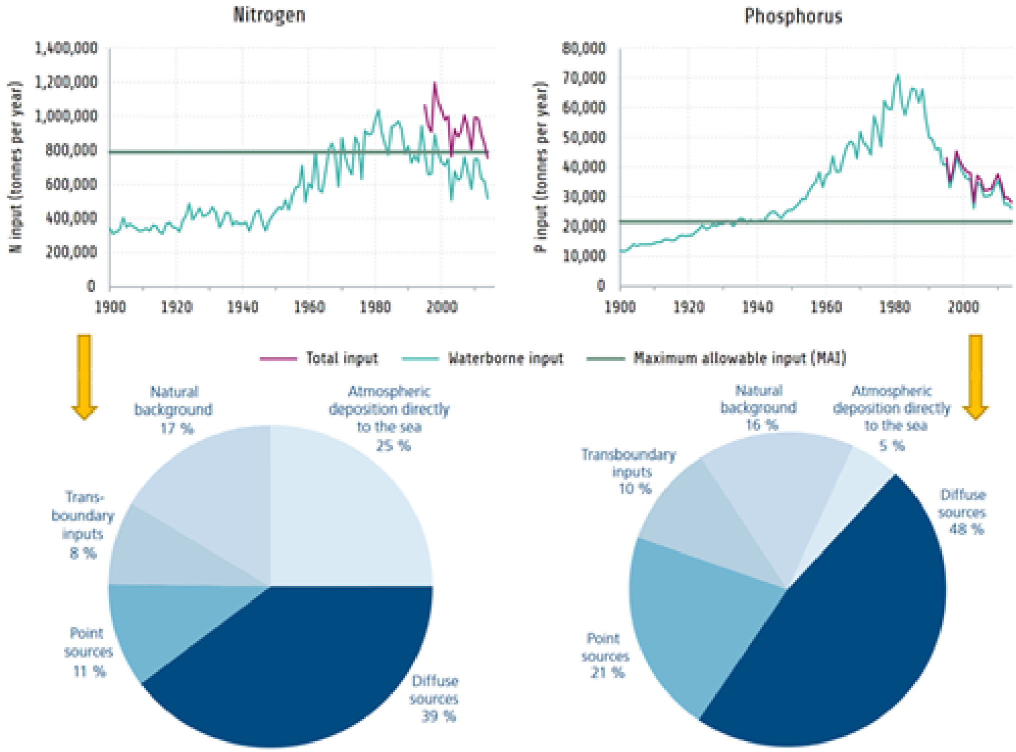

Figure 42: Evolution of annual waterborne and total nutrient loads (of nitrogen and phosphorus) to the Baltic Sea during 1900-2014, and their source attribution for nitrogen (left pie chart) and phosphorus (right pie chart). The maximum allowable load levels in the graphs refer to targets in the Baltic Sea Action Plan (2007). Point sources on the pie charts include both coastal and inland point sources, and transboundary inputs include both point and diffuse sources. Sources: HELCOM, 2010 and 2018.

Since the 1980s, nutrient loads into the Baltic Sea have decreased (graphs in Figure 42), however, they are still greater than the targets agreed for reductions of both nitrogen and phosphorus (HELCOM, 2018) and maintain less than good ecological status in the Baltic Sea and its coastal waters (Vigouroux et al., 2019 and 2020). The historic large nutrient inputs on land also indicate an accumulation of nutrients over time in soils, slow moving groundwater, and sediments that may now be continuously released into the mobile water that flows from land to the sea, in addition to the currently active source inputs on land; the continuous excess loading above targets into the sea over the second part of the last century also implies such excess accumulation within the coastal and marine sediments (corresponding to the area below the annual loads and the targeted load levels shown in the graphs in Figure 42). Such nutrient accumulation and subsequent release are referred to as legacy sources, with unclear sector responsibility for mitigating the associated nutrient loads and also practical difficulties in managing such mitigation, which may require other types of methods than mitigation of inputs from currently active sources (Destouni and Jarsjö, 2018).

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Furthermore, MAL3 is a clear cross-boundary case, i.e. the coastal and marine eutrophication problems in MAL3 do not only occur and depend on the local/regional processes and nutrient loads of the Norrström drainage basin case, but also on such processes and loads occurring on the macro-regional/transboundary scale of the whole semi-enclosed Baltic Sea and its entire catchment, with the open sea conditions also greatly influencing the local coastal conditions, in addition to the influences of the local coastal catchment on the associated local coast. Coastal nutrient loads around the whole Baltic coastline are transported across the open sea and contribute to eutrophication and pollution also in other, remote coastal areas. Important mitigation requirements, responsibilities, and opportunities for the transported amounts of nutrients and pollutants across the open sea thus are also outside and over much larger and transboundary scale than just the local/regional land catchment scale of the specific MAL3 coast.

In addition to these land-sea system characteristics, the human population and the associated human land and water uses (Darracq et al., 2005), as well as the regional hydro-climate conditions (Bring et al., 2015a) in the MAL3 case have changed and will continue to change over time. These changes affect directly the water availability and the waterborne nutrient loads from land to the coast and the sea (Bring et al., 2015b), as well as biodiversity and ecosystem services of water systems on land and in the coast (Elmhagen et al., 2015). How to manage these changes and the still required mitigation of nutrient loads to the inland-coastal-marine water continuum in the short and long term is the key problem addressed for MAL3 and the sustainability of its coastal, rural, and urban development, with influences from and implications for sustainable development also around the whole Baltic Sea coast.

3.3.2 From multi-actor analysis to modelling

The main relevant local and regional land-sea interactions for MAL3 are included in the stakeholder-given unified causal loop diagram (CLD) shown in (Viaene et al., 2020). The CLD was developed and validated by stakeholders in a series of sector and multi-actor workshops organized as part of WP1 (Tiller et al., 2019a and 2019b). The large variety and multiple connections (#160) between 31 system components indicate a general stakeholder perception of high complexity in the dynamic interactions of the MAL3 land-sea system involving 567 feedback loops. Some of these loops are shown in Figure 43.

To address stakeholder system understanding and representation requirements, the system dynamics (SD) model developed for MAL3 focuses on water availability and quality, and their interactions with and implications for key inland and coastal sectors as a land-sea and sector interaction and impact tracer. Water availability interactions among inland and coastal sectors, surface and sub-surface water systems, and hydro-climatic components, affect coastal water flow and have implications also for seawater intrusion into fresh coastal groundwater. Changes in these interactions due to climate change and human activities and their development further affect also the waterborne nutrient loading to inland and coastal waters, and contribute actively to the eutrophication, water quality, and ecosystem status issues on land, in coast and at sea. In combination, these system interactions and

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impacts also affect the need for and effectiveness of, as well as are affected by the implementation off various management and eutrophication/pollution mitigation policies and measures for sustainable development in MAL3. The insights gained from qualitative fuzzy analysis of the co-created CLD aimed at representing these key interactions (as part of WP1) were shared and discussed further with stakeholders and local partners. Their feedback in combination with the data and supporting model (result) availability (screened as part of WP2), led to the two following main themes for SD modelling in MAL3 (Viaene et al., 2020) with a focus on the thus identified quantifiable key land-sea interactions for this case (Figure 43):

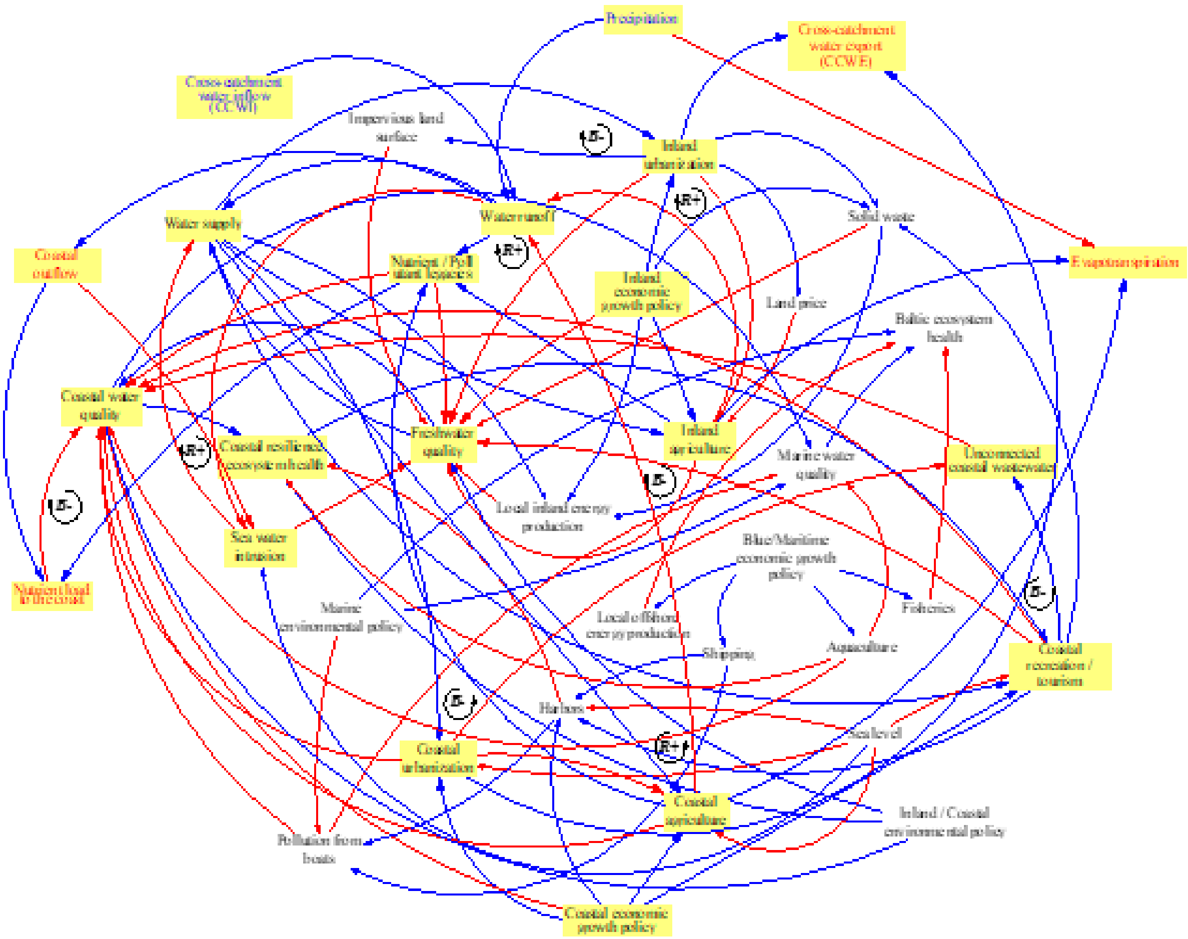

Figure 43: Regional causal loop diagram (CLD) for MAL3. Positive and negative interactions are shown with blue and red arrows, respectively. The key system components/sectors and interactions/implications incorporated in the system dynamics (SD) model are highlighted with yellow background and thick arrows, respectively. System components shown with blue and red font colours along with their relevant interactions with the CLD components are added to the SD sub models after a discussion with stakeholders and local partners, in order to close the loop between resources (shown in blue) and outputs (shown in red) in the MAL3 coastal system. Some of the balancing (B-) and reinforcing (R+) feedback loops are also shown with circle arrows in bold and Italic format.

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i. Cross-(sub)system/sector water availability exchanges (quantity model), and their implications for seawater intrusion into and quality of fresh coastal groundwater (quantity and quality perspective), and inland/coastal sector growth and environmental policy; and
ii. Cross-(sub)system/sector exchanges of waterborne nutrients, their loads through various systems and sectors in the land catchment and into the coastal waters (quality model) and associated sector growth and inland/coastal/marine environmental policy implications.

Development of just one single SD model to address all relevant land-sea interactions for these model themes required high model system complexity. Therefore, two SD sub models were structured separately for each theme (water quantity model, and water quality model) and fully quantified using available data, supporting model (results) and other information from relevant reports and peer-reviewed scientific literature (Kastanidi et al., 2018). All relevant and available quantitative information for MAL3 is summarized in the data and model inventory report (deliverable D06(D2.1) of WP2 - Kastanidi et al., 2018), and the data, supporting model and other information specifically used to quantify the MAL3 SD sub models are included and explained in the deliverable D07(D2.2) of WP2 (Seifollahi-Aghmiuni et al., 2020). The two SD sub models were further connected to develop an integrated MAL3 land-sea system model that will be used to analyse various local/regional change/development model scenarios for MAL3. Such scenario analysis will be conducted in relation to relevant shared socioeconomic pathways (SSPs) for the MAL3 region, representing various land cover changes that involve urbanization, tourism expansion, and agricultural development. In addition, climate change impacts related to different representative concentration pathways (RCPs) will also be considered in the MAL3 scenario analysis, primarily through precipitation and related change propagation through the model system.

3.3.3 Sub model 1: Land-sea inter-sectoral and coastal water exchange

3.3.3.1 Model scope of the land-sea inter-sectoral and coastal water exchange

Sub model 1 investigates inland sectoral and coastal system interactions regarding water flux and availability through natural surface and subsurface water systems and various socio-economic sectors. It also addresses the implications of freshwater flow changes due to hydro-climatic and human activity changes (e.g., in urbanization, tourism, agriculture) for seawater intrusion risks into fresh coastal groundwater. As a result of increased human land and water use over the last century, the interactions between the natural water cycle and societal and engineered water supply/handling systems increase with feedbacks to inland and coastal sectors in turn also affecting growth opportunities in the region (Baresel and Destouni, 2005). In addition, both climate change and increased water extraction from coastal aquifers directly affect the intrusion of seawater into the fresh coastal groundwater with impacts threatening the sustainability of coastal groundwater resources (Mazi et al., 2016).

Figure 44 is developed based on the highlighted parts in the regional CLD in Figure 43 to structure the sub model 1 for MAL3. The main inputs to this sub model are precipitation and cross-catchment water inflow (CCWI) (shown with blue font colour in Figure 44) feeding natural water resources (highlighted

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with green background in Figure 44) and supplying sectoral water uses (highlighted with grey background in Figure 44). The main outputs of this sub model are the fluxes of evapotranspiration, cross-catchment water export (CCWE), water outflow to the coast, and a proxy of critical seawater intrusion risk (shown with red font colour in Figure 44).

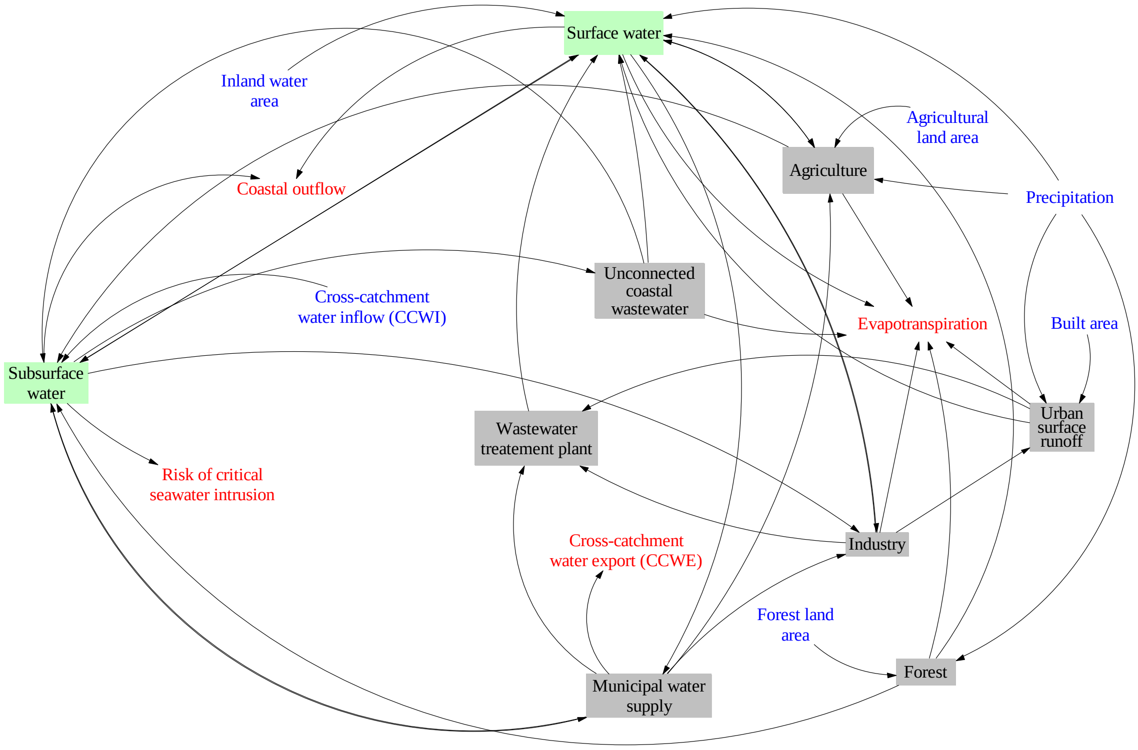

Figure 44: Conceptual representation for sub model 1 in MAL3 including water flux exchanges (represented by arrows) between natural water systems (highlighted with green background) and inland/coastal sectors (highlighted with grey background). The diagram also includes sub model inputs (identified with blue font colour) and outputs (identified with red font colour).

3.3.3.2 Quantification of the Land-sea inter-sectoral and coastal water exchange

The stock-flow structure of sub model 1 is developed as shown in Figure 45, and presented and explained thoroughly in the deliverable D13(4.2) in WP4 (Viaene et al., 2020). Sub model 1 is fully quantified based on the published peer-reviewed outcomes of an integrated input-output analysis (IOA), specifically for recent-current conditions in MAL3 (Baresel and Destouni, 2005; Cseh, 2009). Natural surface and sub-surface water systems and inland/coastal sectors are considered as stock variables. The list of data resources used to quantify sub model 1 is presented in the Annex 6c. Inputs to sub model 1, such as precipitation and CCWI from adjacent aquifers, are defined as auxiliary variables with their values being imported to the sub model from a connected excel file including all the values of all input variables to each sub model. Sub model outputs, such as evapotranspiration, water outflow to the coast, proxy of seawater intrusion risk, and CCWE through drinking water and goods are also defined as auxiliary variables with their values calculated based on stock and/or other auxiliary variables. The first three outputs (evapotranspiration, water outflow to the coast and proxy of seawater intrusion risk) are examples of key performance indicators (KPIs) from sub model 1 used

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to quantify and compare main scenario and roadmap implications in terms of natural system changes, sectoral developments, and (environmental and economic) policies.

Sub model 1 involves 11 additional KPIs, including the contributions of the surface water system and that of the subsurface water systems to the total coastal outflows (2 KPIs), and the water availability for the various socio-economic sectors (9 KPIs) included as stock variables in the sub model. Thus, the outcomes of sub model 1 will be evaluated in terms of, in total, 14 KPIs for various water-related changes and their impacts and implications for different sectors and the overall MAL3 land-sea system behaviour. These KPIs are shown with blue background in Figure 45. The quantification process for sub model 1 is thoroughly explained in the deliverable D13(D4.2) of WP4 (Viaene et al., 2020) and relevant quantitative information, data and equations are reported in the deliverable D07(D2.2) of WP2 (Seifollahi-Aghmiuni, et al., 2020).

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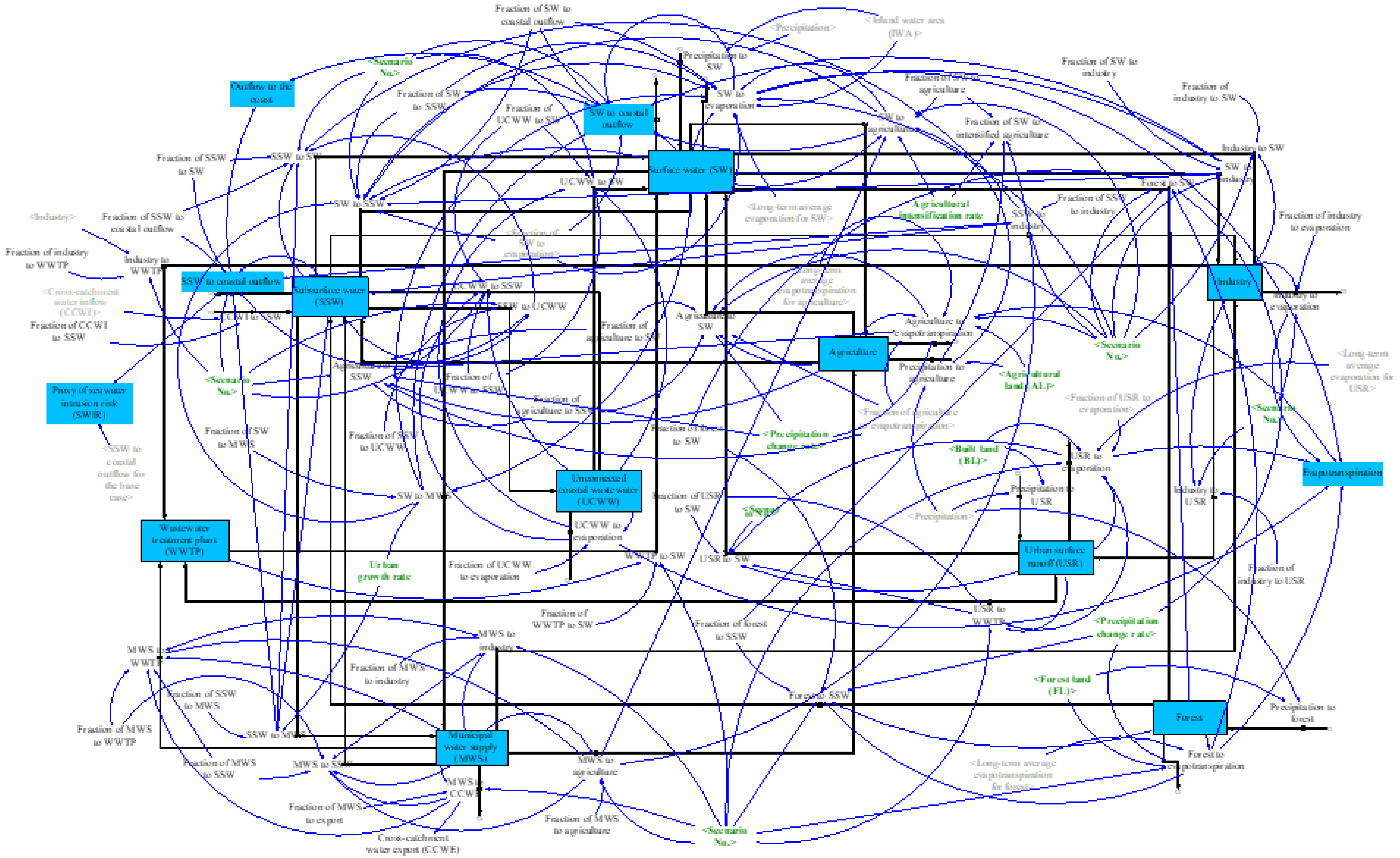

Figure 45: Stock-flow structure of the SD sub model 1 for MAL3 developed in Vensim software. The variables shown with green font colour represent main change-development scenarios. The variables shown with blue background represent the key performance indicators (KPIs) from this sub model.

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3.3.4 Sub model 2: Land-sea inter-sectoral and coastal waterborne nutrient exchange

3.3.4.1 Model scope of the land-sea inter-sectoral and coastal waterborne nutrient exchange

Sub model 2 for MAL3 is used to investigate contributions of different inland and coastal sectors to the waterborne nutrient loads through various socio-economic sectors and surface and subsurface inland water flows to the coastal waters. It represents the relationships between sectoral water flows and nutrient exchanges, with the main nutrient loads in the MAL3 case being predominantly waterborne from land and their changes being mainly driven by water flow changes due to hydro-climatic shifts and human water-use changes. Due to subsurface (soil, groundwater, sediment) accumulation of nutrients as legacy sources and their further release into and transport by mobile subsurface water (Baresel and Destouni, 2006; Lindgren et al., 2007; Darracq et al., 2008; Basu et al., 2010; Destouni and Jarsjö, 2018), nutrient concentrations tend to be higher in the subsurface water than in the surface water flowing to the coast (Destouni et al., 2008), which is why both are considered in sub models 1 and 2. As both hydro-climatic and human activity changes can shift the nutrient-carrying water flows (Destouni and Darracq, 2009; Bring et al., 2015b; Destouni et al., 2017), sub model 2 can be used to evaluate how such flow shifts affect the nutrient loads to inland and coastal waters.

Sub model 2 can also be used to evaluate sector impacts and possible policy feedbacks driven by changes in coastal nutrient loads, e.g., with too large loads driving stricter environmental regulation and/or limiting permits for various development plans. This sub model is structured following the interactions shown in Figure 46 considering nitrogen (N) and phosphorous (P) as the key nutrients. Their connections to other system components follow the water exchange interlinkages between resources and water consumers in inland/coastal sectors. Nutrient exchanges among different sub-systems and sectors as well as coastal nutrient loads in the MAL3 system are evaluated as the main outputs of sub model 2 (shown with red font colour in Figure 46). Also, long-term average nutrient concentrations in surface and subsurface water systems and in the outflow from and inflow to wastewater treatment plants are the main model inputs (shown with blue font colour in Figure 46).

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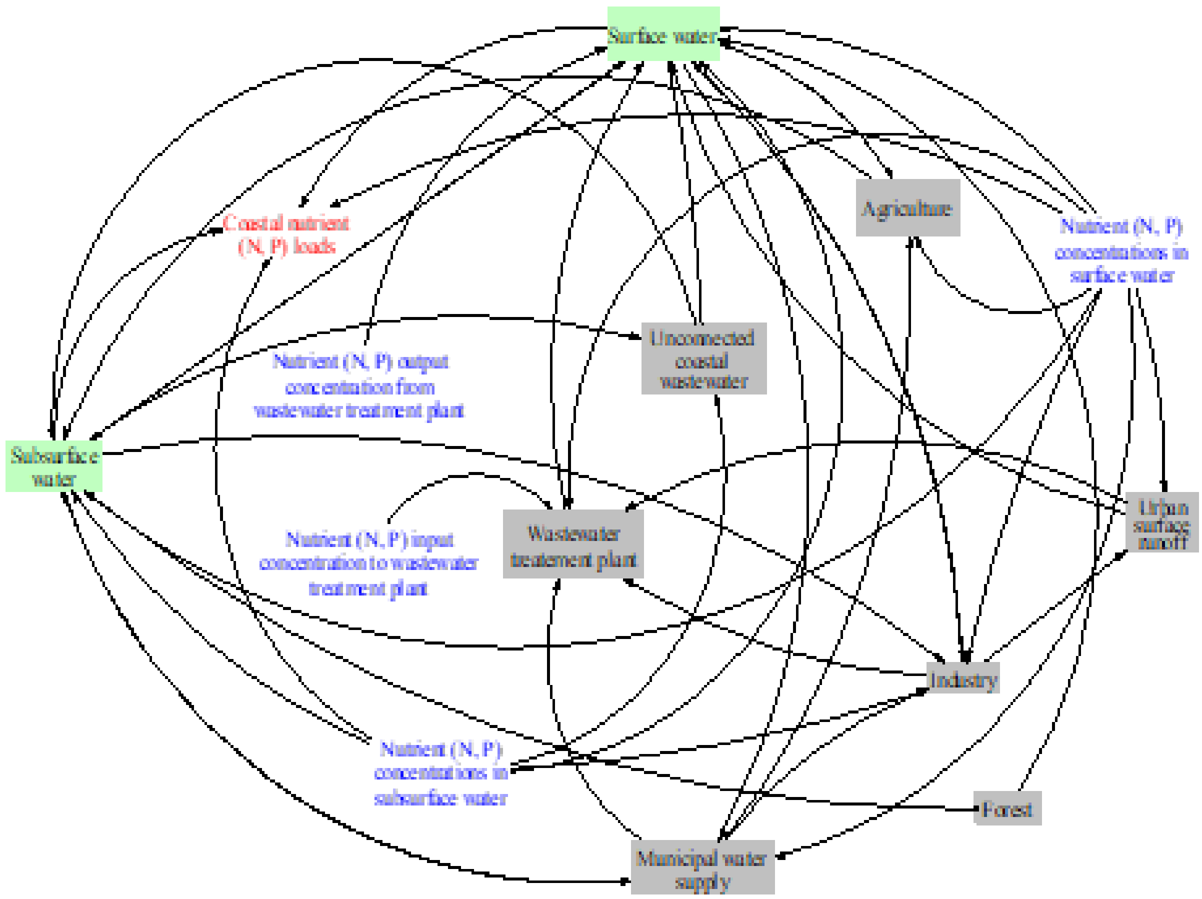


Figure 46: Conceptual representation for sub model 2 in MAL3 including nutrient exchanges (represented by arrows) between natural water systems (highlighted with green background) and inland/coastal sectors (highlighted with grey background). The key sub model inputs and outputs are shown with blue and red font colours, respectively.

3.3.4.2 Quantification of the land-sea inter-sectoral and coastal waterborne nutrient exchange

Since the stock-flow structure of sub model 2 is highly complex with numerous interlinkages and auxiliary variables, a complete layout view of the sub model structure could not be presented in this document. Figure 47 illustrates two parts of sub model structure for nutrient release from agriculture sector and subsurface water system. Figure 48 also shows the stock-flow structure for coastal nutrient loads. It should be noted that nutrient exchanges through natural surface and subsurface water systems are simulated in this sub model by explicitly taking into account the dominant contribution of nutrient legacy sources through nutrient concentration levels in surface and subsurface flows. Similar structures are developed for other inland/coastal sectors depending on their interactions with other system components. All the developed stock-flow structures are then connected build the stock-flow structure of sub model 2 and is fully quantified based on the sources listed in the Annex 6c.

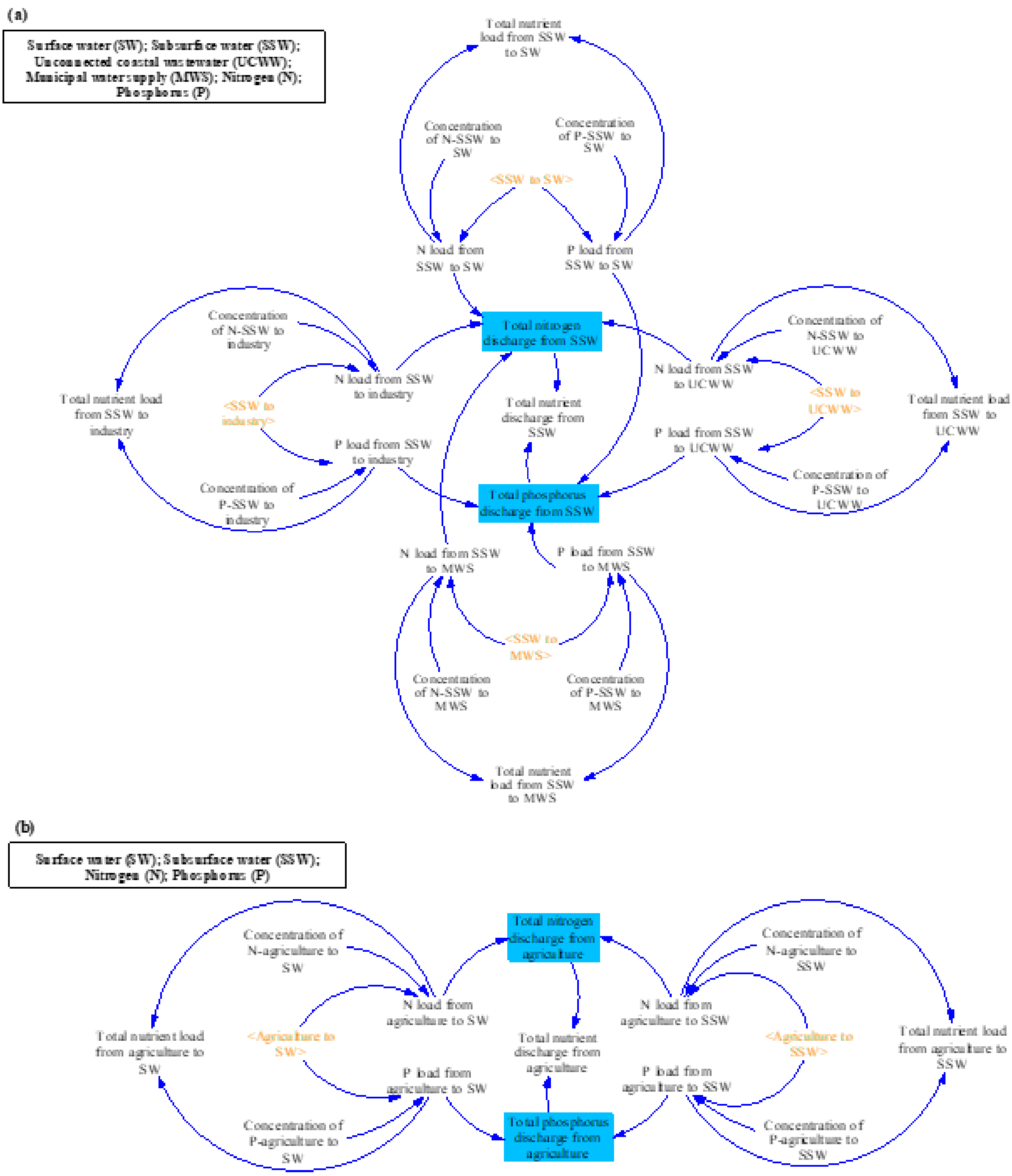


Figure 47: Stock-flow structure of nutrient (N: nitrogen, P: phosphorus) releases from subsurface water system as a natural sub-system (a) and from agriculture as an inland/coastal economic sector (b) to the connected natural sub-systems and inland/coastal sectors in the SD sub model 2 for MAL3 developed in Vensim software. These structures are shown as examples of stock-flow structures developed as part of the SD sub model 2 for MAL3. This sub model is connected to the SD sub model 1 through the variables shown with orange font colour. The variables shown with blue background represent some of the key performance indicators (KPIs) from this sub model.

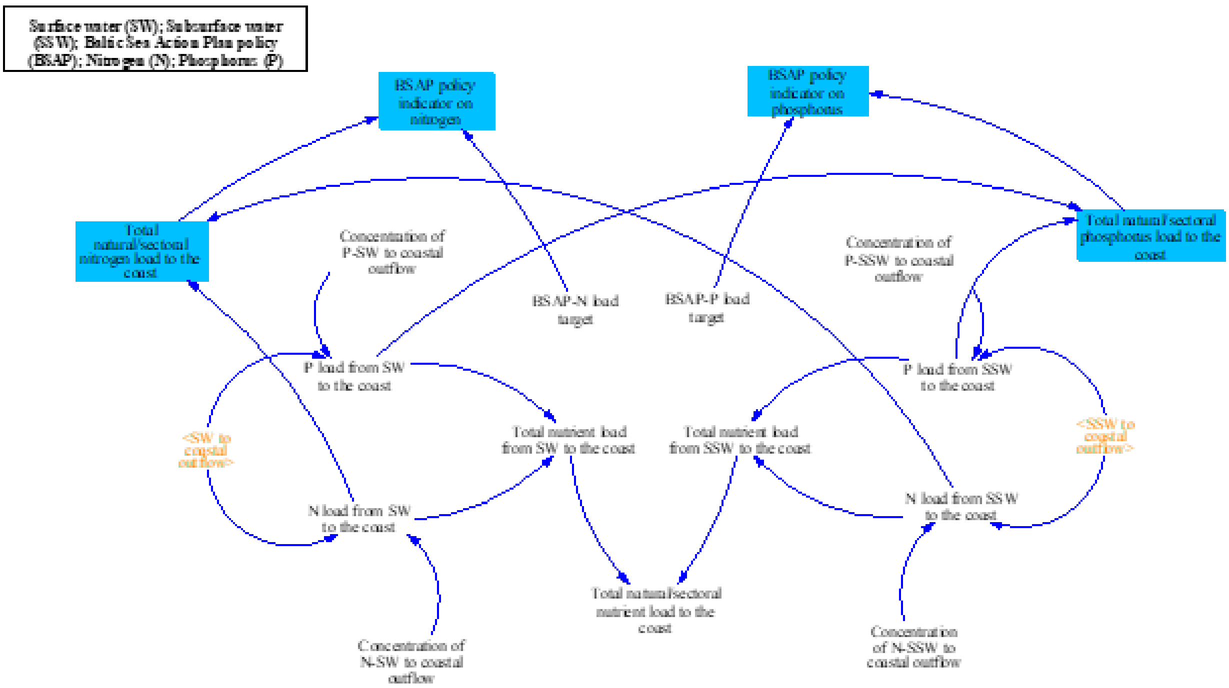


Figure 48: Stock-flow structure of coastal nutrient (N: nitrogen, P: phosphorus) loads in the SD sub model 2 for MAL3 developed in Vensim software. This structure is also connected with the stock-flow structures developed for the inland/coastal sectors as part of the SD sub model 2 for MAL3. The variables shown with orange font colour represent connecting variables to the SD sub model 1. The variables shown with blue background represent some of the key performance indicators from this sub model.

Inputs to sub model 2, such as the average recent-current (possible future) concentration levels of nitrogen and phosphorus in surface and subsurface water and in wastewater treatment plant (WWTP) exchange flows, are defined as auxiliary variables with their values being imported to the sub model from a connected excel file including all the values of all input variables to each sub model. Water flow exchanges among natural (sub-)systems and sectors that are simulated in sub model 1 are also considered as inputs to sub model 2. Outputs of sub model 2, such as nutrient exchanges among natural (sub-)systems and socio-economic sectors and their contributions to the coastal nutrient loads are defined as auxiliary variables with their values calculated based on relevant nutrient concentration levels and water flow exchanges within the MAL3 land-sea system.

Sub model 2 includes 25 KPIs related to the total nitrogen and phosphorus loads to the coast (2 KPIs) and the contributions of surface and subsurface load components to each total coastal load (4 KPIs), and the total nitrogen and phosphorus through flows (discharges from/to) the inland surface and subsurface water systems (4 KPIs), urban runoff (2 KPIs), the green sectors of agriculture and forestry (3 KPIs), WWTPs (2 KPIs), industry (2 KPIs), municipal water supply utilities (2 KPIs), and unconnected coastal wastewater systems (2 KPIs), and the Baltic Sea Action Plan (BSAP) policy indicators for nitrogen and phosphorus (2 KPIs). The outcomes of sub model 2 will be evaluated based in terms of these 25 KPIs in relation to various water- and nutrient-related changes and their impacts and implications for different sectors and the MAL3 region as a whole. Some of the KPIs in sub model 2 are shown with blue background in Figure 47 and Figure 48. The quantification process with associated equations is reported in the deliverable D13(D4.2) of WP4 (Viaene et al., 2020). Also, quantitative information and data used to quantify this sub model are included in the deliverable D07(D2.2) of WP2 (Seifollahi-Aghmiuni, et al., 2020).

3.3.5 Overview of the stock-flow models and land sea interactions

The stakeholder-given CLD for MAL3 involves several interactions between natural sub-systems and socio-economic sectors, selected based on their relevance and importance for the addressed water availability, quality and eutrophication problems and associated data/model availability to be further investigated in the MAL3 SD modelling. The integrated MAL3 model consists of the two described sub models, which are separately developed and quantified and then connected through the water flow variables. Any change in these variables due to human activity developments and/or hydro-climatic changes (simulated in sub model 1), will also affect corresponding waterborne nutrient exchanges among (sub-)systems/sectors and their contribution to coastal nutrient loading (simulated in sub model 2). Therefore, some of the outputs of sub model 1 are used as explicit inputs to sub model 2.

The main changes implemented in the MAL3 SD model since the previous versions described in the deliverable D13(4.2) of WP4 (Viaene et al., 2020) are associated with further quantification of the SD sub model 2, the integration of the two sub models to build the integrated MAL3 SD model, test the model for different variable changes, and understand the outcomes in terms of KPIs (as explained in Section 3.3.3.2 and highlighted in Figure 45 for water availability/quantity from sub model 1, and emphasized in Section 3.3.4.2 and highlighted in Figure 47 and Figure 48 for water quality from sub model 2).

For clarity and facilitated editing, different parts of the integrated SD model and their various components are structured in different views in the Vensim software. The integrated SD model takes into account the fundamental physical mass balance constraints as a general condition for the water and nutrient interactions and their impacts on various natural sub-systems and socio-economic sectors. The model simulates these interactions for annual time steps over a 100-year time horizon starting from 2010. Therefore, the initial conditions of the stock variables are defined as long-term average conditions to current time. The boundary conditions are defined as recent-current average conditions of input water flows and associated nutrient concentrations at the land surface and other main component boundaries in the representative MAL3 coastal hydrological catchment. Dynamic changes within the MAL3 land-sea system can then be assessed as results of possible shifts in the defined boundary (i.e. long-term average) conditions as well as of alternative socio-economic development plans and/or environmental regulations in the MAL3 region. The integrated MAL3 SD model can also aid understanding of nutrient legacy source implications for the dynamics of nutrient load evolution in the MAL3 land-sea system.

Figure 49 shows the main feedback loops between key system components (natural water systems and various socio-economic sectors) addressed in the integrated MAL3 SD model. Water availability and quality conditions are controlled by how agricultural activities, urbanization, tourism, and industrialization developments affect surface and subsurface water systems, which in turn feedback water availability and quality shifts, with economic and growth implications, to these sectors. These interactions and feedback loops are also influenced by changes in hydro-climate conditions and by shifts in growth policies and environmental regulations. These interactions were identified as important by the MAL3 stakeholders through the co-developed regional CLD and are reflected as such in the integrated MAL3 SD model.

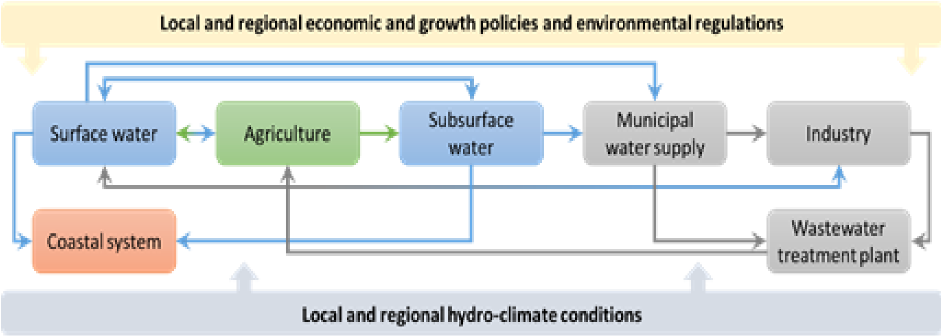


Figure 49: Main feedback loops involved in the integrated system dynamics (SD) model for MAL3. The colour *of interactions is assigned based on the box colour of the influencing system component.*

3.3.6 Business and policy analysis

The integrated land-sea system model for MAL3 will be used to address and test following types of change scenarios (Viaene et al., 2020):

1. Changes in precipitation (due to climate change) and the propagation of associated impacts on renewable water resources for sectoral activities on land and coastal hinterlands;
2. Changes/developments in the green agriculture and forestry sectors and associated impacts on sectoral land shares, freshwater availability and quality as well as coastal water quality;
3. Changes/developments in urbanization and tourism expansion with impacts on sectoral land shares, freshwater availability and quality, as well as coastal water quality;
4. Changes in the nutrient (nitrogen and phosphorus) inputs of different sectors, represented by changed concentration levels and associated nutrient transport by water flows through the land-sea system, and assessing their impacts on freshwater and coastal water quality, and implications for business activities and their development opportunities;
5. Combined impacts of changes mentioned above (the four previous points) on sectoral land shares, freshwater availability and quality, coastal water quality, and implications for business activities and their development opportunities;
6. Implications of national and international environmental regulations and agreements (e.g., Water Framework Directive (WFD), Baltic Sea Action Plan (BSAP), Maritime Spatial Planning (MSP)) in relation to nutrient loading to inland and coastal waters and the Baltic Sea and associated feedbacks to inland and coastal economic activities.

A dashboard view, as shown in Figure 50, is incorporated within the integrated SD model to facilitate use of the model and its key performance results by various stakeholders. The dashboard consists of separate parts for the model inputs and the results related to water availability/quantity and quality. In this dashboard, 9 input variables, associated with the change scenarios described in the above bullet points, are defined as slider variables (Figure 50 (a)).

They include:

- Scenario number – A dimensionless value between 0-5;
- Precipitation change rate – A dimensionless value in the range of [-1, 1] where negative and positive values indicate decrease and increase in precipitation, respectively;
- Urban growth rate – A dimensionless value in the range of [0, 1], indicating inland/coastal urbanization;
- Agricultural intensification rate – A dimensionless value in the range of [0, 1];
- Agricultural land expansion rate – A dimensionless value in the range of [0, 1] indicating inland/coastal agricultural development;
- Average nitrogen and phosphorus concentration levels in surface and subsurface waters – Value (kg/m3) in the range of [0, 1].

Model users can easily define and change the values of these slider variables and test the model outcomes in terms of the KPIs given as output variables from the MAL3 integrated SD model. Model results are shown in the dashboard for the KPIs related to water availability/quantity and quality. Figure 50 (b) shows the 14 KPI variables related to water availability/quantity results from sub model 1 (explained in Section 3.3.3.2 and highlighted with blue background in Figure 45). Figure 50 (c) shows the 25 KPI variables related to water quality results from sub model 2 (explained in Section 3.3.4.2 with some of them highlighted with blue background in Figure 47 and Figure 48). These KPIs quantify various aspects of the MAL3 land-sea system behaviour and its potential changes due to pressures from different socio-economic sectors (with focus on agriculture, urbanization, and tourism developments), along with nutrient legacy sources, on water availability and quality, and the possibilities of achieving the nutrient load targets set by the internationally agreed BSAP (HELCOM, 2007 - will be updated in 2021). All model components, indicators and change scenario variables are well documented with their lists included in this report, in Annexes 4c and 5c.

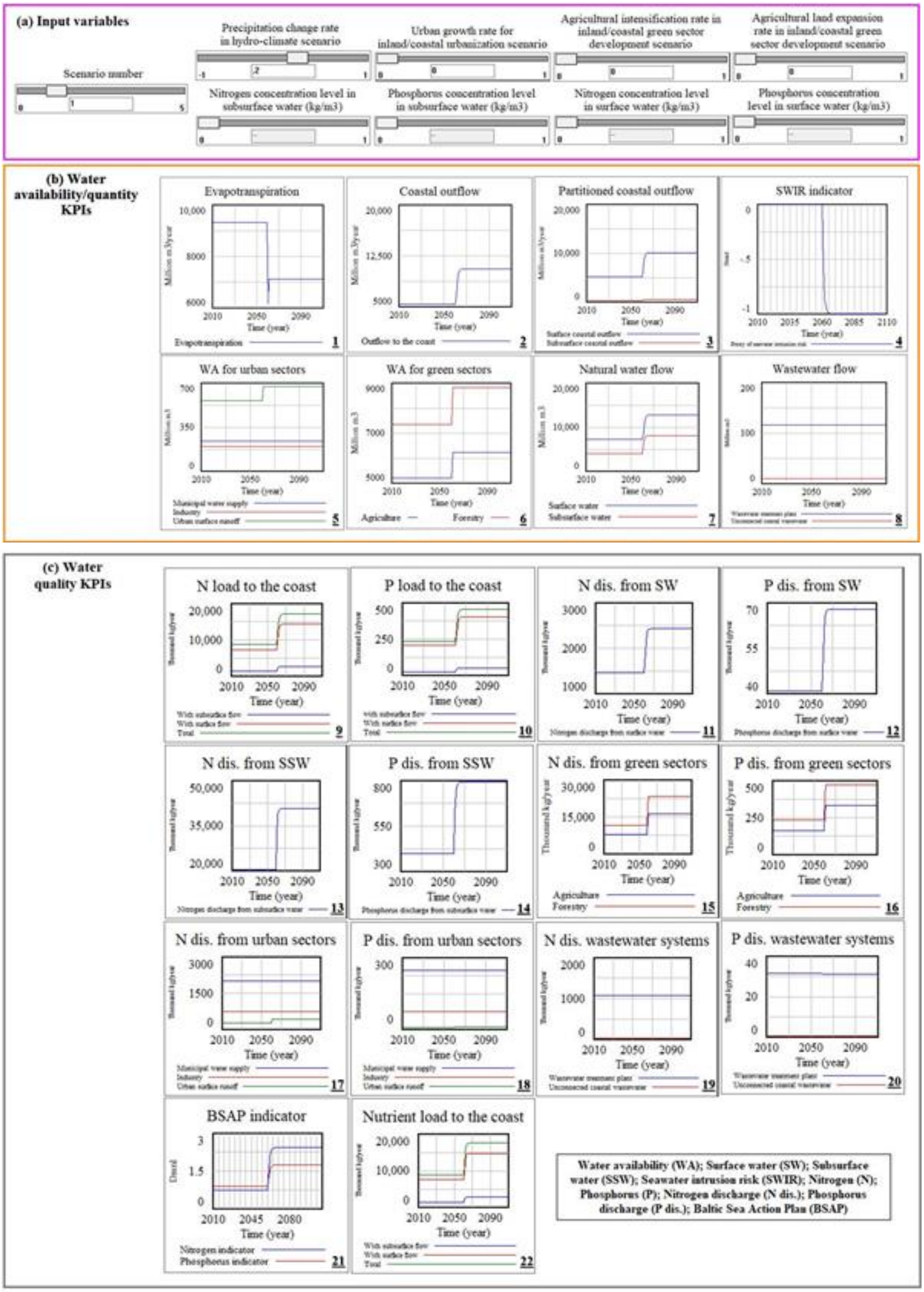


Figure 50: Dashboard view in the integrated SD model for MAL3: (a) Input slider variables; (b) The key performance indicators (KPIs) related to the water availability/quantity results; and (c) The key performance *indicators (KPIs) related to the water quality model results. System dynamics changes shown in these graphs are associated with model simulation for RCP4.5 scenarios with 20% increase in the long-term annual average precipitation in the MAL3 land-sea system over a 100-year period (change scenario 1 mentioned in the beginning of Section 3.3.6).*

The various types of change scenarios outlined above (points 1-6) will be assessed (as part of WP5) in relation to some relevant shared socioeconomic pathway scenarios (SSPs) and representative concentration pathways (RCPs) for the MAL3 land-sea system. The integrated SD model with its dashboard view will also be used for business road map and policy analysis (as part of WP3) in terms of the KPI variables. For example, the RCP4.5 projections indicate 20% increase in the long-term annual average precipitation for the MAL3 region. Results of modelling such change are presented in Figure 50, indicating that coastal outflow would be approximately doubled (graph 2) mainly due to increased surface water flow to the coast (graph 3) in this scenario. More water will then also flow through the green sectors (agriculture and forestry – graph 6) implying that they would experience and need additional, costly drainage infrastructure for managing more waterlogging conditions that would otherwise damage crops and plants, as reflected in resulting evapotranspiration decrease (graph 1). Higher urban surface runoff should also be expected in this scenario (graph 5), highlighting needs for new drainage infrastructure also for urban stormwater handling. Due to the higher coastal outflow, nutrient loads to the coast would also increase under this RCP4.5 scenario (graphs 9 and 10), leading to increased value of the Baltic Sea Action Plan (BSAP) KPI for both nitrogen and phosphorus (graph 21), reflecting that, nutrient loads would then be far above the set environmental targets. As such, further and more costly mitigation actions and measures and/or more restrictive/limiting environmental policies and regulations would be required to meet the BSAP targets and prevent further coastal water quality and ecosystem deterioration. The indicator for seawater intrusion risk (SWIR), however, would decrease in this scenario (graph 4) – i.e. decreased risk for seawater intrusion – due to higher seaward groundwater discharge, pushing the freshwater-seawater interface further seaward and thereby securing more fresh groundwater availability in the coastal zone.

Such scenario analysis by the MAL3 SD modelling will support further sustainability and robustness analyses of case-specific business roadmaps and policy recommendations. The integrated SD model will also allow evaluation of model sensitivity to different scenario assumptions and variations, and identification of potential synergies and/or goal conflicts, e.g., between economic and environmental sustainability targets.

3.3.7 Model confidence building

The SD modelling for MAL3 follows the main land-sea interaction conceptualization co-developed with the local and regional stakeholders (Tiller et al., 2019a and 2019b), and data- and process-based understanding of key water-related problems, behaviour and dynamics reported in published, peer-reviewed literature of relevance for the MAL3 land-sea system (Darracq and Destouni, 2005; Hannerz and Destouni, 2006; Cseh, 2009; Destouni et al., 2017; and Destouni and Jarsjö, 2018). Model confidence building is also developed in further meetings and collaboration with stakeholders, including the MAL3 local partners, for the modelling purposes and boundary conditions in the two SD sub models (the 1st multi-actor workshop held in-person for MAL3 on September 2019 – Tiller et al., 2019b) and the integrated land-sea system model (the 2nd multi-actor workshop held online due to COVID19 pandemic for MAL3 on November 2020). The MAL3 lead partner, local partners and stakeholders together tested the SD model representation of their land-sea interaction perception and the level of detail of system components and their key interactions and feedbacks quantified in the model.

Due to the high complexity of the integrated MAL3 SD model, the original model structures developed in Vensim software could not be directly used by stakeholders during the multi-actor workshops. Although, the software includes a graphical interface to build and show system components and their interactions, it does not support visualized and interactive communication of the model purposes and dynamic behaviour of the land-sea system. Therefore, the Tableau platform[1] was used in the 1st workshop to show and communicate with the workshop participants about the interactions, impacts and feedbacks in the MAL3 SD modelling. Model validation and confidence building with stakeholders in the 2nd multi-actor workshop was more focused on exploring interesting/relevant types of (change) scenarios to analyse in the MAL3 SD modelling. Such scenario analysis can be used to examine various change impacts on water availability and quality for societal sectors and natural systems in the MAL3 case.

To facilitate stakeholder discussions and get feedback on the SD modelling and possible change scenarios in the 2nd multi-actor workshop, the key model variables were presented in four main categories of socio-economic sectors, hydro-climate and bio geophysical characteristics, and policy and market force indicators, as shown in Figure 51. These variables and categories relate to the problem scopes that can be addressed by the MAL3 SD model. Stakeholders were encouraged to react on model structure and components and suggest and further discuss possible relevant future changes that should be considered and related to key SD model variables and also link these to some overarching policy frameworks, including the EU Green Deal (EC, 2020), the UN sustainable development goals (SDGs) in Agenda 2030 (UN, 2015), the SSP scenarios of global climate change scenarios (Riahi et al., 2017), and some relevant goals of the Swedish marine spatial planning for the Baltic Sea (Swedish Agency for Marine and Water Management, 2019).

Figure 51: Key variables included in the integrated MAL3 SD model, summarized in four main categories of socio-economic sectors, hydro-climate and bio geophysical characteristics, and policy and market force indicators. These variable categories were used during the 2nd multi-actor workshop with the MAL3 stakeholders for model validation and confidence building.

The participating stakeholders confirmed the structure of the model, its components, variables, and their interactions, and the model capability to test and analyse various change scenarios for MAL3, such as those listed below from the 2nd multi-actor workshop discussions:

1. Spatial planning and land-use changes in combination with urban population growth and its implications for water supply, wastewater handling and treatment under different hydro-climate conditions;
2. Impacts of extreme climate events;
3. Achieving more resilient food system; which can be tested in the MAL3 model through the land cover system characteristics.
4. Implications of achieving a desirable water quality condition for inland and coastal sectors in the MAL3 case;
5. Impacts of coastal tourism development, e.g., with expansion of summer houses (that are increasingly being converted to permanent housings) in the MAL3 coastal and archipelago regions with no proper water and wastewater management;

The MAL3 stakeholders were interested to investigate both change directions (increase and decrease) for different relevant model variables, rather than assessing some selected development-direction changes. The reason for this is the uncertainties involved in future scenario conditions and the MAL3 stakeholders have a clear understanding and perception of such uncertainty implications for economic activities and development in this region. The participating stakeholders in the MAL3 workshops also tend not to be experts on, or even familiar with scenario analysis in relation to global SSP scenarios and how they may relate to relevant local/regional change and development possibilities for MAL3.

The KPIs explained in Sections 3.3.3.2, 3.3.4.2, and 3.3.6 were also discussed with and validated by stakeholders in the 2nd multi-actor workshop for MAL3, where they confirmed the KPI suitability and relevance for the MAL3 system analysis. Based on the collected stakeholder feedbacks and inputs, the next steps will be further model testing and scenario simulations in relation to relevant SSPs and RCPs, and developed business roadmaps and policy recommendations for MAL3 and the associated KPIs. The outcomes will be shared and discussed with the MAL3 local partners and stakeholders and their feedback will be incorporated in the developed roadmaps.

[1] https://www.tableau.com/

3.4 Multi-Actor Lab 4 - Charente River Basin (France)

3.4.1 General problem scope of the land sea system

The part of the Charente River watershed (10000 km²) located upstream, downstream and beyond the coastal zone is under significant environmental pressure from different economic activities such as summer tourism, agriculture, and shellfish farming (Figure 52).

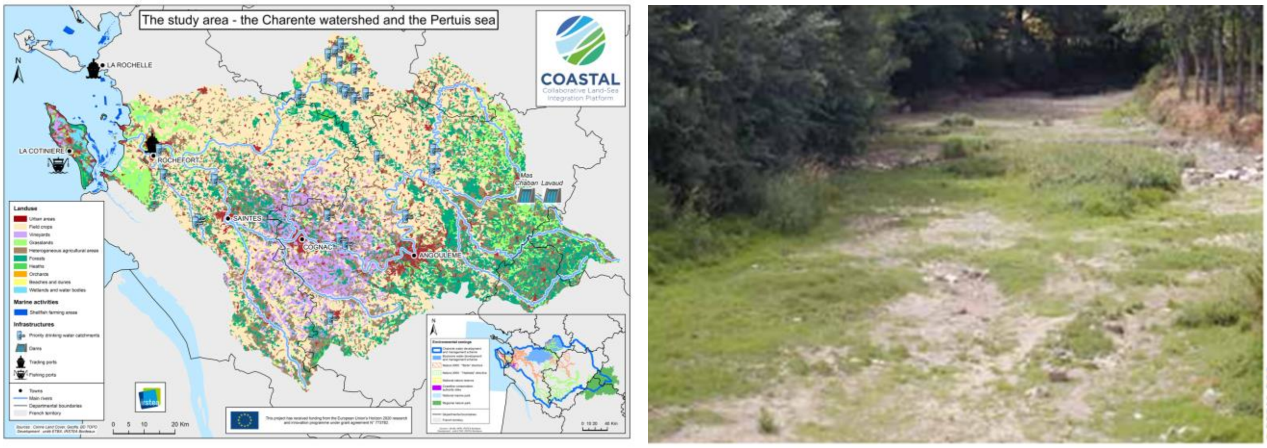


Figure 52: The Charente River basin with illustration of the main concern of this MAL (one tributary of the Charente River in summer).

Environmental issues are even more important as the urban coastal population is steadily increasing, resulting in continued pressure on land availability in rural areas, protected areas and the many salty or freshwater wetlands. The use of water resources for drinking water and irrigation, as well as for the preservation of a minimum instream flow to protect aquatic ecosystems requires large volumes of water. Water resources are limited, and this limitation is even enhanced by the effect of climate change (droughts in spring and summer). This situation, although quite common in France and Europe, is exacerbated in the Charente catchment area. Pressure on water resources affects both quality (i.e., pollution by nitrate and pesticides) and quantity (impact on natural environments and availability of drinking water). In this area, activities carried by agriculture with irrigation of crops (mainly maize), use of nitrate (in particular with cereal crops) and pesticides (notably on vines used for Cognac production) and domestic use have a significant impact on water resources. Changes in farming systems and more sustainable practices are the only solution to improve the quality of fresh water resources. This impact is felt downstream, in coastal areas, in significant sectors for the local economy such as shellfish farming and tourism.

The preservation of coastal water quality (salinity, planktonic and benthic production) is of utmost importance for selfish farming and professional inshore fishing. In addition, due to the flatness of the coast, the presence of important wetlands increases the effects of climate change (sea level rise) and the possible soil salinization of coastal farming areas. At the same time, the two major ports in the area rely on local agricultural products for a sizeable portion of their business. Any significant change in activities and land use in one part of the territory will impact employment in several sectors and location of the rural- and coastal zones.

The situation is further complicated due to the continuous increase of residential or immigrant elderly population and of tourists on coastal zones causing important effect on land prices and changes of demand for products and services.

New development opportunities raise questions that are controversial or sensitive. The development of reservoirs could be a means for farmers to access a reliable source of water to irrigate their crops and ensure production of their main export crops (cereals, maize), on which the activity of La Rochelle port largely depends. Opposes of reservoir development argue for the potential imbalance of the water cycle and the privatization of water resources as a public good. Another new opportunity likely to cause disruption is a shift from present farming systems towards more environmentally friendly systems with less water-dependent crops. The development of diversified crops could be a real opportunity for the second merchant port along the Charente River (Tonnay-Charente), which, due to its more upstream location, is only accessible by smaller vessels.

The main land-sea interactions in the coastal MAL3 region were identified through the sector workshops and the combined multi-actor workshop as part of WP1 in the COASTAL project around two main issues: water needs and land use availability and associated economic concerns.

The land sea interactions considered in the model are:

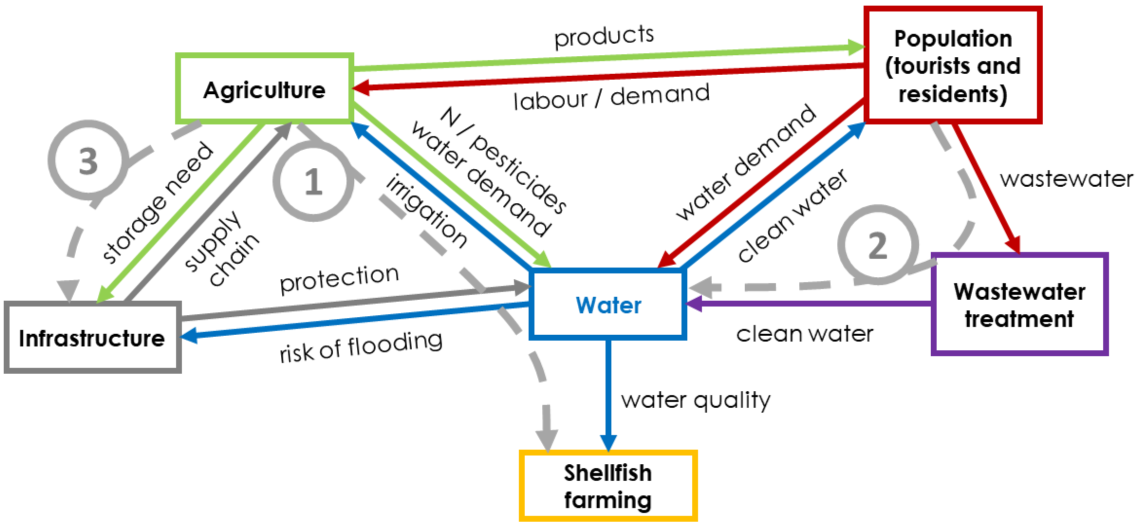
- The dependence of downstream activities (primarily shellfish farming but also coastal tourism) on upstream activities (agriculture) in terms of water quantity and quality.
- Interactions between the development of coastal summer tourism the increase of the coastal population and the development of irrigated crops.
- Interactions between the development of new agricultural supply chains in the hinterland and the development of trading port activities implying infrastructure investments.
- Interactions between the development of organic farming, organic supply chains (short or export) and dedicated infrastructures (specific storage, economic support by regional authorities).
- Interactions between the changes of agricultural systems and the coastal water quality (use of fertilizers and pesticides depending on the evolution of practices).

3.4.2 From Multi-actor analysis to modelling

The integrated model of the MAL4 intends to simulate the rural and coastal activities in a systemic way, and the hydro system within the Charente River basin and its coastal zone. The main hinterland activities located upstream of the Charente River taken into account are agriculture, rural tourism, wastewater treatment and drinking water supply, while the coastal downstream activities are shellfish farming, coastal tourism, wastewater treatment, drinking water supply and infrastructure. The hydro system includes different aquatic ecosystems in the hinterland and on the coastal zone. All these activities and ecosystems interact with each other through water, its available quantity and its quality.

In the integrated model, dedicated sub models simulate the functioning of each activity and the hydrological system. These sub models are coupled, that is each uses as input some variables calculated by other sub models (their outputs). For instance, the concentration of trophic resources in the estuary, calculated by the water sub model, impacts the production of oysters in the shellfish farming sub model. Figure 53 illustrates how the sub models are coupled, showing the central role of the water sub model. This coupling helps to understand the interactions between the activities and the ecosystems and what will be the effect of changes in one activity on another.

For our example, the concentration of trophic resources in the estuary that is calculated in the water sub model depends on the river's flow, which itself depends on irrigation for agriculture (output of the agriculture sub model). Hence, in the integrated model, the production of oysters indirectly depends on irrigation, and so a change in agricultural practices will likely lead to a change in this production. Beyond the interactions among sub models, exogenous variables describing the climatic, regulatory and economic context of the river basin also influence the functioning of the system. Overall, the integrated model allows assessing the effect on some key variables of interest (selected outputs of the sub models) of systemic scenarios that describe changes in the activities and context. The trade-offs and synergies revealed between the key variables allow then to identify which actions can lead to a desired future and to understand how to organise activities together to foster the resilience of the whole system.



1

There is a high dependence of downstream activities on upstream activities in terms of water quantity and quality. Coastal water quality is essential for shellfish farming and tourism and depends on upstream water withdrawals and pollutions.

2

Summer tourism causes coastal congestion and leads to a growing demand for drinking water and needs for larger capacities for wastewater treatment plants (capacities are already stretched beyond their limits with risk of overloading in summer).

3

The development of ports relies on inland agricultural production and any change in farming systems may have large impact on port activities. If crops are diversified, ports should adapt their activities.

Figure 53: General structure of the integrated model with examples of main coastal, rural, and land-sea interactions that can be studied using the integrated model.

As illustrated in Figure 53, simulations with the integrated model allow analysing land-sea interactions and to highlight the behaviour of the system over time. The independent decision variables of the model are set to address decisions and actions foreseen by the stakeholders in the practical roadmaps, as detailed in the following description of the sub models.

In line with the multi-actor approach of COASTAL, the design of the integrated model reflects the representation of the system co-built with the stakeholders during previous workshops. Its architecture

(Figure 53) is in complete accordance with the causal loop diagrams (CLDs) stemming from mind maps (*Figure 54* and cf. deliverable D13). Summarizing the CLDs, costal zones attract people who can afford second homes, retirees and millions of tourists in summer each year. This process increases coastal tourism areas and leisure accommodation capacity, which are strong components of the attractiveness but cause growing urban congestion. In addition, competition for space is combined with the problem of competition over water resource. Indeed, the growth of the residential and seasonal populations results in an increased drinking water demand, in particular during the summer months when irrigation water demand is at its highest. The water shortage calls for more water reservoirs allowing irrigation (R1, *Figure 54*). Development of irrigation and intensive farming systems is balanced by the development of organic and more sustainable farming systems (B2). Water storage however diminishes the availability of groundwater and surface water (R2 and R3) and, with time, causes a depletion of water table levels that may impact groundwater supply (B1), illustrating the tragedy of the common's archetype. The ever-increasing water scarcity also impacts oyster production that needs freshwater downstream for balancing coastal salinity. The more these conditions for a good water quality in the marine environment are met, the better are the growth and reproduction of oysters and the demand for improved water quality (R4). As for the quality of coastal waters, the increase of population results in an overloading of existing waste water treatment plants (WWTPs), particularly during summer months and in the coastal zones. This situation leads to the degradation of coastal waters, impacting shellfish farming activities, and calls for the development of new WWTPs or the upgrading of existing ones for a better quality of reclaimed water (B3). Responding to global market demand, the development of intensive farming systems results in an increase of yields to export through trading ports. This induces an increase of port facilities and the development of new infrastructures and equipment, which in turn stimulates the development of intensive farming systems (R5). The development of organic farming forces organic farms to increase the size of their holdings and competes for space. This process, combined with tourist accommodation development, will constraint the ports' development (B4).

Technical notes for the following sections describing the sub models:

- The model runs on a monthly basis with a time step (dt) of 0.125 month from 2000 to 2040 with the scenario period starting in 2020.
- The variables names are written in italics in the sub models' descriptions.
- In the sub models' SD diagrams, the input variables are marked in yellow, the interaction variables common to several sub models are in green, the variables set in the scenarios (specific type of input) are in orange and the tracked key variables are in blue.

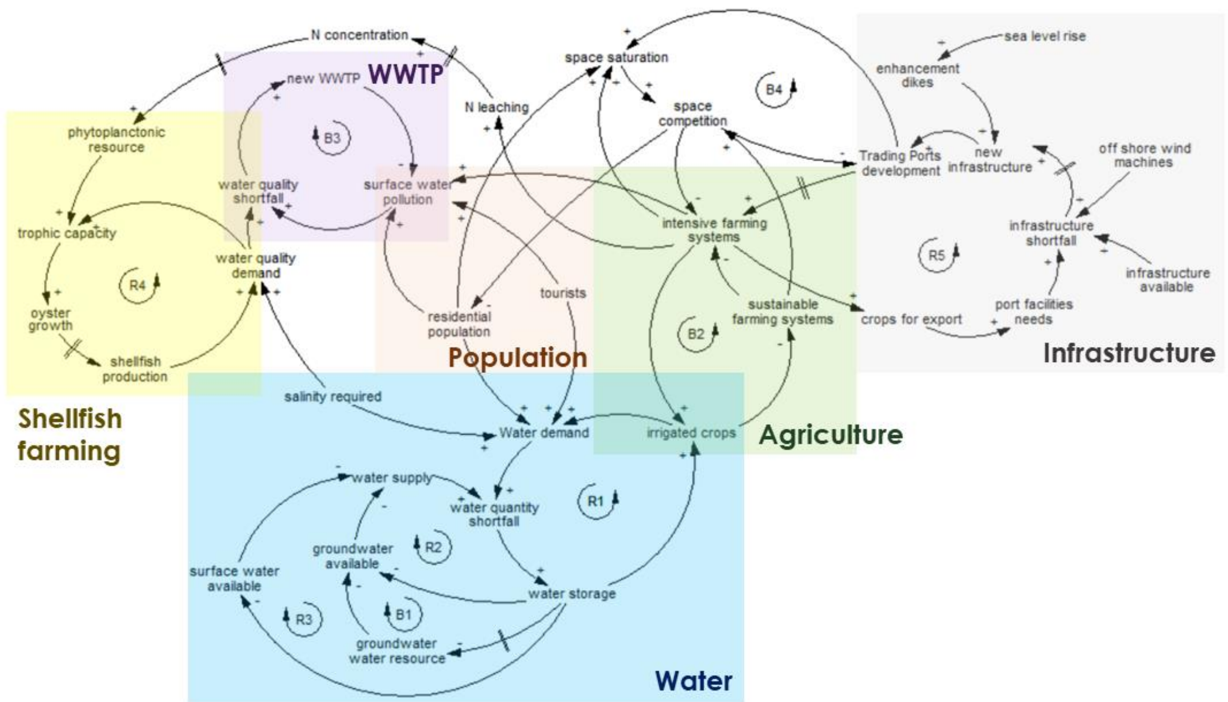


Figure 54: Overview of the Causal Loop Diagram for the main land-sea interactions identified during the sector workshops with links to sector models. R stands for reinforcing feedback loop and B for balancing feedback loop.

3.4.3 Sub model 1: water & wastewater treatment

3.4.3.1 Scope of the water & wastewater treatment sub model

All the stakeholders have expressed the need to ensure water's availability and good quality for their activities. Thus, the water sub model aims at evaluating the impact on water of the different rural and coastal activities, of regulations related to water use and of climate parameters (rainfall and temperature).

To address the stakeholders' interests and expectations, the key output variables of the sub model are the following:

- **The flow of the Charente River:** the *water streams flow*, considered at the most downstream measuring station in Beillant, must be over a certain threshold needed for the good functioning of aquatic ecosystems. The *estuary flow* is also important and monitored, although it is not subject to regulations, in order to maintain conditions in the estuary.
- **The *domestic water deficit*:** restrictions on domestic water use should be avoided as much as possible.
- **The *irrigation water deficit*:** the agricultural actors identified the availability of water as one of the main limiting factors for their production, as well as a main driver of changes in practices (cf. Sub model 3).
- **The *concentration in trophic resource*, the *occurrence of viruses* and the *coastal salinity*:** the oyster farmers identified these three parameters as the most important for determining the quantity and quality of oyster production (cf. Sub model 2).

Furthermore, to depict future actions that stakeholders may consider, the following decision variables (inputs to the sub model) can be set in scenarios:

- ***Abstraction permits for irrigation***: this amount, set by regulations (National Environmental code) and enforced by local authorities, aims at ensuring water availability to all the users. It decreased drastically in the last years and dropped from around 100 million m^3 (Mm^3) in 2010 to around 45 Mm^3 in 2020.
- ***Low-Water Target Flow for water streams***: this minimum allowed flow is usually set at the Q10 flow, which is the 10^{th} percentile flow. This flow, considered at the Beillant station in the model, is reserved for environmental purposes and regularly revised. As a result, when the *water streams flow* is below this limit, abstractions for irrigation can be restricted or even banned to ensure adequate instream flow to support ecosystem functions.
- **The *reservoirs capacity*:** the building of reservoirs to stock water in winter for irrigating in summer is a hot issue over the whole study area. Currently, the whole capacity is around 7 Mm^3, and the people advocating their development propose to increase their capacity to more than 30 Mm^3 while their opponents raise the major risk of disturbing the water cycle, the ecosystems and biodiversity within the area.
- **The *capacity of coastal* and *rural wastewater treatment plants (WWTPs)*:** because both the residential and tourist populations keep growing, the capacity of the WWTPs must be increased, especially in the coastal area where it is already often overloaded.
- **Other sub models' decision variables:** most of the decisions taken in the other sub models will ultimately affect the water resource, notably those concerning agricultural practices (cf. Sub model 3) and domestic water use (cf. Sub model 5).
- ***Rainfall* and *reference evapotranspiration*:** these variables allow to analyse the effect of climate change (changing rainfall patterns and increase of temperature), which is a concern for all the stakeholders.

Because the issue of water availability is seasonal, the model uses a monthly basis to highlight water shortages in summer, when rainfall is scanty, irrigation is intensive, and the tourist population reaches its peak.

Based on the CLD (cf. section 3.4.2 – *Figure* 54), the following dynamic hypotheses shape the structure of the model:

- Water shortages in summer will increase with water use and as a result, regulations will become more constraining. This in turn may foster the development of more efficient and less demanding practices, thus balancing water use and preserving the water cycle.
- The management of water either as a public or private good, which can notably be observed at the level of reservoirs development, will strongly influence the role of the regulations.

3.4.3.2 Quantification of the water & wastewater treatment sub model

The water sub model simulates on a one-month basis the water cycle with seven compartments for the water quantities (Figure 55): *water in soil*, *groundwater*, *surface water*, *water streams* (Charente River and tributaries), *water in marshes*, *dam storage*, *reservoirs* and wastewater treatment plants (*coastal WWTP* and *rural WWTP*). Dedicated stock variables represent theses quantities of water in Mm^3 (million cubic metre).

Over time, these compartments exchange water through different simplified physical processes. Flow variables represent these exchanges in Mm^3/month. They are quantified as follows:

- ***Infiltration*** **and** ***runoff*****:** rain water either infiltrates to the soil or runs off to surface water. The share of rain water that infiltrates is represented by an *infiltration coefficient* (cf. lookup in Figure 56). This latter depends on the ratio of *soil saturation*, which is expressed in Mm^3/m^3 and is equal to the *water in soil* divided per the *volume of soil*, to the *soil saturation limit* (cf. Table 2). The more saturated is the soil, the less water infiltrates. The amount of water running off is equal to *rainfall* minus *infiltration*.
- ***Evapotranspiration*** **and** ***groundwater recharge*****:** a part of *water in soil* is lost through evapotranspiration by land covers. *Evapotranspiration by agricultural covers* is calculated in the agriculture sub model while *evapotranspiration by other covers than agriculture* is retrieved from the SWAT model (cf. Box 1). The water that is not lost to evapotranspiration reaches the aquifers (*groundwater recharg*e) at a *seepage rate* that depends on *soil saturation* (cf. lookup in Figure 56).
- ***Irrigation*****:** 90% of the *irrigation water use* is considered to infiltrate the soil while the rest is directly evaporated (*evaporated share of irrigation*). The calculation of withdrawals for irrigation, either from groundwater or surface water, is explained below.
- ***Groundwater rise*****:** when the groundwater bodies are saturated, the water rises to *surface water*. This phenomenon is significant in the region, where most of the aquifers are alluvial with a low inertia. The *groundwater capacity* (in Mm^3) is a calibrated parameter (cf. calibration procedure below) since this value is not actually measured. Indeed, the amount of water in aquifers is estimated by the water table level. In the model, the amount of rising water is equal to the *groundwater* amount minus the *groundwater capacity* when this difference is positive (otherwise it is null).
- ***Groundwater withdrawal*****,** ***surface water withdrawal*** **and** ***reservoirs refill*** **and** ***use*****:** water is withdrawn from the aquifers and from surface water for domestic uses, irrigation and refilling the reservoirs. The reservoirs are used only for irrigation. Every month, *domestic water demand* and *irrigation water demand* (from May to September, cf. *irrigation per month* in Sub model 3 – Figure 60) are calculated, respectively in the population and the agriculture sub models (cf. Sub model 3 and 5). Reservoirs are filled in winter up to their maximum capacity. At the present time, *reservoirs capacity* is of 7 Mm^3, but as the building of new reservoirs is considered, this capacity is a decision variable that can be set in scenarios. *Irrigation water demand* is bounded by *abstraction permits for irrigation* (decision variable) to calculate the *allowed irrigation water demand*. For withdrawals for domestic, agriculture and reservoir, the shares coming from ground or surface water are based on observed data (cf. Table 2). As a result, three demands are calculated from both the aquifers and surface water. In the case of agriculture, a share of the irrigation water demand is also met by using water from the reservoirs, until they are empty. Then, for each source stock (*groundwater* and *surface water*), demands are met up to the current level of the stock, given that domestic use has the priority over irrigation and reservoirs refill. Also, the *allowed irrigation water demand* is not met at all if, during a month, the simulated *water streams flow* of the Charente River is below the *Low-Water Target Flow for water streams*. Summing over the stocks the levels to which the demands are met gives the amounts of water that are withdrawn every month for domestic use (*domestic water use*), agriculture (*irrigation water use*) and the reservoirs (*reservoirs refill*). Note that for a given demand, a deficit from one stock is not compensated by another stock, e.g., when

the agricultural demand from groundwater is not met, it is not compensated by withdrawals from surface water.

- **Exchanges with the dams (*to dam* and *from dam*):** a single stock of maximum 24 Mm^3 (*dam capacity* in Table 2) represents the merged capacity of the two dams located upstream of the Charente River. In the model, the dams function according to two different regimes. When the simulated *water streams flow* is above the *Low-Water Target Flow for water streams*, the dams refill (*to dam*). When it is below, the dams release water (*from dam*). The rates at which the dams refill and empty themselves are input data (cf. Table 2). In reality, the dams also release water in winter in case they are full, but this can be seen as direct transfer of water with no impact on the water cycle, hence it is not considered in the model.
- **Wastewater flowing into (*to WWTP*) and out of the treatment plants (*from WWTP*):** the coastal and hinterland wastewater treatment plants (WWTPs) are modelled separately. During a month, the amount of water that enters the WWTPs is equal to 70% (fixed share, cf. Table 2) of *domestic water use*. The *coastal* and *rural domestic water demands* are calculated in the population sub model (cf. Sub model 5). The water flow released by a given WWTP (*from WWTP coastal* or *rural*) is modelled with a fixed delay, the value of which is equal to the flow arriving to the WWTP (*to WWTP coastal* or *rural*) and the duration of which depends on the *capacity of coastal/rural WWTP*. The maximum capacity of the WWTPs, initially expressed in population-equivalent, is transformed in a flow capacity (in Mm^3/month) comparable to the *domestic water use* flow. When the flow of water entering one of the WWTPs is below its capacity, water is treated within 3 months (cf. lookup in Figure 56). When the entering flow is above the capacity, the *WWTP overload* is calculated (the water flow entering minus the capacity) and the *WWTP treatment duration* decreases as the overload increases. The shorter is the duration, the less effective is the treatment. Note that the water released by the WWTPs goes only to surface water.
- ***Water streams flow* and *estuary flow*:** once the rainwater has reached the *surface water* stock from *runoff* or *groundwater rise* and after the withdrawals and exchanges with the dams and the WWTPs stocks have occurred, the remaining water flows towards the sea through marshes. The simulated flow of water going *to marshes*, between the *water streams* and the *marshes*, is meant to represent the flow observed in the most downstream measuring station on the Charente River (in Beillant). The simulated flow of water going *to the se*a is considered to represent the *estuary flow*.

Once the flows are calculated, three indicators of water quality are derived:

- **The *concentration in trophic resource* in the coastal area:** trophic resource is consumed by oysters and mostly consists of phytoplankton. Expressed in mg/m^3, this concentration depends on the *estuary flow* (cf. lookup in Figure 56).
- **The *coastal salinity*:** similarly, *coastal salinity* depends in part on the *estuary flow* (cf. lookup in Figure 56). The simulated *coastal salinity* represents a monthly average, although it should be noted that because of tides, salinity varies more on a day-to-day basis over a month, than from one month to another.
- **The *occurrence of viruses*:** the considered viruses are those coming from wastewater that could hardly be stopped by the WWTPs. Their occurrence, represented by an indicator ranging from 0 to 1, depends on the *coastal* and *rural WWTP overload* (cf. lookup in Figure 56).

So far, the calibration of the water sub model has been conducted manually, but more advanced methods will be further applied (cf. Model confidence building section). The fitness of the sub model is measured at the level of different stocks and flows for which observations are available (notably the Charente River flow), according to the least-square method (residual sum of squares). When no observations are available, the model's results are compared with results obtained from the hydrological modelling of the river basin using the SWAT (Soil and Water Assessment Tool) model (cf. Box 1).

Box 1 – The Soil and Water Assessment Tool (SWAT) model

The ecohydrological watershed Soil and Water Assessment Tool (SWAT) is a physically-based and continuous time step and semi-spatially distributed model. It enables environmental impact assessment for decision aid. It takes into account temporal and spatial variabilities of biophysical factors (climate and soils and slopes etc.) and watershed management (dams and canals and ponds) and land use management (agriculture, best management practices and urban uses, etc.). The SWAT's main components simulate the water cycle, nutrient cycle and crop growth. The transport and fate of pollutants issued from human activities in the soils and waters and atmosphere are calculated at the sub-basin level.

The SWAT model has been successfully implemented at INRAE during previous research projects on the Charente River basin: the European SPICOSA (Ballé-Béganton et al., 2012; Bordenave et al., 2020) integrated coastal zone management project and regional Water Agency projects (Vernier et al., 2009).

For the COASTAL project, SWAT model outputs are used for providing ranges of magnitude, calibrating / validating / verifying variables in the SD water model, such as hydrological balance – in particular the streamflow –, as well as evapotranspiration and climate variabilities.

Technically the SWAT Charente model has been run from 1995 to 2018 (with possible extension to 2020); it has been calibrated on the 1998-2008 period and validated on 2009-2018 period with sequential fitting procedure and Nash-Sutcliffe efficiency goodness-of-fit criterion, on institutional observed daily streamflows (and possibly nitrate). From the 107 delineated sub-basins, 16 are monitored for streamflows, 50 for nitrate. The double split calibration procedure is sequentially carried out from upstream to the most downstream monitored sub-basins, at first on streamflows followed by nitrate parameters.
The modelled SWAT Charente includes the whole Charente River basin except the estuary that cannot be modelled as the hydrological natural regime is strongly disturbed by flatness and marine inflows and canals. The model focusses on the highly agricultural hinterland which is the main contributor to fresh water quality impairment due to diffuse pollution and to regular fresh water shortage to irrigation.

Inputs such as the karstic resurgence and the dams' releases aimed at irrigation and maintaining a low flow and irrigation are implemented. 13 ground-based climate stations and 6 hydrometeorological variables at daily time steps are entered. The soils spatial and physical chemical features are issued from previous studies in collaboration with the same stakeholders. The land use and land cover are issued from previous projects and updated to 2017 agricultural census data and the 2016 non-agricultural land cover.
An extrapolation of the results of previous project, statically estimated could be provided for pesticide transport and fate in fresh waters.
Daily model outputs time series are aggregated at the SD time step model and spatially summarized.

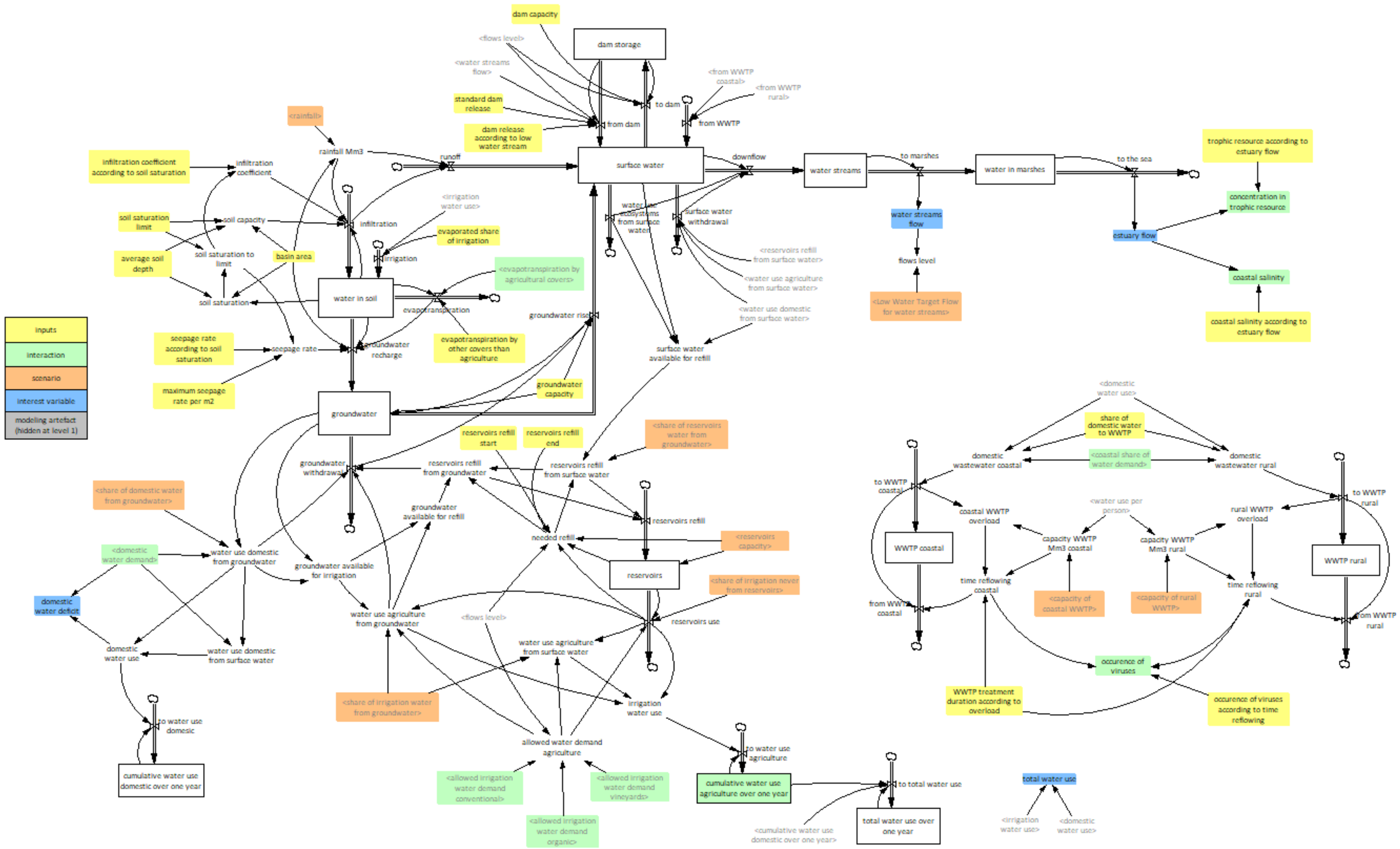


Figure 55: *Overview of the SD water sub model*

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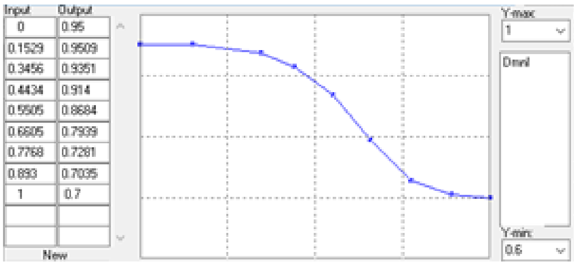
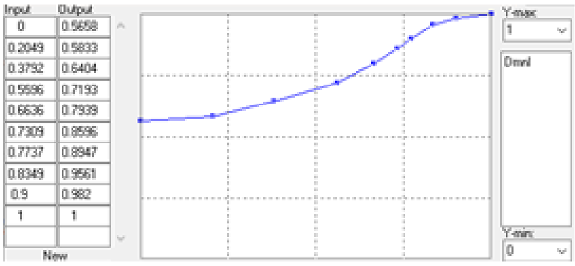
infiltration coefficient according to soil saturation



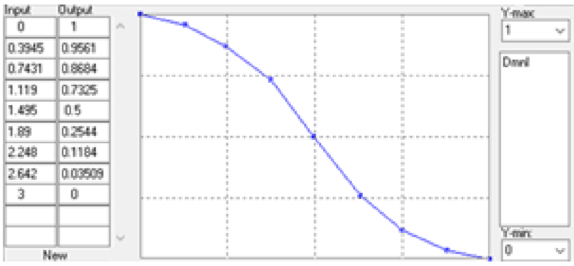
The *infiltration* of rain water in the soil diminishes as the soil becomes more saturated.

seepage rate according to soil saturation



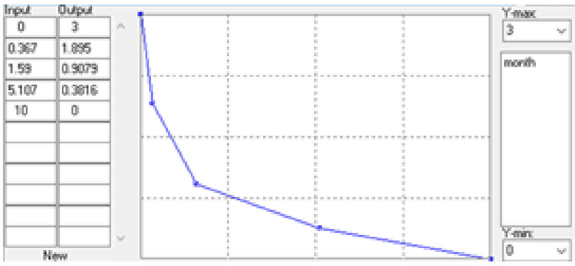
The more saturated is the soil, the faster water goes to the aquifers.

virus frequency according to time reflowing



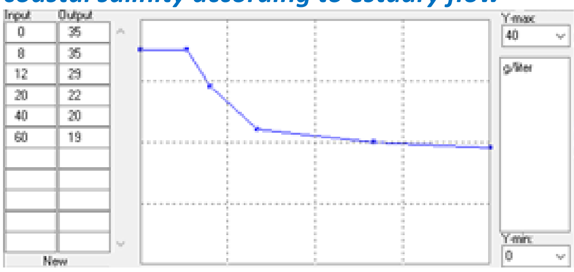
The *occurrence of viruses* increases with the *WWTPs overload*.

WWTP treatment duration according to overload



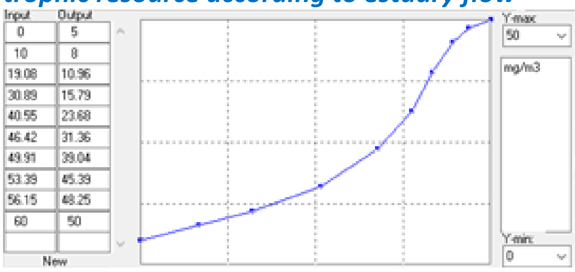
The more overloaded are the WWTPs, the faster water is treated. It can be 0 month (water just goes through) during extreme events.

coastal salinity according to estuary flow



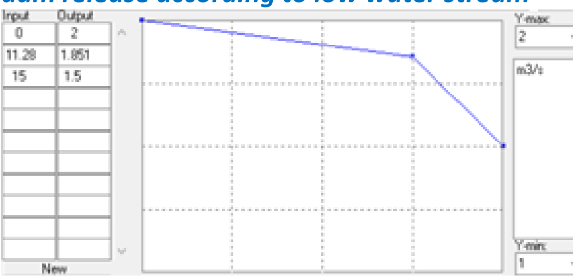
Coastal salinity diminishes with the inflow of fresh water. It never goes above 35g/L because of the ocean's inertia.

trophic resource according to estuary flow



The incoming freshwater brings nutriments and organic matter to the estuary, increasing the *concentration in trophic resources* in the estuary.

dam release according to low water stream



In period of drought, the dams release water at a rate that increases as the *water streams flow* decreases.

Figure 56: Lookups in the water sub model

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Table 2: Inputs to the water sub model.

S.V. = scenario variable. Type: S = stock, C = constant, T = time-series, L = lookup.

Variable	Type	Description	S.V.	Source
initial *water in soil*	S	The initial amount of water in soil is estimated at 900 Mm^3.		Calibrated*
initial *groundwater*	S	The initial amount of water in aquifers is estimated at 1000 Mm^3 (full capacity).		Calibrated*
initial *dam storage*	S	The assumption is that dams are full when the model starts in January.		cf. *dam capacity*
initial *surface water*	S	The initial amount of surface water is estimated at 600 Mm^3.		Calibrated*
initial *water streams*	S	The initial amount of water in streams is estimated at 400 Mm^3.		Calibrated*
initial *water in marshes*	S	The initial amount of water marshes is estimated at 300 Mm^3.		Calibrated*
rainfall	T	Possible future rainfall patterns are retrieved from a climate model based on the IPPC scenarios while monitoring data are used in the past.	X	SWAT simulation (cf. Box 1 in Sub model 1)
basin area	C	The area of the basin is 10550 ha.		Etablissement Public Territorial de Bassin Charente, 2020b
average soil depth	C	The soil is on average 1 m deep in the region.		Bichot & Gennat, 2018
volume of soil in the basin	C	It is calculated in the model as the product of the *basin area* and the *average soil depth*.		Endogenous
soil saturation limit	C	The maximum capacity of the soils is estimated to 0.24 m^3 of water per m^3 of soil.		Bichot & Gennat, 2018
infiltration coefficient according to soil saturation	L	cf. Lookup in Figure 56		Calibrated*
evaporated share of irrigation	C	10% of the water spread for irrigation directly evaporates.		Ruelle et al., 2004
evapotranspiration by other covers than agriculture	T	It is approximately 1.3 times higher than the evapotranspiration by the agricultural covers.		SWAT simulation (cf. Box 1 in Sub model 1)
groundwater capacity	C	The aquifers can stock around 1000 Mm^3 of water.		Calibrated*
seepage rate according to soil saturation	L	cf. Lookup in Figure 56		Calibrated*
share of domestic water from groundwater	C	50 % of the water used for domestic purposes comes from the aquifers, the rest from surface water.		Agence de l'Eau Adour-Garonne, 2021a
share of irrigation water from groundwater	C	40 % of the water used for irrigation comes from the aquifers, the rest from surface water.		Agence de l'Eau Adour-Garonne, 2021a
share of reservoirs water from groundwater	C	The reservoirs are mostly refilled from the aquifers (100% in the model).		Agence de l'Eau Adour-Garonne, 2021a

share of irrigation never from reservoirs	C	20% of the water used for irrigation never comes from reservoirs. Thus, it starts to be withdrawn at the beginning of the irrigation period, while the other 80% first come from the reservoirs before they are withdrawn too.		Discussion with stakeholders
abstraction permits for irrigation	C	The amount of water set by regulations that can be withdrawn for irrigation. It decreased from around 100 Mm^3 in 2010 to around 45 Mm^3 in 2020.	X	Etablissement Public Territorial de Bassin Charente, 2021a
reservoirs capacity	C	The volume of water that is stored in reservoirs during winter to irrigate cultures during summer. The current capacity is 7 Mm^3 and an increase up to 30 Mm^3 is considered.	X	Etablissement Public Territorial de Bassin Charente, 2021a
reservoirs refill start / end	C	Reservoirs are refilled in winter, from December to February.		Etablissement Public Territorial de Bassin Charente, 2021a
Low-Water Target Flow for water streams	C	The threshold flow in the river (in Beillant) that is reserved for environmental purposes and below which irrigation is restricted. It is set as the 10^{th} percentile flow: 15 m^3/s in 2020.	X	Etablissement Public Territorial de Bassin Charente, 2021b
dam capacity	C	The total capacity of the river basin's two dams is equal to 24 Mm^3.		Etablissement Public Territorial de Bassin Charente, 2020a
standard dam release	C	In their standard regime, the dams release water at a rate of 0.05 m^3/s.		Etablissement Public Territorial de Bassin Charente, 2020a
dam release according to low water stream	L	cf. Lookup in Figure 56		Etablissement Public Territorial de Bassin Charente, 2020a
share of domestic water to WWTP	C	90% of domestic water use reaches the WWTPs.		Agence de l'Eau Adour-Garonne, 2021b
capacity of coastal WWTP	C	The coastal WWTP has a capacity of 200000 people equivalents.	X	Agence de l'Eau Adour-Garonne, 2021c
capacity of rural WWTP	C	The rural WWTP has a capacity of 200000 people equivalents.	X	Agence de l'Eau Adour-Garonne, 2021c
WWTP treatment duration according to overload	L	cf. Lookup in Figure 56		Agence de l'Eau Adour-Garonne, 2021c
occurrence of viruses according to time reflowing	L	cf. Lookup in Figure 56		Agence de l'Eau Adour-Garonne, 2021c
coastal salinity according to estuary flow	L	cf. Lookup in Figure 56		Discussion with stakeholders
trophic resource according to estuary flow	L	cf. Lookup in Figure 56		Discussion with stakeholders

* Calibrated based on SWAT simulation (cf. Box 1 in Sub model 1).

3.4.4 Sub model 2: shellfish farming

3.4.4.1 Scope of the shellfish farming sub model

According to oyster farmers, the development of their production in the coastal area of the case study is not limited by the capacity of the natural environment to produce oysters in quantity but by its ability to produce high quality oysters (rich in flesh) and to capture spats. Like all bivalve shellfish (mussels, clams, cockles), oysters are indeed highly sensitive to the quality of water in the marine environment, in our case in the Charente estuary. Currently, more than 75% of the oysters sold under the regional label are grown abroad during a part of their life, notably in the Northern Sea where water quality is more suitable. Although the capture of spats is now at an acceptable level, it could however be affected in the future if water quality continues to worsen. According to the stakeholders, two complementary ways can help improve the quality of the locally grown oysters and maintain the levels of spats' capture to completely relocate the production. On one hand, given the downstream location of oyster parks and spats collection sites, changes in upstream activities (agriculture and wastewater treatment) could have a positive effect on water quality in the estuary and thus on oysters farming. On the other hand, technical solutions (such as rearing oysters in floating bags instead of on tables or reducing the number of oysters in bags) exist to yield higher quality oysters. In this line, the sub model simulates spats capture, oysters' flesh content and the resulting local share of the production depending on water quality and technical aspects. Hence the sub model allows, in the frame of the integrated model, to assess how changes in farming practices and upstream activities will overall impact oyster production.

Note that only the production of oysters is modelled and is considered representative of shellfish farming in general. Although the desirable future mentions a diversification of the produced types of shells, not enough data could be retrieved to simulate other productions than oysters.

The following key indicators (outputs) are tracked to answer the needs of the shellfish farming actors:

- ***Quality index*:** this index is equal to the ratio of flesh weight to the total weight per oyster. Oyster farmers aim to increase this ratio since rich in flesh oysters are more demanded and sold at a higher price. The quality of an oyster mostly depends on the quantity of trophic resources it has assimilated during its life time.
- ***Spats capture* and *spats purchase*:** oyster farmers know the quantity of spats they have to capture to meet production targets. The spats that cannot be captured are purchased in nurseries. The objective of farmers is to capture as many spats as possible because they can be labelled, although the purchase of spats is to some extent always necessary in order to cope with high mortality episodes. The capture of spats depends in particular on the *coastal salinity* and the *concentration in trophic resource*.
- ***Local oyster production share*:** this represents the share of oysters that is only locally grown and has never been transferred to other regions. With the objective to relocate oyster production, this share should be as high as possible.
- ***Produced oyster weight* and *oyster gross margin*:** as reported by the stakeholders, relocating the production will be possible only if yields and profits remain high enough.

A remaining indicator to calculate is employment. However, it is still unclear if employment should be considered as a limiting factor of oyster production, thus influencing the *local oyster production share*, or if more labour force is in fact available, in which case employment will depend on the local development of oyster production. This will be elucidated during the next meeting with stakeholders.

The decision variables (inputs) that influence these indicators and that can be set in scenarios are:

- **Technical choices:** two technical aspects can influence the production of high-quality oysters and will be discussed further with the stakeholders. The first one is the *type of bag* that is used for rearing oysters. Floating bags take less space than bags on tables and thus allow to rear more oysters per hectare. The second one is the *oyster density per bag*. Indeed, the fewer oysters are grown per bag, the more food is available for each oyster that hence produces more flesh.
- ***Authorised oyster farms area*:** the area dedicated to oysters' production in the estuary should remain constant in the coming years. However, this issue is a topic of discussion with the regulating authorities, and its expansion or reduction will depend on the evolution of coastal activities, notably tourism, and on local policy for the development of a sustainable shellfish farming.
- **Other sub models' decision variables:** given the downstream position of oyster parks, most of the changes in activities upstream will have an effect on the estuary's environmental conditions, thus affecting oysters' growth.

Based on the CLD (cf. section 3.4.2 – *Figure* 54), the following dynamic hypotheses shape the structure of the model:

- The capacity to yield high quality oysters will depend on water quality in the estuary and on the technical aspects of the production. The better the water quality and the less intensive the production, the higher will be the quality of the oysters. If water quality, which depends on upstream activities, does not improve, the farmers may be reluctant to adapt their techniques.
- The relocation of oyster production in the area will depend on the capacity to produce high quality oysters and on the price at which these will be sold. As the production becomes more extensive, less oysters will be produced and so a share of the production may still remain abroad. Spats capture will also positively influence the relocation of oyster farming.

3.4.4.2 Quantification of the shellfish farming sub model

The shellfish farming sub model (cf. Figure 57) simulates the *total number of oysters* grown in the coastal area and their average *quality index* over time. The underlying assumption is that all the oysters are of the bestselling category (size 3, cf. *oyster unit weight* in Table 3), which allows to easily convert oyster numbers to tons, the commonly used unit in data.
Considering a standard three years production cycle, the *total number of oysters* is at time t the sum of three stocks: *oysters in first production year*, *second year* and *third year*. Every month, oysters die according to a *mortality rate* per stock, decreasing each stock. Observed data are used for past mortality rates (cf. Table 3) while future rates are simulated according to a lookup (cf. Figure 58). At the beginning of each year, a fixed number of spats is put in production (*spats input* flow) and increases the stock of *oysters in first production year*. Considering that shellfish farmers grow as many oysters as possible, the yearly *spats input* depends on the available leasing ground management. Hence, it is calculated according to the following variable: the total *authorised oyster farms area*, the *type of bag*, the *oyster density per bag* each year and the *spats input*

per sold ton (cf. detail in Table 3 and Annex 4d). At the same time, flow variables transfer the surviving oysters to the *second year* and *third year* stocks. At the end of the third production year, oysters are sold (*to market* flow).

Given the *total number of oysters* and the *available trophic resource* in the estuary, the *cumulative resource per oyster over 3 years* is calculated. This value is used to calculate the *quality index* using a lookup (cf. Figure 58). In detail, the river's biodiversity influences the available fraction of the *trophic resource* (cf. Sub model 1). It is represented by a variable ranging from 0 to 1 that can be considered as a qualitative *biodiversity index* and that can be set in scenarios.

The unit price of oysters depends on the *quality index*, which a lookup represents (cf. Figure 58). All the marketed oysters are either sold locally (80%) or exported (20%) at an almost double price (cf. Table 3). To calculate the *oyster gross margin*, the following costs are taken into account: *production costs*, *transports costs*, *purification costs* and *spats purchase costs*. These costs are calculated using average values per sold ton of oysters or per purchased ton of spat (cf. Table 3). If the missing part of the needed spats that is not captured is totally purchased, the *spats purchase* is equal to the *spats input* minus the *spats capture*. This latter depends on the *available trophic resource* in the estuary (cf. lookup in Figure 58).

In agreement with the stakeholders' point of view, the *local oyster production share* is simulated as the result of a decision based on three criteria: the *oyster gross margin*, the *quality index* and the *spats capture*. It is calculated as follows:

$$s(t) = a\prod_{i=1}^{3} c_i(t)^{w_i}$$

where $s(t)$ is the *local oyster production share* during month t, a is a constant (calibrated), $c_i(t)$ is the value of criteria i (mentioned above) during month t and the weight w_i (calibrated) represents the relative influence of criteria i in explaining the value of $s(t)$, with the sum of all the weights equal to 1.

Calculating the *local oyster production share* as such is useful to simulate a decision that depends on multiple criteria, as the weights w_i allow to evaluate the influence of each criterion i. The values of weights (w_i) and constant a are calibrated using historic data of the *local oyster production share*. The scenarios assume that these weights will remain constant. However, they may be reviewed to reflect changes in decision-making. Furthermore, other criteria that did not influence the *local oyster production share* in the past can be added in the future to understand their potential effect. Such criterion could be, for instance, a regional label showing that the different activities taking place over the river basin cooperate to ensure a good water quality.

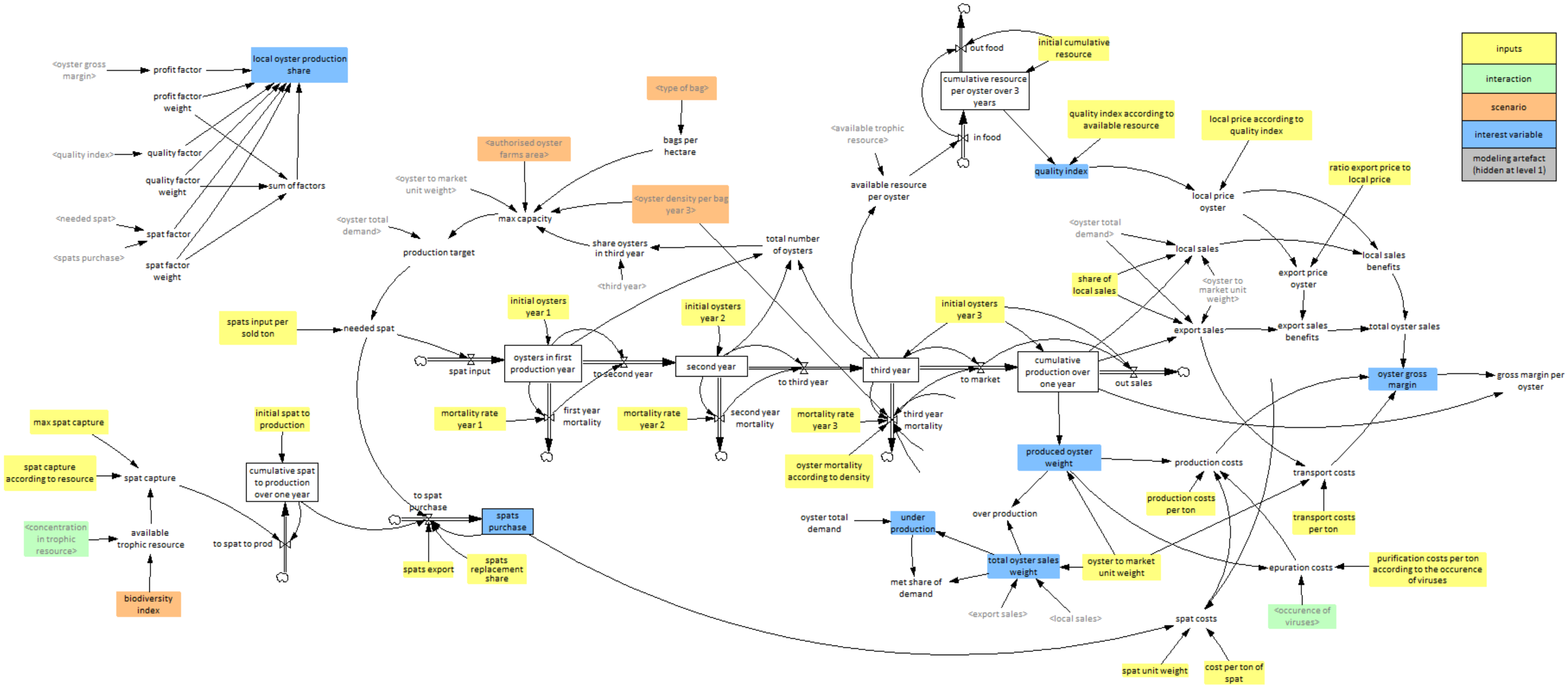

Figure 57: Overview of the SD shellfish farming sub model.

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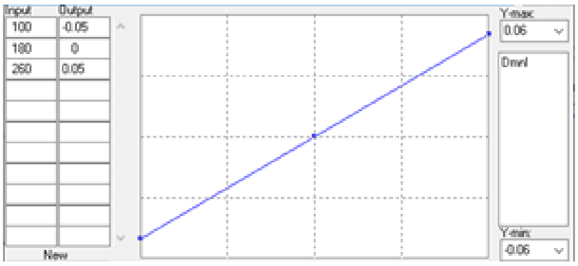
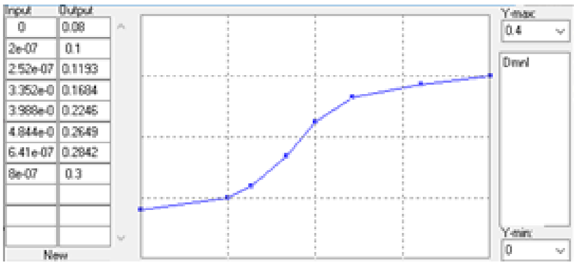
oyster mortality according to density



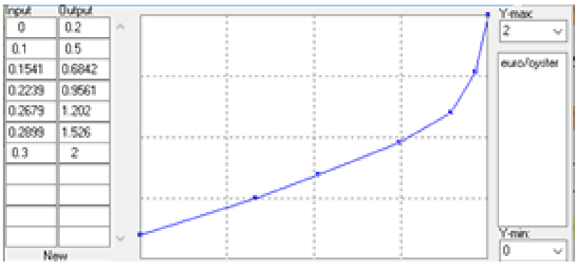
Oysters' mortality increases with the *oyster density per bag*.

quality index according to available resource



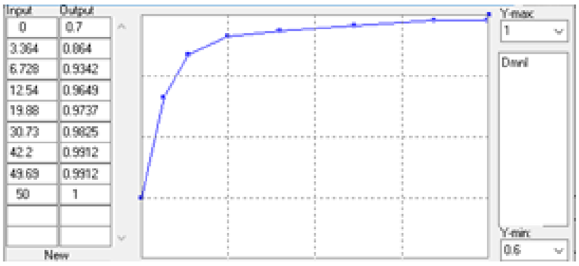
The *quality index* increases with the *cumulative resource per oyster over 3 years*.

local price according to quality index



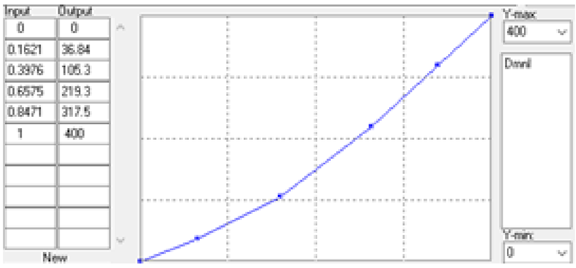
The higher is the *quality index*, the higher is the *local price per oyster*.

spat capture according to resource



The *spats capture* increases with the *available trophic resource* in the estuary.

purification costs per ton according to the occurrence of viruses



Purification costs increase with the *occurrence of viruses*.

Figure 58: Lookups in the shellfish sub model.

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Table 3: Inputs to the shellfish farming sub model.
S.V. = scenario variable. Type: S = stock, C = constant, T = time-series, L = lookup.

Variable	Type	Description	S.V.	Source
oyster unit weight	C	Assuming that the sold oysters are of size 3, they weight on average 69 grams.		Barbier et al., 2021
initial *oyster's year x*	S	In total, around 2.5 billion oysters are grown in the oyster parks.		Calibrated*
mortality rate year x	T	The share of oysters that die every month during each production year x (1 to 3).		Barbier et al., 2021
mortality according to density	L	cf. Lookup in Figure 58		Discussion with stakeholders
initial *spats to production*	S	Around 3.3 billion spats were put in production in 2000.		Barbier et al., 2021
spats input per sold ton	C	Oyster farmers put approximately xxx spats in production to ultimately produce one ton of oysters		Barbier et al., 2021
spat capture according to resource	L	cf. Lookup in Figure 58		Discussion with stakeholders
spats export	C	Every year, around 2.3 billion of spats are exported from the region to other regions or countries.		Agreste, 2012
spats replacement share	C	Oyster farmers purchase spats from nurseries to completely cover their needs (replacement share of 100% when spat captures are too low).	X	Discussion with stakeholders
authorised oyster farms area	C	The total area that can be dedicated to oyster farming by regulations is currently a bit below 700 hectares.	X	Barbier et al., 2021
type of oyster bag	C	Depending on the type of bag used for growing oysters (floating bags or tables), more or less can be set in the oyster parks.	X	Discussion with stakeholders
oyster density per bag year x	C	From the first (x = 1) to the third (x = 3) production year, 500, 250 and 180 oysters are grown per bag.	X	Barbier et al., 2021
initial *cumulative resource per oyster over 3 years*	S	This amount is expressed in concentration of resource (in mg/m^3) per oyster and is around 2e^{-07} (value to confirm).		Calibrated to smooth the simulated curve
quality index according to available resource	L	cf. Lookup in Figure 58		Discussion with stakeholders
local price according to quality index	L	cf. Lookup in Figure 58		Discussion with stakeholders
share of local sales	C	Around 80% of oysters are sold locally. The rest is exported.		Agreste, 2015
ratio export price to local price	C	Exported oysters are sold at a price that is almost twice the local price.		Discussion with stakeholders
production costs per ton	C	The costs associated with oyster production are around 3000 €/ton.		Discussion with stakeholders
transport costs per ton	C	It costs around 720 € to transport one ton of oysters.		Discussion with stakeholders
purification costs per ton according to the occurrence of viruses	L	cf. Lookup in Figure 58		Discussion with stakeholders

* Calibrated to fit observed productions according to observed mortalities.

3.4.5 Sub model 3: agriculture

3.4.5.1 Scope of the agriculture sub model

For the stakeholders of the agricultural sector and for MAL4 local partners, there is little doubt that practices are changing and will continue to change in the future towards more sustainable farming activities. Actors' main interest lies then in understanding to which extent this change will occur, why and how, in the context of the global evolution of the territory.

Here are some of the questions raised by stakeholders: What share of the agriculture could ultimately be sustainable and how fast could this level be reached? What factors may limit or foster this change? Which innovative actions will help achieve a sustainable agriculture? In this line, the sub model simulates the conversion of areas to organic agriculture. Assuming that this conversion will occur, the factors that may encourage this change are identified and their influence is quantified. Over time, several indicators of impacts (e.g., the total irrigation water use) and benefits (e.g., the total gross product) are calculated in order to evaluate the overall effect of the conversion.

In detail, the following decision and context variables (inputs) can be set in scenarios, thus reflecting the specific stakeholders' interests:

- **Conventional and organic practices:** in the model, agricultural areas are either in conventional or organic farming. Then, one conventional or organic hectare is composed of different productions with their own area and practices. Conventional practices are based on current best management practices while organic practices are based on current practices for organic farming. For instance, 20% of conventional areas are maize, which is irrigated, 20% are wheat, which is less irrigated, etc. While these values are fixed for the past, the model's user can define and test the effect of different future compositions of conventional and organic agriculture, in terms of productions and practices. As such, the evolution of both conventional and organic practices can be studied, according to actors' wishes. The number of possible productions per type of agriculture is currently set to 15 but it can easily be increased. For each production, its *share of the agricultural area* is specified, and per hectare, its *irrigation*, the *irrigated share* of its area, *nitrogen use* and *pesticides use*. This level of detail allows assessing, for instance, the effect of growing new species with low irrigation or fertilization needs, identified by the stakeholders as a possible innovation for a more sustainable agriculture.
- **Factors encouraging the conversion towards organic practices:** the five factors that the stakeholders decided to consider (cf. Model confidence building) are 1) the *demand for organic products*, 2) the *organic supply chain*, 3) the *difference in income* with conventional production, 4) the number of *agricultural workers* and 5) the regulations (existing or considered in the scenarios). Their values are either calculated in the model or directly set (cf. below in the quantification of the model).
- **The *reservoirs capacity* for irrigation and *abstraction permits for irrigation*:** because these are important for the agricultural actors, they are mentioned as decision variables in the agriculture sub model. However, reservoirs and irrigation are actually parts of the water sub model, where they are described (cf. Sub model 1).
- ***Rainfall* and *reference evapotranspiration*:** these variables allow analysing the effect of climate change (changing rainfall patterns and increase of temperature) and its effect on yields.

The following indicators (outputs of the sub model) are tracked along the conversion and are key variables of interest for the stakeholders and/or variables interacting with the other sub models:

- **The *conventional area* and the *organic area*:** these areas are the main outputs of the sub model and represent the main objective of the agricultural policies aiming to foster a more sustainable agriculture. In this sense, the *organic share* of the agricultural area represents one target of the scenarios designed with the actors in the WP5.
- ***Irrigation water use*, *nitrogen use* and *pesticides use*:** these are the main agricultural environmental stressors that the stakeholders identified. Each may have an effect on the water resource and, consequently, the other activities within the river basin. In the case of *irrigation water use*, the agricultural sub model in fact calculates an *irrigation water demand* while the water sub model calculates the actual *irrigation water use*.
- ***Yield*, *total gross product* and *agricultural employment*:** these economic indicators are essential for understanding the overall effect of the conversion to organic farming.
- ***Conventional* and *organic storage need*:** organic products have to be stored in dedicated storage. The expansion of these infrastructures will be a challenge for operators (cf. Sub model 4).

In addition, a part of the sub model is dedicated to the vineyards' production of Cognac that may also engage in the conversion to organic practices, although this dynamic is uncertain and motivations are more difficult to explain. As a result, change of practices in viticulture is set in scenarios and the same aforementioned indicators are taken into account in the results.

The model runs on a monthly basis to make possible interactions with the other sub models, notably the water sub model that rules possible irrigation every month (cf. below and Sub model 1).

Based on the CLD (cf. section 3.4.2 – *Figure* 54), the following dynamic hypotheses shape the structure of the model:

- Agriculture will convert towards organic farming at a speed and up to a level that depend on how favourable are the socio-ecological conditions for organic agriculture.
- As organic farming develops, regulations and water availability will become less constraining, which may temper the farmers' will to convert.

3.4.5.2 Quantification of the agricultural model

In the agriculture sub model (cf. Figure 59), three stocks represent the total *conventional area, in transition area* and *organic area*. The *time to convert to organic* is three years. During this period, organic practices are already applied but products cannot be sold as organic and therefore are still sold at conventional prices. This induces a delay to appreciate the benefits, if any, of converting (cf. *difference in income factor* below). The conversion from conventional to organic agriculture is then modelled with two flow variable. The first – *to transition* – transfers areas from the *conventional area* stock to the *in transition area* stock at a *conversion rate* (in %/month) that is endogenously calculated (cf. below). The second – *to organic* – transfers areas from the *in transition area* stock to the *organic area* stock with a 36 months fixed delay. In the standard version of the model, the total agricultural area remains constant but rates of its possible increase or decrease can be considered.

Five factors encouraging the conversion are used to calculate the *conversion rate* over time:

- **The *demand for organic products factor*:** the *demand for organic products* in the region is represented by a normalised indicator ranging from 0 to 1. It is based on observed data for the past (cf. Table 4) and set in scenarios to describe expected future trends.
- **The *organic supply chain factor*:** similarly, a normalised index ranging from 0 to 1 represents the availability of supply chain to distribute organic products. It is fixed for the past (cf. Table 4) and can be set in the scenarios.
- **The *difference in income factor*:** it is calculated as the relative gain in gross margin per hectare due to conversion to organic farming (ratio of the *organic gross margin* per hectare over the *conventional gross margin*). The margins are calculated in the model (cf. below).
- **The *agricultural workers factor*:** it is calculated as the ratio (ranging from 0 to 1) of the available *agricultural workers* (calculated in the population sub model) to the calculated *agricultural workers need* (cf. below).
- **The *regulation factor*:** this factor measures the effect of regulatory constraints on agricultural practices. In the current version of the model, only the effect of restrictions on water abstraction is considered but other regulatory constraints will be added further when needed data are available. This factor is represented by the share of the *irrigation water demand* that cannot be met when water is not available, which partly depends on the *abstraction permits for irrigation* (cf. Sub model 1). The regulation of nitrogen use will also be added after meeting the agricultural stakeholders again.

All these factors have a positive effect on the conversion of agricultural areas towards organic practices since when they increase, areas should convert faster, and inversely.

The model then calculates the *conversion rate* every month as a weighted product of the values of the factors:

$$r(t) = a \prod_{i=1}^{5} f_i(t)^{w_i}$$

where $r(t)$ is the *conversion rate* during month t, a is a constant (calibrated), $f_i(t)$ is the value of factor i (mentioned above) during month t and the weight w_i (calibrated) represents the relative influence of factor i in explaining the value of $r(t)$, with the sum of all the weights equal to 1.

Calculating the *conversion rate* as such is useful to simulate decisions (here the conversion to organic practices) that depend on multiple factors, as the weights allow to assess factors' influence. The values of weights (w_i) and constant a are calibrated using historic data of conversions to organic farming. The scenarios assume that these weights will remain constant. However, they may be reviewed to reflect changes in decision paradigms. Furthermore, other factors that did not influence conversion in the past can be added in the future to understand their potential effect. For instance, a factor could be the deterioration of marine water quality needed for oysters' production, providing grounds for a shift to organic practices in the frame of an integrated territorial policy.

The sub model calculates over time the following variables that either interact with the other sub models or play the role of key indicators of impacts and benefits:

- ***Nitrogen use***: average uses of nitrogen fertilizers per culture per hectare are input data (cf. Table 4) allowing to calculate the total *nitrogen use*.
- ***Irrigation water demand***: average crop *irrigation per culture per hectare* are input data (cf. Table 4) used to calculate the total *irrigation water demand*.
- ***Yield***: crop water production functions (2nd order polynomials) adjusted from observed local data (expert valuation reports) allow to calculate yields.
- ***Conventional* and *organic gross product* and *gross margin***: *prices per culture* (cf. Table 4) enable the calculation of the *gross product*s while the *gross margins* are calculated by subtracting costs, which are expressed as a percentage of the production's value.
- ***Agricultural workers need***: once again, *average employment per hectare* for conventional and organic farming are used (cf. Table 4).
- ***Evapotranspiration by agricultural covers***: it is calculated using the *reference evapotranspiration* estimated in the SWAT model (cf. Box 1 in Sub model 1) and crop coefficients (*Kc per culture* in Table 4).

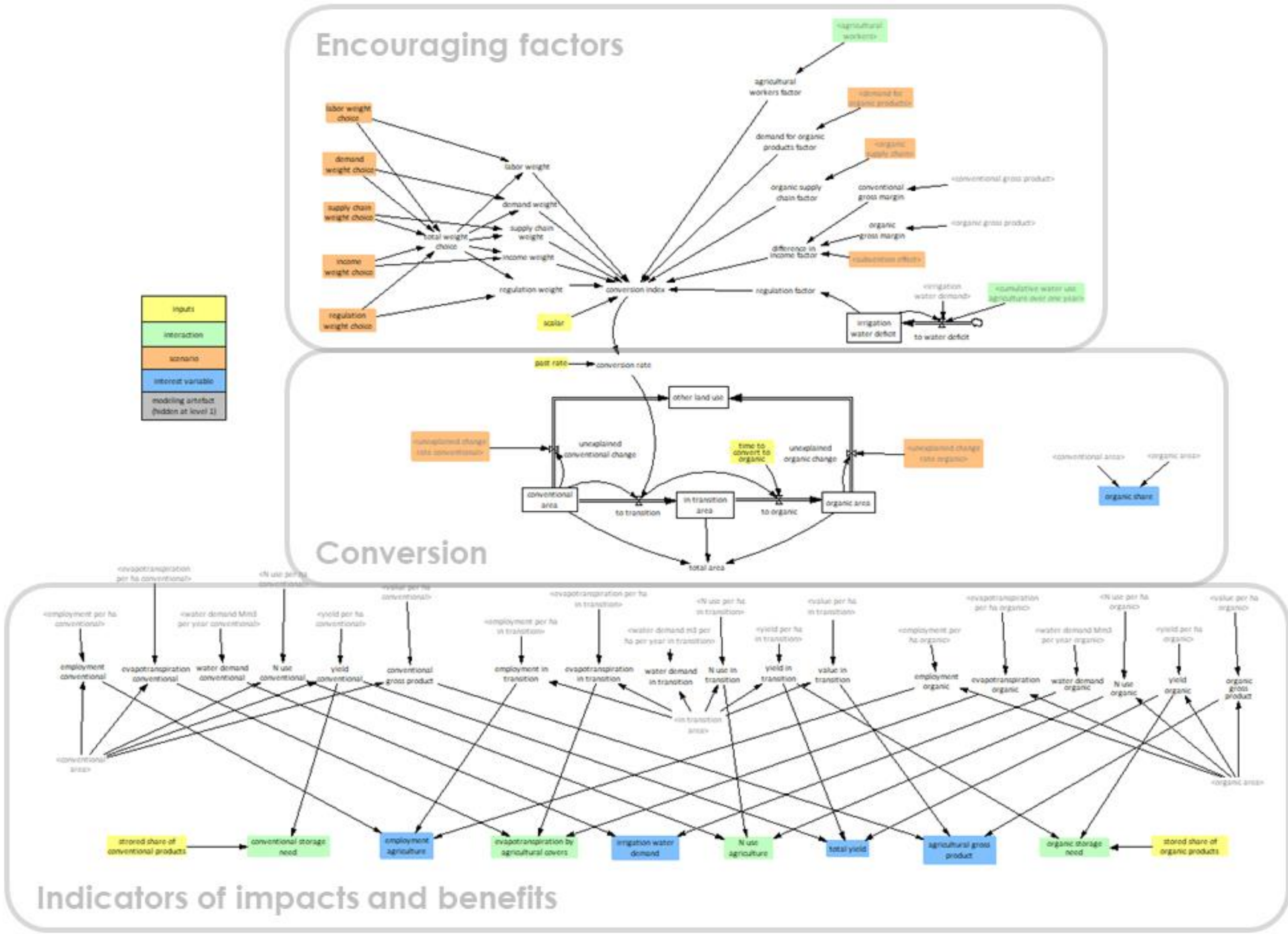

Figure 59: Overview of the SD agriculture sub model.

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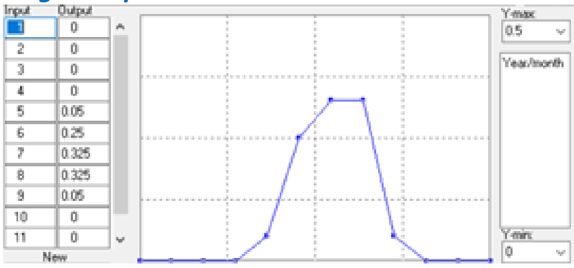
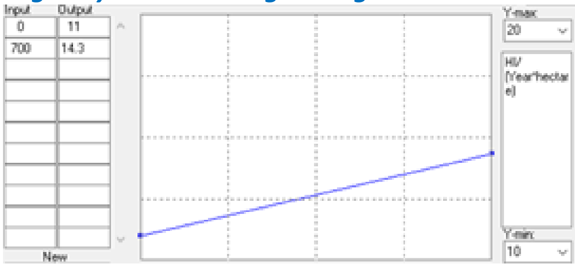
irrigation per month



Irrigation occurs from May to September with a peak during the summer months.

cognac yield according to irrigation



Cognac yield increases linearly (assumption) with irrigation.

Figure 60: Lookups in the agriculture sub model.

Table 4: Inputs to the agriculture sub model.

S.V. = scenario variable. Type: S = stock, C = constant, T = time-series, L = lookup.

Variable	Type	Description	S.V.	Source
initial *conventional area*	S	650000 ha were dedicated to conventional farming in 2000.		Agreste, 2020
initial *in transition area*	S	5000 ha were in transition to organic farming in 2000.		Agence Bio, 2020a
initial *organic area*	S	14000 ha were dedicated to organic farming in 2000.		Agence Bio, 2020a
time to convert to organic	C	Converting to organic farming takes 3 years.		Agence Bio, 2020a
conventional and organic practices	C	*share of the agricultural area per culture*, expressed in %.	X	Agreste, 2020 Agence Bio, 2020a Vernier et al., 2016 Vernier et al., 2017
	C	*nitrogen use per hectare per culture*, expressed in kg.ha-1.yr-1.	X	Vernier et al., 2016 Vernier et al., 2017
	C	*pesticides use per hectare per culture*, expressed in IFT.ha-1.yr-1.	X	Vernier et al., 2016 Vernier et al., 2017
	C	*irrigation per hectare per culture*	X	Vernier et al., 2016 Vernier et al., 2017
	C	*irrigated share per culture*, expressed in %.	X	Vernier et al., 2016 Vernier et al., 2017
irrigation per month	L	cf. Lookup in Figure 60		Vernier et al., 2016
factors encouraging the conversion towards organic practices	T	*demand for organic products*	X	Agence Bio, 2020c
	T	*organic supply chain*	X	Agence Bio, 2020b
price per culture	T	Time-series of monitored prices are used in the past. The ratio of organic to conventional prices is used as reference value to design the scenarios.	X	FranceAgriMer - VISIONet, 2021
subvention effect	C	Ratio representing the additional contribution of subventions to the revenue of organic farmers. It is expressed as a percentage of the total production's value.		Discussion with stakeholders

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employment per hectare conventional / organic	C	On average, conventional agriculture needs 0.9 person per hectare while organic agriculture needs 1.8.	X	Sébille, 2011
production function coefficients	C	Coefficients of the polynomial production functions that output yields according to irrigation. They were calculated from observations of yields against irrigation.		Vernier et al., 2016 Vernier et al., 2017
reference evapotranspiration		The reference value used to estimate crops' evapotranspiration.	X	SWAT simulation (cf. Box 1 in Sub model 1)
Kc per culture	C	Cultural coefficients used to estimate crops' evapotranspiration.		Frenken & Gillet, 2012
stored share of conventional / organic products	C	Approximately 70% of agricultural production is stored.		Discussion with stakeholders
initial *vineyard under production*	S	There were 78000 hectares of vines for Cognac in 2000.		Agreste, 2020
initial *new vineyard*	S	10000 ha of vines were in their growing period in 2000.		Arribard, 2015
initial *demand for cognac*	S	The global demand for Cognac was a bit below 1M hl/year in 2000.		Arribard, 2015
demand for cognac growth rate	C	The demand for Cognac increases by around 2%/year since 2000.		Arribard, 2015
authorized cognac production per hectare	T	Regulations limit cognac yields per hectare, at ~14 hl/ha in 2020.		Comptabilité Gestion Océan, 2021
cognac yield according to irrigation	L	cf. Lookup in Figure 60		Vernier et al., 2016
time to grow vines	C	Vines become productive after [4 or 7] years of growth.		Arribard, 2015
vines replacement rate	C	Around 4% of vines are renewed every year.		Arribard, 2015
vineyards planting rights	T	Regulations limit the expansion of vineyards, at around 3500 ha in 2020.		Comptabilité Gestion Océan, 2020

3.4.6 Sub model 4: infrastructure

3.4.6.1 Scope of the infrastructure sub model

The sub model includes five parts representing the infrastructures linked with other simulated activities. As reported in the quantification section's Table 5, all the required data could not be consolidated so far as several meetings with stakeholders were delayed because of the COVID pandemic. In addition, some parts of the sub model were only recently developed after last meetings with some stakeholders could finally be held and some data are then still missing. All the data will be however consolidated during the calibration of the model and after meeting the remaining stakeholders.

The first part focuses on the storage of cereals over the territory. Agriculture should shift towards agro-ecological practices. To support this change, and particularly for the case of organic products, separate storage facilities will have to be adapted as required by regulation. Then, the main questions are how much this development will cost, what space it will require and how to convert current facilities currently used for conventional agricultural products. To answer these questions, we set a decision variable:

- ***Conventional storage conversion rate***

With associated key variables:

- **Available *organic* and *conventional storage***
- ***Storage development costs***
- ***Area of storage***

The second part focuses on the development of the ports (Port-Atlantique in La Rochelle and the port of Tonnay-Charente). Their development implies investments in storage facilities for operators, the extension of docks to enlarge capacities and support renewable energies (waves and wind power) using a multimodal platform. The engagement of ports in the territorial strategy implies tight relationships with hinterland activities to broaden material flows, notably of cereals and agricultural inputs. It also implies that they adapt their capacities consequently. In addition, Port-Atlantique (La Rochelle) is committed with La Rochelle urban agglomeration regarding its Zero Carbon Territory strategy. The modal shift that they operate in the hinterland from road to rail transport (14 to 25% by 2020) is in line with the EU-TENT policy to enhance rail transport at a European scale and increase public investment in railways. To support their development, the model can provide insights on the trends of agricultural products and storage needs, simulated in the agriculture sub model (cf. Sub model 3). In addition, the model can evaluate the effect of shifting to train transportation in terms of CO2 and traffic. The area issue of developing the entire infrastructure linked to ports is also assessed. Hence, the following key variables are considered in the sub model:

- **Ports' *throughput* and *storage capacities***
- ***Rail transportation capacity***
- ***CO2 savings of rail transportation***
- ***Area of ports***

These depend on the following decision variables:

- ***Planned throughput capacity* and *rail transportation capacity***
- ***Exported share of agricultural products***

The third part focuses on dikes. With its 450 km of coastline, the coastal zone of the MAL4 is particularly vulnerable to sea level rise and strong storms. The coastal protection reinforcement plan, called "Plan Digues", is the largest project of this kind in France. As a result of the expected increases in sea level and in storms' frequency and magnitude, a part of the agricultural land in marshes may be abandoned, notably because of the increased salinization of the soils. Because meeting with key stakeholders was postponed, it is still difficult to simulate the decision-making process behind dikes' development. In order to represent the risk of flooding and whether the reinforcement plan will be fully deployed, which is still uncertain for financial reasons, the following variables are set in scenarios:

- ***Flooding risk***
- ***Planned dikes* for 2050**

While the effect of dikes against flooding is observed with the key variable:

- ***Abandoned coastal land***

The fourth part focuses on housing. The residential population, notably in the coastal zones, has continuously increased for 30 years and this trend is likely to continue. Construction of new housing will thus be needed. New accommodation will also be needed to cater the continuous increase of tourists' population. Regulations can however limit the expansion of built-up areas. The development of housing is measured in the sub model with six key variables:

- ***Coastal* and *rural housing* and *accommodation* (4 variables)**
- ***Coastal* and *rural built-up area***

These depend on the scenario variables:

- ***Allowed coastal* and *rural built-up area***

The driving residential and tourist populations are calculated in the population & tourism sub model (cf. Sub model 5).

The fifth part focuses on roads. Traffic congestion is an issue in tourist areas, notably in the coastal zone. This affects, to some extent, the attractiveness of the region (cf. Sub model 5 on population & tourism). Some of the solutions under consideration, at the regional scale, are the development of railway and biking ways. The key variable of this part is:

- ***Roads congestion***

This is influenced by the following scenario variables:

- ***Planned roads***
- ***Share of people using train or bike***

With the five parts, we calculate another key variable:

- ***Total area required for infrastructure***

Based on the CLD (cf. section 3.4.2 – *Figure* 54), the following dynamic hypotheses shape the structure of the model:

- The risk of coastal flooding will increase and coastal land will be abandoned depending of the dikes' development.
- Ports will develop to increase their throughput and cereals export capacity. In case agriculture decline in the region, they will diversify to other sectors (renewable energy, containerships traffic).
- Railway extension will expand material flow and ports' utilisation until their throughput capacity is reached. It will affect traffic and therefore the region's attractiveness.
- Housing will expand until space competition.

3.4.6.2 Quantification of the infrastructure sub model

In the infrastructure sub model (cf. Figure 62), stock variables describe the available *conventional* and *organic storage* over the territory, in tons, the *dikes*, in km, the ports' *throughput capacity*, in tons/year, the *conventional* and *organic storage capacities of ports*, in ton, the *rail transportation capacity*, in tons/year, the *roads*, in km, the available *coastal* and *rural housing* capacities, in people, and the *coastal* and *rural accommodation* capacities, in people. All stocks follow the same basic dynamics, illustrated by Figure 61 in the case of dikes.

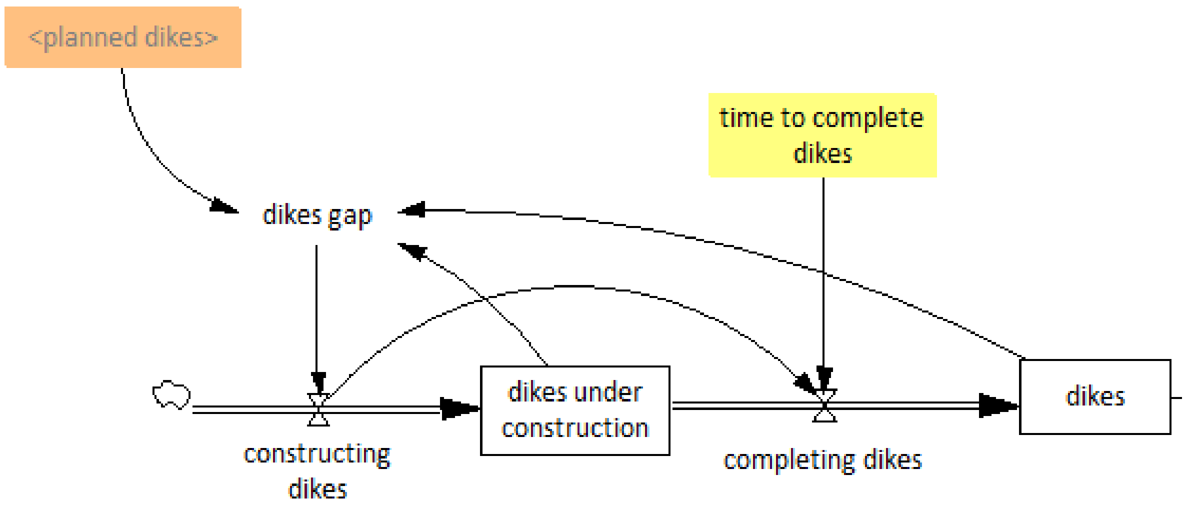

Figure 61: Basic structure of infrastructures' development in the case of dikes.

For a given infrastructure, a variable (*planned infrastructure*) specifies the total amount of infrastructure that should ultimately be present in the region according to current plans. This variable can be specified as a time-series to represent a step-by-step development. Given the current amount of infrastructure that is built or under construction, an *infrastructure gap* is calculated. When it is positive, i.e., when there are infrastructures to build, the construction of this gap starts, as represented by the flow variable *constructing infrastructure* that increases the stock of *infrastructure under construction*. This stock depletes and increases the stock of completed *infrastructure* according to a flow variable *completing infrastructure*. In order to consider the time it takes to build infrastructures, *completing infrastructure* is a fixed delay of *constructing infrastructure* with duration *time to complete infrastructure*. This basic structure is complemented, and sometimes slightly changed, for each part of the sub model.

For the agricultural storage's part, the needs for conventional and organic storage calculated in the agriculture sub model set the planned storage. In addition to the basic structure, the two *conventional* and *organic storage* stocks are linked as conventional facilities may be converted to organic ones. A *conventional storage conversion rate* specifies how much of the *unused conventional storage* is converted and the *time to convert to organic storage* is considered. Several simple stocks and flows represent the transfer of facilities from the *conventional* to the *organic storage* stock. Per unit of facility data (cf. Table 5) are used to assess the *storage development costs* and the *area of storage* over time.

For the ports' part, their storage capacities are simulated like the previous storage capacities. However, their development is driven by the *exported share of agricultural products* (cf. Table 5), which can be set in scenarios. The *throughput capacity* of ports is modelled with the basic structure. The storage facilities and the *throughput capacity* are compared with the simulated trends of agricultural products. Furthermore, the *rail transportation capacity*'s development is also modeled with the basic structure. This capacity is translated into *trucks equivalents* on a weight basis (cf. Table 5). These *trucks equivalents* are then translated into *CO2 savings* using observed data (cf. Table 5) and influence *roads congestion* in the part on roads. The total *area of ports*, including storage and railways, is assessed over time (cf. Table 5).

For the dikes' part, their development is modelled with the basic structure, with *planned dikes* representing the dikes that will effectively be built by 2050. Data on the *protected coastal land per km of dikes* (cf. Table 5) allow calculating the *coastal land at risk* in hectares according to the length of *dikes*. In addition, the *flooding risk* is represented by a dimensionless indicator. A lookup function then specifies the *abandoned share of coastal land at risk according to flooding risk* in order to calculate the amount of *abandoned coastal land*. While the structure behaves as expected, satisfactory data are not yet available for this part, as we could not meet recently the actors involved in dikes' management. In the current state, an indicator from 0 to 1 represents the *flooding risk* (probability from 0 to 100%) and the *abandoned share of coastal land at risk* is proportional to the flooding risk. This part will be made operational with new data during the calibration of the model.

For the part on housing, the driving *coastal* and *rural planned housing* and *accommodation* depend on the populations of residents and tourists. Expressed in people, *coastal* and *rural housing* and *accommodation* are converted into hectares according to observed data (cf. Table 5). This allows calculating the coastal and *rural built-up area.* These areas, and hence their growths, are limited by an *allowed coastal* or *rural housing area* that can be set in scenarios

For the roads' part, the basic structure simulates their development. *Roads congestion* is calculated in vehicles/km as the ratio of the number of *vehicles on the road* to the length of *roads*. The number of *vehicles on the road* depends on the populations of tourists and residents (cf. Table 5), on the *trucks equivalents* of rail transportation and on the *share of people using train or bike*, which can be set in scenarios.

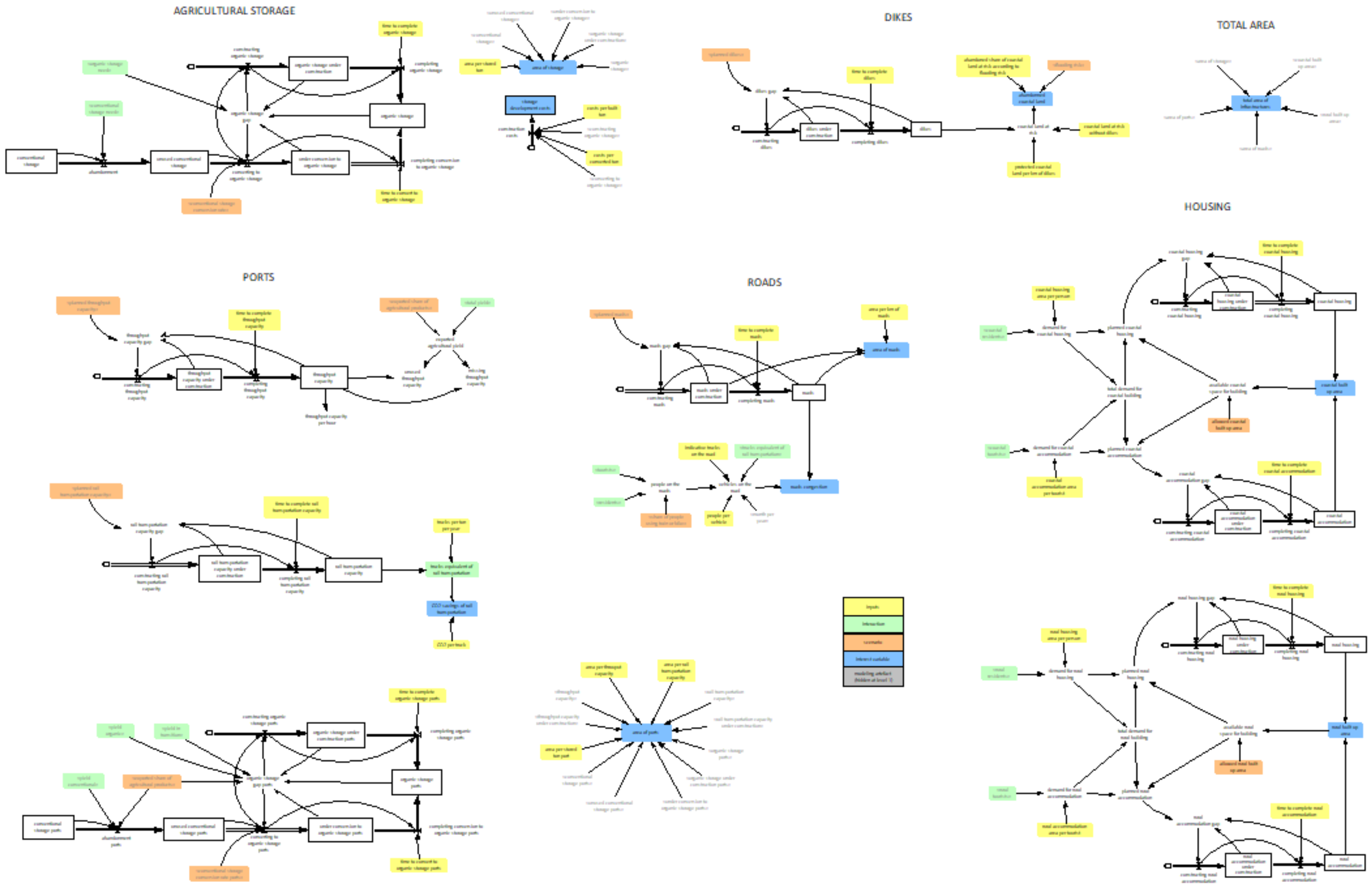

Figure 62: Overview of the SD infrastructure sub model.

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Table 5: Inputs to the infrastructure sub model.

S.V. = scenario variable. Type: S = stock, C = constant, T = time-series, L = lookup.

Variable	Type	Description	S.V.	Source
initial *conventional storage*	S	The tons of conventional products that could be stored in the region in 2000.		Discussion with stakeholders
initial *unused conventional storage*	S	For simplicity, this stock is initialized at 0.		NA
initial *under conversion to organic storage*	S	For simplicity, this stock is initialized at 0.		NA
initial *organic storage*	S	The tons of organic products that could be stored in the region in 2000.		Discussion with stakeholders
initial *organic storage under construction*	S	For simplicity, this stock is initialized at 0.		NA
conventional storage conversion rate	C	The rate at which conventional storage may be converted to organic ones. It is equal to 0 in the past as this process has been marginal so far.	X	NA
time to complete organic storage (ports)	C	Building storage takes 2 years.		Discussion with stakeholders
time to convert to organic storage (ports)	C	Converting conventional storage to organic storage takes 2 years.		NA
area per stored ton	C	The space required to store one ton of agricultural products.		To consolidate
costs per built ton	C	The costs of building storage facilities per ton of agricultural products.		To consolidate
costs per converted ton	C	The costs of converting conventional storage facilities to organic ones per ton.		To consolidate
planned throughput capacity	T	The ports' throughput capacity that will be achieved, over time, until 2050.	X	Port Atlantique La Rochelle, 2015a Discussion with stakeholders
initial *throughput capacity*	S	The throughput capacity of the ports in 2000.		Port Atlantique La Rochelle, 2015a
initial *throughput capacity under construction*	S	For simplicity, this stock is initialized at 0.		NA
exported share of agricultural products	C	The share of agricultural yields that are exported through ports.	X	Port Atlantique La Rochelle, 2015b
planned rail transportation capacity	T	The capacity to transport products to the port by rail that will be achieved, over time, until 2050.	X	Port Atlantique La Rochelle, 2015a Discussion with stakeholders

initial *rail transportation capacity*	S	The capacity to transport products to the port by rail in 2000.		Port Atlantique La Rochelle, 2015a
initial *rail transportation capacity under construction*	S	For simplicity, this stock is initialized at 0.		NA
trucks per ton per year	C	The number of truck travels that are avoided per ton of products transported by rail.		To consolidate
CO2 per truck	C	The CO2 emissions of a truck's travel.		To consolidate
initial *conventional storage ports*	S	The tons of conventional products that could be stored in the ports in 2000.		Port Atlantique La Rochelle, 2015b
initial *unused conventional storage ports*	S	For simplicity, this stock is initialized at 0.		NA
initial *under conversion to organic storage ports*	S	For simplicity, this stock is initialized at 0.		NA
initial *organic storage ports*	S	The tons of organic products that could be stored in the ports in 2000.		Port Atlantique La Rochelle, 2015b
initial *organic storage under construction ports*	S	For simplicity, this stock is initialized at 0.		NA
conventional storage conversion rate ports	C	The rate at which conventional storage may be converted to organic ones in the ports. It is equal to 0 in the past as this process has been marginal so far.	X	NA
area per stored ton port	C	The space required to store one ton of agricultural products.		Port Atlantique La Rochelle, 2015b
area per throughput capacity	C	The space used by docks to transit one ton of products.		Port Atlantique La Rochelle, 2015b
area per rail transportation capacity	C	The space used by railways.		To consolidate
flooding risk	T	Indicator (in the range 0 to 1) that describes the risk of flooding.	X	To consolidate
planned dikes	T	The length of dikes that will actually be built, over time, by 2050.	X	Département Charente Maritime, 2021
initial *dikes*	S	The length of dikes in 2000.		Département Charente Maritime, 2021
initial *dikes under construction*	S	For simplicity, this stock is initialized at 0.		NA
coastal land at risk without dikes	C	The area of coastal land that may be flooded in the absence of dikes.		Département Charente Maritime, 2021
protected coastal land per km of dikes	C	The area of coastal land that is protected by one km of dikes.		To consolidate

abandoned share of coastal land at risk according to flooding risk	L	For now, the lookup is set as the identity function, meaning that the share is equal to the flooding risk indicator.		To consolidate
planned roads	T	The length of roads that will be achieved, over time, by 2050.	X	To consolidate
initial *roads*	S	The length of roads in 2050.		Ministère de la transition écologique, 2021
initial *roads under construction*	S	For simplicity, this stock is initialized at 0.		NA
time to complete roads	C	It takes 5 years to build roads.		Discussion with stakeholders
area per km of roads	C	The space used by one km of road.		Assumed width of roads: 15m
share of people using train or bike	C	The share of the total population that uses bike or train to move in the region.	X	To consolidate
indicative trucks on the road	C	The number of truck travels if there were no rail transportation.		To consolidate
people per vehicle	C	The average number of people per car.		To consolidate
initial *coastal/rural housing/accommodation*	S	The space used for housing or accommodation in the coastal and rural areas in 2000.		Charentes Toursime, 2020
initial *coastal/rural housing/accommodation under construction*	S	For simplicity, this stock is initialized at 0.		NA
coastal/rural housing area per person	C	The space used to house one resident on average.		European Environment Agency, 2021 INSEE, 2020
coastal/rural accommodation area per tourist	C	The space used to accommodate one tourist on average.		Charentes Toursime, 2020
time to complete coastal/rural housing/accommodation	C	It takes 1 year to complete a house or accommodation.		Discussion with stakeholders General knowledge
allowed coastal/rural built-up area	C	The maximum area that can be dedicated to housing or accommodation in the coastal or rural area.	X	Discussion with stakeholders (only in scenarios)

3.4.7 Sub model 5: population & tourism

3.4.7.1 Scope of the population sub model

This sub model simulates the dynamics of the population over the territory of the case study. Stakeholders did not articulate specific needs at the moment other than a vision, in the desirable future, of a population harmoniously spread to preserve the social fabric. In the worst-case scenario, residents and tourists will be concentrated in the coastal zone and their growth will not be curved by regulations and policies. It implies to monitor specifically people and tourists in coastal and rural areas.

Currently, the dynamics of the residents' and tourists' populations are driven by fixed growth rates (inputs) and their distribution between the coastal and rural areas depends on fixed shares (inputs). Coming planned meetings with the stakeholders will help better understand these dynamics and should allow to endogenously model the rates and shares. For this purpose, indicators of attractiveness, which are calculated but not yet calibrated, should be used.

The current scenario variables of the sub model are:

- **The *residents* and *tourists growth rate*:** the annual rates, in %/year, at which these populations grow in total over the territory.
- ***Tourists capacity*:** this limits the number of tourists that can be present at the same time.
- **The *coastal share of residents* and *tourists*:** these ratios determine how many residents and tourists stay in the coastal zone.
- ***Water use per person*:** the average use of water per person serves to calculate a demand that is met or not, which is calculated in the water sub model.
- ***Agricultural workers replacement share*:** while the number of farmers that retire is known, the rate at which they will be replaced by new ones is uncertain.

The key outputs that are tracked in the sub model are:

- **The number of *residents* and *tourists*:** the evolution of the residential population and of touristic affluence are important indicators for the local authorities who have to adapt their policies to demography.
- **The *coastal / rural residents* and *tourists*:** the distribution of the residents and tourists between the coastal and the rural zones influences the previously described activities, notably the treatment of wastewater and the development of infrastructures.
- **The *domestic water demand* and the *coastal share of water demand*:** water use is one of the main pressures that population growth increases. Whether it occurs in the rural or coastal area influences the need to adapt the *capacity of coastal / rural WWTPs*.
- ***Agricultural workers*:** the available labour force is a factor that influences the conversion of agriculture to organic farming (cf. Sub model 3).

- **The *coastal* and *rural attractiveness for residents* and *tourists*:** indicators calculated according to multiple factors represent the attractiveness of both areas for both populations. The currently considered indicators, the list of which will increase after meeting stakeholders, are *roads congestion* (cf. Sub model 4 on infrastructure), the increase in housing and accommodation (cf. Sub model 4) and the basically higher attractiveness of beaches, which we call heliotropism.

Following the next meeting with stakeholders and according to the CLD (cf. section 3.4.2 – *Figure* 54), the following dynamic hypotheses will shape the final structure of the model:

- Residential population and tourists' arrival will keep increasing at a steady rate. The distribution of both between the coastal and rural areas will be in favour of the coastal area as long as it remains attractive. The development of touristic infrastructures and an improved ecosystems' quality on the coast will increase its attractiveness, but this latter will decrease if transport infrastructures are not adapted and congestion occurs.
- The replacement of retiring farmers will not be complete and will depend on multiple factors, among which the profitability of organic farming that most of the newcomers should conduct.

3.4.7.2 Quantification of the population sub model

In the population model (cf. Figure 63), two stocks represent the total number of *residents* living and *tourists* visiting the area each month. On the one hand, the residential population grows every month at a fixed rate (in % per month, cf. Table 6). On the other hand, the tourist population fluctuates over the months. While the total number of tourists over a year is set to constantly increase at a fixed rate (cf. Table 6), this annual population is distributed over the months according to observed affluences (cf. Table 6), with a peak in the summer months. Also, the number of tourists that can be present at a same time is limited by the *tourists capacity*. Fixed shares specify the distribution of *residents* and *tourists* between the coastal zone and the rural area (cf. Table 6).

Given the *water use per person* (considered to be similar for residents and tourists), the model calculates the total *domestic water demand* and the *coastal share for water demand*, which is proportional to the coastal share of the population. These variables are inputs to the water sub model that calculates the actual water use (taking into account the available stock) and simulates the treatment of water by WWTPs (cf. Sub model 1).

A stock represents the number of *agricultural workers*. It diminishes according to a known *agricultural workers retiring rate* and increases according to an *agricultural workers replacement rate*, which is expressed as a percentage of the *retiring workers* and is a scenario variable.

The *coastal* and *rural attractiveness for residents* and *tourists* are modelled by indicators ranging from 0 to 1 and that depend on the increase of housing and accommodation in the areas (cf. Sub model 4), *roads congestion* (cf. Sub model 4) and *heliotropism*. The formula to calculate these indicators is not yet fixed and will be discussed during an upcoming multi-actors meeting.

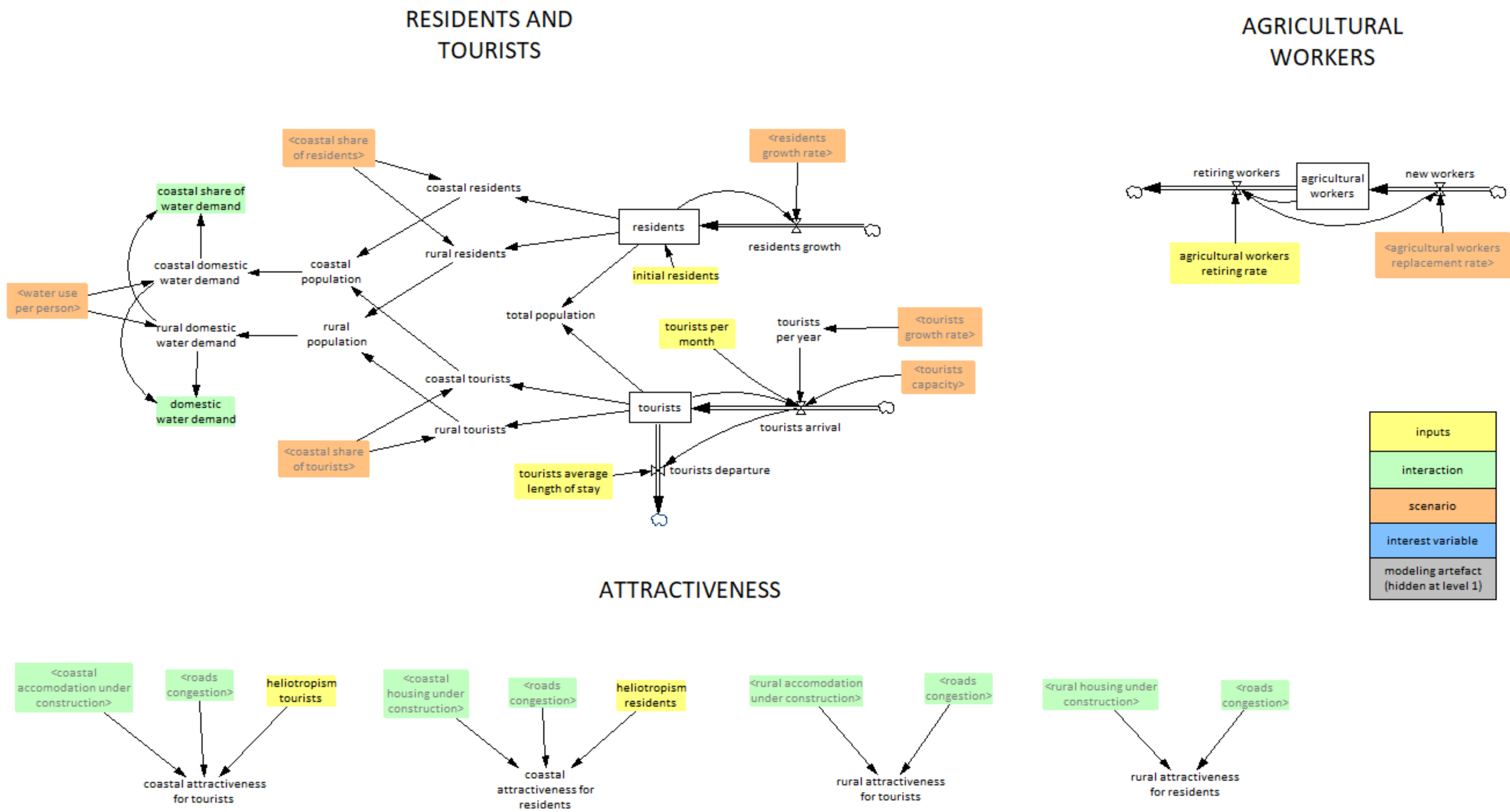
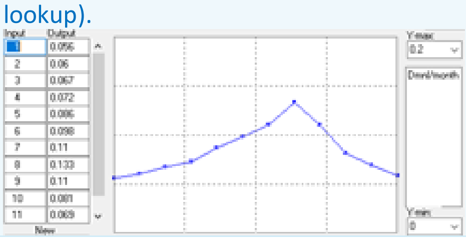


Figure 63: Overview of the SD population sub model.

Table 6: Inputs to the population sub model.

S.V. = scenario variable. Type: S = stock, C = constant, T = time-series, L = lookup.

Variable	Type	Description	S.V.	Source
initial *residents*	S	The residential population was around 585000 people in 2000.		INSEE, 2020
initial *tourists*	S	Around 1.5M tourists visited the region in 2000.		Charentes Toursime, 2020
residents growth rate	C	In the last decade, the residential population increased by approximately 1% per year.	x	INSEE, 2020
tourists growth rate	C	In the last decade, the yearly number of tourists increased by approximately 3% per year.	x	Charentes Toursime, 2020
tourists per month	L	The relative number of tourists per month, with a peak during summer (set with a lookup). 		Charentes Toursime, 2020
tourists capacity	C	Around 300000 tourists could be hosted at the same time in 2000.	x	Charentes Toursime, 2020
coastal share of residents	C	The coastal area gathers around 70% of the residents.	x	Etablissement Public Territorial de Bassin Charente, 2020b
coastal share of tourists	C	The coastal area gathers around 80% of the tourists.	x	Charentes Toursime, 2020
tourists average length of stay	C	On average, tourists stay for 5 days in the region.		Charentes Toursime, 2020
agricultural workers retiring rate	C	The share of farmers who retire every year.		Discussion with stakeholders
agricultural workers replacement rate	C	The rate at which new farmers take the place of retiring ones. It should be between 25% and 50% in the future.	x	Discussion with stakeholders
water use per person	C	On average, people in the region consume approximately 10 m3 of water per month.	x	Eau 17, 2020 Agreste, 2010

3.4.8 Overview of the stock-flow models and land-sea interactions

As illustrated in Figure 53, all the sub models interact (share at least one common variable) in the integrated model. The water sub model plays a central role, as main vector of land-sea interactions. Thanks to this structure, the integrated model allows to assess land-sea interactions in a systemic way. As an example, for a scenario where population is growing and with favourable conditions for change of agriculture towards more sustainable practices, the model can then evaluate the effect of these changes on the river flows and its positive impact on oyster's production downstream on the coastal zone. However, if in parallel the capacity of WWTPs does not increase, these impacts may be hampered by WWTPs overloads. Thus, by highlighting interactions, the model helps its users think about the system as a whole. Other examples of interactions that the model can simulate are mentioned and illustrated in Figure 53.

In parallel, an adaptation of the 4 generic scenarios is being made for the MAL4 territory (WP5), which will be simulated through an associated range of input variables when possible.

Table 7: Technical characteristics of the MAL4 SD integrated model.

Characteristic	Number
Stocks	88
Flows	109
Variables	771
Equations	355
Parameters (constants)	328
Input drivers (scenario variables)	31
Policy levers	12
Policy indicators (key variables)	51

3.4.9 Business and policy analysis

In the integrated model, a scenario is represented by a set of values for all the scenario variables identified in the description of the sub models and listed in Table 8. As defined in WP5, four territory-specific scenarios (i.e., four sets of values) are adapted from the IPCC's SSP scenarios. When simulating a specific scenario, observed data are used for the scenario variables until 2020 and then from 2020, the values specified in the scenario are used. These values are defined beforehand with stakeholders in the frame of the WP5.

The climate scenarios, which include the *rainfall* and *reference evapotranspiration* variables, are used in a special way. Three climate scenarios should be considered, corresponding to the IPCC's RCP 2.6, RCP 4.5 and RCP 8.5 scenarios. Given that the case study's territory is too small to influence global climate, this latter is considered as an exogenous driver. As such, each scenario of territorial development will be simulated against the three climate scenarios, yielding a total of 12 simulations. This will allow to evaluate how each territorial scenario may respond to the uncertain climate change.

When running the integrated model in VenSim PLE, a slider allows the user to select one territorial scenario in the dashboard views, where the dynamics of the key variables (cf. descriptions in Sub model 1 to 5) can be directly observed. Figure 64 illustrates how scenarios can thus be analysed. The

possibility to also select a climate scenario will be added once they have been finalized for the WP5's D19. A specific dashboard was developed to help discussions with stakeholders regarding the 4 scenarios. As can be seen on the dashboard, the user can select a scenario ("Sustainable territory" and "Highway to nowhere" in Figure 64), thus changing the values of the scenario variables (*demand for organic products* and *abstraction permits for irrigation* in Figure 64), and see its effect on the key variables. Note that current outcomes are not validated and may change after complete calibration of the model.
Furthermore, the design of the dashboards will most likely change after feedback from stakeholders. So far, one general dashboard and a dashboard per sector (sub model) are planned. Dashboards dedicated to specific interactions may also be added.

In addition to the simulation of scenarios, it is possible for users to set independently the values of all the scenario variables that are not time-series. In this case, possible values are not restricted to those specified in the scenarios. For this purpose, a slider on the model's dashboards allows switching from the "scenario mode", where the variables are set according the selected scenario, to the "free mode", where the values for scenario variables can be specified with sliders.

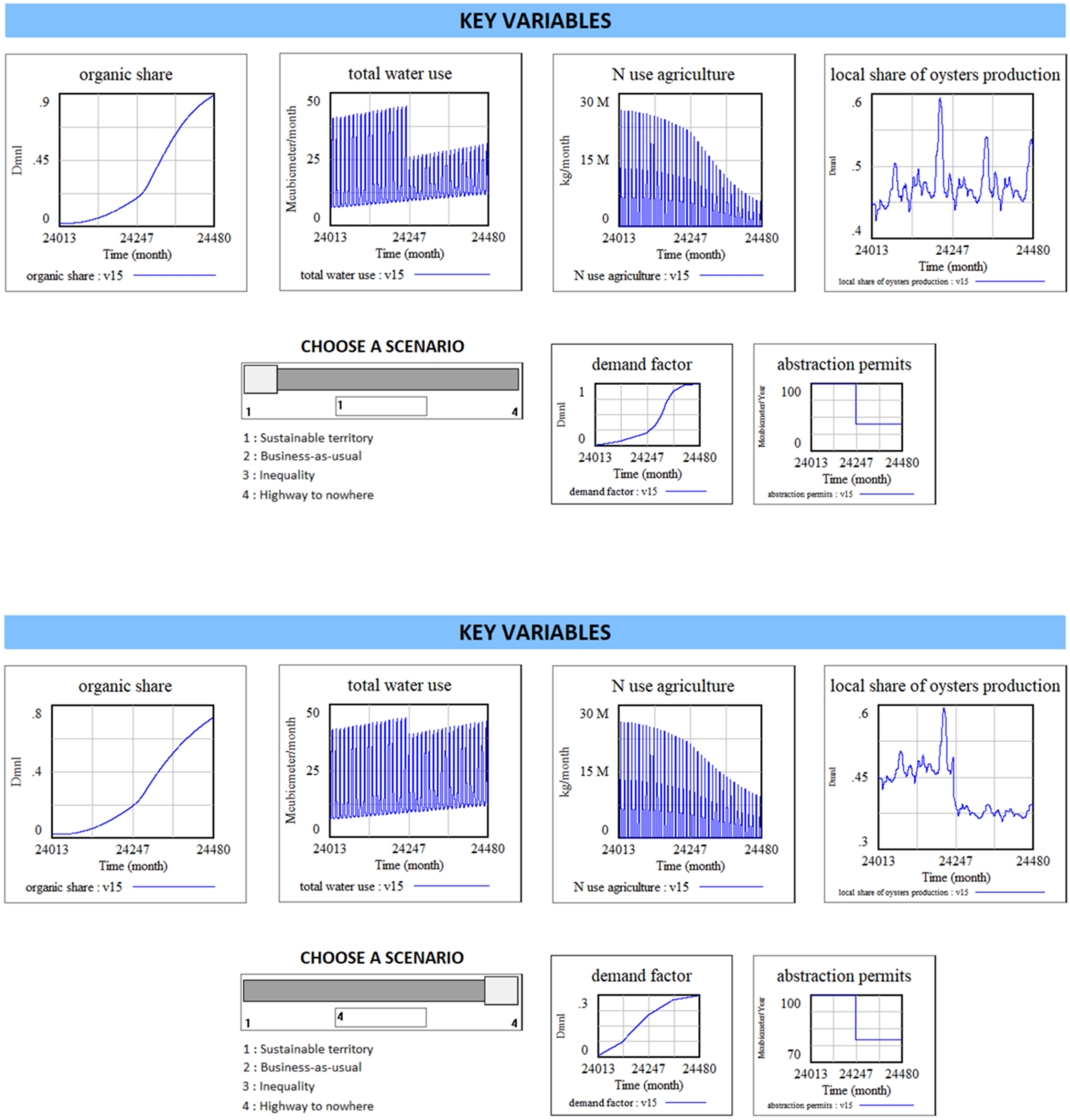


Figure 64: Illustration of a scenario analysis in the integrated model's dashboard (preliminary results without calibration and validation of the model).

Table 8: Scenario variables so far identified in the MAL4's integrated model. The list will be fixed for the WP5's D19. Type: C = constant, T = time-series, L = lookup.

Sub model	Variable	Type
water/agriculture	*reference evapotranspiration*	T
water	*rainfall*	T
water	*abstraction permits for irrigation*	C
water	*Low-Water Target Flow for water streams*	C
water	*reservoirs capacity*	C
water	*capacity of coastal WWTP*	C
water	*capacity of rural WWTP*	C
shellfish	*type of oyster bag*	C
shellfish	*oyster density per bag year x*	C
shellfish	*authorised oyster farms area*	C
agriculture	*conventional and organic practices (several variables)*	C
agriculture	*demand for organic products*	T
agriculture	*organic supply chain*	T
agriculture	*price per culture*	T
agriculture	*employment per hectare conventional / organic*	C
infrastructure	*conventional storage conversion rate*	C
infrastructure	*planned throughput capacity*	T
infrastructure	*planned rail transportation capacity*	T
infrastructure	*exported share of agricultural products*	C
infrastructure	*flooding risk*	T
infrastructure	*planned dikes*	T
infrastructure	*allowed coastal built-up area*	C
infrastructure	*allowed rural built-up area*	C
infrastructure	*planned roads*	T
infrastructure	*share of people using train or bike*	C
population	*residents' growth rate*	C
population	*tourists growth rate*	C
population	*coastal share of residents*	C
population	*coastal share of tourists*	C
population	*agricultural workers replacement share*	C
population	*water use per person*	C

Stakeholders set the common objectives of the MAL4 territories for a desirable future (2050) during the workshops. These consist in both:

- restoring and preserving natural environments and limiting impacts from economic activities and the population on the water resources, soils and biodiversity;
- preserving and/or developing the main economic activities in the area such as agriculture, shellfish farming, tourism and port activities.

There is then a need to explore different scenarios that aim to reach these sometimes-conflicting objectives. By highlighting interdependencies between activities and possible land-sea synergies, stock-flow models can help analyse the potential consequences of actions and highlight possible pathways to reach the sustainable desirable future.

For MAL4, the integrated stock-flow model allows to address the following key issues:

- **The evolution of agriculture:** the model helps to assess the consequences of agriculture development on land and water availability, on infrastructure development and on additional storage needed to develop more sustainable systems. It also allows understanding how economic conditions matter in the shift from conventional to organic farming systems. Above all, it helps to evaluate the consequences of the development of sustainable farming systems on the water demand, water availability and water quality. Analysing the controversial issue of water storage by assessing the consequences of increasing reservoirs' capacity on water availability for other activities than agriculture is also possible with the stock-flow models.
- **The increase of population (residential and tourism):** the increase of population on the coastal zone will very likely continue although the desirable future implies the maintenance of urbans areas and associated services within all the territory. The model allows assessing the consequences that this increase will have on the building of housing, the quality of freshwater inflows into the sea, the need to invest in increasing the capacity of wastewater treatment plants, the traffic congestion and additional water purification costs for shellfish farms.
- **The development of sustainable shellfish farming:** the model can help to identify the conditions for maintaining and developing sustainable shellfish farming in the area. The current use of areas close to the coast implies that the quality of coastal waters (salinity, low concentrations in pesticides and bacteria, level of nutrients) should be enough to grow oysters with a high-enough quality for selling. The model explores in more details the impact of water quality on shellfish production (frequency of mortality, spat capture rate) as well as the impact on local sales of market demand and coastal tourism development.
- **The sustainable development of ports:** the model explores the strong interactions between agriculture, intensive or sustainable, and ports' activity, showing if they are well aligned or not.
- **The development of infrastructures:** the model could assess the effect on coastal land abandonment and coastal urbanization of building dikes to prevent flooding.

3.4.10 Model confidence building

Participatory modelling is an approach developed since the mid-1990s. It was described in a special issue of the "Environmental, Modelling and Software" journal entitled "Modelling with stakeholders" and further developed by Voinov et al. (2016). This type of modelling supports a group of stakeholders – seen as a group of individuals or representatives of institutions – who decide to organize themselves into a community in order to appropriate and deal with a priority issue.

Therefore, interactions with the stakeholders contribute to the model confidence building process. Once the model is fully calibrated, a quantitative assessment of the model and its outputs will complement the approach and will be further discussed with the stakeholders. The inter-sectorial workshop highlighted the links between the mind maps to which the stakeholders contributed, the resulting causal loop diagrams that were designed from these maps and the related stock-flow models developed afterwards. Further discussion on models and scenarios helped us identify some additional topics that stakeholders wished to be dealt by the models. The integrated model and related sub models include most of the elements that are of interest for the stakeholders. According to the feedbacks of the attendees, these exchanges were considered as very positive. Interestingly, contacting the stakeholders to discuss the model and the scenarios (WP5's D19) together was useful since their descriptions of the scenarios revealed new aspects that they wish to study. Further discussions are scheduled.

Following the stakeholders' advice, the model's structure has been aligned with their needs. Thus, in the agriculture sub model, more crops and practices are now considered, and the *agricultural workers factor* has been added as an encouraging factor of conversion. Also, the *demand for organic products factor* is now considered and designed to encompass both economic and social aspects of the demand. Following requests of the shellfish farming actors, we included the *oyster density per bag* as a decision variable playing a major role in oyster quality. Two other factors influencing the relocation of oyster production in the area were also added: *spats capture* and the *oyster gross margin*.

Although without a complete calibration, the behaviour of the model and its underlying feedback structure can be considered as acceptable. The model's outputs make sense to stakeholders in terms of tendency, although the final share of organic farming is considered as too high in the worst-case scenarios, hence requiring further calibration.

The actors of the shellfish farming sector acknowledge that the modelling of oysters' *quality index* and *spats capture* according to water quality is in line with recent studies, regardless of the uncertainty and the lack of robust scientific knowledge on these issues. Economic outputs were seen as correct but still requiring evidence testing through calibration and validation processes.

The usefulness of the model for actual decision-making will be discussed once the model is fully calibrated. So far, the stakeholders testified their interest in having a fully operational tool, and to this end, they will provide us new data that will help finalise the model.

3.5 Multi-Actor Lab 5 -Danube's Mouths and Black Sea (Romania)

3.5.1 General problem scope of the land sea system

In addition to supporting a high level of *biodiversity*, the Danube Delta Region provides many benefits for humans (ecosystem services). It has an important effect on *water quality*, and *nutrient* retention, especially for the Black Sea ecosystems. Moreover, it provides extensive economic and environmental benefits to the entire region: the socio-economic benefits of the wetlands to local communities living in and around the Danube Delta are very important. Practically, all aspects the delta's inhabitants lifes are related to water in one way or another. Agriculture is practised, both in polders for cereal crops (wheat, barley, maize), sunflowers, and, on a smaller scale, for family needs (vegetables, fruit trees, vineyards) (Baboianu, 2016).

A dual challenge for the sustainable development of the Danube Delta is the conservation of its ecological assets, the improvement of the quality of life for its residents, to strike a balance between protecting the unique natural and cultural assets of the DDBR and meeting the aspirations of the region's inhabitants to improve their living conditions and seek better economic opportunities (World Bank, 2014a).

A general conclusion of the stakeholders' meetings outlined that governance and excessive bureaucracy are disturbing the economic activity (planning, facilities for investors (lack of), lack of compensatory measures, tourism, infrastructure) and social areas (health, incomes, protection, jobs), avoid real problems like the conflict between Marine Protected Areas (and restrictive measures) and the exploitation of resources or the Danube Delta's clogged canals and invasive species. Agriculture has clear impacts on both inland and coastal water quality and the locals are not aware of causes, effects and impacts of the pollution on the Black Sea and even on the surrounding neighbourhood. The agriculture is for subsistence and the area is very poor developed. Due to the Danube Delta protected area, there is a pressure down the coastal zone for seasonal tourism (only three - four months/year). Thus, there is an artificial population "growth" that is not sustained by the "real" economic development.

In accordance with its Biosphere Reserve status, the Danube Delta is expected to be governed by policies converging towards an integrated economic, societal, cultural, and environmental sustainability (Petrişor et al., 2016). While past anthropic activities in the Danube Delta led to important impacts on the natural environment there are also economic activities which can be optimized to become sustainable on the long term, such as ecotourism, reed harvesting and processing, small-scale businesses based on traditional activities (Sbarcea et al., 2019).

The unique ecosystem of the North-Western Shelf of the Black Sea is burdened by excessive loads of nutrients and hazardous substances from the coastal countries and the rivers that discharge into it and the Danube is the river with the highest discharge. Pollution inputs and other factors radically changed Black Sea ecosystems beginning around 1960. Other pressures on the Black Sea ecosystems include organic pesticides, heavy metals, incidental and operational spills from oil vessels and ports, overfishing and invasions of exotic species.

Today, the Black Sea catchment is still under pressure from excess nutrients and contaminants due to emissions from agriculture, tourism, industry, and urbanization in the Danube basin. This prevented achieving the Good Environmental Status by 2020, as required by the EU-Marine Strategy Framework Directive. The increased rates of eutrophication, pollution are important stressors for the Black Sea ecosystem (INCDM, 2018).

The goal of the model is to explore alternative scenarios to improve the quality of life and sustainability within the Danube Delta Biosphere Reserve and its marine waters (Black Sea) as one of the most impacted areas along the Romanian littoral. Land-sea interactions in the coastal MAL5 region were identified through separate sector workshops and a combined multi-sectoral workshop as part of WP1 in the COASTAL project. Land-sea interactions are at the core of our study case. (Figure 65). For practical reasons due to data availability and considering that the activity on the area upstream has effect on this highly biodiverse area we will include in the model data collected for the entire county of Tulcea.

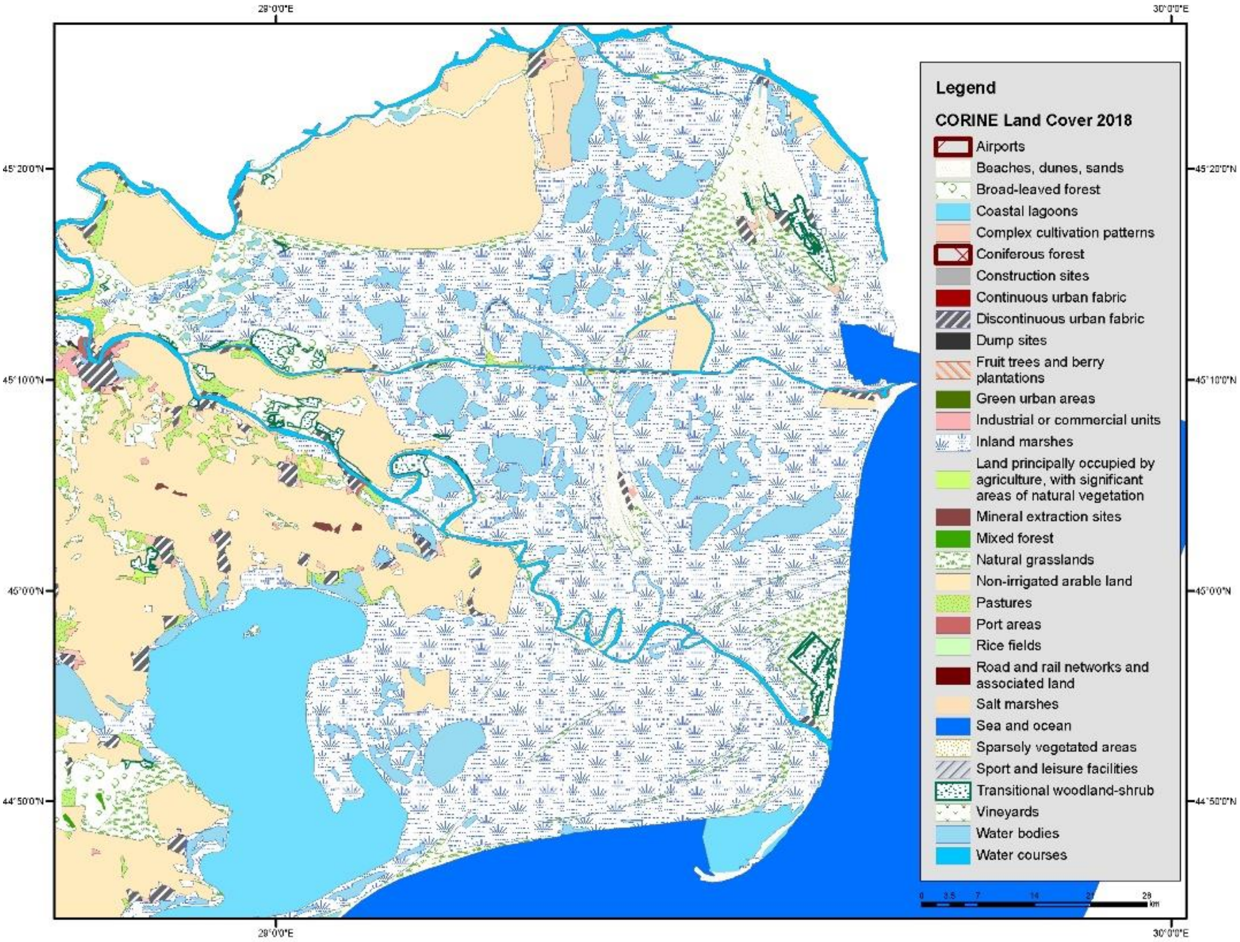


Figure 65: Map of the geographic area - Danube's Mouths – Black Sea case.

3.5.2 From multi-actor analysis to modelling

Even though the environmental aspects and ecosystem management were not an important issue during the stakeholders meeting, we envisaged their clear interlinkages mainly because of the Danube as the end carrier of all substances discharged into the Black Sea and as the physical environment on which these layers rely (Figure 67).

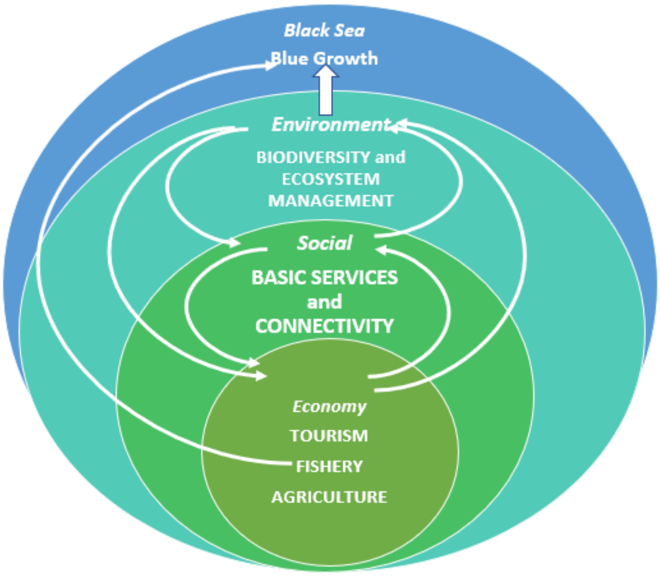


Figure 66: *Land-Sea interactions and sub models in the Danube's Mouths – Black Sea case*.

As the overall CLD produced during WP1 was considered unclear, it was decided to start from the sectoral CLDs when producing the stock-flow model(s). Based on the CLDs derived during the sectoral workshops and layers presented above, we identified several sub model structures from the overall CLD that will be further developed in the following chapters on quantification. More specifically, operational models will be presented for:

- Agriculture
- Fish farming
- Tourism

The transition of CLDs to a stock and flow model is not straightforward. The information for the quantified models is aggregated in the CLDs, represented as links and elements. Extracting stocks, flows and auxiliaries from the CLDs requires further investigation of the links and what they represent. This process may change the number of factors in the system (Binder et al., 2004). Thus, between workshops, we cleaned up the CLDs and met with experts (mainly scientists) that the participants have agreed should be consulted. Thus, the changes to the CLDs, did not go beyond what was agreed during the stakeholder meetings.

3.5.3 Sub model 1: Agriculture

3.5.3.1 Model scope of the agriculture sub model

The initial CLD from the Agriculture stakeholders meeting (Figure 67) was translated to a stock and flow model where the main variables were based on the lexical transformation of the initial variables

Agriculture to Agriculture production➔ *Traditional farm area and eco-farm area*), Farmer rights ➔ *Farmers welfare*➔ *Farmers income* and Pollution ➔*Pollution from Agriculture* ➔ *Nitrogen load* as pollution also is considered in other sub models (More specifically this will be accounted as the impact of agriculture on water quality).

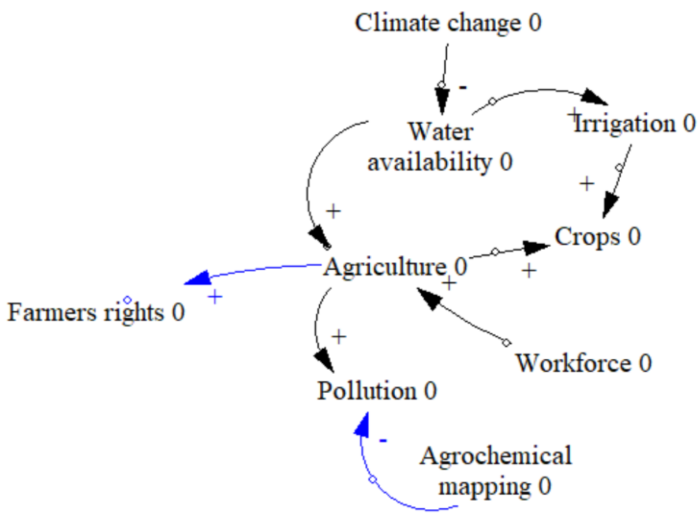


Figure 67: Initial CLD - Agriculture stakeholders meeting -partial view.

Forest belts were also added to the model. The forest belts will improve water availability and this will increase the agricultural productivity. It is to be highlighted that the establishment of protective forest belts and increasing the forested area is part of several policy papers in the development of the Danube Mouths region such as Danube Delta strategy, National Regional Development Program, etc. The forest belts offer multiple beneficial effects including biodiversity increase, reducing soil erosion, mitigating of flood risks, trapping snow, and increasing crop yields.

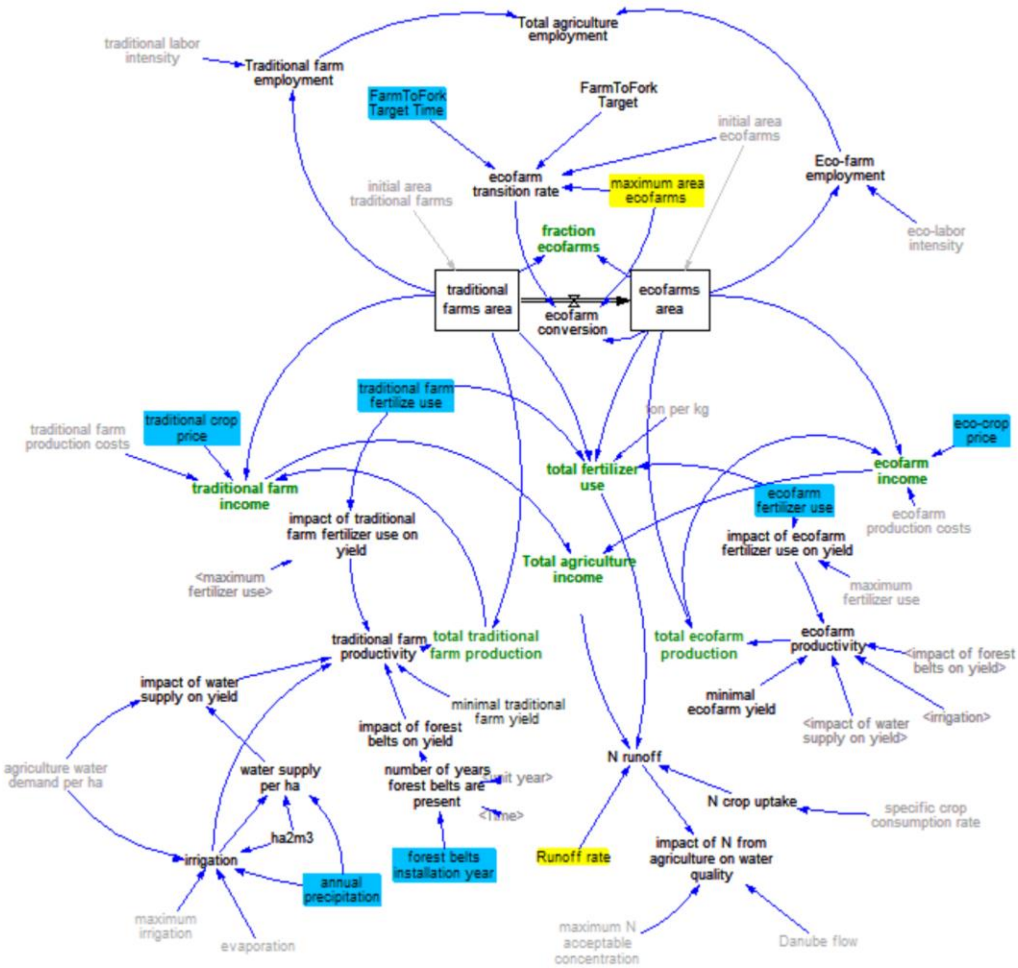
The potential of our case study area for conversion to organic farming is closely related to the presence of protected areas in the Tulcea territory. Over 500,000 hectares have the status of protected areas, which represents more than half of the county's surface. Only organic agriculture can be practiced within these areas, and the use of chemical fertilizers should be prohibited. Inside the Danube Delta Biosphere Reserve, there are over 40,000 hectares suitable for agriculture.

3.5.3.2 Quantification in the agriculture model

The core objective of this sub model is to model the transformation from conventional farming vs eco farming by trying to fulfil the EU's recent recommendations, while assuring food security and farmer's competitiveness on the market.

The conversion to eco-farming is expected to have a beneficial effect on the environment by decreasing the negative impact of farming on soil, water and air quality. Given the land-sea interaction envisaged by the COASTAL project, this sub model is accounting for the impact of farming on water quality.

The model is structured as a generic one crop system, namely wheat production. This crop was chosen taking into account that it has the largest share of the cultivated area in the case study region. Moreover, organic wheat has the highest share in organic production (across the entire country and in the case study area as well) with an average of 30% and a steady increase over the last ten years. For accuracy of official statistics data included in the model equations, we took into account, as a case study region, the entire county of Tulcea. The start time of the model data is 2019 and timeframe was



set to 2050.

Figure 77 : Agriculture stock flow model

The model has two stocks: *traditional farms area* and *eco farms area*. The entire architecture has a symmetric structure for several variables (*farm income, farm production, fertiliser used*) respectively for the traditional farming system and the eco farming system.

The *eco farms area* equation was set taking into account the Farm2Fork strategy of at least 25% of European agricultural area to be cultivated under organic system by 2030. At present, the organic production area in Romania accounts for 2,9% of total agricultural land. Tulcea county is ranking the first in the country with a share of 16% area under ecological farming from total agricultural land of the county (366.3 thousand hectares).

The overall *traditional farm income* is obtained as function of production value (*total traditional farms production* multiplied by *crop price*) *divided by traditional farm area* and subtracting the *traditional farm production cost*. The same rationale was used for *eco-farm income*. The *traditional farm yield* is expressed as tons crop per year and is obtained by multiplying the *average farm production* and the total *area* under traditional farming system. Again, the same rationale applies for *eco-farm yield*. The higher the yield is the higher the productivity and profitability of a farm and this increases the well-being of farmers. Generally improved yields are generated with improved practices (innovation, farming infrastructure, irrigation, crop varieties). As our objective is to study land sea synergies, we have chosen for the modelling the water needs (from *irrigation* and *precipitation*), *fertiliser use* and at the stakeholder's suggestion, the installation of *forest belts*. Regarding the fertilisers, the variables implying this production factor should be read as Nitrogen containing fertilisers. This decision was taken to address the most relevant compound for water quality in the area. Data on fertiliser use were extracted from official statistics and good agricultural practices code for traditional farming and farmers survey and good agricultural practices code for eco-farming.

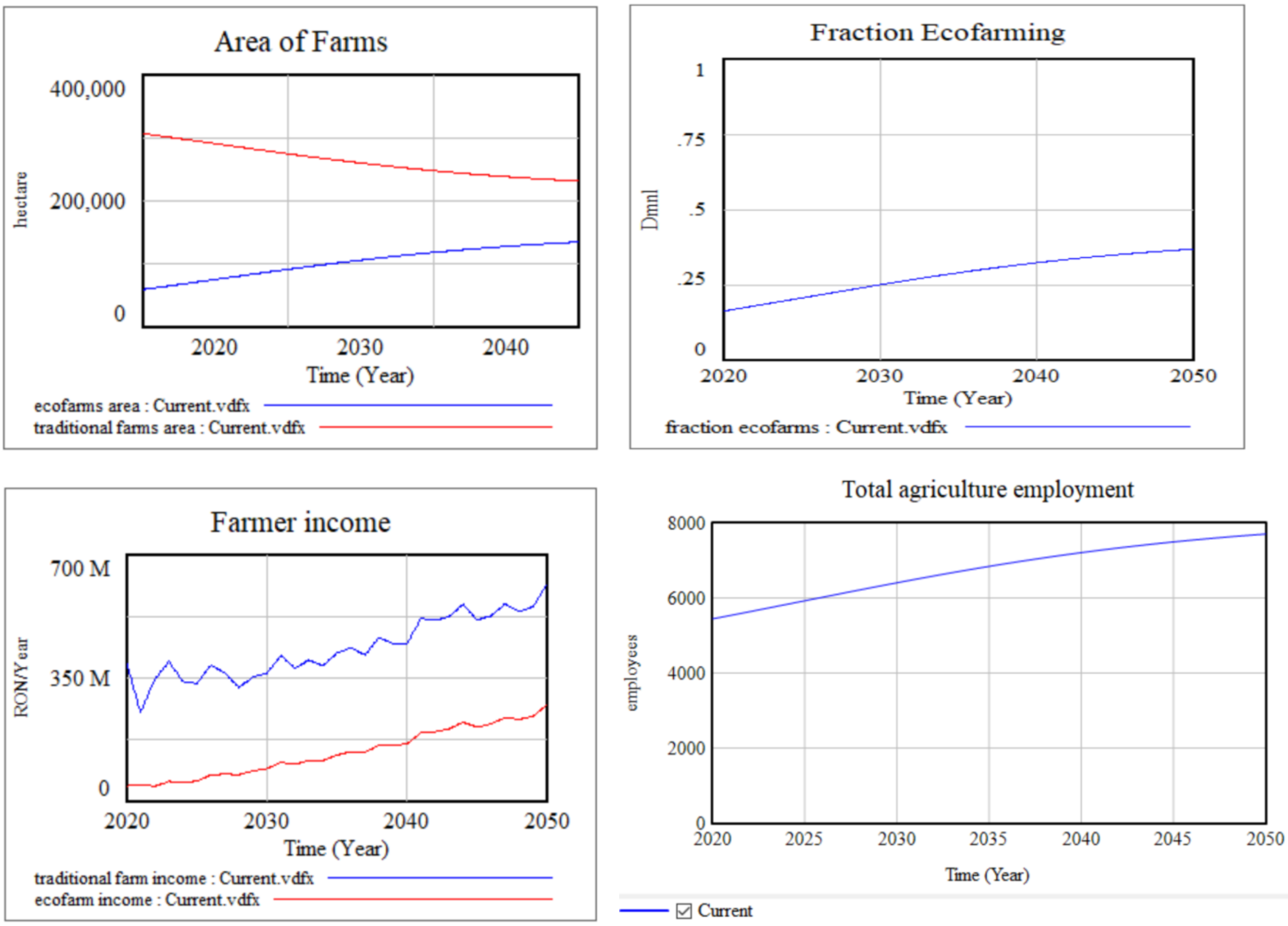


Figure 68: Results for the agriculture sub model: (ul) area of eco/traditional farm land, (ur) fraction of eco-farms, (ll) eco/traditional famer income and (lr) total employment for agriculture.

3.5.4 Sub model 2: Fish farming

3.5.4.1 Model scope

The fishery stakeholders' meeting gathered both freshwater (Danube Delta) and marine (Black Sea) fishermen. Even though several issues were common (e.g., legislation, fish market, fishermen welfare, etc.), we chose to distinguish two types of fish stocks mainly due to the focus on aquaculture. Currently, aquaculture is relatively well developed in the rural area (freshwater) and not present in the Black Sea at all due to the lack of a legislative framework to allow the concession of the coastal waters. Aquaculture is considered one of the future businesses in the Romanian Black Sea.

The intensive aquaculture became of interest because, according to the national reports, the domestic fish production in Romania represented less than 20% of the internal consumption (2016-2019) leaving production at the 18th place in the EU with 12 798 t (0.93% of total EU production). The rest came from imports. Thus, for 2019, it is estimated that the national consumption is over 120 000 t representing approx. 195 million euro. This shortfall of domestic production compared with fish consumption can be interpreted as a potential for the development of the fisheries sector in Romania (over 100 000 t).

According to the national reports and confirmed by research projects and COASTAL stakeholder meetings and experts' judgement, the main causes of potential production were:

- the fishing facilities in the public and private domain of the state and managed by the National Authority for Fisheries and Aquaculture were not fully granted, and those in the perimeter of the Danube Delta Biosphere Reserve were exploited only 57%.
- reduced productivity per hectare, obtained in aquaculture farms, very close to the level of fish productivity of the natural environment.
- lack of production in marine aquaculture.
- poor performance of economic operators, who have insufficient and outdated boats and equipment.
- economically unattractive species for fishermen.
- illegal, unreported, and unregulated (IUU) fishing is estimated as 80%.

3.5.4.2 Quantification in the fish farming model

In the process of the sub model development, the freshwater aquaculture stock was considered as the fish farming area (ha), which has two components – normal and intensive aquaculture stocks. The normal fish farming area is influenced by the development rate, which is a function of the spatial pressure. The normal fish farming area is decreased by the aquaculture intensification and has an impact on the normal aquaculture production, normal fish farm employment, total nitrogen load from aquaculture and total area in use for aquaculture. In turn, aquaculture intensification is the main input for the intensive fish farming area, together with its rate of development. Both stocks have an important output, which is the total aquaculture production as a sum of fish production from normal and intensive aquaculture.

Another output of the model is the number of jobs created by the sector development. The fishery is the main traditional activity for the Danube Delta's inhabitants and represents over 15% of the total workforce. The area has the most important aquaculture resources in Romania representing in 2020, 73 units covering more than 69 000 ha (nurseries and fish farms) with annual revenues of approx. 4 million Euro and 350 employees. The model considers the number of employees as a result of increasing the intensive area and the intensity of the fish farming labour. The latter is estimated now as 0.02 employees/ha.

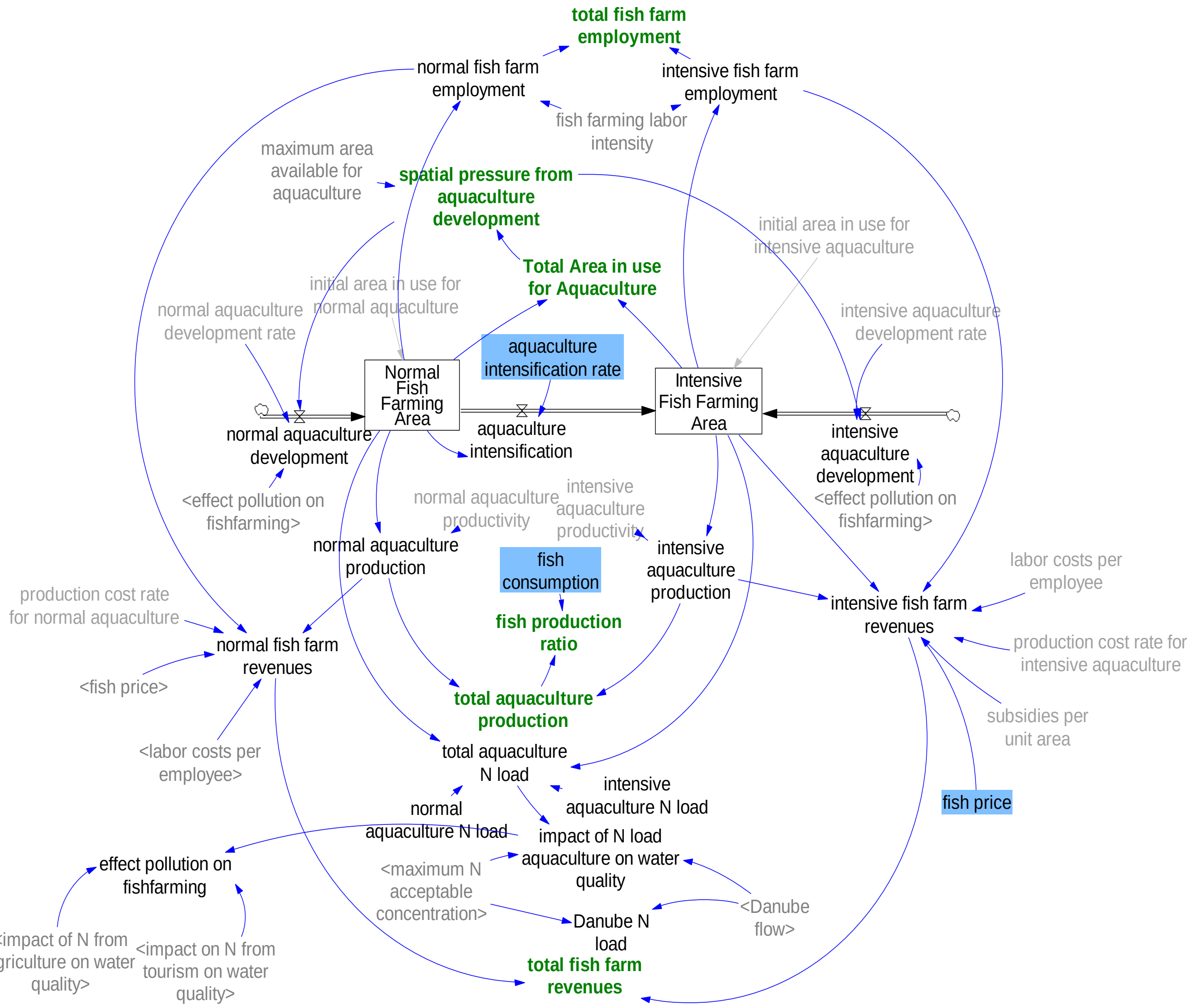


Figure 69: Operational model for the Freshwater Aquaculture

As a future scenario, the aquaculture intensification rate represents the yearly fraction of existing normal aquaculture area, which is changed into intensive aquaculture. The value is to be set according to different scenarios. Another important output of the sub model is the environmental pressure from the sector. It was expressed as the impact of the nitrogen load on the water quality. The model calculated as the water footprint, meaning the total nitrogen load from normal and intensive aquaculture divided to the product of maximum worst case of the nitrogen load (MAC-maximum allowable concentration from the national legislation) and the flow of the Danube's arm.

The fishermen welfare was mentioned many times in the stakeholders meeting, and it is one of the most important targets of the Danube Delta's strategy. In our model, it is quantified as the intensive fish farming revenues and calculated from the difference between income and costs:

(price*intensive aquaculture production +
Intensive Fish Farming Area*subsidies per unit area)
-
(intensive fish farm employment*labour costs per employee +
intensive aquaculture production*production cost rate for intensive aquaculture)

Together, with the other important sectors in the area – eco-farming and tourism, the model serves as an important tool for the sustainable development of a unique area in Europe, which is the Danube Delta and the Black Sea. The results of the sub model (Fig.87) highlighted the increase of the impact of the nitrogen load on the water quality as a result of the intensive aquaculture area and production growth to the estimated . Accordingly, the scenario will consider the different ways of nitrogen removal to keep the water quality at a certain degree – in our case, maximum allowable concentration.

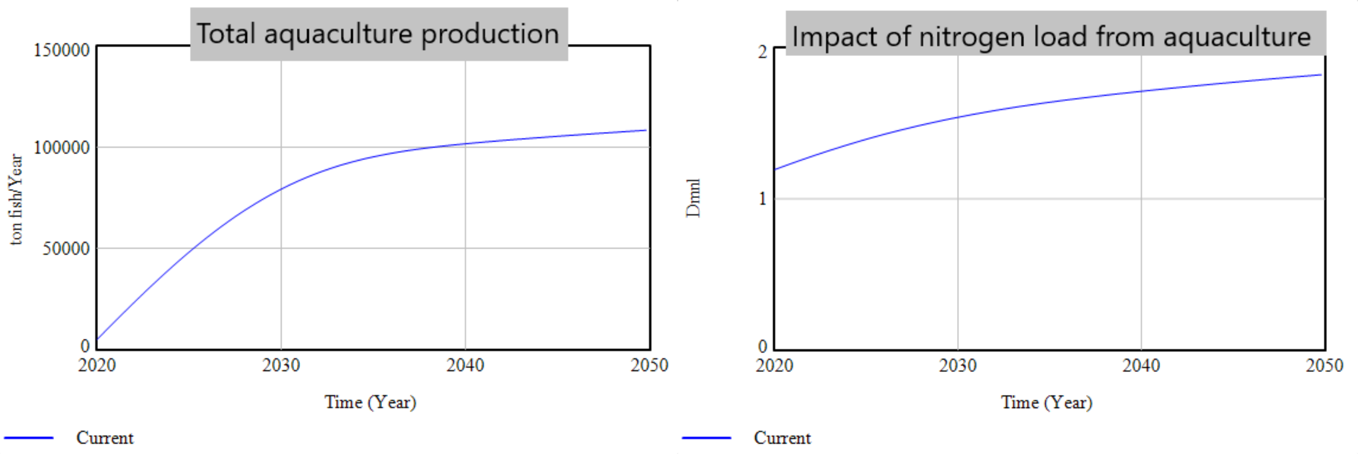


Figure 87 - Results from the Fish Farming sub model – MAL05

3.5.5 Sub model 3: tourism

3.5.5.1 Model scope

The first meetings with stakeholders held together with experts in the field of tourism, which had as main theme "Rural tourism, leisure and other rural activities" and "Rural development", led to the initial CLD diagram as they were described in the deliverable, *"D13 Pilot SD Models for Coastal-Rural interactions"*. For both rural and coastal tourism, the meeting outputs were similar outlining that tourism has significant potential as a driver for growth for the local economy.
The protected areas' restrictions will however limit its growth, which is usually accompanied by significant changes. Thus, the need for ecotourism was emphasized, as well as its diversification (*touristic activities*) leading to slow tourism, benefiting the protected area (*biodiversity*) and local people (*workforce*). Destination planning and development strategies (*marketing*, *social events*) are important steps towards the greening of tourism.

Subsequently, holding other meetings with tourism stakeholders, based on their views and perspectives on the importance of the purpose of the obtained model, which is to determine how far the rural tourism of the area can be developed without damaging the balance with the environment the model was further developed. Among the main variables included in the model presented below (Figure 70), we can mention, in particular: ***number of tourism*** (stock variable), tourism pressure, tourism carrying capacity, employment factor, marketing budget, emergency level and time until the emergency level is reached, tourism development and tourism decline.

3.5.5.2 Quantification

The tourism model (Figure 70) includes representative data for an administrative territorial unit, the Tulcea County area, in order to maintain the accuracy and the significance of the data we used as input for the below model. The model includes a single stock variable, named Number of Tourists, determined over a period of 30 years, taking the year 2020 as the beginning of the simulation and ending of the simulation by the year 2050. We included in the model specific quantitative input variables, such as tourism carrying capacity, employment factor, emergency level, time until emergency level is reached, revenues per tourist day, fraction of revenues used for marketing, initial number of tourists, initial duration of stay, decline rate without development, decline rate without development These variables are determined as constant variables, based on calculations made with data from National Institute of Statistics, in most cases, but also based on others scientific publications of interest for our Tourism model. Secondly, the model includes auxiliary variables, which are calculated and forecasted with a specific given formula, based on the first mentioned category of variables: initial tourist days, Annual Tourist Days, tourism employment. Also, the model worked with variables and runs interactions determined with the look-up function, following the shape of the graph that experts and stakeholders in the field of tourism think that it should be designed, such as: tourism pressure, tourism attractiveness, impact of marketing on development.

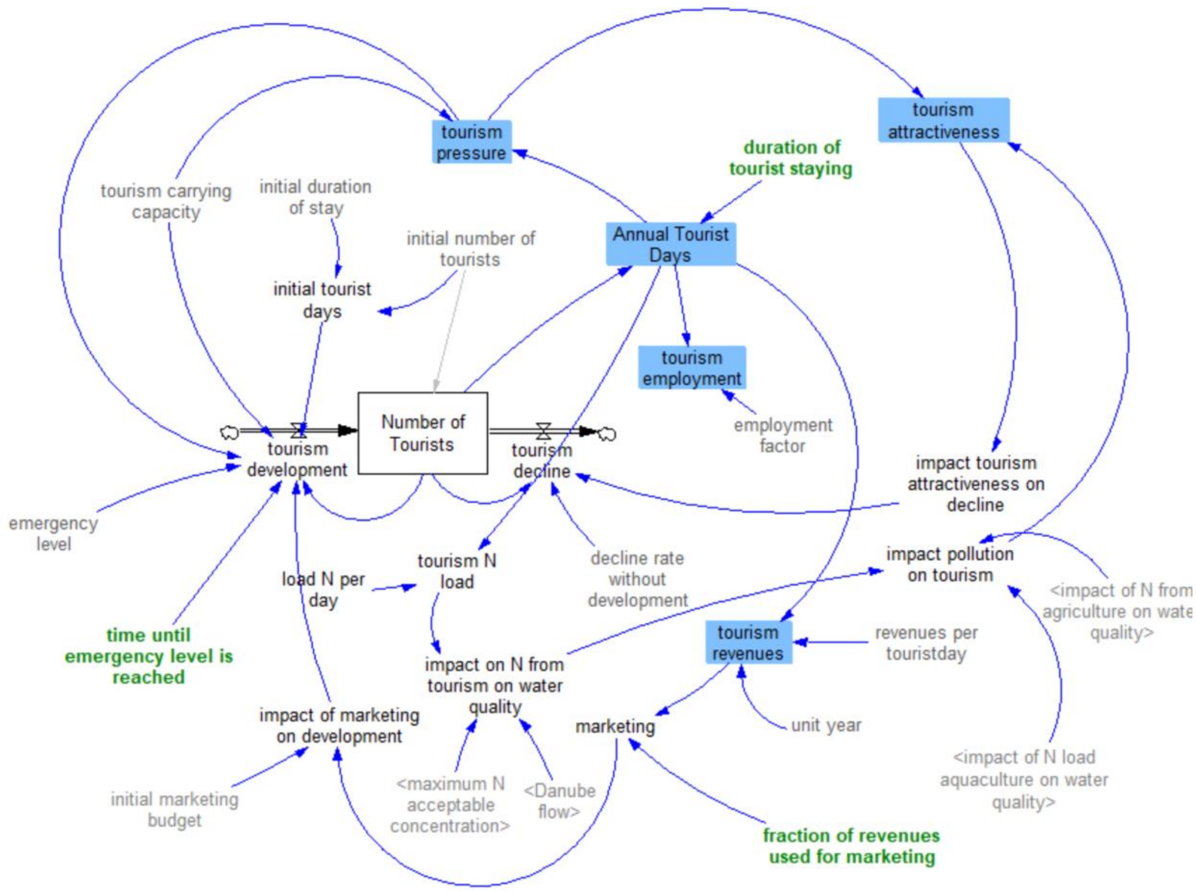


Figure 70: Stock-flow structure of SD sub model MAL5 development in VENSIM (Tourism Development)

The value of stock variable, Number of tourists, is based on the relation between inflow and outflow rate variables more specifically on the difference between the tourism development and decline (Figure 71):

Number of Tourist: Tourism(t - dt) + (tourism_development - tourism_decline) * dt

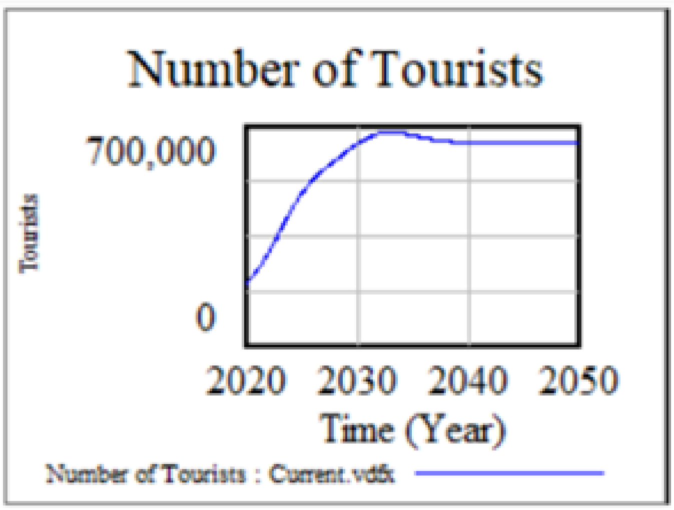


Figure 71: Result of SD sub model Tourism Development: number of Tourist

Thus, we notice an increase of the number of tourists in the area until the year 2031, and then this value slowly decreases in 2032-2040; starting with 2040, the number of tourists remain constant. It is interesting that the variable fraction of revenues used in marketing has a great impact regarding the number of tourists, and on the other variables, such as: tourist days, tourism pressure, tourism revenues, tourism attractiveness, tourism employment(Figure 72).

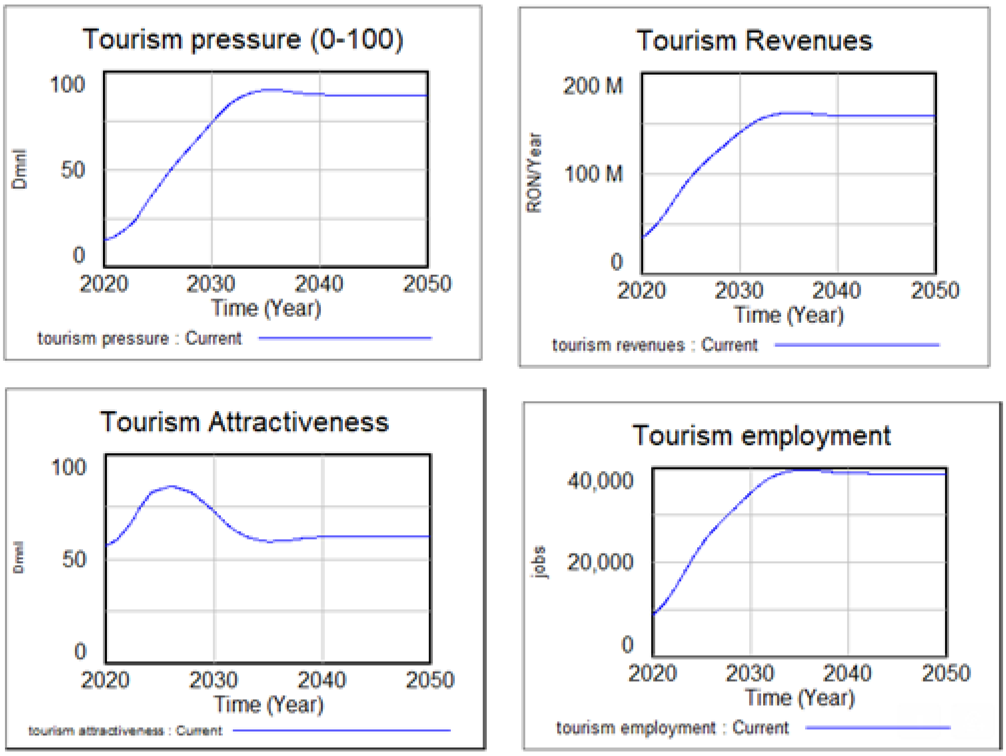


Figure 72: Results of the SD sub model for Tourism Development.

A higher marketing budget leads to faster growth of the number of tourists because of the increased level of the development rate of the area, but when the time interval in which the values of the presented variables increases, it shortens. After this increase, all variables follow a decreasing trend and then remain constant.

The formula that we've used for quantifying the interaction between the variables in this model are presented below:

- ***Tourism pressure***: Annual Tourist Days/tourism carrying capacity, with Look up function, the higher the number of tourists, the higher will be the pressure from tourism on the environment;
- ***Tourism revenues***: Annual Tourist Days*revenues per tourist day/unit year;
- ***Tourism attractiveness***: with the Look up function, based on the idea that the higher the pressure on the environment, the lower the attractiveness of the tourist area will be;
- ***Tourism employment***: employment_factor*Tourism.

3.5.6 Overview of the stock-flow models and land-sea interactions

The main objective of the project is to investigate how the different coastal-rural sub sectors that are considered affect each other. In our case the interaction is through the water quality. The three sub models are integrated through the impact of the nitrogen input from each modelled sector and how each sector is influencing the others and the overall impact. Thus, the eco-farming practices are reducing the nitrogen input in the water and during the time of modelling the impact of pollution is reduced (Figure 73).

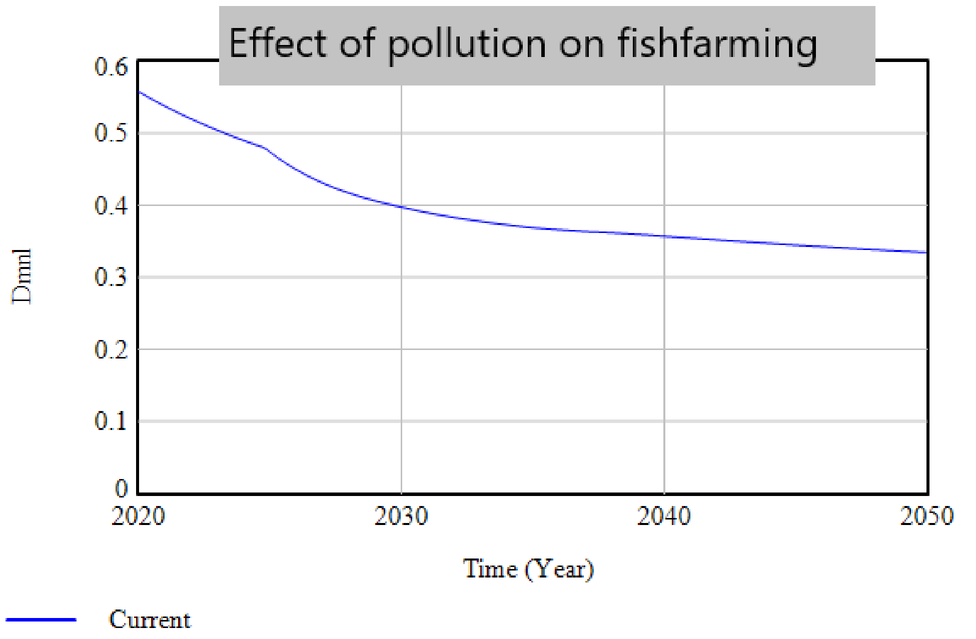


Figure 73: Effect of pollution from all sectors on fish farming – MAL05

Regarding the tourism model and the results obtained from the model simulation, we can say that the tourism capacity development is beneficial but up to a certain critical point, reaching this point leading to environmental damage. We observed in the tourism model, as in fish farming model or in eco farming model, the fact that during the modelling time, the impact of pollution is reduced (Figure 82).

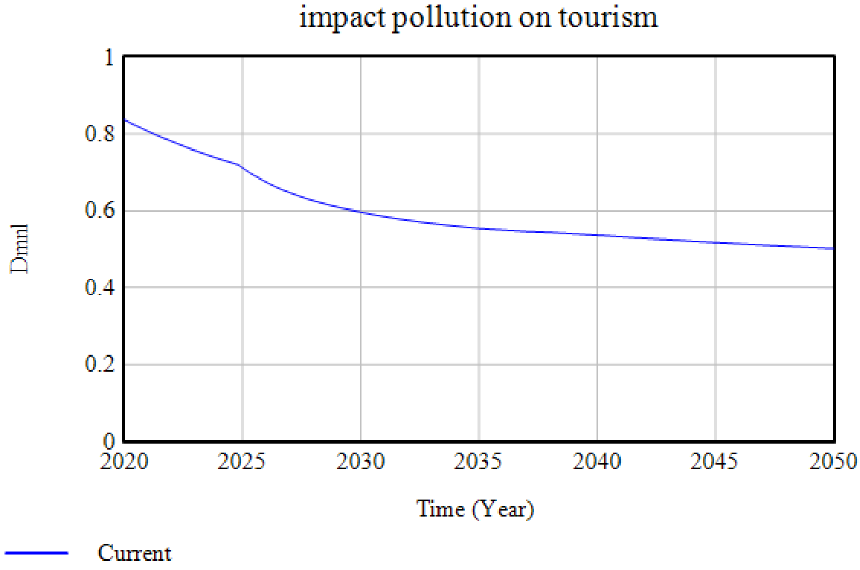


Figure 82: effect of pollution regarding from all sectors on tourism

3.5.7 Business and policy analysis

Overall, the model can used to investigate the possibilities of using the key points of growth within the rural areas (that is agriculture, tourism and fishery) to improve the socio- economic state of the area, while conserving the environmental assets. Therefore, several problems were addressed upon the stakeholders' requirements: increasing the efficiency of agricultural activity (e.g., value added products; crops obtained in organic production system; planting forest belts for improving efficiency of agricultural practices); Supporting the diversification of income for local citizens (e.g., from tourism activities related to the specific of the area: fishery, cultural heritage, eco-tourism; from establishment of aquaculture business) to create jobs, encouraging the active involvement of local communities.

The agriculture sub model scope is strongly linked to the Farm to Fork strategy set out by the EC in 2020. The European Commission's "Farm to Fork" strategy (Farm2Fork) is a response to the global challenges of providing access to healthy food, protecting biodiversity and adapting to climate changes. Farmers working in agriculture will need to produce more with less resource consumption while protecting the environment. The Agriculture sub model is built so as to remember that farmers and their work are part of the solution not the problem as we move towards a transition to a bio-economy. The model can contribute to the Green Deal implementation and Greening the Common Agricultural Policy as follows:

- Support to the objective of at least 25% of the EU's agricultural land under organic farming by 2030 from Farm2Fork strategy by encouraging the expansion of organic area,
- Encouraging the establishment of agro-forestry practices from Farm2Fork strategy by planting forest belts

3.5.8 Model confidence building

The model aims to support and guide the transition to the stakeholder's vision and the national strategy for the Danube Delta by providing insight into the impact of potential solutions on the unique ecosystem. Therefore, the goal of the model is to explore alternative scenarios to improve the quality of life and sustainability within the Danube Delta Biosphere reserve and its marine waters (Black Sea) as one of the most impacted areas along the Romanian littoral. Thus, "an attractive area – with precious biodiversity and small/medium scale agriculture and business - where people live in harmony with nature; integrating economies of tourism, farming and fishery; and supported by urban service centres" represents a vision for challenge and reconciling the economy, society and the environment which becomes prominent in biosphere reserves. The human settlements situated within Danube Delta must be managed such that they achieve equally social, economic and environmental sustainability and make up a successful case study (MDRAP, 2016).

The model considered the cumulative impacts of the most important activities and interdependent sub models for eco-farming, aquaculture and tourism in the Danube Delta. The sectors' development could be monitored by the model and managed for the sustainability of the area.
The integrated model was developed with important input from the stakeholders, actors (LAGs) and intensive literature research. The basis was the combined CLD developed during the WP1 experts meeting and after the sectoral workshops. Furthermore, we developed the structure of the model in deliverable 13, we organized the second multi-actor workshop and had meetings with separate experts. We showed them the pilot versions of the sub models and preliminary results and even obtained some data which were not available (e.g., the labour cost in a fish farm).

Full model behaviour has not been tested by stakeholders yet but will be part of the next workshop or dissemination activities planned. The last MAL5 stakeholders have shown more interest and confidence in the relative values of the key performance indicators based on different scenarios of implementation of solutions than in their absolute values. Thus, the final goal of the model will be to support a business roadmap by considering all interactions between sectors. All this feedback has affected the model structure, increasing the level of detail in some aspects and becoming more comprehensive and correct, reflecting interactions between model variables and using the most reliable data. Especially, some new scenarios have been developed, sometimes replacing old ones that were not as relevant or realistic for stakeholders. During model development, we have also continuously tested how changes in the model have affected main outputs to determine how reasonable they were by comparing output with historic observed data.

In general, the following actions are planned in MAL05:

- To develop the rural development and ecosystem management sub models and the integrated model by using the results of the sector sub models and new variables upon their availability. For example – the ecological restoration of the Danube Delta is a variable that might be quantified in different ways like *fish natural reproduction* or *fish migration routes*.
- To validate the pilot model and prepare the final results and dashboard to be discussed with the stakeholders in the final meeting.

- To fine-tune and extend the model considering the stakeholders' feedback and requirements.
- To determine the model validity utilizing qualitative and quantitative testing, focusing on the model structure, simulated dynamic behaviour of the systems as a whole, and policy or business implications.

3.6 Multi-Actor Lab 6 - Mar Menor Coastal Lagoon (Spain)

3.6.1 General problem scope of the land sea system

The Mar Menor coastal lagoon (135 km^2) is located in the Region of Murcia (SE Spain). The catchment draining into the Mar Menor covers an area of 1.255 km2 and is mainly covered by intensive irrigated agriculture with horticulture, tree crops and greenhouses, while the coastline is occupied by villages and tourist accommodations (*Figure 74*). The area is characterized by multiple environmental, social-cultural and economic interests, often competing for scarce resources, water being the most important. There is a high potential for complementarity, win-win scenarios, development of sustainable business cases based on public-private collaboration, efficient use of water, innovative farming practices and a transition to sustainable models of tourism and agriculture.

Figure 74: Cropland area in the Campo de Cartagena near the Mar Menor lagoon (Author: Javier Jiménez).

The intensive and highly profitable irrigated agriculture mainly depends on scarce low-quality groundwater and water from inland inter-basin water transfers. Agriculture provides labour and income to the region but forms a source of excessive nutrients, sediments and other forms of contamination into the Mar Menor coastal lagoon. The resulting poor water quality affects the ecology of the lagoon with severe implications for its potential function for tourism and fisheries. The coastal lagoon forms part of a Specially Protected Area of Mediterranean Importance (SPAMI).

The Mar Menor is one of the hotspots for tourism in the Region of Murcia, with a total number of 346,000 tourists and 1.4 million overnight stays in 2016. Beside international visitors, the Mar Menor has an important touristic function for the regional population (1.5 million inhabitants). The availability of water for irrigation and drinking water for tourism will be further reduced under future climate conditions. As such, the Mar Menor is strongly influenced by interactions between inland agriculture on the one side, and coastal tourism, salt pans and fisheries affecting natural ecological values and socioeconomic sustainability on the other side.

The need to move towards sustainable modes of agriculture and tourism is increasingly recognized and recently revived strongly due to a sudden increase in contamination levels resulting in a strong drop in tourism. The main driver that has caused a hydrological and nutrient imbalance in the study area is intensive agriculture, and to a lesser extent due to insufficient urban waste water treatment and historic mining activities in the area. The opening of the Tajo-Segura water transfer in the 80's promoted an uncontrolled flourishing of irrigated croplands in an area that had been traditionally dominated by rainfed agriculture. Public administration has not been very successful in controlling the implementation of best agricultural practices, and there is a general lack of support for touristic activities by the local and regional governments. This favours the uncontrolled development of agriculture and tourism expansion leading to the ecological collapse of the Mar Menor lagoon. This crash is negatively affecting the attractiveness and touristic potential of the area and impoverishing local communities.

The identification of most effective solutions and possible trade-offs requires careful assessment of system interactions and feedback mechanisms, which is the focus of the system dynamics model. Following the outcomes of the sectoral and multi sector stakeholder workshops, the main processes that the SD model for Mar Menor and its catchment area considers and will affect land-sea interactions are:

- The impacts of the export of nutrients to the lagoon from intensive irrigated agriculture in the catchment area (Campo de Cartagena) due to the excessive use of fertilizers and lack of mitigation measures, causing the degradation of the Mar Menor lagoon affecting also tourism and local populations.
- The environmental, social and economic impacts of implementation of sustainable land management practices in the development of the agricultural sector, the good ecological status of the Mar Menor lagoon and with sustainable rural and coastal tourism compatibility.
- The potential for the development of rural and coastal ecotourism and the development of solar photovoltaic energy production facilities and their effects on job creation and recreation activities in the rural and coastal areas.
- The effect of a more integrated management strategy by means of participatory governance on a more environmentally aware society and more effective environmental control and regulation.

3.6.2 From Multi-actor analysis to modelling

Figure 75 shows a high-level mind map of the main land-sea interactions identified during the sector and multi sectoral workshops. Some examples of main topics discussed during the stakeholder workshops were in relation to different variables, such as intensive agriculture, social wellbeing (mainly dependent on number and quality of jobs), eco- and agrotourism, sustainable agricultural practices, participatory governance, climate change, lagoon water quality (as a proxy of ecological status), environmental social awareness, the promotion of renewable energy facilities, and the tourism seasonality.

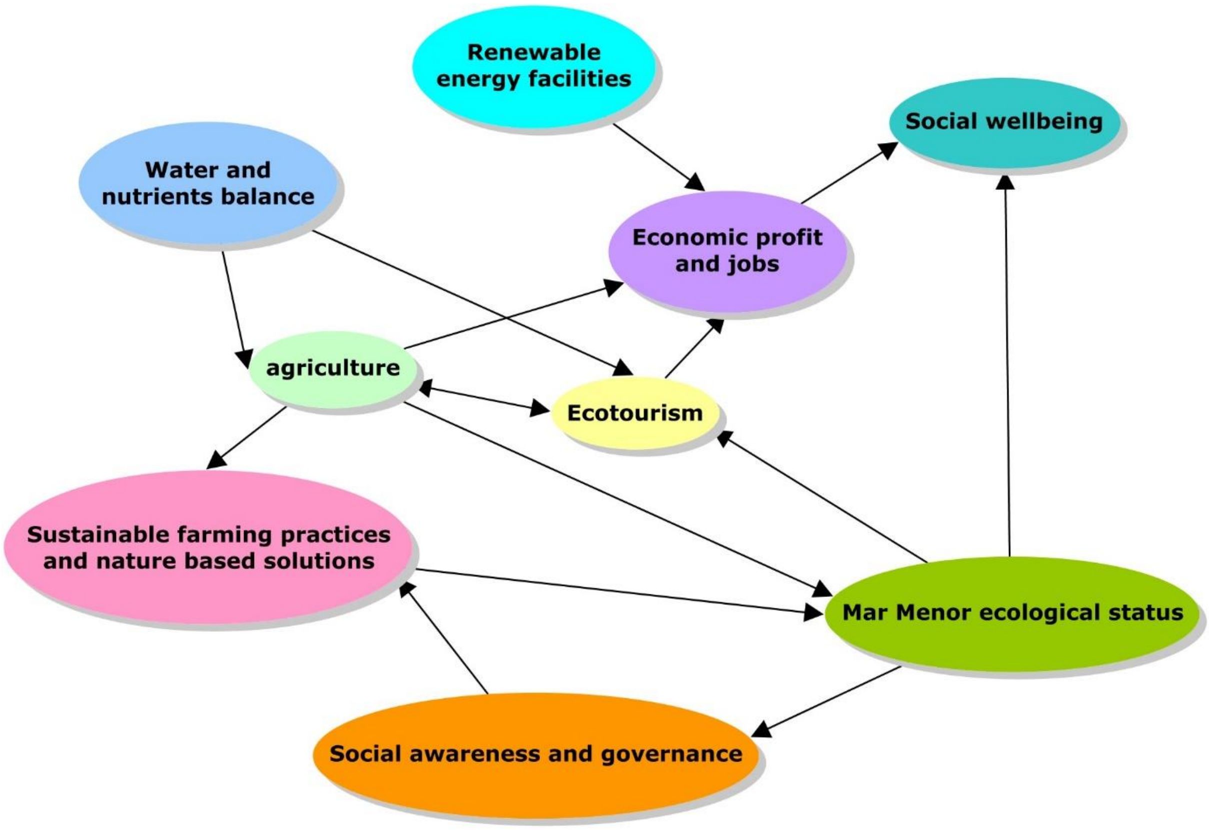


Figure 75: High level Mind Map of the MAL6 based on the stakeholder workshops.

Some typical **land-sea system interactions** for the region, identified during the sector and multi sectoral workshops were:

- Habitat degradation and biodiversity loss in the lagoon and associated wetlands around the Mar Menor lagoon due to eutrophication (nutrients and sediment from agriculture, urban areas and cattle manure, heavy metals from the old mining areas and wastewater inputs).

- Decrease in recreational opportunities for tourists and for local populations living around the Mar Menor lagoon due to poor water quality.
- Unsustainable use of low-quality groundwater resources due to an excessive growth of agricultural areas that exacerbates the export of nutrients to the Mar Menor lagoon due to brine wastes.

In *Figure 76,* we show the full Causal Loop Diagram (CLD) for MAL6. Although the complexity and size of the CLD makes the figure illegible at this scale, it is clear that directly converting the whole CLD into a corresponding system dynamics model is not feasible. So, instead of attempting to address all the problems outlined in the overall CLD in one single stock-flow model, we have identified a number of partial problem domains based on the interaction categories identified by stakeholders and listed above. In the next chapters, we define the stock-flow models that we developed for each of these problem domains. Each of the next chapters starts with the model scope and the CLD that corresponds to that model scope and then convert this information step by step into a stock-flow model structure based on system dynamics principles.

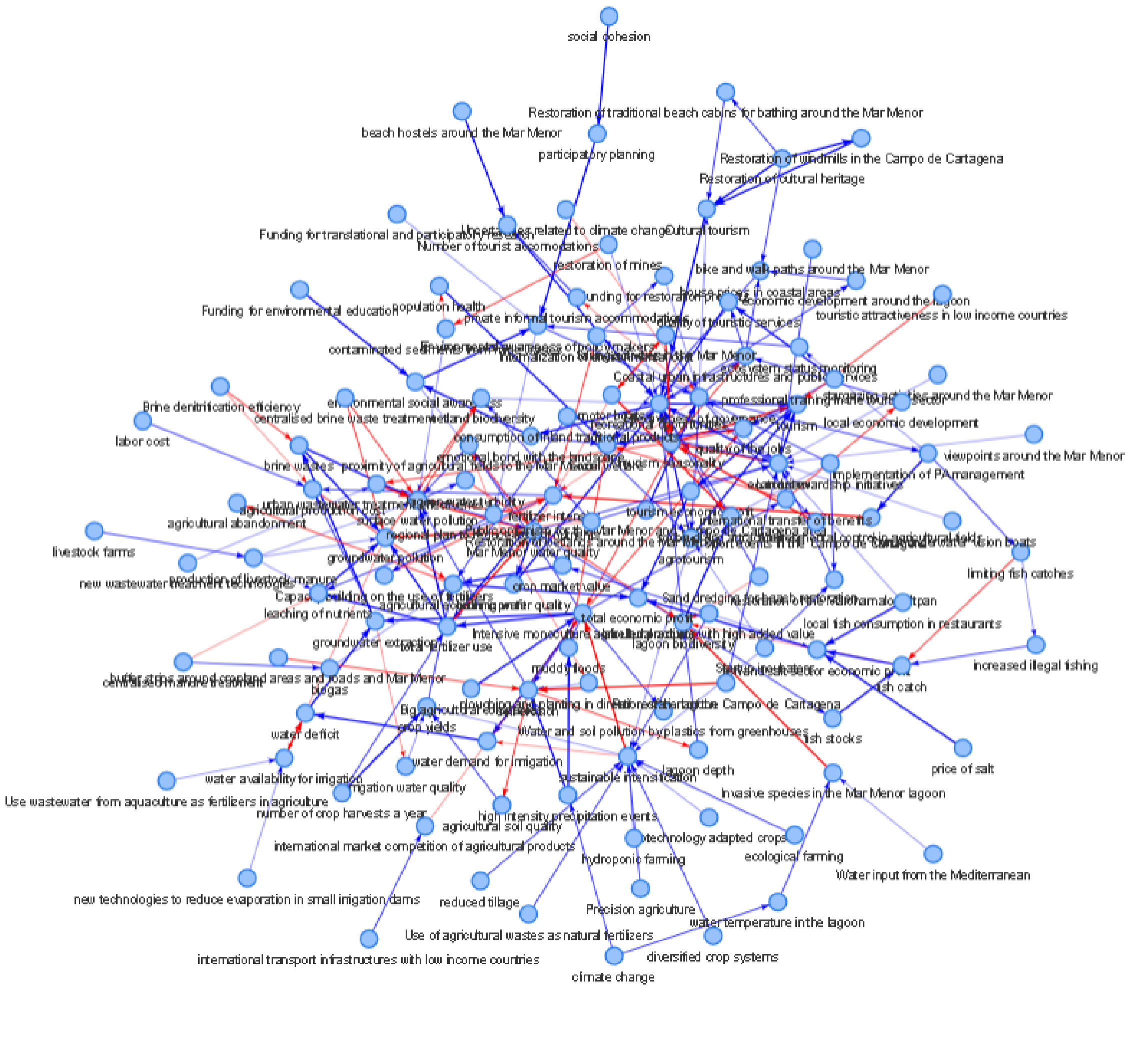


Figure 76: Full CLD reported by WP1 for MAL6. Red and blue arrows represent negative and positive relationships, respectively as were identified during stakeholder workshops.

Feedback loops are of special interest in stock-flow modelling since they can explain complex relations between variables and synergies and trade-offs between different sectors. One of the main feedback loops identified in the CLD that has driven the design of the MAL6 stock-flow model is the feedback between Mar Menor water quality, environmental awareness, effectiveness of governance and the reduction of nutrients input to the Mar Menor lagoon via effectively controlling fertilizer use by public administrations (*Figure 77*).

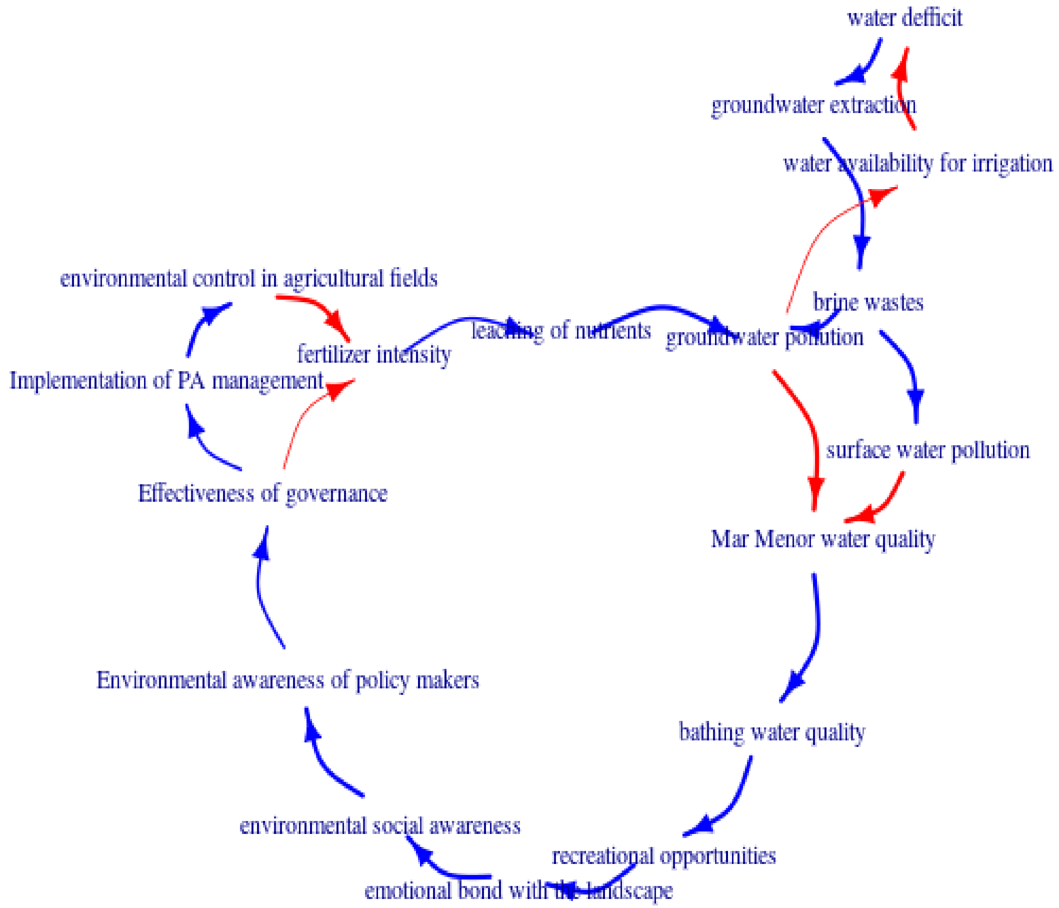


Figure 77: Excerpt from the CLD showing several loops. Red and blue arrows represent negative and positive relationships, respectively.

The CLD also shows how effectiveness of governance is a potential driver of another feedback loop based on rural-coastal interactions, since effectiveness of governance is expected to be a disincentive for intensive agricultural activity and support the promotion of inland tourism activities, such as agrotourism and ecotourism, which would enhance recreational opportunities and raise environmental awareness (*Figure 78*).

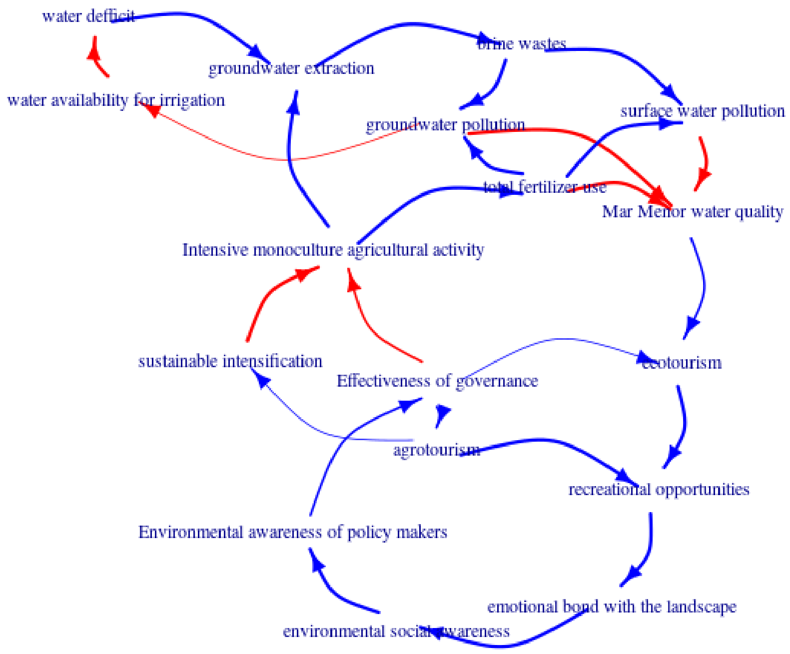


Figure 78: Excerpt from the CLD showing several loops. Red and blue arrows represent negative and positive relationships, respectively.

Moreover, a good ecological status of the Mar Menor lagoon, thereby harbouring higher biodiversity and endemic species, would have an indirect effect on social environmental awareness and effectiveness of governance, which would promote sustainable coastal recreational activities, such as scuba diving and sailing, and regulate harmful touristic activities, such as motor boats (*Figure 79*).

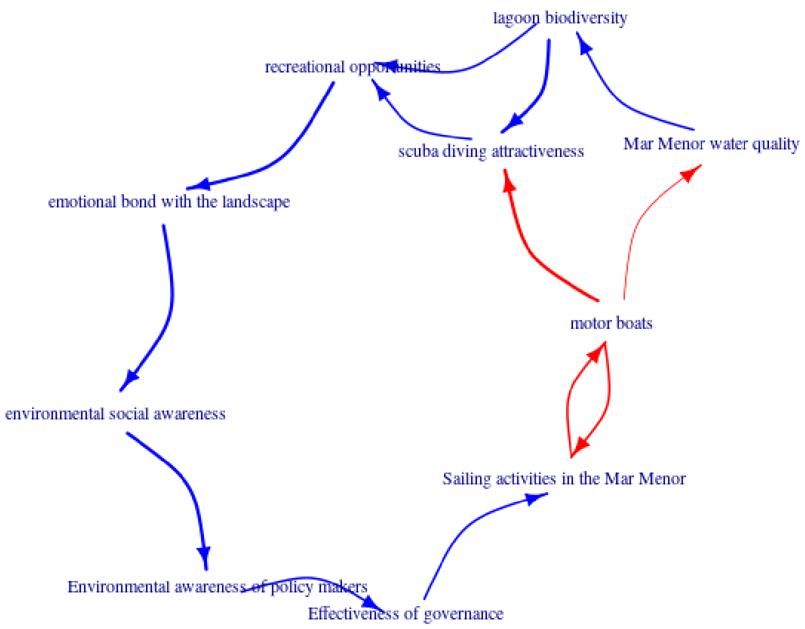


Figure 79: Excerpt from the CLD showing several loops developed during stakeholder meetings. Red and blue arrows represent negative and positive relationships, respectively.

In the next sections we present in detail how we developed the MAL6 stock-flow models of the interactions between different sectors of the Mar Menor and campo de Cartagena area based on the initial CLD developed with stakeholders during the sectoral and multisectoral workshops. All sub models presented in this report are linked and share the same model temporal and spatial boundaries: t***he Campo de Cartagena catchment linked to the Mar Menor lagoon from 1964 until 2070 on a yearly basis***. The sub models we describe in the next paragraphs are:

- Agricultural water balance
- Agricultural nutrients balance
- Sectorial development and economic profit
- Mar Menor degradation
- Coastal-rural recreation potential
- Social awareness and governance
- Sustainable land management practices

3.6.3 Sub model 1: Agricultural water balance

During the sectoral and multi-actor stakeholder workshops, no technical information was given about the agricultural water balance, but it was emphasized by all stakeholders that the water balance was central to study and understand the sustainability of the system in terms of water resources use and potential of agriculture. Given the structural water scarcity in the region, the high amount of groundwater extraction, together with the opening of the Tagus-Segura water transfer were mentioned as the main drivers of the expansion of irrigated agricultural areas.

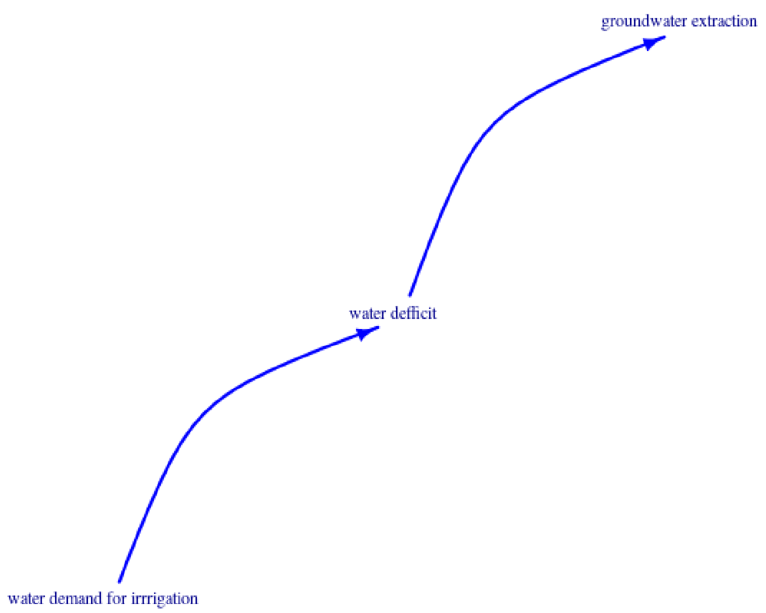


Figure 80: Excerpt from the CLD related to agricultural water balance. Blue arrows represent positive relationships.

3.6.3.1 Model scope of Agricultural water balance

This sub model characterizes the agricultural water balance in the Mar Menor catchment, which represents around 85% of the total water consumption in this area, and how the available water for irrigation determines to a large extent the potential expansion of irrigated crops. The water demand is driven by the expansion of irrigated land areas. The sub model includes some scenarios (variables in green colour) in relation to climate change and related to potential regulatory management actions proposed by the regional and national authorities and stakeholders.

3.6.3.2 Quantification of Agricultural water balance

In the stock-flow model of the agricultural water balance (*Figure 81*), we included all variables that determine water demand from agriculture and water supply from all different sources. Groundwater extraction is calculated based on water deficit. 'ATS opened' is a binary variable that becomes 1 in 1979 when Tagus-Segura (TS) water transfer was opened. The available water from TS water transfer for the Campo de Cartagena is obtained by multiplying the average total TS water transfer (330 hm3/year; Morote et al., 2017) by the fixed share of ATS water for the 'Comunidad de Regantes del Campo de Cartagena' (CRCC) of 15% (TRAGSATEC, 2019). Available water from Tagus river is constant for the historical period covered by the model in the Business as Usual scenario (BAU) but can be changed to create future scenarios of climate change based on existing literature that gives estimates for the RCP4.5 (123.3 hm3/year; Pellicer-Martínez and Martínez-Paz, 2018) and RCP8.5 (86.2 hm3/year; Pellicer-Martínez and Martínez-Paz, 2018) projections and how these change the water availability for transfer between Tajo and Segura catchments. A scenario of gradually stopping the TS water transfer until 2070 is also considered.

The available surface water for agriculture is the sum of: (1) the available water from TS water transfer, (2) other catchment water sources (11 hm3/year; TRAGSATEC, 2019), (3) the sea water desalination (by default 8.2 hm3/year; TRAGSATEC, 2019), (4) urban wastewater treatment plant effluents (29.8 hm3/year; TRAGSATEC, 2019) and eventually (5) the additional water extracted from the aquifer if the Vertido Cero (VC) Plan starts (annual water pumped by the VC). The 'VC plan' (VCOnOff) might be eventually launched by the National government and aims to extract polluted water from the aquifer, clean it from salt and nitrogen, and give it back to farmers for irrigation at an agreed price. In the sub model, when this scenario is activated, the amount of surface water available for agriculture is increased by the expected Annual water pumped by the VC (12 hm3/year; TRAGSATEC, 2019). The sea water desalination is a function of the yearly average of sea water desalination and the change in sea water desalination amount (a variable that can be changed from -1 to any positive value with zero meaning no change).

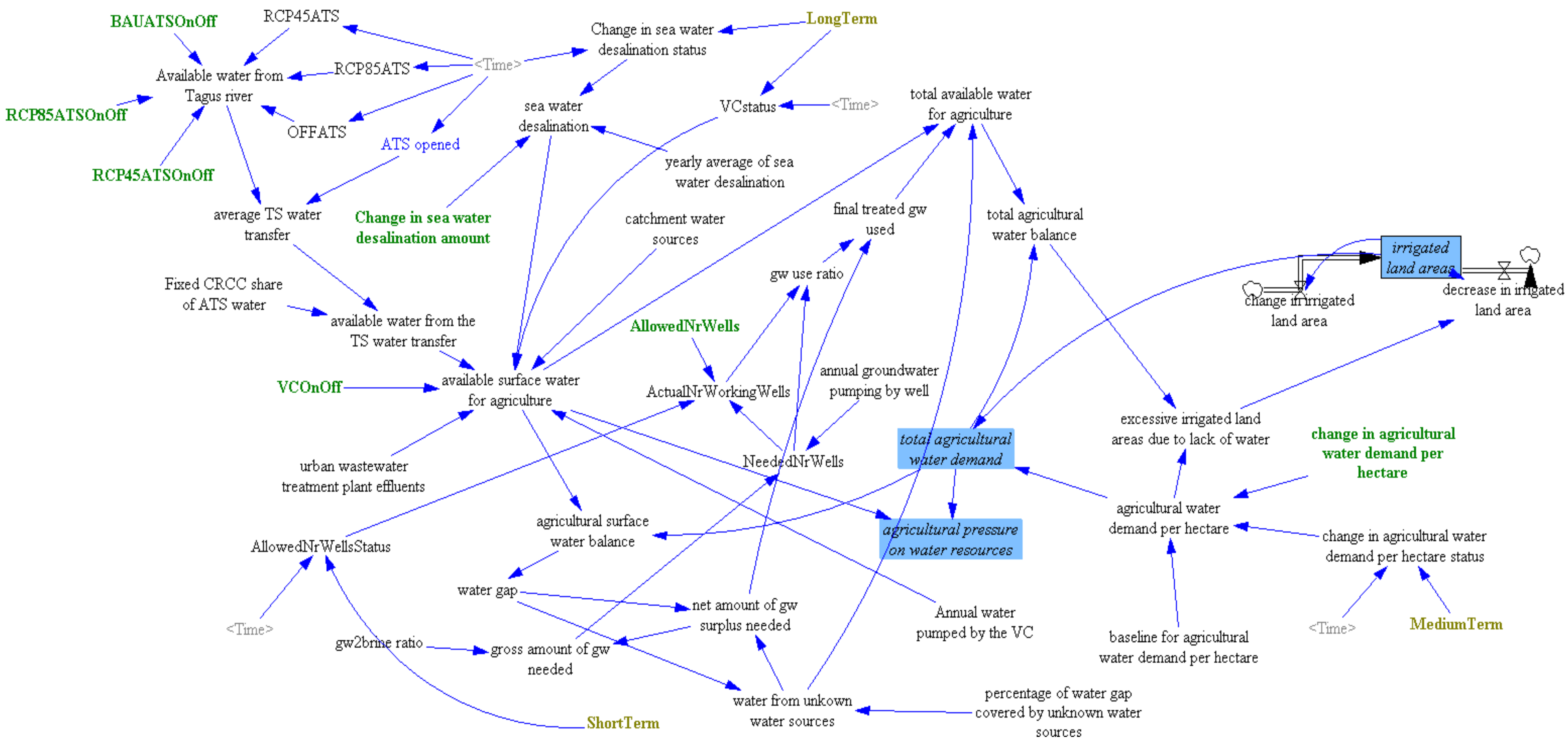


Figure 81: stock-flow model structure for the agricultural water balance sector. Green colour variables represent main scenarios. Variables with blue background represent key performance indicators.

The total agricultural water demand is calculated by multiplying the agricultural water demand per hectare by the irrigated land areas (in hectares). The agricultural water demand per hectare is a function of the baseline for agricultural water demand per hectare (0.004 hm3/ha; TRAGSATEC, 2019) and the change in agricultural water demand per hectare, which can be modified based on climate change assumptions or the implementation of less water demanding crops. Agricultural surface water balance is computed by subtracting the total agricultural water demand from the available surface water for agriculture. The water gap (in hm3) is zero if the agricultural surface water balance is positive and otherwise it corresponds to its absolute value. The net amount of groundwater (gw) surplus needed is a function of the water gap minus the water from unknown water sources. This latter variable is a function of the water gap multiplied by the percentage of water gap covered by unknown water sources (30%; Personal communication during expert interviews). The gross amount of gw needed is then computed by multiplying the net amount of gw surplus needed by 2 minus the gw2brine ratio (75% of water in groundwater excluding salt and nutrients; TRAGSATEC, 2019), in order to account for the extra water needed when considering the amount of brine present in the groundwater. The gross amount of gw needed it then used to calculate the NeededNrWells by dividing it by the annual groundwater pumping by well - the model considers an average value by wells of 0.19 hm3 per year (TRAGSATEC, 2019). The ActualNrWorkingWells corresponds to the NeededNrWells unless this is higher than the AllowedNrWells, which is then the final maximum value assigned. AllowedNrWells acts here as a scenario in which the number of allowed wells (or the corresponding allowed water pumped) can be established by regulations (by default the value is considered unlimited in the model). The gw use ratio is computed by dividing the ActualNrWorkingWells by the NeededNrWells.

Total available water for agriculture is the sum of the available surface water for agriculture, the final treated groundwater produced, and the water from unknown water sources. The final treated groundwater used is a function of the net amount of groundwater surplus needed and the groundwater use ratio. The total agricultural water balance is computed as the total available water for agriculture minus the total agricultural water demand. The agricultural pressure on water resources is a function of the available surface water for agriculture and the total agricultural water demand. It is zero if the available surface water for agriculture is higher than the total agricultural water demand and otherwise equals to the total agricultural water demand minus the available surface water for agriculture, divided by the total agricultural water demand.

The decrease in irrigated land area is a function of the excessive irrigated land areas due to lack of water and the amount of irrigated land areas. The excessive irrigated land areas due to lack of water is a function of the total agricultural water balance and the agricultural water demand per hectare.

All variables in the model that are named “status” for this or any other sub model represent binary variables that are turned on when the specific time period to which they are linked starts. These periods (LongTerm: 2030, MediumTerm: 2026 and ShortTerm: 2022) are linked to different solutions according to the timing proposed by stakeholders.

3.6.4 Sub model 2: Agricultural nutrients balance

Based on the CLD developed by the stakeholders, the most important source of nutrient inputs leading to degradation of the Mar Menor lagoon was the excessive fertilization of the irrigated agricultural areas in the Campo de Cartagena, which caused ground-and surface water pollution coming principally from fertilizers.

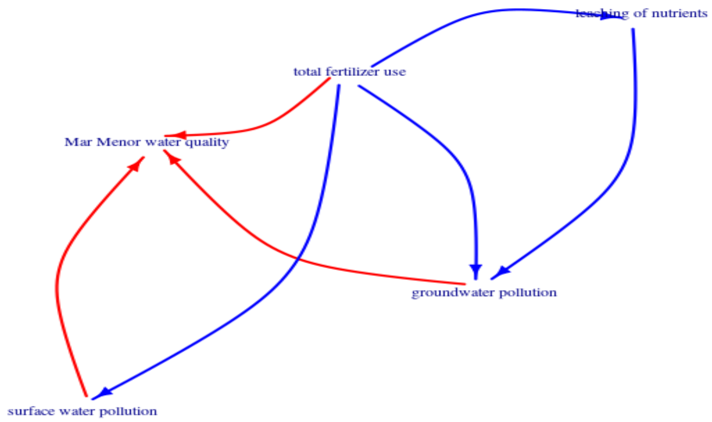


Figure 82: Excerpt from the CLD related to agricultural nutrients balance developed during stakeholder workshops. Red and blue arrows represent negative and positive relationships, respectively.

3.6.4.1 Model scope of Agricultural nutrients balance

This sub model focuses on the quantification of the nutrient's export from irrigated agricultural areas to the Mar Menor lagoon based on the amount of fertilization. It includes some scenarios (variables in green colour) in relation to some potential end-of-pipe solutions, according to the current set of proposed management actions by the regional and national authorities, and supported by some of the stakeholder groups.

3.6.4.2 Quantification of Agricultural nutrients balance

There are three main sources of agricultural nutrient inputs to the Mar Menor lagoon (*Figure 83*), i.e., nutrients contained in (1) surface water (sw) runoff (net NO3 export via sw), (2) in groundwater (estimated NO3 input to MM from Quaternary aquifer) and (3) in brine wastes (gw nitrate from brine - resulting from polluted water being pumped from the aquifer and then treated to remove excessive salts and nutrients). This sub model is primarily driven by the excessive use of fertilizers per hectare (average excess of fertilizer use) and by agricultural expansion (hectares of irrigated land areas).

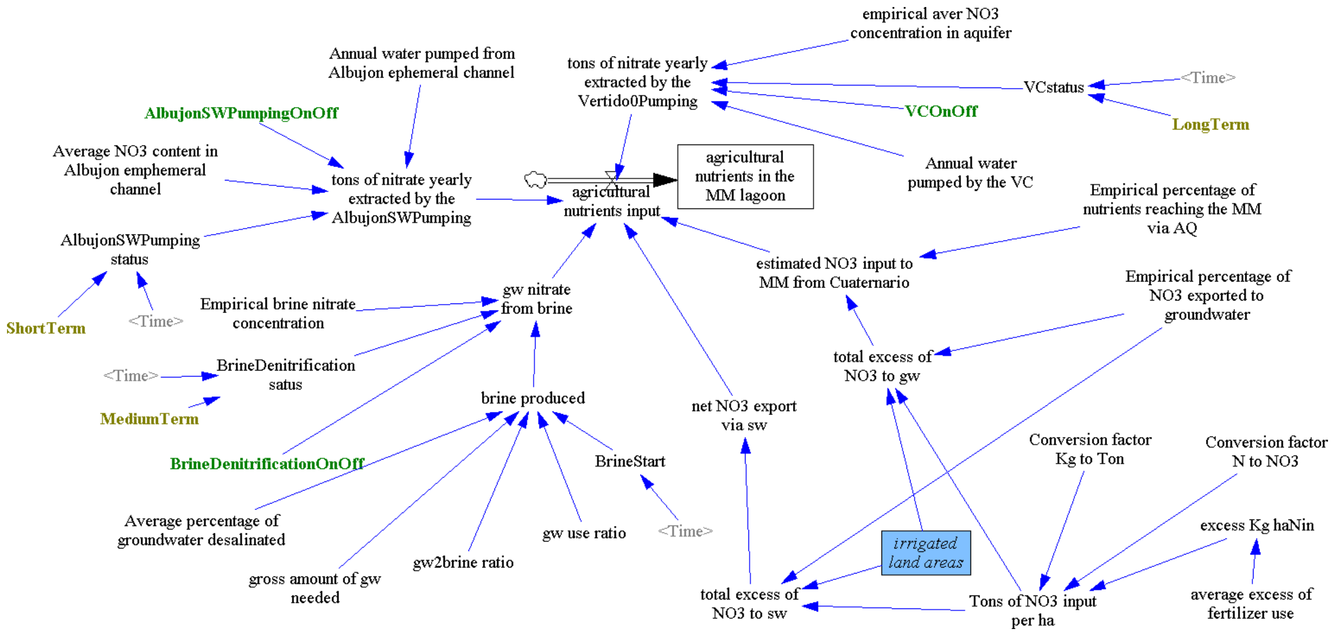


Figure 83: stock-flow model structure for the agricultural nutrients balance sector. Green colour variables represent main solution scenarios. Variables with blue background represent key performance indicators.

The average excess of fertilizer use refers to Kg/ha of Nitrogen that is not taken up by the crops (40 Kg/ha; TRAGSATEC, 2019), which is then converted into tons of nitrate (NO3) per hectare. The total excess of NO3 to gw and *sw* are calculated as a function of the tons of NO3 input per ha, the number of irrigated areas and the empirical percentage of NO3 exported to ground- and surface-water, estimated as 85% and 15% respectively (TRAGSATEC, 2019). The water and nutrient fluxes in the soil and aquifers are highly complex processes that would require a different dynamic modelling approach and significant additional field data collection. Therefore, we established an empirical percentage of nutrients reaching the MM via the aquifer (AQ) of 18% based on most recent literature data reporting on measured fluxes from the aquifer to the MM (TRAGSATEC, 2019). This percentage is then multiplied by the total excess of NO3 to gw and gives the estimated NO3 input to MM from the Quaternary aquifer. For the surface water nutrients export, another variable is included, the net NO3 export via sw, as a function of the total excess of NO3 to sw reduced by the effect of sustainable land management practices that could be implemented as a scenario. This scenario is however not indicated in this sub model but explained in the section corresponding to sub model 7.

Since the aquifer is polluted with nutrients, when groundwater is pumped to be used for irrigation around 50% of it is filtered to exclude salts and nutrients (average percentage of groundwater desalinated) starting in 1995 (BrineStart personal communication during expert interviews), thereby producing brine, which is discarded by farmers and in the absence of an operational recollection or denitrification system, drained to the lagoon. The variable ‘gw nitrate from brine’ corresponds to the tons of nitrate produced and exported to the lagoon and is calculated as a function of the brine produced, the empirical brine nitrate concentration (199.35 tons/hm3; Álvarez-Rogel et al., 2020) and the BrineDenitrificationOnOff scenario. The effect of a brine denitrification technology being currently developed is therefore included in the model as a scenario (BrineDenitrificationOnOff) that would avoid the export of these brine wastes to the lagoon. The brine produced is calculated as a function of the average percentage of groundwater desalinated, the gross amount of gw needed, the gw use ratio and the gw2brine ratio (explained in sub model 1).

The Vertido Cero Plan (VCOnOff), as explained in the previous section, is based on extracting water from the aquifer in order to reuse the water, once denitrified, and is also expected to decrease the nutrient inputs from the aquifer to the lagoon directly (via groundwater flux) or indirectly (via superficial base flow coming from the aquifer). The 'tons of nitrate yearly extracted by the Vertido0Pumping' refer to the amount of nutrients that would not reach the Mar Menor once the infrastructure would start working based on the annual water pumped by the VC (see sub model 1) and the empirical average NO3 concentration measured in the aquifer (180 t/hm3; TRAGSATEC, 2019). The surface water pumping from the Albujón ephemeral river (AlbujonSWPumpingOnOff) is considered in the model as another of the planned initiatives. The tons of nitrate yearly extracted by the AlbujonSWPumping are computed as a function of the annual water pumped from Albujón ephemeral channel (2 hm3; CHS, 2019) and the average NO3 content in Albujón emphemeral channel (175 tons/hm3; TRAGSATEC, 2019).

Agricultural nutrients input to the lagoon is finally computed as the sum of the estimated NO3 input to MM from Quaternary aquifer, the gw nitrate from brine, and the net NO3 export via sw minus the tons of nitrate yearly extracted by the Vertido0Pumping and the tons of nitrate yearly extracted by the AlbujonSWPumping. The nutrients in the MM lagoon are then accumulated and will be related to the degradation status of the lagoon, as explained in the section corresponding to sub model 4.

3.6.5 Sub model 3: Sectorial development and economic profit

As Figure 84 extracted from the CLD, shows, the discussions during the workshops pointed out that most of the economic profit in the study area depended on the development of the agricultural and tourist sectors and partially also on the fisheries and salt pans sector. However, it was also suggested that promoting different economic sectors, including the renewable energy sector, could increase or maintain the total economic profit and help create new jobs, and support sustainable development.

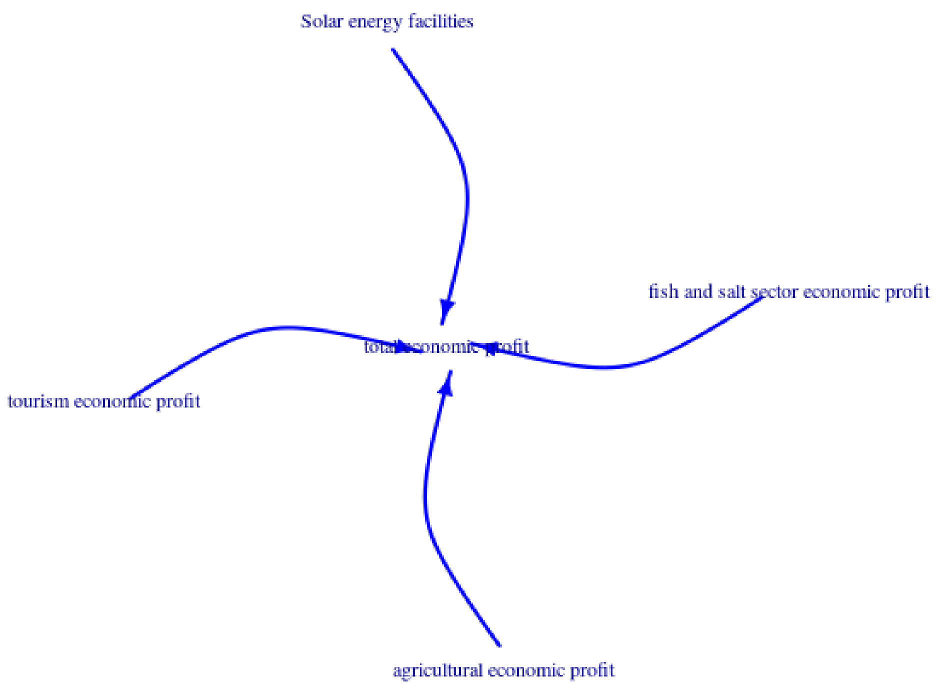


Figure 84: Excerpt from the CLD related to sectorial development and economic profit. Red and blue arrows represent negative and positive relationships, respectively.

3.6.5.1 Model scope of Sectorial development and economic profi*t*

This sub model aims to reproduce and predict the development of the three main sectors mentioned during the workshops, i.e., agriculture, tourism and solar photovoltaic facilities, in the study area. The model includes the development of each sector together with the number of jobs created and its economic profit. The development of the fisheries and the saltpan sector in the Mar Menor lagoon are not taken into account because, given its small scale, it does not contribute significantly to the total economic benefit in the study area. The next subsection presents the development of each sector individually.

3.6.5.2 Quantification of Sectorial development and economic profit

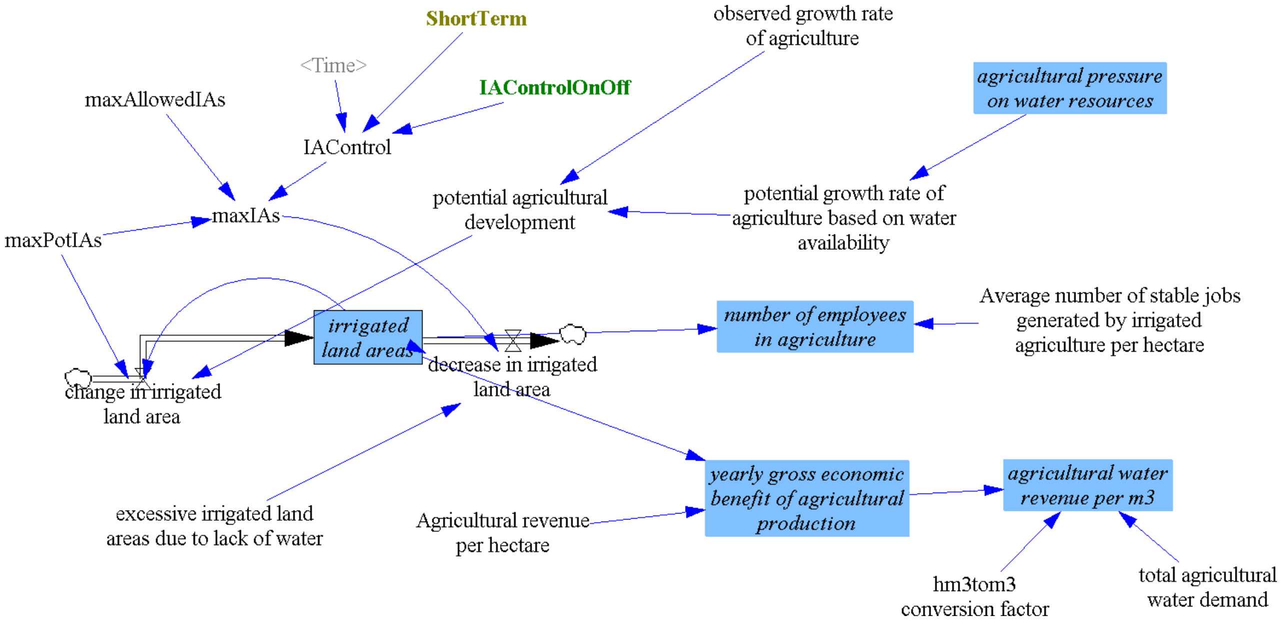


Figure 85: stock-flow model structure related to agricultural development. Variables with blue background represent relevant indicators.

In relation to agricultural development (*Figure 85*), the change in irrigated land area is a function of the existing irrigated land areas and the potential agricultural development, which is driven by the potential growth rate of agriculture based on water availability (a function of the agricultural pressure on water resources and the observed growth rate of agriculture based on its historical observed growth rate (7%; Carreño et al., 2015)). The agricultural pressure on water resources does not account for groundwater that could be used to decrease the water scarcity because the main driver of the agricultural expansion is indeed the Tagus-Segura water transfer. Groundwater has been historically very limited and its current availability is only due to the high recharge rates by irrigation effluents. The model imposes a limit of 90,000 hectares to the irrigated land areas (maxPotIAs) based on spatial constraints of the geographical area (CARM, 2017). Besides, the model can further limit the amount of irrigated land areas (IAControlOnOff) down to the current area with legal access to water sources (maxAllowedIAs = 41,562 ha; CARM, 2017). The number of irrigated land areas is a function of the change in irrigated land area and the decrease in irrigated land area, with an initial value of 4,366 has in 1964 (López Ortiz, 1999). The decrease in irrigated land area is a function of an eventual policy-imposed limitation in irrigated areas, previously mentioned, and an excess in irrigated land areas due to lack of water (see sub model 1).

The number of employees in agriculture is based on the extent of irrigated land areas and the average number of stable jobs generated by irrigated agriculture per hectare (0.5 employees per hectare; CHS, 2015). On the other hand, the yearly gross economic benefit of the irrigated agricultural production is a function of the agricultural gross revenue per hectare (7,885 EUR/ha; CHS, 2020) and the extent of irrigated land areas. An agricultural water revenue per m3 is also calculated as a function of the yearly gross economic benefit of agricultural production and the total agricultural water demand.

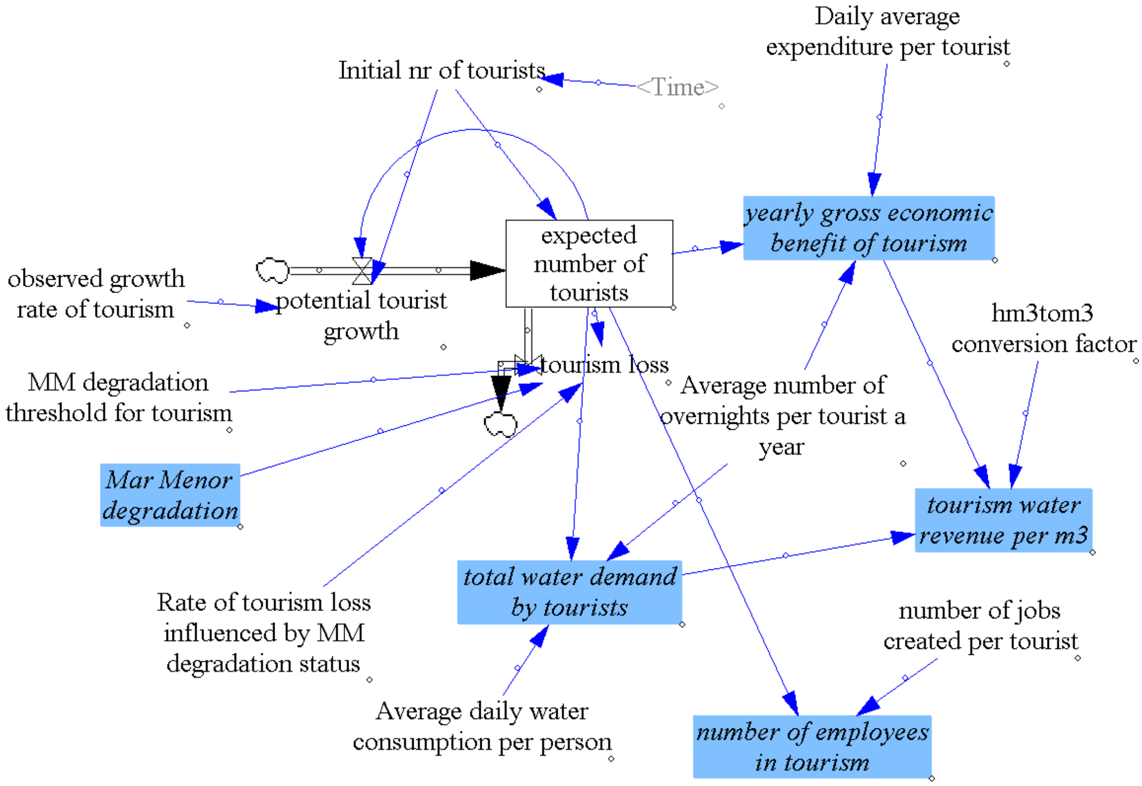


Figure 86: stock-flow model structure related to tourism development.

In relation to tourism development (*Figure 86*), the yearly gross economic benefit of tourism depends on the expected number of tourists, the daily average expenditure per tourist (57 EUR/tourist*day; Arroyo Mompeán and Vegas Juez, 2019), and the average number of overnights per tourist per year (9.7 days/year; Arroyo Mompeán, 2018). The expected number of tourists increases as a function of the initial number of tourists (2 million in 1999; ECONET, 2020a) and the potential tourist growth and decreases based on the tourism loss. The potential tourist growth depends on the observed growth rate of tourism over the past years (3% per year in 2000-2019; ECONET, 2020a), the initial number of tourists and the current expected number of tourists. The tourism loss is a function of the expected number of tourists, the Mar Menor degradation, the Mar Menor degradation threshold for tourism (0.95 Dmnl; ECONET, 2020a), and the rate of tourism loss influenced by MM degradation status (1.5% per year; ECONET, 2020a). The number of employees in tourism is calculated based on the expected number of tourists and the number of jobs created per tourist (1 job every 85 tourists; ECONET, 2020a). The model also calculates the tourism water revenue per m^3, which is a function of the yearly gross economic benefit of tourism and the total water demand by tourists. The total water demand by tourists is calculated based on the Average daily water consumption per person (2×10^{-7} hm^3/tourist; Ayuntamiento de Torre Pacheco, 2019), the expected number of tourists, and the average number of overnights per tourist a year.

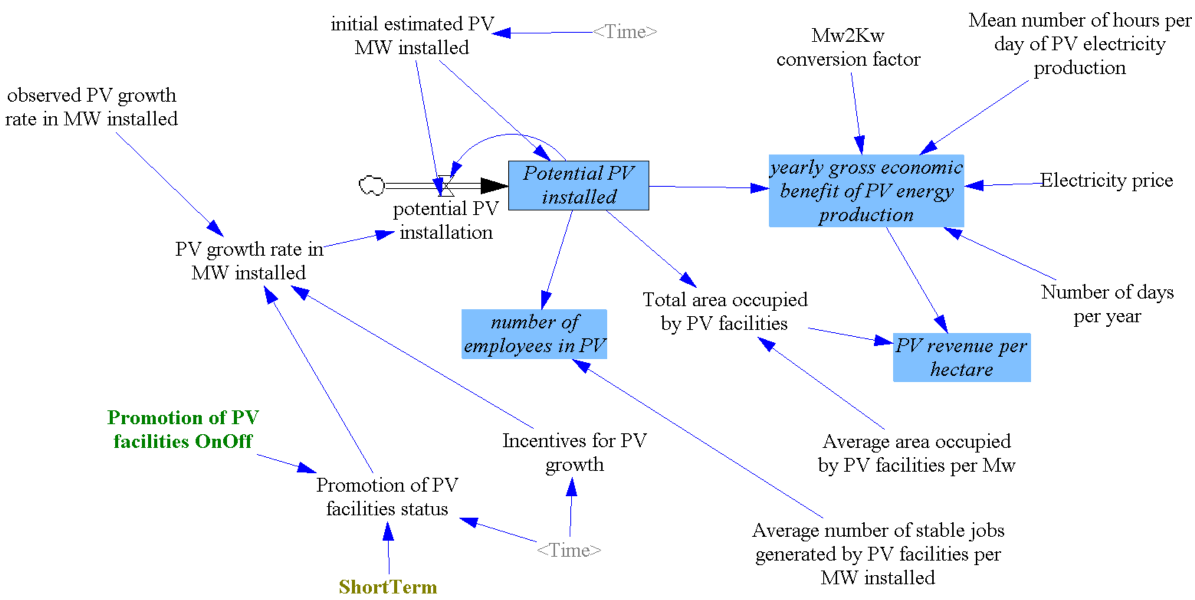


Figure 87: stock-flow model structure related to renewable energy development.

In relation to the development of photovoltaic energy facilities (*Figure 87*), the potential PV installed refers to the total power capacity of solar photovoltaic energy installed measured in Megawatts and it is a function of the initial estimated PV MW installed in the Campo de Cartagena (224 Mw in 2019; ECONET, 2020b) and the potential PV installation. The potential PV installation depends on the initial estimated PV MW installed, the potential PV installed, and the PV growth rate in MW installed, which depends on the observed PV growth rate in MW installed (1.6% per year; ECONET, 2020b), the incentives for PV growth (additional growth of 5.4% per year starting in 2021 and ending in 2050; APPA, 2018), and the promotion of PV facilities status, which is activated by a scenario (Promotion of PV facilities OnOff) at a specific time (ShortTerm). The number of employees in PV depends on the potential PV installed and the average number of stable jobs generated by PV facilities per MW installed (3 jobs/Mw; APPA, 2018). The yearly gross economic benefit of PV energy production is a function of the potential PV installed, the electricity price (0.05 EUR/Kw*hour; APPA, 2018), the average number of hours per day of PV electricity production (5 hours/day; APPA, 2018) and the number of days per year (365 days). The model computes the PV gross revenue per hectare based on the yearly gross economic benefit of PV energy production and the total area occupied by PV facilities, which is a function of the potential PV installed and the average area occupied by PV facilities per Mw (2 ha/Mw; personal communication expert interviews).

3.6.6 Sub model 4: Mar Menor degradation

Figure 88 shows the main drivers of the degradation of the Mar Menor lagoon based on the CLD developed during the stakeholder workshops, being most of them related to the input of fertilizers to the lagoon via surface- or ground-water sources. No specific mechanism was described during the workshops that could explain in detail the ecological processes within the lagoon that led to the collapse that the lagoon started suffering in 2016. However, the scientific knowledge clearly points at eutrophication episodes caused by long term agricultural export of fertilizers as main driver of the environmental degradation.

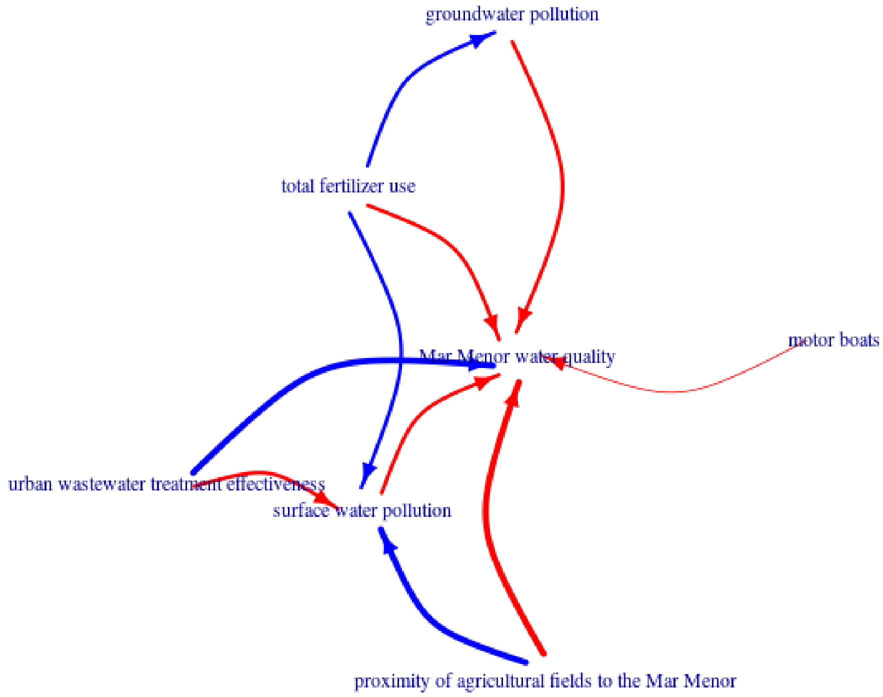


Figure 88: Excerpt from the CLD related to the Mar Menor degradation developed during stakeholder meetings. Red and blue arrows represent negative and positive relationships, respectively.

3.6.6.1 Model scope of Mar Menor degradation

Based on the CLD and the limited scientific knowledge about the process of ecosystem collapse in the lagoon, this sub model aims to exemplify the degradation of the Mar Menor lagoon linked to the long-term non-point-source inputs of nutrients observed and modelled in the Agricultural nutrients balance sector and other point-source pollution sources.

3.6.6.2 Quantification of Mar Menor degradation

One of the main challenges was to quantify degradation of the Mar Menor lagoon over time (*Figure 89*) since it went through a rapid and recurrent ecological collapse starting in 2016. The amount and complexity of ecological processes occurring at different scales and realms within the lagoon made it impractical to develop an accurate model of ecological processes within the lagoon. Therefore, we had to simplify the model equations and calibrate the model outputs based on observed patterns and identify the most important causes and drivers.

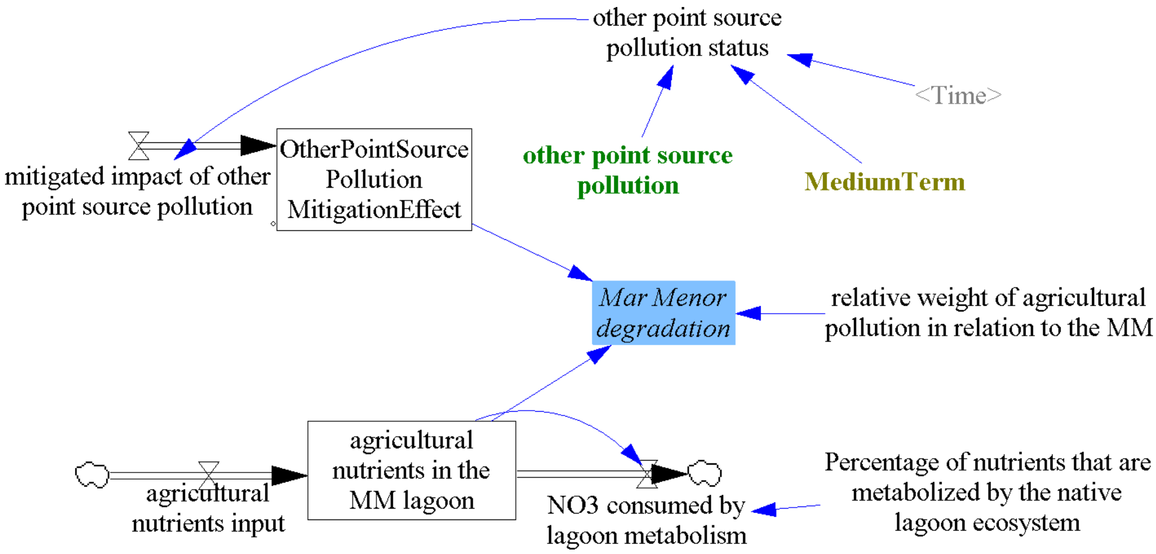


Figure 89: stock-flow model structure for the Mar Menor degradation sector.

The Mar Menor degradation is a function of the input from agricultural nutrients and other point-sources towards the MM lagoon. Other point-source pollution sources are measured in relative terms, from 0 to 1 and are assumed to be constant with a value of 1 at least until 2026 (MediumTerm), when a scenario of pollution reduction can be activated. This reduction in point-source pollution would increase the mitigated impact (1 - other point source pollution status), which would slowly increase the mitigation effect that is zero by default (when other point source pollution is equal to one). Based on stakeholders and expert opinion, the model considers that the maximum amount of point source pollution is the historical and current one and does not account for a potential increase in point source pollution.

The contribution of agricultural pollution sources in the Mar Menor degradation is reflected in a relative weight of agricultural pollution in relation to the MM (versus other point source pollution) of 85% (Guaita-García et al., 2020). The agricultural nutrients in the Mar Menor lagoon are accumulated over time and are calculated as the difference between the agricultural nutrients input (explained in the section corresponding to sub model 2) and the NO_3 consumed by lagoon metabolism, which is a function of the agricultural nutrients in the Mar Menor lagoon and the percentage of nutrients that are metabolized by the native lagoon ecosystem (20% of the total nutrients accumulated; Comité de Asesoramiento Científico del Mar Menor, 2017). The Mar Menor degradation goes from 0 to 1, from undegraded to degraded status and is calculated using an exponential function to match the observed degradation status over time.

3.6.7 Sub model 5: Coastal-rural recreation potential

The importance of decreasing tourism seasonality by increasing inland and coastal recreation potential in the study area was pointed out in the workshops and included in the CLD (*Figure 90* and *Figure 91*) as one of the main solutions to promote the local economy and move towards more sustainable business solutions, making the region economically less dependent on intensive agriculture. Stakeholders pointed out a strong need to foster development of agritourism (sustainable agriculture) and ecotourism (educational and sports activities with low environmental impact, such as fishing tourism and diving/snorkelling). To support these ideas, stakeholders considered important to promote quality brands (labelling) of local products from agriculture, as well as short marketing channels (consumption of local products), thereby creating synergies between agriculture and tourism. They also proposed promoting tourism related to nautical activities without motors as the main priority: e.g., sailing (especially sailing adapted for disabled people) and rowing, taking advantage of the exclusive conditions for practicing sports throughout the year in a semi-enclosed lagoon protected from high waves. They also highlighted the need to exemplify good agricultural practices in demonstration farms, fairs and eco-markets, as well as to promote gastronomic tourism based on local agricultural products. This combination of initiatives would improve the quality of the services sector and increase environmental awareness while promoting a transition towards more sustainable tourism and agriculture sectors because they would both benefit from a good environmental status and synergistic development.

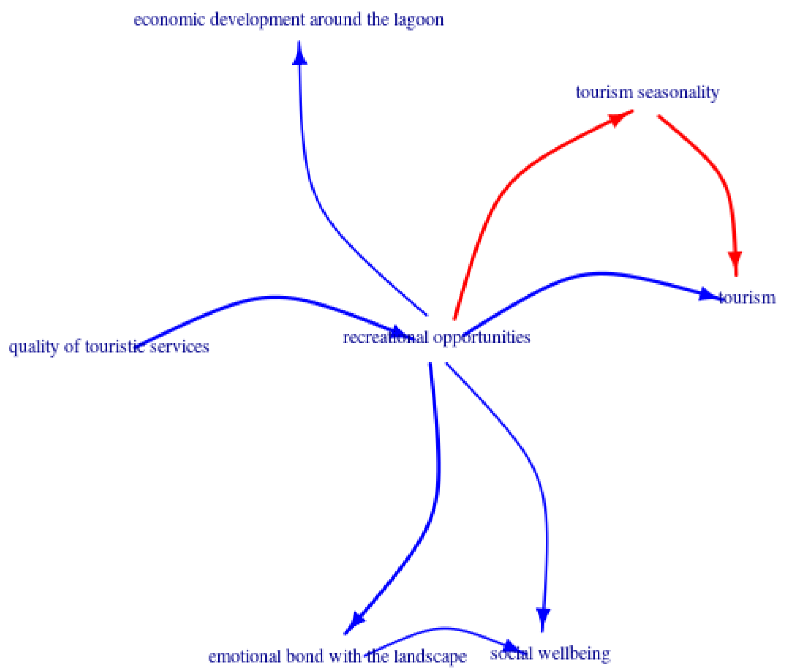


Figure 90: Excerpt from the CLD related to coastal-rural recreation potential outgoing variables developed during stakeholder meetings. Red and blue arrows represent negative and positive relationships, respectively.

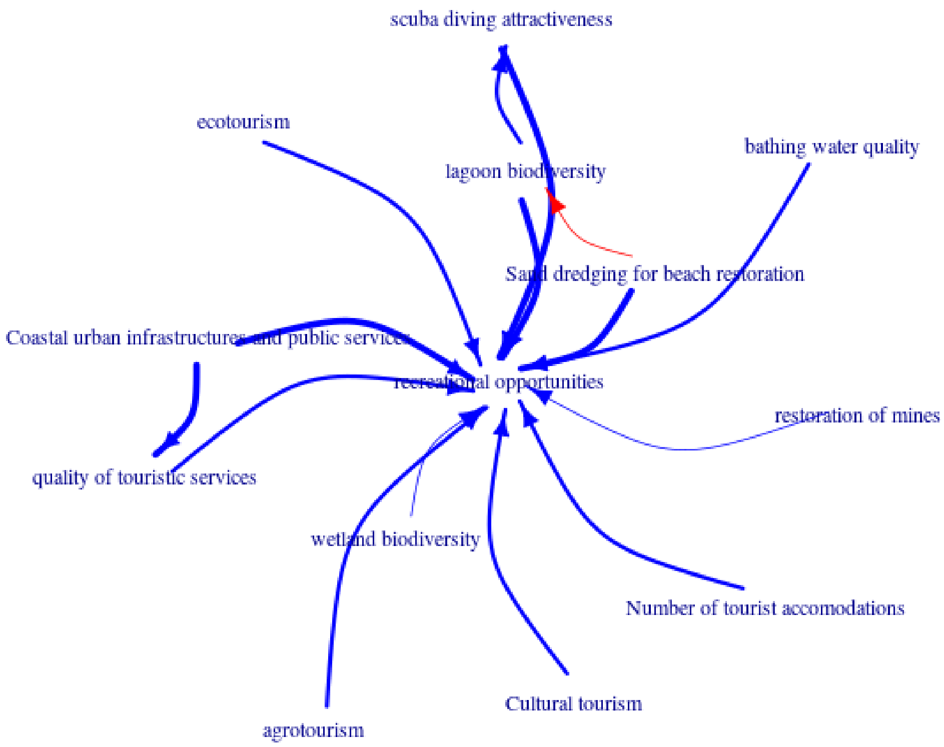


Figure 91: Excerpt from the CLD related to coastal-rural recreation potential incoming variables developed during stakeholder meetings. Red and blue arrows represent negative and positive relationships, respectively.

3.6.7.1 *Model scope of coastal-rural recreation potential*

In this sub model, we assess the influence of the degradation of the Mar Menor on the coastal recreation potential, as well as the effect of increasing the rural and coastal recreation potential on the tourist growth through the promotion of coastal and rural ecotourism activities.

3.6.7.2 *Quantification of coastal-rural recreation potential*

The potential tourism growth variable (*Figure 92*), primarily depending on the observed growth of tourism, as explained in sub model 3, also accounts for the coastal-rural recreation potential, which is the average of the coastal and rural recreation potential. The rural and coastal ecotourism activities variables represent scenarios, going from 0 to 1 and defaulting in 0, that reflect the increase in the number of rural and coastal ecotourism activities. Both scenario variables affect the impact of coastal or rural ecotourism, which is then slowly increasing the coastal or rural ecotourism effect (CoastalEcoEffect and RuralEcoEffect), ultimately affecting the coastal or rural recreation potential. The coastal recreation potential is a function of the CoastalEcoEffect and the Mar Menor degradation, whereas the rural recreation potential is a function of the RuralEcoEffect and the coastal recreation potential, highlighting an important synergy between coastal and rural areas. Based on stakeholders and expert opinion, the rural recreation potential can be first promoted by attracting tourists from the coastal area.

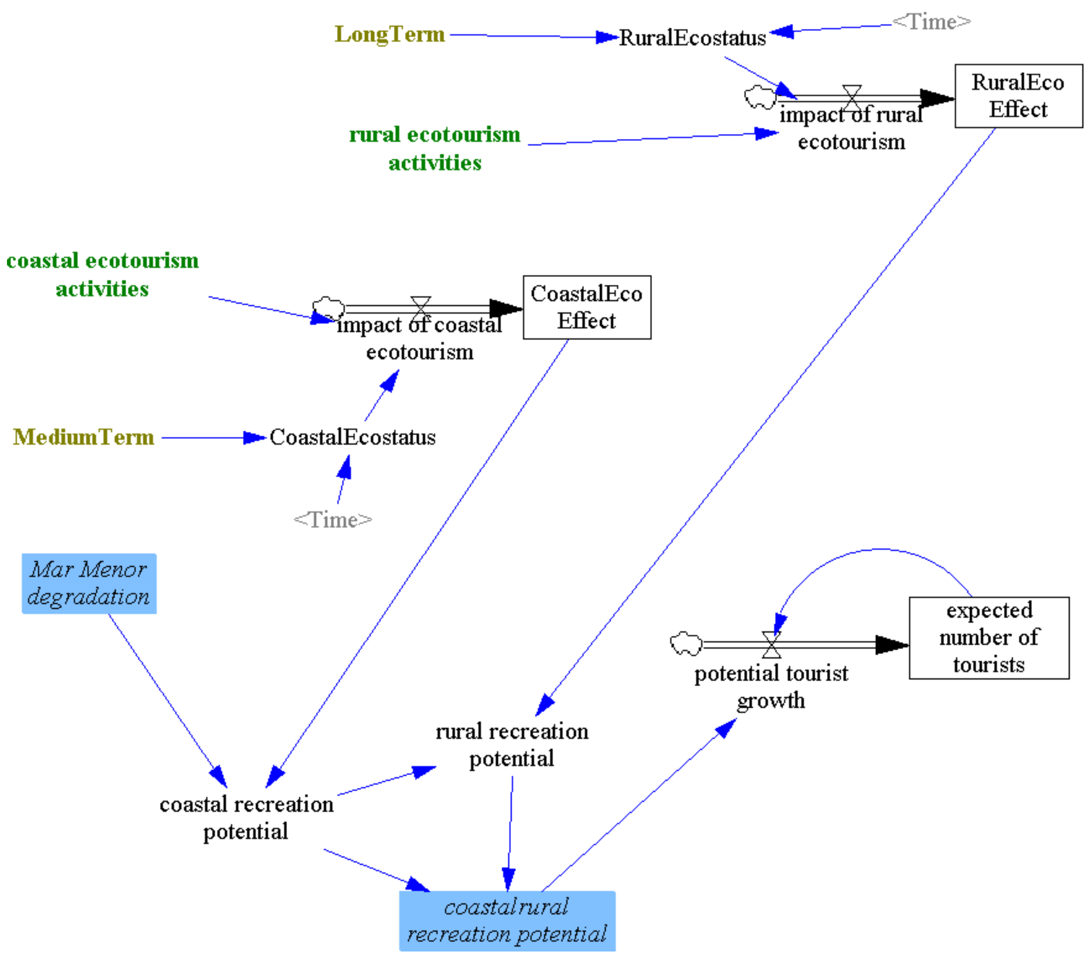


Figure 92: stock-flow model structure for the coastal-rural recreation potential sub model.

3.6.8 Sub model 6: Social awareness and governance

During the workshops, environmental education, social awareness, territorial bonding and participatory governance were pointed out to be crucial in order to overcome the current ecological crisis while promoting sustainable economic development. *Figure 93* and *Figure 94* show examples from the CLD developed during stakeholder workshops in which those variables play an important role. More specifically, stakeholders considered crucial to increasing the public awareness of the environmental and economic value of the lagoon through the promotion of participatory workshops on environmental topics, including environmental values of the territory, to explain the ecosystem services of the lagoon in the entire Murcia Region, Mar Menor and Campo de Cartagena catchment, since most tourists in the Mar Menor are from the Region of Murcia. To further support implementation and a more effective management, they proposed creating a specific coordinating body for the Mar Menor and its catchment area, formed mainly by public administration, but closely collaborating with other stakeholders through participatory governance. They suggested promoting integrated planning in the medium and long term by collaboration between public administration. These initiatives could favour that the population remains in the territory and could promote the regeneration of the Mar Menor ecosystem by means of providing resources and financing studies to improve the water quality levels, as well as to avoid contamination by nutrients runoff from the catchment.

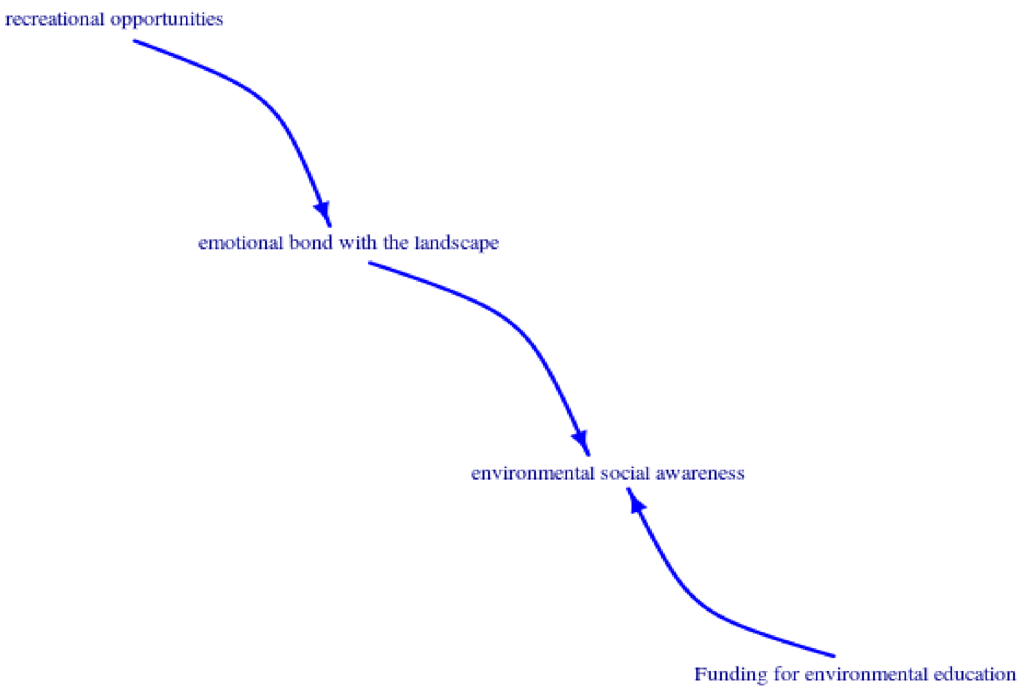


Figure 93: Excerpt from the CLD related to the promotion of social awareness and governance developed during stakeholder workshops. Red and blue arrows represent negative and positive relationships, respectively.

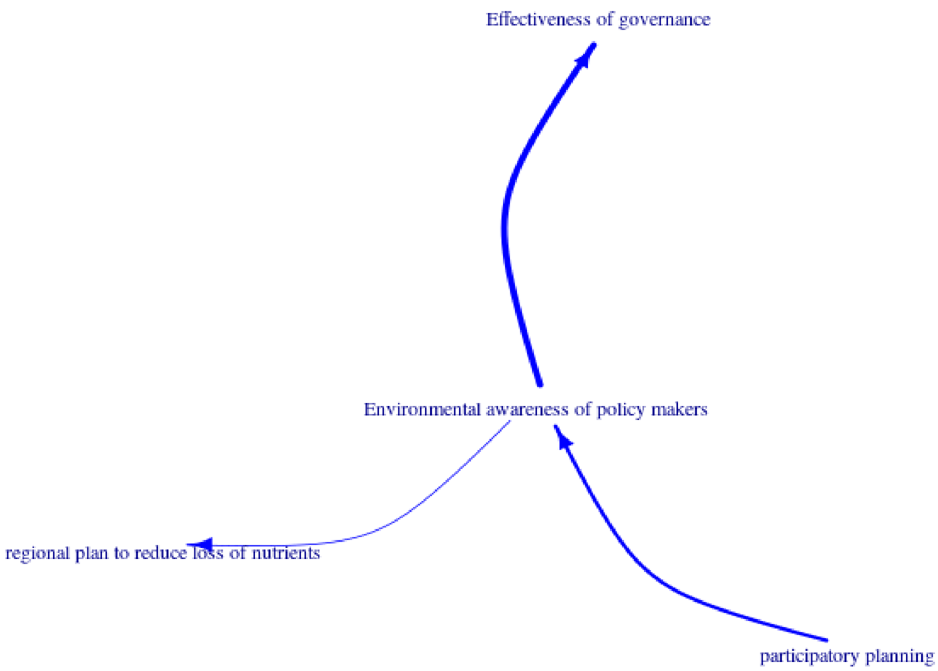


Figure 94: Excerpt from the CLD related to the effects of social awareness and governance developed during stakeholder workshops. Red and blue arrows represent negative and positive relationships, respectively.

3.6.8.1 Model scope Social awareness and governance

Given the importance that stakeholders attributed to territorial bonding and environmental education, this sub model includes the effect of environmental education on social and governance feedback mechanisms in relation to the regulation and development of the agricultural sector.

3.6.8.1.1 Quantification Social awareness and governance

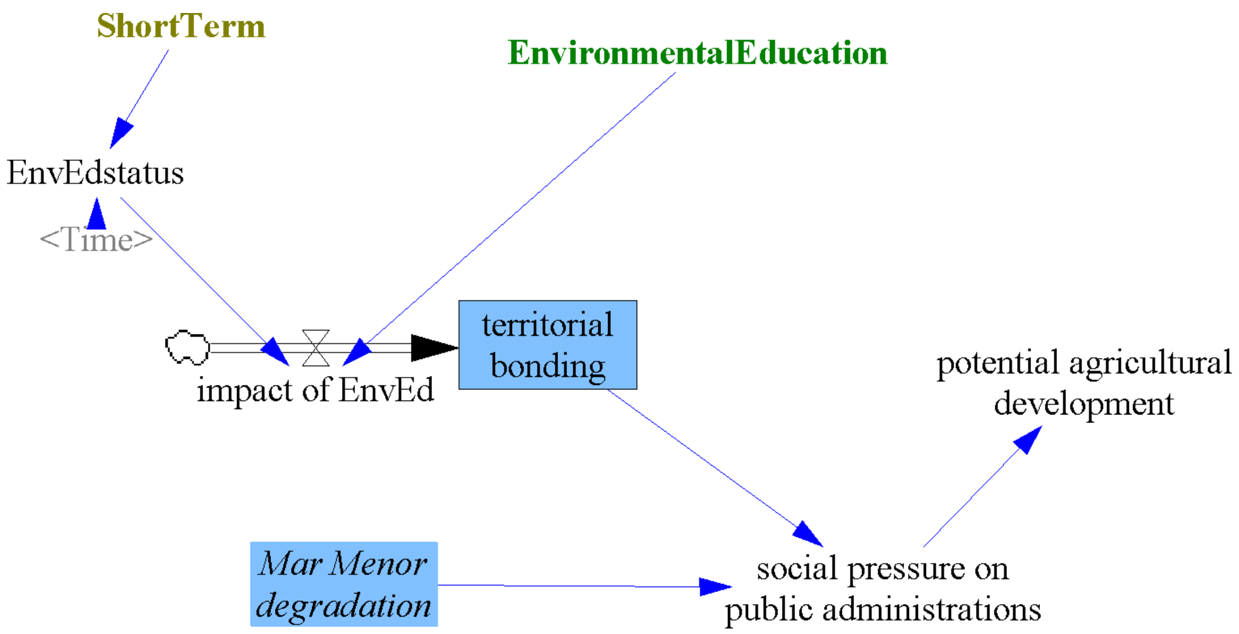


Figure 95: stock-flow model structure for the social awareness and governance sub model. Green colour variables represent main solution scenarios. Blue boxes represent key performance indicators

The potential agricultural development variable (*Figure 95*), explained in sub model 3, can also be negatively affected by the social pressure on public administrations, which is a function of the Mar Menor lagoon degradation and the territorial bonding. Environmental education is a scenario variable that goes from 0 to 1, defaulting in 0, and can be increased when the number of environmental education activities increases. This variable slowly affects territorial bonding by means of the impact of environmental education variable ("impact of EnvEd").

3.6.9 Sub model 7: Sustainable land management practices

Sustainable land management (SLM) practices in agriculture, such as a decrease in the use of fertilizers, or their retention through buffer strips and establishing green covers or crop diversification, can have several beneficial effects on agricultural production and the environment, as can be seen in *Figure 96* based on the CLD.

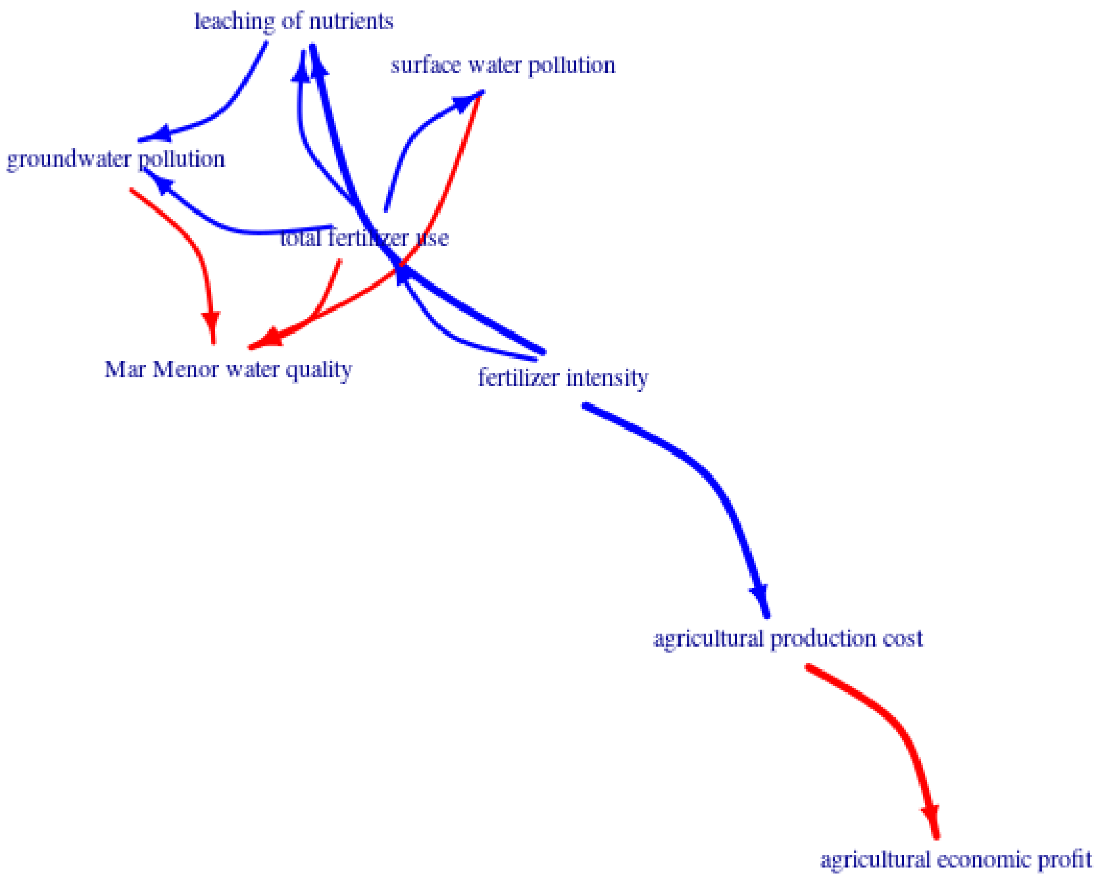


Figure 96: Excerpt from the CLD related to sustainable land management practices developed during the stakeholder workshops. Red and blue arrows represent negative and positive relationships, respectively.

3.6.9.1 Model scope Sustainable land management practices

In this sub model, we have quantified the benefits of implementing two SLM practices in our case study, such as the decrease in the application of fertilizers and the implementation of nutrient soil and water retention measures (e.g., vegetation buffers around agricultural fields or cover crops).

3.6.9.2 Quantification Sustainable land management practices

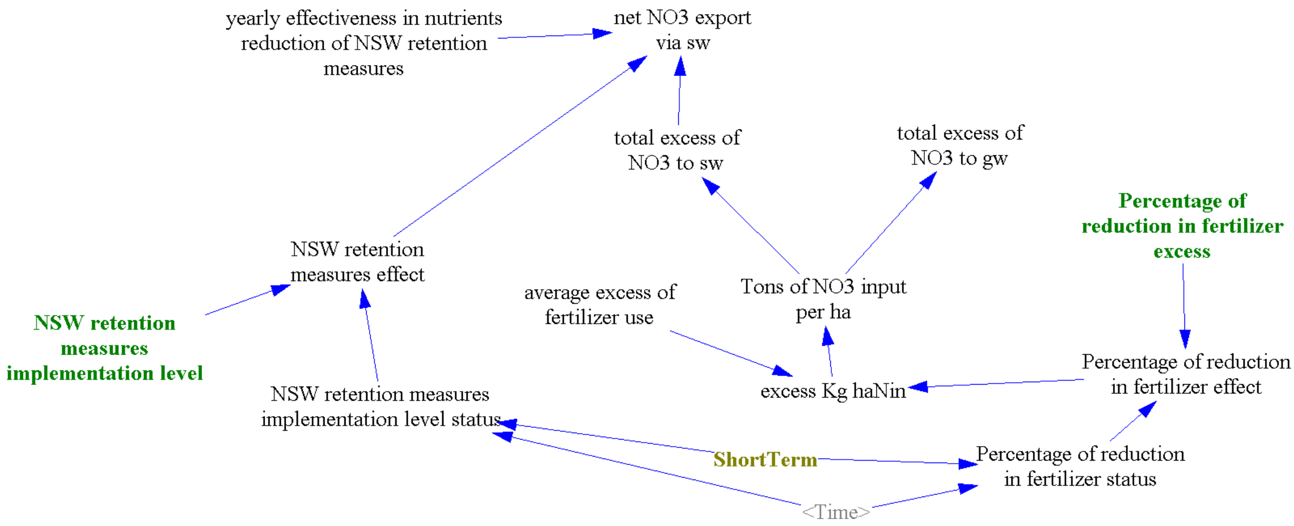


Figure 97: stock-flow model structure for the sustainable land management practices sub model. Green colour variables represent main scenarios.

The model variable 'excess Kg haNin' (*Figure 97*), explained as part of sub model 2, is influenced by the average excess of fertilizer use (Kg/ha of Nitrogen input) and weighted by a short-term scenario based on the percentage of reduction in fertilizer excess. This scenario influences the input of nutrients via surface- and groundwater. On the other hand, in relation to surface water nutrients input, the implementation of nutrients, soil and water retention measures is also included as a scenario (NSW retention measures implementation level; from 0 to 1, ranging from a scenario with no retention measures to a complete implementation), which affects the net NO3 export via sw by means of the yearly effectiveness in nutrients reduction of NSW retention measures (70%; Pärn et al., 2012).

3.6.10 Overview of the stock-flow models and land sea interactions

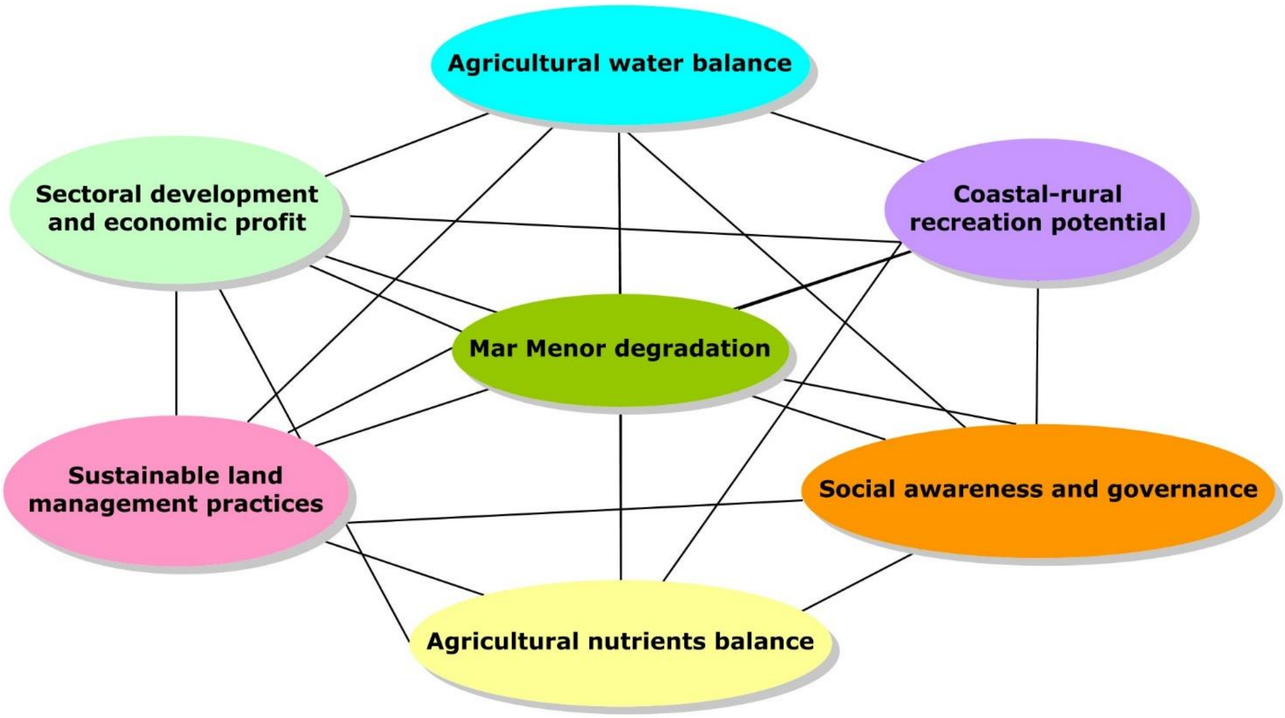


Figure 98: Overview of the sub models of the MAL6 system dynamic model representing land sea interactions.

Figure 98 shows an overview of the system dynamic model developed in MAL6 presented in detail in previous paragraphs, highlighting the relationships among the different topics modelled and between coastal and rural aspects. All three economic sectors (agriculture, tourism, photovoltaic renewable energy) contribute to the total economic profit and jobs in the study area. The Mar Menor ecological status is influenced by the agricultural development via water and nutrients input and the implementation of SLM practices and nature-based solutions. On the other hand, the ecological status of the lagoon affects coastal and rural tourism development and social awareness and governance, which in turn could lead to the adoption of SLM practices and regulate the development of the agricultural sector. Besides, there is a potential synergy between the agricultural and the tourist sectors via promoting agrotourism activities.

Figure 99 shows the main feedback loops contained in the model structure. The Mar Menor degradation, mainly caused by agricultural nutrient inputs and indirectly affecting tourist growth via coastal recreation potential, also affects social pressure on public administrations, which in turn negatively affects agricultural development. Besides, the expansion of irrigated land areas increases water demand and agricultural pressures on water resources, which in turn decreases the potential growth of agriculture based on water availability. Furthermore, the increase in agricultural water demand also increases the groundwater needed, thereby producing brine wastes and more nutrients inputs to the lagoon. The social pressure on public administrations and the implications for agricultural and tourism growth potential are central in the effectiveness of this feedback loop.

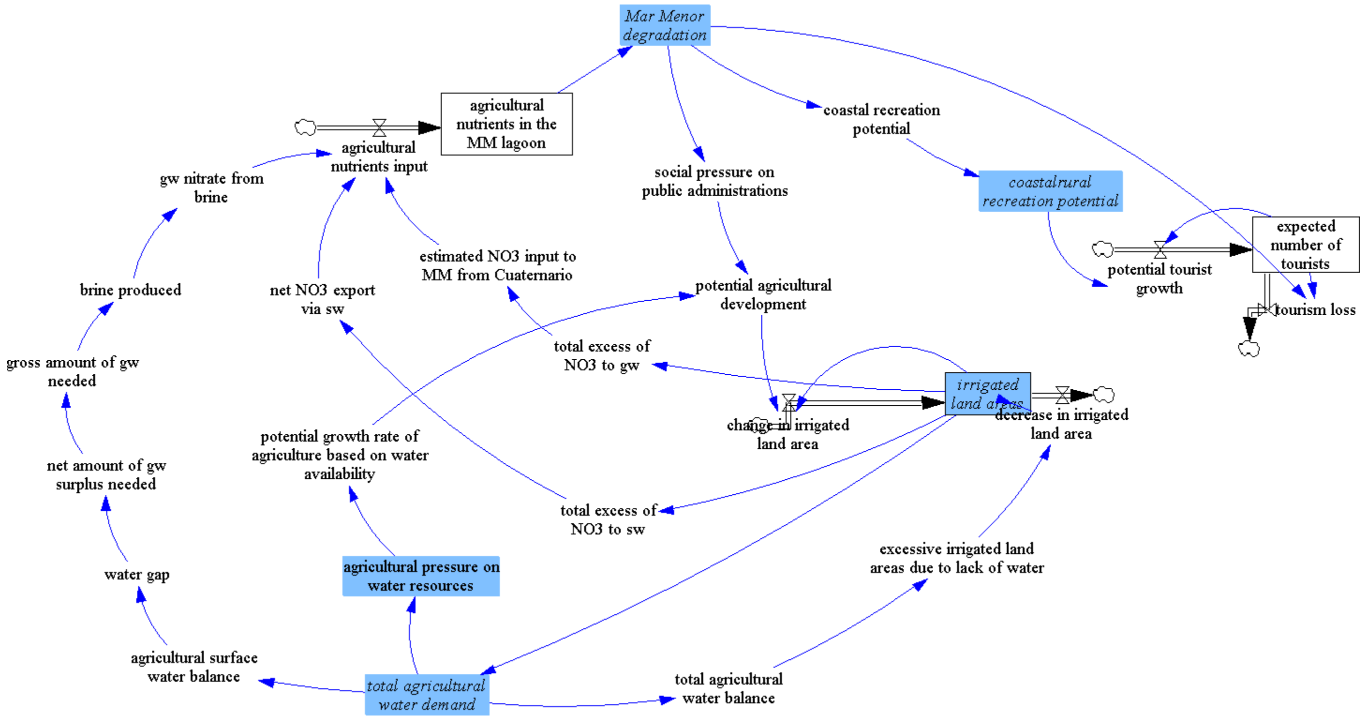


Figure 99: Main feedback loops of the MAL6 pilot system dynamic model.

3.6.11 Business and policy analysis

The list of scenarios that can be evaluated with the stock-flow model corresponds to the potential business and policy solutions that were identified during the stakeholder workshops and also includes climate change scenarios related to water availability and water demand. The scenarios that can be evaluated with the stock flow model (indicated in the detailed model description of previous paragraphs by green coloured variables) are:

1. Water pumping from the aquifer to extract pollutants and provide additional irrigation water (Vertido Cero Plan).
2. Surface water pumping from the Albujón ephemeral river to extract pollutants.
3. Limitation in the number of groundwater wells.
4. Increase in water desalination for agriculture.
5. Control and compliance of the extension of irrigated agricultural areas without water rights.
6. Control of other point-source pollution to the Mar Menor lagoon.
7. Implementation of nutrients, water and soil retention measures.
8. Promotion of environmental education among local population.
9. Promotion of photovoltaic energy facilities.
10. Enforcement of reduced application of fertilizers (also following Biodiversity and farm-to-fork strategy of the EU Green Deal).

11. Implementation of brine denitrification technologies.
12. Effect of a decrease in water transfer from the Tagus-Segura transfer driven by climate change (RCP4.5 and 8.5) on water availability.
13. Effect of a change in agricultural water demand per hectare based on higher potential evapotranspiration due to climate change or the use of low water consumption crops as climate change adaptation strategy.
14. Promotion of coastal ecotourism activities.
15. Promotion of rural ecotourism activities.

Scenarios can be activated individually or in different combinations. The different combinations of solutions will also be tested under different projected socioeconomic scenarios (developed under WP5), based on the Shared Socioeconomic Pathways (O'Neil et al 2017), which might affect several model input variables. The model also includes an extensive list of 17 key performance indicators in relation to different environmental and socioeconomic aspects. These variables are highlighted with a blue background in the previous sub model graphs and correspond to the agricultural pressure on water resources, the total agricultural water demand, the coastal-rural recreation potential, the Mar Menor degradation, the agricultural water revenue per m3, the amount of irrigated land areas, the number of employees in agriculture, the number of employees in photovoltaic energy facilities, number of employees in tourism, the potential photovoltaic energy installed, the photovoltaic energy revenue per hectare, the total water demand by tourists, the tourism water revenue per m3, the yearly gross economic benefit of agricultural production, the yearly gross economic benefit of photovoltaic energy production, the yearly gross economic benefit of tourism, and the territorial bonding.

All variables in the Vensim model are documented, and the model also includes a dashboard that allows any user with limited knowledge of stock flow models to play with scenarios and see the outputs graphs of the main key performance indicators (KPI). Some useful examples of policy and business simulations are exemplified in *Figure 100* and *Figure 101* showing the VenSim output graphs of some key performance indicators.

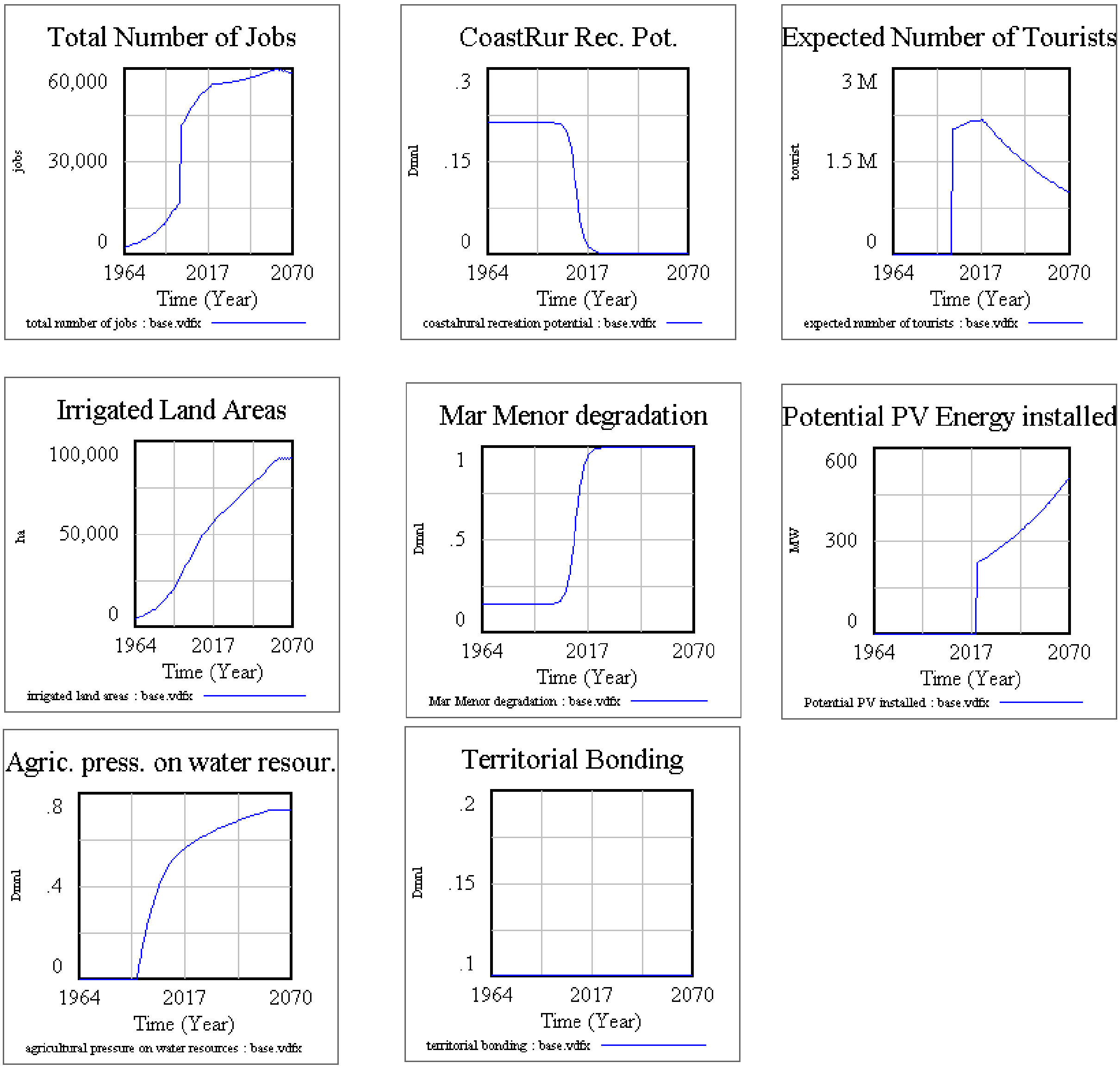


Figure 100: Main model results for a selection of key performance indicators under the business as usual scenario.

The model is particularly useful for assessment of policy and business solutions since it allows for direct comparison of the impact of individual or combined solutions on the key performance indicators (KPI) that represent all sectors involved. For example, when comparing the business as usual scenario (*Figure 100*) and a potential business and policy roadmap (*Figure 101*) (under development in WP3) that includes the implementation of the whole set of potential solutions listed above, we see how the KPIs generally improve (note that the scale on the y-axis can vary): there is an increase in the total number of jobs; the coastal-rural recreation potential and the expected number of tourists increase instead of decrease; the hectares of agricultural irrigated land areas is controlled and remains within the allowed boundaries; the degradation of the Mar Menor shows a peak and then decreases due to the reduced export of agricultural nutrients from the catchment and the reduction of other point-source pollution; the potential photovoltaic energy installed increases; the agricultural pressure on water resources decreases; and finally territorial bonding increases due to the promotion of environmental education activities.

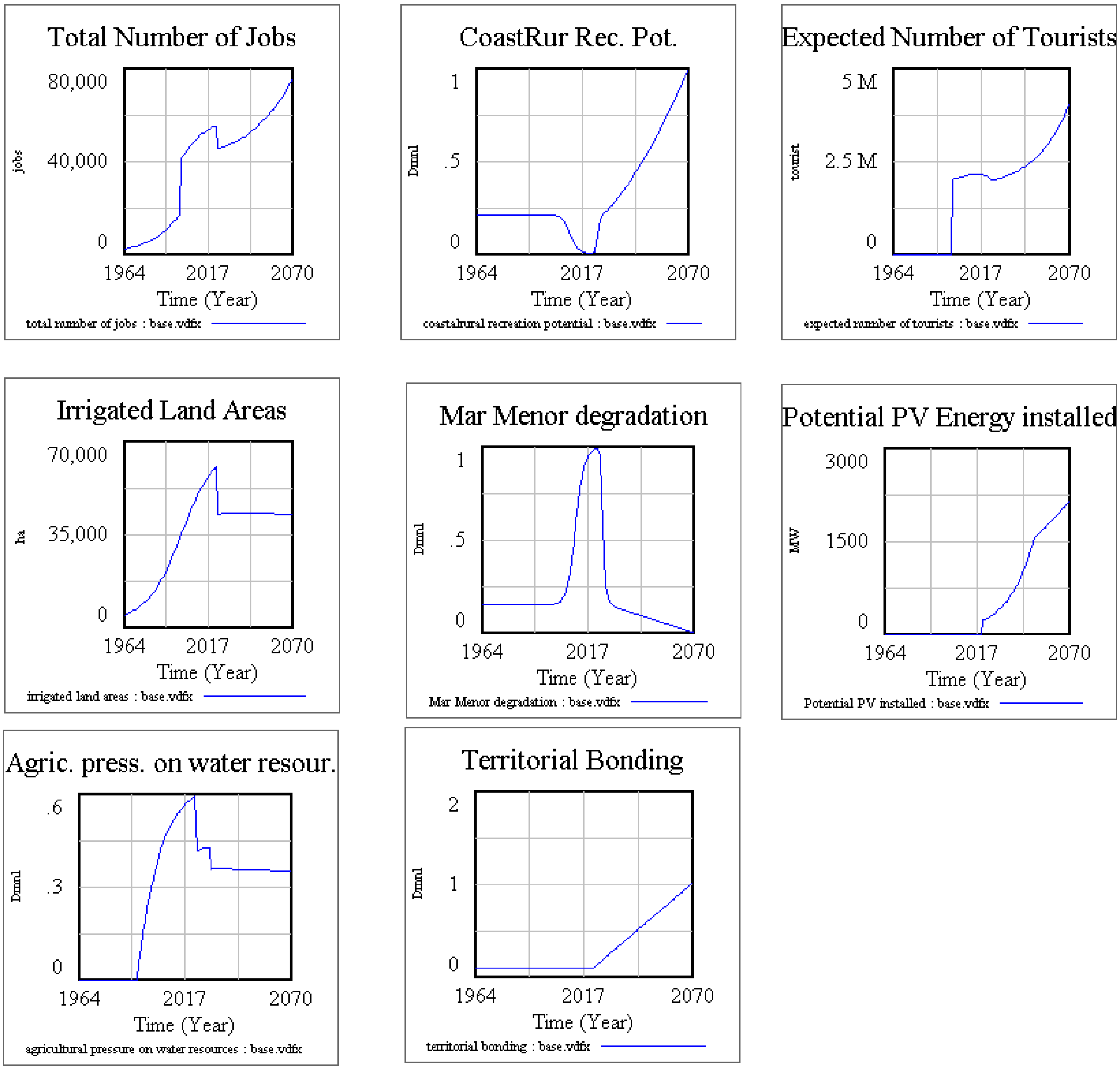


Figure 101: Main model results for a selection of key performance indicators when implementing the whole set of potential solutions defined as a Business and Policy Roadmap.

3.6.12 Model confidence building

The ultimate goal of the stock flow system dynamic model is to support and guide the transition to a stakeholder defined Future Vision of the Mar Menor and its catchment area in the Campo de Cartagena by providing insight into the impact of potential solutions on the performance of the entire system. The Future Vision, developed by stakeholders during the COASTAL workshops, aims to promote a transition to a condition in which the Campo de Cartagena and Mar Menor lagoon are internationally recognized as well developed coastal and rural ecotourism destinations, in which there is also room for sustainable agriculture, and synergistic development between agriculture and tourism. The tourism and agriculture sectors will be interdependent and collaborating for sustainable development. The strong presence of sustainable tourism activities creates the incentives for developing and preserving healthy rural areas, sea and coasts, combined with good quality infrastructure and level of general well-being for people living in the area. All sectors will work together following a problem-based approach and promoting economic benefit transfer from coastal to rural areas and vice versa. New regulations from the local to the national level will be developed, incorporating and considering the environmental, social and economic aspects of sustainable development. All economic sectors will have internalized environmental costs and benefits in their business models. The agricultural sector will be aware of its role and impact on the Mar Menor lagoon driven by a change in attitude from local and international consumers, who will consciously buy vegetables and fruits produced by means of sustainable land management practices. Thus, agriculture in the area will make a transition to high quality products with a high added value, applying the latest technology for water and nutrient efficiency and concepts of sustainable intensification. Production will be more oriented to local markets and tourism, and solar energy will become an attractive alternative for agricultural land use. There will be an expansion of tourism activities linked to agriculture (agrotourism) and to alternative activities in rural and coastal areas that attract international (water and land) sport events taking advantage of the soft winters. There will be a coordinating body for the Mar Menor and its catchment area formed by public administrations and representatives from all socio-economic sectors that will co-manage the area with strong participation from all stakeholders. All sectors will follow a common regulation to minimize and mitigate nutrient and pollutant emissions as a long-term goal. This will also be supported by building new green infrastructures based on nature-based solutions and the wide scale adoption of sustainable land management practices in the agriculture sector that help protecting the lagoon and villages from flooding and contamination. Ultimately, the stock flow model is meant to assess what combination of stakeholder defined business and policy solutions best support the transition to the envisioned future.

The stock flow model was developed with a high level of input and co-evaluation with stakeholders at different phases of model development. As explained in the detailed model descriptions in previous paragraphs, the combined CLD that was developed during the sectoral and first multisector workshop forms the basis of the stock flow model design. Furthermore, before the second multi-actor workshop, several expert interviews took place via online meetings and e-mail exchanges, during which we showed pilot versions of the model and preliminary results to different domain experts to get a first round of feedback. This helped getting more model input data and be better prepared for the second multi-actor workshop during which we showed and discussed the advanced pilot version of the model. The topics covered during the expert interviews were in relation to the agricultural water and nutrient balances, sustainable land management practices, the development of the agricultural, tourism and photovoltaic energy sectors, the coastal-rural recreation potential and the social awareness and governance sub models. These interviews helped us to update some data sources for several input variables, include new scenarios that were missing and were considered relevant, as well as new key performance indicators (see bullet points with specific model changes below).

The second multi-actor workshop, conducted online in December 2020, lasted two and a half hours and a total of 15 participants attended, representing 5 sectors (public administrations, tourism, local populations, agriculture, and environmental sector), including 2 workshop facilitators from the CSIC team. The workshop started with an update on project progress, including an explanation of the development of the System Dynamics model based on the CLD that was presented and discussed during the previous multi actor workshop, the sub models and main interactions, the Business and Policy Roadmaps (BRM) based on the stakeholder defined solution scenarios, and the use of Shared Socioeconomic Pathways (SSP). This introduction and progress overview session lasted for about 45 minutes, and was followed by three main sessions: (a) Model validation and confidence building; (b) Business roadmap development; and (c) Shared Socioeconomic Pathways. In order to get feedback, we used an online questionnaire that was filled in by the participants during (or shortly after) the online workshop. Following this, we had a facilitated open discussion on the solutions, expectations, and how they were implemented in the model. The model was well received, and participants provided many constructive comments, especially in relation to data. During the workshop, participants confirmed their agreement with the general model structure, the different sub models and the interactions represented. Participants also assessed the timing and potential impact of the set of solutions already included in the model. On requests of some of the participants during the workshop, we organised few additional expert interviews to receive more detailed feedback and suggestions on particular aspects of the model or input data.

Full model behaviour has not been tested by stakeholders yet but will be part of the next workshop or dissemination activities planned. MAL6 stakeholders have shown more interest and confidence in the relative values of the key performance indicators based on different scenarios of implementation of solutions than in their absolute values. Thus, the final goal of the model will be to support a business roadmap by considering all interactions between sectors and realms.

All this feedback has affected the model structure, increasing the level of detail in some aspects and becoming more comprehensive and correct, reflecting interactions between model variables and using most reliable data. Especially, some new scenarios have been developed, sometimes replacing old ones that were not as relevant or realistic for stakeholders. During model development, we have also continuously tested how changes in the model have affected main outputs to determine how reasonable they were by comparing output with historic observed data. Besides, new variables have been added in order to represent 3 different dates (years) in which the different scenarios are be eventually activated (short-, medium- and long-term) according to our stakeholders. The main model changes implemented in relation to the previous version described in Deliverable 13 are:

- In relation to the development of the tourism sector, we have now added an outflow variable in the stock of yearly tourists related to the Mar Menor degradation. The total water consumed and the economic revenue per cubic meter of water used has been now added. The data regarding number of tourists is now better quantified, although experts stressed the fact that it is extremely difficult to make any projections due to the impact of the COVID19 pandemic on short-medium term tourism development.
- The photovoltaic sector is now related to an economic profit, including the revenue per hectare and the number of jobs have been simplified into one category. The total area occupied by photovoltaic energy facilities and a new scenario of promotion of photovoltaic energy facilities have been added.
- In the Mar Menor degradation sector, a variable representing other point source pollution has been added, including a gradual mitigation effect, as well as the relative weight of agricultural pollution in relation to the degradation of the Mar Menor.
- In the agricultural nutrients sector, a new scenario has been added that accounts for the Albujón surface water pumping. Besides, the total amount of nutrients in brine has been now better quantified.
- In the coastal-rural recreation potential sector, we have now introduced a gradual effect for the coastal and rural ecotourism activities and have made the rural recreation potential also dependent on the coastal recreation potential.
- In relation to the development of the agricultural sector we have now merged the different job types generated into one single category. Also, the gross economic benefit is now referred only to the production to make it more comparable with other sectors and the revenue per cubic meter of water used has been now added. A new scenario of control of the expansion of irrigated agricultural areas has been also added. Besides, an outflow variable has been added in the stock of irrigated land areas to account for a decrease in their extent.
- In relation to sustainable land management practices, the implementation of vegetation buffers has now been extended to the implementation of nutrient, soil and water retention measures.
- In relation to social awareness and governance, the sectorial feedback scenario has been removed due to lack of relevance and impact in the main outputs of the model. However, a new scenario in the development of the photovoltaic energy sector has been added to specifically address this issue in that sector. Besides, a new variable related to territorial

bonding has been added, which now mediates between the environmental education scenario and the social pressure on public administrations.

- In relation to the agricultural water balance sector, new RCP based scenarios of amount of water transfer in the Tagus-Segura aqueduct have been added. Two new scenarios have been added to account for the change in seawater desalination amount for agriculture, as well as for the change in agricultural water demand per hectare. The latter could be increased by climate change scenarios and decreased through the implementation of water saving measures in small dams or the cultivation of less water demanding crops. Besides, a new variable has been added representing the percentage of the water gap covered by unknown water sources. A new variable was also added to account for an excessive amount of irrigated land areas due to lack of water, which is used to compute the outflow in irrigated land areas in the agricultural development sector.
- New variables have been added that calculate the total economic profit from all sectors and the total number of jobs.

4 Synthesis

WP4 contributes to the toolbox of instruments and project outcomes aimed at making business road maps and policy recommendations **evidence-based**. When developing quantitative stock-flow models one should be clear on why this type of modelling is needed, how the models can be used, and who will use the models. Quantitative modelling has three important advantages:

1. inconsistencies in the complex mind maps of land-sea interactions are revealed automatically,
2. the models can be applied for stress testing policy and business decisions while visualizing the impact on key indicators, and
3. models and model constructs can be collected in generic libraries to enable reuse and increase the interoperability.

System innovation can be supported by applying the models to identify counterintuitive response to planned policy decisions, to obtain understanding of the role of the feedback structure, and to anticipate tipping points. This all comes at a cost. Effort and expertise are needed for designing and implementing the models and collecting the necessary data. In addition, the validity of the models should be explained to stakeholders as part of the confidence building process. This can be a challenge when model development is still in progress, or when model complexity reduces the communication value of the models. Nevertheless, this confidence building is an essential aspect of the co-creation activities planned in WP1.

One of the challenges for WP4 and in particular Task 4.2 - modelling of land-sea interactions - was that most of the modelling teams had different backgrounds and levels of experience with modelling in general and only a few of the COASTAL modelers were familiar with System Dynamics and stock-flow or SD-modelling. In SD-modelling the emphasis is on identifying policy problems and the dynamics generated by the underlying feedback structures. This requires a different mindset from process-based modelling. This is further detailed in Figure 2 and Table 1: whereas research models aim to describe in detail all the processes involved, the emphasis in policy-oriented modelling is on describing the problems in a way sufficient to support policy analysis. SD modelling is not the only tool available but can serve this purpose well. The SD-model should therefore not be a complete representation of the system in all its detail, but a simplification of reality. A further complication for the modelling process was that the modelling teams needed time to familiarize themselves with the Vensim software. This impeded a smooth adoption of stock-flow modelling at the very beginning of the project. A more interesting challenge faced by WP4 was related to the pivotal role of the SD modelling in the project. During the second reporting period the stock-flow models were serving as an anchor point for integrating the qualitative and quantitative work tasks, given the central role of the systems modelling in the project workflow (Figure 3). Completion of the models was essential to clarify and discuss the interactions with the qualitative work tasks, in particular the design of road maps and scenarios driving the models. This was anticipated and embedded in the project work plan (Figure 1) but the timing of WP4 deliverables and models turned out to be significantly more important than anticipated. This was addressed by letting the different WPs work in parallel and increase the exchanges between the MALs and WP lead partners to discuss their models and jointly address technical difficulties, one of the recommendations that was already made in the consolidated review report for the first period (M1-M18).

A general, comparative, self-assessment for the models was made by the end of March 2021 (see Annex 2). The assessment included criteria related to the quality and state of completion of the model design, the quantification of the model in terms of equations, parameters and functional relationships, the model behaviour, visualization and documentation, and finally the feedback of stakeholders obtained during the second multi-actor workshops and informal or bi-lateral exchanges with the local actor partners and stakeholders.

The typical **strengths of the current COASTAL model library** can be summarized as follows:

a) Together the **graphical interface** and **policy dashboard** of the models surpass research models in communication value, although additional documentation and tutorial examples are needed for the more complex models;
b) All SD models allow **rapid policy analysis** while the **data demands are limited**;
c) The modelled priorities, key stock variables, scenario drivers and policy indicators were identified **based on direct engagements** with a broad selection of over 500 stakeholders, in interactive, holistic settings covering a wide range of themes across the land-sea interface (agriculture, water management, renewable energy, tourism, spatial planning, ….);
d) All models were systematically **screened** in terms of design, completeness and usefulness (see Annex 2) and passed tests to verify the **consistency of equations and dimensions**;
e) Where possible, the complexity of the models and model scope has been addressed by a **modular design** of the models, with interconnections between sub models managed in separate 'views' or highlighted model fragments;
f) Model **granularity has been minimized** to the extent possible, i.e. the models are well-balance in terms of the level of detail throughout the model. This increases the model transparency;
g) **Flexibility of the models** for making adaptations to the model structure, model equations, scenarios, parameter settings and other data is relatively easy due to the modular model structure, use of external files for data management, and high degree of model granularity;
h) Though stock-flow modelling is a technical expertise the stock-flow models or underlying principles have been **communicated to the stakeholders and discussed** to identify any potential for improvement or adjustment of the models;
i) All models were developed in the VenSim® **common software platform** for SD modelling, enabling interoperability of models and exchange of reusable model constructs. Runtime versions can be shared with third parties or stakeholders for further distribution;
j) A **complete and harmonized documentation** of the model equations, variables and parameters has been generated automatically, and can be found in Annex 6 of this document.

By May 2021 the general progress with the modelling can be summarized as follows:

- Together the six MALS developed a total 14 operational stock-flow models. All these models have been polished, tested for dimensional consistencies, can be used to run alternative policy options, and are ready for integration with scenarios (WP5) or supporting the design of road maps (WP3);
- Looking at the self-assessment (Annex 2) one can conclude that model documentation and feedback from stakeholders (confidence building) were given less attention than other aspects of the model design and implementation;
- Thematically the models cover topics ranging from renewable energy, tourism and aquaculture to land management and agriculture. Nevertheless, the general focus of the models is on agriculture and (coastal) water quality. Policy and business indicators related to or relevant for employment, food production, and the EU Green Deal are included in most of the models;
- Due to the differences in model scope (themes and delineation of the model), model detail, granularity (balancing in detail) and the number of sub models the MAL models are not interoperable at this stage, despite of the modelling guidelines and examples provided. However, model constructs used and technical solutions for problems have an added, generic value surpassing their use in the MAL models. These will be collected in a model library and documented in an oncoming WP4 deliverable (D15). In several cases the MALs already reused model constructs to expand or adjust their model design. For example, the Greek and Romanian MAL use a similar stock-flow structure for modelling the impact of agriculture transition on water quality, food production and employment.
- Who will use the models and how is an open question. The graphical complexity of most model reduces their communicative value. This problem was recognized at an early stage and has been addressed by preparing supportive template presentation building up the models step-by-step to clarify the added value for policy analysis, by standardizing the model design with guidelines, and by asking each MAL to add a “policy dashboard” to their VenSim models. The dashboards should provide quick access to the key policy levers, scenarios and indicators without requiring access the underlying model structures.

At the end of the second reporting period the combined set of operational SD Models for Coastal-Rural Interactions meet some but not all the objectives set for Task 4.2. Some of the models developed will be interchangeable and connectable and will concern relevant problems and activities for more than one MAL such as the transition to more sustainable agriculture, tourism or coastal eutrophication. Ultimately, the exchange of knowledge, data and models between the MALs is of key importance for the success of COASTAL.

In general, one cannot conclude that the stock-flow modelling has been fully completed as planned by the summer of 2021. Several models need to be polished, fine-tuned, documented and the integration of the sub models examined. However, in terms of capacity building the work on making the SD models operational has been very important for all MALs. Considering the differences in modelling expertise between the MALs , the late starting point of the modelling by the end of the first reporting period, and the impacts of the covid-19 pandemic considerable progress has been made with the design and implementation of the models. Together, the operational models, expertise gained by the MALs teams in developing these models, data collected and engagement with stakeholders provide sufficient basis for finalizing all models, supporting the definition of the road maps with WP3, and analysing policy robustness by linking up with the narrative scenarios of WP5 within the project life time. In view of the remaining time and resources it is of vital importance to organise the collaboration between the WPs and MALs efficiently and maximize the sharing of expertise with the local actor partners and stakeholders.

The management, maintenance and post-project exploitation of SD models should be considered in the larger context of the COASTAL methodology and modelling capacity developed in the project so far. SD models are of little value to end users or new modelers without proper guidelines, tutorial examples and data, and above all understanding of their use which should be embedded in the trajectory followed for developing the road maps. The purpose, potential and limitations of SD modelling should be clear to anyone interested in using or further developing the models. To enable collaboration between the MALs the activities of WP4 were already supported with technical guidelines for the design and implementation of the models, examples and a format for structuring the documentation of models and data (see Chapter 3 and Annexes 4, 5 and 6). A strategy for data management has been set out in the COASTAL Data Management Plan (deliverable D26) while post-project exploitation (Figure 102) is considered in the Draft Exploitation Plan (deliverable D22).

All models should be self-explaining, made available together with the required input data, documented in an appropriate manner, validated and tested to run without technical errors or other anomalies. Considerable effort was already made by the MALs to address these requirements. For example, all models were fitted with a “policy dashboard” providing an overview of the key policy indicators and control levers of the models without a need to locate these in the underlying model structures. Depending on the level of complexity and scope of the models, direct reuse to a different context or region is generally not feasible without significant modification. However, generic and reusable model constructs or system archetypes can be derived from or were already used in the models. These are expected to be of more value for facilitating the design of new model applications[9]. This is the focus of work task 4.3 – Generic Toolbox – and upcoming deliverable D15.

[9] De Kok, J.L., Engelen, G., and Maes, J., 2015, Functional design of reusable model components for environmental simulation – A case study for integrated coastal zone management. Environmental Modelling and Software 68, 42-54.

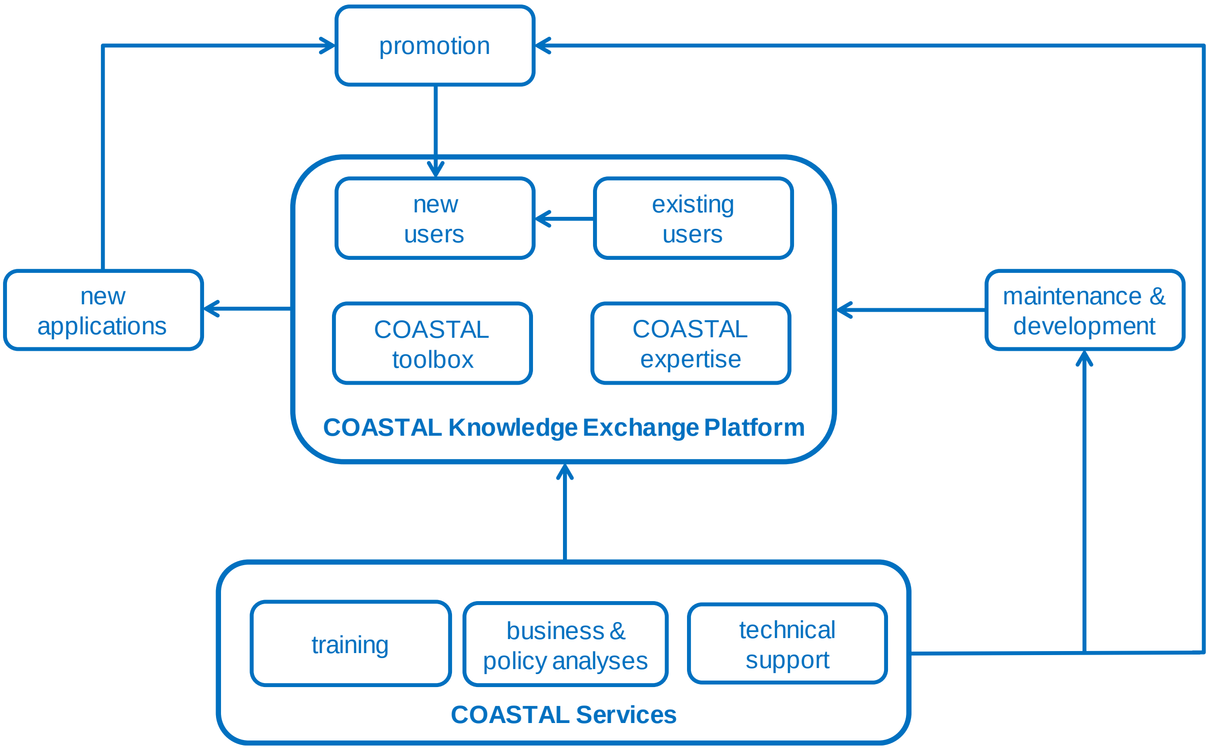


Figure 102: Proposal for post-project maintenance, development and promotion of the COASTAL toolbox and models.

5 General bibliography stock-flow modelling of human-environment systems

Ackhoff RL. The art and science of Mess Management, TIMS Interfaces, Vol II, no.1, Feb. 1981, 20-26, 1981.

Argent RM. An overview of model integration for environmental applications–components, frameworks and semantics. Environmental Modelling & Software 19 (3), 219–234, 2004.

Bassi AM and Shilling JD. Informing the US Energy Policy Debate with Threshold 21. Technological Forecasting and Social Change 77(3), 396-410, 2010.

CMap Tools. Institute for Human and Machine Cognition. http://cmap.ihmc.us/

Coyle RG. System Dynamics Modelling, A Practical Approach. London: Chapman & Hall, 1996.

Dale MB. Systems Analysis and Ecology. Ecology 51(1), 2-16, 1970.

Daly, H. & Cobb, J. (1989), For the Common Good. Beacon Press, Boston.

Deaton, Michael L. and Winebrake, James I.. Dynamic Modelling of Environmental Systems. Springer Science & Business Media. 2000. 194 p. ISBN 978-1-4612-7085-0.

De Kok, J.L., Engelen, G., and Maes, J., 2015, Functional design of reusable model components for environmental simulation – A case study for integrated coastal zone management. Environmental Modelling and Software 68, 42-54.

De Kok J.-L., Overloop S. en Engelen G. Screening models for integrated environmental planning – A feasibility study for Flanders. Futures 88, 55-68. 2017. https://www.sciencedirect.com/science/article/pii/S0016328716300441

De Kok, J.-L., Viaene P., Notebaert B., Karageorgis A., Panagopoulos Y., Kastanidi E., Destouni G., Kalantari Z., Seifollahi S., Maneas G., Lescot J.-M., Vernier F., Lazar L., Pop R., De Vente J., Martinéz-Lopez J. Model Scope and Feedback Structure. Deliverable D12. H2020-COASTAL. Grant Nr. 773782. https://h2020-COASTAL.eu/. 2019.

European Environment Agency (EEA). European environment — State and Outlook 2015: Assessment of global megatrends, European Environment Agency, Copenhagen, 2015.

Engelen G, Uljee I and Van de Ven K. WadBOS: Integrating Knowledge to Support Policy-making for the Wadden Sea. In: Planning Support Systems in Practice, Geertman S. and Stillwell J. (Eds). , 513-537, Springer, 2003.

Engelen G. Models in Policy Formulation and Assessment: The WadBOS Decision Support System. In: Environmental Modelling: Finding Simplicity in Complexity, edited by: John Wainwright and Mark Mulligan, p.257-271. John Wiley & Sons Ltd, Chichester, England, 2004.

Featherston C and Doolan M. A Critical Review of the Criticisms of System Dynamics. Proceedings of the 30th International Conference of the System Dynamics Society. The 30th International Conference of the System Dynamics Society: St Gallen, Switzerland. 2012.

Ford, Andrew. Modeling the Environment. 2nd ed. Island Press. 380 p. ISBN 978-1-59726-473-0.

Foresight Land Use Futures. Systems maps. The Government Office for Science, London (UK), 2010.

Forrester JW. Principles of Systems. Cambridge (Ma.). Wright-Allen Press, 1968.

Forrester JW. Urban Dynamics. Pegasus Communications, 1969.

Forrester JW. World Dynamics. Cambridge (Ma.). Wright-Allen Press, 1971.

Forrester, J.W. and Senge, P.M. (1980). Tests for building confidence in system dynamics models. TIMS Studies in the Management Sciences 14, 209 – 228.

Hovmand, P.S. Community Based System Dynamics. Springer, New York. 2014.

ImagineThat Inc, 2013. User Manual ExtendSim 9. www.extendsim.com

Jørgensen SE and Bendoricchio G. Fundamentals of Ecological Modelling. 2001. Elsevier Science. 530 p. ISBN 0-080-44028-2.

Kim DH. Guidelines for Drawing Causal Loop Diagrams. The Systems Thinker Vol. 3(1), Pegasus Communications, 1992. http://www.thesystemsthinker.com/tstgdlines.html

Kirk J. 2007. https://www.mathworks.com/matlabcentral/fileexchange/10722-count-loops-in-a-graph

Lighthouse Leadership Ltd. A Critique of the "World3" Model Used in "The Limits to Growth". Essary completed as part of MSc S. Rogers in Environmental Systems Engineering, University College London, UK. April, 2010.

Meadows, DH. Limits to Growth. NewYork: University Books , 1972.

Meadows D, Randers J en Meadows D. Limits to Growth, the 30-Year Update. Routledge, 2004.

Meadows D. Thinking in Systems. A primer. Earthscan, 2008.

Millenium Institute. A General Introduction to the Threshold21 Integrated Development Model. Arlington, Va. 2013a. www.millenium-institute.org

Millenium Institute. A Technical Introduction to the Threshold21 Integrated Development Model. Arlington, Va. 2013b. www.millenium-institute.org

Montes de Oca Munguia O, Andrew O and Lennox J. The Use of A New Zealand Dynamic Ecological-Economic Model To Address Future Scenarios. In Oxley, L. and Kulasiri, D. (eds) MODSIM 2007 International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand. pp. 1131-1137. December, 2007.

O'Neill, B.C., Kriegler, E., Ebi, K.L., Kemp-Benedict, E., Riahi, K., Rothman, D.S., van Ruijven, B.J., van Vuuren, D.P., Birkmann, J., Kok, K., Levy, M., Solecki, W., 2017. The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century. Global Environmental Change 42, 169–180. doi:10.1016/j.gloenvcha.2015.01.004

Randers J. (Ed.). Elements of the System Dynamics Method. Cambridge (Ma.). Productivity Press, 1980.

Ruth, Matthias and Lindholm, James (Eds.). 2002. Dynamic Modelling for Marine Conservation. Springer Science & Business Media. 449 p. ISBN 978-1-4612-6544-3.

Sato, J.B. What counts as an explanation for system behavior? A brief history of SD from a dominance perspective. Proceedings of a meeting held 16-20 July 2017, Cambridge, Massachusetts, USA. 35th International Conference of the System Dynamics Society 2017. Vol. 3. pp 1503-1533. ISBN 9781510851078. http://www.proceedings.com/36907.html

Senge PM. The Fifth Discipline: The Art and Practice of the Learning Organization. New York: Doubleday/Currency. Second Ed. 2006.

Stave SK. Using system dynamics to improve public participation in environmental decisions. System Dynamics Review 18(2), 139-167, 2002.

Stancheva M. Burgas Case Study: Land-Sea interactions. June 15-16, 2017. https://www.msp-platform.eu/events/msp-conference-addressing-land-sea-interactions

Sterman John D. Business Dynamics: Systems Thinking and Modeling for a Complex World, McGraw Hill, 2000.

Tiller, R., Kok, J.-L.d., Notebaert, B., Wouters, N., Stubbe, F., Motmans, S., Stubbe, W., Dauwe, S., Pirlet, H., Vernier, F., Lescot, J.-M., Jean -Luc Fort, Sabatié, S., Lazar, L., Timofte, F., Nenciu, M.-I., Golumbeanu, M., Destouni, G., Seifollahi-Aghmiuni, S., Kalantari, Z., Prieto, C., Chen, Y., Maneas, G., Kastanidi, E., Panagopoulos, I., Karageorgis, A., Guittard, A., BergJavier, H., Martínez-López, Vente, J.d., Boix-Fayos, C., Albaladejo, J., 2019. Sectoral Analysis of Coastal and Rural Development (D03), in: H2020, C. (Ed.), WP1 Multi Actor Analysis T1.1 - Sectoral Analysis of Coastal & Rural Development.

Turner GM. A comparison of The Limits to Growth with 30 years of reality. Global Environmental Change 18(3), 397-411, 2008.

Voinov A. Systems Science and Modeling for Ecological Economics, Academic Press, 2008.

Winz I, Brierley G and Trowsdale S. The Use of System Dynamics Simulation in Water Resources Management. Water Resources Management 23, 1301-1323, 2009.

Wolstenholme EF and Coyle RG. The development of system dynamics as a methodology for system description and qualitative analysis. Journal of the Operations Research Society 34(7), 569-581, 1983.

Wolstenholme EF. System enquiry; a system dynamics approach. Wiley, Chichester, 1990.

Annex 1 Technical guidelines for systematic model development.

Objective: to prepare for the multi-actor workshops and modelling workshop of General Assembly in Methoni - to be discussed during online Quarterly Progress Meeting I (March 6, 2019). The aim of this discussion paper is to clarify some modelling-related questions and put some issues on the agenda. The modelling workshop on Day 4 will be preceded by an introduction and modelling related sessions on Day 3.

Proposed modelling guidelines (for general workflow see project description):

- Use cleaned up Causal Loop Diagrams (CLDs) as model architecture – start from sector CLDs (see attached example of a CLD for farming at end of this document). CLDs provide more information on the feedback structure than mind maps and do this preferably using less detail.
- Appoint one or two core modelers for each MAL and organise quarterly online meetings (starting with modelling workshop in Methoni)
- Together the core modelers will develop a generic library of VenSim models addressing issues relevant for multiple MALs to facilitate the modelling, taking into consideration the added value for communicating with; this will save time that we can instead use for developing good applications and examples. Examples of generic stock-flow models: age-cohort model, business cycles, land pressure, COASTAL eutrophication, ….
- Collection of data (statistics, field data, …) should focus on historic calibration, initialization of stock variables, and model validation at the appropriate level of detail
- If necessary, we can use graphical (table) functions instead of equations to describe the relationship between variables. This functionality is supported by VenSim
- Organise models in multiple VenSim 'Views' with one view per sector, this will provide a better overview and make it easier for users to understand the model structure documentation and model user control – focus model output on existing and new Key Policy and Business Indicators (like KPIs)
- Focus the pilot model of the system (Milestone 4, due April 2020) on land-sea interactions as this is the topic of the project
- Use the Knowledge Exchange Platform for model exchange, maintenance and documentation, and as data repository (Open Data Pilot)

Typical questions and possible answers (not exhaustive):

1. <u>Why do we need models?</u> Model simulations are essential because it is very difficult to understand the mid- and long-term impacts of policy and business decisions, particularly for complex systems with multiple interactions.
2. <u>What do we include?</u> Here it is important to have a clearly defined purpose for your model, regardless of whether it is a conceptual or fully quantified model. Just modelling the 'total system' without reason is not a good idea (Sterman, 2001). It is better to address a specific problem or topic with your model. For COASTAL this could be regional development and land-

sea interaction, but also a narrower purpose – for example, how to develop a new business (seafood, agro-tourism, …) in the area. This model purpose will also help set the boundaries of the model. We will not model climate change, the world energy market etc. These will be input for your model as scenarios driving the model. What's to be included or not in the model and the time horizon will also depend on the model purpose.

3. Should we model the complete system or parts first? We need both. After we have decided what the complete system and its boundaries are (see point 1) we'll have to identify and understand the impact of land-sea interactions, and cross-sectoral interactions in this system. All the time we should keep in mind the purpose of the model (see point 1). We also need models for the sectors (to explain the sector dynamics). For example, how does a new business such as aquaculture develop over time?

4. How should we confront our stakeholders with our models? The best is to do this carefully and step-by-step. A complex diagram of the total system can be discouraging to them and may even raise criticism on the practical usefulness. A good way is to start from the sector problems, present the conceptual models for the sectors first, followed by a simplified diagram for the total system (showing the main feedback loops), and finally the diagram for the total system with all land-sea interactions. It's also good to use the functionalities for visualisation in VenSim (different colours for the sectors, fat arrows to highlight the feedback loops etc.)

5. When to use mental maps, mind maps, Causal Loop Diagrams and Fuzzy Cognitive Maps? Mental maps or mind maps are the diagrams developed during the sector workshops: the stakeholders defined their problems, priorities, obstacles and opportunities and helped us identify the causal linkages (positive and negative). Causal Loop Diagrams and Fuzzy Cognitive Maps (FCMs) are more polished and show the key state variables of the system and feedback structure of the system. The difference with CLDs is that in FCMs weights are assigned to each interaction (VenSim arrow) and FCMs can be used to generate scenarios. Stock-Flow models, finally, require more data, but are the best tool to examine the dynamics of the system because we can include time delays, threshold values, and non-linearity.

6. Why is system feedback important and how can we find the feedback loops? The dynamics of the system (linear or exponential growth, limited growth, collapse, …) can be explained from the internal feedback structure – some examples can be found in Deliverable D12. Feedback loops are quickly found in VenSim by selecting a variable and using the Loops tool (left menu bar).

7. Should we include human behaviour and other 'soft' variables and how can we do this? We should include these if they are important and were mentioned by the stakeholders –

COASTAL follows a multi-disciplinary approach. Human behaviour (for example 'Social Cohesion') can be quantified on a 0-100 range, equations replaced with graphical functions. This is very common in stock-flow modelling and always better than leaving out these variables (Sterman, 2001).

8. What happens if something important is overlooked in the mind map? We add it; it is normal for stakeholders to focus their mind map on what they consider important – system feedback is not their priority. Some interactions are implicitly assumed. The MAL modelling teams should clean up the mind maps into CLDs capturing the feedback explaining the problems raised by the stakeholders.

9. Should our models be developed from scratch? We will develop and exchange generic sub models, which can be adapted to the needs of the MALs to avoid duplicate work and make our modelling task easier. A good generic stock-flow model explains a historic behaviour of the system, is well calibrated, sensitive to changes in scenarios/policy settings, and has some documentation explaining its use.

10. How can we validate our models? The aim is to develop **evidence-based** solutions, using scientific data and expertise. WP4 (System Modelling) and WP2 (Knowledge Transition) will collaborate to collect the data needed to calibrate and validate the system models, set the initial conditions etc. These data will include statistics, but also time series and other output generated with other models. Tests to 'build confidence in the model' may include extreme condition testing, the sensitivity of model results for simplifying the model, and surprising behaviour testing (Forrester & Senge, 1980).

11. Why do we use VenSim? VenSim was already considered during the proposal stage. The free software VenSim PLE and cheap upgrade VenSim PLP are easy to use. For comparison of the functionalities see the comparison table. In addition, there is a free read-only version of VenSim, the VenSim Model Reader. The causal tracing and loop tracing tools of VenSim PLE are useful functionalities, in addition VenSim has functionalities for checking the model and units used (see User Manual). For FCMs we recommend MentalModeller. It's also possible to extract FCMs from a VenSim CLD, for processing in R or MatLab.

12. How will the models be used? System Dynamics models can be used for holistic analysis of systems with feedback, often referred to as 'policy analysis' (Sterman, 2001). Policy analysis is more than just adjusting model parameters, we will use our understanding of the system feedback to compare different solutions. This can also include changes to the feedback (changing model structure by removing or adding loops). The model application will be coordinated with WP3 (Business & Policy solutions) and WP5 (scenarios & transition pathways). Stakeholders can be expected to be more interested in the business and policy

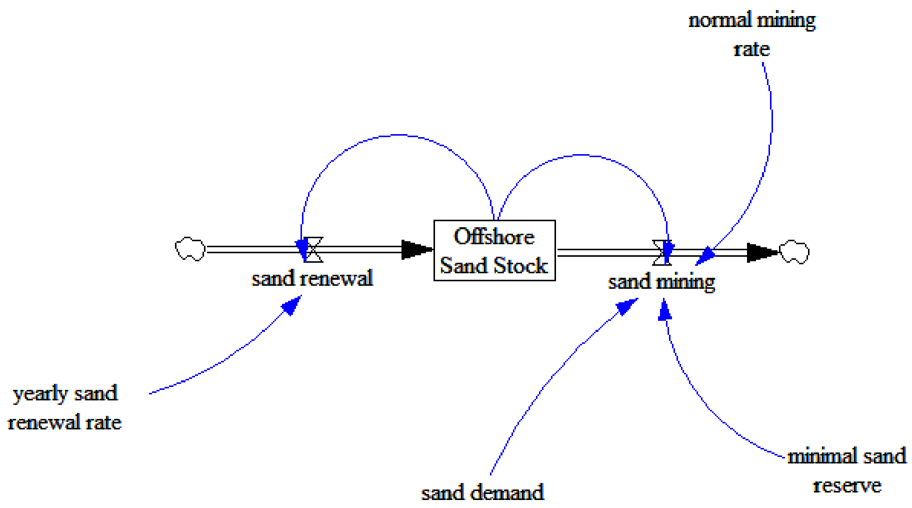
recommendations, i.e. well-documented examples, than the models themselves. Well-polished models could be made available for use with the VenSim Model Reader.

13. How do we avoid duplicate work in the MALs? It's important to control our budget for modelling and data collection. The COASTAL website and knowledge exchange platform will be used to exchange expertise, test models and used as a modelling forum. Project Task 4.3 is aimed at developing the generic structures – model constructs which can easily be exchanged and used for a different purpose (for example, a demand-supply model).

14. When should our models be ready? The sooner we start modelling the better – it is unavoidable that we will run into problems and by doing so we'll gradually be learn from our experiences and be able to improve the models. Task 4.2 runs until project month 36 (April 2021). We have two milestones: the completion of the pilot models (April 2020) and the operational models which should be ready for use by WP1 and WP3 by March 2021.

The following table with an example model was sent to participants in November 2019. They were requested to inventorise the variables in their models.

Example: sand mining model



MAL	Topic	Stock variable (identify one)	Incoming driver	Flow variables	Parameters	Time resolution & horizon
1	Sand Mining	Sand Stock (ton)	Sand demand (ton/yr)	Sand renewal (ton/yr); Sand mining (ton/yr)	Sand renewal rate (1/year); normal sand mining rate (ton/year)	Month; (2020-2050)

YOUR MODEL:

MAL	Topic	Stock variable (identify one)	Incoming driver	Flow variables	Parameters	Time resolution & horizon

Annex 2 Model checklist

This is the result of the self-assessment by the MALs of their models in April 2021. Green fields indicate that the MAL considered this aspect covered, range is for those points not covered (yet). Aspects that were considered not be relevant by the MAL were left blank.

		MAL01-Polder	MAL01-Decommissioning	MAL02-Lagoon	MAL02-Agriculture	MAL02-Tourism	MAL03	MAL04-Shellfish	MAL04-Agriculture	MAL04-Water	MAL04-Infrastructure	MAL05-Tourism	MAL05-Fish Farming	MAL05-Ecofarming	MAL06
Model Scope	to what degree does the model adequately cover the problems and solutions raised by the stakeholders?	2	3	3	3	3	3	3	4	3	3	3	3	3	5
	is the model a system model or is it already linked to other submodels?	yes	no	no	no	no	yes	no	no	no	no	no	no	no	yes
Model structure	all relevant stocks are available with measurable units	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	all flow variables are available with measurable units	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	all relevant indicators are available with measurable units	yes	yes	yes	no	no	no	yes	yes	yes	no	no	no	no	yes
	model can calculate policy indicators related to EU Green Deal and/or Blue Growth Strategy	yes	yes		yes	yes	no	yes	yes	yes		yes	yes	yes	yes
	model boundaries and input variables are fixed with units	yes	yes	yes	yes	yes	yes	yes	yes	no	no	yes	yes	yes	yes
	model feedback structure of interactions is fixed	yes	yes	yes	yes	yes	yes	yes	no	yes	no	no	no	no	yes
	sub-models are integrated by connecting views (if relevant)	yes	yes		yes	yes	yes	yes	yes	no	yes	no	no	no	no
	level of model detail is acceptable for stakeholders	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	level of detail is balanced throughout the model	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Quantification and data	all interactions are quantified with equations and/or look-up functions	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	no	yes
	model uses real data where possible	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	initial conditions for all stock variables are determined	yes	yes	yes	yes	yes	yes	yes	yes	no	no	yes	yes	yes	yes
	values for systemic limits, time horizon and time delays, and other parameters are quantified as model inputs or auxiliary variables	yes	yes	no			yes	yes		no	no	yes	yes	yes	yes
	time series for model input are used by model (if relevant)	yes	yes	yes		yes	no	yes	yes	yes	no	yes	yes	yes	yes
	scenarios for model input are used by model	yes	no	yes		no	no	yes	yes	yes	yes	yes	no	yes	yes
Model behavior & testing	model runs without error messages	yes	yes	yes		yes	yes	yes	yes	no	yes	yes	yes	yes	yes
	model runs without technical anomalies (no technical errors)	yes	yes	yes		yes	yes	yes	no	no	no	yes	yes	yes	yes
	model runs without policy anomalies (incorrect impacts/behaviors)	yes	yes	yes			yes	yes	no	no	no	yes	yes	yes	yes
Visualization/documentation	dashboard is used for quick access to indicators and controls	yes	yes		no	no	no	yes	yes	yes	yes	no	no	no	yes
	model graphic is acceptable for interactive use	yes	yes	yes			no	yes		yes	yes	yes	yes	yes	yes
	all equations and variables are documented with comment	no	no	no	no	no	no	yes		no	no	no	no	no	yes
	all data is documented with source where relevant	no	no		no	yes	yes	yes		no	no	yes	yes	yes	yes
	presentation for model structure and functionalities is available	yes	yes	yes	no	no	no	yes	yes	yes	yes	yes	yes	yes	yes
Validation	stakeholders examined model structure with feedback	yes	yes	yes	yes	yes	yes	yes	yes	no	no	yes	yes	yes	yes
	stakeholders examined model behavior with feedback	yes	yes	yes	no	no	no	yes	no	no	no	no	no	no	no

Annex 3 Guidelines for confidence building

Following Forrester and Senge (1979) model validation was referred to as “confidence building” to distinguish the process from classical validation approaches used for numerical and thematic models (such as statistical testing). Depending on the status of the modelling (Figure 103) the confidence building process can focus on:

- **Model Structure**: verifying feedback structure, parameters and settings, extreme condition testing beyond normal operating range, model boundaries, consistency of dimensions in equations (VenSim unit check);
- **Model Behavior**: problem symptom generation, predictive patterns and events, behavior anomalies, surprising behavior, extreme policy testing, boundary adequacy testing, sensitivity testing, … ;
- **Policy Testing**: real system improvement (e.g. covid-19), plausibility of policy impact on behavior, correspondence between model boundaries and policy recommendations, parameter sensitivity of policy recommendations

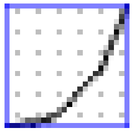
FOCUS OF TEST	Causal Loop Diagrams	Stock-Flow structures	Model running	Model applied
STRUCTURE	■	■		
BEHAVIOR			■	■
POLICY				■

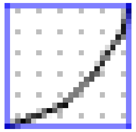
Figure 103: Focus of the confidence building process as related to the progress made in the policy modelling cycle.

Annex 4a Overview of equations MAL01 – Belgium

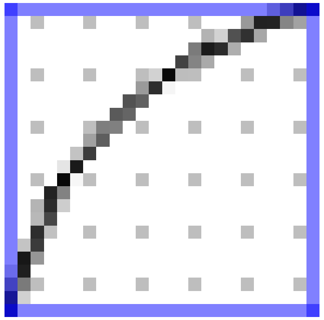
Oudland polder model

	Equation	Properties	Units	Documentation
LAND_USE_CHANGE:				
Agricultural_Land_Cover(t)	Agricultural_Land_Cover(t - dt) + (Agricultural_Land_Cover_net_flow) * dt	INIT Agricultural_Land_Cover = initial_agricultural_land_cover	ha	
Agricultural_Land_Cover_net_flow	(IF -nature_development-urban_sprawl < 0 THEN (-nature_development-urban_sprawl)/impact_of_suitability_agriculture ELSE (-nature_development-urban_sprawl)*impact_of_suitability_agriculture)		ha/Month	
agricultural_production_index	(1-degree_of_water_to_land_subsystem_feedback+degree_of_water_to_land_subsystem_feedback*impact_of_suitability_agriculture)*(Agricultural_Land_Cover/initial_agricultural_land_cover)*initial_production_index		Dmnl	
Average_Farm_Size(t)	Average_Farm_Size(t - dt) + (farm_size_increase) * dt	INIT Average_Farm_Size = initial_farm_size	ha/farm	
coastal_tourism_employment_growth_rate	0{GET_XLS_CONSTANTS('polder.xlsx','constanten','L45')}		1/Month	
degree_of_water_to_land_subsystem_feedback	0		Dmnl	
farm_size_2050_SSP1	0{GET_XLS_CONSTANTS('polder.xlsx','constanten','C50')}		ha/farm	

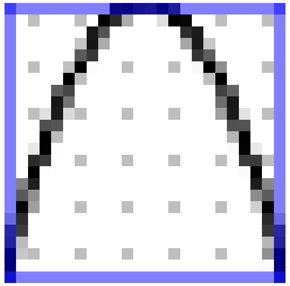
farm_size_2050_SSP2	0{GET_XLS_CONSTANTS('polder.xlsx','constanten','C51')}		ha/farm	
farm_size_2050_SSP4	0{GET_XLS_CONSTANTS('polder.xlsx','constanten','C52')}		ha/farm	
farm_size_2050_SSP5	0{GET_XLS_CONSTANTS('polder.xlsx','constanten','C53')}		ha/farm	
farm_size_increase	(IF ruimtescenario = 1 THEN farm_size_increase_rate*Average_Farm_Size*(1-(Average_Farm_Size/farm_size_2050_SSP1)) ELSE (IF ruimtescenario = 2 THEN farm_size_increase_rate*Average_Farm_Size*(1-(Average_Farm_Size/farm_size_2050_SSP2)) ELSE (IF ruimtescenario = 3 THEN farm_size_increase_rate*Average_Farm_Size*(1-(Average_Farm_Size/farm_size_2050_SSP4)) ELSE farm_size_increase_rate*Average_Farm_Size*(1-(Average_Farm_Size/farm_size_2050_SSP5)))))		ha/(farm*Month)	
farm_size_increase_rate	0{GET_XLS_CONSTANTS('polder.xlsx','constanten','C55')}		1/Month	
gentrification	gentrification_rate*Number_of_Gentrified_Farms*(1-(Number_of_Gentrified_Farms/maximum_number_of_gentrified_farms))*impact_of_landscape_quality_on_gentrification		farm/Month	
gentrification_rate	0,005		1/Month	
ha_to_m2	10000		m*m/ha	
impact_of_landscape_quality_on_gentrification	GRAPH(rural_landscape_quality) Points: (0,0, 1,000), (20,7792, 1,36842), (22,0779, 1,11579), (36,1039, 1,7193), (54,2857, 3,01754), (77,9221, 5,15789), (100,0, 10,1053)		Dmnl	

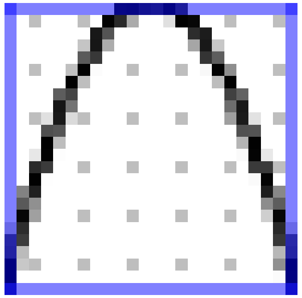
impact_of_landscape_quality_on_rural_tourism_development	GRAPH(rural_landscape_quality) Points: (0,0, 0,500), (17,4026, 1,12281), (47,7922, 2,24561), (70,6494, 4,45614), (92,7273, 7,54386), (100,0, 10,000)		Dmnl	
impermeable_area	0{GET_XLS_DATA('polder.xlsx','WATER_TS','D','J3')}		m*m	Time series based on "Ruimtemodel Vlaanderen", refers to area OUTSIDE the polder which is sealed surface and from which water can be collected to be used as water supply for the polder
initial_agricultural_land_cover	0{GET_XLS_CONSTANTS('polder.xlsx','LAND_USE_CHANGE','C3')}		ha	
initial_coastal_tourism_employment	0{GET_XLS_CONSTANTS('polder.xlsx','constanten','C47')}		FTE	
initial_farm_size	0{GET_XLS_CONSTANTS('polder.xlsx','constanten','C54')}		ha/farm	
initial_natural_land_cover	0{GET_XLS_CONSTANTS('polder.xlsx','LAND_USE_CHANGE','D3')}		ha	
initial_number_of_gentrified_farms	0{GET_XLS_CONSTANTS('polder.xlsx','constanten','C45')}		farm	
initial_number_of_standard_farms	0{GET_XLS_CONSTANTS('polder.xlsx','constanten','C44')}		farm	
initial_production_index	0{GET_XLS_CONSTANTS('polder.xlsx','constanten','C56')}		Dmnl	
initial_residential_land_cover	0{GET_XLS_CONSTANTS('polder.xlsx','LAND_USE_CHANGE','B3')}		ha	
initial_rural_tourism_employment	0{GET_XLS_CONSTANTS('polder.xlsx','constanten','C46')}		FTE	
initial_year	2013		Year	
maximum_coastal_tourism_employment	0{GET_XLS_CONSTANTS('polder.xlsx','constanten','G46')}		FTE	

maximum_number_of_gentrified_farms	0{GET_XLS_CONSTANTS('polder.xlsx','constanten','G44')}		farm	
maximum_potential_natural_land_cover	0{GET_XLS_CONSTANTS('polder.xlsx','constanten','G47')}		ha	
maximum_rural_tourism_employment	0{GET_XLS_CONSTANTS('polder.xlsx','constanten','G45')}		FTE	
Months_per_year	12		Month/Year	
Natural_Land_Cover(t)	Natural_Land_Cover(t - dt) + (Natural_Land_Cover_net_flow) * dt	INIT Natural_Land_Cover = initial_natural_land_cover	ha	
Natural_Land_Cover_net_flow	(IF nature_development < 0 THEN nature_development/impact_of_suitability_nature ELSE nature_development*impact_of_suitability_nature)		ha/Month	
nature_development	(IF ruimtescenario = 1 THEN LOOKUP(nature_devt_SSP1; TIME/STARTTIME) ELSE (IF ruimtescenario = 2 THEN LOOKUP(nature_devt_SSP4; TIME/STARTTIME) ELSE (IF ruimtescenario = 3 THEN LOOKUP(nature_devt_SSP2; TIME/STARTTIME) ELSE LOOKUP(nature_devt_SSP5; TIME/STARTTIME))))		ha/Month	
nature_devt_SSP1	0{GET_XLS_LOOKUPS('polder.xlsx','LAND_USE_CHANGE','F3:F11','H3:H11')}		ha/Month	scenario Anti-Urban-Sprawl (AUS) coupled to SSP1
nature_devt_SSP2	0{GET_XLS_LOOKUPS('polder.xlsx','LAND_USE_CHANGE','F15:F23','H15:H23')}		ha/Month	Scenario Business-As-Usual (BAU) coupled to SSP2
nature_devt_SSP4	0{GET_XLS_LOOKUPS('polder.xlsx','LAND_USE_CHANGE','F27:F35','H27:H35')}		ha/Month	cenario Growth-As-Usual (GAU) coupled to SSP4

nature_devt_SSP5	0{GET_XLS_LOOKUPS('polder.xlsx','LAND_USE_CHANGE','F39:F47','H39:H47')}		ha/Month	scenario Beleidsplan Ruimte Vlaanderen (Policy Plan Space Flanders or BRV) coupled to SSP5
Number_of_Gentrified_Farms(t)	Number_of_Gentrified_Farms(t - dt) + (gentrification) * dt	INIT Number_of_Gentrified_Farms = initial_number_of_gentrified_farms	farm	
Number_of_Standard_Farms(t)	Number_of_Standard_Farms(t - dt) + (- gentrification - upscaling_loss) * dt	INIT Number_of_Standard_Farms = initial_number_of_standard_farms	farm	
PolderArea	PolderAreaAgriculture+PolderAreaNature		m*m	
PolderAreaAgriculture	ha_to_m2*Agricultural_Land_Cover		m*m	conversion ha to m2
PolderAreaNature	ha_to_m2*Natural_Land_Cover		m*m	Conversion ha to m2
Residential_Land_Cover(t)	Residential_Land_Cover(t - dt) + (urban_sprawl) * dt	INIT Residential_Land_Cover = initial_residential_land_cover	ha	~ :SUPPLEMENTARY
return_period	12		Month	
ruimtescenario	4		Dmnl	1=Anti-Urban Sprawl (AUS/SSP1); 2= Growth-As-Usual (GAU/SSP4); 3=Business-As-Usual (BAU/SSP2); 4=Beleidsplan Ruimte Vlaanderen (BRV/SSP5)
rural_landscape_quality	GRAPH((1-degree_of_water_to_land_subsystem_feedback+degree_of_water_to_land_subsystem_feedback*impact_of_suitability_nature)*(Natural_Land_Cover-initial_natural_land_cover)/(maximum_potential_natural_land_cover-initial_natural_land_cover)) Points: (0,000, 25,00), (0,0623377, 38,5965), (0,155844, 53,3333), (0,394805, 74,0351), (0,646753, 88,7719), (0,828571, 95,7895), (1,000, 100,00)		Dmnl	

rural_tourism_employment_increase_rate	0{GET_XLS_CONSTANTS('polder.xlsx','constanten','L44')}		1/Month	
upscaling_loss	Number_of_Standard_Farms*farm_size_increase/Average_Farm_Size		farm/Month	
urban_sprawl	(IF ruimtescenario = 1 THEN LOOKUP(urban_sprawl_SSP1; TIME/STARTTIME) ELSE (IF ruimtescenario = 2 THEN LOOKUP(urban_sprawl_SSP4; TIME/STARTTIME) ELSE (IF ruimtescenario = 3 THEN LOOKUP(urban_sprawl_SSP2; TIME/STARTTIME) ELSE LOOKUP(urban_sprawl_SSP5; TIME/STARTTIME))))		ha/Month	
urban_sprawl_SSP1	0{GET_XLS_LOOKUPS('polder.xlsx','LAND_USE_CHANGE','F3:F11','G3:G11')}		ha/Month	scenario Anti-Urban-Sprawl (AUS) coupled to SSP1
urban_sprawl_SSP2	0{GET_XLS_LOOKUPS('polder.xlsx','LAND_USE_CHANGE','F15:F23','G15:G23')}		ha/Month	Scenario Business-As-Usual (BAU) coupled to SSP2
urban_sprawl_SSP4	0{GET_XLS_LOOKUPS('polder.xlsx','LAND_USE_CHANGE','F27:F35','G27:G35')}		ha/Month	scenario Growth-As-Usual (GAU) coupled to SSP4
urban_sprawl_SSP5	0{GET_XLS_LOOKUPS('polder.xlsx','LAND_USE_CHANGE','F39:F47','G39:G47')}		ha/Month	scenario Beleidsplan Ruimte Vlaanderen (Policy Plan Space Flanders or BRV) coupled to SSP5
year	initial_year+((TIME-STARTTIME)/Months_per_year)		Year	conversion simulation time in month to actual year ~ :SUPPLEMENTARY
Suitability:				
GWLDepthAgriculture	top_soil_level-Polder_GWLevel_Agriculture		m	
GWLDepthNature	top_soil_level-Polder_GWlevel_Nature		m	
GWLRatioAgriculture	GWLDepthAgriculture/optimallGWLDepthAgriculture		Dmnl	A measure for the suitability for agriculte

GWLRatioNature	GWLDepthNature/optimalGWLDepthNature		Dmnl	
impact_of_suitability_agriculture	(MAX(minimumSuitability; suitabilityAgriculture))^sensitivity_suitability_agriculture		Dmnl	
impact_of_suitability_nature	(MAX(minimumSuitability; suitabilityNature))^sensitivity_suitability_nature		Dmnl	
minimumSuitability	0,01		Dmnl	A technical pparameter > 0 to prevent dividing by 0 later on
optimalGWLDepthNature	top_soil_level-optimal_GW_Level_Nature			
optimallGWLDepthAgriculture	top_soil_level-optimal_GW_level_Agriculture		m	
sensitivity_suitability_agriculture	0,5		Dmnl	
sensitivity_suitability_nature	0,5		Dmnl	
suitabilityAgriculture	GRAPH(MAX(0; MIN(2; GWLRatioAgriculture))) Points: (0,000, 0,000), (0,050, 0,098), (0,100, 0,190), (0,150, 0,278), (0,200, 0,360), (0,250, 0,438), (0,300, 0,510), (0,350, 0,577), (0,400, 0,640), (0,450, 0,698), (0,500, 0,750), (0,550, 0,798), (0,600, 0,840), (0,650, 0,878), (0,700, 0,910), (0,750, 0,938), (0,800, 0,960), (0,850, 0,978), (0,900, 0,990), (0,950, 0,997), (1,000, 1,000), (1,050, 0,998), (1,100, 0,990), (1,150, 0,978), (1,200, 0,960), (1,250, 0,938), (1,300, 0,910), (1,350, 0,878), (1,400, 0,840), (1,450, 0,798), (1,500, 0,750), (1,550, 0,698), (1,600, 0,640), (1,650, 0,577), (1,700, 0,510), (1,750, 0,438), (1,800, 0,360), (1,850, 0,278), (1,900, 0,190), (1,950, 0,098), (2,000, 0,000)			

suitabilityNature	GRAPH(MAX(0; MIN(2; GWLRatioNature))) Points: (0,000, 0,000), (0,050, 0,098), (0,100, 0,190), (0,150, 0,278), (0,200, 0,360), (0,250, 0,438), (0,300, 0,510), (0,350, 0,577), (0,400, 0,640), (0,450, 0,698), (0,500, 0,750), (0,550, 0,798), (0,600, 0,840), (0,650, 0,878), (0,700, 0,910), (0,750, 0,938), (0,800, 0,960), (0,850, 0,978), (0,900, 0,990), (0,950, 0,997), (1,000, 1,000), (1,050, 0,998), (1,100, 0,990), (1,150, 0,978), (1,200, 0,960), (1,250, 0,938), (1,300, 0,910), (1,350, 0,878), (1,400, 0,840), (1,450, 0,798), (1,500, 0,750), (1,550, 0,698), (1,600, 0,640), (1,650, 0,577), (1,700, 0,510), (1,750, 0,438), (1,800, 0,360), (1,850, 0,278), (1,900, 0,190), (1,950, 0,098), (2,000, 0,000)			
top_soil_level	0{GET_XLS_CONSTANTS('polder.xlsx','constanten','C28')}		m	
WATER:				
ActualDivDesiredDischarge_Agr	(IF desired_discharge_Agriculture > 0 THEN discharge_from_polder_Agriculture/desired_discharge_Agriculture ELSE 1)		Dmnl	~ :SUPPLEMENTARY
ActualDivDesiredDischarge_Nature	(IF desired_discharge_Nature > 0 THEN discharge_from_polder_Nature/desired_discharge_Nature ELSE 1)		Dmnl	~ :SUPPLEMENTARY
buffer_in_capacity	0{GET_XLS_CONSTANTS('polder.xlsx','constanten','C11')}		m*m*m	eventueel kan een bepaalde hoeveelheid van de watertoevoer voor de polder tijdelijk worden opgeslagen
buffer_inflow_rate	water_available_each_month_for_polder		m*m*m/Month	

buffer_loss_and_not_used	MAX(0; Water_Buffer-buffer_in_capacity-(recharge_to_polder_Nature*PolderAreaNature+recharge_to_polder_Agriculture*PolderAreaAgriculture+water_used_for_animals)*OneMonth)/OneMonth		m*m*m/Month	water not used/needed as water supply for the polder is discarded
compartimentation	1		Dmnl	1: fully separated / 0 : fully connected GET XLS CONSTANTS('polder.xlsx','constanten','C31')
cumulative_water_balance_Agr(t)	cumulative_water_balance_Agr(t - dt) + (recharge_agr - discharge_agr) * dt	INIT cumulative_water_balance_Agr = 0	m	~ :SUPPLEMENTARY
cumulative_water_balance_Nature(t)	cumulative_water_balance_Nature(t - dt) + (recharge_nature - discharge_nature) * dt	INIT cumulative_water_balance_Nature = 0	m	~ :SUPPLEMENTARY
desired_discharge_Agriculture	MAX((differenceDesiredLevelAgr*SpecificYield)/OneMonth+Ef_P_Agr; 0)		m/Month	differenceDesiredAgr > 0 means that discharge is needed
desired_discharge_Nature	MAX((differenceDesiredLevelNat*SpecificYield)/OneMonth+ef_P_Nat; 0)		m/Month	differenceDesiredNat > 0 means that discharge is needed
Desired_GW_level_Agr	optimal_GW_level_Agriculture+ABS(QualityWaterManagement-1)*UNIFORM(-1*ABS(optimal_GW_level_Agriculture-Polder_GWLevel_Agriculture); ABS(optimal_GW_level_Agriculture-Polder_GWLevel_Agriculture); 0)		m	
Desired_GW_level_Nature	optimal_GW_Level_Nature+ABS(QualityWaterManagement-1)*UNIFORM(-1*ABS(optimal_GW_Level_Nature-Polder_GWlevel_Nature); ABS(optimal_GW_Level_Nature-Polder_GWlevel_Nature); 0)		m	

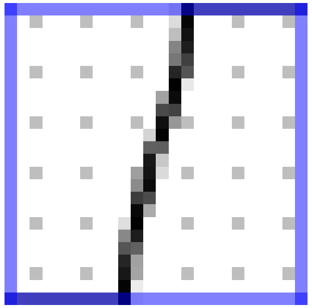
desired_recharge_Agriculture	MAX((-differenceDesiredLevelAgr*SpecificYield)/OneMonth-Ef_P_Agr; 0)		m/Month	differenceDesiredDepthAGr < 0 : recharge needed
desired_recharge_Nature	MAX((-differenceDesiredLevelNat*SpecificYield)/OneMonth-ef_P_Nat; 0)		m/Month	differenceDesiredDepthNat < 0 : recharge needed
differenceDesiredLevelAgr	Polder_GWLevel_Agriculture-Desired_GW_level_Agr		m	-: polder GW level below optimal level: recharge needed +: polder GW level above optimal level: discharge needed
differenceDesiredLevelNat	Polder_GWlevel_Nature-Desired_GW_level_Nature		m	-: polder GW level below optimal level: recharge needed +: polder GW level above optimal level: discharge needed
discharge_agr	discharge_from_polder_Agriculture		m/Month	
discharge_from_polder_Agriculture	MIN(desired_discharge_Agriculture; WaterRemovalCapacity/PolderArea)		m/Month	water removed per month from polder area designated to agriculture
discharge_from_polder_Nature	MIN(desired_discharge_Nature; (WaterRemovalCapacity/PolderArea))		m/Month	water removed per month from polder area designated to nature
discharge_nature	discharge_from_polder_Nature		m/Month	
dischargeDesired	desired_discharge_Agriculture*PolderAreaAgriculture+desired_discharge_Nature*PolderAreaNature		m*m*m/Month	
Ef_P_Agr	precipitation-ET_agriculture		m/Month	
ef_P_Nat	precipitation-ET_nature		m/Month	

Flow_from_Nat2Agr	(IF only_to_nature = 0 THEN (Polder_GWlevel_Nature-Polder_GWLevel_Agriculture)*(1-compartimentation)/OneMonth ELSE MAX(0; (Polder_GWLevel_Agriculture-Polder_GWlevel_Nature)*(1-compartimentation)/OneMonth))		m/Month	
FlowResistance	0,1		Month	Flow resistance is time for unit displacement with with unit gradient Assuming a constant resistance should vary with gradient (difference groundwater level/canal level and distance between canals) + soil type GET XLS CONSTANTS('polder.xlsx', 'constanten', 'C30')
InitialPolderGWDepthAgriculture	0{GET_XLS_CONSTANTS('polder.xlsx','constanten','C26')}		m	Initial polder groundwater head in areas designated to agriculture
InitialPolderGWDepthNature	0{GET_XLS_CONSTANTS('polder.xlsx','constanten','C27')}		m	Initial polder groundwater head in areas designated to nature
OneMonth	1		Month	
only_to_nature	0		Dmnl	
optimal_GW_level_Agriculture	0{GET_XLS_DATA('polder.xlsx',_'WATER_TS','D',_'K3')}		m	optimal groundwater level assuming an agriculture oriented management
optimal_GW_Level_Nature	0{GET_XLS_DATA('polder.xlsx',_'WATER_TS','D',_'L3')}		m	optimal ground water level or head for nature
Polder_GWLevel_Agriculture(t)	Polder_GWLevel_Agriculture(t - dt) + (Polder_GWLevel_Agriculture_net_flow) * dt	INIT Polder_GWLevel_Agriculture = InitialPolderGWDepthAgriculture	m	polder GW level is defined as head in m: increase in discharge results in lower head

Polder_GWLevel_Agriculture_net_flow	(DELAY1(recharge_to_polder_Agriculture-discharge_from_polder_Agriculture+Flow_from_Nat2Agr; FlowResistance)+Ef_P_Agr)/SpecificYield		m/Month	
Polder_GWlevel_Nature(t)	Polder_GWlevel_Nature(t - dt) + (Polder_GWlevel_Nature_net_flow) * dt	INIT Polder_GWlevel_Nature = InitialPolderGWDepthNature	m	polder GW level is defined as head in m: increase in discharge result in lower head
Polder_GWlevel_Nature_net_flow	(DELAY1(recharge_to_polder_Nature-discharge_from_polder_Nature-Flow_from_Nat2Agr; FlowResistance)+ef_P_Nat)/SpecificYield		m/Month	
QualityWaterManagement	1		Dmnl	
recharge_agr	recharge_to_polder_Agriculture+Ef_P_Agr		m/Month	
recharge_nature	recharge_to_polder_Nature+ef_P_Nat		m/Month	
recharge_to_polder_Agriculture	MIN(desired_recharge_Agriculture+discharge_from_polder_Agriculture; ((Water_Buffer/OneMonth)/(PolderAreaAgriculture))*(desired_recharge_Agriculture*PolderAreaAgriculture/rechargeDesired))		m/Month	water added per month from outside polder to fulfill water demand from agriculture
recharge_to_polder_Nature	MIN(desired_recharge_Nature+discharge_from_polder_Nature; (Water_Buffer/(PolderAreaNature*OneMonth))*(desired_recharge_Nature*PolderAreaNature/rechargeDesired))		m/Month	water added per month from outside polder to fulfill water demand from nature
recharge_volume_agriculture	PolderAreaAgriculture*recharge_to_polder_Agriculture		m*m*m/Month	~ :SUPPLEMENTARY
recharge_volume_nature	PolderAreaNature*recharge_to_polder_Nature		m*m*m/Month	
RechargeDeficitAgr	MAX(desired_recharge_Agriculture-recharge_to_polder_Agriculture; 0)*PolderAreaAgriculture		m*m*m/Month	~ :SUPPLEMENTARY

RechargeDeficitNature	MAX(desired_recharge_Nature-recharge_to_polder_Nature; 0)*PolderAreaNature		m*m*m/Month	~ :SUPPLEMENTARY
rechargeDesired	animal_drinking_water_required+desired_recharge_Agriculture*PolderAreaAgriculture+desired_recharge_Nature*PolderAreaNature		m*m*m/Month	
SpecificYield	0{GET_XLS_CONSTANTS('polder.xlsx','constanten','C29')}		1	the specific yield is the amount of water released per unit of head change
Water_Buffer(t)	Water_Buffer(t - dt) + (Water_Buffer_net_flow) * dt	INIT Water_Buffer = buffer_in_capacity/2	m*m*m	to disconnect the supply from the demand and at the same time allow for buffering
Water_Buffer_net_flow	buffer_inflow_rate-buffer_loss_and_not_used-recharge_to_polder_Agriculture*PolderAreaAgriculture-recharge_to_polder_Nature*PolderAreaNature-water_used_for_animals		m*m*m/Month	
water_used_for_animals	MIN(animal_drinking_water_required; (Water_Buffer/OneMonth)*(animal_drinking_water_required/rechargeDesired))		m*m*m/Month	
waterAvailableForPolder:				
Climate_Scenario	0		Dmnl	
discharge_canal	0{GET_XLS_DATA('polder.xlsx','WATER_TS','D','H3')}		m*m*m/Month	
fraction_recovered_for_polder	0{GET_XLS_CONSTANTS('polder.xlsx', 'constanten','C10')}		Dmnl	fraction of water recoveerd from sealed surfaces (caravan park Bredene) actually used for the polder
fraction_WWTP_for_polder	0{GET_XLS_CONSTANTS('polder.xlsx','constanten','C8')}		Dmnl	fraction WWTP discharge used for polder
maximum_canal_discharge	1e+08		m*m*m/Month	

minimum_canal_discharge	0{GET_XLS_CONSTANTS('polder.xlsx','constanten','C5')}		m*m*m/Month	minimum canal discharge to avoid salinification
month_index	INT(MODULO((TIME-STARTTIME)/DT; 12)+1+0,5)		Dmnl	OLD CODE 1+MIN(12,MAX(0,INTEGER(MODULO(12*(Time-INITIAL TIME),12)))) ~ :SUPPLEMENTARY
precipitation	(IF Climate_Scenario = 0 THEN precipitation_0 ELSE 2*precipitation_1)		m/Month	precipitation
precipitation_0	0{GET_XLS_DATA('polder.xlsx','WATER_TS','D','E3')}		m/Month	precipitation
precipitation_1	0{GET_XLS_DATA('polder.xlsx','WATER_TS','D','N3')}		m/Month	precipitation
required_for_water_production	0{GET_XLS_CONSTANTS('polder.xlsx','constanten','C6')}		m*m*m/Month	drinking water production from canal
water_available_each_month_for_polder	water_available_each_month_for_polder_from_canal+water_available_each_month_for_polder_from_sealed_surface+water_available_each_month_for_polder_from_WWTP		m*m*m/Month	
water_available_each_month_for_polder_from_canal	0*MAX(MIN(maximum_canal_discharge; discharge_canal)-minimum_canal_discharge-required_for_water_production; 0)		m*m*m/Month	
water_available_each_month_for_polder_from_sealed_surface	fraction_recovered_for_polder*impermeable_area*precipitation		m*m*m/Month	
water_available_each_month_for_polder_from_WWTP	fraction_WWTP_for_polder*WWTP_discharge		m*m*m/Month	
WWTP_discharge	0{GET_XLS_DATA('polder.xlsx', 'WATER_TS', 'D', 'I3')}		m*m*m/Month	water discharge from WWTP (RWZI)

waterRemovalFromPolder:				
animal_drinking_water_required	0{GET_XLS_DATA('polder.xlsx', 'WATER_TS', 'D', 'M3')}		m*m*m/Month	water needed for animals in the polder area
DischargeLevel	MIN(Polder_GWLevel_Agriculture; Polder_GWlevel_Nature)		m	Level from which discharge takes place As the whole system is interconnected this will be lowest level in the polder (= min level(agr, nat)
ET_agriculture	(IF Climate_Scenario = 0 THEN ET_agriculture_0 ELSE ET_agriculture_1)		m/Month	evapotranspiration from agriculture areas in polder
ET_agriculture_0	0{GET_XLS_DATA('polder.xlsx','WATER_TS' ,'D','G3')}		m/Month	evapotranspiration from agriculture areas in polder
ET_agriculture_1	0{GET_XLS_DATA('polder.xlsx','WATER_TS' ,'D','P3')}		m/Month	evapotranspiration from agriculture areas in polder
ET_nature	(IF Climate_Scenario = 0 THEN ET_nature_0 ELSE ET_nature_1)		m/Month	evapotranspiration from natural areas in polder
ET_nature_0	0{GET_XLS_DATA('polder.xlsx','WATER_TS' ,'D','F3')}		m/Month	evapotranspiration from natural areas in polder
ET_nature_1	0{GET_XLS_DATA('polder.xlsx','WATER_TS' ,'D','O3')}		m/Month	evapotranspiration from natural areas in polder
FractionTimeAvailableDischarge	GRAPH((DischargeLevel-sea_level+sea_level_correction)/unit_level) Points: (-10,00, 0,000), (-2,05, 0,000), (-2,00, 0,0724698), (-1,80, 0,164098), (-1,60, 0,222407), (-1,40, 0,269055), (-1,20, 0,310704), (-1,00, 0,349021), (-0,75, 0,391504), (-0,50, 0,422741), (0,00, 0,500), (0,50, 0,564348), (0,75, 0,605998), (1,00, 0,650979), (1,20, 0,689296), (1,40, 0,730945), (1,60, 0,777593), (1,80, 0,835902), (1,90, 0,874219), (2,00, 0,92753), (2,05, 1,000), (10,00, 1,000)		Dmnl	fraction total time during which polder discharge level is above the sea level taking into account a simple average constant diurnal tidal pattern. pattern assumes a (constant) amplitude of 4.10 m which is based on historical series for Oostende.

GravitationalDischarge	FractionTimeAvailableDischarge*dischargeDesired		m*m*m/Month	
initial_sea_level	2,51		m	
MissingDischargeCapacity	MAX(0; dischargeDesired-WaterRemovalCapacity)		m*m*m/Month	
PumpingCapacity	0{GET_XLS_CONSTANTS('polder.xlsx','constanten','C19')}		m*m*m/Month	pumping capacity for polder water removal
sea_level(t)	sea_level(t - dt) + (sea_level_rise_per_month) * dt	INIT sea_level = initial_sea_level	m	
sea_level_correction	2,8		m	Constant added because the level specified by the model for the sea level and the polder are apparently not compatible and result in a very strong reduction of the polder outflow to sea. Now set by trial and error so that initially there is no reduction of the outflow capacity
"sea_level_increase_2000-2100"	1		m	
sea_level_rise_per_month	0,01*("sea_level_increase_2000-2100"/unit_year)/Months_per_year		m/Month	
unit_level	1		m	unit correction factor for consistency
unit_year	1		Year	
WaterRemovalCapacity	GravitationalDischarge+PumpingCapacity		m*m*m/Month	

Port and Energy Sub model

	Equation	Properties	Units	Documentation
DASHBOARD:				
EMPLOYMENT:				
Employment_Generated	jobs_commissioning+jobs_decommissioning+jobs_maintenance+other_jobs		FTE	~ :SUPPLEMENTARY
jobs_commissioning	Annual_Installations*labor_factor_commissioning*unit_year		FTE	
jobs_decommissioning	Annual_Decommissioning_Rate*labor_factor_decommissioning*unit_year		FTE	
jobs_maintenance	Actual_Number_of_Turbines*labor_factor_maintenance		FTE	
other_jobs	Actual_Number_of_Turbines*labor_factor_other		FTE	
INFRA_&_ENV:				
"Belgian_electricity_demand_2009-2020"	85		TeraWatt*hour/Year	https://www.febeg.be/statistieken-elektriciteit
electricity_demand	(IF TIME < 2020 THEN "Belgian_electricity_demand_2009-2020" ELSE "Belgian_electricity_demand_2009-2020"+(Belgian_direct_electricity_demand_2050-"Belgian_electricity_demand_2009-2020")*(TIME-2020)/(STOPTIME-2020))		TeraWatt*hour/Year	
percentage_demand	100*Energy_Production/electricity_demand		Dmnl	~ :SUPPLEMENTARY
use_of_port_space	(unit_year*Annual_Decommissioning_Rate*port_area_per_decommissioned_turbine+unit_year*Annual_Installations*port_area_per_installed_turbine+Actual_Number_of_Turbines*port_area_per_operational_turbine)/maximum_space_in_port_for_decommissioning_and_services		Dmnl	~ :SUPPLEMENTARY
use_of_space_offshore	LOOKUP(area_per_operational_turbine; TIME/unit_year)*Actual_Number_of_Turbines/maximum_space_for_offshore_wind_energy		Dmnl	~ :SUPPLEMENTARY

INPUT_LOOKUP_FUNCTIONS:				
impact_of_age_on_cost_ratio	0{GET_XLS_LOOKUPS('MAL01_DecomRatev9.xlsx','LOOKUPS','A','B2')}		Dmnl	
INPUT_PARAMETERS:				
Belgian_direct_electricity_demand_2050	0{GET_XLS_CONSTANTS('MAL01_DecomRatev9.xlsx','PARAMETERS','C18')}		TeraWatt*hour/Year	
decommissioning_time	0{GET_XLS_CONSTANTS('MAL01_DecomRatev9.xlsx','PARAMETERS','C3')}		Year	
installation_time	0{GET_XLS_CONSTANTS('MAL01_DecomRatev9.xlsx','PARAMETERS','C2')}		Year	
labor_factor_commissioning	0{GET_XLS_CONSTANTS('MAL01_DecomRatev9.xlsx','PARAMETERS','C15')}		FTE/turbine	
labor_factor_decommissioning	0{GET_XLS_CONSTANTS('MAL01_DecomRatev9.xlsx','PARAMETERS','C14')}		FTE/turbine	
labor_factor_maintenance	0{GET_XLS_CONSTANTS('MAL01_DecomRatev9.xlsx','PARAMETERS','C13')}		FTE/turbine	
labor_factor_other	0{GET_XLS_CONSTANTS('MAL01_DecomRatev9.xlsx','PARAMETERS','C16')}		FTE/turbine	
maximum_space_for_offshore_wind_energy	0{GET_XLS_CONSTANTS('MAL01_DecomRatev9.xlsx','PARAMETERS','C7')}		ha	
maximum_space_in_port_for_decommissioning_and_services	0{GET_XLS_CONSTANTS('MAL01_DecomRatev9.xlsx','PARAMETERS','C8')}		ha	
operational_effectiveness	0{GET_XLS_CONSTANTS('MAL01_DecomRatev9.xlsx','PARAMETERS','C6')}		Dmnl	
port_area_per_decommissioned_turbine	0{GET_XLS_CONSTANTS('MAL01_DecomRatev9.xlsx','PARAMETERS','C10')}		ha/turbine	

port_area_per_installed_turbine	0{GET_XLS_CONSTANTS('MAL01_DecomRatev9.xlsx','PARAMETERS','C11')}		ha/turbine	
port_area_per_operational_turbine	0{GET_XLS_CONSTANTS('MAL01_DecomRatev9.xlsx','PARAMETERS','C12')}		ha/turbine	
yearly_operational_hours	0{GET_XLS_CONSTANTS('MAL01_DecomRatev9.xlsx','PARAMETERS','C4')}		hour/Year	
yearly_power_loss_rate	0{GET_XLS_CONSTANTS('MAL01_DecomRatev9.xlsx','PARAMETERS','C5')}		Dmnl	
INPUT_TIMESERIES:				
MAINTENANCE:				
Actual_LCOE	GRAPH(TIME/unit_year) Points: (2007,00, 80,00), (2008,00, 80,00), (2020,00, 64,00), (2025,00, 60,00), (2029,60, 55,4386), (2036,25, 48,4211), (2041,16, 44,5614), (2045,31, 43,1579), (2049,13, 39,2982), (2050,00, 38,2456)		EUR/(MegaWatt*hour)	Levelized Cost Of Energy in EUR/Megawatt*hour
C0	P0*WF0*yearly_operational_hours*M0*Actual_LCOE		EUR/Year	
C1	P1*WF1*yearly_operational_hours*M1*Actual_LCOE		EUR/Year	
C10	P10*WF10*yearly_operational_hours*M10*Actual_LCOE		EUR/Year	
C11	P11*WF11*yearly_operational_hours*M11*Actual_LCOE		EUR/Year	
C12	P12*WF12*yearly_operational_hours*M12*Actual_LCOE		EUR/Year	
C13	P13*WF13*yearly_operational_hours*M13*Actual_LCOE		EUR/Year	
C14	P14*WF14*yearly_operational_hours*M14*Actual_LCOE		EUR/Year	
C15	P15*WF15*yearly_operational_hours*M15*Actual_LCOE		EUR/Year	
C16	P16*WF16*yearly_operational_hours*M16*Actual_LCOE		EUR/Year	
C17	P17*WF17*yearly_operational_hours*M17*Actual_LCOE		EUR/Year	
C18	P18*WF18*yearly_operational_hours*M18*Actual_LCOE		EUR/Year	
C19	P19*WF19*yearly_operational_hours*M19*Actual_LCOE		EUR/Year	
C2	P2*WF2*yearly_operational_hours*M2*Actual_LCOE		EUR/Year	

C20	P20*WF20*yearly_operational_hours*M20*Actual_LCOE		EUR/Year	
C21	P21*WF21*yearly_operational_hours*M21*Actual_LCOE		EUR/Year	
C22	P22*WF22*yearly_operational_hours*M22*Actual_LCOE		EUR/Year	
C23	P23*WF23*yearly_operational_hours*M23*Actual_LCOE		EUR/Year	
C24	P24*WF24*yearly_operational_hours*M24*Actual_LCOE		EUR/Year	
C25	P25*WF25*yearly_operational_hours*M25*Actual_LCOE		EUR/Year	
C26	P26*WF26*yearly_operational_hours*M26*Actual_LCOE		EUR/Year	
C27	P27*WF27*yearly_operational_hours*M27*Actual_LCOE		EUR/Year	
C28	P28*WF28*yearly_operational_hours*M28*Actual_LCOE		EUR/Year	
C3	P3*WF3*yearly_operational_hours*M3*Actual_LCOE		EUR/Year	
C4	P4*WF4*yearly_operational_hours*M4*Actual_LCOE		EUR/Year	
C5	P5*WF5*yearly_operational_hours*M5*Actual_LCOE		EUR/Year	
C6	P6*WF6*yearly_operational_hours*M6*Actual_LCOE		EUR/Year	
C7	P7*WF7*yearly_operational_hours*M7*Actual_LCOE		EUR/Year	
C8	P8*WF8*yearly_operational_hours*M8*Actual_LCOE		EUR/Year	
C9	P9*WF9*yearly_operational_hours*M9*Actual_LCOE		EUR/Year	
M0	LOOKUP(impact_of_age_on_cost_ratio; 1)		Dmnl	
M1	LOOKUP(impact_of_age_on_cost_ratio; 2)		Dmnl	
M10	LOOKUP(impact_of_age_on_cost_ratio; 11)		Dmnl	
M11	LOOKUP(impact_of_age_on_cost_ratio; 12)		Dmnl	
M12	LOOKUP(impact_of_age_on_cost_ratio; 13)		Dmnl	
M13	LOOKUP(impact_of_age_on_cost_ratio; 14)		Dmnl	
M14	LOOKUP(impact_of_age_on_cost_ratio; 15)		Dmnl	
M15	LOOKUP(impact_of_age_on_cost_ratio; 16)		Dmnl	

M16	LOOKUP(impact_of_age_on_cost_ratio; 17)		Dmnl	
M17	LOOKUP(impact_of_age_on_cost_ratio; 18)		Dmnl	
M18	LOOKUP(impact_of_age_on_cost_ratio; 19)		Dmnl	
M19	LOOKUP(impact_of_age_on_cost_ratio; 20)		Dmnl	
M2	LOOKUP(impact_of_age_on_cost_ratio; 3)		Dmnl	
M20	LOOKUP(impact_of_age_on_cost_ratio; 21)		Dmnl	
M21	LOOKUP(impact_of_age_on_cost_ratio; 22)		Dmnl	
M22	LOOKUP(impact_of_age_on_cost_ratio; 23)		Dmnl	
M23	LOOKUP(impact_of_age_on_cost_ratio; 24)		Dmnl	
M24	LOOKUP(impact_of_age_on_cost_ratio; 24)		Dmnl	
M25	LOOKUP(impact_of_age_on_cost_ratio; 25)		Dmnl	
M26	LOOKUP(impact_of_age_on_cost_ratio; 26)		Dmnl	
M27	LOOKUP(impact_of_age_on_cost_ratio; 27)		Dmnl	
M28	LOOKUP(impact_of_age_on_cost_ratio; 28)		Dmnl	
M3	LOOKUP(impact_of_age_on_cost_ratio; 4)		Dmnl	
M4	LOOKUP(impact_of_age_on_cost_ratio; 5)		Dmnl	
M5	LOOKUP(impact_of_age_on_cost_ratio; 6)		Dmnl	
M6	LOOKUP(impact_of_age_on_cost_ratio; 7)		Dmnl	
M7	LOOKUP(impact_of_age_on_cost_ratio; 8)		Dmnl	
M8	LOOKUP(impact_of_age_on_cost_ratio; 9)		Dmnl	
M9	LOOKUP(impact_of_age_on_cost_ratio; 10)		Dmnl	
Maintenance_Costs	cost_unit_convertor*(C0+C1+C2+C3+C4+C5+C6+C7+C8+C9+C10+C11+C12+C13+C14 +C15+C16+C17+C18+C19+C20+C21+C22+C23+C24+C25+C26+C27+C28)		MEUR/Year	~ :SUPPLEMENTARY

MODEL_STRUCTURE:				
Actual_Number_of_Turbines	WF0+WF1+WF2+WF3+WF4+WF5+WF6+WF7+WF8+WF9+WF10+WF11+WF12+WF13+WF14+WF15+WF16+WF17+WF18+WF19+WF20+WF21+WF22+WF23+WF24+WF25+WF26+WF27+WF28+WF_plus_28		turbine	
ageing_28_plus	(IF decom28 = 0 THEN WF28/unit_year ELSE 0)		turbine/Year	
ageing1	WF0/unit_year		turbine/Year	
ageing10	WF9/unit_year		turbine/Year	
ageing11	WF10/unit_year		turbine/Year	
ageing12	WF11/unit_year		turbine/Year	
ageing13	WF12/unit_year		turbine/Year	
ageing14	WF13/unit_year		turbine/Year	
ageing15	WF14/unit_year		turbine/Year	
ageing16	WF15/unit_year		turbine/Year	
ageing17	WF16/unit_year		turbine/Year	
ageing18	WF17/unit_year		turbine/Year	
ageing19	WF18/unit_year		turbine/Year	
ageing2	WF1/unit_year		turbine/Year	
ageing20	WF19/unit_year		turbine/Year	
ageing21	(IF decom20 = 0 THEN WF20/unit_year ELSE 0)		turbine/Year	
ageing22	(IF decom21 = 0 THEN WF21/unit_year ELSE 0)		turbine/Year	
ageing23	(IF decom22 = 0 THEN WF22/unit_year ELSE 0)		turbine/Year	
ageing24	(IF decom23 = 0 THEN WF23/unit_year ELSE 0)		turbine/Year	
ageing25	(IF decom24 = 0 THEN WF24/unit_year ELSE 0)		turbine/Year	
ageing26	(IF decom25 = 0 THEN WF25/unit_year ELSE 0)		turbine/Year	
ageing27	(IF decom26 = 0 THEN WF26/unit_year ELSE 0)		turbine/Year	

ageing28	(IF decom27 = 0 THEN WF27/unit_year ELSE 0)		turbine/Year	
ageing3	WF2/unit_year		turbine/Year	
ageing4	WF3/unit_year		turbine/Year	
ageing5	WF4/unit_year		turbine/Year	
ageing6	WF5/unit_year		turbine/Year	
ageing7	WF6/unit_year		turbine/Year	
ageing8	WF7/unit_year		turbine/Year	
ageing9	WF8/unit_year		turbine/Year	
Annual_Decommissioning_Rate	decom20+decom21+decom22+decom23+decom24+decom25		turbine/Year	
Annual_Installations	(LOOKUP(turbine_installations_commission_1; year/unit_year)+LOOKUP(turbine_installations_commission_2; year/unit_year))/installation_time		turbine/Year	
Average_Turbine_Age	(IF Actual_Number_of_Turbines > 0 THEN unit_year*(0*WF0+1*WF1+2*WF2+3*WF3+4*WF4+5*WF5+6*WF6+7*WF7+8*WF8+9*WF9+10*WF10+11*WF11+12*WF12+13*WF13+14*WF14+15*WF15+16*WF16+17*WF17+18*WF18+19*WF19+20*WF20+21*WF21+22*WF22+23*WF23+24*WF24+25*WF25)/Actual_Number_of_Turbines ELSE 0)		Year	~ :SUPPLEMENTARY
decom20	(IF year <= STARTTIME+20 THEN 0 ELSE (IF LOOKUP(turbine_life_time; (year-20)/unit_year) = 20 THEN WF20/decommissioning_time ELSE 0))		turbine/Year	
decom21	(IF year <= STARTTIME+21 THEN 0 ELSE (IF LOOKUP(turbine_life_time; (year-21)/unit_year) = 21 THEN WF21/decommissioning_time ELSE 0))		turbine/Year	
decom22	(IF year <= STARTTIME+22 THEN 0 ELSE (IF LOOKUP(turbine_life_time; (year-22)/unit_year) = 22 THEN WF22/decommissioning_time ELSE 0))		turbine/Year	
decom23	(IF year <= STARTTIME+23 THEN 0 ELSE (IF LOOKUP(turbine_life_time; (year-23)/unit_year) = 23 THEN WF23/decommissioning_time ELSE 0))		turbine/Year	
decom24	(IF year <= STARTTIME+24 THEN 0 ELSE (IF LOOKUP(turbine_life_time; (year-24)/unit_year) = 24 THEN WF24/decommissioning_time ELSE 0))		turbine/Year	

decom25	(IF year <= STARTTIME+25 THEN 0 ELSE (IF LOOKUP(turbine_life_time; (year-25)/unit_year) = 25 THEN WF25/decommissioning_time ELSE 0))		turbine/Year	
decom26	(IF year <= STARTTIME+26 THEN 0 ELSE (IF LOOKUP(turbine_life_time; (year-26)/unit_year) = 26 THEN WF26/decommissioning_time ELSE 0))		turbine/Year	
decom27	(IF year <= STARTTIME+27 THEN 0 ELSE (IF LOOKUP(turbine_life_time; (year-27)/unit_year) = 27 THEN WF27/decommissioning_time ELSE 0))		turbine/Year	
decom28	WF28/decommissioning_time		turbine/Year	
Maximum_Turbine_Age	(IF TIME = STARTTIME THEN 0 ELSE (IF WF28 > 0 THEN 28 ELSE (IF WF27 > 0 THEN 27 ELSE (IF WF26 > 0 THEN 26 ELSE (IF WF25 > 0 THEN 25 ELSE (IF WF24 > 0 THEN 24 ELSE (IF WF23 > 0 THEN 23 ELSE (IF WF22 > 0 THEN 22 ELSE (IF WF21 > 0 THEN 21 ELSE (IF WF20 > 0 THEN 20 ELSE (IF WF19 > 0 THEN 19 ELSE (IF WF18 > 0 THEN 18 ELSE (IF WF17 > 0 THEN 17 ELSE (IF WF16 > 0 THEN 16 ELSE (IF WF15 > 0 THEN 15 ELSE (IF WF14 > 0 THEN 14 ELSE (IF WF13 > 0 THEN 13 ELSE (IF WF12 > 0 THEN 12 ELSE (IF WF11 > 0 THEN 11 ELSE (IF WF10 > 0 THEN 10 ELSE (IF WF9 > 0 THEN 9 ELSE (IF WF8 > 0 THEN 8 ELSE (IF WF7 > 0 THEN 7 ELSE (IF WF6 > 0 THEN 6 ELSE (IF WF5 > 0 THEN 5 ELSE (IF WF4 > 0 THEN 4 ELSE (IF WF3 > 0 THEN 3 ELSE (IF WF2 > 0 THEN 2 ELSE (IF WF1 > 0 THEN 1 ELSE (IF WF0 > 0 THEN 0 ELSE 0)		1	~ :SUPPLEMENTARY
Minimum_Turbine_Age	(IF TIME = STARTTIME THEN 0 ELSE (IF WF0 > 0 THEN 0 ELSE (IF WF1 > 0 THEN 1 ELSE (IF WF2 > 0 THEN 2 ELSE (IF WF3 > 0 THEN 3 ELSE (IF WF4 > 0 THEN 4 ELSE (IF WF5 > 0 THEN 5 ELSE (IF WF6 > 0 THEN 6 ELSE (IF WF7 > 0 THEN 7 ELSE (IF WF8 > 0 THEN 8 ELSE (IF WF9 > 0 THEN 9 ELSE (IF WF10 > 0 THEN 10 ELSE (IF WF11 > 0 THEN 11 ELSE (IF WF12 > 0 THEN 12 ELSE (IF WF13 > 0 THEN 13 ELSE (IF WF14 > 0 THEN 14 ELSE (IF WF15 > 0 THEN 15 ELSE (IF WF16 > 0 THEN 16 ELSE (IF WF17 > 0 THEN 17 ELSE (IF WF18 > 0 THEN 18 ELSE (IF WF19 > 0 THEN 19 ELSE (IF WF20 > 0 THEN 20 ELSE (IF WF21 > 0 THEN 21 ELSE (IF WF22 > 0 THEN 22 ELSE (IF WF23 > 0 THEN 23 ELSE (IF WF24 > 0 THEN 24 ELSE (IF WF25 > 0 THEN 25 ELSE (IF WF26 > 0 THEN 26 ELSE (IF WF27 > 0 THEN 27 ELSE (IF WF28 > 0 THEN 28 ELSE 29)		Year	~ :SUPPLEMENTARY
Net_Installations	Annual_Installations-Annual_Decommissioning_Rate		turbine/Year	~ :SUPPLEMENTARY
WF_plus_28(t)	WF_plus_28(t - dt) + (ageing_28_plus) * dt	INIT WF_plus_28 = 0	turbine	
WF0(t)	WF0(t - dt) + (Annual_Installations - ageing1) * dt	INIT WF0 = 0	turbine	new turbines installed as read from XLS
WF1(t)	WF1(t - dt) + (ageing1 - ageing2) * dt	INIT WF1 = 0	turbine	

WF10(t)	WF10(t - dt) + (ageing10 - ageing11) * dt	INIT WF10 = 0	turbine	
WF11(t)	WF11(t - dt) + (ageing11 - ageing12) * dt	INIT WF11 = 0	turbine	
WF12(t)	WF12(t - dt) + (ageing12 - ageing13) * dt	INIT WF12 = 0	turbine	
WF13(t)	WF13(t - dt) + (ageing13 - ageing14) * dt	INIT WF13 = 0	turbine	
WF14(t)	WF14(t - dt) + (ageing14 - ageing15) * dt	INIT WF14 = 0	turbine	
WF15(t)	WF15(t - dt) + (ageing15 - ageing16) * dt	INIT WF15 = 0	turbine	
WF16(t)	WF16(t - dt) + (ageing16 - ageing17) * dt	INIT WF16 = 0	turbine	
WF17(t)	WF17(t - dt) + (ageing17 - ageing18) * dt	INIT WF17 = 0	turbine	
WF18(t)	WF18(t - dt) + (ageing18 - ageing19) * dt	INIT WF18 = 0	turbine	
WF19(t)	WF19(t - dt) + (ageing19 - ageing20) * dt	INIT WF19 = 0	turbine	
WF2(t)	WF2(t - dt) + (ageing2 - ageing3) * dt	INIT WF2 = 0	turbine	
WF20(t)	WF20(t - dt) + (ageing20 - ageing21 - decom20) * dt	INIT WF20 = 0	turbine	
WF21(t)	WF21(t - dt) + (ageing21 - ageing22 - decom21) * dt	INIT WF21 = 0	turbine	
WF22(t)	WF22(t - dt) + (ageing22 - ageing23 - decom22) * dt	INIT WF22 = 0	turbine	
WF23(t)	WF23(t - dt) + (ageing23 - ageing24 - decom23) * dt	INIT WF23 = 0	turbine	
WF24(t)	WF24(t - dt) + (ageing24 - ageing25 - decom24) * dt	INIT WF24 = 0	turbine	
WF25(t)	WF25(t - dt) + (ageing25 - ageing26 - decom25) * dt	INIT WF25 = 0	turbine	
WF26(t)	WF26(t - dt) + (ageing26 - ageing27 - decom26) * dt	INIT WF26 = 0	turbine	
WF27(t)	WF27(t - dt) + (ageing27 - ageing28 - decom27) * dt	INIT WF27 = 0	turbine	
WF28(t)	WF28(t - dt) + (ageing28 - ageing_28_plus - decom28) * dt	INIT WF28 = 0	turbine	
WF3(t)	WF3(t - dt) + (ageing3 - ageing4) * dt	INIT WF3 = 0	turbine	
WF4(t)	WF4(t - dt) + (ageing4 - ageing5) * dt	INIT WF4 = 0	turbine	
WF5(t)	WF5(t - dt) + (ageing5 - ageing6) * dt	INIT WF5 = 0	turbine	
WF6(t)	WF6(t - dt) + (ageing6 - ageing7) * dt	INIT WF6 = 0	turbine	

WF7(t)	WF7(t - dt) + (ageing7 - ageing8) * dt	INIT WF7 = 0	turbine	
WF8(t)	WF8(t - dt) + (ageing8 - ageing9) * dt	INIT WF8 = 0	turbine	
WF9(t)	WF9(t - dt) + (ageing9 - ageing10) * dt	INIT WF9 = 0	turbine	
SPECIFIC_POWER_BY_AGE:				
Average_power	(IF Actual_Number_of_Turbines = 0 THEN 0 ELSE (P0*WF0+P1*WF1+P2*WF2+P3*WF3+P4*WF4+P5*WF5+P6*WF6+P7*WF7+P8*WF8+P9*WF9+P10*WF10+P11*WF11+P12*WF12+P13*WF13+P14*WF14+P15*WF15+P16*WF16+P17*WF17+P18*WF18+P19*WF19+P20*WF20+P21*WF21+P22*WF22+P23*WF23+P24*WF24+P25*WF25)/(WF0+WF1+WF2+WF3+WF4+WF5+WF6+WF7+WF8+WF9+WF10+WF11+WF12+WF13+WF14+WF15+WF16+WF17+WF18+WF19+WF20+WF21+WF22+WF23+WF24+WF25))		MegaWatt/turbine	~ :SUPPLEMENTARY
P0	(IF year = STARTTIME THEN 0 ELSE (IF LOOKUP(turbine_installations_commission_1; (year-1)/unit_year)+LOOKUP(turbine_installations_commission_2; (year-1)/unit_year) > 0 THEN (LOOKUP(initial_turbine_power_commission_1; year/unit_year)*LOOKUP(turbine_installations_commission_1; (year-1)/unit_year)+LOOKUP(initial_turbine_power_commission_2; year/unit_year)*LOOKUP(turbine_installations_commission_2; (year-1)/unit_year))/(LOOKUP(turbine_installations_commission_1; (year-1)/unit_year)+LOOKUP(turbine_installations_commission_2; (year-1)/unit_year)) ELSE 0))		MegaWatt/turbine	weighted average of the two commission based on initial power per turbine and number of turbines for commission
P1	DELAY(P0*(1-yearly_power_loss_rate); 1; 0)		MegaWatt/turbine	
P10	DELAY(P0*(1-10*yearly_power_loss_rate); 10; 0)		MegaWatt/turbine	
P11	DELAY(P0*(1-11*yearly_power_loss_rate); 11; 0)		MegaWatt/turbine	
P12	DELAY(P0*(1-12*yearly_power_loss_rate); 12; 0)		MegaWatt/turbine	
P13	DELAY(P0*(1-13*yearly_power_loss_rate); 13; 0)		MegaWatt/turbine	

P14	DELAY(P0*(1-14*yearly_power_loss_rate); 14; 0)		MegaWatt/turbine	
P15	DELAY(P0*(1-15*yearly_power_loss_rate); 15; 0)		MegaWatt/turbine	
P16	DELAY(P0*(1-16*yearly_power_loss_rate); 16; 0)		MegaWatt/turbine	
P17	DELAY(P0*(1-17*yearly_power_loss_rate); 17; 0)		MegaWatt/turbine	
P18	DELAY(P0*(1-18*yearly_power_loss_rate); 18; 0)		MegaWatt/turbine	
P19	DELAY(P0*(1-19*yearly_power_loss_rate); 19; 0)		MegaWatt/turbine	
P2	DELAY(P0*(1-2*yearly_power_loss_rate); 2; 0)		MegaWatt/turbine	
P20	DELAY(P0*(1-20*yearly_power_loss_rate); 20; 0)		MegaWatt/turbine	
P21	DELAY(P0*(1-21*yearly_power_loss_rate); 21; 0)		MegaWatt/turbine	
P22	DELAY(P0*(1-22*yearly_power_loss_rate); 22; 0)		MegaWatt/turbine	
P23	DELAY(P0*(1-23*yearly_power_loss_rate); 23; 0)		MegaWatt/turbine	
P24	DELAY(P0*(1-24*yearly_power_loss_rate); 24; 0)		MegaWatt/turbine	
P25	DELAY(P0*(1-25*yearly_power_loss_rate); 25; 0)		MegaWatt/turbine	
P26	DELAY(P0*(1-26*yearly_power_loss_rate); 26; 0)		MegaWatt/turbine	
P27	DELAY(P0*(1-27*yearly_power_loss_rate); 27; 0)		MegaWatt/turbine	

P28	DELAY(P0*(1-28*yearly_power_loss_rate); 28; 0)		MegaWatt/turbine	
P3	DELAY(P0*(1-3*yearly_power_loss_rate); 3; 0)		MegaWatt/turbine	
P4	DELAY(P0*(1-4*yearly_power_loss_rate); 4; 0)		MegaWatt/turbine	
P5	DELAY(P0*(1-5*yearly_power_loss_rate); 5; 0)		MegaWatt/turbine	
P6	DELAY(P0*(1-6*yearly_power_loss_rate); 6; 0)		MegaWatt/turbine	
P7	DELAY(P0*(1-7*yearly_power_loss_rate); 7; 0)		MegaWatt/turbine	
P8	DELAY(P0*(1-8*yearly_power_loss_rate); 8; 0)		MegaWatt/turbine	
P9	DELAY(P0*(1-9*yearly_power_loss_rate); 9; 0)		MegaWatt/turbine	
TOTAL_POWER:				
Annual_Commissioned_Power	P0*Annual_Installations		MegaWatt/Year	~ :SUPPLEMENTARY
Annual_Decommissioned_Power	P20*decom20+P21*decom21+P22*decom22+P23*decom23+P24*decom24+P25*decom25		MegaWatt/Year	~ :SUPPLEMENTARY
Energy_Production	Operational_Power*yearly_operational_hours*energy_unit_convertor		TeraWatt*hour/Year	
Maximum_Power	capacity_unit_convertor*(P0*WF0+P1*WF1+P2*WF2+P3*WF3+P4*WF4+P5*WF5+P6*WF6+P7*WF7+P8*WF8+P9*WF9+P10*WF10+P11*WF11+P12*WF12+P13*WF13+P14*WF14+P15*WF15+P16*WF16+P17*WF17+P18*WF18+P19*WF19+P20*WF20+P21*WF21+P22*WF22+P23*WF23+P24*WF24+P25*WF25+P26*WF26+P27*WF27+P28*WF28)		GigaWatt	
Operational_Power	Maximum_Power*operational_effectiveness		GigaWatt	
UNIT_CONVERTORS:				

capacity_unit_convertor	0,001		GigaWatt/MegaWatt	
cost_unit_convertor	1e-06		MEUR/EUR	
energy_unit_convertor	0,001		TeraWatt/GigaWatt	
unit_year	1		Year	
year	INT(TIME)		Year	

Annex 4b – Overview of equations MAL02 – SW Messinia

	Equation	Properties	Units	Documentation
"%_of_CF_farmers'_willing_to_change"(t)	"%_of_CF_farmers'_willing_to_change"(t - dt) + (willigness_increase - willingness_dercrease) * dt	INIT "%_of_CF_farmers'_willing_to_change" = CF_farmers_positive_to_change	percentage	
Alluvial_groundwater(t)	Alluvial_groundwater(t - dt) + (alluvial_recharge - alluvial_abstractions - alluvial_discharge_as_groundwater_to_lagoon) * dt	INIT Alluvial_groundwater = alluvial_stock+120000	m*m*m	
"Build-Land"(t)	"Build-Land"(t - dt) + (loss_of_CF_Land + loss_of_IF_land + Loss_of_OF_Land + Loss_of_Other_AgriLand) * dt	INIT "Build-Land" = initial_built_land	m*m	
expected_tourists(t)	expected_tourists(t - dt) + (arrival) * dt	INIT expected_tourists = initial_number_of_tourists	tourists/Year	
Olives_under_CF(t)	Olives_under_CF(t - dt) + (- CF_to_IF_change_area - loss_of_CF_Land) * dt	INIT Olives_under_CF = initial_area_of_olives_in_2020*"%_of_olives_under_CF"	m*m	
Olives_under_IF(t)	Olives_under_IF(t - dt) + (CF_to_IF_change_area - IF_to_OF_change_area - loss_of_IF_land) * dt	INIT Olives_under_IF = initial_area_of_olives_in_2020*"%_of_olives_under_IF"	m*m	
Olives_under_OF(t)	Olives_under_OF(t - dt) + (IF_to_OF_change_area - Loss_of_OF_Land) * dt	INIT Olives_under_OF = initial_area_of_olives_in_2020*"%_of_olives_under_OF"	m*m	
Other_Crops(t)	Other_Crops(t - dt) + (- Loss_of_Other_AgriLand) * dt	INIT Other_Crops = Initial_Other_AgriLand	m*m	
"Salt_mass_(lagoon)"(t)	"Salt_mass_(lagoon)"(t - dt) + (salinization - "de-salinization") * dt	INIT "Salt_mass_(lagoon)" = current_salt_mass	g	
Tyflomitis_groundwater(t)	Tyflomitis_groundwater(t - dt) + (Tyflomitis_recharge - Tyflomitis_abstractions - Tyflomitis_discharge_as_groundwater_to_lagoon - Tyflomitis_discharge_as_surface_to_Giannouzagas - Tyflomitis_discharge_as_surface_to_springs) * dt	INIT Tyflomitis_groundwater = Tyflomitis_stock+1,9e+06	m*m*m	
alluvial_abstractions	irrigation_demand_per_well*alluvial_wells*effect_of_evidence_based_irrigation_on_water_abstraction		m*m*m/Year	

alluvial_discharge_as_groundwater_to_lagoon	(Alluvial_groundwater-alluvial_stock)/unit_Year		m*m*m/Year	(Alluvial groundwater-alluvial stock)/unit month
alluvial_recharge	climatic_inputs_to_alluvial+(IF "groundwater_inputs_to_alluvial_(from_neogenic)" > 0 THEN "groundwater_inputs_to_alluvial_(from_neogenic)" ELSE 0)		m*m*m/Year	
arrival	(IF Nights_control < 0,8 THEN initial_number_of_tourists*(Potential_Destination_Increase+observed_increase) ELSE initial_number_of_tourists*((Potential_Destination_Increase+observed_increase)*0,8))		tourists/Year/Year	
CF_to_IF_change_area	(Olives_under_CF*CF_to_IF_rate-Olives_under_IF)/unit_Year_0		m*m/Year	
"de-salinization"	(IF Saline_vs_fresh_water_inputs < 0 THEN ("Mean_Annual_Salinity_(MAS)"/salinity_units)*Saline_vs_fresh_water_inputs*"water_volume_inputs/_lagoon_volume" ELSE 0)		g/Year	
IF_to_OF_change_area	(Olives_under_IF*IF_to_OF_rate-Olives_under_OF)/unit_Year_0		m*m/Year	
loss_of_CF_Land	Agri_Land_loss_rate*Olives_under_CF		m*m/Year	
loss_of_IF_land	Agri_Land_loss_rate*Olives_under_IF		m*m/Year	
Loss_of_OF_Land	Agri_Land_loss_rate*Olives_under_OF		m*m/Year	
Loss_of_Other_AgriLand	Agri_Land_loss_rate*Other_Crops		m*m/Year	
salinization	(IF Saline_vs_fresh_water_inputs > 0 THEN (Sea_salinity/salinity_units)*Saline_vs_fresh_water_inputs*"water_volume_inputs/_lagoon_volume" ELSE 0)		g/Year	
Tyflomitis_abstractions	irrigation_demand_per_well*Tyflomitis_wells*effect_of_evidence_based_irrigation_on_water_abstraction+annual_water_abstraction_for_water_demand		m*m*m/Year	irrigation demand per well*Tyflomitis wells*effect of awareness on water saving from irrigation+montlhy water abstraction for water demand
Tyflomitis_discharge_as_groundwater_to_lagoon	(IF Tyflomitis_groundwater-Tyflomitis_stock > 0 THEN (Tyflomitis_groundwater-Tyflomitis_stock)*"fraction_discharge_to_Ginnouzagas/_alluvial" ELSE 0)		m*m*m/Year	(Tyflomitis groundwater-Tyflomitis stock)*"fraction discharge to Ginnouzagas/ alluvial"

Tyflomitis_discharge_as_surface_to_Giannouzagas	(IF Tyflomitis_groundwater-Tyflomitis_stock > 0 THEN (Tyflomitis_groundwater-Tyflomitis_stock)*"fraction_discharge_to_Ginnouzagas/_alluvial" ELSE 0)		m*m*m/Year	(Tyflomitis groundwater-Tyflomitis stock)*"fraction discharge to Ginnouzagas/ alluvial"
Tyflomitis_discharge_as_surface_to_springs	(IF Tyflomitis_groundwater-Tyflomitis_stock > 0 THEN (Tyflomitis_groundwater-Tyflomitis_stock)*fraction_discharge_to_springs ELSE 0)		m*m*m/Year	(Tyflomitis groundwater-Tyflomitis stock)*fraction discharge to springs
Tyflomitis_recharge	climatic_inputs_to_Tyflomitis+"groundwater_inputs_to_Tyflomitis_(from_Flysch)"		m*m*m/Year	
willigness_increase	(positive_perceptions*effect_of_awareness_campaigns_on_positive_perceptions)/unit_Year_0		percentage/Year	positive perceptions + subcidies to support transition + structured support
willingness_dercrease	(negative_perceptions/effect_of_awareness_campaigns_on_negative_perceptions)/unit_Year_0		percentage/Year	
"%_of_CF_farmers_applying_herbicides/_tillage"	0,7		Dmnl	
"%_of_CF_farmers_using_pesticides"	0,7		Dmnl	
"%_of_CF_farmers_using_synthetic_fertilizers"	0,63		Dmnl	
"%_of_farmers_in_cooperative"	"%_of_CF_farmers'_willing_to_change"			
"%_of_olives_under_CF"	0,88		Dmnl	
"%_of_olives_under_IF"	0,1		Dmnl	
"%_of_olives_under_OF"	0,02		Dmnl	
"2ndary_home_population"	Average_number_of_persons_per_2nd_home*Number_of_secondary_homes*Second_home_occupancy		persons	
Accessibility	0,3		Dmnl	What does accessibility measure? Is it road infrasturcture network, AMEA infrastructure? Easy access to beaches? bus network?

Agri_Land_loss_rate	0,003*(Tourism_Infrastructure_Impact+Tourism_Policy_Impact)		1/Year	Current rate is the calculated rate of built up land based on a 20 year average It is set at 1/10th of what it has been in the last 20 years
"alluvial_groundwater_deficit,_saline_water_intrusion"	-alluvial_discharge_as_groundwater_to_lagoon		m*m*m/Year	
alluvial_stock	7e+06		m*m*m	
alluvial_wells	80		Dmnl	
annual_fresh_water_inputs_to_lagoon_from_catchemnt	groundwater_to_lagoon+surface_water_to_lagoon		m*m*m/Year	
annual_water_abstraction_for_water_demand	annual_water_demand_0*increased_abstraction_due_to_network_status*rate_of_water_demand_linked_to_Tyflomitis		m*m*m/Year	
annual_water_demand_0	(nights_spent*tourism_per_capita_water_demand)+((Local_population+"2ndary_home_population")*local_population_per_capita_water_demand*365)		m*m*m	
aquatic_vegetation_tolerance_ratio	"Mean_Annual_Salinity_(MAS)"/max_MAS_for_aquatic_vegetation		1	
archaelogical_importance	1		Dmnl	
Archaeological_monumens	0,2			
Area_attractiviness	(((Area_character_Identity+lagoon_status+river_status)*Wetland_Status_&_Identity_weight_&_river_status)+((coastal_status+marine_status)*Coast_&_marine_status_weight)+(archaelogical_importance*Archaeological_monumens)+Thematic_tourism_activities+Waste_management+climatic_conditions+Accessibility)/10		Dmnl	+(archaelogical importance*Archaeological monumens)
Average_days_of_stay	3,4		days	
Average_number_of_persons_per_2nd_home	2		persons/house	
beaches	1,2e+06		m*m	
beds_per_area_allowed	0,01		beds	

branding	GRAPH("%_of_farmers_in_cooperative") Points: (10,00, 1,100), (20,00, 1,200), (30,00, 1,300), (40,00, 1,400), (50,00, 2,000), (60,00, 2,200), (70,00, 2,400), (80,00, 2,600), (90,00, 2,800), (100,00, 3,000)		Dmnl	
catchment_runoff	Tyflomitis_discharge_as_surface_to_springs+Xerolagados_runoff		m*m*m/Year	
CF_farmers_positive_to_change	22		percentage	
CF_N_load	olive_area_treated_with_synthetic_fertilizers*CF_N_load_rate		Kg/Year	
CF_N_load_rate	0,0008		Kg/(m*m*Year)	
"CF_olives_treated_with_non-synthetic_ferilizers"	Olives_under_CF-olive_area_treated_with_synthetic_fertilizers		m*m	
CF_production	Olives_under_CF*"mean_annual_olive-oil_production_per_m2"		lt/Year	
CF_selling_price	3,3		euro/lt	
CF_to_IF_rate	transition_factors*"%_of_CF_farmers'_willing_to_change"/(100*unit_percentage)		Dmnl	
Climate_change	1			AoA projections
climatic_conditions	1*Climate_change		Dmnl	
climatic_inputs_to_alluvial	"P-PET_inputs_coastal_annual"*fix_rate_alluvial		m*m*m/Year	
climatic_inputs_to_neogenic	"P-PET_inputs_inland_annual"*fix_rate_neogenic		m*m*m/Year	
climatic_inputs_to_Tyflomitis	"P-PET_inputs_inland_annual"*fix_rate_Tyflomitis		m*m*m/Year	
"climatic_inputs/outputs_to/from_lagoon"	"P-PET_coastal"*fix_rate_lagoon		m*m*m/Year	

Coast_&_marine_status_weight	0,265		Dmnl	Based on ranking of possibilities during MAL2 It might be best to modify the weights (0-10) to differentiate between the different aspects. - The area now is known for its beaches and coastline - if the ecotourism destination is successful then other parameters such as wetland status and area identity also food might be more important
coastal_status	0,6		Dmnl	cars per m*m Is this value an average of the summer months? again maybe with fuzzy membership
consumers'_health	0,12		Dmnl	
cooperation	1		Dmnl	
cooperation_weight	0,126		Dmnl	
Curent_Bed_Capacity	3450+New_Bed_availability			
Current_employment	INIT(1000)			
current_salt_mass	33*1000*1,5e+06		g	current annual salinity*lagoon volume
decision_to_restore_connectivity	0*fish_tolerance_ratio*"nutrients_(as_N)_ratio"			connected with salinity, N pollution
difficulties_in_controlling_pests	0,26		Dmnl	
easier_to_sell	0,07		Dmnl	
economic_bebefits	0,06		Dmnl	
education	1		Dmnl	

education_weight	0,221		Dmnl	
effect_of_awareness_campaigns_on_negative_perceptions	0{GET_XLS_DATA('MAL02-inputs_FINAL.xlsx',_ 'Olives_annual',_ 'B',_ 'F3')}			
effect_of_awareness_campaigns_on_positive_perceptions	0{GET_XLS_DATA('MAL02-inputs_FINAL.xlsx',_ 'Olives_annual',_ 'B',_ 'F3')}			
effect_of_cooperative_on_transition_factors	GRAPH("%_of_farmers_in_cooperative") Points: (10,00, 1,100), (20,00, 1,200), (30,00, 1,300), (40,00, 1,400), (50,00, 2,000), (60,00, 2,200), (70,00, 2,400), (80,00, 2,600), (90,00, 2,800), (100,00, 3,000)			on education, technology, cooperation
effect_of_evidence_based_irrigation_on_water_abstraction	1		Dmnl	to be connected with a lookup with cooperatives (smart agriculture)
effect_of_olive_price_on_transition_factors	GRAPH("olive-oil_price") Points: (1,000, 0,000), (2,000, 0,000), (3,000, 0,000), (4,000, 1,000), (5,000, 1,500), (6,000, 2,000), (7,000, 2,500), (8,000, 3,000), (9,000, 4,000), (10,000, 5,000)			
effect_of_salinity_on_lagoon_status	GRAPH("Mean_Annual_Salinity_(MAS)") Points: (10, 50,00), (15, 60,00), (20, 80,00), (25, 90,00), (29, 98,00), (30, 100,00), (31, 95,00), (32, 80,00), (33, 70,00), (34, 65,00), (35, 50,00), (36, 45,00), (37, 40,00), (38, 35,00), (39, 30,00), (40, 25,00), (50, 20,00), (60, 15,00), (70, 10,00), (80, 5,00), (90, 3,00), (100, 1,00), (500, 1,00), (1500, 1,00)			
effect_of_transition_on_water_pollution	N_load_from_olives_as_runoff/101775			
"Employees/night_spent"	0,01			
Employment_in_agriculture	"%_of_farmers_in_cooperative"*Current_employment		Dmnl	
environmental_benefits	0,25		Dmnl	
fish_tolerance_ratio	"Mean_Annual_Salinity_(MAS)"/max_MAS_for_fish		1	
fix_rate_alluvial	0{GET_XLS_CONSTANTS(_'MAL02-inputs_FINAL.xlsx'_, _'Constants'_,_ _'N2')}		m*m	alluvial area*infiltration rate (0.08)
fix_rate_Flysch	0{GET_XLS_CONSTANTS(_'MAL02-inputs_FINAL.xlsx'_, _'Constants'_,_ _'O2')}		m*m	Flysch area*infiltration rate(0.23)*rate to Tyflomitis(0.75)
fix_rate_lagoon	0{GET_XLS_CONSTANTS(_'MAL02-inputs_FINAL.xlsx'_, _'Constants'_,_ _'F2')}		m*m	lagoon area
fix_rate_neogenic	0{GET_XLS_CONSTANTS(_'MAL02-inputs_FINAL.xlsx'_, _'Constants'_,_ _'M2')}		m*m	neogenic area*infiltration rate (0.08)

fix_rate_Tyflomitis	0{GET_XLS_CONSTANTS(_'MAL02-inputs_FINAL.xlsx'_, _'Constants'_,_ _'L2')}		m*m	Tyflomitis area*infiltration rate(0.23)
fix_rate_Xerolagados	0{GET_XLS_CONSTANTS(_'MAL02-inputs_FINAL.xlsx'_, _'Constants'_,_ _'Q2')}		m*m	
forests	2,307e+07		m*m	Mixed forest, broad leave forest,
"fraction_discharge_to_Ginnouzagas/_alluvial"	0,15		1/Year	
fraction_discharge_to_springs	0,7		1/Year	
fraction_of_Tyflomitis_springs_to_lagoon	0,1+Tyflomitis_restoration		Dmnl	
fraction_of_Xerolagados_to_lagoon	0+Xerolagados_restoration		1	
GDP_from_olives	Total_production*"olive-oil_price"		euro/Year	
"groundwater_inputs_to_alluvial_(from_neogenic)"	(climatic_inputs_to_neogenic-irrigation_demand_per_well*neogenic_wells*effect_of_evidence_based_irrigation_on_water_abstraction)*rate_of_neogenic_to_alluvial		m*m*m/Year	
"groundwater_inputs_to_Tyflomitis_(from_Flysch)"	"P-PET_inputs_inland_annual"*fix_rate_Flysch		m*m*m/Year	
groundwater_to_lagoon	Tyflomitis_discharge_as_groundwater_to_lagoon+(IF alluvial_discharge_as_groundwater_to_lagoon > 0 THEN alluvial_discharge_as_groundwater_to_lagoon ELSE 0)		m*m*m/Year	
"Household/100beds"	Curent_Bed_Capacity/number_of_households		Dmnl	Social Sustainability tourism KPI
hypersaline_ratio	"Mean_Annual_Salinity_(MAS)"/Sea_salinity		1	
IF_N_load	("CF_olives_treated_with_non-synthetic_ferilizers"+Olives_under_IF)*IF_N_load_rate		Kg/Year	
IF_N_load_rate	0,0006		Kg/(m*m*Year)	
IF_production	Olives_under_IF*"mean_annual_olive-oil_production_per_m2"		lt/Year	
IF_selling_price	3,8		euro/lt	
IF_to_OF_rate	{GET_XLS_DATA('MAL02-inputs_FINAL.xlsx','Olives_annual','B','D3')}		Dmnl	

increased_abstraction_due_to_network_status	1,67		Dmnl	
initial_area_of_olives_in_2020	1,4512e+08		m*m	
initial_built_land	INIT(5,39e+06)		m*m	
initial_number_of_tourists	INIT(67000)		tourists	Hellenic statistics 2010 - 2019 arrivals ([(2010,60000)-(2019,200000)],(2010,67594),(2011,72799),(2012,78404),(2013,84441),(2014,90943),(2015,97946),(2016,105488),(2017,113610),(2018,122358),(2019,131780))
Initial_Other_AgriLand	INIT(3,263e+07)		m*m	
irrigation_demand_per_well	0{GET_XLS_DATA('MAL02-inputs_FINAL.xlsx','Water-Lagoon_annual','B','I3')}		m*m*m/Year	
lack_of_knowledge	0,21		Dmnl	
lagoon_status	effect_of_salinity_on_lagoon_status			
lagoon_volume	1,5e+06		m*m*m	
Local_Food_&_Products	0,119			
Local_population	14301		persons	The last 10 years have shown a significant decrease of 10% at the local resident population. However, as it is common with these calculations population is seen as constant and will consider changes as part of the scenario analysis
local_population_per_capita_water_demand	0,25		m*m*m/persons	
lower_profit	0,37		Dmnl	

marine_status	0,8		Dmnl	That can relate to the measurements somehow We can do a fuzzyfication based on wfd limits and using the measured data to show were we stand now for good - status... - connect to waste water management Fuzzy membership function similar to river status but combine with active population as well
marketing	GRAPH("%_of_farmers_in_cooperative") Points: (10,00, 1,100), (20,00, 1,200), (30,00, 1,300), (40,00, 1,400), (50,00, 2,000), (60,00, 2,200), (70,00, 2,400), (80,00, 2,600), (90,00, 2,800), (100,00, 3,000)		Dmnl	
max_MAS_for_aquatic_vegetation	22,5		g/lt	
max_MAS_for_fish	35		g/lt	
maximum_active_population	NAN(maximum_active_population)			
Maximum_nights_availability	Curent_Bed_Capacity*Number_of_days_per_year_hotels_are_open			
"mean_annual_olive-oil_production_per_m2"	0,11		lt/(Year*m*m)	
"Mean_Annual_Salinity_(MAS)"	("Salt_mass_(lagoon)"/lagoon_volume)*salinity_units		g/lt	
month_index	INT(MODULO((TIME-STARTTIME)/DT; 12)+1+0,5)		Dmnl	
"N_load_from_build-up_land"	"Build-Land"*"N_load_rate_from_build-up_land"		Kg/Year	
N_load_from_olives_as_runoff	CF_N_load+IF_N_load+OF_N_load		Kg/Year	
N_load_from_other_agricultural_practices	Other_Crops*N_load_rate_from_other_agricultural_practices		Kg/Year	
"N_load_rate_from_build-up_land"	0,0005		Kg/(m*m*Year)	
N_load_rate_from_other_agricultural_practices	0,0006		Kg/(m*m*Year)	
natural_land	beaches+wetlands+shrubs+forests		m*m	

negative_perceptions	difficulties_in_controlling_pests+lack_of_knowledge+lower_profit+no_suitable_fertilizers+"time/_effort_demanding"			
negotiation_power	GRAPH("%_of_farmers_in_cooperative") Points: (10,00, 1,100), (20,00, 1,200), (30,00, 1,300), (40,00, 1,400), (50,00, 2,000), (60,00, 2,200), (70,00, 2,400), (80,00, 2,600), (90,00, 2,800), (100,00, 3,000)		Dmnl	(cooperative to manage the whole production)
neogenic_wells	36		1	
New_Bed_availability	(("Build-Land"-initial_built_land)*beds_per_area_allowed)/unit_area		beds	3435+(Built up land-initial built up land)*"beds/ha allowed"
Nights_control	nights_spent/Maximum_nights_availability			80% of possible available nights are covered
nights_spent	Average_days_of_stay*expected_tourists		tourists*days/Year	
no_suitable_fertilizers	0,13			
Number_of_days_per_year_hotels_are_open	120			Assumption that all hotels in the are open for 4 months (most are open for 4-5 but as some - especially in pylos are available thoughtout the year, and 2/3 of the rooms are indeed open for 6 months)
number_of_households	6500		households	επιβεβαίωση τιμής ΕΛΣΤΑΤ - η προηγούμενη τιμή πιθανώς να αντιστοιχεί και σε Κορώνη - Μεθώνη που είναι εκτός περιοχής μελέτης
Number_of_secondary_homes	3000		house	Set as constant but there is a rate of increase (included at the mo as part of hotel development)

"nutrients_(as_N)_ratio"	3			based on inputs from land uses model
observed_increase	0,08			Observed increase based on 10 years average (2010 -2019)
OF_N_load	Olives_under_OF*OF_N_load_rate		Kg/Year	
OF_N_load_rate	0,0004		Kg/(m*m* Year)	
OF_production	(Olives_under_OF*"mean_annual_olive-oil_production_per_m2")		lt/Year	
OF_selling_price	4,5		euro/lt	
olive_area_treated_with_pesticides	Olives_under_CF*"%_of_CF_farmers_using_pesticides"+Olives_under_IF*prudent_use_of_pesticides_under_IF		m*m	
olive_area_treated_with_synthetic_fertilizers	Olives_under_CF*"%_of_CF_farmers_using_synthetic_fertilizers"		m*m	
Olive_Orchards	Olives_under_CF+Olives_under_IF+Olives_under_OF		m*m	
olive_orchards_that_support_biodiversity	Olive_Orchards-(olive_area_treated_with_pesticides+olives_area_vulnarable_to_soil_degradation)/2		m*m	
"olive-oil_price"	"olive-oil_price_variation_based_on_farming_practices"*(negotiation_power+branding+marketing)/3		euro/lt	
"olive-oil_price_variation_based_on_farming_practices"	(CF_production*CF_selling_price+IF_production*IF_selling_price+OF_production*OF_selling_price)/Total_production		euro/lt	
"olive-oil_price_weight"	0,151		Dmnl	
olives_area_vulnarable_to_soil_degradation	Olives_under_CF*"%_of_CF_farmers_applying_herbicides/_tillage"		m*m	
own_health	0,25		Dmnl	
"P-PET_coastal"	0{GET_XLS_DATA('MAL02-inputs_FINAL.xlsx',_ 'Water-Lagoon_annual',_ 'B',_ 'N3')}		m/Year	
"P-PET_inputs_coastal_annual"	0{GET_XLS_DATA('MAL02-inputs_FINAL.xlsx',_ 'Water-Lagoon_annual',_ 'B',_ 'M3')}		m/Year	

"P-PET_inputs_inland_annual"	0{GET_XLS_DATA('MAL02-inputs_FINAL.xlsx',_ 'Water-Lagoon_annual',_ 'B',_ 'L3')}		m/Year	
policies	1			
policies_weight	0,137		Dmnl	
positive_perceptions	consumers'_health+easier_to_sell+economic_bebefits+environmental_benefits+own_health+product_quality		Dmnl	
Potential_Destination_Increase	Area_attractiviness*0		Dmnl	improve values again with some kind of fuzzy set membership function
product_quality	0,25		Dmnl	
prudent_use_of_pesticides_under_IF	0,5		Dmnl	
rate_of_neogenic_to_alluvial	0,3		Dmnl	
rate_of_water_demand_linked_to_Tyflomitis	0,4		1/Year	
river_status	0,6		Dmnl	HCMR measurements CONNECT to measurements maybe through some kind of fuzzy membership (if RIVER NO above certain amount then ... if in between then ... if below then ...
Saline_vs_fresh_water_inputs	Sea_water_inputs-annual_fresh_water_inputs_to_lagoon_from_catchemnt		m*m*m/Year	
salinity_units	1/1000		m*m*m/lt	
Sea_salinity	38,5		g/lt	
Sea_water_inputs	-"climatic_inputs/outputs_to/from_lagoon"		m*m*m/Year	
Second_home_occupancy	0,31		Dmnl	Annual average occupancy

shrubs	1,53e+07		m*m	traditional woodland-shrub, sclerophyllus vegetation
subsidies	1		Dmnl	
subsidies_weight	0,197		Dmnl	
surface_water_to_lagoon	Tyflomitis_discharge_as_surface_to_springs*fraction_of_Tyflomitis_springs_to_lagoon+Xerolagados_runoff*fraction_of_Xerolagados_to_lagoon		m*m*m/Year	
technology	1		Dmnl	
technology_weight	0,168		Dmnl	
Thematic_tourism_activities	0,166*0,4			0.3 is the scale of the thematic activities on offer according to what can be potentially offered
"time/_effort_demanding"	0,03		Dmnl	
Total_area	Olive_Orchards+"Build-Land"+natural_land+Other_Crops		m*m	
TOTAL_EMPLOYMENT	Employment_in_agriculture+Tourism_Employment			
Total_N_load	N_load_from_olives_as_runoff+N_load_from_other_agricultural_practices+"N_load_from_build-up_land"		Kg/Year	
Total_production	(CF_production+IF_production+OF_production)		lt/Year	
Tourism_Employment	"Employees/night_spent"*nights_spent			
Tourism_Infrastructure_Impact	0,5		Dmnl	
tourism_per_capita_water_demand	0,5		m*m*m*days/tourists	per overnight stay tourists*days/Year
Tourism_Policy_Impact	0,5		Dmnl	
tourism_pressure	1		Dmnl	
transition_factors	(cooperation*effect_of_cooperative_on_transition_factors*cooperation_weight+education*effect_of_cooperative_on_transition_factors*education_weight+policies*policies_weight+subsidies*subsidies_weight+technology*effect_of_cooperative_on_transition_factors*technolog		Dmnl	

	y_weight+effect_of_olive_price_on_transition_factors*"olive-oil_price_weight")			
Tyflomitis_restoration	0		Dmnl	
Tyflomitis_stock	6,5e+06		m*m*m	
Tyflomitis_wells	20		Dmnl	
unit_area	1		m*m	
unit_percentage	1		percentage	
unit_Year	1		Year	
unit_Year_0	1		Year	
Waste_management	0,5		Dmnl	active population/capacity recycling infrastructure CONNECT with active population
"waste-water_management"	1*tourism_pressure			active population/capacity
"water_volume_inputs/_lagoon_volume"	Saline_vs_fresh_water_inputs*unit_Year/lagoon_volume		1	
Wetland_Status_&_Identity_weight_&_river_status	0,25		Dmnl	
wetlands	7,24e+06		m*m	lagoons, marshes, natural grasslands
Xerolagados_restoration	0		Dmnl	
Xerolagados_runoff	(IF "P-PET_inputs_inland_annual" > 0 THEN "P-PET_inputs_inland_annual"*fix_rate_Xerolagados ELSE 0)		m*m*m/Year	

Area_character_Identity	(100-(100*((("Build-Land"/(Total_area-natural_land)/3)*3)+((Other_Crops/(Total_area-natural_land)/3)*2)+((Olive_Orchards/(Total_area-natural_land)/3)*1))))/100		Dmnl	Area character is assessed based on the hemeroby index landscape assesment which quantifies human impact on the landscape based on land use. In this case the same concept is being used to measure land use impact on the cultural identity of the landscape which is the olive orchards. What it does is quantifying the effect of land use changes on the olive orchards which give Messinian Landscape its identity.

Annex 4c Overview of equations MAL03 – Baltic

The equations used to quantify the main variables included in the integrated MAL3 SD model are presented in Table 9 including the variable names, their equations or values, and their unit.

Table 9: Overview of equations used to quantify the integrated MAL3 SD model

	Equation	Properties	Units	Documentation
Top-Level Model:				
Agriculture(t)	Agriculture(t - dt) + (SW_to_agriculture + Precipitation_to_agriculture + MWS_to_agriculture - Agriculture_to_SW - Agriculture_to_SSW - Agriculture_to_evapotranspiration) * dt	INIT Agriculture = 5192	Million m3	Total flow through agricultural areas in each time step The initial value is the long-term average total flow through agricultural areas. Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
Forest(t)	Forest(t - dt) + (Precipitation_to_forest - Forest_to_SW - Forest_to_SSW - Forest_to_evapotranspiration) * dt	INIT Forest = 7341	Million m3	Total flow through forest areas in each time step The initial value is the long-term average total flow through forest areas. Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
Industry(t)	Industry(t - dt) + (SW_to_industry + SSW_to_industry + MWS_to_industry - Industry_to_WWTP - Industry_to_USR - Industry_to_SW - Industry_to_evaporation) * dt	INIT Industry = 195	Million m3	Total flow through industry in each time step The initial value is the long-term average total flow through industry. Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2

"Municipal_water_supply_(MWS)"(t)	"Municipal_water_supply_(MWS)"(t - dt) + (SW_to_MWS + SSW_to_MWS - MWS_to_CCWE - MWS_to_SSW - MWS_to_WWTP - MWS_to_industry - MWS_to_agriculture) * dt	INIT "Municipal_water_supply_(MWS)" = 240	Million m3	Total flow through municipal water supply system in each time step The initial value is the long-term average total flow through municipal water supply system. Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
"Subsurface_water_(SSW)"(t)	"Subsurface_water_(SSW)"(t - dt) + (Agriculture_to_SSW + Forest_to_SSW + CCWI_to_SSW + MWS_to_SSW + SW_to_SSW + UCWW_to_SSW - SSW_to_coastal_outflow - SSW_to_industry - SSW_to_SW - SSW_to_MWS - SSW_to_UCWW) * dt	INIT "Subsurface_water_(SSW)" = 4048	Million m3	Total flow through subsurface water system in each time step The initial value is the long-term average total flow through SW. Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
"Surface_water_(SW)"(t)	"Surface_water_(SW)"(t - dt) + (Agriculture_to_SW + Forest_to_SW + Industry_to_SW + Precipitation_to_SW + SSW_to_SW + UCWW_to_SW + USR_to_SW + WWTP_to_SW - SW_to_MWS - SW_to_agriculture - SW_to_coastal_outflow - SW_to_evaporation - SW_to_industry - SW_to_SSW) * dt	INIT "Surface_water_(SW)" = 7206	Million m3	Total flow through surface water system in each time step The initial value is the long-term average total flow through SW.
"Unconnected_coastal_wastewater_(UCWW)"(t)	"Unconnected_coastal_wastewater_(UCWW)"(t - dt) + (SSW_to_UCWW - UCWW_to_evaporation - UCWW_to_SSW - UCWW_to_SW) * dt	INIT "Unconnected_coastal_wastewater_(UCWW)" = 10	Million m3	Total unconnected coastal wastewater in each time step The initial value is the long-term average total unconnected coastal waterwater. Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
"Urban_surface_runoff_(USR)"(t)	"Urban_surface_runoff_(USR)"(t - dt) + (Industry_to_USR + Precipitation_to_USR - USR_to_evaporation - USR_to_SW - USR_to_WWTP) * dt	INIT "Urban_surface_runoff_(USR)" = 561	Million m3	Total flow through built areas as urban surface runoff in each time step The initial value is the long-term average total flow through built areas as urban surface runoff. Source: Cseh, M. (2009) Multi-approach

				comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
"Wastewater_treatment_plant_(WWTP)"(t)	"Wastewater_treatment_plant_(WWTP)"(t - dt) + (Industry_to_WWTP + MWS_to_WWTP + USR_to_WWTP - WWTP_to_SW) * dt	INIT "Wastewater_treatment_plant_(WWTP)" = 116	Million m3	Total flow through wastewater treatment plant in each time step The initial value is the long-term average total flow through wastewater treatment plant. Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
Agriculture_to_evapotranspiration	(IF ("Scenario_No." = 3 AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; Fraction_of_agriculture_to_evapotranspiration*Agriculture*Unit_correction_1) ELSE (IF (("Scenario_No." = 1 OR "Scenario_No." = 2) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; (1-2*Precipitation_change_rate)*Fraction_of_agriculture_to_evapotranspiration*Unit_correction_1*Agriculture) ELSE (IF (("Scenario_No." = 4 OR "Scenario_No." = 5) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; ("Agricultural_land_(AL)"*"Long-term_average_evapotranspiration_for_agriculture")/(Unit_correction_2*Unit_correction_3)) ELSE ("Agricultural_land_(AL)"*"Long-term_average_evapotranspiration_for_agriculture")/(Unit_correction_2*Unit_correction_3))))		Million m3/year	Total evapotranspiration from agricultural lands according to their areas and the long-term average evapotranspiration height
Agriculture_to_SSW	(IF ("Scenario_No." = 3 AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; Agriculture*Fraction_of_agriculture_to_SSW*Unit_correction_1) ELSE (IF (("Scenario_No." = 1 OR "Scenario_No." = 2) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; Fraction_of_agriculture_to_SSW*((1-(1-2*Precipitation_change_rate)*Fraction_of_agriculture_to_evapotranspiration)/(1-Fraction_of_agriculture_to_evapotranspiration))*Agriculture*Unit_correction_1) ELSE (IF (("Scenario_No." = 4 OR "Scenario_No." = 5) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; (Agriculture*Unit_correction_1-Agriculture_to_evapotranspiration)*(Fraction_of_agriculture_to_SSW/		Million m3/year	Flow from agricultural lands that goes to subsurface water system according to the associated fraction and the total flow through agricultural lands

	(Fraction_of_agriculture_to_SSW+Fraction_of_agriculture_to_SW))) ELSE MAX(0; Agriculture*Fraction_of_agriculture_to_SSW*Unit_correction_1))))			
Agriculture_to_SW	(IF ("Scenario_No." = 3 AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; Agriculture*Fraction_of_agriculture_to_SW*Unit_correction_1) ELSE (IF (("Scenario_No." = 1 OR "Scenario_No." = 2) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; Fraction_of_agriculture_to_SW*((1-(1-2*Precipitation_change_rate)*Fraction_of_agriculture_to_evapotranspiration)/(1-Fraction_of_agriculture_to_evapotranspiration))*Agriculture*Unit_correction_1) ELSE (IF (("Scenario_No." = 4 OR "Scenario_No." = 5) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; (Agriculture*Unit_correction_1-Agriculture_to_evapotranspiration)*(Fraction_of_agriculture_to_SW/(Fraction_of_agriculture_to_SW+Fraction_of_agriculture_to_SSW))) ELSE MAX(0; Agriculture*Fraction_of_agriculture_to_SW*Unit_correction_1))))		Million m3/year	Flow from agricultural lands that goes to surface water system according to the associated fraction and the total flow through agricultural lands
CCWI_to_SSW	MAX(0; "Cross-catchment_water_inflow_(CCWI)"*Fraction_of_CCWI_to_SSW*Unit_correction_1)		Million m3/year	Total cross-catchment water inflow from adjacent catchments to the system
Forest_to_evapotranspiration	(IF (("Scenario_No." = 1 OR "Scenario_No." = 2) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; (1-2*Precipitation_change_rate)*Fraction_of_forest_to_evapotranspiration*Unit_correction_1*Forest) ELSE (IF (("Scenario_No." = 3 OR "Scenario_No." = 4 OR "Scenario_No." = 5) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN ("Forest_land_(FL)"*"Long-term_average_evapotranspiration_for_forest")/(Unit_correction_2*Unit_correction_3) ELSE ("Forest_land_(FL)"*"Long-term_average_evapotranspiration_for_forest")/(Unit_correction_2*Unit_correction_3)))		Million m3/year	Total evapotranspiration from forest lands according to their areas and the long-term average evapotranspiration height
Forest_to_SSW	(IF (("Scenario_No." = 1 OR "Scenario_No." = 2) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; Fraction_of_forest_to_SSW*((1-(1-2*Precipitation_change_rate)*Fraction_of_forest_to_evapotranspiration)/(1-Fraction_of_forest_to_evapotranspiration))*Forest*Unit_correction_1) ELSE (IF (("Scenario_No." = 3 OR "Scenario_No." = 4 OR		Million m3/year	Flow from forest lands that goes to subsurface water system according to the associated fraction and the total flow through forest lands

	"Scenario_No." = 5) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; (Forest*Unit_correction_1-Forest_to_evapotranspiration)*(Fraction_of_forest_to_SSW/(Fraction_of_forest_to_SSW+Fraction_of_forest_to_SW))) ELSE Fraction_of_forest_to_SSW*Forest*Unit_correction_1))			
Forest_to_SW	(IF (("Scenario_No." = 1 OR "Scenario_No." = 2) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; Fraction_of_forest_to_SW*((1-(1-2*Precipitation_change_rate)*Fraction_of_forest_to_evapotranspiration)/(1-Fraction_of_forest_to_evapotranspiration))*Forest*Unit_correction_1) ELSE (IF (("Scenario_No." = 3 OR "Scenario_No." = 4 OR "Scenario_No." = 5) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; (Forest*Unit_correction_1-Forest_to_evapotranspiration)*(Fraction_of_forest_to_SW/(Fraction_of_forest_to_SW+Fraction_of_forest_to_SSW))) ELSE Fraction_of_forest_to_SW*Unit_correction_1*Forest))		Million m3/year	Flow from forest lands that goes to surface water system according to the associated fraction and the total flow through forest lands
Industry_to_evaporation	(IF (("Scenario_No." = 1 OR "Scenario_No." = 2 OR "Scenario_No." = 3 OR "Scenario_No." = 4 OR "Scenario_No." = 5) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; Fraction_of_industry_to_evaporation*Initial_Industry*Unit_correction_1) ELSE Fraction_of_industry_to_evaporation*Industry*Unit_correction_1)		Million m3/year	Total evaporation from industry in built areas according to total flow through industry and associated fraction for evaporation
Industry_to_SW	(IF (("Scenario_No." = 1 OR "Scenario_No." = 2 OR "Scenario_No." = 3 OR "Scenario_No." = 4 OR "Scenario_No." = 5) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; Fraction_of_industry_to_SW*Initial_Industry*Unit_correction_1) ELSE Fraction_of_industry_to_SW*Industry*Unit_correction_1)		Million m3/year	Flow from industry that goes to surface water according to the associated fraction and the total flow through industry
Industry_to_USR	(IF (("Scenario_No." = 1 OR "Scenario_No." = 2 OR "Scenario_No." = 3 OR "Scenario_No." = 4 OR "Scenario_No." = 5) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; Fraction_of_industry_to_USR*Initial_Industry*Unit_correction_1) ELSE Fraction_of_industry_to_USR*Industry*Unit_correction_1)		Million m3/year	Flow from industry that goes to urban surface runoff according to the associated fraction and the total flow through industry
Industry_to_WWTP	(IF (("Scenario_No." = 1 OR "Scenario_No." = 2 OR "Scenario_No." = 3 OR "Scenario_No." = 4 OR "Scenario_No." = 5) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; Fraction_of_industry_to_WWTP*Initial_Industry*Unit_correction_1) ELSE Fraction_of_industry_to_WWTP*Industry*Unit_correction_1)		Million m3/year	Flow from industry that goes to wastewater treatment plant according to the associated fraction and the total flow through industry
MWS_to_agriculture	(IF (("Scenario_No." = 1 OR "Scenario_No." = 2 OR "Scenario_No." = 3 OR "Scenario_No." = 4 OR "Scenario_No." = 5) AND TIME >=		Million m3/year	Flow from municipal water supply that goes to agricultural areas according to the

	(STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; Fraction_of_MWS_to_agriculture*Initial_MWS*Unit_correction_1) ELSE Fraction_of_MWS_to_agriculture*"Municipal_water_supply_(MWS)"* Unit_correction_1)			associated fraction and the total flow through municipal water supply
MWS_to_CCWE	(IF (("Scenario_No." = 1 OR "Scenario_No." = 2 OR "Scenario_No." = 3 OR "Scenario_No." = 4 OR "Scenario_No." = 5) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; Fraction_of_MWS_to_export*Initial_MWS*Unit_correction_1) ELSE Fraction_of_MWS_to_export*"Municipal_water_supply_(MWS)"*Unit_correction_1)		Million m3/year	Flow from municipal water supply that is exported from the inland catchment according to the associated fraction and the total flow through municipal water supply
MWS_to_industry	(IF (("Scenario_No." = 1 OR "Scenario_No." = 2 OR "Scenario_No." = 3 OR "Scenario_No." = 4 OR "Scenario_No." = 5) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; Fraction_of_MWS_to_industry*Initial_MWS*Unit_correction_1) ELSE Fraction_of_MWS_to_industry*"Municipal_water_supply_(MWS)"*Unit_correction_1)		Million m3/year	Flow from municipal water supply that goes to industry according to the associated fraction and the total flow through municipal water supply
MWS_to_SSW	(IF (("Scenario_No." = 1 OR "Scenario_No." = 2 OR "Scenario_No." = 3 OR "Scenario_No." = 4) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; Fraction_of_MWS_to_SSW*Initial_MWS*Unit_correction_1) ELSE (IF ("Scenario_No." = 5 AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; ("Municipal_water_supply_(MWS)"*Unit_correction_1-MWS_to_agriculture-MWS_to_CCWE-MWS_to_industry)*(Fraction_of_MWS_to_SSW/(Fraction_of_MWS_to_SSW+Fraction_of_MWS_to_WWTP))) ELSE Fraction_of_MWS_to_SSW*"Municipal_water_supply_(MWS)"*Unit_correction_1))		Million m3/year	Flow from municipal water supply that goes to subsurface water system according to the associated fraction and the total flow through municipal water supply
MWS_to_WWTP	(IF (("Scenario_No." = 1 OR "Scenario_No." = 2 OR "Scenario_No." = 3 OR "Scenario_No." = 4) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; Fraction_of_MWS_to_WWTP*Initial_MWS*Unit_correction_1) ELSE (IF ("Scenario_No." = 5 AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; ("Municipal_water_supply_(MWS)"*Unit_correction_1-MWS_to_agriculture-MWS_to_CCWE-MWS_to_industry)*(Fraction_of_MWS_to_WWTP/(Fraction_of_MWS_to_SSW+Fraction_of_MWS_to_WWTP))) ELSE		Million m3/year	Flow from municipal water supply that goes to wastewater treatment plant according to the associated fraction and the total flow through municipal water supply

	"Municipal_water_supply_(MWS)"*Fraction_of_MWS_to_WWTP*Unit_correction_1))			
Precipitation_to_agriculture	MAX(0; ("Agricultural_land_(AL)"*Precipitation)/(Unit_correction_2*Unit_correction_3))		Million m3/year	Total precipitation volume that agricultural lands recieve according to their areas and the precipitation height over the inland catchment area
Precipitation_to_forest	MAX(0; ("Forest_land_(FL)"*Precipitation)/(Unit_correction_2*Unit_correction_3))		Million m3/year	Total precipitation volume that forest lands recieve according to their areas and the precipitation height over the inland catchment area
Precipitation_to_SW	MAX(0; (Precipitation*"Inland_water_area_(IWA)")/(Unit_correction_2*Unit_correction_3))		Million m3/year	Total precipitation volume that inland surface waters recieve according to their areas and the precipitation height over the inland catchment area
Precipitation_to_USR	MAX(0; (Precipitation*"Built_land_(BL)")/(Unit_correction_2*Unit_correction_3))		Million m3/year	Total precipitation volume that built areas recieve as urban surface runoff according to their land areas and the precipitation height over the inland catchment area
SSW_to_coastal_outflow	(IF (("Scenario_No." = 1 OR "Scenario_No." = 2 OR "Scenario_No." = 3 OR "Scenario_No." = 4 OR "Scenario_No." = 5) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; ("Subsurface_water_(SSW)"*Unit_correction_1-SSW_to_industry-SSW_to_MWS-SSW_to_UCWW)*(Fraction_of_SSW_to_coastal_outflow/(Fraction_of_SSW_to_coastal_outflow+Fraction_of_SSW_to_SW))) ELSE Fraction_of_SSW_to_coastal_outflow*"Subsurface_water_(SSW)"*Unit_correction_1)		Million m3/year	Total subsurface flow to the coast according to the total flow through subsurface water system and the associated fraction for coastal outflow
SSW_to_industry	(IF (("Scenario_No." = 1 OR "Scenario_No." = 2 OR "Scenario_No." = 3 OR "Scenario_No." = 4 OR "Scenario_No." = 5) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; Fraction_of_SSW_to_industry*Initial_SSW*Unit_correction_1) ELSE "Subsurface_water_(SSW)"*Fraction_of_SSW_to_industry*Unit_correction_1)		Million m3/year	Flow from subsurface water that goes to industry according to the associated fraction and the total flow through subsurface water
SSW_to_MWS	(IF (("Scenario_No." = 1 OR "Scenario_No." = 2 OR "Scenario_No." = 3 OR "Scenario_No." = 4) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; Fraction_of_SSW_to_MWS*Initial_SSW*Unit_correction_1) ELSE (IF ("Scenario_No." = 5 AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; (1+Urban_growth_rate)*Fraction_of_SSW_to_MWS*Initial_SSW*Unit		Million m3/year	Flow from subsurface water system that goes to municipal water supply according to the associated fraction and the total flow through subsurface water

	_correction_1) ELSE Fraction_of_SSW_to_MWS*"Subsurface_water_(SSW)"*Unit_correction_1))			
SSW_to_SW	(IF (("Scenario_No." = 1 OR "Scenario_No." = 2 OR "Scenario_No." = 3 OR "Scenario_No." = 4 OR "Scenario_No." = 5) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; ("Subsurface_water_(SSW)"*Unit_correction_1-SSW_to_industry-SSW_to_MWS-SSW_to_UCWW)*(Fraction_of_SSW_to_SW/(Fraction_of_SSW_to_coastal_outflow+Fraction_of_SSW_to_SW))) ELSE Fraction_of_SSW_to_SW*"Subsurface_water_(SSW)"*Unit_correction_1)		Million m3/year	Flow from subsurface water that goes to surface water according to the associated fraction and the total flow through subsurface water
SSW_to_UCWW	(IF (("Scenario_No." = 1 OR "Scenario_No." = 2 OR "Scenario_No." = 3 OR "Scenario_No." = 4 OR "Scenario_No." = 5) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; Fraction_of_SSW_to_UCWW*Initial_SSW*Unit_correction_1) ELSE Fraction_of_SSW_to_UCWW*"Subsurface_water_(SSW)"*Unit_correction_1)		Million m3/year	Flow from subsurface water system that goes to unconnected coastal wastewater according to the associated fraction and the total flow through subsurface water system
SW_to_agriculture	(IF (("Scenario_No." = 1 OR "Scenario_No." = 2 OR "Scenario_No." = 4 OR "Scenario_No." = 5) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; Fraction_of_SW_to_agriculture*Initial_SW*Unit_correction_1) ELSE (IF ("Scenario_No." = 3 AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; ((1+Agricultural_intensification_rate)*Initial_Agriculture*Unit_correction_1-Precipitation_to_agriculture-MWS_to_agriculture)) ELSE Fraction_of_SW_to_agriculture*"Surface_water_(SW)"*Unit_correction_1))		Million m3/year	Flow from surface water that goes to agricultural areas according to the associated fraction and the total flow through surface water
SW_to_coastal_outflow	(IF (("Scenario_No." = 1 OR "Scenario_No." = 4) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; ("Surface_water_(SW)"*Unit_correction_1-SW_to_agriculture-SW_to_evaporation-SW_to_industry-SW_to_MWS)*(Fraction_of_SW_to_coastal_outflow/(Fraction_of_SW_to_coastal_outflow+Fraction_of_SW_to_SSW))) ELSE (IF (("Scenario_No." = 2 OR "Scenario_No." = 3 OR "Scenario_No." = 5) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; ("Surface_water_(SW)"*Unit_correction_1-SW_to_agriculture-SW_to_industry-SW_to_MWS)*(Fraction_of_SW_to_coastal_outflow/(Fraction_of_SW_to_coastal_outflow+Fraction_of_SW_to_SSW+Fraction_of_SW_to_ev		Million m3/year	Total surface flow to the coast according to the total flow through surface water system and the associated fraction for coastal outflow

	aporation))) ELSE Fraction_of_SW_to_coastal_outflow*"Surface_water_(SW)"*Unit_correction_1))			
SW_to_evaporation	(IF (("Scenario_No." = 1 OR "Scenario_No." = 4) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; ("Inland_water_area_(IWA)"*"Long-term_average_evaporation_for_SW")/(Unit_correction_2*Unit_correction_3)) ELSE (IF (("Scenario_No." = 2 OR "Scenario_No." = 3 OR "Scenario_No." = 5) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; ("Surface_water_(SW)"*Unit_correction_1-SW_to_agriculture-SW_to_industry-SW_to_MWS)*(Fraction_of_SW_to_evaporation/(Fraction_of_SW_to_coastal_outflow+Fraction_of_SW_to_SSW+Fraction_of_SW_to_evaporation))) ELSE ("Inland_water_area_(IWA)"*"Long-term_average_evaporation_for_SW")/(Unit_correction_2*Unit_correction_3)))		Million m3/year	Total evaporation from inland surface waters according to their surface areas and the long-term average evaporation height
SW_to_industry	(IF (("Scenario_No." = 1 OR "Scenario_No." = 2 OR "Scenario_No." = 3 OR "Scenario_No." = 4 OR "Scenario_No." = 5) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; Fraction_of_SW_to_industry*Initial_SW*Unit_correction_1) ELSE Fraction_of_SW_to_industry*"Surface_water_(SW)"*Unit_correction_1)		Million m3/year	Flow from surface water that goes to industry according to the associated fraction and the total flow through surface water
SW_to_MWS	(IF (("Scenario_No." = 1 OR "Scenario_No." = 2 OR "Scenario_No." = 3 OR "Scenario_No." = 4) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; Fraction_of_SW_to_MWS*Initial_SW*Unit_correction_1) ELSE (IF ("Scenario_No." = 5 AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; (1+Urban_growth_rate)*Fraction_of_SW_to_MWS*Initial_SW*Unit_correction_1) ELSE Fraction_of_SW_to_MWS*"Surface_water_(SW)"*Unit_correction_1))		Million m3/year	Flow from surface water system that goes to municipal water supply according to the associated fraction and the total flow through surface water
SW_to_SSW	(IF (("Scenario_No." = 1 OR "Scenario_No." = 4) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; ("Surface_water_(SW)"*Unit_correction_1-SW_to_agriculture-SW_to_evaporation-SW_to_industry-SW_to_MWS)*(Fraction_of_SW_to_SSW/(Fraction_of_SW_to_SSW+Fraction_of_SW_to_coastal_outflow))) ELSE (IF (("Scenario_No." = 2 OR "Scenario_No." = 3 OR "Scenario_No." = 5) AND TIME >=		Million m3/year	Flow from surface water system that goes to subsurface water according to the associated fraction and the total flow through surface water

	(STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; ("Surface_water_(SW)"*Unit_correction_1-SW_to_agriculture-SW_to_industry-SW_to_MWS)*(Fraction_of_SW_to_SSW/(Fraction_of_SW_to_SSW+Fraction_of_SW_to_coastal_outflow+Fraction_of_SW_to_evaporation))) ELSE Fraction_of_SW_to_SSW*"Surface_water_(SW)"*Unit_correction_1))			
UCWW_to_evaporation	(IF (("Scenario_No." = 2 OR "Scenario_No." = 3 OR "Scenario_No." = 4 OR "Scenario_No." = 5) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; Fraction_of_UCWW_to_evaporation*"Unconnected_coastal_wastewater_(UCWW)"*Unit_correction_1) ELSE (IF ("Scenario_No." = 1 AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; Fraction_of_UCWW_to_evaporation*Initial_UCWW*Unit_correction_1) ELSE Fraction_of_UCWW_to_evaporation*"Unconnected_coastal_wastewater_(UCWW)"*Unit_correction_1))		Million m3/year	Total evaporation from unconnected coastal wastewater according to its total flow and associated evaporation fraction
UCWW_to_SSW	(IF (("Scenario_No." = 2 OR "Scenario_No." = 3 OR "Scenario_No." = 4 OR "Scenario_No." = 5) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; Fraction_of_UCWW_to_SSW*"Unconnected_coastal_wastewater_(UCWW)"*Unit_correction_1) ELSE (IF ("Scenario_No." = 1 AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; (Fraction_of_UCWW_to_SSW/(Fraction_of_UCWW_to_SSW+Fraction_of_UCWW_to_SW))*("Unconnected_coastal_wastewater_(UCWW)"*Unit_correction_1-UCWW_to_evaporation)) ELSE Fraction_of_UCWW_to_SSW*"Unconnected_coastal_wastewater_(UCWW)"*Unit_correction_1))		Million m3/year	Flow from unconnected coastal wastewater that goes to subsurface water system according to the associated fraction and the total unconnected coastal wastewater
UCWW_to_SW	(IF (("Scenario_No." = 2 OR "Scenario_No." = 3 OR "Scenario_No." = 4 OR "Scenario_No." = 5) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; Fraction_of_UCWW_to_SW*"Unconnected_coastal_wastewater_(UCWW)"*Unit_correction_1) ELSE (IF ("Scenario_No." = 1 AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; (Fraction_of_UCWW_to_SW/(Fraction_of_UCWW_to_SSW+Fraction_of_UCWW_to_SW))*("Unconnected_coastal_wastewater_(UCWW)"*Unit_correction_1-UCWW_to_evaporation)) ELSE Fraction_of_UCWW_to_SW*"Unconnected_coastal_wastewater_(UCWW)"*Unit_correction_1))		Million m3/year	Flow from unconnected coastal wastewater that goes to surface water system according to the associated fraction and the total unconnected coastal wastewater

USR_to_evaporation	(IF ("Scenario_No." = 2 AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; Fraction_of_USR_to_evaporation*"Urban_surface_runoff_(USR)"*Unit_correction_1) ELSE (IF ("Scenario_No." = 1 AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; ("Long-term_average_evaporation_for_USR"*"Built_land_(BL)")/(Unit_correction_2*Unit_correction_3)) ELSE (IF (("Scenario_No." = 3 OR "Scenario_No." = 4) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN ("Long-term_average_evaporation_for_USR"*"Built_land_(BL)")/(Unit_correction_2*Unit_correction_3) ELSE (IF ("Scenario_No." = 5 AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; Fraction_of_USR_to_evaporation*Unit_correction_1*Initial_USR) ELSE ("Long-term_average_evaporation_for_USR"*"Built_land_(BL)")/(Unit_correction_2*Unit_correction_3)))))		Million m3/year	Total evaporation from urban surface runoff in built areas according to their land areas and the long-term average evaporation height
USR_to_SW	(IF ("Scenario_No." = 2 AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; Fraction_of_USR_to_SW*"Urban_surface_runoff_(USR)"*Unit_correction_1) ELSE (IF ("Scenario_No." = 1 AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; 1*("Urban_surface_runoff_(USR)"*Unit_correction_1-USR_to_evaporation-USR_to_WWTP)) ELSE (IF (("Scenario_No." = 3 OR "Scenario_No." = 4 OR "Scenario_No." = 5) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; ("Urban_surface_runoff_(USR)"*Unit_correction_1-USR_to_evaporation)*(Fraction_of_USR_to_SW/(Fraction_of_USR_to_SW+Fraction_of_USR_to_WWTP))) ELSE Fraction_of_USR_to_SW*"Urban_surface_runoff_(USR)"*Unit_correction_1)))		Million m3/year	Flow from urban surface runoff that goes to surface water system according to the associated fraction and the total flow through built areas as surface runoff
USR_to_WWTP	(IF ("Scenario_No." = 2 AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; Fraction_of_USR_to_WWTP*"Urban_surface_runoff_(USR)"*Unit_correction_1) ELSE (IF ("Scenario_No." = 1 AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; Fraction_of_USR_to_WWTP*Initial_USR*Unit_correction_1) ELSE (IF (("Scenario_No." = 3 OR "Scenario_No." = 4 OR "Scenario_No." = 5) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; ("Urban_surface_runoff_(USR)"*Unit_correction_1-USR_to_evaporation)*(Fraction_of_USR_to_WWTP/(Fraction_of_USR_		Million m3/year	Flow from urban surface runoff that goes to wastewater treatment plant according to the associated fraction and the total flow through built areas as surface runoff

	to_WWTP+Fraction_of_USR_to_SW))) ELSE Fraction_of_USR_to_WWTP*"Urban_surface_runoff_(USR)"*Unit_correction_1)))			
WWTP_to_SW	(IF (("Scenario_No." = 2 OR "Scenario_No." = 3 OR "Scenario_No." = 4 OR "Scenario_No." = 5) AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; Fraction_of_WWTP_to_SW*"Wastewater_treatment_plant_(WWTP)"*Unit_correction_1) ELSE (IF ("Scenario_No." = 1 AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN MAX(0; Fraction_of_WWTP_to_SW*Initial_WWTP*Unit_correction_1) ELSE Fraction_of_WWTP_to_SW*"Wastewater_treatment_plant_(WWTP)"*Unit_correction_1))		Million m3/year	Flow from wastewater treatment plant that goes to surface water system according to the associated fraction and the total flow through wastewater treatment plant
"Scenario_No."	Scenario		Dmnl	Parameter setting to define scenario number and control the boundary conditions for each.
Agricultural_intensification_rate	0		Dmnl	Parameter setting for scenario of agricultural intensification without land expansion which is defined based on increased required flow through agricultural areas, indicating the percentage of change in total flow through agricultural areas. The value should be positive. This is defined as a slider variable in the 'Dashboard view'
"Agricultural_land_(AL)"	(IF ("Scenario_No." = 4 AND TIME >= (STARTTIME+INT((1/2)*(STOPTIME-STARTTIME)))) THEN MAX(0; Fraction_of_L_to_AL*(1+Fraction_of_FL_to_AL)*"Total_catchment_area_(L)") ELSE MAX(0; Fraction_of_L_to_AL*"Total_catchment_area_(L)"))		m2	The total inland catchment area covered by agricultural areas Scenario #4 is defined based on agricultural expansion that happens in the middle of the simulation period, where agricultural land area increases at the cost of a decrease in the forest area.
BSAP_policy_indicator_on_nitrogen	(IF "BSAP-N_load_target" > 0 THEN ("Total_natural/sectoral_nitrogen_load_to_the_coast"-"BSAP-N_load_target")/"BSAP-N_load_target" ELSE (IF "BSAP-N_load_target" < 0 THEN "Total_natural/sectoral_nitrogen_load_to_the_coast"/ABS("BSAP-N_load_target") ELSE (IF "Total_natural/sectoral_nitrogen_load_to_the_coast" < 1 THEN "Total_natural/sectoral_nitrogen_load_to_the_coast" ELSE		Dmnl	Policy indicator based on the nitrogen load reduction target defined in the Baltic Sea Action Plan (BSAP)

	"Total_natural/sectoral_nitrogen_load_to_the_coast"/INT("Total_natural/sectoral_nitrogen_load_to_the_coast"))))			
BSAP_policy_indicator_on_phosphorus	(IF "BSAP-P_load_target" > 0 THEN ("Total_natural/sectoral_phosphorus_load_to_the_coast"-"BSAP-P_load_target")/"BSAP-P_load_target" ELSE (IF "BSAP-P_load_target" < 0 THEN "Total_natural/sectoral_phosphorus_load_to_the_coast"/ABS("BSAP-P_load_target") ELSE (IF "Total_natural/sectoral_phosphorus_load_to_the_coast" < 1 THEN "Total_natural/sectoral_phosphorus_load_to_the_coast" ELSE "Total_natural/sectoral_phosphorus_load_to_the_coast"/INT("Total_natural/sectoral_phosphorus_load_to_the_coast"))))		Dmnl	Policy indicator based on the phosphorus load reduction target defined in the Baltic Sea Action Plan (BSAP)
"BSAP-N_load_target"	Initial_coastal_nitrogen_load-(22600*94000)/571600		Thousand kg/year	Nitrogen load target in the Baltic Sea Action Plan (BSAP) for the Norrström outflow to the coast Source: Hannerz, F., and Destouni, G. (2006) Spatial characterization of the Baltic Sea drainage basin and its unmonitored catchments. AMBIO, 35(5), pp. 214-219 Source: HELCOM Baltic Sea Action Plan (2007) HELCOM Ministerial Meeting, Krakow, Poland - Page 8.
"BSAP-P_load_target"	Initial_coastal_phosphorus_load-(22600*12500)/571600		Thousand kg/year	Phosphorus load target in the Baltic Sea Action Plan (BSAP) for the Norrström outflow to the coast Source: Hannerz, F., and Destouni, G. (2006) Spatial characterization of the Baltic Sea drainage basin and its unmonitored catchments. AMBIO, 35(5), pp. 214-219 Source: HELCOM Baltic Sea Action Plan (2007) HELCOM Ministerial Meeting, Krakow, Poland - Page 8.
"Built_land_(BL)"	(IF ("Scenario_No." = 5 AND TIME >= (STARTTIME+INT((1/2)*(STOPTIME-STARTTIME)))) THEN MAX(0; Fraction_of_L_to_BL*(1+Fraction_of_FL_to_BL)*"Total_catchment_ar		m2	The total inland catchment area covered by built (urban) areas

	ea_(L)") ELSE MAX(0; Fraction_of_L_to_BL*"Total_catchment_area_(L)"))			
CCWI_change_rate	Precipitation_change_rate		Dmnl	Parameter setting for scenario of climate change which is defined based on cross-catchment water inflow (CCWI) following precipitation changes, indicating the percentage of change in CCWI which is considered the same as precipitation. The value can be positive or negative depending on precipitation increase or decrease.
"Concentration_of_N-agriculture_to_SSW"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'NitrogenCon.'_,'C9'_)}		kg/m3	Nitrogen concentration in flow from agricultural lands to subsurface water Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2 Source: Hannerz F. and Destouni G. (2006) Spatial characterization of the Baltic Sea drainage basin and its unmonitored catchments, AMBIO Source: Levi, L., Cvetkovic, V., and Destouni, G. (2018) Data-driven analysis of nutrient inputs and transfers through nested catchments. STOTEN --> Figure 8 a-b
"Concentration_of_N-agriculture_to_SW"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'NitrogenCon.'_,'B9'_)}		kg/m3	Nitrogen concentration in flow from agricultural lands to surface water Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2
"Concentration_of_N-forest_to_SSW"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'NitrogenCon.'_,_'C8'_)}		kg/m3	Nitrogen concentration in flow from forest lands to subsurface water Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change

				simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2 Source: Hannerz F. and Destouni G. (2006) Spatial characterization of the Baltic Sea drainage basin and its unmonitored catchments, AMBIO Source: Levi, L., Cvetkovic, V., and Destouni, G. (2018) Data-driven analysis of nutrient inputs and transfers through nested catchments. STOTEN --> Figure 8 a-b
"Concentration_of_N-forest_to_SW"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'NitrogenCon.'_,_'B8'_)}		kg/m3	Nitrogen concentration in flow from forest lands to surface water Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2
"Concentration_of_N-industry_to_SW"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'NitrogenCon.'_,_'B5'_)}		kg/m3	Nitrogen concentration in flow from industry to surface water Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2
"Concentration_of_N-industry_to_USR"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'NitrogenCon.'_,_'G5'_)}		kg/m3	Nitrogen concentration in flow from industry to urban surface runoff Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2
"Concentration_of_N-industry_to_WWTP"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'NitrogenCon.'_,_'D5'_)}		kg/m3	Nitrogen concentration in flow from industry to wastewater treatment plant Source: Swedish EPA report on Wastewater treatment in Sweden 2016, pages 12 & 13

				https://www.naturvardsverket.se/Documents/publikationer6400/978-91-620-8809-5.pdf?pid=22471
"Concentration_of_N-MWS_to_agriculture"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'NitrogenCon.'_,'I6'_)}		kg/m3	Nitrogen concentration in flow from municipal water supply to industry Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2
"Concentration_of_N-MWS_to_industry"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'NitrogenCon.'_,_'E6'_)}		kg/m3	Nitrogen concentration in flow from municipal water supply to industry Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2
"Concentration_of_N-MWS_to_SSW"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'NitrogenCon.'_,_'C6'_)}		kg/m3	Nitrogen concentration in flow from municipal water supply to subsurface water Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2 Source: Hannerz F. and Destouni G. (2006) Spatial characterization of the Baltic Sea drainage basin and its unmonitored catchments, AMBIO Source: Levi, L., Cvetkovic, V., and Destouni, G. (2018) Data-driven analysis of nutrient inputs and transfers through nested catchments. STOTEN --> Figure 8 a-b
"Concentration_of_N-MWS_to_WWTP"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'NitrogenCon.'_,_'D6'_)}		kg/m3	Nitrogen concentration in flow from municipal water supply to wastewater treatment plant Source: Swedish EPA report on Wastewater

				treatment in Sweden 2016, pages 12 & 13 https://www.naturvardsverket.se/Documents/publikationer6400/978-91-620-8809-5.pdf?pid=22471
"Concentration_of_N-SSW_to_coastal_outflow"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'NitrogenCon.'_,_'K3'_)}		kg/m3	Nitrogen concentration in coastal subsurface water flow
"Concentration_of_N-SSW_to_industry"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'NitrogenCon.'_,'E3'_)}		kg/m3	Nitrogen concentration in flow from subsurface water to industry Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2 Source: Hannerz F. and Destouni G. (2006) Spatial characterization of the Baltic Sea drainage basin and its unmonitored catchments, AMBIO Source: Levi, L., Cvetkovic, V., and Destouni, G. (2018) Data-driven analysis of nutrient inputs and transfers through nested catchments. STOTEN --> Figure 8 a-b
"Concentration_of_N-SSW_to_MWS"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'NitrogenCon.'_,'F3'_)}		kg/m3	Nitrogen concentration in flow from subsurface water to municipal water supply Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2 Source: Hannerz F. and Destouni G. (2006) Spatial characterization of the Baltic Sea drainage basin and its unmonitored catchments, AMBIO Source: Levi, L., Cvetkovic, V., and Destouni, G. (2018) Data-driven analysis of nutrient inputs and transfers through nested catchments. STOTEN --> Figure 8 a-b

"Concentration_of_N-SSW_to_SW"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'NitrogenCon.'_,'B3'_)}		kg/m3	Nitrogen concentration in flow from subsurface water to surface water Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2 Source: Hannerz F. and Destouni G. (2006) Spatial characterization of the Baltic Sea drainage basin and its unmonitored catchments, AMBIO Source: Levi, L., Cvetkovic, V., and Destouni, G. (2018) Data-driven analysis of nutrient inputs and transfers through nested catchments. STOTEN --> Figure 8 a-b
"Concentration_of_N-SSW_to_UCWW"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'NitrogenCon.'_,'J3'_)}		kg/m3	Nitrogen concentration in flow from subsurface water to unconnected coastal wastewater Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2 Source: Hannerz F. and Destouni G. (2006) Spatial characterization of the Baltic Sea drainage basin and its unmonitored catchments, AMBIO Source: Levi, L., Cvetkovic, V., and Destouni, G. (2018) Data-driven analysis of nutrient inputs and transfers through nested catchments. STOTEN --> Figure 8 a-b
"Concentration_of_N-SW_to_agriculture"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'NitrogenCon.'_,_'I2'_)}		kg/m3	Nitrogen concentration in flow from surface water to agricultural lands Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term

				riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2
"Concentration_of_N-SW_to_coastal_outflow"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'NitrogenCon.'_,_'K2'_)}		kg/m3	Nitrogen concentration in coastal surface water flow Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2
"Concentration_of_N-SW_to_industry"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'NitrogenCon.'_,_'E2'_)}		kg/m3	Nitrogen concentration in flow from surface water to industry Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2
"Concentration_of_N-SW_to_MWS"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'NitrogenCon.'_,_'F2'_)}		kg/m3	Nitrogen concentration in flow from surface water to municipal water supply Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2
"Concentration_of_N-SW_to_SSW"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'NitrogenCon.'_,_'C2'_)}		kg/m3	Nitrogen concentration in flow from surface water to subsurface water Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2
"Concentration_of_N-UCWW_to_SSW"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'NitrogenCon.'_,_'C10'_)}		kg/m3	Nitrogen concentration in flow from unconnected coastal wastewater to subsurface water Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change

				simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2 Source: Hannerz F. and Destouni G. (2006) Spatial characterization of the Baltic Sea drainage basin and its unmonitored catchments, AMBIO Source: Levi, L., Cvetkovic, V., and Destouni, G. (2018) Data-driven analysis of nutrient inputs and transfers through nested catchments. STOTEN --> Figure 8 a-b
"Concentration_of_N-UCWW_to_SW"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'NitrogenCon.'_,_'B10'_)}		kg/m3	Nitrogen concentration in flow from unconnected coastal wastewater to surface water Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2
"Concentration_of_N-USR_to_SW"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'NitrogenCon.'_,_'B7'_)}		kg/m3	Nitrogen concentration in flow from urban surface runoff to surface water Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2
"Concentration_of_N-USR_to_WWTP"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'NitrogenCon.'_,_'D7'_)}		kg/m3	Nitrogen concentration in flow from urban surface runoff to wastewater treatment plant Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2
"Concentration_of_N-WWTP_to_SW"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'NitrogenCon.'_,'B4'_)}		kg/m3	Nitrogen concentration in flow from wastewater treatment plant to surface water

				Source: Wastewater treatment in Sweden 2016 (Swedish EPA report) --> Page 12
"Concentration_of_P-agriculture_to_SSW"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'PhosphorusCon.'_,'C9'_)}		kg/m3	Phosphorus concentration in flow from agricultural lands to subsurface water Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2 Source: Hannerz F. and Destouni G. (2006) Spatial characterization of the Baltic Sea drainage basin and its unmonitored catchments, AMBIO Source: Levi, L., Cvetkovic, V., and Destouni, G. (2018) Data-driven analysis of nutrient inputs and transfers through nested catchments. STOTEN --> Figure 8 a-b
"Concentration_of_P-agriculture_to_SW"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'PhosphorusCon.'_,'B9'_)}		kg/m3	Phosphorus concentration in flow from agricultural lands to surface water Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2
"Concentration_of_P-forest_to_SSW"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'PhosphorusCon.'_,_'C8'_)}		kg/m3	Phosphorus concentration in flow from forest lands to subsurface water Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2 Source: Hannerz F. and Destouni G. (2006) Spatial characterization of the Baltic Sea drainage basin and its unmonitored catchments, AMBIO Source: Levi, L., Cvetkovic, V., and Destouni,

				G. (2018) Data-driven analysis of nutrient inputs and transfers through nested catchments. STOTEN --> Figure 8 a-b
"Concentration_of_P-forest_to_SW"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'PhosphorusCon.'_,_'B8'_)}		kg/m3	Phosphorus concentration in flow from forest lands to surface water Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2
"Concentration_of_P-industry_to_SW"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'PhosphorusCon.'_,_'B5'_)}		kg/m3	Phosphorus concentration in flow from industry to surface water Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2
"Concentration_of_P-industry_to_USR"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'PhosphorusCon.'_,_'G5'_)}		kg/m3	Phosphorus concentration in flow from industry to urban surface runoff Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2
"Concentration_of_P-industry_to_WWTP"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'PhosphorusCon.'_,_'D5'_)}		kg/m3	Phosphorus concentration in flow from industry to wastewater treatment plant Source: Swedish EPA report on Wastewater treatment in Sweden 2016, pages 12 & 13 https://www.naturvardsverket.se/Documents/publikationer6400/978-91-620-8809-5.pdf?pid=22471
"Concentration_of_P-MWS_to_agriculture"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'PhosphorusCon.'_,_'I6'_)}		kg/m3	Phosphorus concentration in flow from municipal water supply to industry Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change

				simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2
"Concentration_of_P-MWS_to_industry"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'PhosphorusCon.'_,_'E6'_)}		kg/m3	Phosphorus concentration in flow from municipal water supply to industry Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2
"Concentration_of_P-MWS_to_SSW"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'PhosphorusCon.'_,_'C6'_)}		kg/m3	Phosphorus concentration in flow from municipal water supply to subsurface water Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2 Source: Hannerz F. and Destouni G. (2006) Spatial characterization of the Baltic Sea drainage basin and its unmonitored catchments, AMBIO Source: Levi, L., Cvetkovic, V., and Destouni, G. (2018) Data-driven analysis of nutrient inputs and transfers through nested catchments. STOTEN --> Figure 8 a-b
"Concentration_of_P-MWS_to_WWTP"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'PhosphorusCon.'_,_'D6'_)}		kg/m3	Phosphorus concentration in flow from municipal water supply to wastewater treatment plant Source: Swedish EPA report on Wastewater treatment in Sweden 2016, pages 12 & 13 https://www.naturvardsverket.se/Documents/publikationer6400/978-91-620-8809-5.pdf?pid=22471
"Concentration_of_P-SSW_to_coastal_outflow"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'PhosphorusCon.'_,_'K3'_)}		kg/m3	Phosphorus concentration in coastal subsurface water flow

				Source: Hanners F. and Destouni G. (2006) Spatial characterization of the Baltic Sea drainage basin and its unmonitored catchments, AMBIO Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2
"Concentration_of_P-SSW_to_industry"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'PhosphorusCon.'_,'E3'_)}		kg/m3	Phosphorus concentration in flow from subsurface water to industry Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2 Source: Hannerz F. and Destouni G. (2006) Spatial characterization of the Baltic Sea drainage basin and its unmonitored catchments, AMBIO Source: Levi, L., Cvetkovic, V., and Destouni, G. (2018) Data-driven analysis of nutrient inputs and transfers through nested catchments. STOTEN --> Figure 8 a-b
"Concentration_of_P-SSW_to_MWS"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'PhosphorusCon.'_,'F3'_)}		kg/m3	Phosphorus concentration in flow from subsurface water to municipal water supply Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2 Source: Hannerz F. and Destouni G. (2006) Spatial characterization of the Baltic Sea drainage basin and its unmonitored catchments, AMBIO Source: Levi, L., Cvetkovic, V., and Destouni, G. (2018) Data-driven analysis of nutrient

				inputs and transfers through nested catchments. STOTEN --> Figure 8 a-b
"Concentration_of_P-SSW_to_SW"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'PhosphorusCon.'_,'B3'_)}		kg/m3	Phosphorus concentration in flow from subsurface water to surface water Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2 Source: Hannerz F. and Destouni G. (2006) Spatial characterization of the Baltic Sea drainage basin and its unmonitored catchments, AMBIO Source: Levi, L., Cvetkovic, V., and Destouni, G. (2018) Data-driven analysis of nutrient inputs and transfers through nested catchments. STOTEN --> Figure 8 a-b
"Concentration_of_P-SSW_to_UCWW"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'PhosphorusCon.'_,'J3'_)}		kg/m3	Phosphorus concentration in flow from subsurface water to unconnected coastal wastewater Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2 Source: Hannerz F. and Destouni G. (2006) Spatial characterization of the Baltic Sea drainage basin and its unmonitored catchments, AMBIO Source: Levi, L., Cvetkovic, V., and Destouni, G. (2018) Data-driven analysis of nutrient inputs and transfers through nested catchments. STOTEN --> Figure 8 a-b
"Concentration_of_P-SW_to_agriculture"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'PhosphorusCon.'_,_'I2'_)}		kg/m3	Phosphorus concentration in flow from surface water to agricultural lands Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change

				simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2
"Concentration_of_P-SW_to_coastal_outflow"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'PhosphorusCon.'_,_'K2'_)}		kg/m3	Phosphorus concentration in coastal surface water flow Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2
"Concentration_of_P-SW_to_industry"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'PhosphorusCon.'_,_'E2'_)}		kg/m3	Phosphorus concentration in flow from surface water to industry Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2
"Concentration_of_P-SW_to_MWS"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'PhosphorusCon.'_,_'F2')}		kg/m3	Phosphorus concentration in flow from surface water to municipal water supply Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2
"Concentration_of_P-SW_to_SSW"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'PhosphorusCon.'_,_'C2'_)}		kg/m3	Phosphorus concentration in flow from surface water to subsurface water Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2
"Concentration_of_P-UCWW_to_SSW"	0{GET_XLS_CONSTANTS('Input_Data.xlsx','PhosphorusCon.'_,_'C10'_)}		kg/m3	Phosphorus concentration in flow from unconnected coastal wastewater to subsurface water Source: Bring, A., Rogberg, P., and Destouni,

				G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2 Source: Hannerz F. and Destouni G. (2006) Spatial characterization of the Baltic Sea drainage basin and its unmonitored catchments, AMBIO Source: Levi, L., Cvetkovic, V., and Destouni, G. (2018) Data-driven analysis of nutrient inputs and transfers through nested catchments. STOTEN --> Figure 8 a-b
"Concentration_of_P-UCWW_to_SW"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'PhosphorusCon.'_,_'B10'_)}		kg/m3	Phosphorus concentration in flow from unconnected coastal wastewater to surface water Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2
"Concentration_of_P-USR_to_SW"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'PhosphorusCon.'_,_'B7'_)}		kg/m3	Phosphorus concentration in flow from urban surface runoff to surface water Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2
"Concentration_of_P-USR_to_WWTP"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'PhosphorusCon.'_,_'D7'_)}		kg/m3	Phosphorus concentration in flow from urban surface runoff to wastewater treatment plant Source: Bring, A., Rogberg, P., and Destouni, G. (2005) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea. AMBIO --> Table 2
"Concentration_of_P-WWTP_to_SW"	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'PhosphorusCon.'_,'B4'_)}		kg/m3	Phosphorus concentration in flow from wastewater treatment plant to surface

				water Source: Wastewater treatment in Sweden 2016 (Swedish EPA report) --> Page 12
"Cross-catchment_water_export_(CCWE)"	MWS_to_CCWE		Million m3/year	Total water flow that is exported from the inland catchment to adjacent catchments through drinking water and good exports ~ :SUPPLEMENTARY
"Cross-catchment_water_inflow_(CCWI)"	(IF (Scenario_on_CCWI = 1 AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN ((1+CCWI_change_rate)*"Long-term_average_cross-catchment_water_inflow_(LTA-CCWI)") ELSE (IF (Scenario_on_CCWI = 1 AND TIME < (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN "Long-term_average_cross-catchment_water_inflow_(LTA-CCWI)" ELSE (IF (Scenario_on_CCWI = 2 AND TIME <= (STARTTIME+INT((1/3)*(STOPTIME-STARTTIME)))) THEN "Long-term_average_cross-catchment_water_inflow_(LTA-CCWI)" ELSE (IF (Scenario_on_CCWI = 2 AND (STARTTIME+INT((1/3)*(STOPTIME-STARTTIME))) < TIME AND TIME <= (STARTTIME+INT((2/3)*(STOPTIME-STARTTIME)))) THEN ((1+(TIME-1-(STARTTIME+INT((1/3)*(STOPTIME-STARTTIME))))*(1/(1+(STARTTIME+INT((1/3)*(STOPTIME-STARTTIME)))))*CCWI_change_rate)*"Long-term_average_cross-catchment_water_inflow_(LTA-CCWI)") ELSE (IF (Scenario_on_CCWI = 2 AND TIME > (STARTTIME+INT((2/3)*(STOPTIME-STARTTIME)))) THEN ((1+CCWI_change_rate)*"Long-term_average_cross-catchment_water_inflow_(LTA-CCWI)") ELSE (IF Scenario_on_CCWI = 0 THEN "Long-term_average_cross-catchment_water_inflow_(LTA-CCWI)" ELSE 0))))))		Million m3	The long-term annual average cross-catchment water inflow (CCWI) volume after applying changes related to various scenarios in the model.
Evapotranspiration	Agriculture_to_evapotranspiration+Forest_to_evapotranspiration+Industry_to_evaporation+SW_to_evaporation+UCWW_to_evaporation+USR_to_evaporation		Million m3/year	Total evapotranspiration from inland and coastal system components and sectoral activities ~ :SUPPLEMENTARY
"Forest_land_(FL)"	(IF ("Scenario_No." = 4 AND TIME >= (STARTTIME+INT((1/2)*(STOPTIME-STARTTIME)))) THEN MAX(0; "Total_catchment_area_(L)"*(1-Fraction_of_L_to_BL-Fraction_of_L_to_IWL-Fraction_of_L_to_OL-(Fraction_of_L_to_AL*(1+Fraction_of_FL_to_AL)))) ELSE (IF ("Scenario_No." = 5 AND TIME >= (STARTTIME+INT((1/2)*(STOPTIME-STARTTIME)))) THEN MAX(0; "Total_catchment_area_(L)"*(1-Fraction_of_L_to_AL-Fraction_of_L_to_IWL-Fraction_of_L_to_OL-		m2	The total inland catchment area covered by forest areas

	(Fraction_of_L_to_BL*(1+Fraction_of_FL_to_BL)))) ELSE MAX(0; Fraction_of_L_to_FL*"Total_catchment_area_(L)")))			
Fraction_of_agriculture_to_evapotranspiration	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'WaterQuantity',_'K9'_)}		Dmnl	The fraction of total flow through agricultural areas that contributes to the regional evapotranspiration over the inland catchment Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
Fraction_of_agriculture_to_SSW	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'WaterQuantity',_'C9'_)}		Dmnl	The fraction of total flow through agriculture that goes to subsurface water system Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
Fraction_of_agriculture_to_SW	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'WaterQuantity',_'B9'_)}		Dmnl	The fraction of total flow through agriculture that goes to surface water system Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
Fraction_of_CCWI_to_SSW	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'WaterQuantity'_,_'C12'_)}		Dmnl	The fraction of total cross-catchment water inflow to the catchment that goes to subsurface water system Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
Fraction_of_FL_to_AL	0		Dmnl	Parameter setting for scenario of agricultural expansion while competing with forest on land areas, indicating the fraction of forest areas that will be changed to agricultural areas under this scenario

				This is defined as a slider variable in the 'Dashboard view'
Fraction_of_FL_to_BL	Urban_growth_rate		Dmnl	Parameter setting for scenario of urban development while competing with forest on land areas, indicating the fraction of forest areas that will be changed to urban built areas under this scenario This is defined as a slider variable in the 'Dashboard view'
Fraction_of_forest_to_evapotranspiration	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'WaterQuantity',_'K8'_)}		Dmnl	The fraction of total flow through forest areas that contirbutes to the regional evapotranspiration over the inland catchment Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
Fraction_of_forest_to_SSW	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'WaterQuantity'_,_'C8'_)}		Dmnl	The fraction of total flow through forest areas that goes to subsurface water system Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
Fraction_of_forest_to_SW	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'WaterQuantity',_'B8'_)}		Dmnl	The fraction of total flow through forest that goes to surface water system Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
Fraction_of_industry_to_evaporation	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'WaterQuantity',_'K5'_)}		Dmnl	The fraction of total flow through industry that contributes to industrial evaporation Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2

Fraction_of_industry_to_SW	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'WaterQuantity'_,_'B5'_)}		Dmnl	The fraction of total flow through industry that goes to surface water system Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
Fraction_of_industry_to_USR	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'WaterQuantity',_'G5'_)}		Dmnl	The fraction of total flow through industry that contributes to the urban surface runoff Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
Fraction_of_industry_to_WWTP	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'WaterQuantity'_,_'D5'_)}		Dmnl	The fraction of total flow through industry that goes into the wastewater treatment plant Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
Fraction_of_L_to_AL	0{GET_XLS_CONSTANTS(_'Input_Data.xlsx'_,_'LandCover'_,_'B2'_)}		Dmnl	The fraction of total inland catchment covered by agricultural areas Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, page 10
Fraction_of_L_to_BL	0{GET_XLS_CONSTANTS(_'Input_Data.xlsx'_,_'LandCover'_,_'B3'_)}		Dmnl	The fraction of total inland catchment covered by built (urban) areas Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, page 10
Fraction_of_L_to_FL	0{GET_XLS_CONSTANTS(_'Input_Data.xlsx'_,_'LandCover'_,_'B5'_)}		Dmnl	The fraction of total inland catchment covered by forest areas Source: Cseh, M. (2009) Multi-approach

				comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, page 10
Fraction_of_L_to_IWL	0{GET_XLS_CONSTANTS(_'Input_Data.xlsx'_,_'LandCover'_,_'B4'_)}		Dmnl	The fraction of total inland catchment covered by inland surface water Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, page 10
Fraction_of_L_to_OL	0{GET_XLS_CONSTANTS(_'Input_Data.xlsx'_,_'LandCover'_,_'B6'_)}		Dmnl	The fraction of total inland catchment (remaining from the other land-use types) covered by other types of land cover e.g. passtures Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, page 10
Fraction_of_MWS_to_agric ulture	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'WaterQuantity',_'I6'_)}		Dmnl	The fraction of total flow through municipal water supply system that goes to agriculture Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
Fraction_of_MWS_to_expor t	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'WaterQuantity'_,_'M6'_)}		Dmnl	The fraction of total flow municipal water supply system that goes to cross-catchment water export Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
Fraction_of_MWS_to_indus try	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'WaterQuantity',_'E6'_)}		Dmnl	The fraction of total flow through municipal water supply that goes to industry Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the

				Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
Fraction_of_MWS_to_SSW	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'WaterQuantity'_,_'C6'_)}		Dmnl	The fraction of total flow through municipal water supply that goes to subsurface water system Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
Fraction_of_MWS_to_WWTP	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'WaterQuantity'_,_'D6'_)}		Dmnl	The fraction of total flow through municipal water supply that goes to wastewater treatment plant Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
Fraction_of_SSW_to_coastal_outflow	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'WaterQuantity',_'L3'_)}		Dmnl	The fraction of total flow through subsurface water system that contributes to coastal outflow Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
Fraction_of_SSW_to_industry	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'WaterQuantity'_,_'E3'_)}		Dmnl	The fraction of total flow through subsurface water system that goes to industry Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
Fraction_of_SSW_to_MWS	0{GET_XLS_CONSTANTS('Input_Data.xlsx','WaterQuantity',_'F3'_)}		Dmnl	The fraction of total flow through subsurface water system that goes to municipal water supply system Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the

				Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
Fraction_of_SSW_to_SW	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'WaterQuantity'_,_'B3'_)}		Dmnl	The fraction of total flow through subsurface water that contributes to the surface water inflow Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
Fraction_of_SSW_to_UCWW	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'WaterQuantity',_'J3'_)}		Dmnl	The fraction of total flow through subsurface water system that goes to unconnected coastal watewater Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
Fraction_of_SW_to_agriculture	0{GET_XLS_CONSTANTS(_'Input_Data.xlsx',_'WaterQuantity',_'I2')}		Dmnl	The fraction of total flow through surface water system that goes to agriculture Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
Fraction_of_SW_to_coastal_outflow	0{GET_XLS_CONSTANTS(_'Input_Data.xlsx',_'WaterQuantity',_'L2')}		Dmnl	The fraction of total flow through surface water that contributes to the coastal outflow Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
Fraction_of_SW_to_evaporation	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'WaterQuantity',_'K2'_)}		Dmnl	The fraction of total flow through surface water sub-system that contributes to the regional evapotranspiration over the inland catchment Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the

				Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
Fraction_of_SW_to_industry	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'WaterQuantity'_,_'E2'_)}		Dmnl	The fraction of total flow through surface water system that goes to industry Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
Fraction_of_SW_to_intensified_agriculture	(Fraction_of_SW_to_agriculture/(Fraction_of_SW_to_agriculture*Initial_SW*Unit_correction_1))*(Initial_Agriculture*(1+Agricultural_intensification_rate)*Unit_correction_1-MWS_to_agriculture-Precipitation_to_agriculture)		Dmnl	The fraction of total flow through surface water that goes to agricultural areas under the scenario of agricultural intensification, as the total excess required water to supply agriculture is taken from the surface water system. This is an adjusted fraction used only for this scenario. ~ :SUPPLEMENTARY
Fraction_of_SW_to_MWS	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'WaterQuantity'_,_'F2'_)}		Dmnl	The fraction of total flow through surface water system that goes to municipal water supply Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
Fraction_of_SW_to_SSW	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'WaterQuantity'_,_'C2'_)}		Dmnl	The fraction of total flow through surface water that contributes to the subsurface water inflow Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
Fraction_of_UCWW_to_evaporation	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'WaterQuantity'_,_'K10'_)}		Dmnl	The fraction of total unconnected coastal waterwater that is evaporated Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2

Fraction_of_UCWW_to_SSW	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'WaterQuantity',_'C10'_)}		Dmnl	The fraction of total unconnected coastal wastewater that goes to the subsurface water system Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
Fraction_of_UCWW_to_SW	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'WaterQuantity'_,_'B10'_)}		Dmnl	The fraction of total unconnected coastal wastewater that goes to the surface water system Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
Fraction_of_USR_to_evaporation	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'WaterQuantity',_'K7'_)}		Dmnl	The fraction of total flow through build areas as urban surface runoff that contirbutes to the regional evapotranspiration over the inland catchment Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
Fraction_of_USR_to_SW	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'WaterQuantity',_'B7'_)}		Dmnl	The fraction of total urban surface runoff that goes to surface water system Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
Fraction_of_USR_to_WWTP	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'WaterQuantity'_,_'D7'_)}		Dmnl	The fraction of total urban surface runoff that goes to wastewater treatment plant Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2

Fraction_of_WWTP_to_SW	0{GET_XLS_CONSTANTS('Input_Data.xlsx',_'WaterQuantity',_'B4'_)}		Dmnl	The fraction of total flow through wastewater treatment plant that goes to surface water system Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2
Initial_Agriculture	INIT(Agriculture)		Million m3	Initial flow through agricultural areas within the base case scenario
Initial_coastal_nitrogen_load	INIT("Total_natural/sectoral_nitrogen_load_to_the_coast")		Thousand kg/year	Total natural/sectoral nitrogen load to the coast under the base case scenario
Initial_coastal_phosphorus_load	INIT("Total_natural/sectoral_phosphorus_load_to_the_coast")		Thousand kg/year	Total natural/sectoral phosphorus load to the coast under the base case scenario
Initial_Forest	INIT(Forest)		Million m3	Initial flow through forest areas within the base case scenario
Initial_Industry	INIT(Industry)		Million m3	Initial flow through industry within the base case scenario
Initial_MWS	INIT("Municipal_water_supply_(MWS)")		Million m3	Initial flow through municipal water supply system within the base case scenario
Initial_SSW	INIT("Subsurface_water_(SSW)")		Million m3	Initial flow through subsurface water system within the base case scenario
Initial_SW	INIT("Surface_water_(SW)")		Million m3	Initial flow through surface water system within the base case scenario
Initial_UCWW	INIT("Unconnected_coastal_wastewater_(UCWW)")		Million m3	Initial unconnected coastal waterwater volume within the base case scenario
Initial_USR	INIT("Urban_surface_runoff_(USR)")		Million m3	Initial flow through built areas as urban surface runoff within the base case scenario
Initial_WWTP	INIT("Wastewater_treatment_plant_(WWTP)")		Million m3	Initial flow through wastewater treatment plant within the base case scenario
"Inland_water_area_(IWA)"	MAX(0; Fraction_of_L_to_IWL*"Total_catchment_area_(L)")		m2	The total inland catchment area covered by inland surface water
"Long-term_average_cross-catchment_water_inflow_(LTA-CCWI)"	0{GET_XLS_CONSTANTS(_'Input_Data.xlsx'_,_'WaterQuantity'_,_'N12'_)}		Million m3	The long-term annual average cross-catchment water inflow (CCWI) volume over the inland catchment area Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2

"Long-term_average_evaporation_for_SW"	MAX(0; "Long-term_average_evaporation_for_SW_(volume)"/(Fraction_of_L_to_IWL*"Total_catchment_area_(L)")*Unit_correction_2*Unit_correction_3)		m/year	The long-term annual average evapotration height for the inland surface water sub-system, calculated based on the inland surface water areas
"Long-term_average_evaporation_for_SW_(volume)"	MAX(0; Fraction_of_SW_to_evaporation*Initial_SW*Unit_correction_1)		Million m3/year	The long-term annual average evapotration volume from inland surface water sub-system based on the base case condition
"Long-term_average_evaporation_for_USR"	MAX(0; "Long-term_average_evaporation_for_USR_(volume)"/(Fraction_of_L_to_BL*"Total_catchment_area_(L)")*Unit_correction_2*Unit_correction_3)		m/year	The long-term annual average evapotration height for the urban surface runoff in the built areas, calculated based on the built land areas
"Long-term_average_evaporation_for_USR_(volume)"	MAX(0; Fraction_of_USR_to_evaporation*Initial_USR*Unit_correction_1)		Million m3/year	The long-term annual average evaporation volume from urban surface runoff in built areas based on the base case condition
"Long-term_average_evapotranspiration_for_agriculture"	MAX(0; "Long-term_average_evapotranspiration_for_agriculture_(volume)"/(Fraction_of_L_to_AL*"Total_catchment_area_(L)")*Unit_correction_2*Unit_correction_3)		m/year	The long-term annual average evapotranspiration height for the agricultural areas, calculated based on the agricultural land areas
"Long-term_average_evapotranspiration_for_agriculture_(volume)"	MAX(0; Fraction_of_agriculture_to_evapotranspiration*Initial_Agriculture*Unit_correction_1)		Million m3/year	The long-term annual average evapotranspiration volume from agricultural areas based on the base case condition
"Long-term_average_evapotranspiration_for_forest"	MAX(0; "Long-term_average_evapotranspiration_for_forest_(volume)"/(Fraction_of_L_to_FL*"Total_catchment_area_(L)")*Unit_correction_2*Unit_correction_3)		m/year	The long-term annual average evapotranspiration height for the forest areas, calculated based on the forest land areas
"Long-term_average_evapotranspiration_for_forest_(volume)"	MAX(0; Fraction_of_forest_to_evapotranspiration*Initial_Forest*Unit_correction_1)		Million m3/year	The long-term annual average evapotranspiration volume from forest areas based on the base case condition
"Long-term_average_precipitation"	MAX(0; "Long-term_average_precipitation_(volume)"/"Total_catchment_area_(L)"*Unit_correction_2*Unit_correction_3)		m/year	The long-term annual average precipitation height over the inland catchment area
"Long-term_average_precipitation_(volume)"	0{GET_XLS_CONSTANTS(_'Input_Data.xlsx'_,_'WaterQuantity'_,_'N11'_)}		Million m3/year	The long-term annual average precipitation volume over the inland catchment area Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Table 2

N_load_from_agriculture_to_SSW	MAX(0; ("Concentration_of_N-agriculture_to_SSW"*Agriculture_to_SSW*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Total nitrogen load from agricultural lands to subsurface water
N_load_from_agriculture_to_SW	MAX(0; ("Concentration_of_N-agriculture_to_SW"*Agriculture_to_SW*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Total nitrogen load from agricultural lands to surface water
N_load_from_forest_to_SSW	MAX(0; ("Concentration_of_N-forest_to_SSW"*Forest_to_SSW*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Nitrogen load from forest lands to subsurface water
N_load_from_forest_to_SW	MAX(0; ("Concentration_of_N-forest_to_SW"*Forest_to_SW*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Nitrogen load from forest lands to surface water
N_load_from_industry_to_SW	MAX(0; ("Concentration_of_N-industry_to_SW"*Industry_to_SW*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Nitrogen load from industry to surface water
N_load_from_industry_to_USR	MAX(0; ("Concentration_of_N-industry_to_USR"*Industry_to_USR*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Nitrogen load from industry to urban surface runoff
N_load_from_industry_to_WWTP	MAX(0; ("Concentration_of_N-industry_to_WWTP"*Industry_to_WWTP*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Nitrogen load from industry to wastewater treatment plant
N_load_from_MWS_to_agriculture	MAX(0; ("Concentration_of_N-MWS_to_agriculture"*MWS_to_agriculture*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Total nitrogen load from municipal water supply to agricultural lands
N_load_from_MWS_to_industry	MAX(0; ("Concentration_of_N-MWS_to_industry"*MWS_to_industry*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Total nitrogen load from municipal water supply to industry
N_load_from_MWS_to_SSW	MAX(0; ("Concentration_of_N-MWS_to_SSW"*MWS_to_SSW*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Total nitrogen load from municipal water supply to subsurface water
N_load_from_MWS_to_WWTP	MAX(0; ("Concentration_of_N-MWS_to_WWTP"*MWS_to_WWTP*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Total nitrogen load from municipal water supply to wastewater treatment plant
N_load_from_SSW_to_industry	MAX(0; ("Concentration_of_N-SSW_to_industry"*SSW_to_industry*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Total nitrogen load from subsurface water to industry
N_load_from_SSW_to_MWS	MAX(0; ("Concentration_of_N-SSW_to_MWS"*SSW_to_MWS*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Total nitrogen load from subsurface water to municipal water supply
N_load_from_SSW_to_SW	MAX(0; ("Concentration_of_N-SSW_to_SW"*SSW_to_SW*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Total nitrogen load from subsurface water to surface water

N_load_from_SSW_to_the_coast	("Concentration_of_N-SSW_to_coastal_outflow"*SSW_to_coastal_outflow*Unit_correction_5)/Unit_correction_4		Thousand kg/year	
N_load_from_SSW_to_UCWW	MAX(0; ("Concentration_of_N-SSW_to_UCWW"*SSW_to_UCWW*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Total nitrogen load from subsurface water to unconnected coastal wastewater
N_load_from_SW_to_agriculture	MAX(0; ("Concentration_of_N-SW_to_agriculture"*SW_to_agriculture*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Nitrogen load from surface water to agricultural lands
N_load_from_SW_to_industry	MAX(0; ("Concentration_of_N-SW_to_industry"*SW_to_industry*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Nitrogen load from surface water to industry
N_load_from_SW_to_MWS	MAX(0; ("Concentration_of_N-SW_to_MWS"*SW_to_MWS*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Nitrogen load from surface water to municipal water supply
N_load_from_SW_to_SSW	MAX(0; ("Concentration_of_N-SW_to_SSW"*SW_to_SSW*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Nitrogen load from surface water to subsurface water
N_load_from_SW_to_the_coast	("Concentration_of_N-SW_to_coastal_outflow"*SW_to_coastal_outflow*Unit_correction_5)/Unit_correction_4		Thousand kg/year	
N_load_from_UCWW_to_SSW	MAX(0; ("Concentration_of_N-UCWW_to_SSW"*UCWW_to_SSW*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Total nitrogen load from unconnected coastal wastewater to subsurface water
N_load_from_UCWW_to_SW	MAX(0; ("Concentration_of_N-UCWW_to_SW"*UCWW_to_SW*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Total nitrogen load from unconnected coastal wastewater to surface water
N_load_from_USR_to_SW	MAX(0; ("Concentration_of_N-USR_to_SW"*USR_to_SW*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Nitrogen load from urban surface runoff to surface water
N_load_from_USR_to_WWTP	MAX(0; ("Concentration_of_N-USR_to_WWTP"*USR_to_WWTP*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Nitrogen load from urban surface runoff to wastewater treatment plant
N_load_from_WWTP_to_SW	MAX(0; ("Concentration_of_N-WWTP_to_SW"*WWTP_to_SW*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Total nitrogen load from wastewater treatment plant to surface water
"Other_areas_(OL)"	MAX(0; "Total_catchment_area_(L)"*Fraction_of_L_to_OL)		m2	The total inland catchment area (remaining from the other land-use types) covered by other types of land cover e.g. passtures ~ :SUPPLEMENTARY
Outflow_to_the_coast	SSW_to_coastal_outflow+SW_to_coastal_outflow		Million m3/year	The total annual water outflow (volume) to the coast ~ :SUPPLEMENTARY

P_load_from_agriculture_to_SSW	MAX(0; ("Concentration_of_P-agriculture_to_SSW"*Agriculture_to_SSW*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Total phosphorus load from agricultural lands to subsurface water
P_load_from_agriculture_to_SW	MAX(0; ("Concentration_of_P-agriculture_to_SW"*Agriculture_to_SW*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Total phosphorus load from agricultural lands to surface water
P_load_from_forest_to_SSW	MAX(0; ("Concentration_of_P-forest_to_SSW"*Forest_to_SSW*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Phosphorus load from forest lands to subsurface water
P_load_from_forest_to_SW	MAX(0; ("Concentration_of_P-forest_to_SW"*Forest_to_SW*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Phosphorus load from forest lands to surface water
P_load_from_industry_to_SW	MAX(0; ("Concentration_of_P-industry_to_SW"*Industry_to_SW*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Phosphorus load frm industry to surface water
P_load_from_industry_to_USR	MAX(0; ("Concentration_of_P-industry_to_USR"*Industry_to_USR*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Phosphorus load from industry to urban surface runoff
P_load_from_industry_to_WWTP	MAX(0; ("Concentration_of_P-industry_to_WWTP"*Industry_to_WWTP*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Phosphorus load from industry to wastewater treatment plant
P_load_from_MWS_to_agriculture	MAX(0; ("Concentration_of_P-MWS_to_agriculture"*MWS_to_agriculture*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Total phosphorus load from municipal water supply to agricultural lands
P_load_from_MWS_to_industry	MAX(0; ("Concentration_of_P-MWS_to_industry"*MWS_to_industry*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Total phosphorus load from municipal water supply to industry
P_load_from_MWS_to_SSW	MAX(0; ("Concentration_of_P-MWS_to_SSW"*MWS_to_SSW*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Total phosphorus load from municipal water supply to subsurface water
P_load_from_MWS_to_WWTP	MAX(0; ("Concentration_of_P-MWS_to_WWTP"*MWS_to_WWTP*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Total phosphorus load from municipal water supply to wastewater treatment plant
P_load_from_SSW_to_industry	MAX(0; ("Concentration_of_P-SSW_to_industry"*SSW_to_industry*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Total phosphorus load from subsurface water to industry
P_load_from_SSW_to_MWS	MAX(0; ("Concentration_of_P-SSW_to_MWS"*SSW_to_MWS*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Total phosphorus load from subsurface water to municipal water supply
P_load_from_SSW_to_SW	MAX(0; ("Concentration_of_P-SSW_to_SW"*SSW_to_SW*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Total phosphorus load from subsurface water to surface water

P_load_from_SSW_to_the_coast	("Concentration_of_P-SSW_to_coastal_outflow"*SSW_to_coastal_outflow*Unit_correction_5)/Unit_correction_4		Thousand kg/year	
P_load_from_SSW_to_UCWW	MAX(0; (SSW_to_UCWW*"Concentration_of_P-SSW_to_UCWW"*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Total phosphorus load from subsurface water to unconnected coastal wastewater
P_load_from_SW_to_agriculture	MAX(0; ("Concentration_of_P-SW_to_agriculture"*SW_to_agriculture*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Phosphorus load from surface water to agricultural lands
P_load_from_SW_to_industry	MAX(0; ("Concentration_of_P-SW_to_industry"*SW_to_industry*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Phosphorus load from surface water to industry
P_load_from_SW_to_MWS	MAX(0; ("Concentration_of_P-SW_to_MWS"*SW_to_MWS*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Phosphorus load from surface water to municipal water supply
P_load_from_SW_to_SSW	MAX(0; ("Concentration_of_P-SW_to_SSW"*SW_to_SSW*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Phosphorus load from surface water to subsurface water
P_load_from_SW_to_the_coast	("Concentration_of_P-SW_to_coastal_outflow"*SW_to_coastal_outflow*Unit_correction_5)/Unit_correction_4		Thousand kg/year	
P_load_from_UCWW_to_SSW	MAX(0; ("Concentration_of_P-UCWW_to_SSW"*UCWW_to_SSW*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Total phosphorus load from unconnected coastal wastewater to subsurface water
P_load_from_UCWW_to_SW	MAX(0; ("Concentration_of_P-UCWW_to_SW"*UCWW_to_SW*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Total phosphorus load from unconnected coastal wastewater to surface water
P_load_from_USR_to_SW	MAX(0; ("Concentration_of_P-USR_to_SW"*USR_to_SW*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Phosphorus load from urban surface runoff to surface water
P_load_from_USR_to_WWTP	MAX(0; ("Concentration_of_P-USR_to_WWTP"*USR_to_WWTP*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Phosphorus load from urban surface runoff to wastewater treatment plant
P_load_from_WWTP_to_SW	MAX(0; ("Concentration_of_P-WWTP_to_SW"*WWTP_to_SW*Unit_correction_5)/Unit_correction_4)		Thousand kg/year	Total phosphorus load from wastewater treatment plant to surface water
Precipitation	(IF (Scenario_on_Precipitation = 1 AND TIME >= (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN ((1+Precipitation_change_rate)*"Long-term_average_precipitation") ELSE (IF (Scenario_on_Precipitation = 1 AND TIME < (STARTTIME+INT(0,5*(STOPTIME-STARTTIME)))) THEN "Long-term_average_precipitation" ELSE (IF (Scenario_on_Precipitation = 2 AND TIME <= (STARTTIME+INT((1/3)*(STOPTIME-STARTTIME)))) THEN "Long-term_average_precipitation" ELSE (IF		m/year	The long-term annual average precipitation height after applying changes related to various scenarios in the model.

	(Scenario_on_Precipitation = 2 AND (STARTTIME+INT((1/3)*(STOPTIME-STARTTIME))) < TIME AND TIME <= (STARTTIME+INT((2/3)*(STOPTIME-STARTTIME)))) THEN ((1+(TIME-1-(STARTTIME+INT((1/3)*(STOPTIME-STARTTIME))))*(1/(1+(STARTTIME+INT((1/3)*(STOPTIME-STARTTIME)))))*Precipitation_change_rate)*"Long-term_average_precipitation") ELSE (IF (Scenario_on_Precipitation = 2 AND TIME > (STARTTIME+INT((2/3)*(STOPTIME-STARTTIME)))) THEN ((1+Precipitation_change_rate)*"Long-term_average_precipitation") ELSE (IF Scenario_on_Precipitation = 0 THEN "Long-term_average_precipitation" ELSE 0)))))			
"Precipitation_(volume)"	MAX(0; (Precipitation*"Total_catchment_area_(L)")/(Unit_correction_2*Unit_correction_3))		Million m3/year	The long-term annual average precipitation volume after applying changes related to various scenarios in the model. ~ :SUPPLEMENTARY
Precipitation_change_rate	0		Dmnl	Parameter setting for scenario of climate change which is defined based on precipitation changes, indicating the percentage of change in precipitation. The value can be positive or negative depending on precipitation increase or decrease. This is defined as a slider variable in the 'Dashboard view'
"Proxy_of_seawater_intrusion_risk_(SWIR)"	1-(SSW_to_coastal_outflow/SSW_to_coastal_outflow_for_the_base_case)		Dmnl	A proxy of seawater intrusion risk, its positive (negative) value means subsurface water flow to the coast has decreased (increased) compared to the base case scenario, and the risk of critical seawater intrusion has increased (decreased), implying decreased (increased) quality of fresh coastal groundwater; and of coastal water, by associated increased (decreased) recirculation of seawater after intrusion into the coastal aquifer, and through that more (less) dissolution and loading of nutrients or other pollutants to the coastal waters. Source: Mazi K, Koussis AD, Destouni G, Quantifying a sustainable management

				space for human use of coastal groundwater under multiple change pressures, Water Resources Management, 30, 4063-4080, 2016. ~ :SUPPLEMENTARY
Scenario	0		Dmnl	Parameter setting to define scenario number and control the boundary conditions for each. This is defined as a slider variale on the 'Dashboard view'
Scenario_on_CCWI	Scenario_on_Precipitation		Dmnl	Parameter setting to define change pattern (instant at the middle of the simulation period or linear between the 1/3 and 2/3 of the simulation period) for cross-catchment water inflow (CCWI) which follows precipitation condition under the climate change scenarios
Scenario_on_Precipitation	0		Dmnl	Parameter setting to define change pattern (instant at the middle of the simulation period or linear between the 1/3 and 2/3 of the simulation period) for precipitation under the climate change scenarios This is defined as a slider variable in the 'Dashboard view'
SSW_to_coastal_outflow_for_the_base_case	MAX(0; Fraction_of_SSW_to_coastal_outflow*Initial_SSW*Unit_correction_1)		Million m3/year	Total subsurface flow to the coast under the base case scenario defined according to the initial value of the total flow through subsurface water system and the associated fraction for coastal outflow
"Total_catchment_area_(L)"	0{GET_XLS_CONSTANTS(_'Input_Data.xlsx'_,_'LandCover'_,_'B1'_)}		m2	The total area of the inland catchment basin Source: Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, page 10

"Total_natural/sectoral_nitrogen_load_to_agriculture"	N_load_from_MWS_to_agriculture+N_load_from_SW_to_agriculture		Thousand kg/year	Total nitrogen load from the system to agriculture
"Total_natural/sectoral_nitrogen_load_to_industry"	N_load_from_SW_to_industry+N_load_from_SSW_to_industry+N_load_from_MWS_to_industry		Thousand kg/year	Total nitrogen load from the system to industry
"Total_natural/sectoral_nitrogen_load_to_MWS"	N_load_from_SSW_to_MWS+N_load_from_SW_to_MWS		Thousand kg/year	Total nitrogen load from the system to municipal water supply
"Total_natural/sectoral_nitrogen_load_to_SSW"	N_load_from_agriculture_to_SSW+N_load_from_forest_to_SSW+N_load_from_MWS_to_SSW+N_load_from_SW_to_SSW+N_load_from_UCWW_to_SSW		Thousand kg/year	Total nitrogen load from the system to subsurface water
"Total_natural/sectoral_nitrogen_load_to_SW"	N_load_from_agriculture_to_SW+N_load_from_forest_to_SW+N_load_from_industry_to_SW+N_load_from_SSW_to_SW+N_load_from_USR_to_SW+N_load_from_UCWW_to_SW+N_load_from_WWTP_to_SW		Thousand kg/year	Total nitrogen load from the system to surface water
"Total_natural/sectoral_nitrogen_load_to_the_coast"	N_load_from_SSW_to_the_coast+N_load_from_SW_to_the_coast		Thousand kg/year	Total nitrogen load to the coast through both surface and subsurface water ~ :SUPPLEMENTARY
"Total_natural/sectoral_nitrogen_load_to_UCWW"	N_load_from_SSW_to_UCWW		Thousand kg/year	Total nitrogen load from the system to unconnected coastal wastewater
"Total_natural/sectoral_nitrogen_load_to_USR"	N_load_from_industry_to_USR		Thousand kg/year	Total nitrogen load from the system to urban surface runoff
"Total_natural/sectoral_nitrogen_load_to_WWTP"	N_load_from_industry_to_WWTP+N_load_from_USR_to_WWTP+N_load_from_MWS_to_WWTP		Thousand kg/year	Total nitrogen load from the system to wastewater treatment plant
"Total_natural/sectoral_nutrient_load_to_agriculture"	"Total_natural/sectoral_nitrogen_load_to_agriculture"+"Total_natural/sectoral_phosphorus_load_to_agriculture"		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load from the system to agriculture ~ :SUPPLEMENTARY
"Total_natural/sectoral_nutrient_load_to_industry"	"Total_natural/sectoral_nitrogen_load_to_industry"+"Total_natural/sectoral_phosphorus_load_to_industry"		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load from the system to industry ~ :SUPPLEMENTARY
"Total_natural/sectoral_nutrient_load_to_MWS"	"Total_natural/sectoral_nitrogen_load_to_MWS"+"Total_natural/sectoral_phosphorus_load_to_MWS"		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load from the system to municipal water supply ~ :SUPPLEMENTARY
"Total_natural/sectoral_nutrient_load_to_SSW"	"Total_natural/sectoral_nitrogen_load_to_SSW"+"Total_natural/sectoral_phosphorus_load_to_SSW"		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load from the system to subsurface water ~ :SUPPLEMENTARY
"Total_natural/sectoral_nutrient_load_to_SW"	"Total_natural/sectoral_phosphorus_load_to_SW"+"Total_natural/sectoral_nitrogen_load_to_SW"		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load from the system to surface water ~ :SUPPLEMENTARY
"Total_natural/sectoral_nutrient_load_to_the_coast"	Total_nutrient_load_from_SSW_to_the_coast+Total_nutrient_load_from_SW_to_the_coast		Thousand kg/year	Total nutrient (nitrogen and phosphorus) loads to the coast through both surface and

				subsurface water ~ :SUPPLEMENTARY
"Total_natural/sectoral_nutrient_load_to_UCWW"	"Total_natural/sectoral_nitrogen_load_to_UCWW"+"Total_natural/sectoral_phosphorus_load_to_UCWW"		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load from the system to unconnected coastal wastewater ~ :SUPPLEMENTARY
"Total_natural/sectoral_nutrient_load_to_USR"	"Total_natural/sectoral_nitrogen_load_to_USR"+"Total_natural/sectoral_phosphorus_load_to_USR"		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load from the system to urban surface runoff ~ :SUPPLEMENTARY
"Total_natural/sectoral_nutrient_load_to_WWTP"	"Total_natural/sectoral_nitrogen_load_to_WWTP"+"Total_natural/sectoral_phosphorus_load_to_WWTP"		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load from the system to wastewater treatment plant ~ :SUPPLEMENTARY
"Total_natural/sectoral_phosphorus_load_to_agriculture"	P_load_from_MWS_to_agriculture+P_load_from_SW_to_agriculture		Thousand kg/year	Total phosphorus load from the system to agriculture
"Total_natural/sectoral_phosphorus_load_to_industry"	P_load_from_MWS_to_industry+P_load_from_SSW_to_industry+P_load_from_SW_to_industry		Thousand kg/year	Total phosphorus load from the system to industry
"Total_natural/sectoral_phosphorus_load_to_MWS"	P_load_from_SSW_to_MWS+P_load_from_SW_to_MWS		Thousand kg/year	Total phosphorus load from the system to municipal water supply
"Total_natural/sectoral_phosphorus_load_to_SSW"	P_load_from_agriculture_to_SSW+P_load_from_forest_to_SSW+P_load_from_UCWW_to_SSW+P_load_from_MWS_to_SSW+P_load_from_SW_to_SSW		Thousand kg/year	Total phosphorus load from the system to subsurface water
"Total_natural/sectoral_phosphorus_load_to_SW"	P_load_from_agriculture_to_SW+P_load_from_forest_to_SW+P_load_from_industry_to_SW+P_load_from_SSW_to_SW+P_load_from_USR_to_SW+P_load_from_UCWW_to_SW+P_load_from_WWTP_to_SW		Thousand kg/year	Total phosphorus load from the system to surface water
"Total_natural/sectoral_phosphorus_load_to_the_coast"	P_load_from_SSW_to_the_coast+P_load_from_SW_to_the_coast		Thousand kg/year	Total phosphorus load to the coast through both surface and subsurface water ~ :SUPPLEMENTARY
"Total_natural/sectoral_phosphorus_load_to_UCWW"	P_load_from_SSW_to_UCWW		Thousand kg/year	Total phosphorus load from the system to unconnected coastal wastewater
"Total_natural/sectoral_phosphorus_load_to_USR"	P_load_from_industry_to_USR		Thousand kg/year	Total phosphorus load from the system to urban surface runoff
"Total_natural/sectoral_phosphorus_load_to_WWTP"	P_load_from_MWS_to_WWTP+P_load_from_industry_to_WWTP+P_load_from_USR_to_WWTP		Thousand kg/year	Total phosphorus load from the system to wastewater treatment plant
Total_nitrogen_discharge_from_agriculture	N_load_from_agriculture_to_SSW+N_load_from_agriculture_to_SW		Thousand kg/year	Total nitrogen load discharged from agricultural lands to the system
Total_nitrogen_discharge_from_forest	N_load_from_forest_to_SSW+N_load_from_forest_to_SW		Thousand kg/year	Total nitrogen load discharged from forest lands to the system

Total_nitrogen_discharge_from_industry	N_load_from_industry_to_SW+N_load_from_industry_to_USR+N_load_from_industry_to_WWTP		Thousand kg/year	Total nitrogen load discharged from industry to the system
Total_nitrogen_discharge_from_MWS	N_load_from_MWS_to_agriculture+N_load_from_MWS_to_industry+N_load_from_MWS_to_SSW+N_load_from_MWS_to_WWTP		Thousand kg/year	Total nitrogen load discharged from municipal water supply to the system
Total_nitrogen_discharge_from_SSW	N_load_from_SSW_to_industry+N_load_from_SSW_to_MWS+N_load_from_SSW_to_SW+N_load_from_SSW_to_UCWW		Thousand kg/year	Total nitrogen load discharged from subsurface water to the system
Total_nitrogen_discharge_from_SW	N_load_from_SW_to_agriculture+N_load_from_SW_to_industry+N_load_from_SW_to_MWS+N_load_from_SW_to_SSW		Thousand kg/year	Total nitrogen load discharged from surface water to the system
Total_nitrogen_discharge_from_UCWW	N_load_from_UCWW_to_SSW+N_load_from_UCWW_to_SW		Thousand kg/year	Total nitrogen load discharged from unconnected coastal wastewater to the system
Total_nitrogen_discharge_from_USR	N_load_from_USR_to_SW+N_load_from_USR_to_WWTP		Thousand kg/year	Total nitrogen load discharged from urban surface runoff to the system
Total_nitrogen_discharge_from_WWTP	N_load_from_WWTP_to_SW		Thousand kg/year	Total nitrogen load discharged from wastewater treatment plant to the system
Total_nutrient_discharge_from_agriculture	Total_nitrogen_discharge_from_agriculture+Total_phosphorus_discharge_from_agriculture		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load discharged from agricultural lands to the system ~ :SUPPLEMENTARY
Total_nutrient_discharge_from_forest	Total_nitrogen_discharge_from_forest+Total_phosphorus_discharge_from_forest		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load discharged from forest lands to the system ~ :SUPPLEMENTARY
Total_nutrient_discharge_from_industry	Total_nitrogen_discharge_from_industry+Total_phosphorus_discharge_from_industry		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load discharged from industry to the system ~ :SUPPLEMENTARY
Total_nutrient_discharge_from_MWS	Total_nitrogen_discharge_from_MWS+Total_phosphorus_discharge_from_MWS		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load discharged from municipal water supply to the system ~ :SUPPLEMENTARY
Total_nutrient_discharge_from_SSW	Total_nitrogen_discharge_from_SSW+Total_phosphorus_discharge_from_SSW		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load discharged from subsurface water to the system ~ :SUPPLEMENTARY
Total_nutrient_discharge_from_SW	Total_nitrogen_discharge_from_SW+Total_phosphorus_discharge_from_SW		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load discharged from surface water to the system ~ :SUPPLEMENTARY
Total_nutrient_discharge_from_UCWW	Total_nitrogen_discharge_from_UCWW+Total_phosphorus_discharge_from_UCWW		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load discharged from unconnected coastal

				wastewater to the system ~ :SUPPLEMENTARY
Total_nutrient_discharge_from_USR	Total_nitrogen_discharge_from_USR+Total_phosphorus_discharge_from_USR		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load discharged from urban surface runoff to the system ~ :SUPPLEMENTARY
Total_nutrient_discharge_from_WWTP	Total_nitrogen_discharge_from_WWTP+Total_phosphorus_discharge_from_WWTP		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load discharged from wastewater treatment plant to the system ~ :SUPPLEMENTARY
Total_nutrient_load_from_agriculture_to_SSW	N_load_from_agriculture_to_SSW+P_load_from_agriculture_to_SSW		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load from agricultural lands to subsurface water ~ :SUPPLEMENTARY
Total_nutrient_load_from_agriculture_to_SW	N_load_from_agriculture_to_SW+P_load_from_agriculture_to_SW		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load from agricultural lands to surface water ~ :SUPPLEMENTARY
Total_nutrient_load_from_forest_to_SSW	N_load_from_forest_to_SSW+P_load_from_forest_to_SSW		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load from forest lands to subsurface water ~ :SUPPLEMENTARY
Total_nutrient_load_from_forest_to_SW	N_load_from_forest_to_SW+P_load_from_forest_to_SW		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load from forest lands to surface water ~ :SUPPLEMENTARY
Total_nutrient_load_from_industry_to_SW	N_load_from_industry_to_SW+P_load_from_industry_to_SW		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load from industry to surface water ~ :SUPPLEMENTARY
Total_nutrient_load_from_industry_to_USR	N_load_from_industry_to_USR+P_load_from_industry_to_USR		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load from industry to urban surface runoff ~ :SUPPLEMENTARY
Total_nutrient_load_from_industry_to_WWTP	N_load_from_industry_to_WWTP+P_load_from_industry_to_WWTP		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load from industry to wastewater treatment plant ~ :SUPPLEMENTARY
Total_nutrient_load_from_MWS_to_agriculture	N_load_from_MWS_to_agriculture+P_load_from_MWS_to_agriculture		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load from municipal water supply to agricultural lands ~ :SUPPLEMENTARY
Total_nutrient_load_from_MWS_to_industry	N_load_from_MWS_to_industry+P_load_from_MWS_to_industry		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load from municipal water supply to industry ~ :SUPPLEMENTARY

Total_nutrient_load_from_MWS_to_SSW	N_load_from_MWS_to_SSW+P_load_from_MWS_to_SSW		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load from municipal water supply to subsurface water ~ :SUPPLEMENTARY
Total_nutrient_load_from_MWS_to_WWTP	N_load_from_MWS_to_WWTP+P_load_from_MWS_to_WWTP		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load from municipal water supply to wastewater treatment plant ~ :SUPPLEMENTARY
Total_nutrient_load_from_SSW_to_industry	N_load_from_SSW_to_industry+P_load_from_SSW_to_industry		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load from subsubsurface water to industry ~ :SUPPLEMENTARY
Total_nutrient_load_from_SSW_to_MWS	N_load_from_SSW_to_MWS+P_load_from_SSW_to_MWS		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load from subsubsurface water to municipal water supply ~ :SUPPLEMENTARY
Total_nutrient_load_from_SSW_to_SW	N_load_from_SSW_to_SW+P_load_from_SSW_to_SW		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load from subsubsurface water to surface water ~ :SUPPLEMENTARY
Total_nutrient_load_from_SSW_to_the_coast	P_load_from_SSW_to_the_coast+N_load_from_SSW_to_the_coast		Thousand kg/year	Total nutrient (nitrogen and phosphorus) loads to the coast through subsurface water
Total_nutrient_load_from_SSW_to_UCWW	N_load_from_SSW_to_UCWW+P_load_from_SSW_to_UCWW		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load from subsubsurface water to unconnected coastal wastewater ~ :SUPPLEMENTARY
Total_nutrient_load_from_SW_to_agriculture	N_load_from_SW_to_agriculture+P_load_from_SW_to_agriculture		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load from surface water to agricultural lands ~ :SUPPLEMENTARY
Total_nutrient_load_from_SW_to_industry	N_load_from_SW_to_industry+P_load_from_SW_to_industry		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load from surface water to industry ~ :SUPPLEMENTARY
Total_nutrient_load_from_SW_to_MWS	N_load_from_SW_to_MWS+P_load_from_SW_to_MWS		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load from surface water to municipal water supply ~ :SUPPLEMENTARY
Total_nutrient_load_from_SW_to_SSW	N_load_from_SW_to_SSW+P_load_from_SW_to_SSW		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load from surface water to subsurface water ~ :SUPPLEMENTARY
Total_nutrient_load_from_SW_to_the_coast	P_load_from_SW_to_the_coast+N_load_from_SW_to_the_coast		Thousand kg/year	

Total_nutrient_load_from_UCWW_to_SSW	N_load_from_UCWW_to_SSW+P_load_from_UCWW_to_SSW		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load from unconnected coastal wastewater to subsubsurface water ~ :SUPPLEMENTARY
Total_nutrient_load_from_UCWW_to_SW	N_load_from_UCWW_to_SW+P_load_from_UCWW_to_SW		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load from unconnected coastal wastewater to surface water ~ :SUPPLEMENTARY
Total_nutrient_load_from_USR_to_SW	N_load_from_USR_to_SW+P_load_from_USR_to_SW		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load from urban surface runoff to surface water ~ :SUPPLEMENTARY
Total_nutrient_load_from_USR_to_WWTP	N_load_from_USR_to_WWTP+P_load_from_USR_to_WWTP		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load from urban surface runoff to wastewater treatment plant ~ :SUPPLEMENTARY
Total_nutrient_load_from_WWTP_to_SW	N_load_from_WWTP_to_SW+P_load_from_WWTP_to_SW		Thousand kg/year	Total nutrient (nitrogen and phosphorus) load from wastewater treatment plant to surface water ~ :SUPPLEMENTARY
Total_phosphorus_discharge_from_agriculture	P_load_from_agriculture_to_SSW+P_load_from_agriculture_to_SW		Thousand kg/year	Total phosphorus load discharged from agricultural lands to the system
Total_phosphorus_discharge_from_forest	P_load_from_forest_to_SSW+P_load_from_forest_to_SW		Thousand kg/year	Total phosphorus load discharged from forest lands to the system
Total_phosphorus_discharge_from_industry	P_load_from_industry_to_SW+P_load_from_industry_to_USR+P_load_from_industry_to_WWTP		Thousand kg/year	Total phosphorus load discharged from industry to the system
Total_phosphorus_discharge_from_MWS	P_load_from_MWS_to_agriculture+P_load_from_MWS_to_industry+P_load_from_MWS_to_SSW+P_load_from_MWS_to_WWTP		Thousand kg/year	Total phosphorus load discharged from municipal water supply to the system
Total_phosphorus_discharge_from_SSW	P_load_from_SSW_to_industry+P_load_from_SSW_to_MWS+P_load_from_SSW_to_SW+P_load_from_SSW_to_UCWW		Thousand kg/year	Total phosphorus load discharged from subsurface water to the system
Total_phosphorus_discharge_from_SW	P_load_from_SW_to_agriculture+P_load_from_SW_to_industry+P_load_from_SW_to_MWS+P_load_from_SW_to_SSW		Thousand kg/year	Total phosphorus load discharged from surface water to the system
Total_phosphorus_discharge_from_UCWW	P_load_from_UCWW_to_SSW+P_load_from_UCWW_to_SW		Thousand kg/year	Total phosphorus load discharged from unconnected coastal wastewater to the system
Total_phosphorus_discharge_from_USR	P_load_from_USR_to_SW+P_load_from_USR_to_WWTP		Thousand kg/year	Total phosphorus load discharged from urban surface runoff to the system
Total_phosphorus_discharge_from_WWTP	P_load_from_WWTP_to_SW		Thousand kg/year	Total phosphorus load discharged from wastewater treatment plant to the system
Unit_correction_1	1		1/year	Parameter setting for time unit correction

Unit_correction_2	1e+06		m/Million m3	Parameter setting for volume unit correction
Unit_correction_3	1		m2	Parameter setting for area unit correction
Unit_correction_4	1000		kg/Thousand kg	Parameter setting for mass unit correction
Unit_correction_5	1e+06		m3/Million m3	Parameter setting for volume unit correction
Urban_growth_rate	0		Dmnl	Parameter setting for scenario of urbanization with land expansion which is defined based on increased required flow through municipal water supply, indicating the percentage of change in total flow through municipal water supply and urban surface runoff. The value should be positive. This is defined as a slider variable in the 'Dashboard view'
Water_storage_change_within_the_system_at_the_catchment_scale	"Precipitation_(volume)"+"Cross-catchment_water_inflow_(CCWI)"-"Cross-catchment_water_export_(CCWE)"-Evapotranspiration-Outflow_to_the_coast		Million m3/year	Total water storage change (DS) in the whole integrated system to keep the mass balance at the catchment scale

Annex 4d – Overview of equations MAL04 – Charente

Table 10: Overview of equations used to quantify the integrated MAL4 SD model

	Equation	Properties	Units
Agriculture:			
agricultural_gross_product	conventional_gross_product+value_in_transition+organic_gross_product		euro/Year
agricultural_workers_factor	agricultural_workers/(50000*one_person)		Dmnl
agricultural_workers_weight	agricultural_workers_weight_choice/total_weight_choice		Dmnl
agricultural_workers_weight_choice	0		Dmnl
conventional_area(t)	conventional_area(t - dt) + (conventional_area_net_flow) * dt	INIT conventional_area = 650000	hectare
conventional_area_net_flow	unexplained_conventional_change-to_transition		hectare/month
conventional_gross_margin	0.25*conventional_gross_product		euro/Year
conventional_gross_product	conventional_area*value_per_ha_conventional		euro/Year
conventional_storage_need	stored_share_of_conventional_products*yield_conventional*one_year		ton
conversion_index	scalar*agricultural_workers_factor^agricultural_workers_weight*demand_for_organic_products_factor^demand_weight*organic_supply_chain_factor^supply_chain_weight*difference_in_income_factor^income_weight*regulation_factor^regulation_weight		Dmnl
conversion_rate	(IF TIME < 24240 THEN (TIME-STARTTIME)*past_rate/(240*one_month) ELSE conversion_index)/one_month		Dmnl/month
demand_for_organic_products_factor	demand_for_organic_products		Dmnl
demand_weight	demand_weight_choice/total_weight_choice		Dmnl
demand_weight_choice	0.4		Dmnl
difference_in_income_factor	MAX(0.001, MIN(1, ((organic_gross_margin-conventional_gross_margin)/(conventional_gross_margin))+(IF TIME < scenarios_first_month THEN 0 ELSE (TIME/one_month-24240)*subvention_effect/240)))		Dmnl
employment_agriculture	employment_conventional+employment_in_transition+employment_organic		person
employment_conventional	conventional_area*employment_per_ha_conventional		person
employment_in_transition	in_transition_area*employment_per_ha_in_transition		person

employment_organic	organic_area*employment_per_ha_organic		person
evapotranspiration_by_agricultural_covers	evapotranspiration_conventional+evapotranspiration_in_transition+evapotranspiration_organic		Mcubicmeter/month
evapotranspiration_conventional	conventional_area*evapotranspiration_per_ha_conventional		Mcubicmeter/month
evapotranspiration_in_transition	in_transition_area*evapotranspiration_per_ha_in_transition		Mcubicmeter/month
evapotranspiration_organic	organic_area*evapotranspiration_per_ha_organic		Mcubicmeter/month
g_per_l	1		g/L
in_transition_area(t)	in_transition_area(t - dt) + (to_transition - to_organic) * dt	INIT in_transition_area = 5000	hectare
income_weight	income_weight_choice/total_weight_choice		Dmnl
income_weight_choice	0.4		Dmnl
irrigation_water_deficit(t)	irrigation_water_deficit(t - dt) + (to_water_deficit) * dt	INIT irrigation_water_deficit = 0	Dmnl
irrigation_water_demand	water_demand_conventional+water_demand_organic+water_demand_Mm3_per_year_vineyards		Mcubicmeter/Year
N_use_agriculture	N_use_conventional+N_use_in_transition+N_use_organic		kg/month
N_use_conventional	conventional_area*N_use_per_ha_conventional		kg/month
N_use_in_transition	in_transition_area*N_use_per_ha_in_transition		kg/month
N_use_organic	organic_area*N_use_per_ha_organic		kg/month
organic_area(t)	organic_area(t - dt) + (to_organic - unexplained_organic_change) * dt	INIT organic_area = 14000	hectare
organic_gross_margin	0.8*organic_gross_product		euro/Year
organic_gross_product	organic_area*value_per_ha_organic		euro/Year
organic_share	organic_area/(conventional_area+organic_area)		Dmnl
organic_storage_need	stored_share_of_organic_products*(yield_in_transition+yield_organic)*one_year		ton
organic_supply_chain_factor	organic_supply_chain		Dmnl
other_land_use(t)	other_land_use(t - dt) + (unexplained_conventional_change + unexplained_organic_change) * dt	INIT other_land_use = 0	hectare
past_rate	0.002		Dmnl
regulation_factor	irrigation_water_deficit		Dmnl
regulation_weight	regulation_weight_choice/total_weight_choice		Dmnl
regulation_weight_choice	0.3		Dmnl

scalar	0.015		Dmnl
stored_share_of_conventional_products	0.7		Dmnl
stored_share_of_organic_products	0.7		Dmnl
supply_chain_weight	supply_chain_weight_choice/total_weight_choice		Dmnl
supply_chain_weight_choice	0.6		Dmnl
time_to_convert_to_organic	36		month
to_organic	DELAY(to_transition, time_to_convert_to_organic, 0)		hectare/month
to_transition	conversion_rate*conventional_area		hectare/month
to_water_deficit	(IF month_index = 1 AND INT(TIME) = TIME AND TIME > STARTTIME THEN ((1-MIN(1, cumulative_water_use_agriculture_over_one_year/irrigation_water_demand))/one_year-irrigation_water_deficit)/DT ELSE 0)		Dmnl/month
total_area	conventional_area+in_transition_area+organic_area		hectare
total_weight_choice	agricultural_workers_weight_choice+demand_weight_choice+supply_chain_weight_choice +income_weight_choice+regulation_weight_choice		Dmnl
total_yield	yield_conventional+yield_in_transition+yield_organic		ton/Year
unexplained_conventional_change	unexplained_change_rate_conventional*conventional_area		hectare/month
unexplained_organic_change	organic_area*unexplained_change_rate_organic		hectare/month
value_in_transition	in_transition_area*value_per_ha_in_transition		euro/Year
water_demand_conventional	water_demand_Mm3_per_year_conventional		Mcubicmeter/Year
water_demand_in_transition	water_demand_m3_per_ha_per_year_in_transition*in_transition_area		Mcubicmeter/Year
water_demand_organic	water_demand_Mm3_per_year_organic		Mcubicmeter/Year
yield_conventional	conventional_area*yield_per_ha_conventional		ton/Year
yield_in_transition	in_transition_area*yield_per_ha_in_transition		ton/Year
yield_organic	organic_area*yield_per_ha_organic		ton/Year
Common_inputs:			
evapotranspiration_potential	GRAPH(month_index) Points: (1.00, 12.00), (2.00, 19.2982), (3.00, 24.5614), (4.00, 32.0175), (5.00, 36.00), (6.00, 48.00), (7.00, 56.00), (8.00, 57.0175), (9.00, 48.00), (10.00, 28.5088), (11.00, 18.00), (12.00, 12.00)		mm/month
hour_per_year	365*24		hour/Year
m2_per_ha	10000		m2/hectare

Mm3_per_ha_per_mm	1e-05		Mcubicmeter/(hectare*mm)
Mm3_per_m2_per_mm	1e-09		Mcubicmeter/(m2*mm)
Mm3_per_m3	1e-06		Mcubicmeter/m3
Mm3_per_month_per_m3_per_sec	2.592		Mcubicmeter*s/(month*m3)
month_index	(1+MIN(12, MAX(0, INT(MODULO((TIME-STARTTIME), 12)))))/one_month		Dmnl
month_per_year	12		month/Year
one_bag	1		bag
one_euro_per_oyster	1		euro/oyster
one_euro_per_year	1		euro/Year
one_g_per_liter	1		g/liter
one_hectare	1		hectare
one_km	1		km
one_m3_per_ha_per_year	1		m3/(Year*hectare)
one_m3_per_sec	1		m3/s
one_mg_per_m3	1		mg/m3
one_mg_per_m3_per_oyster	1		mg/(m3*oyster)
one_mm_per_month	1		mm/month
one_Mm3	1		Mcubicmeter
one_month	1		month
one_month_per_year	1		month/Year
one_month_x_month	1		month*month
one_oyster	1		oyster
one_oyster_per_bag	1		oyster/bag
one_person	1		person
one_ton_per_year	1		ton/Year
one_vehicle_per_km	1		vehicle/km
one_year	1		Year

reference_evapotranspiration	GRAPH(0+0) Points: (1.00, 12.00), (2.00, 19.2982), (3.00, 24.5614), (4.00, 32.0175), (5.00, 36.00), (6.00, 48.00), (7.00, 56.00), (8.00, 57.0175), (9.00, 48.00), (10.00, 28.5088), (11.00, 18.00), (12.00, 12.00)		mm/month
reference_evapotranspiration_Mm3_per_ha	LOOKUP(reference_evapotranspiration, month_index)*Mm3_per_ha_per_mm		Mcubicmeter/(hectare*month)
scenarios_first_month	(2020*12)+1		month
Conventional_cultures:			
allowed_irrigation_water_demand_conventional	allowed_water_demand_per_year_conventional*LOOKUP(irrigation_per_month_conventional, month_index)		Mcubicmeter/month
allowed_water_demand_per_year_conventional	MIN(abstraction_permits_for_irrigation, water_demand_per_year_agriculture)*water_demand_Mm3_per_year_conventional/water_demand_per_year_agriculture		Mcubicmeter/Year
cumulative_irrigation_conventional	water_demand_Mm3_per_year_conventional*cumulative_irrigation_over_one_year/(water_demand_per_year_agriculture*one_year)		Mcubicmeter/Year
cumulative_irrigation_m3_per_hectare_conventional	cumulative_irrigation_conventional/(conventional_area*Mm3_per_m3)		m3/(hectare*Year)
cumulative_irrigation_over_one_year(t)	cumulative_irrigation_over_one_year(t - dt) + (to_cumul_irrigation) * dt	INIT cumulative_irrigation_over_one_year = 0	Mcubicmeter
employment_per_ha_conventional	0.9		person/hectare
evapotranspiration_per_ha_conventional	reference_evapotranspiration_Mm3_per_ha*(LOOKUP(Kc_1_conventional, month_index)*share_1_conventional+LOOKUP(Kc_2_conventional, month_index)*share_2_conventional+LOOKUP(Kc_3_conventional, month_index)*share_3_conventional+LOOKUP(Kc_4_conventional, month_index)*share_4_conventional+LOOKUP(Kc_5_conventional, month_index)*share_5_conventional+LOOKUP(Kc_6_conventional, month_index)*share_6_conventional+LOOKUP(Kc_7_conventional, month_index)*share_7_conventional+LOOKUP(Kc_8_conventional, month_index)*share_8_conventional+LOOKUP(Kc_9_conventional, month_index)*share_9_conventional+LOOKUP(Kc_10_conventional, month_index)*share_10_conventional+LOOKUP(Kc_11_conventional, month_index)*share_11_conventional+LOOKUP(Kc_12_conventional, month_index)*share_12_conventional+LOOKUP(Kc_13_conventional, month_index)*share_13_conventional+LOOKUP(Kc_14_conventional, month_index)*share_14_conventional+LOOKUP(Kc_15_conventional, month_index)*share_15_conventional)		Mcubicmeter/(hectare*month)
irrigation_per_month_conventional	GRAPH(0+0) Points: (1.00, 0.0000), (2.00, 0.0000), (3.00, 0.0000), (4.00, 0.0000), (5.00, 0.0500), (6.00, 0.2500), (7.00, 0.3250), (8.00, 0.3250), (9.00, 0.0500), (10.00, 0.0000), (11.00, 0.0000), (12.00, 0.0000)		Year/month

N_use_per_ha_conventional	LOOKUP(N_use_per_month_conventional, month_index)*(share_1_conventional*(LOOKUP(N_use_per_culture_conventional, 1)+LOOKUP(N_extra_use_if_irrigated_conventional, 1)*LOOKUP(irrigated_share_per_culture_conventional, 1))+share_2_conventional*(LOOKUP(N_use_per_culture_conventional, 2)+LOOKUP(N_extra_use_if_irrigated_conventional, 2)*LOOKUP(irrigated_share_per_culture_conventional, 2))+share_3_conventional*(LOOKUP(N_use_per_culture_conventional, 3)+LOOKUP(N_extra_use_if_irrigated_conventional, 3)*LOOKUP(irrigated_share_per_culture_conventional, 3))+share_4_conventional*(LOOKUP(N_use_per_culture_conventional, 4)+LOOKUP(N_extra_use_if_irrigated_conventional, 4)*LOOKUP(irrigated_share_per_culture_conventional, 4))+share_5_conventional*(LOOKUP(N_use_per_culture_conventional, 5)+LOOKUP(N_extra_use_if_irrigated_conventional, 5)*LOOKUP(irrigated_share_per_culture_conventional, 5))+share_6_conventional*(LOOKUP(N_use_per_culture_conventional, 6)+LOOKUP(N_extra_use_if_irrigated_conventional, 6)*LOOKUP(irrigated_share_per_culture_conventional, 6))+share_7_conventional*(LOOKUP(N_use_per_culture_conventional, 7)+LOOKUP(N_extra_use_if_irrigated_conventional, 7)*LOOKUP(irrigated_share_per_culture_conventional, 7))+share_8_conventional*(LOOKUP(N_use_per_culture_conventional, 8)+LOOKUP(N_extra_use_if_irrigated_conventional, 8)*LOOKUP(irrigated_share_per_culture_conventional, 8))+share_9_conventional*(LOOKUP(N_use_per_culture_conventional, 9)+LOOKUP(N_extra_use_if_irrigated_conventional, 9)*LOOKUP(irrigated_share_per_culture_conventional, 9))+share_10_conventional*(LOOKUP(N_use_per_culture_conventional, 10)+LOOKUP(N_extra_use_if_irrigated_conventional, 10)*LOOKUP(irrigated_share_per_culture_conventional, 10))+share_11_conventional*(LOOKUP(N_use_per_culture_conventional, 11)+LOOKUP(N_extra_use_if_irrigated_conventional, 11)*LOOKUP(irrigated_share_per_culture_conventional, 11))+share_12_conventional*(LOOKUP(N_use_per_culture_conventional, 12)+LOOKUP(N_extra_use_if_irrigated_conventional, 12)*LOOKUP(irrigated_share_per_culture_conventional, 12))+share_13_conventional*(LOOKUP(N_use_per_culture_conventional, 13)+LOOKUP(N_extra_use_if_irrigated_conventional, 13)*LOOKUP(irrigated_share_per_culture_conventional, 13))+share_14_conventional*(LOOKUP(N_use_per_culture_conventional, 14)+LOOKUP(N_extra_use_if_irrigated_conventional, 14)*LOOKUP(irrigated_share_per_culture_conventional, 14))+share_15_conventional*(LOOKUP(N_use_per_culture_conventional, 15)+LOOKUP(N_extra_use_if_irrigated_conventional, 15)*LOOKUP(irrigated_share_per_culture_conventional, 15)))		kg/(hectare*month)

N_use_per_month_conventional	GRAPH(0+0) Points: (1.00, 0.0000), (2.00, 0.0000), (3.00, 0.0000), (4.00, 0.0000), (5.00, 0.1000), (6.00, 0.2000), (7.00, 0.4000), (8.00, 0.2000), (9.00, 0.1000), (10.00, 0.0000), (11.00, 0.0000), (12.00, 0.0000)		Year/month
price_1_conventional	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'prices_conventional'_,_'A'_,_'B2'_)}		euro/ton
price_10_conventional	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'prices_conventional'_,_'A'_,_'K2'_)}		euro/ton
price_11_conventional	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'prices_conventional'_,_'A'_,_'L2'_)}		euro/ton
price_12_conventional	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'prices_conventional'_,_'A'_,_'M2'_)}		euro/ton
price_13_conventional	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'prices_conventional'_,_'A'_,_'N2'_)}		euro/ton
price_14_conventional	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'prices_conventional'_,_'A'_,_'O2'_)}		euro/ton
price_15_conventional	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'prices_conventional'_,_'A'_,_'P2'_)}		euro/ton
price_2_conventional	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'prices_conventional'_,_'A'_,_'C2'_)}		euro/ton
price_3_conventional	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'prices_conventional'_,_'A'_,_'D2'_)}		euro/ton
price_4_conventional	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'prices_conventional'_,_'A'_,_'E2'_)}		euro/ton
price_5_conventional	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'prices_conventional'_,_'A'_,_'F2'_)}		euro/ton
price_6_conventional	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'prices_conventional'_,_'A'_,_'G2'_)}		euro/ton
price_7_conventional	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'prices_conventional'_,_'A'_,_'H2'_)}		euro/ton
price_8_conventional	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'prices_conventional'_,_'A'_,_'I2'_)}		euro/ton
price_9_conventional	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'prices_conventional'_,_'A'_,_'J2'_)}		euro/ton
share_1_conventional(t)	share_1_conventional(t - dt) + (share_1_conventional_net_flow) * dt	INIT share_1_conventional = LOOKUP(share_of_the_agricultural_area_per_culture_conventional, 1)	Dmnl
share_1_conventional_net_flow	0/one_month		Dmnl/month
share_10_conventional(t)	share_10_conventional(t - dt) + (share_10_conventional_net_flow) * dt	INIT share_10_conventional = LOOKUP(share_of_the_agricultural_area_per_culture_conventional, 10)	Dmnl
share_10_conventional_net_flow	0/one_month		Dmnl/month
share_11_conventional(t)	share_11_conventional(t - dt) + (share_11_conventional_net_flow) * dt	INIT share_11_conventional = LOOKUP(share_of_the_agri	Dmnl

		cultural_area_per_culture_conventional, 11)	
share_11_conventional_net_flow	0/one_month		Dmnl/month
share_12_conventional(t)	share_12_conventional(t - dt) + (share_12_conventional_net_flow) * dt	INIT share_12_conventional = LOOKUP(share_of_the_agricultural_area_per_culture_conventional, 12)	Dmnl
share_12_conventional_net_flow	0/one_month		Dmnl/month
share_13_conventional(t)	share_13_conventional(t - dt) + (share_13_conventional_net_flow) * dt	INIT share_13_conventional = LOOKUP(share_of_the_agricultural_area_per_culture_conventional, 13)	Dmnl
share_13_conventional_net_flow	0/one_month		Dmnl/month
share_14_conventional(t)	share_14_conventional(t - dt) + (share_14_conventional_net_flow) * dt	INIT share_14_conventional = LOOKUP(share_of_the_agricultural_area_per_culture_conventional, 14)	Dmnl
share_14_conventional_net_flow	0/one_month		Dmnl/month
share_15_conventional(t)	share_15_conventional(t - dt) + (share_15_conventional_net_flow) * dt	INIT share_15_conventional = LOOKUP(share_of_the_agricultural_area_per_culture_conventional, 15)	Dmnl
share_15_conventional_net_flow	0/one_month		Dmnl/month
share_2_conventional(t)	share_2_conventional(t - dt) + (share_2_conventional_net_flow) * dt	INIT share_2_conventional = LOOKUP(share_of_the_agricultural_area_per_culture_conventional, 2)	Dmnl
share_2_conventional_net_flow	0/one_month		Dmnl/month
share_3_conventional(t)	share_3_conventional(t - dt) + (share_3_conventional_net_flow) * dt	INIT share_3_conventional = LOOKUP(share_of_the_agricultural_area_per_culture_conventional, 3)	Dmnl
share_3_conventional_net_flow	0/one_month		Dmnl/month

share_4_conventional(t)	share_4_conventional(t - dt) + (share_4_conventional_net_flow) * dt	INIT share_4_conventional = LOOKUP(share_of_the_agricultural_area_per_culture_conventional, 4)	Dmnl
share_4_conventional_net_flow	0/one_month		Dmnl/month
share_5_conventional(t)	share_5_conventional(t - dt) + (share_5_conventional_net_flow) * dt	INIT share_5_conventional = LOOKUP(share_of_the_agricultural_area_per_culture_conventional, 5)	Dmnl
share_5_conventional_net_flow	0/one_month		Dmnl/month
share_6_conventional(t)	share_6_conventional(t - dt) + (share_6_conventional_net_flow) * dt	INIT share_6_conventional = LOOKUP(share_of_the_agricultural_area_per_culture_conventional, 6)	Dmnl
share_6_conventional_net_flow	0/one_month		Dmnl/month
share_7_conventional(t)	share_7_conventional(t - dt) + (share_7_conventional_net_flow) * dt	INIT share_7_conventional = LOOKUP(share_of_the_agricultural_area_per_culture_conventional, 7)	Dmnl
share_7_conventional_net_flow	0/one_month		Dmnl/month
share_8_conventional(t)	share_8_conventional(t - dt) + (share_8_conventional_net_flow) * dt	INIT share_8_conventional = LOOKUP(share_of_the_agricultural_area_per_culture_conventional, 8)	Dmnl
share_8_conventional_net_flow	0/one_month		Dmnl/month
share_9_conventional(t)	share_9_conventional(t - dt) + (share_9_conventional_net_flow) * dt	INIT share_9_conventional = LOOKUP(share_of_the_agricultural_area_per_culture_conventional, 9)	Dmnl
share_9_conventional_net_flow	0/one_month		Dmnl/month
storage_need_per_ha_conventional	yield_per_ha_conventional*stored_share_of_production_conventional		ton/hectare
stored_share_of_production_conventional	0.7		Year

to_cumul_irrigation	irrigation-(IF month_index = 1 AND INT(TIME) = TIME THEN cumulative_irrigation_over_one_year/DT ELSE 0)		Mcubicmeter/month
value_per_ha_conventional	price_1_conventional*yield_1_conventional+price_2_conventional*yield_2_conventional+price_3_conventional*yield_3_conventional+price_4_conventional*yield_4_conventional+price_5_conventional*yield_5_conventional+price_6_conventional*yield_6_conventional+price_7_conventional*yield_7_conventional+price_8_conventional*yield_8_conventional+price_9_conventional*yield_9_conventional+price_10_conventional*yield_10_conventional+price_11_conventional*yield_11_conventional+price_12_conventional*yield_12_conventional+price_13_conventional*yield_13_conventional+price_14_conventional*yield_14_conventional+price_15_conventional*yield_15_conventional		euro/(hectare*Year)
water_demand_m3_per_ha_per_year_conventional	share_1_conventional*LOOKUP(irrigated_share_per_culture_conventional, 1)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 1)+share_2_conventional*LOOKUP(irrigated_share_per_culture_conventional, 2)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 2)+share_3_conventional*LOOKUP(irrigated_share_per_culture_conventional, 3)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 3)+share_4_conventional*LOOKUP(irrigated_share_per_culture_conventional, 4)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 4)+share_5_conventional*LOOKUP(irrigated_share_per_culture_conventional, 5)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 5)+share_6_conventional*LOOKUP(irrigated_share_per_culture_conventional, 6)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 6)+share_7_conventional*LOOKUP(irrigated_share_per_culture_conventional, 7)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 7)+share_8_conventional*LOOKUP(irrigated_share_per_culture_conventional, 8)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 8)+share_9_conventional*LOOKUP(irrigated_share_per_culture_conventional, 9)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 9)+share_10_conventional*LOOKUP(irrigated_share_per_culture_conventional, 10)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 10)+share_11_conventional*LOOKUP(irrigated_share_per_culture_conventional, 11)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 11)+share_12_conventional*LOOKUP(irrigated_share_per_culture_conventional, 12)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 12)+share_13_conventional*LOOKUP(irrigated_share_per_culture_conventional, 13)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 13)+share_14_conventional*LOOKUP(irrigated_share_per_culture_conventional, 14)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 14)+share_15_conventional*LOOKUP(irrigated_share_per_culture_conventional, 15)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 15)		m3/(hectare*Year)
water_demand_Mm3_per_month_conventional	water_demand_Mm3_per_year_conventional*LOOKUP(irrigation_per_month_conventional, month_index)		Mcubicmeter/month
water_demand_Mm3_per_year_conventional	water_demand_m3_per_ha_per_year_conventional*conventional_area*Mm3_per_m3		Mcubicmeter/Year

water_demand_per_year_agriculture	water_demand_Mm3_per_year_conventional+water_demand_Mm3_per_year_organic+water_demand_Mm3_per_year_vineyards		Mcubicmeter/Year
yield_1_conventional	(LOOKUP(production_function_coefficient_intercept_conventional, 1)+LOOKUP(production_function_coefficient_x_conventional, 1)*cumulative_irrigation_m3_per_hectare_conventional*share_1_conventional*LOOKUP(irrigated_share_per_culture_conventional, 1)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 1)/water_demand_m3_per_ha_per_year_conventional+LOOKUP(production_function_coefficient_x2_conventional, 1)*(cumulative_irrigation_m3_per_hectare_conventional*share_1_conventional*LOOKUP(irrigated_share_per_culture_conventional, 1)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 1)/water_demand_m3_per_ha_per_year_conventional)^2)		ton/(hectare*Year)
yield_10_conventional	share_10_conventional*(LOOKUP(production_function_coefficient_intercept_conventional, 10)+LOOKUP(production_function_coefficient_x_conventional, 10)*cumulative_irrigation_m3_per_hectare_conventional*share_10_conventional*LOOKUP(irrigated_share_per_culture_conventional, 10)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 10)/water_demand_m3_per_ha_per_year_conventional+LOOKUP(production_function_coefficient_x2_conventional, 10)*(cumulative_irrigation_m3_per_hectare_conventional*share_10_conventional*LOOKUP(irrigated_share_per_culture_conventional, 10)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 10)/water_demand_m3_per_ha_per_year_conventional)^2)		ton/(hectare*Year)
yield_11_conventional	share_11_conventional*(LOOKUP(production_function_coefficient_intercept_conventional, 11)+LOOKUP(production_function_coefficient_x_conventional, 11)*cumulative_irrigation_m3_per_hectare_conventional*share_11_conventional*LOOKUP(irrigated_share_per_culture_conventional, 11)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 11)/water_demand_m3_per_ha_per_year_conventional+LOOKUP(production_function_coefficient_x2_conventional, 11)*(cumulative_irrigation_m3_per_hectare_conventional*share_11_conventional*LOOKUP(irrigated_share_per_culture_conventional, 11)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 11)/water_demand_m3_per_ha_per_year_conventional)^2)		ton/(hectare*Year)
yield_12_conventional	share_12_conventional*(LOOKUP(production_function_coefficient_intercept_conventional, 12)+LOOKUP(production_function_coefficient_x_conventional, 12)*cumulative_irrigation_m3_per_hectare_conventional*share_12_conventional*LOOKUP(irrigated_share_per_culture_conventional, 12)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 12)/water_demand_m3_per_ha_per_year_conventional+LOOKUP(production_function_coefficient_x2_conventional, 12)*(cumulative_irrigation_m3_per_hectare_conventional*share_12_conventional*LOOKUP(irrigated_share_per_culture_conventional,		ton/(hectare*Year)

	12)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 12)/water_demand_m3_per_ha_per_year_conventional)^2)		
yield_13_conventional	share_13_conventional*(LOOKUP(production_function_coefficient_intercept_conventional, 13)+LOOKUP(production_function_coefficient_x_conventional, 13)*cumulative_irrigation_m3_per_hectare_conventional*share_13_conventional*LOOKUP(irrigated_share_per_culture_conventional, 13)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 13)/water_demand_m3_per_ha_per_year_conventional+LOOKUP(production_function_coefficient_x2_conventional, 13)*(cumulative_irrigation_m3_per_hectare_conventional*share_13_conventional*LOOKUP(irrigated_share_per_culture_conventional, 13)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 13)/water_demand_m3_per_ha_per_year_conventional)^2)		ton/(hectare*Year)
yield_14_conventional	share_14_conventional*(LOOKUP(production_function_coefficient_intercept_conventional, 14)+LOOKUP(production_function_coefficient_x_conventional, 14)*cumulative_irrigation_m3_per_hectare_conventional*share_14_conventional*LOOKUP(irrigated_share_per_culture_conventional, 14)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 14)/water_demand_m3_per_ha_per_year_conventional+LOOKUP(production_function_coefficient_x2_conventional, 14)*(cumulative_irrigation_m3_per_hectare_conventional*share_14_conventional*LOOKUP(irrigated_share_per_culture_conventional, 14)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 14)/water_demand_m3_per_ha_per_year_conventional)^2)		ton/(hectare*Year)
yield_15_conventional	share_15_conventional*(LOOKUP(production_function_coefficient_intercept_conventional, 15)+LOOKUP(production_function_coefficient_x_conventional, 15)*cumulative_irrigation_m3_per_hectare_conventional*share_15_conventional*LOOKUP(irrigated_share_per_culture_conventional, 15)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 15)/water_demand_m3_per_ha_per_year_conventional+LOOKUP(production_function_coefficient_x2_conventional, 15)*(cumulative_irrigation_m3_per_hectare_conventional*share_15_conventional*LOOKUP(irrigated_share_per_culture_conventional, 15)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 15)/water_demand_m3_per_ha_per_year_conventional)^2)		ton/(hectare*Year)
yield_2_conventional	share_2_conventional*(LOOKUP(production_function_coefficient_intercept_conventional, 2)+LOOKUP(production_function_coefficient_x_conventional, 2)*cumulative_irrigation_m3_per_hectare_conventional*share_2_conventional*LOOKUP(irrigated_share_per_culture_conventional, 2)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 2)/water_demand_m3_per_ha_per_year_conventional+LOOKUP(production_function_coefficient_x2_conventional, 1)*(cumulative_irrigation_m3_per_hectare_conventional*share_2_conventional*LOOKUP(irrigated_share_per_culture_conventional,		ton/(hectare*Year)

	2)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 2)/water_demand_m3_per_ha_per_year_conventional)^2)		
yield_3_conventional	share_3_conventional*(LOOKUP(production_function_coefficient_intercept_conventional, 3)+LOOKUP(production_function_coefficient_x_conventional, 3)*cumulative_irrigation_m3_per_hectare_conventional*share_3_conventional*LOOKUP(irrigated_share_per_culture_conventional, 3)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 3)/water_demand_m3_per_ha_per_year_conventional+LOOKUP(production_function_coefficient_x2_conventional, 3)*(cumulative_irrigation_m3_per_hectare_conventional*share_3_conventional*LOOKUP(irrigated_share_per_culture_conventional, 3)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 3)/water_demand_m3_per_ha_per_year_conventional)^2)		ton/(hectare*Year)
yield_4_conventional	share_4_conventional*(LOOKUP(production_function_coefficient_intercept_conventional, 4)+LOOKUP(production_function_coefficient_x_conventional, 4)*cumulative_irrigation_m3_per_hectare_conventional*share_4_conventional*LOOKUP(irrigated_share_per_culture_conventional, 4)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 4)/water_demand_m3_per_ha_per_year_conventional+LOOKUP(production_function_coefficient_x2_conventional, 4)*(cumulative_irrigation_m3_per_hectare_conventional*share_4_conventional*LOOKUP(irrigated_share_per_culture_conventional, 4)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 4)/water_demand_m3_per_ha_per_year_conventional)^2)		ton/(hectare*Year)
yield_5_conventional	share_5_conventional*(LOOKUP(production_function_coefficient_intercept_conventional, 5)+LOOKUP(production_function_coefficient_x_conventional, 5)*cumulative_irrigation_m3_per_hectare_conventional*share_5_conventional*LOOKUP(irrigated_share_per_culture_conventional, 5)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 5)/water_demand_m3_per_ha_per_year_conventional+LOOKUP(production_function_coefficient_x2_conventional, 5)*(cumulative_irrigation_m3_per_hectare_conventional*share_5_conventional*LOOKUP(irrigated_share_per_culture_conventional, 5)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 5)/water_demand_m3_per_ha_per_year_conventional)^2)		ton/(hectare*Year)
yield_6_conventional	share_6_conventional*(LOOKUP(production_function_coefficient_intercept_conventional, 6)+LOOKUP(production_function_coefficient_x_conventional, 6)*cumulative_irrigation_m3_per_hectare_conventional*share_6_conventional*LOOKUP(irrigated_share_per_culture_conventional, 6)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 6)/water_demand_m3_per_ha_per_year_conventional+LOOKUP(production_function_coefficient_x2_conventional, 6)*(cumulative_irrigation_m3_per_hectare_conventional*share_6_conventional*LOOKUP(irrigated_share_per_culture_conventional,		ton/(hectare*Year)

	6)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 6)/water_demand_m3_per_ha_per_year_conventional)^2)		
yield_7_conventional	share_7_conventional*(LOOKUP(production_function_coefficient_intercept_conventional, 7)+LOOKUP(production_function_coefficient_x_conventional, 7)*cumulative_irrigation_m3_per_hectare_conventional*share_7_conventional*LOOKUP(irrigated_share_per_culture_conventional, 7)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 7)/water_demand_m3_per_ha_per_year_conventional+LOOKUP(production_function_coefficient_x2_conventional, 7)*(cumulative_irrigation_m3_per_hectare_conventional*share_7_conventional*LOOKUP(irrigated_share_per_culture_conventional, 7)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 7)/water_demand_m3_per_ha_per_year_conventional)^2)		ton/(hectare*Year)
yield_8_conventional	share_8_conventional*(LOOKUP(production_function_coefficient_intercept_conventional, 8)+LOOKUP(production_function_coefficient_x_conventional, 8)*cumulative_irrigation_m3_per_hectare_conventional*share_8_conventional*LOOKUP(irrigated_share_per_culture_conventional, 8)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 8)/water_demand_m3_per_ha_per_year_conventional+LOOKUP(production_function_coefficient_x2_conventional, 8)*(cumulative_irrigation_m3_per_hectare_conventional*share_8_conventional*LOOKUP(irrigated_share_per_culture_conventional, 8)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 8)/water_demand_m3_per_ha_per_year_conventional)^2)		ton/(hectare*Year)
yield_9_conventional	share_9_conventional*(LOOKUP(production_function_coefficient_intercept_conventional, 9)+LOOKUP(production_function_coefficient_x_conventional, 9)*cumulative_irrigation_m3_per_hectare_conventional*share_9_conventional*LOOKUP(irrigated_share_per_culture_conventional, 9)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 9)/water_demand_m3_per_ha_per_year_conventional+LOOKUP(production_function_coefficient_x2_conventional, 9)*(cumulative_irrigation_m3_per_hectare_conventional*share_9_conventional*LOOKUP(irrigated_share_per_culture_conventional, 9)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_conventional, 9)/water_demand_m3_per_ha_per_year_conventional)^2)		ton/(hectare*Year)
yield_per_ha_conventional	yield_1_conventional+yield_2_conventional+yield_3_conventional+yield_4_conventional+yield_5_conventional+yield_6_conventional+yield_7_conventional+yield_8_conventional+yield_9_conventional+yield_10_conventional+yield_11_conventional+yield_12_conventional+yield_13_conventional+yield_14_conventional+yield_15_conventional		ton/(hectare*Year)
In_transition_cultures:			
employment_per_ha_in_transition	employment_per_ha_organic		person/hectare
evapotranspiration_per_ha_in_transition	evapotranspiration_per_ha_organic		Mcubicmeter/(hectare*month)

N_use_per_ha_in_transition	N_use_per_ha_organic		kg/(hectare*month)
storage_need_per_ha_in_transition	storage_need_per_ha_organic		ton/hectare
value_per_ha_in_transition	value_per_ha_conventional		euro/(hectare*Year)
water_demand_m3_per_ha_per_year_in_transition	water_demand_m3_per_ha_per_year_organic*Mm3_per_m3		Mcubicmeter/(hectare*Year)
yield_per_ha_in_transition	yield_per_ha_organic		ton/(Year*hectare)
Infrastructure:			
abandoned_share_of_coastal_land_at_risk_according_to_flooding_risk	GRAPH(0+0) Points: (0.000, 0.000), (1.000, 1.000)		Dmnl
abandonment	(conventional_storage-conventional_storage_need)/one_month		ton/month
abandonment_ports	(conventional_storage_ports-yield_conventional*exported_share_of_agricultural_products*one_year)/one_month		ton/month
abandonned_coastal_land	coastal_land_at_risk*LOOKUP(abandoned_share_of_coastal_land_at_risk_according_to_flooding_risk, flooding_risk)		hectare
allowed_coastal_built_up_area	50000		hectare
allowed_rural_built_up_area	50000		hectare
area_of_ports	area_per_rail_transportation_capacity*(rail_transportation_capacity+rail_transportation_capacity_under_construction)+area_per_throuput_capacity*(throughput_capacity+throughput_capacity_under_construction)+area_per_stored_ton_port*(conventional_storage_ports+organic_storage_ports+organic_storage_under_construction_ports+under_conversion_to_organic_storage_ports+unused_conventional_storage_ports)		hectare
area_of_roads	area_per_km_of_roads*(roads+roads_under_construction)		hectare
area_of_storage	area_per_stored_ton*(unused_conventional_storage+conventional_storage+organic_storage+organic_storage_under_construction+under_conversion_to_organic_storage)		hectare
area_per_km_of_roads	2		hectare/km
area_per_rail_transportation_capacity	10		hectare*Year/ton
area_per_stored_ton	0.001		hectare/ton
area_per_stored_ton_port	0.001		hectare/ton
area_per_throuput_capacity	10		hectare*Year/ton
available_coastal_space_for_building	MAX(0, allowed_coastal_built_up_area-coastal_built_up_area)		hectare
available_rural_space_for_building	MAX(0, allowed_rural_built_up_area-rural_built_up_area)		hectare
CO2_per_truck	1		tCO2/vehicle

CO2_savings_of_rail_transportation	CO2_per_truck*trucks_equivalent_of_rail_transportation		tCO2/Year
coastal_accommodation(t)	coastal_accommodation(t - dt) + (completing_coastal_accommodation) * dt	INIT coastal_accommodation = 0	hectare
coastal_accommodation_area_per_tourist	0.0015		hectare/person
coastal_accommodation_gap	MAX(planned_coastal_accommodation-(coastal_accommodation_under_construction+coastal_accommodation), 0)		hectare
coastal_accommodation_under_construction(t)	coastal_accommodation_under_construction(t - dt) + (constructing_coastal_accommodation - completing_coastal_accommodation) * dt	INIT coastal_accommodation_under_construction = 0	hectare
coastal_built_up_area	coastal_housing+coastal_accommodation		hectare
coastal_housing(t)	coastal_housing(t - dt) + (completing_coastal_housing) * dt	INIT coastal_housing = 0	hectare
coastal_housing_area_per_person	0.002		hectare/person
coastal_housing_gap	MAX(planned_coastal_housing-(coastal_housing_under_construction+coastal_housing), 0)		hectare
coastal_housing_under_construction(t)	coastal_housing_under_construction(t - dt) + (constructing_coastal_housing - completing_coastal_housing) * dt	INIT coastal_housing_under_construction = 0	hectare
coastal_land_at_risk	coastal_land_at_risk_without_dikes-(dikes*protected_coastal_land_per_km_of_dikes)		hectare
coastal_land_at_risk_without_dikes	48200		hectare
completing_coastal_accommodation	DELAY(constructing_coastal_accommodation, time_to_complete_coastal_accommodation, 0)		hectare/month
completing_coastal_housing	DELAY(constructing_coastal_housing, time_to_complete_coastal_housing, 0)		hectare/month
completing_conversion_to_organic_storage	DELAY(converting_to_organic_storage, time_to_convert_to_organic_storage, 0)		ton/month
completing_conversion_to_organic_storage_ports	DELAY(converting_to_organic_storage_ports, time_to_convert_to_organic_storage_ports, 0)		ton/month
completing_dikes	DELAY(constructing_dikes, time_to_complete_dikes, 0)		km/month
completing_organic_storage	DELAY(constructing_organic_storage, time_to_complete_organic_storage, 0)		ton/month
completing_organic_storage_ports	DELAY(constructing_organic_storage_ports, time_to_complete_organic_storage_ports, 0)		ton/month
completing_rail_transportation_capacity	DELAY(constructing_rail_transportation_capacity, time_to_complete_rail_transportation_capacity, 0)		ton/(Year*month)
completing_roads	DELAY(constructing_roads, time_to_complete_roads, 0)		km/month
completing_rural_accommodation	DELAY(constructing_rural_accommodation, time_to_complete_rural_accommodation, 0)		hectare/month
completing_rural_housing	DELAY(constructing_rural_housing, time_to_complete_rural_housing, 0)		hectare/month

completing_throughput_capacity	DELAY(constructing_throughput_capacity, time_to_complete_throughput_capacity, 0)		ton/(Year*month)
constructing_coastal_accommodation	coastal_accommodation_gap/one_month		hectare/month
constructing_coastal_housing	coastal_housing_gap/one_month		hectare/month
constructing_dikes	dikes_gap/one_month		km/month
constructing_organic_storage	MAX(0, organic_storage_gap/one_month-converting_to_organic_storage)		ton/month
constructing_organic_storage_ports	MAX(0, organic_storage_gap_ports/one_month-converting_to_organic_storage_ports)		ton/month
constructing_rail_transportation_capacity	rail_transportation_capacity_gap/one_month		ton/(Year*month)
constructing_roads	roads_gap/one_month		km/month
constructing_rural_accommodation	rural_accommodation_gap/one_month		hectare/month
constructing_rural_housing	rural_housing_gap/one_month		hectare/month
constructing_throughput_capacity	throughput_capacity_gap/one_month		ton/(Year*month)
construction_costs	(costs_per_built_ton*constructing_organic_storage+costs_per_converted_ton*converting_to _organic_storage)		euro/month
conventional_storage(t)	conventional_storage(t - dt) + (- abandonment) * dt	INIT conventional_storage = 2.2e+06	ton
conventional_storage_ports(t)	conventional_storage_ports(t - dt) + (- abandonment_ports) * dt	INIT conventional_storage_ports = 2.2e+06	ton
converting_to_organic_storage	MIN(organic_storage_gap/one_month, unused_conventional_storage*conventional_storage_conversion_rate)		ton/month
converting_to_organic_storage_ports	MIN(organic_storage_gap_ports/one_month, unused_conventional_storage_ports*conventional_storage_conversion_rate_ports)		ton/month
costs_per_built_ton	1000		euro/ton
costs_per_converted_ton	1000		euro/ton
demand_for_coastal_accommodation	coastal_tourists*coastal_accommodation_area_per_tourist		hectare
demand_for_coastal_housing	coastal_residents*coastal_housing_area_per_person		hectare
demand_for_rural_accommodation	rural_tourists*rural_accommodation_area_per_tourist		hectare
demand_for_rural_housing	rural_residents*rural_housing_area_per_person		hectare
dikes(t)	dikes(t - dt) + (completing_dikes) * dt	INIT dikes = 20	km
dikes_gap	MAX(0, planned_dikes-(dikes_under_construction+dikes))		km

dikes_under_construction(t)	dikes_under_construction(t - dt) + (constructing_dikes - completing_dikes) * dt	INIT dikes_under_construction = 0	km
exported_agricultural_yield	exported_share_of_agricultural_products*total_yield		ton/Year
indicative_trucks_on_the_road	10000		vehicle
missing_throughput_capacity	MAX(0, exported_agricultural_yield-throughput_capacity)		ton/Year
organic_storage(t)	organic_storage(t - dt) + (completing_conversion_to_organic_storage + completing_organic_storage) * dt	INIT organic_storage = 5000	ton
organic_storage_gap	MAX(0, organic_storage_need-(organic_storage+organic_storage_under_construction+under_conversion_to_organic_storage))		ton
organic_storage_gap_ports	MAX(0, (yield_in_transition+yield_organic)*exported_share_of_agricultural_products*one_year-(organic_storage_ports+organic_storage_under_construction_ports+under_conversion_to_organic_storage_ports))		ton
organic_storage_ports(t)	organic_storage_ports(t - dt) + (completing_conversion_to_organic_storage_ports + completing_organic_storage_ports) * dt	INIT organic_storage_ports = 5000	ton
organic_storage_under_construction(t)	organic_storage_under_construction(t - dt) + (constructing_organic_storage - completing_organic_storage) * dt	INIT organic_storage_under_construction = 0	ton
organic_storage_under_construction_ports(t)	organic_storage_under_construction_ports(t - dt) + (constructing_organic_storage_ports - completing_organic_storage_ports) * dt	INIT organic_storage_under_construction_ports = 0	ton
people_on_the_roads	(1-share_of_people_using_train_or_bike)*(residents+tourists)		person
people_per_vehicle	4		person/vehicle
planned_coastal_accommodation	MIN(demand_for_coastal_accommodation, available_coastal_space_for_building)*demand_for_coastal_accommodation/total_demand_for_coastal_building		hectare
planned_coastal_housing	MIN(total_demand_for_coastal_building, available_coastal_space_for_building)*demand_for_coastal_housing/total_demand_for_coastal_building		hectare
planned_rural_accommodation	MIN(demand_for_rural_accommodation, available_rural_space_for_building)*demand_for_rural_accommodation/total_demand_for_rural_building		hectare
planned_rural_housing	MIN(total_demand_for_rural_building, available_rural_space_for_building)*demand_for_rural_housing/total_demand_for_rural_building		hectare

protected_coastal_land_per_km_of_dikes	100		hectare/km
rail_transportation_capacity(t)	rail_transportation_capacity(t - dt) + (completing_rail_transportation_capacity) * dt	INIT rail_transportation_capacity = 200	ton/Year
rail_transportation_capacity_gap	MAX(planned_rail_transportation_capacity-(rail_transportation_capacity_under_construction+rail_transportation_capacity), 0)		ton/Year
rail_transportation_capacity_under_construction (t)	rail_transportation_capacity_under_construction(t - dt) + (constructing_rail_transportation_capacity - completing_rail_transportation_capacity) * dt	INIT rail_transportation_capacity _under_construction = 0	ton/Year
roads(t)	roads(t - dt) + (completing_roads) * dt	INIT roads = 200	km
roads_congestion	vehicles_on_the_road/roads		vehicle/km
roads_gap	MAX(planned_roads-(roads_under_construction+roads), 0)		km
roads_under_construction(t)	roads_under_construction(t - dt) + (constructing_roads - completing_roads) * dt	INIT roads_under_construction = 0	km
rural_accommodation(t)	rural_accommodation(t - dt) + (completing_rural_accommodation) * dt	INIT rural_accommodation = 0	hectare
rural_accommodation_area_per_tourist	0.0015		hectare/person
rural_accommodation_gap	MAX(planned_rural_accommodation-(rural_accommodation_under_construction+rural_accommodation), 0)		hectare
rural_accommodation_under_construction(t)	rural_accommodation_under_construction(t - dt) + (constructing_rural_accommodation - completing_rural_accommodation) * dt	INIT rural_accommodation_under _construction = 0	hectare
rural_built_up_area	rural_housing+rural_accommodation		hectare
rural_housing(t)	rural_housing(t - dt) + (completing_rural_housing) * dt	INIT rural_housing = 0	hectare
rural_housing_area_per_person	0.002		hectare/person
rural_housing_gap	MAX(planned_rural_housing-(rural_housing_under_construction+rural_housing), 0)		hectare
rural_housing_under_construction(t)	rural_housing_under_construction(t - dt) + (constructing_rural_housing - completing_rural_housing) * dt	INIT rural_housing_under_constr uction = 0	hectare
storage_development_costs(t)	storage_development_costs(t - dt) + (construction_costs) * dt	INIT storage_development_costs = 0	euro
throughput_capacity(t)	throughput_capacity(t - dt) + (completing_throughput_capacity) * dt	INIT throughput_capacity = 4e+06	ton/Year

throughput_capacity_gap	MAX(0, planned_throughput_capacity-(throughput_capacity_under_construction+throughput_capacity))		ton/Year
throughput_capacity_per_hour	throughput_capacity/hour_per_year		ton/hour
throughput_capacity_under_construction(t)	throughput_capacity_under_construction(t - dt) + (constructing_throughput_capacity - completing_throughput_capacity) * dt	INIT throughput_capacity_under_construction = 0	ton/Year
time_to_complete_coastal_accommodation	12		month
time_to_complete_coastal_housing	12		month
time_to_complete_dikes	24		month
time_to_complete_organic_storage	24		month
time_to_complete_organic_storage_ports	24		month
time_to_complete_rail_transportation_capacity	96		month
time_to_complete_roads	60		month
time_to_complete_rural_accommodation	12		month
time_to_complete_rural_housing	12		month
time_to_complete_throughput_capacity	48		month
time_to_convert_to_organic_storage	24		month
time_to_convert_to_organic_storage_ports	24		month
total_area_of_infrastructures	coastal_built_up_area+area_of_ports+area_of_roads+rural_built_up_area+area_of_storage		hectare
total_demand_for_coastal_building	demand_for_coastal_housing+demand_for_coastal_accommodation		hectare
total_demand_for_rural_building	demand_for_rural_housing+demand_for_rural_accommodation		hectare
trucks_equivalent_of_rail_transportation	rail_transportation_capacity*trucks_per_ton_per_year		vehicle/Year
trucks_per_ton_per_year	0.3		vehicle/ton
under_conversion_to_organic_storage(t)	under_conversion_to_organic_storage(t - dt) + (converting_to_organic_storage - completing_conversion_to_organic_storage) * dt	INIT under_conversion_to_organic_storage = 0	ton
under_conversion_to_organic_storage_ports(t)	under_conversion_to_organic_storage_ports(t - dt) + (converting_to_organic_storage_ports - completing_conversion_to_organic_storage_ports) * dt	INIT under_conversion_to_organic_storage_ports = 0	ton
unused_conventional_storage(t)	unused_conventional_storage(t - dt) + (abandonment - converting_to_organic_storage) * dt	INIT unused_conventional_storage = 10000	ton

unused_conventional_storage_ports(t)	unused_conventional_storage_ports(t - dt) + (abandonment_ports - converting_to_organic_storage_ports) * dt	INIT unused_conventional_storage_ports = 10000	ton
unused_throughput_capacity	MAX(0, throughput_capacity-exported_agricultural_yield)		ton/Year
vehicles_on_the_road	(people_on_the_roads/people_per_vehicle)+indicative_trucks_on_the_road-(one_month*trucks_equivalent_of_rail_transportation/month_per_year)		vehicle
Organic_cultures:			
allowed_irrigation_water_demand_organic	allowed_water_demand_per_year_organic*LOOKUP(irrigation_per_month_organic, month_index)		Mcubicmeter/month
allowed_water_demand_per_year_organic	MIN(abstraction_permits_for_irrigation, water_demand_per_year_agriculture)*water_demand_Mm3_per_year_organic/water_demand_per_year_agriculture		Mcubicmeter/Year
cumulative_irrigation_organic	water_demand_Mm3_per_year_organic*cumulative_irrigation_over_one_year/(water_demand_per_year_agriculture*one_year)		Mcubicmeter/Year
cumulative_irrigation_per_hectare_organic	cumulative_irrigation_organic/((organic_area+in_transition_area)*Mm3_per_m3)		m3/(hectare*Year)
employment_per_ha_organic	1.8		person/hectare
evapotranspiration_per_ha_organic	reference_evapotranspiration_Mm3_per_ha*(LOOKUP(Kc_1_organic, month_index)*share_1_organic+LOOKUP(Kc_2_organic, month_index)*share_2_organic+LOOKUP(Kc_3_organic, month_index)*share_3_organic+LOOKUP(Kc_4_organic, month_index)*share_4_organic+LOOKUP(Kc_5_organic, month_index)*share_5_organic+LOOKUP(Kc_6_organic, month_index)*share_6_organic+LOOKUP(Kc_7_organic, month_index)*share_7_organic+LOOKUP(Kc_8_organic, month_index)*share_8_organic+LOOKUP(Kc_9_organic, month_index)*share_9_organic+LOOKUP(Kc_10_organic, month_index)*share_10_organic+LOOKUP(Kc_11_organic, month_index)*share_11_organic+LOOKUP(Kc_12_organic, month_index)*share_12_organic+LOOKUP(Kc_13_organic, month_index)*share_13_organic+LOOKUP(Kc_14_organic, month_index)*share_14_organic+LOOKUP(Kc_15_organic, month_index)*share_15_organic)		Mcubicmeter/(hectare*month)
irrigation_per_month_organic	GRAPH(0+0) Points: (1.00, 0.0000), (2.00, 0.0000), (3.00, 0.0000), (4.00, 0.0000), (5.00, 0.0500), (6.00, 0.2500), (7.00, 0.3250), (8.00, 0.3250), (9.00, 0.0500), (10.00, 0.0000), (11.00, 0.0000), (12.00, 0.0000)		Year/month
N_use_per_ha_organic	LOOKUP(N_use_per_month_organic, month_index)*(share_1_organic*(LOOKUP(N_use_per_culture_organic, 1)+LOOKUP(N_extra_use_if_irrigated_organic, 1)*LOOKUP(irrigated_share_per_culture_organic, 1))+share_2_organic*(LOOKUP(N_use_per_culture_organic,		kg/(hectare*month)

	2)+LOOKUP(N_extra_use_if_irrigated_organic, 2)*LOOKUP(irrigated_share_per_culture_organic, 2))+share_3_organic*(LOOKUP(N_use_per_culture_organic, 3)+LOOKUP(N_extra_use_if_irrigated_organic, 3)*LOOKUP(irrigated_share_per_culture_organic, 3))+share_4_organic*(LOOKUP(N_use_per_culture_organic, 4)+LOOKUP(N_extra_use_if_irrigated_organic, 4)*LOOKUP(irrigated_share_per_culture_organic, 4))+share_5_organic*(LOOKUP(N_use_per_culture_organic, 5)+LOOKUP(N_extra_use_if_irrigated_organic, 5)*LOOKUP(irrigated_share_per_culture_organic, 5))+share_6_organic*(LOOKUP(N_use_per_culture_organic, 6)+LOOKUP(N_extra_use_if_irrigated_organic, 6)*LOOKUP(irrigated_share_per_culture_organic, 6))+share_7_organic*(LOOKUP(N_use_per_culture_organic, 7)+LOOKUP(N_extra_use_if_irrigated_organic, 7)*LOOKUP(irrigated_share_per_culture_organic, 7))+share_8_organic*(LOOKUP(N_use_per_culture_organic, 8)+LOOKUP(N_extra_use_if_irrigated_organic, 8)*LOOKUP(irrigated_share_per_culture_organic, 8))+share_9_organic*(LOOKUP(N_use_per_culture_organic, 9)+LOOKUP(N_extra_use_if_irrigated_organic, 9)*LOOKUP(irrigated_share_per_culture_organic, 9))+share_10_organic*(LOOKUP(N_use_per_culture_organic, 10)+LOOKUP(N_extra_use_if_irrigated_organic, 10)*LOOKUP(irrigated_share_per_culture_organic, 10))+share_11_organic*(LOOKUP(N_use_per_culture_organic, 11)+LOOKUP(N_extra_use_if_irrigated_organic, 11)*LOOKUP(irrigated_share_per_culture_organic, 11))+share_12_organic*(LOOKUP(N_use_per_culture_organic, 12)+LOOKUP(N_extra_use_if_irrigated_organic, 12)*LOOKUP(irrigated_share_per_culture_organic, 12))+share_13_organic*(LOOKUP(N_use_per_culture_organic, 13)+LOOKUP(N_extra_use_if_irrigated_organic, 13)*LOOKUP(irrigated_share_per_culture_organic, 13))+share_14_organic*(LOOKUP(N_use_per_culture_organic, 14)+LOOKUP(N_extra_use_if_irrigated_organic, 14)*LOOKUP(irrigated_share_per_culture_organic, 14))+share_15_organic*(LOOKUP(N_use_per_culture_organic, 15)+LOOKUP(N_extra_use_if_irrigated_organic, 15)*LOOKUP(irrigated_share_per_culture_organic, 15)))		
N_use_per_month_organic	GRAPH(0+0) Points: (1.00, 0.0000), (2.00, 0.0000), (3.00, 0.0000), (4.00, 0.0000), (5.00, 0.1000), (6.00, 0.2000), (7.00, 0.4000), (8.00, 0.2000), (9.00, 0.1000), (10.00, 0.0000), (11.00, 0.0000), (12.00, 0.0000)		Year/month
price_1_organic	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'prices_organic'_,_'A'_,_'B2'_)}		euro/ton
price_10_organic	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'prices_organic'_,_'A'_,_'K2'_)}		euro/ton

price_11_organic	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'prices_organic'_,_'A'_,_'L2'_)}		euro/ton
price_12_organic	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'prices_organic'_,_'A'_,_'M2'_)}		euro/ton
price_13_organic	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'prices_organic'_,_'A'_,_'N2'_)}		euro/ton
price_14_organic	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'prices_organic'_,_'A'_,_'O2'_)}		euro/ton
price_15_organic	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'prices_organic'_,_'A'_,_'P2'_)}		euro/ton
price_2_organic	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'prices_organic'_,_'A'_,_'C2'_)}		euro/ton
price_3_organic	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'prices_organic'_,_'A'_,_'D2'_)}		euro/ton
price_4_organic	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'prices_organic'_,_'A'_,_'E2'_)}		euro/ton
price_5_organic	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'prices_organic'_,_'A'_,_'F2'_)}		euro/ton
price_6_organic	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'prices_organic'_,_'A'_,_'G2'_)}		euro/ton
price_7_organic	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'prices_organic'_,_'A'_,_'H2'_)}		euro/ton
price_8_organic	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'prices_organic'_,_'A'_,_'I2'_)}		euro/ton
price_9_organic	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'prices_organic'_,_'A'_,_'J2'_)}		euro/ton
share_1_organic(t)	share_1_organic(t - dt) + (share_1_organic_net_flow) * dt	INIT share_1_organic = LOOKUP(share_of_the_agricultural_area_per_culture_organic, 1)	Dmnl
share_1_organic_net_flow	0/one_month		Dmnl/month
share_10_organic(t)	share_10_organic(t - dt) + (share_10_organic_net_flow) * dt	INIT share_10_organic = LOOKUP(share_of_the_agricultural_area_per_culture_organic, 10)	Dmnl
share_10_organic_net_flow	0/one_month		Dmnl/month
share_11_organic(t)	share_11_organic(t - dt) + (share_11_organic_net_flow) * dt	INIT share_11_organic = LOOKUP(share_of_the_agricultural_area_per_culture_organic, 11)	Dmnl
share_11_organic_net_flow	0/one_month		Dmnl/month
share_12_organic(t)	share_12_organic(t - dt) + (share_12_organic_net_flow) * dt	INIT share_12_organic = LOOKUP(share_of_the_agricultural_area_per_culture_organic, 12)	Dmnl
share_12_organic_net_flow	0/one_month		Dmnl/month

share_13_organic(t)	share_13_organic(t - dt) + (share_13_organic_net_flow) * dt	INIT share_13_organic = LOOKUP(share_of_the_agricultural_area_per_culture_organic, 13)	Dmnl
share_13_organic_net_flow	0/one_month		Dmnl/month
share_14_organic(t)	share_14_organic(t - dt) + (share_14_organic_net_flow) * dt	INIT share_14_organic = LOOKUP(share_of_the_agricultural_area_per_culture_organic, 14)	Dmnl
share_14_organic_net_flow	0/one_month		Dmnl/month
share_15_organic(t)	share_15_organic(t - dt) + (share_15_organic_net_flow) * dt	INIT share_15_organic = LOOKUP(share_of_the_agricultural_area_per_culture_organic, 15)	Dmnl
share_15_organic_net_flow	0/one_month		Dmnl/month
share_2_organic(t)	share_2_organic(t - dt) + (share_2_organic_net_flow) * dt	INIT share_2_organic = LOOKUP(share_of_the_agricultural_area_per_culture_organic, 2)	Dmnl
share_2_organic_net_flow	0/one_month		Dmnl/month
share_3_organic(t)	share_3_organic(t - dt) + (share_3_organic_net_flow) * dt	INIT share_3_organic = LOOKUP(share_of_the_agricultural_area_per_culture_organic, 3)	Dmnl
share_3_organic_net_flow	0/one_month		Dmnl/month
share_4_organic(t)	share_4_organic(t - dt) + (share_4_organic_net_flow) * dt	INIT share_4_organic = LOOKUP(share_of_the_agricultural_area_per_culture_organic, 4)	Dmnl
share_4_organic_net_flow	0/one_month		Dmnl/month
share_5_organic(t)	share_5_organic(t - dt) + (share_5_organic_net_flow) * dt	INIT share_5_organic = LOOKUP(share_of_the_agricultural_area_per_culture_organic, 5)	Dmnl
share_5_organic_net_flow	0/one_month		Dmnl/month
share_6_organic(t)	share_6_organic(t - dt) + (share_6_organic_net_flow) * dt	INIT share_6_organic = LOOKUP(share_of_the_agri	Dmnl

		cultural_area_per_culture_organic, 6)	
share_6_organic_net_flow	0/one_month		Dmnl/month
share_7_organic(t)	share_7_organic(t - dt) + (share_7_organic_net_flow) * dt	INIT share_7_organic = LOOKUP(share_of_the_agricultural_area_per_culture_organic, 7)	Dmnl
share_7_organic_net_flow	0/one_month		Dmnl/month
share_8_organic(t)	share_8_organic(t - dt) + (share_8_organic_net_flow) * dt	INIT share_8_organic = LOOKUP(share_of_the_agricultural_area_per_culture_organic, 8)	Dmnl
share_8_organic_net_flow	0/one_month		Dmnl/month
share_9_organic(t)	share_9_organic(t - dt) + (share_9_organic_net_flow) * dt	INIT share_9_organic = LOOKUP(share_of_the_agricultural_area_per_culture_organic, 9)	Dmnl
share_9_organic_net_flow	0/one_month		Dmnl/month
storage_need_per_ha_organic	yield_per_ha_organic*stored_share_of_production_organic		ton/hectare
stored_share_of_production_organic	0.7		Year
value_per_ha_organic	(price_1_organic*yield_1_organic+price_2_organic*yield_2_organic+price_3_organic*yield_3_organic+price_4_organic*yield_4_organic+price_5_organic*yield_5_organic+price_6_organic*yield_6_organic+price_7_organic*yield_7_organic+price_8_organic*yield_8_organic+price_9_organic*yield_9_organic+price_10_organic*yield_10_organic+price_11_organic*yield_11_organic+price_12_organic*yield_12_organic+price_13_organic*yield_13_organic+price_14_organic*yield_14_organic+price_15_organic*yield_15_organic)		euro/(hectare*Year)
water_demand_m3_per_ha_per_year_organic	share_1_organic*LOOKUP(irrigated_share_per_culture_organic, 1)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 1)+share_2_organic*LOOKUP(irrigated_share_per_culture_organic, 2)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 2)+share_3_organic*LOOKUP(irrigated_share_per_culture_organic, 3)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 3)+share_4_organic*LOOKUP(irrigated_share_per_culture_organic, 4)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 4)+share_5_organic*LOOKUP(irrigated_share_per_culture_organic, 5)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 5)+share_6_organic*LOOKUP(irrigated_share_per_culture_organic, 6)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 6)+share_7_organic*LOOKUP(irrigated_share_per_culture_organic, 7)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic,		m3/(hectare*Year)

	7)+share_8_organic*LOOKUP(irrigated_share_per_culture_organic, 8)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 8)+share_9_organic*LOOKUP(irrigated_share_per_culture_organic, 9)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 9)+share_10_organic*LOOKUP(irrigated_share_per_culture_organic, 10)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 10)+share_11_organic*LOOKUP(irrigated_share_per_culture_organic, 11)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 11)+share_12_organic*LOOKUP(irrigated_share_per_culture_organic, 12)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 12)+share_13_organic*LOOKUP(irrigated_share_per_culture_organic, 13)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 13)+share_14_organic*LOOKUP(irrigated_share_per_culture_organic, 14)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 14)+share_15_organic*LOOKUP(irrigated_share_per_culture_organic, 15)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 15)		
water_demand_Mm3_per_month_organic	water_demand_Mm3_per_year_organic*LOOKUP(irrigation_per_month_organic, month_index)		Mcubicmeter/month
water_demand_Mm3_per_year_organic	water_demand_m3_per_ha_per_year_organic*(organic_area+in_transition_area)*Mm3_per_m3		Mcubicmeter/Year
yield_1_organic	share_1_organic*(LOOKUP(production_function_coefficient_intercept_organic, 1)+LOOKUP(production_function_coefficient_x_organic, 1)*cumulative_irrigation_per_hectare_organic*share_1_organic*LOOKUP(irrigated_share_per_culture_organic, 1)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 1)/water_demand_m3_per_ha_per_year_organic+LOOKUP(production_function_coefficient_x2_organic, 1)*(cumulative_irrigation_per_hectare_organic*share_1_organic*LOOKUP(irrigated_share_per_culture_organic, 1)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 1)/water_demand_m3_per_ha_per_year_organic)^2)		ton/(hectare*Year)
yield_10_organic	share_10_organic*(LOOKUP(production_function_coefficient_intercept_organic, 10)+LOOKUP(production_function_coefficient_x_organic, 10)*cumulative_irrigation_per_hectare_organic*share_10_organic*LOOKUP(irrigated_share_per_culture_organic, 10)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 10)/water_demand_m3_per_ha_per_year_organic+LOOKUP(production_function_coefficient_x2_organic, 10)*(cumulative_irrigation_per_hectare_organic*share_10_organic*LOOKUP(irrigated_share_per_culture_organic, 10)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 10)/water_demand_m3_per_ha_per_year_organic)^2)		ton/(hectare*Year)
yield_11_organic	share_11_organic*(LOOKUP(production_function_coefficient_intercept_organic, 11)+LOOKUP(production_function_coefficient_x_organic, 11)*cumulative_irrigation_per_hectare_organic*share_11_organic*LOOKUP(irrigated_share_per_culture_organic, 11)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 11)/water_demand_m3_per_ha_per_year_organic+LOOKUP(production_function_coefficie		ton/(hectare*Year)

	nt_x2_organic, 11)*(cumulative_irrigation_per_hectare_organic*share_11_organic*LOOKUP(irrigated_share_per_culture_organic, 11)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 11)/water_demand_m3_per_ha_per_year_organic)^2)		
yield_12_organic	share_12_organic*(LOOKUP(production_function_coefficient_intercept_organic, 12)+LOOKUP(production_function_coefficient_x_organic, 12)*cumulative_irrigation_per_hectare_organic*share_12_organic*LOOKUP(irrigated_share_per_culture_organic, 12)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 12)/water_demand_m3_per_ha_per_year_organic+LOOKUP(production_function_coefficient_x2_organic, 12)*(cumulative_irrigation_per_hectare_organic*share_12_organic*LOOKUP(irrigated_share_per_culture_organic, 12)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 12)/water_demand_m3_per_ha_per_year_organic)^2)		ton/(hectare*Year)
yield_13_organic	share_13_organic*(LOOKUP(production_function_coefficient_intercept_organic, 13)+LOOKUP(production_function_coefficient_x_organic, 13)*cumulative_irrigation_per_hectare_organic*share_13_organic*LOOKUP(irrigated_share_per_culture_organic, 13)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 13)/water_demand_m3_per_ha_per_year_organic+LOOKUP(production_function_coefficient_x2_organic, 13)*(cumulative_irrigation_per_hectare_organic*share_13_organic*LOOKUP(irrigated_share_per_culture_organic, 13)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 13)/water_demand_m3_per_ha_per_year_organic)^2)		ton/(hectare*Year)
yield_14_organic	share_14_organic*(LOOKUP(production_function_coefficient_intercept_organic, 14)+LOOKUP(production_function_coefficient_x_organic, 14)*cumulative_irrigation_per_hectare_organic*share_14_organic*LOOKUP(irrigated_share_per_culture_organic, 14)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 14)/water_demand_m3_per_ha_per_year_organic+LOOKUP(production_function_coefficient_x2_organic, 14)*(cumulative_irrigation_per_hectare_organic*share_14_organic*LOOKUP(irrigated_share_per_culture_organic, 14)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 14)/water_demand_m3_per_ha_per_year_organic)^2)		ton/(hectare*Year)
yield_15_organic	share_15_organic*(LOOKUP(production_function_coefficient_intercept_organic, 15)+LOOKUP(production_function_coefficient_x_organic, 15)*cumulative_irrigation_per_hectare_organic*share_15_organic*LOOKUP(irrigated_share_per_culture_organic, 15)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 15)/water_demand_m3_per_ha_per_year_organic+LOOKUP(production_function_coefficient_x2_organic, 15)*(cumulative_irrigation_per_hectare_organic*share_15_organic*LOOKUP(irrigated_share_per_culture_organic, 15)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 15)/water_demand_m3_per_ha_per_year_organic)^2)		ton/(hectare*Year)

yield_2_organic	share_2_organic*(LOOKUP(production_function_coefficient_intercept_organic, 2)+LOOKUP(production_function_coefficient_x_organic, 2)*cumulative_irrigation_per_hectare_organic*share_2_organic*LOOKUP(irrigated_share_per_culture_organic, 2)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 2)/water_demand_m3_per_ha_per_year_organic+LOOKUP(production_function_coefficient_x2_organic, 1)*(cumulative_irrigation_per_hectare_organic*share_2_organic*LOOKUP(irrigated_share_per_culture_organic, 2)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 2)/water_demand_m3_per_ha_per_year_organic)^2)		ton/(hectare*Year)
yield_3_organic	share_3_organic*(LOOKUP(production_function_coefficient_intercept_organic, 3)+LOOKUP(production_function_coefficient_x_organic, 3)*cumulative_irrigation_per_hectare_organic*share_3_organic*LOOKUP(irrigated_share_per_culture_organic, 3)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 3)/water_demand_m3_per_ha_per_year_organic+LOOKUP(production_function_coefficient_x2_organic, 3)*(cumulative_irrigation_per_hectare_organic*share_3_organic*LOOKUP(irrigated_share_per_culture_organic, 3)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 3)/water_demand_m3_per_ha_per_year_organic)^2)		ton/(hectare*Year)
yield_4_organic	share_4_organic*(LOOKUP(production_function_coefficient_intercept_organic, 4)+LOOKUP(production_function_coefficient_x_organic, 4)*cumulative_irrigation_per_hectare_organic*share_4_organic*LOOKUP(irrigated_share_per_culture_organic, 4)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 4)/water_demand_m3_per_ha_per_year_organic+LOOKUP(production_function_coefficient_x2_organic, 4)*(cumulative_irrigation_per_hectare_organic*share_4_organic*LOOKUP(irrigated_share_per_culture_organic, 4)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 4)/water_demand_m3_per_ha_per_year_organic)^2)		ton/(hectare*Year)
yield_5_organic	share_5_organic*(LOOKUP(production_function_coefficient_intercept_organic, 5)+LOOKUP(production_function_coefficient_x_organic, 5)*cumulative_irrigation_per_hectare_organic*share_5_organic*LOOKUP(irrigated_share_per_culture_organic, 5)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 5)/water_demand_m3_per_ha_per_year_organic+LOOKUP(production_function_coefficient_x2_organic, 5)*(cumulative_irrigation_per_hectare_organic*share_5_organic*LOOKUP(irrigated_share_per_culture_organic, 5)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 5)/water_demand_m3_per_ha_per_year_organic)^2)		ton/(hectare*Year)
yield_6_organic	share_6_organic*(LOOKUP(production_function_coefficient_intercept_organic, 6)+LOOKUP(production_function_coefficient_x_organic, 6)*cumulative_irrigation_per_hectare_organic*share_6_organic*LOOKUP(irrigated_share_per_culture_organic, 6)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 6)/water_demand_m3_per_ha_per_year_organic+LOOKUP(production_function_coefficient_x2_organic, 6)*(cumulative_irrigation_per_hectare_organic*share_6_organic*LOOKUP(irrigated_share_per_culture_organic, 6)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 6)/water_demand_m3_per_ha_per_year_organic)^2)		ton/(hectare*Year)

yield_7_organic	share_7_organic*(LOOKUP(production_function_coefficient_intercept_organic, 7)+LOOKUP(production_function_coefficient_x_organic, 7)*cumulative_irrigation_per_hectare_organic*share_7_organic*LOOKUP(irrigated_share_per_culture_organic, 7)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 7)/water_demand_m3_per_ha_per_year_organic+LOOKUP(production_function_coefficient_x2_organic, 7)*(cumulative_irrigation_per_hectare_organic*share_7_organic*LOOKUP(irrigated_share_per_culture_organic, 7)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 7)/water_demand_m3_per_ha_per_year_organic)^2)		ton/(hectare*Year)
yield_8_organic	share_8_organic*(LOOKUP(production_function_coefficient_intercept_organic, 8)+LOOKUP(production_function_coefficient_x_organic, 8)*cumulative_irrigation_per_hectare_organic*share_8_organic*LOOKUP(irrigated_share_per_culture_organic, 8)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 8)/water_demand_m3_per_ha_per_year_organic+LOOKUP(production_function_coefficient_x2_organic, 8)*(cumulative_irrigation_per_hectare_organic*share_8_organic*LOOKUP(irrigated_share_per_culture_organic, 8)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 8)/water_demand_m3_per_ha_per_year_organic)^2)		ton/(hectare*Year)
yield_9_organic	share_9_organic*(LOOKUP(production_function_coefficient_intercept_organic, 9)+LOOKUP(production_function_coefficient_x_organic, 9)*cumulative_irrigation_per_hectare_organic*share_9_organic*LOOKUP(irrigated_share_per_culture_organic, 9)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 9)/water_demand_m3_per_ha_per_year_organic+LOOKUP(production_function_coefficient_x2_organic, 9)*(cumulative_irrigation_per_hectare_organic*share_9_organic*LOOKUP(irrigated_share_per_culture_organic, 9)*LOOKUP(irrigation_per_culture_m3_per_ha_per_year_organic, 9)/water_demand_m3_per_ha_per_year_organic)^2)		ton/(hectare*Year)
yield_per_ha_organic	yield_1_organic+yield_2_organic+yield_3_organic+yield_4_organic+yield_5_organic+yield_6_organic+yield_7_organic+yield_8_organic+yield_9_organic+yield_10_organic+yield_11_organic+yield_12_organic+yield_13_organic+yield_14_organic+yield_15_organic		ton/(hectare*Year)
Population:			
agricultural_workers(t)	agricultural_workers(t - dt) + (new_workers - retiring_workers) * dt	INIT agricultural_workers = 50000	person
agricultural_workers_retiring_rate	0.01		Dmnl/month
coastal_attractiveness_for_residents	heliotropism_residents+((coastal_housing_under_construction/one_hectare)^0.5*(one_vehicle_per_km/roads_congestion)^0.5)		Dmnl
coastal_attractiveness_for_tourists	heliotropism_tourists+((coastal_accommodation_under_construction/one_hectare)^0.5*(one_vehicle_per_km/roads_congestion)^0.5)		Dmnl
coastal_domestic_water_demand	coastal_population*water_use_per_person		Mcubicmeter/month
coastal_population	coastal_residents+coastal_tourists		person

coastal_residents	residents*coastal_share_of_residents		person
coastal_share_of_water_demand	coastal_domestic_water_demand/(coastal_domestic_water_demand+rural_domestic_water_demand)		Dmnl
coastal_tourists	tourists*coastal_share_of_tourists		person
domestic_water_demand	coastal_domestic_water_demand+rural_domestic_water_demand		Mcubicmeter/month
heliotropism_residents	0.5		Dmnl
heliotropism_tourists	0.5		Dmnl
initial_residents	585400		person
new_workers	agricultural_workers_replacement_rate*retiring_workers		person/month
residents(t)	residents(t - dt) + (residents_growth) * dt	INIT residents = initial_residents	person
residents_growth	residents*residents_growth_rate		person/month
retiring_workers	agricultural_workers_retiring_rate*agricultural_workers		person/month
rural_attractiveness_for_residents	(rural_housing_under_construction/one_hectare)^0.5*(one_vehicle_per_km/roads_congestion)^0.5		Dmnl
rural_attractiveness_for_tourists	(rural_accommodation_under_construction/one_hectare)^0.5*(one_vehicle_per_km/roads_congestion)^0.5		Dmnl
rural_domestic_water_demand	rural_population*water_use_per_person		Mcubicmeter/month
rural_population	rural_residents+rural_tourists		person
rural_residents	residents*(1-coastal_share_of_residents)		person
rural_tourists	tourists*(1-coastal_share_of_tourists)		person
total_population	residents+tourists		person
tourists(t)	tourists(t - dt) + (tourists_arrival - tourists_departure) * dt	INIT tourists = 200000	person
tourists_arrival	MIN(MAX(0, (tourists_capacity-tourists)/one_month), tourists_per_year*LOOKUP(tourists_per_month, month_index))		person/month
tourists_average_length_of_stay	1		month
tourists_departure	DELAY(tourists_arrival, tourists_average_length_of_stay, 200000)		person/month
tourists_per_month	GRAPH(0+0) Points: (1.00, 0.056), (2.00, 0.06), (3.00, 0.067), (4.00, 0.072), (5.00, 0.086), (6.00, 0.098), (7.00, 0.11), (8.00, 0.133), (9.00, 0.11), (10.00, 0.081), (11.00, 0.069), (12.00, 0.058)		Dmnl/month
tourists_per_year	1.5e+06+(TIME-STARTTIME)*tourists_growth_rate		person

Scenarios_data:			
abstraction_permits_for_irrigation	(IF TIME < scenarios_first_month THEN abstraction_permits_for_irrigation_past ELSE (IF main_scenario_mode = 0 THEN abstraction_permits_for_irrigation_value_choice ELSE (IF main_scenario_choice = 1 THEN abstraction_permits_for_irrigation_scenario_1 ELSE (IF main_scenario_choice = 2 THEN abstraction_permits_for_irrigation_scenario_2 ELSE (IF main_scenario_choice = 3 THEN abstraction_permits_for_irrigation_scenario_3 ELSE (IF main_scenario_choice = 4 THEN abstraction_permits_for_irrigation_scenario_4 ELSE 0))))))		Mcubicmeter/Year
abstraction_permits_for_irrigation_past	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'abstraction_permits'_,_'A'_,_'B2'_)}		Mcubicmeter/Year
abstraction_permits_for_irrigation_scenario_1	0{GET_XLS_DATA(_'data_scenarios.xlsx'_,_'abstraction_permits'_,_'A'_,_'B2'_)}		Mcubicmeter/Year
abstraction_permits_for_irrigation_scenario_2	0{GET_XLS_DATA(_'data_scenarios.xlsx'_,_'abstraction_permits'_,_'A'_,_'C2'_)}		Mcubicmeter/Year
abstraction_permits_for_irrigation_scenario_3	0{GET_XLS_DATA(_'data_scenarios.xlsx'_,_'abstraction_permits'_,_'A'_,_'D2'_)}		Mcubicmeter/Year
abstraction_permits_for_irrigation_scenario_4	0{GET_XLS_DATA(_'data_scenarios.xlsx'_,_'abstraction_permits'_,_'A'_,_'E2'_)}		Mcubicmeter/Year
abstraction_permits_for_irrigation_value_choice	40		Mcubicmeter/Year
agricultural_workers_replacement_rate	(IF TIME < scenarios_first_month THEN agricultural_workers_replacement_rate_past ELSE (IF main_scenario_mode = 0 THEN agricultural_workers_replacement_rate_value_choice ELSE LOOKUP(agricultural_workers_replacement_rate_per_scenario, main_scenario_choice)))		Dmnl
agricultural_workers_replacement_rate_past	0.33		Dmnl
agricultural_workers_replacement_rate_per_scenario	GRAPH(0+0) Points: (1.000, 0.3300), (2.000, 0.3000), (3.000, 0.2500), (4.000, 0.2000)		Dmnl
agricultural_workers_replacement_rate_value_choice	0.33		Dmnl
authorised_oyster_farms_area	(IF TIME < scenarios_first_month THEN authorised_oyster_farms_area_past ELSE (IF main_scenario_mode = 0 THEN authorised_oyster_farms_area_value_choice ELSE (IF main_scenario_choice = 1 THEN authorised_oyster_farms_area_scenario_1 ELSE (IF main_scenario_choice = 2 THEN authorised_oyster_farms_area_scenario_2 ELSE (IF main_scenario_choice = 3 THEN authorised_oyster_farms_area_scenario_3 ELSE (IF main_scenario_choice = 4 THEN authorised_oyster_farms_area_scenario_4 ELSE 0))))))		hectare
authorised_oyster_farms_area_past	597		hectare
authorised_oyster_farms_area_scenario_1	0{GET_XLS_DATA(_'data_scenarios.xlsx'_,_'oyster_farms_area'_,_'A'_,_'B2'_)}		hectare
authorised_oyster_farms_area_scenario_2	0{GET_XLS_DATA(_'data_scenarios.xlsx'_,_'oyster_farms_area'_,_'A'_,_'C2'_)}		hectare
authorised_oyster_farms_area_scenario_3	0{GET_XLS_DATA(_'data_scenarios.xlsx'_,_'oyster_farms_area'_,_'A'_,_'D2'_)}		hectare
authorised_oyster_farms_area_scenario_4	0{GET_XLS_DATA(_'data_scenarios.xlsx'_,_'oyster_farms_area'_,_'A'_,_'E2'_)}		hectare

authorised_oyster_farms_area_value_choice	597		hectare
biodiversity_index_estuary	(IF TIME < scenarios_first_month THEN biodiversity_index_estuary_past ELSE (IF main_scenario_mode = 0 THEN biodiversity_index_estuary_value_choice ELSE LOOKUP(biodiversity_index_estuary_per_scenario, main_scenario_choice)))		Dmnl
biodiversity_index_estuary_past	0.5		Dmnl
biodiversity_index_estuary_per_scenario	GRAPH(0+0) Points: (1.000, 0.6000), (2.000, 0.5000), (3.000, 0.4000), (4.000, 0.4000)		Dmnl
biodiversity_index_estuary_value_choice	0.5		Dmnl
capacity_of_coastal_WWTP	(IF TIME < scenarios_first_month THEN capacity_of_coastal_WWTP_past ELSE (IF main_scenario_mode = 0 THEN capacity_of_coastal_WWTP_value_choice ELSE LOOKUP(capacity_of_coastal_WWTP_per_scenario, main_scenario_choice)))		person
capacity_of_coastal_WWTP_past	200000		person
capacity_of_coastal_WWTP_per_scenario	GRAPH(0+0) Points: (1.000, 200000.000), (2.000, 200000.000), (3.000, 200000.000), (4.000, 200000.000)		person
capacity_of_coastal_WWTP_value_choice	200000		person
capacity_of_rural_WWTP	(IF TIME < scenarios_first_month THEN capacity_of_rural_WWTP_past ELSE (IF main_scenario_mode = 0 THEN capacity_of_rural_WWTP_value_choice ELSE LOOKUP(capacity_of_rural_WWTP_per_scenario, main_scenario_choice)))		person
capacity_of_rural_WWTP_past	200000		person
capacity_of_rural_WWTP_per_scenario	GRAPH(0+0) Points: (1.000, 200000.000), (2.000, 200000.000), (3.000, 200000.000), (4.000, 200000.000)		person
capacity_of_rural_WWTP_value_choice	200000		person
coastal_share_of_residents	(IF TIME < scenarios_first_month THEN coastal_share_of_residents_past ELSE (IF main_scenario_mode = 0 THEN coastal_share_of_residents_value_choice ELSE LOOKUP(coastal_share_of_residents_per_scenario, main_scenario_choice)))		Dmnl
coastal_share_of_residents_past	0.7		Dmnl
coastal_share_of_residents_per_scenario	GRAPH(0+0) Points: (1.000, 0.6000), (2.000, 0.7000), (3.000, 0.8000), (4.000, 0.9000)		Dmnl
coastal_share_of_residents_value_choice	0.7		Dmnl
coastal_share_of_tourists	(IF TIME < scenarios_first_month THEN coastal_share_of_tourists_past ELSE (IF main_scenario_mode = 0 THEN coastal_share_of_tourists_value_choice ELSE LOOKUP(coastal_share_of_tourists_per_scenario, main_scenario_choice)))		Dmnl
coastal_share_of_tourists_past	0.8		Dmnl
coastal_share_of_tourists_per_scenario	GRAPH(0+0) Points: (1.000, 0.6000), (2.000, 0.7000), (3.000, 0.8000), (4.000, 0.9000)		Dmnl
coastal_share_of_tourists_value_choice	0.8		Dmnl

conventional_storage_conversion_rate	0.01		Dmnl/month
conventional_storage_conversion_rate_ports	0.01		Dmnl/month
demand_for_cognac_growth_rate	(IF TIME < scenarios_first_month THEN demand_for_cognac_growth_rate_past ELSE (IF main_scenario_mode = 0 THEN demand_for_cognac_growth_rate_value_choice ELSE LOOKUP(demand_for_cognac_growth_rate_per_scenario, main_scenario_choice)))		Dmnl/month
demand_for_cognac_growth_rate_past	0.0017		Dmnl/month
demand_for_cognac_growth_rate_per_scenario	GRAPH(0+0) Points: (1.000, 0.0017), (2.000, 0.0017), (3.000, 0.0017), (4.000, 0.0017)		Dmnl/month
demand_for_cognac_growth_rate_value_choice	0.0017		Dmnl/month
demand_for_organic_products	(IF TIME < scenarios_first_month THEN demand_for_organic_products_past ELSE (IF main_scenario_mode = 0 THEN (IF demand_for_organic_products_scenario_id_choice = 1 THEN demand_for_organic_products_scenario_1 ELSE (IF demand_for_organic_products_scenario_id_choice = 2 THEN demand_for_organic_products_scenario_2 ELSE (IF demand_for_organic_products_scenario_id_choice = 3 THEN demand_for_organic_products_scenario_3 ELSE (IF demand_for_organic_products_scenario_id_choice = 4 THEN demand_for_organic_products_scenario_4 ELSE 0)))) ELSE (IF main_scenario_choice = 1 THEN demand_for_organic_products_scenario_1 ELSE (IF main_scenario_choice = 2 THEN demand_for_organic_products_scenario_2 ELSE (IF main_scenario_choice = 3 THEN demand_for_organic_products_scenario_3 ELSE (IF main_scenario_choice = 4 THEN demand_for_organic_products_scenario_4 ELSE 0))))))		Dmnl
demand_for_organic_products_past	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'demand_for_organic'_,_'A'_,_'B2'_)}		Dmnl
demand_for_organic_products_scenario_1	0{GET_XLS_DATA(_'data_scenarios.xlsx'_,_'demand_for_organic'_,_'A'_,_'B2'_)}		Dmnl
demand_for_organic_products_scenario_2	0{GET_XLS_DATA(_'data_scenarios.xlsx'_,_'demand_for_organic'_,_'A'_,_'C2'_)}		Dmnl
demand_for_organic_products_scenario_3	0{GET_XLS_DATA(_'data_scenarios.xlsx'_,_'demand_for_organic'_,_'A'_,_'D2'_)}		Dmnl
demand_for_organic_products_scenario_4	0{GET_XLS_DATA(_'data_scenarios.xlsx'_,_'demand_for_organic'_,_'A'_,_'E2'_)}		Dmnl
demand_for_organic_products_scenario_id_choice	1		Dmnl
environmental_flow_requirement_estuary	(IF TIME < scenarios_first_month THEN environmental_flow_requirement_estuary_past ELSE (IF main_scenario_mode = 0 THEN environmental_flow_requirement_estuary_value_choice ELSE LOOKUP(environmental_flow_requirement_estuary_per_scenario, main_scenario_choice)))		m3/s
environmental_flow_requirement_estuary_past	8.1		m3/s
environmental_flow_requirement_estuary_per_scenario	GRAPH(0+0) Points: (1.000, 8.100), (2.000, 8.100), (3.000, 8.100), (4.000, 8.100)		m3/s

environmental_flow_requirement_estuary_value_choice	8.1		m3/s
exported_share_of_agricultural_products	0.5		Dmnl
flooding_risk	0.1		Dmnl
Low_Water_Target_Flow_for_water_streams	(IF TIME < scenarios_first_month THEN Low_Water_Target_Flow_for_water_streams_past ELSE (IF main_scenario_mode = 0 THEN Low_Water_Target_Flow_for_water_streams_value_choice ELSE LOOKUP(Low_Water_Target_Flow_for_water_streams_per_scenario, main_scenario_choice)))		m3/s
Low_Water_Target_Flow_for_water_streams_past	15		m3/s
Low_Water_Target_Flow_for_water_streams_per_scenario	GRAPH(0+0) Points: (1.000, 15.000), (2.000, 15.000), (3.000, 15.000), (4.000, 15.000)		m3/s
Low_Water_Target_Flow_for_water_streams_value_choice	15		m3/s
main_scenario_choice	1		Dmnl
main_scenario_mode	0		Dmnl
max_authorized_production_per_ha	(IF TIME < scenarios_first_month THEN max_authorized_production_per_ha_past ELSE (IF main_scenario_mode = 0 THEN max_authorized_production_per_ha_value_choice ELSE LOOKUP(max_authorized_production_per_ha_per_scenario, main_scenario_choice)))		Hl/(hectare*Year)
max_authorized_production_per_ha_past	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'allowed_cognac_yield'_,_'A'_,_'B2'_)}		Hl/(Year*hectare)
max_authorized_production_per_ha_per_scenario	GRAPH(0+0) Points: (1.000, 14.640), (2.000, 14.640), (3.000, 14.640), (4.000, 14.640)		Hl/(Year*hectare)
max_authorized_production_per_ha_value_choice	14.64		Hl/(Year*hectare)
organic_share_of_vineyards	(IF TIME < scenarios_first_month THEN organic_share_of_vineyards_past ELSE (IF main_scenario_mode = 0 THEN organic_share_of_vineyards_value_choice ELSE LOOKUP(organic_share_of_vineyards_per_scenario, main_scenario_choice)))		Dmnl
organic_share_of_vineyards_past	0.02		Dmnl
organic_share_of_vineyards_per_scenario	GRAPH(0+0) Points: (1.000, 0.05), (2.000, 0.04), (3.000, 0.02), (4.000, 0.02)		Dmnl
organic_share_of_vineyards_value_choice	0.02		Dmnl
organic_supply_chain	(IF TIME < scenarios_first_month THEN organic_supply_chain_past ELSE (IF main_scenario_mode = 0 THEN (IF organic_supply_chain_scenario_id_choice = 1 THEN organic_supply_chain_scenario_1 ELSE (IF organic_supply_chain_scenario_id_choice = 2 THEN organic_supply_chain_scenario_2 ELSE (IF organic_supply_chain_scenario_id_choice = 3 THEN organic_supply_chain_scenario_3		Dmnl

	ELSE (IF organic_supply_chain_scenario_id_choice = 4 THEN organic_supply_chain_scenario_4 ELSE 0)))) ELSE (IF main_scenario_choice = 1 THEN organic_supply_chain_scenario_1 ELSE (IF main_scenario_choice = 2 THEN organic_supply_chain_scenario_2 ELSE (IF main_scenario_choice = 3 THEN organic_supply_chain_scenario_3 ELSE (IF main_scenario_choice = 4 THEN organic_supply_chain_scenario_4 ELSE 0))))))		
organic_supply_chain_past	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'organic_supply_chain'_,_'A'_,_'B2'_)}		Dmnl
organic_supply_chain_scenario_1	0{GET_XLS_DATA(_'data_scenarios.xlsx'_,_'organic_supply_chain'_,_'A'_,_'B2'_)}		Dmnl
organic_supply_chain_scenario_2	0{GET_XLS_DATA(_'data_scenarios.xlsx'_,_'organic_supply_chain'_,_'A'_,_'C2'_)}		Dmnl
organic_supply_chain_scenario_3	0{GET_XLS_DATA(_'data_scenarios.xlsx'_,_'organic_supply_chain'_,_'A'_,_'D2'_)}		Dmnl
organic_supply_chain_scenario_4	0{GET_XLS_DATA(_'data_scenarios.xlsx'_,_'organic_supply_chain'_,_'A'_,_'E2'_)}		Dmnl
organic_supply_chain_scenario_id_choice	1		Dmnl
oyster_density_per_bag_year_3	(IF TIME < scenarios_first_month THEN oyster_density_per_bag_year_3_past ELSE (IF main_scenario_mode = 0 THEN oyster_density_per_bag_year_3_value_choice ELSE LOOKUP(third_year_density_per_scenario, main_scenario_choice)))		oyster/bag
oyster_density_per_bag_year_3_past	180		oyster/bag
oyster_density_per_bag_year_3_value_choice	180		oyster/bag
planned_dikes	30		km
planned_rail_transportation_capacity	25000		ton/Year
planned_roads	1		km
planned_throughput_capacity	6e+06		ton/Year
planting_rights	(IF TIME < scenarios_first_month THEN planting_rights_past ELSE (IF main_scenario_mode = 0 THEN planting_rights_value_choice ELSE LOOKUP(planting_rights_per_scenario, main_scenario_choice)))		hectare/month
planting_rights_past	275		hectare/month
planting_rights_per_scenario	GRAPH(0+0) Points: (1.000, 275.000), (2.000, 275.000), (3.000, 275.000), (4.000, 275.000)		hectare/month
planting_rights_value_choice	275		hectare/month
rainfall	(IF TIME < scenarios_first_month THEN rainfall_past ELSE (IF main_scenario_mode = 0 THEN (IF rainfall_scenario_id_choice = 1 THEN rainfall_scenario_1 ELSE (IF rainfall_scenario_id_choice = 2 THEN rainfall_scenario_2 ELSE (IF rainfall_scenario_id_choice = 3 THEN rainfall_scenario_3 ELSE (IF rainfall_scenario_id_choice = 4 THEN rainfall_scenario_4 ELSE 0)))) ELSE (IF main_scenario_choice = 1 THEN rainfall_scenario_1 ELSE (IF main_scenario_choice = 2 THEN rainfall_scenario_2 ELSE (IF main_scenario_choice = 3 THEN rainfall_scenario_3 ELSE (IF main_scenario_choice = 4 THEN rainfall_scenario_4 ELSE 0))))))		mm/month

rainfall_past	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'rainfall'_,_'A'_,_'B2'_)}		mm/month
rainfall_scenario_1	0{GET_XLS_DATA(_'data_scenarios.xlsx'_,_'rainfall'_,_'A'_,_'B2'_)}		mm/month
rainfall_scenario_2	0{GET_XLS_DATA(_'data_scenarios.xlsx'_,_'rainfall'_,_'A'_,_'C2'_)}		mm/month
rainfall_scenario_3	0{GET_XLS_DATA(_'data_scenarios.xlsx'_,_'rainfall'_,_'A'_,_'D2'_)}		mm/month
rainfall_scenario_4	0{GET_XLS_DATA(_'data_scenarios.xlsx'_,_'rainfall'_,_'A'_,_'E2'_)}		mm/month
rainfall_scenario_id_choice	1		Dmnl
reservoirs_capacity	(IF TIME < scenarios_first_month THEN reservoirs_capacity_past ELSE (IF main_scenario_mode = 0 THEN reservoirs_capacity_value_choice ELSE LOOKUP(reservoirs_capacity_per_scenario, main_scenario_choice)))		Mcubicmeter
reservoirs_capacity_past	7		Mcubicmeter
reservoirs_capacity_per_scenario	GRAPH(0+0) Points: (1.000, 10.00), (2.000, 20.00), (3.000, 40.00), (4.000, 30.00)		Mcubicmeter
reservoirs_capacity_value_choice	7		Mcubicmeter
residents_growth_rate	(IF TIME < scenarios_first_month THEN residents_growth_rate_past ELSE (IF main_scenario_mode = 0 THEN residents_growth_rate_value_choice ELSE LOOKUP(residents_growth_rate_per_scenario, main_scenario_choice)))		Dmnl/month
residents_growth_rate_past	0.0005		Dmnl/month
residents_growth_rate_per_scenario	GRAPH(0+0) Points: (1.000, 0.0005), (2.000, 0.0005), (3.000, 0.0005), (4.000, 0.0005)		Dmnl/month
residents_growth_rate_value_choice	0.0005		Dmnl/month
share_of_domestic_water_from_groundwater	(IF TIME < scenarios_first_month THEN share_of_domestic_water_from_groundwater_past ELSE (IF main_scenario_mode = 0 THEN share_of_domestic_water_from_groundwater_value_choice ELSE LOOKUP(share_of_domestic_water_from_groundwater_per_scenario, main_scenario_choice)))		Dmnl
share_of_domestic_water_from_groundwater_past	0.5		Dmnl
share_of_domestic_water_from_groundwater_per_scenario	GRAPH(0+0) Points: (1.000, 0.500), (2.000, 0.500), (3.000, 0.500), (4.000, 0.500)		Dmnl
share_of_domestic_water_from_groundwater_value_choice	0.5		Dmnl
share_of_irrigated_vineyards	(IF TIME < scenarios_first_month THEN share_of_irrigated_vineyards_past ELSE (IF main_scenario_mode = 0 THEN share_of_irrigated_vineyards_value_choice ELSE LOOKUP(share_of_irrigated_vineyards_per_scenario, main_scenario_choice)))		Dmnl
share_of_irrigated_vineyards_past	0.02		Dmnl
share_of_irrigated_vineyards_per_scenario	GRAPH(0+0) Points: (1.000, 0.020), (2.000, 0.020), (3.000, 0.020), (4.000, 0.020)		Dmnl

share_of_irrigated_vineyards_value_choice	0.02		Dmnl
share_of_irrigation_never_from_reservoirs	(IF TIME < scenarios_first_month THEN share_of_irrigation_never_from_reservoirs_past ELSE (IF main_scenario_mode = 0 THEN share_of_irrigation_never_from_reservoirs_value_choice ELSE LOOKUP(share_of_irrigation_never_from_reservoirs_per_scenario, main_scenario_choice)))		Dmnl
share_of_irrigation_never_from_reservoirs_past	0.2		Dmnl
share_of_irrigation_never_from_reservoirs_per_scenario	GRAPH(0+0) Points: (1.000, 0.200), (2.000, 0.200), (3.000, 0.200), (4.000, 0.200)		Dmnl
share_of_irrigation_never_from_reservoirs_value_choice	0.2		Dmnl
share_of_irrigation_water_from_groundwater	(IF TIME < scenarios_first_month THEN share_of_irrigation_water_from_groundwater_past ELSE (IF main_scenario_mode = 0 THEN share_of_irrigation_water_from_groundwater_value_choice ELSE LOOKUP(share_of_irrigation_water_from_groundwater_per_scenario, main_scenario_choice)))		Dmnl
share_of_irrigation_water_from_groundwater_past	0.4		Dmnl
share_of_irrigation_water_from_groundwater_per_scenario	GRAPH(0+0) Points: (1.000, 0.4000), (2.000, 0.4000), (3.000, 0.4000), (4.000, 0.4000)		Dmnl
share_of_irrigation_water_from_groundwater_value_choice	0.4		Dmnl
share_of_people_using_train_or_bike	0.2		Dmnl
share_of_reservoirs_water_from_groundwater	(IF TIME < scenarios_first_month THEN share_of_reservoirs_water_from_groundwater_past ELSE (IF main_scenario_mode = 0 THEN share_of_reservoirs_water_from_groundwater_value_choice ELSE LOOKUP(share_of_reservoirs_water_from_groundwater_per_scenario, main_scenario_choice)))		Dmnl
share_of_reservoirs_water_from_groundwater_past	0		Dmnl
share_of_reservoirs_water_from_groundwater_per_scenario	GRAPH(0+0) Points: (1.000, 0.000), (2.000, 0.000), (3.000, 0.000), (4.000, 0.000)		Dmnl
share_of_reservoirs_water_from_groundwater_value_choice	0		Dmnl
subvention_effect	(IF TIME < scenarios_first_month THEN subvention_effect_past ELSE (IF main_scenario_mode = 0 THEN subvention_effect_value_choice ELSE (IF main_scenario_choice = 1 THEN subvention_effect_scenario_1 ELSE (IF main_scenario_choice = 2 THEN subvention_effect_scenario_2 ELSE (IF		Dmnl

	main_scenario_choice = 3 THEN subvention_effect_scenario_3 ELSE (IF main_scenario_choice = 4 THEN subvention_effect_scenario_4 ELSE 0)))))		
subvention_effect_past	0.02		Dmnl
subvention_effect_scenario_1	0{GET_XLS_DATA(_'data_scenarios.xlsx'_,_'subvention_effect'_,_'A'_,_'B2'_)}		Dmnl
subvention_effect_scenario_2	0{GET_XLS_DATA(_'data_scenarios.xlsx'_,_'subvention_effect'_,_'A'_,_'C2'_)}		Dmnl
subvention_effect_scenario_3	0{GET_XLS_DATA(_'data_scenarios.xlsx'_,_'subvention_effect'_,_'A'_,_'D2'_)}		Dmnl
subvention_effect_scenario_4	0{GET_XLS_DATA(_'data_scenarios.xlsx'_,_'subvention_effect'_,_'A'_,_'E2'_)}		Dmnl
subvention_effect_value_choice	0.02		Dmnl
third_year_density_per_scenario	GRAPH(0+0) Points: (1.000, 150.00), (2.000, 170.00), (3.000, 180.00), (4.000, 180.00)		oyster/bag
tourists_capacity	(IF TIME < scenarios_first_month THEN tourists_capacity_past ELSE (IF main_scenario_mode = 0 THEN tourists_capacity_value_choice ELSE LOOKUP(tourists_capacity_per_scenario, main_scenario_choice)))		person
tourists_capacity_past	1e+06		person
tourists_capacity_per_scenario	GRAPH(0+0) Points: (1.000, 1500000), (2.000, 1500000), (3.000, 2000000), (4.000, 3000000)		person
tourists_capacity_value_choice	1e+06		person
tourists_growth_rate	(IF TIME < scenarios_first_month THEN tourists_growth_rate_past ELSE (IF main_scenario_mode = 0 THEN tourists_growth_rate_value_choice ELSE LOOKUP(tourists_growth_rate_per_scenario, main_scenario_choice)))		person/month
tourists_growth_rate_past	14000		person/month
tourists_growth_rate_per_scenario	GRAPH(0+0) Points: (1.000, 14000.000), (2.000, 14000.000), (3.000, 14000.000), (4.000, 14000.000)		person/month
tourists_growth_rate_value_choice	14000		person/month
type_of_bag	(IF TIME < scenarios_first_month THEN type_of_bag_past ELSE (IF main_scenario_mode = 0 THEN type_of_bag_value_choice ELSE LOOKUP(type_of_bag_per_scenario, main_scenario_choice)))		Dmnl
type_of_bag_past	1		Dmnl
type_of_bag_per_scenario	GRAPH(0+0) Points: (1.000, 2.000), (2.000, 2.000), (3.000, 1.000), (4.000, 1.000)		Dmnl
type_of_bag_value_choice	1		Dmnl
unexplained_change_rate_conventional	(IF TIME < scenarios_first_month THEN unexplained_change_rate_conventional_past ELSE (IF main_scenario_mode = 0 THEN unexplained_change_rate_conventional_value_choice ELSE LOOKUP(unexplained_change_rate_conventional_per_scenario, main_scenario_choice)))		Dmnl/month

unexplained_change_rate_conventional_past	0		Dmnl/month
unexplained_change_rate_conventional_per_scenario	GRAPH(0+0) Points: (1.000, 0.000), (2.000, 0.000), (3.000, 0.000), (4.000, 0.000)		Dmnl/month
unexplained_change_rate_conventional_value_choice	0		Dmnl/month
unexplained_change_rate_organic	(IF TIME < scenarios_first_month THEN unexplained_change_rate_organic_past ELSE (IF main_scenario_mode = 0 THEN unexplained_change_rate_organic_value_choice ELSE LOOKUP(unexplained_change_rate_organic_per_scenario, main_scenario_choice)))		Dmnl/month
unexplained_change_rate_organic_past	0		Dmnl/month
unexplained_change_rate_organic_per_scenario	GRAPH(0+0) Points: (1.000, 0.000), (2.000, 0.000), (3.000, 0.000), (4.000, 0.000)		Dmnl/month
unexplained_change_rate_organic_value_choice	0		Dmnl/month
water_use_per_person	(IF TIME < scenarios_first_month THEN water_use_per_person_past ELSE (IF main_scenario_mode = 0 THEN water_use_per_person_value_choice ELSE LOOKUP(water_use_per_person_per_scenario, main_scenario_choice)))		Mcubicmeter/(month*person)
water_use_per_person_past	1e-05		Mcubicmeter/(month*person)
water_use_per_person_per_scenario	GRAPH(0+0) Points: (1.000, 0.00001), (2.000, 0.00001), (3.000, 0.00001), (4.000, 0.00001)		Mcubicmeter/(month*person)
water_use_per_person_value_choice	1e-05		Mcubicmeter/(month*person)
Shellfish_farming:			
available_resource_per_oyster	available_trophic_resource/third_year		mg/(m3*oyster)
available_trophic_resource	biodiversity_index_estuary*concentration_in_trophic_resource		mg/m3
bags_per_hectare	LOOKUP(bags_per_hectare_according_to_type_of_bag, type_of_bag)		bag/hectare
bags_per_hectare_according_to_type_of_bag	GRAPH(0+0) Points: (1.000, 20000), (2.000, 40000)		bag/hectare
cost_per_ton_of_spat	100		euro/ton
cumulative_production_over_one_year(t)	cumulative_production_over_one_year(t - dt) + (to_market - out_sales) * dt	INIT cumulative_production_over_one_year = initial_oysters_year_3	oyster
cumulative_resource_per_oyster_over_3_years(t)	cumulative_resource_per_oyster_over_3_years(t - dt) + (in_food - out_food) * dt	INIT cumulative_resource_per_oyster_over_3_years = initial_cumulative_resource	mg/(m3*oyster)

cumulative_spat_to_production_over_one_year(t)	cumulative_spat_to_production_over_one_year(t - dt) + (to_spat_to_prod) * dt	INIT cumulative_spat_to_production_over_one_year = initial_spat_to_production	oyster
epuration_costs	produced_oyster_weight*LOOKUP(purification_costs_per_ton_according_to_the_occurence_of_viruses, occurence_of_viruses)		euro/Year
export_price_oyster	ratio_export_price_to_local_price*local_price_oyster		euro/oyster
export_sales	MIN(cumulative_production_over_one_year/one_year, oyster_total_demand/oyster_to_market_unit_weight)*(1-share_of_local_sales)		oyster/Year
export_sales_benefits	export_sales*export_price_oyster		euro/Year
first_year_mortality	oysters_in_first_production_year*mortality_rate_year_1		oyster/month
gross_margin_per_oyster	(IF cumulative_production_over_one_year = 0 THEN 0 ELSE oyster_gross_margin/(cumulative_production_over_one_year/one_year))		euro/oyster
in_food	available_resource_per_oyster/one_month		mg/(m3*oyster*month)
initial_cumulative_resource	1e-07		mg/(m3*oyster)
initial_oysters_year_1	1e+09		oyster
initial_oysters_year_2	8e+08		oyster
initial_oysters_year_3	7e+08		oyster
initial_spat_to_production	3.3e+09		oyster
local_oyster_production_share	profit_factor^(profit_factor_weight/sum_of_factors)*quality_factor^(quality_factor_weight/sum_of_factors)*spat_factor^(spat_factor_weight/sum_of_factors)		Dmnl
local_price_according_to_quality_index	GRAPH(0+0) Points: (0.0000, 0.200), (0.1000, 0.500), (0.154128, 0.684211), (0.223853, 0.95614), (0.26789, 1.20175), (0.289908, 1.52632), (0.3000, 2.000)		euro/oyster
local_price_oyster	LOOKUP(local_price_according_to_quality_index, quality_index)		euro/oyster
local_sales	MIN(cumulative_production_over_one_year/one_year, oyster_total_demand/oyster_to_market_unit_weight)*share_of_local_sales		oyster/Year
local_sales_benefits	local_sales*local_price_oyster		euro/Year
max_capacity	authorised_oyster_farms_area*bags_per_hectare*oyster_density_per_bag_year_3*oyster_to_market_unit_weight*share_oysters_in_third_year/one_year*0+1*authorised_oyster_farms_area*bags_per_hectare*oyster_density_per_bag_year_3*oyster_to_market_unit_weight*0.28/one_year		ton/Year
max_spat_capture	(3.5e+09)/12		oyster/month
met_share_of_demand	total_oyster_sales_weight/(total_oyster_sales_weight+under_production)		Dmnl

mortality_rate_year_1	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'oyster_mortality'_,_'A'_,_'B2'_)}		Dmnl/month
mortality_rate_year_2	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'oyster_mortality'_,_'A'_,_'C2'_)}		Dmnl/month
mortality_rate_year_3	0{GET_XLS_DATA(_'data_integrated.xlsx'_,_'oyster_mortality'_,_'A'_,_'B2'_)}		Dmnl/month
needed_spat	production_target*spats_input_per_sold_ton		oyster/Year
out_food	DELAY(in_food, 12, initial_cumulative_resource/(12*one_month))		mg/(m3*oyster*month)
out_sales	DELAY(to_market, 12, initial_oysters_year_3/(12*one_month))		oyster/month
over_production	MAX(produced_oyster_weight-total_oyster_sales_weight, 0)		ton/Year
oyster_gross_margin	total_oyster_sales-(transport_costs+production_costs)		euro/Year
oyster_mortality_according_to_density	GRAPH(0+0) Points: (100.0, -0.05), (180.0, 0), (260.0, 0.05)		Dmnl/month
oyster_to_market_unit_weight	6.9e-05		ton/oyster
oyster_total_demand	70000*one_ton_per_year		ton/Year
oysters_in_first_production_year(t)	oysters_in_first_production_year(t - dt) + (spat_input - first_year_mortality - to_second_year) * dt	INIT oysters_in_first_production_year = initial_oysters_year_1	oyster
produced_oyster_weight	cumulative_production_over_one_year*oyster_to_market_unit_weight/one_year		ton/Year
production_costs	produced_oyster_weight*production_costs_per_ton+epuration_costs+spat_costs		euro/Year
production_costs_per_ton	3000		euro/ton
production_target	MIN(oyster_total_demand, max_capacity)		ton/Year
profit_factor	MIN(1, oyster_gross_margin/one_euro_per_year)		Dmnl
profit_factor_weight	0.5		Dmnl
purification_costs_per_ton_according_to_the_occurence_of_viruses	GRAPH(0+0) Points: (0.000, 0.0), (0.16208, 36.8421), (0.397554, 105.263), (0.657492, 219.298), (0.847095, 317.544), (1.000, 400.0)		euro/ton
quality_factor	quality_index/0.3		Dmnl
quality_factor_weight	0.5		Dmnl
quality_index	LOOKUP(quality_index_according_to_available_resource, cumulative_resource_per_oyster_over_3_years/one_mg_per_m3_per_oyster)		Dmnl
quality_index_according_to_available_resource	GRAPH(0+0) Points: (0, 0.0800), (0.0000703364, 0.0877193), (0.000126911, 0.112281), (0.000191132, 0.147368), (0.000250765, 0.189474), (0.000325688, 0.236842), (0.000376147, 0.27193), (0.000437309, 0.291228), (0.0005, 0.3000)		Dmnl
ratio_export_price_to_local_price	1.9		Dmnl

second_year(t)	second_year(t - dt) + (to_second_year - second_year_mortality - to_third_year) * dt	INIT second_year = initial_oysters_year_2	oyster
second_year_mortality	second_year*mortality_rate_year_2		oyster/month
share_of_local_sales	0.8		Dmnl
share_oysters_in_third_year	third_year/total_number_of_oysters		Dmnl
spat_capture	max_spat_capture*LOOKUP(spat_capture_according_to_resource, available_trophic_resource/one_mg_per_m3)		oyster/month
spat_capture_according_to_resource	GRAPH(0+0) Points: (0.00, 0.7000), (3.36391, 0.864035), (6.72783, 0.934211), (12.5382, 0.964912), (19.8777, 0.973684), (30.7339, 0.982456), (42.2018, 0.991228), (49.6942, 0.991228), (50.00, 1.0000)		Dmnl
spat_costs	spats_purchase*spat_unit_weight*cost_per_ton_of_spat/one_year		euro/Year
spat_factor	spats_purchase/(needed_spat*one_year)		Dmnl
spat_factor_weight	0.5		Dmnl
spat_input	(IF month_index = 1 AND TIME = INT(TIME) THEN needed_spat*one_year/DT ELSE 0)*0+1*needed_spat*one_year/(12*one_month)		oyster/month
spat_unit_weight	1.6e-11		ton/oyster
spats_export	2.3e+09		oyster/Year
spats_input_per_sold_ton	27000		oyster/ton
spats_purchase(t)	spats_purchase(t - dt) + (to_spat_purchase) * dt	INIT spats_purchase = 1e+08	oyster
spats_replacement_share	1		Dmnl
sum_of_factors	profit_factor_weight+quality_factor_weight+spat_factor_weight		Dmnl
third_year(t)	third_year(t - dt) + (to_third_year - third_year_mortality - to_market) * dt	INIT third_year = initial_oysters_year_3	oyster
third_year_mortality	third_year*(mortality_rate_year_3+(IF TIME < scenarios_first_month THEN 0 ELSE LOOKUP(oyster_mortality_according_to_density, oyster_density_per_bag_year_3/one_oyster_per_bag)))		oyster/month
to_market	((third_year/one_month)-third_year_mortality)/12		oyster/month
to_second_year	((oysters_in_first_production_year/one_month)-first_year_mortality)/12		oyster/month
to_spat_purchase	(IF month_index = 1 AND INT(TIME) = TIME THEN (MAX(0, (needed_spat*one_year-(cumulative_spat_to_production_over_one_year-spats_export*one_year))*spats_replacement_share)-spats_purchase)/DT ELSE 0)		oyster/month

to_spat_to_prod	spat_capture-(IF month_index = 1 AND INT(TIME) = TIME THEN cumulative_spat_to_production_over_one_year/DT ELSE 0)		oyster/month
to_third_year	((second_year/one_month)-second_year_mortality)/12		oyster/month
total_number_of_oysters	oysters_in_first_production_year+second_year+third_year		oyster
total_oyster_sales	local_sales_benefits+export_sales_benefits		euro/Year
total_oyster_sales_weight	(local_sales+export_sales)*oyster_to_market_unit_weight		ton/Year
transport_costs	export_sales*oyster_to_market_unit_weight*transport_costs_per_ton		euro/Year
transport_costs_per_ton	720		euro/ton
under_production	MAX(oyster_total_demand-total_oyster_sales_weight, 0)		ton/Year
Vineyards:			
allowed_irrigation_water_demand_vineyards	allowed_water_demand_per_year_vineyards*LOOKUP(irrigation_per_month_vineyard, month_index)		Mcubicmeter/month
allowed_water_demand_per_year_vineyards	MIN(abstraction_permits_for_irrigation, water_demand_per_year_agriculture)*water_demand_Mm3_per_year_vineyards/water_demand_per_year_agriculture		Mcubicmeter/Year
change_of_demand_for_cognac	demand_for_cognac_growth_rate*demand_for_cognac		Hl/(Year*month)
Cognac_production	(vineyard_under_production-irrigated_vineyards)*LOOKUP(cognac_yield_according_to_irrigation, 0)+irrigated_vineyards*LOOKUP(cognac_yield_according_to_irrigation, cumulative_irrigation_per_hectare_vineyards/one_m3_per_ha_per_year)		Hl/Year
cognac_yield_according_to_irrigation	GRAPH(0+0) Points: (0.0, 11.000), (700.0, 14.300)		Hl/(Year*hectare)
cumulative_irrigation_per_hectare_vineyards	cumulative_irrigation_vineyards/(irrigated_vineyards*Mm3_per_m3)		m3/(Year*hectare)
cumulative_irrigation_vineyards	water_demand_Mm3_per_year_vineyards*cumulative_irrigation_over_one_year/(water_demand_per_year_agriculture*one_year)		Mcubicmeter/Year
demand_for_cognac(t)	demand_for_cognac(t - dt) + (change_of_demand_for_cognac) * dt	INIT demand_for_cognac = 1e+06	Hl/Year
extra_desired_production	DELAY(production_gap, time_to_respond_to_demand, 138000)		Hl/Year
grubbing_up	vines_replacement_rate*vineyard_under_production		hectare/month
irrigated_vineyards	vineyard_under_production*share_of_irrigated_vineyards		hectare
irrigation_per_ha_conventional_vineyards	700		m3/(hectare*Year)
irrigation_per_ha_organic_vineyards	0		m3/(hectare*Year)

irrigation_per_month_vineyard	GRAPH(0+0) Points: (1.00, 0.0000), (2.00, 0.0000), (3.00, 0.0000), (4.00, 0.0000), (5.00, 0.0500), (6.00, 0.2500), (7.00, 0.3250), (8.00, 0.3250), (9.00, 0.0500), (10.00, 0.0000), (11.00, 0.0000), (12.00, 0.0000)		Year/month
new_vineyard(t)	new_vineyard(t - dt) + (vine_planting - production) * dt	INIT new_vineyard = 10000	hectare
not_sold_production	MAX(0, Cognac_production-(max_authorized_production_per_ha*vineyard_under_production))		Hl/Year
production	DELAY(vine_planting, time_to_grow_vines, vine_planting)		hectare/month
production_gap	demand_for_cognac-Cognac_production		Hl/Year
time_to_grow_vines	84		month
time_to_respond_to_demand	48		month
treatments_per_ha_conventional_vineyards	19.11		IFT/(hectare*Year)
treatments_per_ha_organic_vineyards	8.75		IFT/(hectare*Year)
treatments_vineyards	(vineyard_under_production+new_vineyard)*(treatments_per_ha_conventional_vineyards*(1-organic_share_of_vineyards)+treatments_per_ha_organic_vineyards*organic_share_of_vineyards)		IFT/Year
vine_planting	grubbing_up+vineyard_expansion		hectare/month
vines_replacement_rate	0.0033		Dmnl/month
vineyard_expansion	MIN(extra_desired_production/LOOKUP(cognac_yield_according_to_irrigation, 0)/one_month, planting_rights)		hectare/month
vineyard_under_production(t)	vineyard_under_production(t - dt) + (production - grubbing_up) * dt	INIT vineyard_under_production = 78000	hectare
water_demand_Mm3_per_year_vineyards	Mm3_per_m3*irrigated_vineyards*(irrigation_per_ha_conventional_vineyards*(1-organic_share_of_vineyards)+irrigation_per_ha_organic_vineyards*organic_share_of_vineyards)		Mcubicmeter/Year
Water:			
allowed_water_demand_agriculture	(allowed_irrigation_water_demand_conventional+allowed_irrigation_water_demand_organic+allowed_irrigation_water_demand_vineyards)*flows_level		Mcubicmeter/month
average_soil_depth	1		m
basin_area	1.055e+10		m2
capacity_WWTP_Mm3_coastal	capacity_of_coastal_WWTP*water_use_per_person		Mcubicmeter/month
capacity_WWTP_Mm3_rural	capacity_of_rural_WWTP*water_use_per_person		Mcubicmeter/month

coastal_salinity	LOOKUP(coastal_salinity_according_to_estuary_flow, estuary_flow/one_m3_per_sec)		g/liter
coastal_salinity_according_to_estuary_flow	GRAPH(0+0) Points: (0.00, 35.00), (8.00, 35.00), (12.00, 29.00), (20.00, 22.00), (40.00, 20.00), (60.00, 19.00)		g/liter
coastal_WWTP_overload	MAX(0, to_WWTP_coastal-capacity_WWTP_Mm3_coastal)		Mcubicmeter/month
concentration_in_trophic_resource	LOOKUP(trophic_resource_according_to_estuary_flow, estuary_flow/one_m3_per_sec)		mg/m3
cumulative_water_use_agriculture_over_one_year(t)	cumulative_water_use_agriculture_over_one_year(t - dt) + (to_water_use_agriculture) * dt	INIT cumulative_water_use_agriculture_over_one_year = 0	Mcubicmeter
cumulative_water_use_domestic_over_one_year(t)	cumulative_water_use_domestic_over_one_year(t - dt) + (to_water_use_domesic) * dt	INIT cumulative_water_use_domestic_over_one_year = 0	Mcubicmeter
dam_capacity	24		Mcubicmeter
dam_release_according_to_low_water_stream	GRAPH(0+0) Points: (0.00, 2.0000), (11.2844, 1.85088), (15.00, 1.5000)		m3/s
dam_storage(t)	dam_storage(t - dt) + (to_dam - from_dam) * dt	INIT dam_storage = 23.75	Mcubicmeter
domestic_wastewater_coastal	domestic_water_use*share_of_domestic_water_to_WWTP*coastal_share_of_water_demand		Mcubicmeter/month
domestic_wastewater_rural	domestic_water_use*share_of_domestic_water_to_WWTP*(1-coastal_share_of_water_demand)		Mcubicmeter/month
domestic_water_deficit	MAX(0, domestic_water_demand-domestic_water_use)		Mcubicmeter/month
domestic_water_use	water_use_domestic_from_groundwater+water_use_domestic_from_surface_water		Mcubicmeter/month
downflow	(surface_water/one_month)-(surface_water_withdrawal+water_use_ecosystems_from_surface_water)		Mcubicmeter/month
estuary_flow	to_the_sea*(60/400)/Mm3_per_month_per_m3_per_sec		m3/s
evaporated_share_of_irrigation	0.1		Dmnl
evapotranspiration	MIN(water_in_soil/one_month, evapotranspiration_by_agricultural_covers+evapotranspiration_by_other_covers_than_agriculture)		Mcubicmeter/month
evapotranspiration_by_other_covers_than_agriculture	1.34*evapotranspiration_by_agricultural_covers		Mcubicmeter/month
flows_level	(IF water_streams_flow < Low_Water_Target_Flow_for_water_streams THEN 0 ELSE 1)		Dmnl
from_dam	(IF flows_level = 1 THEN MIN(dam_storage/one_month, Mm3_per_month_per_m3_per_sec*standard_dam_release) ELSE MIN(dam_storage/one_month, Mm3_per_month_per_m3_per_sec*LOOKUP(dam_release_according_to_low_water_stream, MIN(15, water_streams_flow)/one_m3_per_sec)))		Mcubicmeter/month

from_WWTP	from_WWTP_coastal+from_WWTP_rural		Mcubicmeter/month
from_WWTP_coastal	DELAY(to_WWTP_coastal, time_reflowing_coastal, to_WWTP_coastal)		Mcubicmeter/month
from_WWTP_rural	DELAY(to_WWTP_rural, time_reflowing_rural, to_WWTP_rural)		Mcubicmeter/month
groundwater(t)	groundwater(t - dt) + (groundwater_recharge - groundwater_rise - groundwater_withdrawal) * dt	INIT groundwater = groundwater_capacity	Mcubicmeter
groundwater_available_for_irrigation	(groundwater/one_month)-water_use_domestic_from_groundwater		Mcubicmeter/month
groundwater_available_for_refill	groundwater_available_for_irrigation-water_use_agriculture_from_groundwater		Mcubicmeter/month
groundwater_capacity	1000		Mcubicmeter
groundwater_recharge	MIN(water_in_soil/one_month-evapotranspiration, seepage_rate*basin_area)		Mcubicmeter/month
groundwater_rise	MAX(0, (groundwater-groundwater_withdrawal*one_month)-groundwater_capacity)/one_month		Mcubicmeter/month
groundwater_withdrawal	water_use_agriculture_from_groundwater+water_use_domestic_from_groundwater+reservoirs_refill_from_groundwater		Mcubicmeter/month
infiltration	MIN(MAX(soil_capacity-water_in_soil, 0)/one_month, rainfall_Mm3*infiltration_coefficient)		Mcubicmeter/month
infiltration_coefficient	LOOKUP(infiltration_coefficient_according_to_soil_saturation, soil_saturation_to_limit)		Dmnl
infiltration_coefficient_according_to_soil_saturation	GRAPH(0+0) Points: (0.000, 0.9500), (0.152905, 0.950877), (0.345566, 0.935088), (0.443425, 0.914035), (0.550459, 0.868421), (0.66055, 0.79386), (0.776758, 0.72807), (0.892966, 0.703509), (1.000, 0.7000)		Dmnl
irrigation	irrigation_water_use*(1-evaporated_share_of_irrigation)		Mcubicmeter/month
irrigation_water_use	water_use_agriculture_from_groundwater+reservoirs_use+water_use_agriculture_from_surface_water		Mcubicmeter/month
maximum_seepage_rate_per_m2	4.5e-07		Mcubicmeter/(month*m2)
needed_refill	(IF month_index < reservoirs_refill_start AND month_index > reservoirs_refill_end THEN 0 ELSE flows_level*MAX(0, reservoirs_capacity-(reservoirs-reservoirs_use*one_month)))		Mcubicmeter
occurence_of_viruses	LOOKUP(occurence_of_viruses_according_to_time_reflowing, time_reflowing_coastal/one_month)		Dmnl
occurence_of_viruses_according_to_time_reflowing	GRAPH(0+0) Points: (0.000, 1.000), (0.394495, 0.95614), (0.743119, 0.868421), (1.11927, 0.732456), (1.49541, 0.500), (1.88991, 0.254386), (2.24771, 0.118421), (2.6422, 0.0350877), (3.000, 0.000)		Dmnl
rainfall_Mm3	rainfall*basin_area*Mm3_per_m2_per_mm		Mcubicmeter/month
reservoirs(t)	reservoirs(t - dt) + (reservoirs_refill - reservoirs_use) * dt	INIT reservoirs = reservoirs_capacity	Mcubicmeter

reservoirs_refill	reservoirs_refill_from_groundwater+reservoirs_refill_from_surface_water		Mcubicmeter/month
reservoirs_refill_end	2		Dmnl
reservoirs_refill_from_groundwater	MIN(groundwater_available_for_refill, (needed_refill/one_month)-reservoirs_refill_from_surface_water)		Mcubicmeter/month
reservoirs_refill_from_surface_water	(1-share_of_reservoirs_water_from_groundwater)*MAX(0, MIN(needed_refill, surface_water_available_for_refill))/one_month		Mcubicmeter/month
reservoirs_refill_start	12		Dmnl
reservoirs_use	MIN(reservoirs/one_month, allowed_water_demand_agriculture)*(1-share_of_irrigation_never_from_reservoirs)		Mcubicmeter/month
runoff	rainfall_Mm3-infiltration		Mcubicmeter/month
rural_WWTP_overload	MAX(0, to_WWTP_rural-capacity_WWTP_Mm3_rural)		Mcubicmeter/month
seepage_rate	LOOKUP(seepage_rate_according_to_soil_saturation, soil_saturation_to_limit)*maximum_seepage_rate_per_m2		Mcubicmeter/(month*m2)
seepage_rate_according_to_soil_saturation	GRAPH(0+0) Points: (-0.0030581, 0.565789), (0.204893, 0.583333), (0.379205, 0.640351), (0.559633, 0.719298), (0.663609, 0.79386), (0.730887, 0.859649), (0.7737, 0.894737), (0.834862, 0.95614), (0.900, 0.982014), (1.000, 1.0000)		Dmnl
share_of_domestic_water_to_WWTP	0.9		Dmnl
soil_capacity	soil_saturation_limit*average_soil_depth*basin_area		Mcubicmeter
soil_saturation	water_in_soil/(basin_area*average_soil_depth)		Mcubicmeter/(m2*m)
soil_saturation_limit	2.4e-07		Mcubicmeter/(m2*m)
soil_saturation_to_limit	soil_saturation/soil_saturation_limit		Dmnl
standard_dam_release	0.05		m3/s
surface_water(t)	surface_water(t - dt) + (from_dam + from_WWTP + groundwater_rise + runoff - downflow - to_dam - water_use_ecosystems_from_surface_water - surface_water_withdrawal) * dt	INIT surface_water = 600	Mcubicmeter
surface_water_available_for_refill	MAX(0, surface_water-(water_use_domestic_from_surface_water+water_use_ecosystems_from_surface_water)*one_month)		Mcubicmeter
surface_water_withdrawal	reservoirs_refill_from_surface_water+water_use_agriculture_from_surface_water+water_use_domestic_from_surface_water		Mcubicmeter/month
time_reflowing_coastal	LOOKUP(WWTP_treatment_duration_according_to_overload, coastal_WWTP_overload/capacity_WWTP_Mm3_coastal)		month
time_reflowing_rural	LOOKUP(WWTP_treatment_duration_according_to_overload, rural_WWTP_overload/capacity_WWTP_Mm3_rural)		month

to_dam	(IF flows_level = 1 THEN MAX(0, dam_capacity-dam_storage)/one_month ELSE 0)		Mcubicmeter/month
to_marshes	water_streams/one_month		Mcubicmeter/month
to_the_sea	water_in_marshes/one_month		Mcubicmeter/month
to_total_water_use	(IF month_index = 1 AND INT(TIME) = TIME AND TIME > STARTTIME THEN (cumulative_water_use_agriculture_over_one_year+cumulative_water_use_domestic_over_one_year-total_water_use_over_one_year)/DT ELSE 0)		Mcubicmeter/month
to_water_use_agriculture	irrigation_water_use-(IF month_index = 1 AND INT(TIME) = TIME THEN cumulative_water_use_agriculture_over_one_year/DT ELSE 0)		Mcubicmeter/month
to_water_use_domesic	domestic_water_use-(IF month_index = 1 AND INT(TIME) = TIME THEN cumulative_water_use_domestic_over_one_year/DT ELSE 0)		Mcubicmeter/month
to_WWTP_coastal	domestic_wastewater_coastal		Mcubicmeter/month
to_WWTP_rural	domestic_wastewater_rural		Mcubicmeter/month
total_water_use	irrigation_water_use+domestic_water_use		Mcubicmeter/month
total_water_use_over_one_year(t)	total_water_use_over_one_year(t - dt) + (to_total_water_use) * dt	INIT total_water_use_over_one_year = 185	Mcubicmeter
trophic_resource_according_to_estuary_flow	GRAPH(0+0) Points: (0.00, 5.00), (10.00, 8.00), (19.0826, 10.9649), (30.8869, 15.7895), (40.5505, 23.6842), (46.422, 31.3596), (49.9083, 39.0351), (53.3945, 45.3947), (56.1468, 48.2456), (60.00, 50.00)		mg/m3
water_in_marshes(t)	water_in_marshes(t - dt) + (to_marshes - to_the_sea) * dt	INIT water_in_marshes = 50	Mcubicmeter
water_in_soil(t)	water_in_soil(t - dt) + (infiltration + irrigation - evapotranspiration - groundwater_recharge) * dt	INIT water_in_soil = 900	Mcubicmeter
water_streams(t)	water_streams(t - dt) + (downflow - to_marshes) * dt	INIT water_streams = 50	Mcubicmeter
water_streams_flow	to_marshes/Mm3_per_month_per_m3_per_sec		m3/s
water_use_agriculture_from_groundwater	MIN(groundwater_available_for_irrigation, (allowed_water_demand_agriculture-reservoirs_use)*share_of_irrigation_water_from_groundwater)		Mcubicmeter/month
water_use_agriculture_from_surface_water	(allowed_water_demand_agriculture-reservoirs_use)*(1-share_of_irrigation_water_from_groundwater)		Mcubicmeter/month
water_use_domestic_from_groundwater	MIN(groundwater*share_of_domestic_water_from_groundwater/one_month, domestic_water_demand)		Mcubicmeter/month
water_use_domestic_from_surface_water	domestic_water_demand-water_use_domestic_from_groundwater		Mcubicmeter/month
water_use_ecosystems_from_surface_water	0		Mcubicmeter/month
WWTP_coastal(t)	WWTP_coastal(t - dt) + (to_WWTP_coastal - from_WWTP_coastal) * dt	INIT WWTP_coastal = 195000	Mcubicmeter

WWTP_rural(t)	WWTP_rural(t - dt) + (to_WWTP_rural - from_WWTP_rural) * dt	INIT WWTP_rural = 195000	Mcubicmeter
WWTP_treatment_duration_according_to_overload	GRAPH(0+0) Points: (0.0, 3.000), (1.0, 1.000), (100.0, 0.000)		month

Annex 4e Overview of equations MAL05 – Danube Mouth and Black Sea

Table 11: Overview of equations used to quantify the integrated MAL5 SD model

	Equation	Properties	Units	Documentation
ECOFARMING				
agriculture_water_demand_per_ha	1000		m3/(Year*hectare)	
annual_precipitation	0{GET_XLS_DATA('MAL05_Input.xlsx','ecofarming','A','F2')}		mm/Year	
Danube_flow	2.02e+14		l/Year	FLOW IN XLS SEEMS TOO SMALL: GET XLS DATA('MAL05_Input.xlsx','fish farming','A','H2')
"eco-crop_price"	0{GET_XLS_DATA('MAL05_Input.xlsx','ecofarming','A','I2')}		RON/ton crop	
"Eco-farm_employment"	"eco-labor_intensity"*ecofarms_area		employees	
"eco-labor_intensity"	0.04		employees/hectare	72 h
ecofarm_conversion	ecofarm_transition_rate*ecofarms_area*(1-(ecofarms_area/maximum_area_ecofarms))		hectare/Year	
ecofarm_fertilizer_use	0{GET_XLS_DATA('MAL05_Input.xlsx','ecofarming','A','J2')}		kg N/(Year*hectare)	in ecofarming no chemical fertilizers are used
ecofarm_income	("eco-crop_price"*total_ecofarm_production)-ecofarm_production_costs*ecofarms_area		RON/Year	
ecofarm_production_costs	0{GET_XLS_DATA('MAL05_Input.xlsx','ecofarming','A','E2')}		RON/(Year*hectare)	
ecofarm_productivity	impact_of_ecofarm_fertilizer_use_on_yield*minimal_ecofarm_yield*impact_of_water_supply_on_yield*(IF irrigation > 0 THEN impact_of_forest_belts_on_yield ELSE 1)		ton crop/(hectare*Year)	

ecofarm_transition_rate	LN((maximum_area_ecofarms-initial_area_ecofarms)*FarmToFork_Target*total_agriculture_area/(initial_area_ecofarms*(maximum_area_ecofarms-FarmToFork_Target*total_agriculture_area)))/FarmToFork_Target_Time		1/Year	growth rate obtained from solution logistic growth equation see Sterman (2000), page 298.
ecofarms_area(t)	ecofarms_area(t - dt) + (ecofarm_conversion) * dt	INIT ecofarms_area = initial_area_ecofarms	hectare	
evaporation	0{GET_XLS_DATA('MAL05_Input.xlsx','ecofarming','A','H2')}		mm/Year	
FarmToFork_Target	0.25		Dmnl	fraction ecofarming as part of Farm-To-Fork Strategy
FarmToFork_Target_Time	10		Year	target year for reaching target FarmToFork conversion to ecofarming, calculated from initial year 2020
forest_belts_installation_year	2020		Year	policy setting: 0 is without forest belts, 1 = with forest belts
fraction_ecofarms	ecofarms_area/(traditional_farms_area+ecofarms_area)		Dmnl	~ :SUPPLEMENTARY
ha2m3	10		m3/(mm*hectare)	unit convertor for consistency of equations 1 mm per ha = 10 m3
impact_of_ecofarm_fertilizer_use_on_yield	GRAPH(ecofarm_fertilizer_use/maximum_fertilizer_use) Points: (0.000, 0.500), (0.179221, 1.38947), (0.428571, 2.27368), (0.618182, 2.77895), (0.838961, 2.95789), (1.000, 3.000)		Dmnl	
impact_of_forest_belts_on_yield	GRAPH(number_of_years_forest_belts_are_present) Points: (0.00, 1.0000), (1.74026, 1.01053), (2.15584, 1.01404), (3.01299, 1.02526), (4.1039, 1.03789), (5.50649, 1.06526), (6.57143, 1.10175), (8.72727, 1.21754), (10.00, 1.29474), (15.00, 1.3000), (25.00, 1.3000)		Dmnl	
impact_of_N_from_agriculture_on_water_quality	GRAPH(10*N_runoff/(Danube_flow*maximum_N_acceptable_concentration)) Points: (0.00, 0.00), (0.152905, 1.66667), (0.183486, 1.53509), (0.275229, 3.11404), (0.611621, 5.52632), (1.31498, 7.14912), (2.38532, 8.11403), (3.27217, 8.77193), (4.28135, 8.99123), (5.41284, 9.16667), (7.15596, 9.51754), (10.00, 10.00)		Dmnl	
impact_of_traditional_farm_fertilizer_use_on_yield	GRAPH(traditional_farm_fertilize_use/maximum_fertilizer_use) Points: (0.000, 0.500), (0.116883, 1.10526), (0.254545, 1.62105), (0.400, 2.03158), (0.607792, 2.45263), (0.872727, 2.84211), (1.000, 3.000)		Dmnl	
impact_of_water_supply_on_yield	GRAPH((water_supply_per_ha-agriculture_water_demand_per_ha)/agriculture_water_demand_per_ha) Points: (-1.000, 0.000), (-0.579221, 0.526316), (0.000, 1.000), (1.04156, 1.44561), (2.78701, 1.81053), (3.87792, 1.90175), (5.000, 2.000)		Dmnl	
initial_area_ecofarms	59526		hectare	MARD DATA

initial_area_traditional_farms	306766		hectare	APIA data- request for info from ICEADR
irrigation	MAX(0, MIN(maximum_irrigation, agriculture_water_demand_per_ha-annual_precipitation*ha2m3+evaporation*ha2m3))		m3/(Year*hectare)	
maximum_area_ecofarms	150000		hectare	THIS SHOULD ALWAYS BE HIGHER THAN "Farm to Fork Target" times "Total Farm Area"
maximum_fertilizer_use	130		kg N/(Year*hectare)	hypothetical maximum to be set
maximum_irrigation	800		m3/(Year*hectare)	
maximum_N_acceptable_concentration	1.13e-09		ton N/l	Europen limit value of 50 mg NO3/l -> 11.3 mgN/l -> 11.3 e-9 Ton N/l 11.3 mgN/l
minimal_ecofarm_yield	0{GET_XLS_DATA('MAL05_Input.xlsx','ecofarming','A','k2')}		ton crop/(Year*hectare)	
minimal_traditional_farm_yield	2		ton crop/(Year*hectare)	
N_crop_uptake	(specific_crop_consumption_rate*total_agriculture_area)/total_production		ton N/ton crop	https://ars.els-cdn.com/content/image/1-s2.0-S116103011830491X-gr6_lrg.jpg; https://www.sciencedirect.com/science/article/pii/S116103011830491X COGAP
N_runoff	Runoff_rate*(total_fertilizer_use-total_production*N_crop_uptake)		ton N/Year	https://waterfootprint.org/media/downloads/Report65-GreyWaterFootprint-Guidelines_1.pdf, page 17 nutient runoff
number_of_years_forest_belts_are_present	MAX(0, (forest_belts_installation_year-TIME)/unit_year)		Dmnl	
Runoff_rate	0.1		Dmnl	
specific_crop_consumption_rate	0.026		ton N/(Year*hectare)	
ton_per_kg	0.001		ton N/kg N	unit convertor to ensure unit check runs ok

total_agriculture_area	initial_area_ecofarms+initial_area_traditional_farms		hectare	
Total_agriculture_employment	"Eco-farm_employment"+Traditional_farm_employment		employees	
Total_agriculture_income	ecofarm_income+traditional_farm_income		RON/Year	
total_ecofarm_production	ecofarm_productivity*ecofarms_area		ton crop/Year	
total_fertilizer_use	ton_per_kg*(traditional_farms_area*traditional_farm_fertilize_use+ecofarms_area*ecofarm_fertilizer_use)		ton N/Year	
total_production	total_traditional_farm_production+total_ecofarm_production		ton crop/Year	
total_traditional_farm_production	traditional_farm_productivity*traditional_farms_area		ton crop/Year	
traditional_crop_price	0{GET_XLS_DATA('MAL05_Input.xlsx','ecofarming','A','B2')}		RON/ton crop	Average price for agricultural products according to INSSE statistical data base.
Traditional_farm_employment	traditional_farms_area*traditional_labor_intensity		employees	
traditional_farm_fertilize_use	0{GET_XLS_DATA('MAL05_Input.xlsx','ecofarming','A','G2')}		kg N/(hectare*Year)	NIS DATA: AGR104A, and AGR105A
traditional_farm_income	(traditional_crop_price*total_traditional_farm_production)-traditional_farm_production_costs*traditional_farms_area		RON/Year	
traditional_farm_production_costs	0{GET_XLS_DATA('MAL05_Input.xlsx','ecofarming','A','D2')}		RON/(hectare*Year)	value based on ICEADR calculation, (Ghid practic tehnico-economic pentru agricultura conven?ionala ?i agricultura ecologicaAna URSU, Elena ?URCA, Ionu? PETRE, ICEADR ; ADER 1312)
traditional_farm_productivity	impact_of_traditional_farm_fertilizer_use_on_yield*minimal_traditional_farm_yield*impact_of_water_supply_on_yield*(IF irrigation > 0 THEN impact_of_forest_belts_on_yield ELSE 1)		ton crop/(Year*hectare)	
traditional_farms_area(t)	traditional_farms_area(t - dt) + (- ecofarm_conversion) * dt	INIT traditional_farms_area = initial_area_traditional_farms	hectare	

traditional_labor_intensity	0.01		employees/hectare	27 h la hectar grau conventional ICEADR calculations 2017
water_supply_per_ha	irrigation+annual_precipitation*ha2m3		m3/(Year *hectare)	
FISH FARMING				
aquaculture_intensification	Normal_Fish_Farming_Area*aquaculture_intensification_rate		ha/Year	
aquaculture_intensification_rate	0{GET_XLS_DATA('MAL05_Input.xlsx','fish_farming','A','F2')}		1/Year	yearly fraction of existing normal aquaculture area which is changed into intensive aquaculture. Value to be set and possible linking with investment and/or technological evolution 10% per year
Danube_N_load	Danube_flow*maximum_N_acceptable_concentration		ton N/Year	
effect_pollution_on_fishfarming	1/(MAX(1, impact_of_N_from_agriculture_on_water_quality)*MAX(impact_on_N_from_tourism_on_water_quality, 1)*MAX(1.5*impact_of_N_load_aquaculture_on_water_quality, 1))		Dmnl	
fish_consumption	0{GET_XLS_DATA('MAL05_Input.xlsx','fish_farming','A','C2')}		ton fish/Year	time series SCENARIO
fish_farming_labor_intensity	0.27		employees/ha	Annual revenues= 4 mil. Euro, 350 jobs https://www.mlpda.ro/uploads/articole/attachments/5dc54ff7023d2687491643.pdf 350/19738=0.02 employees/ha This could be changed as a result of investment, new/improve tech The same source estimates as global average of aquculture employess as 0.27/t
fish_price	0{GET_XLS_DATA('MAL05_Input.xlsx','fish_farming','A','B2')}		RON/ton fish	average price 10RON/kg source:FLAG Delta Dunarii rate of increase=1%/year
fish_production_ratio	total_aquaculture_production/fish_consumption		Dmnl	~ :SUPPLEMENTARY
impact_of_N_load_aquaculture_on_water_quality	GRAPH(total_aquaculture_N_load/(Danube_flow*maximum_N_acceptable_concentration)) Points: (0.000, 0.0), (0.114286, 3.50877), (0.350649, 11.2281), (0.496104, 42.4561), (0.605195, 71.5789), (0.802597, 90.8772), (1.000, 100.0)		Dmnl	the total aquaculture load seems very high => comparable to what is in the danube ???
initial_area_in_use_for_intensive_aquaculture	0		ha	value to be completed for initial condition 2020

initial_area_in_use_for_normal_aquaculture	19738		ha	Actual granted area by National Euthorithy for Aquculture http://www.madr.ro/docs/fep/programare-2014-2020/draft-PSNMA-2014-2020.pdf http://www.curteadeconturi.ro/Publicatii/SINTEZA%20Raport%20AP%20PESCUIT%20si%20ACVACULTURA%202016-2019.pdf
intensive_aquaculture_development	intensive_aquaculture_development_rate*(1-(spatial_pressure_from_aquaculture_development/100))*effect_pollution_on_fishfarming		ha/Year	
intensive_aquaculture_development_rate	2000		ha/Year	yearly newly developed area for INTENSIVE aquaculture . CAN BE REMOVED IF THIS IS NOT OCCURRING
intensive_aquaculture_N_load	0.5		ton N/(ha*Year)	
intensive_aquaculture_production	Intensive_Fish_Farming_Area*intensive_aquaculture_productivity		ton fish/Year	
intensive_aquaculture_productivity	0{GET_XLS_DATA('MAL05_Input.xlsx','fish_farming','A','E2')}		ton fish/(ha*Year)	http://www.curteadeconturi.ro/Publicatii/SINTEZA%20Raport%20AP%20PESCUIT%20si%20ACVACULTURA%202016-2019.pdf intensive aquculture productivity for optimum fertilzer is 2-4 t/ha
intensive_fish_farm_employment	Intensive_Fish_Farming_Area*fish_farming_labor_intensity		employees	
intensive_fish_farm_revenues	fish_price*intensive_aquaculture_production-intensive_fish_farm_employment*labor_costs_per_employee-intensive_aquaculture_production*production_cost_rate_for_intensive_aquaculture+Intensive_Fish_Farming_Area*subsidies_per_unit_area		RON/Year	
Intensive_Fish_Farming_Area(t)	Intensive_Fish_Farming_Area(t - dt) + (aquaculture_intensification + intensive_aquaculture_development) * dt	INIT Intensive_Fish_Farming_Area = initial_area_in_use_for_intensive_aquaculture	ha	
labor_costs_per_employee	42000		RON/(employees*Year)	3500 RON/month - source: FLAG Delta Dunarii

maximum_area_available_for_aquaculture	34628		ha	http://www.curteadeconturi.ro/Publicatii/SINTEZA%20Raport%20AP%20PESCUIT%20si%20ACVACULTURA%202016-2019.pdf
normal_aquaculture_development	normal_aquaculture_development_rate*(1-(spatial_pressure_from_aquaculture_development/100))*effect_pollution_on_fishfarming		ha/Year	
normal_aquaculture_development_rate	1		ha/Year	yearly fnewly developed area for normal aquaculture. CAN BE REMOVED IF THIS IS NOT OCCURRING
normal_aquaculture_N_load	0.45		ton N/(Year*ha)	
normal_aquaculture_production	Normal_Fish_Farming_Area*normal_aquaculture_productivity		ton fish/Year	
normal_aquaculture_productivity	0{GET_XLS_DATA('MAL05_Input.xlsx','fish_farming','A','D2')}		ton fish/(ha*Year)	http://www.curteadeconturi.ro/Publicatii/SINTEZA%20Raport%20AP%20PESCUIT%20si%20ACVACULTURA%202016-2019.pdf
normal_fish_farm_employment	Normal_Fish_Farming_Area*fish_farming_labor_intensity		employees	
normal_fish_farm_revenues	fish_price*normal_aquaculture_production-normal_fish_farm_employment*labor_costs_per_employee-normal_aquaculture_production*production_cost_rate_for_normal_aquaculture		RON/Year	
Normal_Fish_Farming_Area(t)	Normal_Fish_Farming_Area(t - dt) + (normal_aquaculture_development - aquaculture_intensification) * dt	INIT Normal_Fish_Farming_Area = initial_area_in_use_for_normal_aquaculture	ha	
production_cost_rate_for_intensive_aquaculture	1000		RON/ton fish	
production_cost_rate_for_normal_aquaculture	200		RON/ton fish	
spatial_pressure_from_aquaculture_development	100*Total_Area_in_use_for_Aquaculture/maximum_area_available_for_aquaculture		Dmnl	
subsidies_per_unit_area	0{GET_XLS_DATA('MAL05_Input.xlsx','fish_farming','A','G2')}		RON/(ha*Year)	162 euro=810 RON https://agrointel.ro/156846/subventia-apia-minima-pe-hectar-in-2020/

total_aquaculture_N_load	Normal_Fish_Farming_Area*normal_aquaculture_N_load+Intensive_Fish_Farming_Area*intensive_aquaculture_N_load		ton N/Year	
total_aquaculture_production	normal_aquaculture_production+intensive_aquaculture_production		ton fish/Year	SHOULD BE 3500 Ton/Year initially
Total_Area_in_use_for_Aquaculture	Normal_Fish_Farming_Area+Intensive_Fish_Farming_Area		ha	
total_fish_farm_employment	normal_fish_farm_employment+intensive_fish_farm_employment		employees	should be 350 employees initially. PLEASE NOTE: this is assuming the labor intensity for normal and intensive aquaculture is the same
total_fish_farm_revenues	normal_fish_farm_revenues+intensive_fish_farm_revenues		RON/Year	
TOURISM				
Annual_Tourist_Days	Number_of_Tourists*duration_of_tourist_staying		Tourist Days	
decline_rate_without_development	0.1		1/Year	to be verified with the Excel tool provided for estimating growth and decline parameters
duration_of_tourist_staying	0{GET_XLS_DATA('MAL05_Input.xlsx','tourism','A','B2')}		Tourist Days/Tourists	INITIAL VALUE based on INSSE report. retrived at https://insse.ro/cms/sites/default/files/com_presa/com_pdf/turism10r19.pdf
emergency_level	0.9		Dmnl	fraction of carrying capacity, according to literature overwiew, http://webspace.ulbsibiu.ro/dumitru.troanca/html/resurse/Ecoturism%20-%20B02%20an%201/Ecoturism%20si%20conservarea%20mediului.pdf
employment_factor	0.02		employees/Tourist Days	
fraction_of_revenues_used_for_marketing	0.08		Dmnl	According to the literature overview, it is recommended spending 7 to 8 percent of the gross revenue for marketing and advertising.
impact_of_marketing_on_development	GRAPH(marketing/initial_marketing_budget) Points: (0.00, 0.500), (1.00, 1.000), (3.48052, 1.62105), (5.71429, 2.04211), (8.31169, 2.38947), (10.6494, 2.63158), (14.0779, 2.86316), (20.00, 3.000)		Dmnl	
impact_on_N_from_tourism_on_water_quality	GRAPH(500*tourism_N_load/(maximum_N_acceptable_concentration*Danube_flow)) Points: (0.00, 0.000), (0.00001, 0.100), (0.0001, 0.500), (0.01, 0.750), (0.366972, 1.08772), (0.50, 1.29825), (0.75, 1.65789), (1.00, 1.86842), (10.00, 2.000)		Dmnl	

impact_pollution_on_tourism	1/(MAX(1, impact_of_N_from_agriculture_on_water_quality)*MAX(1, impact_of_N_load_aquaculture_on_water_quality)*MAX(1, impact_on_N_from_tourism_on_water_quality))		Dmnl	
impact_tourism_attractiveness_on_decline	GRAPH(tourism_attractiveness) Points: (0.0, 0.000), (16.8831, 0.126316), (37.4026, 0.305263), (67.5325, 0.768421), (79.7403, 1.32632), (90.3896, 2.200), (100.0, 5.000)		Dmnl	
initial_duration_of_stay	0{GET_XLS_CONSTANTS('MAL05_input.xlsx','tourism','B2')}		Tourist Days/Tourists	
initial_marketing_budget	1.1768e+06		RON/Year	Based on the ratio of average revenues of economic agents in Tulcea county (hotels and restaurants)and the fraction of revenues used for marketing, according to INSSE statistical data.
initial_number_of_tourists	200000		Tourists	
initial_tourist_days	initial_duration_of_stay*initial_number_of_tourists		Tourist Days	
load_N_per_day	0.0001		ton N/(Tourist Days*Year)	Total Kjeldal Nitrogen from an article = 10 mg/l/day, 0.1 kg/day (100 g/day)
marketing	fraction_of_revenues_used_for_marketing*tourism_revenues		RON/Year	
Number_of_Tourists(t)	Number_of_Tourists(t - dt) + (tourism_development - tourism_decline) * dt	INIT Number_of_Tourists = initial_number_of_tourists	Tourists	Note: a tourist day = 1 tourist staying 1 day in the area
revenues_per_touristday	81		RON/Tourist Days	According to the data of National Institute of Statistics, own calculation, based on the revenues indicator and the number of tourist days
time_until_emergency_level_is_reached	17		Year	According to the data of National Institute of Statistics, own calculation, based on the number of tourist and the average length stay, taking into account the critical threshold of 2120000

tourism_attractiveness	GRAPH(tourism_pressure*impact_pollution_on_tourism) Points: (0.00, 10.00), (4.15584, 24.9123), (12.987, 55.0877), (25.1948, 73.6842), (35.5844, 82.1053), (49.6104, 84.9123), (61.2987, 81.7544), (74.5455, 72.6316), (84.9351, 63.5088), (99.4805, 50.5263)		Dmnl	attractiveness will be low when tourism is underdeveloped (no facilities) and will gradually increase, at a certain point crowding will be a problem for the attractiveness, though less than in the case of underdevelopment
tourism_carrying_capacity	2.12e+06		Tourist Days	Tourism development stops when carrying capacity is approached - cannot be exceeded According to the reports made by the Tulcea County Directorate of Statistics and Tulcea Local Promotion and Development Association during 2017-2019. (https://focuspress.ro/turismul-o-industrie-cu-probleme-la-tulcea/), based on an average length of stay per tourist of 2 touristic days
tourism_decline	Number_of_Tourists*decline_rate_without_development*impact_tourism_attractiveness_on_decline		Tourists/Year	
tourism_development	(IF initial_tourist_days >= emergency_level*tourism_carrying_capacity THEN 0 ELSE LN((emergency_level/(1-emergency_level))*(tourism_carrying_capacity-initial_tourist_days)/initial_tourist_days)/time_until_emergency_level_is_reached)*impact_of_marketing_on_development*Number_of_Tourists*(1-0.01*tourism_pressure)		Tourists/Year	
tourism_employment	employment_factor*Annual_Tourist_Days		employees	
tourism_N_load	load_N_per_day*Annual_Tourist_Days		ton N/Year	Was set to 1.2e+06 => calculate from number of tourists and load/tourist/year
tourism_pressure	GRAPH(Annual_Tourist_Days/tourism_carrying_capacity) Points: (0.000, 10.00), (0.148052, 11.5789), (0.254545, 15.4386), (0.38961, 23.5088), (0.576623, 42.4561), (0.78961, 69.8246), (1.000, 100.00)		Dmnl	
tourism_revenues	Annual_Tourist_Days*revenues_per_touristday/unit_year		RON/Year	
unit_year	1		Year	

Annex 4f Overview of equations MAL06 – Mar Menor

	Equation	Properties	Units	Documentation
Top-Level Model:				
agricultural_nutrients_in_the_MM_lagoon(t)	agricultural_nutrients_in_the_MM_lagoon(t - dt) + (agricultural_nutrients_input - NO3_consumed_by_lagoon_metabolism) * dt	INIT agricultural_nutrients_in_the_MM_lagoon = 0	t	Total amount of nitrates in the Mar Menor lagoon
CoastalEcoEffect(t)	CoastalEcoEffect(t - dt) + (CoastalEcoEffect_net_flow) * dt	INIT CoastalEcoEffect = 0	Dmnl	Source: calibrated based on expected trends. Gradual increase in the relative coastal ecotourism effect
expected_number_of_tourists(t)	expected_number_of_tourists(t - dt) + (potential_tourist_growth + Initial_nr_of_tourists - tourism_loss) * dt	INIT expected_number_of_tourists = 0	tourist	La Manga tourists are included here. Total number of yearly tourists expected
irrigated_land_areas(t)	irrigated_land_areas(t - dt) + (change_in_irrigated_land_area - decrease_in_irrigated_land_area) * dt	INIT irrigated_land_areas = 4366	ha	Initial value for 1964 - source: Lopez Ortiz 1999 Extent of irrigated agricultural areas
OtherPointSourcePollutionMitigationEffect(t)	OtherPointSourcePollutionMitigationEffect(t - dt) + (OtherPointSourcePollutionMitigationEffect_net_flow) * dt	INIT OtherPointSourcePollutionMitigationEffect = 0	Dmnl	Relative value of the other point source pollution mitigation effect
Potential_PV_installed(t)	Potential_PV_installed(t - dt) + (potential_PV_installation + initial_estimated_PV_MW_installed) * dt	INIT Potential_PV_installed = 0	MW	Total power of photovoltaic energy installed
RuralEcoEffect(t)	RuralEcoEffect(t - dt) + (RuralEcoEffect_net_flow) * dt	INIT RuralEcoEffect = 0	Dmnl	Gradual increase in the relative rural ecotourism effect
territorial_bonding(t)	territorial_bonding(t - dt) + (territorial_bonding_net_flow) * dt	INIT territorial_bonding = 0,1	Dmnl	Relative level of territorial bonding by local populations

agricultural_nutrients_input	(IF gw_nitrate_from_brine+net_NO3_export_via_sw +estimated_NO3_input_to_MM_from_Cuaternario-tons_of_nitrate_yearly_extracted_by_the_Vertido0Pumping-tons_of_nitrate_yearly_extracted_by_the_AlbujonSWPumping > 0 THEN gw_nitrate_from_brine+net_NO3_export_via_sw+estimated_NO3_input_to_MM_from_Cuaternario-tons_of_nitrate_yearly_extracted_by_the_Vertido0Pumping-tons_of_nitrate_yearly_extracted_by_the_AlbujonSWPumping ELSE 0)		t/Year	Total nitrate input to the Mar Menor lagoon
change_in_irrigated_land_area	(IF irrigated_land_areas <= maxPotIAs THEN potential_agricultural_development*irrigated_land_areas ELSE 0)		ha/Year	Yearly increase in irrigated land area
CoastalEcoEffect_net_flow	impact_of_coastal_ecotourism/44		Dmnl/Year	
decrease_in_irrigated_land_area	(IF irrigated_land_areas <= maxIAs THEN excessive_irrigated_land_areas_due_to_lack_of_water ELSE irrigated_land_areas-maxIAs)		ha/Year	Decrease in irrigated land area
initial_estimated_PV_MW_installed	GRAPH(TIME) Points: (1961,00, 0,0), (2018,00, 0,0), (2019,00, 224,0), (2020,00, 0,0)		MW/Year	Source: ECONET 2020 - 672 in 2019 in Murcia region and we assume a third in CCT. Initial estimated amount of photovoltaic energy power installed
Initial_nr_of_tourists	GRAPH(TIME) Points: (1961,00, 0), (1998,00, 0), (1999,00, 2000000), (2000,00, 0)		tourist/Year	Source: ECONET 2020 Initial number of tourists
NO3_consumed_by_lagoon_metabolism	agricultural_nutrients_in_the_MM_lagoon*Percentage_of_nutrients_that_are_metabolized_by_the_native_lagoon_ecosystem		t/Year	Amount of nutrient being processed by the Mar Menor lagoon ecosystem
OtherPointSourcePollutionMitigationEffect_net_flow	mitigated_impact_of_other_point_source_pollution/44		Dmnl/Year	
potential_PV_installation	(initial_estimated_PV_MW_installed+Potential_PV_installed)*PV_growth_rate_in_MW_installed		MW/Year	Increase in renewable PV energy facilities power installed
potential_tourist_growth	(Initial_nr_of_tourists+expected_number_of_tourists)*(coastalrural_recreation_potential*observed_growth_rate_of_tourism)		tourist/Year	Potential yearly increase in tourists

RuralEcoEffect_net_flow	impact_of_rural_ecotourism/40		Dmnl/Year	
territorial_bonding_net_flow	impact_of_EnvEd/53		Dmnl/Year	
tourism_loss	(IF Mar_Menor_degradation > MM_degradation_threshold_for_tourism THEN Rate_of_tourism_loss_influenced_by_MM_degradation_status ELSE 0)*expected_number_of_tourists		tourist/Year	Amount of tourist loss influenced by the Mar Menor degradation status
ActualNrWorkingWells	(IF NeededNrWells <= AllowedNrWells THEN NeededNrWells ELSE (AllowedNrWellsStatus*AllowedNrWells+(1-AllowedNrWellsStatus)*NeededNrWells))		well	Number of active wells
agricultural_pressure_on_water_resources	(IF available_surface_water_for_agriculture > total_agricultural_water_demand THEN 0 ELSE (total_agricultural_water_demand-available_surface_water_for_agriculture)/total_agricultural_water_demand)		Dmnl	The fraction of the total agricultural water demand that is not met by the available surface water for agriculture
Agricultural_revenue_per_hectare	7885		EUR/ha	Source: CHS ETI 2021 Agricultural revenue per hectare
agricultural_surface_water_balance	available_surface_water_for_agriculture-total_agricultural_water_demand		hm3	Available surface water for agriculture (plus the VC water pumped) minus the total agricultural water demand
agricultural_water_demand_per_hectare	baseline_for_agricultural_water_demand_per_hectare+(baseline_for_agricultural_water_demand_per_hectare*change_in_agricultural_water_demand_per_hectare*change_in_agricultural_water_demand_per_hectare_status)		hm3/ha	Average agricultural water demand per hectare and per year
agricultural_water_revenue_per_m3	yearly_gross_economic_benefit_of_agricultural_production/(1+total_agricultural_water_demand*hm3tom3_conversion_factor)		EUR/m3	Agricultural water revenue per cubic meter
AlbujonSWPumping_status	(IF TIME >= ShortTerm THEN 1 ELSE 0)		Dmnl	Dummy variable that allows to activate the AlbujonSWPumping scenario at a specific time period
AlbujonSWPumpingOnOff	0		Dmnl	Scenario of water and nutrients extraction of the Albujón ephemeral river

AllowedNrWells	2000		well	Aprox. 500 currently for 88hm3 gw pumping allowed (expert interviews and VC). This variable represents a scenario in which the number of allowed wells can be set
AllowedNrWellsStatus	(IF TIME >= ShortTerm THEN 1 ELSE 0)		Dmnl	Dummy variable that allows to activate the AllowedNrWells scenario at a specific time period
annual_groundwater_pumping_by_well	0,189383		hm3/well	Source: TRAGSATEC, 2019 Average annual groundwater pumping by well
Annual_water_pumped_by_the_VC	12		hm3	Source: TRAGSATEC, 2019 Water extracted from the aquifer by the Vertido Cero Plan
Annual_water_pumped_from_Albujon_ephemeral_channel	2		hm3	Source: CHS 2019 (Colector de vertido cero al Mar Menor Norte) Amount of annual water pumped from Albujon ephemeral channel
ATS_opened	GRAPH(TIME) Points: (1961,00, 0,000), (1978,00, 0,000), (1979,00, 1,000)		Dmnl	A switcher that opens the Tagus-Segura water transfer in 1979
available_surface_water_for_agriculture	available_water_from_the_TS_water_transfer+catchment_water_sources+sea_water_desalination+urban_wastewater_treatment_plant_effluents+(VCstatus*Annual_water_pumped_by_the_VC*VCOnOff)		hm3	The sum of all surface water sources
Available_water_from_Tagus_river	((BAUATSOnOff*330)+((1-BAUATSOnOff)*OFFATS))+RCP45ATSOnOff*RCP45ATS+RCP85ATSOnOff*RCP85ATS		hm3	Source: Morote et al. 2017 (BAU) The yearly average amount of water that has been transferred or is predicted to be transferred based on CC scenarios
available_water_from_the_TS_water_transfer	average_TS_water_transfer*Fixed_CRCC_share_of_ATS_water		hm3	The water diverted to the Campo de Cartagena from the Tagus-Segura aqueduct

Average_area_occupied_by_PV_facilities_per_Mw	2		ha/MW	Source: expert interviews Average area occupied by photovoltaic facilities per megawatt
Average_daily_water_consumption_per_person	2e-07		hm3/tourist	Source: EDUSI TP 2019 (data for RM) Average daily water consumption per person
average_excess_of_fertilizer_use	40		kg/ha	Source: TRAGSATEC, 2019 Average excess of Nitrogen (fertilizer) use
Average_NO3_content_in_Albujon_emphemeral_channel	175		t/hm3	Source: TRAGSATEC, 2019 Empirical average of nitrate content in Albujon emphemeral channel
Average_number_of_overnights_per_tourist_a_year	9,7		day	Source: expert interview and tourism report RM 2017 (considering all accomodation types). Average number of overnights per tourist a year
Average_number_of_stable_jobs_generated_by_irrigated_agriculture_per_hectare	0,5		jobs/ha	Source: CHS, 2015 Average number of stable jobs generated by irrigated agriculture per hectare
Average_number_of_stable_jobs_generated_by_PV_facilities_per_MW_installed	3		jobs/MW	Source: APPA 2018 Average number of stable jobs generated by photovoltaic facilities per megawatt installed
Average_percentage_of_groundwater_desalinated	0,5		Dmnl	Source: Expert interviews. Average percentage of groundwater desalinated when pumped

average_TS_water_transfer	ATS_opened*Available_water_from_Tagus_river		hm3	The water actually transferred as long as the aqueduct is opened
baseline_for_agricultural_water_demand_per_hectare	0,004		hm3/ha	Source: TRAGSATEC, 2019 Baseline value for agricultural water demand per hectare of irrigated land areas
BAUATSOnOff	1		Dmnl	Scenario of business as usual water transfer from Tagus-Segura
brine_produced	gross_amount_of_gw_needed*gw_use_ratio*(1-gw2brine_ratio)*Average_percentage_of_groundwater_desalinated*BrineStart		hm3	Total amount of brine exported to the Mar Menor lagoon
BrineDenitrification_satus	(IF TIME >= MediumTerm THEN 1 ELSE 0)		Dmnl	Dummy variable that allows to activate the BrineDenitrificatio scenario at a specific time period
BrineDenitrificationOnOff	0		Dmnl	Binary variable acting as a switch to (de)activate the brine denitrification scenario
BrineStart	GRAPH(TIME) Points: (1961,00, 0,000), (1994,00, 0,000), (1995,00, 1,000)		Dmnl	Source: Expert interviews. Dummy variable that starts the production of brine in 1995
catchment_water_sources	11		hm3	Source: TRAGSATEC, 2019 Additional sources of surface water available for the Campo de Cartagena
change_in_agricultural_water_demand_per_hectare	0		Dmnl	From -1 to +1 Scenario of relative change in agricultural water demand per hectare
change_in_agricultural_water_demand_per_hectare_status	(IF TIME >= MediumTerm THEN 1 ELSE 0)		Dmnl	Dummy variable that allows to activate the change in agricultural water demand per hectare scenario at a specific time period

Change_in_sea_water_desalination_amount	0		Dmnl	From -1 to n (zero is no change) Scenario of relative change in sea water desalination amount for agriculture
Change_in_sea_water_desalination_status	(IF TIME >= LongTerm THEN 1 ELSE 0)		Dmnl	Dummy variable that allows to activate the change in sea water desalination amount scenario at a specific time period
coastal_ecotourism_activities	0		Dmnl	0-1 Scenario variable of relative increase in the number of coastal ecotourism activities
coastal_recreation_potential	((1-Mar_Menor_degradation)+CoastalEcoEffect)/2		Dmnl	Relative coastal recreation potential value
CoastalEcostatus	(IF TIME >= MediumTerm THEN 1 ELSE 0)		Dmnl/Year	Dummy variable that allows to activate the impact of coastal ecotoruism at a specific time period
coastalrural_recreation_potential	(coastal_recreation_potential+rural_recreation_potential)/2		Dmnl	Relative total coastal-rural recreation potential value
Conversion_factor_Kg_to_Ton	0,001		t/kg	Conversion factor
Conversion_factor_N_to_NO3	4,428		Dmnl	Conversion factor
Daily_average_expenditure_per_tourist	57		EUR/(tourist*day)	Source: tourism report RM 2018 Daily average expenditure per tourist
Electricity_price	0,05		EUR/(Kw*hour)	Source: APPA 2018 and expert interview Electricity price
empirical_aver_NO3_concentration_in_aquifer	180		t/hm3	Source: TRAGSATEC, 2019 Empirically measured average of NO3 concentration in the Cuaternario aquifer

Empirical_brine_nitrate_concentration	199,35		t/hm3	Source: Alvarez-Rogel et al 2020 Empirical brine nitrate concentration
Empirical_percentage_of_NO3_exported_to_groundwater	0,85		Dmnl	Source: TRAGSATEC, 2019 Empirical percentage of nitrate exported to groundwater
Empirical_percentage_of_nutrients_reaching_the_MM_via_AQ	0,18		Dmnl	Source: TRAGSATEC, 2019 Empirical percentage of nitrate reaching the Mar Menor lagoon via aquifer
EnvEdstatus	(IF TIME >= ShortTerm THEN 1 ELSE 0)		Dmnl	Dummy variable that allows to activate the EnvironmentalEducation scenario at a specific time period
EnvironmentalEducation	0		Dmnl	0-1 Scenario variable representing the relative number of environmental education activities
estimated_NO3_input_to_MM_from_Cuaternario	total_excess_of_NO3_to_gw*Empirical_percentage_of_nutrients_reaching_the_MM_via_AQ		t	Total estimated amount of nitrate input to the Mar Menor lagoon from the aquifer
excess_Kg_haNin	average_excess_of_fertilizer_use-(average_excess_of_fertilizer_use*Percentage_of_reduction_in_fertilizer_effect)		kg/ha	Nitrogen leached in agricultural fields per hectare
excessive_irrigated_land_areas_due_to_lack_of_water	(IF total_agricultural_water_balance >= 0 THEN 0 ELSE ABS(total_agricultural_water_balance)/agricultural_water_demand_per_hectare)		ha	Number of hectares of agricultural irrigated land areas that exceed the total irrigation capacity
final_treated_gw_used	net_amount_of_gw_surplus_needed*gw_use_ratio		hm3	Final amount of groundwater extracted
Fixed_CRCC_share_of_ATS_water	0,15		Dmnl	Source: TRAGSATEC, 2019 The percentage of water that is assigned to the Comunidad de

				Regantes del Campo de Cartagena
gross_amount_of_gw_needed	net_amount_of_gw_surplus_needed*(2-gw2brine_ratio)		hm3	Total amount of groundwater needed to meet the agricultural water demand
gw_nitrate_from_brine	brine_produced*Empirical_brine_nitrate_concentration*(1-BrineDenitrificationOnOff*BrineDenitrification_satus)		t	Total amount of nitrates from brine exported to the Mar Menor lagoon
gw_use_ratio	(ActualNrWorkingWells+1)/(NeededNrWells+1)		Dmnl	The fraction of groundwater needed that is actually pumped based on the number of working wells
gw2brine_ratio	0,75		Dmnl	Source: TRAGSATEC, 2019 Percentage of usable water contained in the groundwater pumped from the aquifer
hm3tom3_conversion_factor	1e+06		m3/hm3	Conversion factor
IAControl	(IF TIME >= ShortTerm THEN IAControlOnOff ELSE 0)		Dmnl	Dummy variable that allows to activate the control of irrigated land areas scenario at a specific time period
IAControlOnOff	0		Dmnl	Scenario variable that limits the amount of irrigated land areas
impact_of_coastal_ecotourism	coastal_ecotourism_activities*CoastalEcostatus		Dmnl/Year	Relative impact of coastal ecotourism
impact_of_EnvEd	EnvironmentalEducation*EnvEdstatus		Dmnl/Year	EnvironmentalEducation scenario mediated by the status variable
impact_of_rural_ecotourism	rural_ecotourism_activities*RuralEcostatus		Dmnl/Year	Relative impact of rural ecotourism

Incentives_for_PV_growth	GRAPH(TIME) Points: (1961,0, 0), (2020,0, 0), (2021,0, 0,054), (2049,0, 0,054), (2050,0, 0), (2070,0, 0)		Dmnl	Source: APPA 2018 and expert interviews Positive incentives by public administrations in relation to the development of the photovoltaic renewable energy sector
LongTerm	2030		Dmnl	
Mar_Menor_degradation	(1/(1+EXP(-0,0005*(agricultural_nutrients_in_the_MM_lagoon-20000))))*relative_weight_of_agricultural_pollution_in_relation_to_the_MM+(1-OtherPointSourcePollutionMitigationEffect)*(1-relative_weight_of_agricultural_pollution_in_relation_to_the_MM)		Dmnl	Relative degradation status of the Mar Menor lagoon
maxAllowedIAs	41562		ha	Source: ITI 2017 Current agricultural area with legal access to water sources
maxIAs	(IF IAControl > 0 THEN maxAllowedIAs ELSE maxPotIAs)		ha	Effective maximum number of irrigated agricultural areas
maxPotIAs	90000		ha	Source: ITI Mar Menor 2017 Available space for agricultural areas
Mean_number_of_hours_per_day_of_PV_electricity_production	5		hour/day	Source: APPA 2018 and expert interview Mean number of hours per day of PV electricity production
MediumTerm	2026		Dmnl	
mitigated_impact_of_other_point_source_pollution	1-other_point_source_pollution_status		Dmnl/Year	Mitigated impact of other point source pollution
MM_degradation_threshold_for_tourism	0,95		Dmnl	Source: ECONET 2020 - value calibrated based on number of visitors. Mar Menor degradation threshold negatively affecting tourism

Mw2Kw_conversion_factor	1000		Kw/MW	Conversion factor
NeededNrWells	gross_amount_of_gw_needed/annual_groundwater_pumping_by_well		well	The number of wells needed in order to pump all the groundwater demanded
net_amount_of_gw_surplus_needed	water_gap-water_from_unknown_water_sources		hm3	Total amount of groundwater needed
net_NO3_export_via_sw	total_excess_of_NO3_to_sw-(total_excess_of_NO3_to_sw*yearly_effectiveness_in_nutrients_reduction_of_NSW_retention_measures*NSW_retention_measures_effect)		t	Net nitrate export to the Mar Menor lagoon via surface water
NSW_retention_measures_effect	NSW_retention_measures_implementation_level*NSW_retention_measures_implementation_level_status		Dmnl	NSW retention measures effect mediated by the status variable
NSW_retention_measures_implementation_level	0		Dmnl	0-1 Scenario of relative precentage of implementation of nutrient, soil and water retention measures
NSW_retention_measures_implementation_level_status	(IF TIME >= ShortTerm THEN 1 ELSE 0)		Dmnl	Dummy variable that allows to activate the NSW retention measures implementation level scenario at a specific time period
Number_of_days_per_year	365		day	Number of days per year
number_of_employees_in_agriculture	irrigated_land_areas*Average_number_of_stable_jobs_generated_by_irrigated_agriculture_per_hectare		jobs	Total number of employees in agriculture
number_of_employees_in_PV	Potential_PV_installed*Average_number_of_stable_jobs_generated_by_PV_facilities_per_MW_installed		jobs	Total number of employees in photovoltaic renewable energy facilities
number_of_employees_in_tourism	expected_number_of_tourists*number_of_jobs_created_per_tourist		jobs	Total number of employees in tourism
number_of_jobs_created_per_tourist	0,0117647		jobs/tourist	Source: ECONET 2020 (1 job every 85 tourists) Average number of jobs created per tourist

observed_growth_rate_of_agriculture	0,07		Dmnl	Source: Carreño et al., 2015 Historical rate of agricultural growth
observed_growth_rate_of_tourism	0,03		Dmnl/Year	Source: ECONET 2020 Historical rate of tourism growth rate
observed_PV_growth_rate_in_MW_installed	0,016		Dmnl	Source: ECONET 2020 - we assume the same pattern as in Murcia region. Historical rate of photovoltaic energy power growth
OFFATS	GRAPH(TIME) Points: (1961,0, 330,0), (2021,0, 330,0), (2070,0, 0,0)		hm3	Source: Morote et al. 2017 Dummy variable that allows for non BAU Tagus-Segura water transfer scenarios
other_point_source_pollution	1		Dmnl	1 by default assuming continued max. pollution currently. Scenario variable of the relative amount of point-source pollution sources
other_point_source_pollution_status	(IF TIME >= MediumTerm THEN other_point_source_pollution ELSE 1)		Dmnl	We consider the max. amount of point source pollution is the current one. We do not account for a potential increase in point source pollution. Dummy variable that allows to activate the other point-source pollution scenario at a specific time period
Percentage_of_nutrients_that_are_metabolized_by_the_native_lagoon_ecosystem	0,2		Dmnl	Source: Comité de Asesoramiento Científico del Mar Menor, 2017 Percentage of nitrate naturally assimilated by the lagoon metabolism

Percentage_of_reduction_in_fertilizer_effect	Percentage_of_reduction_in_fertilizer_excess*Percentage_of_reduction_in_fertilizer_status		Dmnl	Percentage of reduction in fertilizer excess mediated by the status variable
Percentage_of_reduction_in_fertilizer_excess	0		Dmnl	0-1 Scenario of percentage of reduction in fertilizer excess
Percentage_of_reduction_in_fertilizer_status	(IF TIME >= ShortTerm THEN 1 ELSE 0)		Dmnl	Dummy variable that allows to activate the Percentage_of_reduction_in_fertilizer_excess scenario at a specific time period
percentage_of_water_gap_covered_by_unknown_water_sources	0,3		Dmnl	Source: Expert interviews. Percentage of water gap covered by unknown water sources
potential_agricultural_development	(potential_growth_rate_of_agriculture_based_on_water_availability*observed_growth_rate_of_agriculture)-(social_pressure_on_public_administrations*observed_growth_rate_of_agriculture*potential_growth_rate_of_agriculture_based_on_water_availability)		Dmnl	Potential growth rate for agricultural development
potential_growth_rate_of_agriculture_based_on_water_availability	1-agricultural_pressure_on_water_resources		Dmnl	The fraction of the total agricultural water demand that is met by the available surface water for agriculture
Promotion_of_PV_facilities_OnOff	0		Dmnl	Scenario of positive incentives by public administrations in relation to the development of the photovoltaic renewable energy sector
Promotion_of_PV_facilities_status	(IF TIME >= ShortTerm THEN Promotion_of_PV_facilities_OnOff ELSE 0)		Dmnl	Dummy variable that allows to activate the promotion of photovoltaic facilities scenario at a specific time period
PV_growth_rate_in_MW_installed	observed_PV_growth_rate_in_MW_installed+(Incentives_for_PV_growth*Promotion_of_PV_facilities_status)		Dmnl	Photovoltaic growth rate expressed in megawatts installed

PV_revenue_per_hectare	(yearly_gross_economic_benefit_of_PV_energy_production+1)/ (Total_area_occupied_by_PV_facilities+1)		EUR/ha	Photovoltaic revenue per hectare
Rate_of_tourism_loss_influenced_ by_MM_degradation_status	0,015		Dmnl/Year	Source: ECONET 2020 Observed rate of tourism loss influenced by the Mar Menor degradation status
RCP45ATS	GRAPH(TIME) Points: (1961,0, 330,0), (2020,0, 330,0), (2070,0, 123,3)		hm3	Source: Pellicer-Martínez and Martínez-Paz 2018 Predicted water from Tagus-Segura transferred under the RCP4.5 scenario
RCP45ATSOnOff	0		Dmnl	Dummy variable that activates the RCP4.5 scenario
RCP85ATS	GRAPH(TIME) Points: (1961,0, 330,0), (2020,0, 330,0), (2070,0, 86,2)		hm3	Source: Pellicer-Martínez and Martínez-Paz 2018 Predicted water from Tagus-Segura transferred under the RCP8.5 scenario
RCP85ATSOnOff	0		Dmnl	Dummy variable that activates the RCP8.5 scenario
relative_weight_of_agricultural_pol lution_in_relation_to_the_MM	0,85		Dmnl	Source: Guaita-García 2020 Relative weight of agricultural pollution in relation to the Mar Menor degradation versus other point source pollution
rural_ecotourism_activities	0		Dmnl	0-1 Scenario variable of relative increase in the number of rural ecotourism activities
rural_recreation_potential	RuralEcoEffect*coastal_recreation_potential		Dmnl	0.5-2 Relative rural recreation potential value

RuralEcostatus	(IF TIME >= LongTerm THEN 1 ELSE 0)		Dmnl/Year	Dummy variable that allows to activate the impact of rural ecotourism at a specific time period
sea_water_desalination	yearly_average_of_sea_water_desalination+(Change_in_sea_water_desalination_amount*yearly_average_of_sea_water_desalination*Change_in_sea_water_desalination_status)		hm3	Sea water desalinated that serves as an input for the agricultural water demand
ShortTerm	2022		Dmnl	
social_pressure_on_public_administrations	(Mar_Menor_degradation+territorial_bonding)/2		Dmnl	Relative pressure exerted by an environmentally-aware society on the public administration
tons_of_nitrate_yearly_extracted_by_the_AlbujonSWPumping	Annual_water_pumped_from_Albujon_ephemeral_channel*Average_NO3_content_in_Albujon_emphemeral_channel*AlbujonSWPumpingOnOff*AlbujonSWPumping_status		t	Amount of nitrate yearly extracted by the Albujon surface water pumping plan
tons_of_nitrate_yearly_extracted_by_the_Vertido0Pumping	Annual_water_pumped_by_the_VC*empirical_aver_NO3_concentration_in_aquifer*VCstatus*VCOnOff		t	Tons of nitrates extracted from the aquifer by the Vertido Cero water pumping
Tons_of_NO3_input_per_ha	excess_Kg_haNin*Conversion_factor_N_to_NO3*Conversion_factor_Kg_to_Ton		t/ha	Nitrate leached in agricultural fields per hectare
total_agricultural_water_balance	total_available_water_for_agriculture-total_agricultural_water_demand		hm3	Difference between the total available water for agriculture and the total agricultural water demand
total_agricultural_water_demand	agricultural_water_demand_per_hectare*irrigated_land_areas		hm3	Total agricultural water demand
Total_area_occupied_by_PV_facilities	Potential_PV_installed*Average_area_occupied_by_PV_facilities_per_Mw		ha	Total area occupied by photovoltaic facilities
total_available_water_for_agriculture	available_surface_water_for_agriculture+final_treated_gw_used+water_from_unknown_water_sources		hm3	The sum of the available surface water for agriculture and the groundwater pumped
total_excess_of_NO3_to_gw	Tons_of_NO3_input_per_ha*Empirical_percentage_of_NO3_exported_to_groundwater*irrigated_land_areas		t	Total amount of nitrate leached to groundwater

total_excess_of_NO3_to_sw	Tons_of_NO3_input_per_ha*(1-Empirical_percentage_of_NO3_exported_to_groundwater)*irrigated_land_areas		t	Total amount of nitrate leached to surface water
total_gross_economic_benefit	yearly_gross_economic_benefit_of_agricultural_production+yearly_gross_economic_benefit_of_tourism+yearly_gross_economic_benefit_of_PV_energy_production		EUR	Total gross economic benefit including all sectors
total_number_of_jobs	number_of_employees_in_agriculture+number_of_employees_in_tourism+number_of_employees_in_PV		jobs	Total number of jobs including all sectors
Total_water_demand	total_agricultural_water_demand+total_water_demand_by_tourists		hm3	Total water demand including agriculture and tourism
total_water_demand_by_tourists	Average_daily_water_consumption_per_person*expected_number_of_tourists*Average_number_of_overnights_per_tourist_a_year		hm3	Total water demand by tourists
tourism_water_revenue_per_m3	yearly_gross_economic_benefit_of_tourism/(1+total_water_demand_by_tourists*hm3tom3_conversion_factor)		EUR/m3	Tourism water revenue per cubic meter
urban_wastewater_treatment_plant_effluents	29,8		hm3	Source: TRAGSATEC, 2019 Urban wastewater treatment plant effluents that serve as an input for the agricultural water demand
VCOnOff	0		Dmnl	Binary variable to switch on or off the Vertido Cero scenario
VCstatus	(IF TIME >= LongTerm THEN 1 ELSE 0)		Dmnl	Dummy variable that allows to activate the VC scenario at a specific time period
water_from_unknown_water_sources	water_gap*percentage_of_water_gap_covered_by_unknown_water_sources		hm3	Amount of water used coming from unknown sources
water_gap	(IF agricultural_surface_water_balance < 0 THEN ABS(agricultural_surface_water_balance) ELSE 0)		hm3	The agricultural water needed not met by the surface water sources
yearly_average_of_sea_water_desalination	8,2		hm3	Source: TRAGSATEC, 2019 Yearly average of sea water desalinated for agriculture

yearly_effectiveness_in_nutrients_reduction_of_NSW_retention_measures	0,7		Dmnl	Source: Parn et al. 2012 Average percentage of yearly nutrients reduction of nutrients, soil and water retention measures
yearly_gross_economic_benefit_of_agricultural_production	irrigated_land_areas*Agricultural_revenue_per_hectare		EUR	Yearly gross economic benefit of agricultural production
yearly_gross_economic_benefit_of_PV_energy_production	Potential_PV_installed*Electricity_price*Mean_number_of_hours_per_day_of_PV_electricity_production*Mw2Kw_conversion_factor*Number_of_days_per_year		EUR	Yearly gross economic benefit of photovoltaic energy production
yearly_gross_economic_benefit_of_tourism	expected_number_of_tourists*Average_number_of_overnights_per_tourist_a_year*Daily_average_expenditure_per_tourist		EUR	Yearly gross economic benefit of tourism

Annex 5a Overview of variables MAL01 – Belgian Coastal Zone

Table 12: Main variables in the MAL01 model (Role: I: input, O: indicator); SD: S: stock, F: flow, A: auxiliary).

Topic	Name	Unit	Role	SD	Definition
Water	Polder Level	m	O	S	The ground water level for the polder
Water	recharge to polder	m3/month	O	F	Actual water flow to the polder area
Water	discharge from polder	m3/month	O	F	Actual water flow from the polder area
Water	Specific Yield	m/m	I	A	The amount of water released with change in groundwater level
Water	FlowResistance	month	I	A	Hydraulic resistance to exchange between the groundwater and the ditches in the polder; dependent on topology of the ditches and soil characteristics
Water	Precipitation	m/month	I	A	Natural surface recharge to the polder area
Water	Evapotranspiration	m/month	I	A	Natural surface discharge from the polder area due to crop water uptake and evaporation
Water	Sealevel	m	I	A	Average monthly sea level
Water	Compartimentation	-	I	C	Parameter that determines to what extent the areas assigned to nature and agriculture are hydrologically separated. A value of 1 signifies that no water is exchanged between these areas while zero effectively means that the areas behave as one area.
Water	Water buffer in	m3	O	S	Water buffer for water supplied to the polder
Water	Buffer in capacity	m	I	C	Water buffering capacity for water supplied to the polder
Water	Buffer Inflow Rate	m3/month	I	F	Inflow to the polder from different sources (canal, rainfall recovery, …)
Water	Buffer loss and not used	m3/month	O	F	Part of the Buffer inflow rate that can't be stored in the water buffer in and is also not used as recharge to the polder
Water	Capacity for water removal	m/month	I	F	Water that can be removed from the polder (gravitational discharge, pumping)
Water	Water used for farm animals	m3/month	O	F	Polder water used in agriculture for animals (cattle, poultry, …)
Water	Optimal level	m	I	C	Optimal groundwater level according to the land use agriculture/nature

Water	Desired Level	m	I	A	Desired taking into account the optimal groundwater level and the water management
Water	Difference Desired depth Agr/Nat	m	O	A	Difference between the actual ground water level in the area occupied by agriculture/nature and the desired level according to the water management
Water	Desired recharge Agriculture/Nature	m/month	O	A	Recharge needed to the area occupied by agriculture/nature to reduce the difference between the desired and actual groundwater level in those areas
Water	Desired discharge Agriculture/Nature	m/month	O	A	Discharge needed from the area occupied by agriculture/nature to reduce the difference between the desired and actual groundwater level in those areas
Water	GWLRatio	-	O	A	Ratio between the actual and the desired groundwater level
Water	Suitability	-	O	A	Index between 0 and 1 where 1 is optimal and 0 means unsuitable
Water / Land use	Impact of suitability	-	O	A	Index between 0 (very large impact) and 1 (no impact) taking into account the sensitivity to the Suitability.
Land use	Agricultural land cover	ha	I	S	Area used for farming
Land use	Natural land cover	ha	I/O	S	Area not used for farming or residential purposes
Land use	Residential land cover	ha	I	S	Area used for residential purposes
Land use	urban sprawl	ha/month	I	F	Conversion rate of agricultural to residential land cover
Land use	nature development	ha/month	I	F	Conversion rate of agricultural to natural land cover
Gentrification	Number of Standard Farms	#farm	O	S	Farms actively being used for agriculture
Gentrification	Number of Gentrified Farms	#farm	O	S	Farms that are no longer used for agriculture but as residences
Gentrification	Gentrification	#farm/month	O	F	Rate at which active farms are converted to residential farms
Gentrification	Gentrificationrate	#farm/month	I	F	Rate at which active farms are under current conditions being converted to residential farms
Gentrification	Maximum number of gentrified farms	#farm	I	A	Maximum number of gentrified farms
Gentrification	Upscaling loss	#farm/month	I/O	F	Loss of standard farms due to merging farms into bigger farms
Gentrification	Average Farm Size	ha	O	S	Area occupied by a single farm
Gentrification	Farm size increase	ha/month	I	F	Change in farm area
Gentrification	Impact of landscape quality on gentrification	-	O	A	Index that translates the rural landscape quality to the impact this has on the gentrification rate
Gentrification	Rural landscape quality	-	O	A	Index between 0 and 100

Annex 5b Overview of variables MAL02 – SW Messinia

Table 13: Main variables in the MAL02 model (Role: I: input, O: indicator); SD: S: stock, F: flow, A: auxiliary).

Topic	Name	Unit	Role	SD	Definition
Water Wetland	Tyflomitis groundwater	m^3	O	S	The ground water volume for the aquifer
Water Wetland	Tyflomitis recharge	m^3/Year	I	F	Volume rescharge (via precipitation, adjacent aquifers)
Water Wetland	Tyflomitis discharge (x3)	m^3/Year	I	F	Volumes of natural discharge
Water Wetland	Tyflomitis abstractions	m^3/Year	I	F	The sum of groundwater abstraction for irrigation and municipal use
Water Wetland	irrigation demand per well	m^3/Year	I	A	The volume of water abstraction per well
Water Wetland	water demand for municipal use	m^3/Year	I	A	The volume of water to cover the needs for the municipality
Water Wetland	Alluvial grounwater	m^3	O	S	The ground water volume for the aquifer
Water Wetland	Alluvial recharge	m^3/Year	I	F	Volume rescharge (via precipitation, adjacent aquifers)
Water Wetland	Alluvial discharge	m^3/Year	I	F	Volumes of natural discharge
Water Wetland	Alluvial abstractions	m^3/Year	I	F	The volume of groundwater abstraction for irrigation
Water Wetland	Salt mass	g	O	S	The salt mass for the lagoon
Water Wetland	salinization	g/Year		F	The mass of salt which is added in the lagoon
Water Wetland	de-salinization	g/Year		F	The mass of salt which is removed from the lagoon
Water Wetland	Mean Annual Salinity	g/L	O	A	The salinity of the lagoon (salt mass/lagoon volume)
Water Wetland	alluvial groundwater deficit, saline water intrusion	m^3/Year	O	A	The volume of groundwater deficit generated each year due to irrigation and CC.

Water Wetland	Saline vs fresh water inputs	m^3/Year	O	A	Water volume balance (Sea water – fresh water)
Water Wetland	lagoon status	Dmnl	O	A	The status of the lagoon based on salinity values (as a look up of salinity)
Water Wetland	decision to restore connectivity	Dmnl	O	A	0 or 1, depending on lagoon salinity and nutrient quality of nearby water bodies
Water Wetland	P-PET inputs (inland)	m/Year	I	F	Climate projections for inland precipitation (P) and evatranspiration (ET)
Water Wetland	P-PET inputs (coastal)	m/Year	I	F	Climate projections for coastal P and ET
Water Wetland	P-PET coastal	m/Year	I	F	Climate projections for coastal P and evaporation (E)
Tourism	Participation in off beach activities	People/month	O	S	
Tourism	Pollution	Mg/l/day	O	S	Fraction of waste polluting
Tourism	State Landscape Character Identity	Hectares	O	S	Hectares with mixed shrubs and olive groves
Tourism	Nights Spent	Nights/month	O	A	Total number of nights recorded in hotels each month
Tourism	Beach crowdedness	Persons/sq. m	O	A	How many people visit the beach relative to total beach area
Shift in Agriculture	Membership in cooperatives	Number of farms	I	S	
Shift in Agriculture	Integrated/conventional ratio	fraction	O	S	
Shift in Agriculture	Budget for cooperative services	Euros	I	S	
Shift in Agriculture	Olive oil Price	Euros	I	S	
Shift in Agriculture	Farmers Profit	Euros	O	S	
Shift in Agriculture	Cost of production	Euros	O	S	

Annex 5c Overview of variables Norrström/Baltic Sea

The main variables that are used and quantified in the integrated MAL3 SD model are listed in Table 14, with some updates based on the model evolution in MAL3 since the deliverable D13(D4.2) of WP4.

Table 14: Main variables in the integrated MAL03 model (I: input, O: indicator, S: stock, F: flow, A: auxiliary, SW: surface water, SSW: subsurface water, MWS: municipal water supply, UCWW: unconnected coastal wastewater, USR: urban surface runoff, WWTP: wastewater treatment plant, CCWI: cross-catchment water inflow, CCWE: cross-catchment water export)

Topic	Name	Unit	Role	SD	Definition
Catchment definition	Total catchment area	m^2	I	A	Total or representative inland catchment of considered coastline
Water area	SW area	m^2	I	A	SW area within catchment
Land area	Agricultural land area	m^2	I	A	Agricultural area within catchment
Land area	Forest land area	m^2	I	A	Forest area within catchment
Land area	Built land area	m^2	I	A	Urban built area within catchment
Land area	Other areas	m^2	I	A	Land area without built, agriculture, forest and water cover within catchment
Water input	Precipitation	m/year	I	A	Long-term average precipitation over catchment
Water input	CCWI to SSW	Million m^3/year	I	F	Additional long-term average net groundwater inflow from adjacent basins (CCWI) to the catchment SSW
Water input partitioning	Precipitation to SW	Million m^3/year	I	F	Annual water input flux from precipitation to SW – proportional to relative SW area
Green water output	Evapotranspiration	Million m^3/year	O	A	Total annual evapotranspiration
Green-blue water output partitioning	SW to evaporation	Million m^3/year	O	F	Annual water output flux by evaporation from SW – proportional to relative SW area
Inter-system/ sector water flow exchanges	Flows between natural water systems and inland/coastal sectors	Million m^3/year	O	F	Exchange (factor) matrix for annual water flows among SW and SSW as natural water systems, and agriculture, forest, USR, industry, MWS, UCWW and WWTP sectors
Main system/ sector water availability	SW	Million m^3	O	S	Total annual SW availability (including also sector return flows to SW)
Main system/ sector water availability	SSW	Million m^3	O	S	Total annual SSW availability (including also sector return flows to SSW)
Main system/ sector water availability	Agriculture	Million m^3	O	S	Total annual water availability for agriculture (including also other sector return flows to agriculture)
Main system/ sector water availability	MWS	Million m^3	O	S	Total annual water availability for MWS
Main system/ sector water availability	Industry	Million m^3	O	S	Total annual water availability for industry (including also other sector return flows to industry)
Blue water output	Total water outflow to coast	Million m^3/year	O	A	Total annual water outflow to the coast
Blue water output partitioning	SW outflow to coast	Million m^3/year	O	F	Annual water flow to the coast through SW and riverine network
Blue water output partitioning	SSW outflow to coast	Million m^3/year	O	F	Annual water flow to the coast through SSW and subsurface flows

Water output	MWS to CCWE	Million m^3/year	O	F	Additional long-term average drinking water export from the catchment MWS
Inland-coastal water interaction	Proxy of seawater intrusion risk (SWIR)	Dmnl	O	A	Proxy of seawater intrusion risk for coastal groundwater – related to SSW outflow to coast
Water flows	Water flows related to systems and sectors listed in this table	Million m^3/year	I	F	Various system-sector average annual water flows obtained from sub model 1
Nutrient concentrations	P and N concentrations in SW	kg/m^3	I	A	Average phosphorous and nitrogen concentration levels in SW
Nutrient concentrations	P and N concentrations in SSW	kg/m^3	I	A	Average phosphorous and nitrogen concentration levels in SSW
Nutrient concentrations	P and N concentrations in WWTP input flows	kg/m^3	I	A	Average phosphorous and nitrogen concentration levels in input flows to WWTP
Nutrient concentrations	P and N concentrations in WWTP outputs	kg/m^3	I	A	Average phosphorous and nitrogen concentration levels in discharges from WWTP into SW
Nutrient loads	P and N load exchanges among natural water systems and inland/coastal sectors	Ton/year	O	A	Average annual phosphorous and nitrogen load exchanges among SW and SSW as natural water systems, and agriculture, forest, USR, industry, MWS, UCWW and WWTP sectors
Nutrient loads	Total P and N loads to the coast	Ton/year	O	A	Average annual phosphorous and nitrogen loads to the coast (through SW, SSW and both)
Policy indicator	P and N indicators based on BSAP	Dmnl	O	A	Indicators for P and N target loads defined within the Baltic Sea Action Plan (BSAP) for the associated Baltic Proper marine basin to the MAL3 inland catchment and its surrounding coastal regions.

Annex 5d Overview of variables MAL04 Charente

Table 15: Main variables in the MAL04 model (Role: I: input, O: indicator); SD: S: stock, F: flow, A: auxiliary).

Topic	Name	Unit	Role	SD	Definition
water & agriculture	reference evapotranspiration	mm/month	I	A	Reference value (ET_0) used to calculate evapotranspiration by culture.
water	rainfall	mm/month	I	A	Rainfall per month.
water	abstraction permits for irrigation	Mm^3/year	I	A	Maximum amount of water that can be withdrawn for irrigation per year (regulation).
water	Low-Water Target Flow for water streams	m^3/sec	I	A	Minimum allowed flow of the Charente river (regulation).
water	reservoirs capacity	Mm^3	I	A	Amount of water that can be stored in reservoirs over the territory.
water	capacity of coastal / rural WWTP	population-eq.	I	A	Treatment capacity of the WWTPs in the coastal and rural areas, expressed in population equivalent.
water	water streams flow	m^3/sec	O	F	Flow of the Charente River in Beillant station.
water	estuary flow	m^3/sec	O	F	Flow of water at the estuary.
water	domestic water deficit	Mm^3/month	O	A	Missing amount of water to meet demand for domestic water.
water	irrigation water deficit	Mm^3/month	O	A	Missing amount of water to meet demand for irrigation water.
water	concentration in trophic resource	mg/m^3	O	A	Water's concentration in trophic resource for oysters in the estuary.
water	occurrence of viruses	Dmnl	O	A	Indicator of viruses' presence in water.
water	coastal salinity	g/litre	O	A	Water's salinity in the estuary.
shellfish	type of oyster bag	Dmnl	I	A	Type of bag (table or floating) that is used to grow oysters.
shellfish	oyster density per bag year x	oyster/bag	I	A	Number of oysters grown per bag during their x^{th} production year.
shellfish	authorised oyster farms area	hectare	I	A	Total area that can be dedicated to oyster farming.

shellfish	quality index	Dmnl (g of flesh per g of oyster)	O	A	Index of oysters' quality representing their content in flesh.
shellfish	spats capture	oyster/month	O	A	Number of spats captured in the region.
shellfish	spats purchase	oyster/year	O	A	Number of spats that are bought to compensate for missing captures or unexpected mortality.
shellfish	local oyster production share	Dmnl	O	A	Percentage of the produced oysters that have grown only in the region.
shellfish	produced oyster weight	ton/year	O	S	Total weight of produced oysters.
shellfish	oyster gross margin	euro/year	O	A	The profit of oyster farmers.
agriculture	conventional and organic practices (several variables)	% m^3/(ha*year) kg/(ha*year) IFT/(ha*year)	I	A	Percentage of conventional and organic areas dedicated to different cultures and, per hectare of each culture, water demand, nitrogen use and pesticides use.
agriculture	demand for organic products	Dmnl	I	A	Indicator of the evolution of demand for organic products.
agriculture	organic supply chain	Dmnl	I	A	Indicator of the evolution of supply chains for organic products.
agriculture	price per culture	euro/ton	I	A	Price, for each culture, of one ton of products.
agriculture	employment per hectare conventional / organic	person/ha	I	A	Number of people needed to exploit one hectare of conventional or organic agriculture.
agriculture	conventional area	hectare	O	S	Area dedicated to conventional agriculture.
agriculture	organic area	hectare	O	S	Area dedicated to organic agriculture.
agriculture	irrigation water use	Mm3/month	O	A	Amount of water used for irrigation every month.
agriculture	nitrogen use	kg/month	O	A	Amount of nitrogen used every month.
agriculture	pesticides use	IFT/month	O	A	Amount of pesticides used every month
agriculture	yield	ton/year	O	A	Total yield of agriculture.
agriculture	total gross product	euro/year	O	A	Profits of agriculture.
agriculture	agricultural employment	person	O	A	Number of people employed in agriculture.

agriculture	conventional / organic storage need	ton	O	A	Needed storage capacity for conventional and organic products.
infrastructure	conventional storage conversion rate	%/month	I	A	Rate at which unused conventional storage facilities are converted to organic ones.
infrastructure	exported share of agricultural products	%	I	A	Share of agricultural products that is exported through ports.
infrastructure	flooding risk	%	I	A	Risk of flooding in the coastal area.
infrastructure	allowed coastal / rural built-up area	hectare	I	A	Maximum area that can be dedicated to housing or accommodation in the coastal and rural areas (regulation).
infrastructure	share of people using train or bike	%	I	A	Share of people (residents and tourists) who use train or bike for moving.
infrastructure	conventional / organic storage	ton	O	S	Weight of conventional and organic agricultural products that can be stored in the region.
infrastructure	throughput capacity	ton/year	O	S	Amount of products that can transit through the ports.
infrastructure	conventional / organic storage ports	ton	O	S	Weight of conventional and organic agricultural products that can be stored in the ports.
infrastructure	rail transportation capacity	ton/year	O	S	Amount of products that can be transported by train to the ports.
infrastructure	CO_2 savings of rail transportation	tCO_2/year	O	A	CO_2 emissions saved by the use of train for transporting products to the ports.
infrastructure	area of ports	hectare	O	A	Total area dedicated to ports' infrastructures.
infrastructure	dikes	km	O	S	Length of dikes on the coast.
infrastructure	abandoned coastal land	hectare	O	A	Area of coastal land that is abandoned because of flooding.
infrastructure	coastal / rural housing	hectare	O	S	Area of housing in the costal and rural areas.
infrastructure	coastal / rural accommodation	hectare	O	S	Area of accommodation in the coastal and rural areas.
infrastructure	coastal / rural built-up area	hectare	O	A	Total area dedicated to housing or

					accommodation in the coastal and rural zones.
infrastructure	roads	km	O	S	Length of roads in the region.
infrastructure	roads congestion	vehicle/km	O	A	Indicator of roads' congestion.
infrastructure	total area required for infrastructure	hectare	O	A	Total area dedicated to all infrastructures (storage, ports, roads, housing and accommodation).
population	residents growth rate	%/month	I	A	Rate at which the population of residents grows.
population	tourists growth rate	%/month	I	A	Rate at which the annual number of tourists grows.
population	coastal share of residents	%	I	A	Share of residents living on the coast.
population	coastal share of tourists	%	I	A	Share of tourists traveling on the coast.
population	agricultural workers replacement share	%/month	I	A	Share of retiring agricultural workers who are replaced by new workers.
population	water use per person	Mm^3/ (person*month)	I	A	Amount of water used by one person on average.
population	residents	person	O	S	Total population of residents.
population	tourists	person	O	S	Total population of tourists.
population	coastal / rural tourists / residents	person	O	A	Number of tourists or residents located in the coastal or rural area.
population	domestic water demand	Mm^3/month	O	A	Total demand for domestic water per month.
population	coastal / rural share of water demand	Mm^3/month	O	A	Share of the total domestic water demand that occurs in the coastal or rural area.
population	agricultural workers	person	O	S	People available for working in agriculture.
population	coastal attractiveness for residents / tourists	Dmnl	O	A	Indicators of the coastal area's attractiveness for residents and tourists.
population	rural attractiveness for residents / tourists	Dmnl	O	A	Indicators of the rural area's attractiveness for residents and tourists.

Annex 5e Overview of variables MAL05 Danube River Mouth and Black Sea

Table 16: Main variables in the MAL05 model (Role: I: input, O: indicator); SD: S: stock, F: flow, A: auxiliary).

Topic	Name	Unit	Role	SD	Definition
Agriculture	agriculture_water_demand_per_ha	m3/(Year*hectare)	I	A	
Agriculture	annual_precipitation	mm/Year	I	A	The annual average quantity of precipitation in the case study area
Agriculture	crop_consumption_factor	ton crop/(Year*persons)	I	A	The average consuption wheat, Romania per person
Agriculture	crop_price	RON/ton crop	I	A	Average price for agricultural products according to INSSE statistical data base.
Agriculture	"eco-crop_price"	RON/ton crop	I	A	Average price for agricultural products according to farmers survey.
Agriculture	"Eco-farm_employment"	employees	O	A	Number of yearly person months needed for ecofarming production
Agriculture	"eco-labor_intensity"	employees /hectare	I	A	Number of employees needed to work 1 hectare of crop
Agriculture	Ecofarm productivity	ton crop/(hectare*Year)	O	A	Yearly Ecofarm production per hectare
Agriculture	ecofarm_fertilizer_use	kg N/(Year*hectare)	I	A	Quantity of fertilisers used for ecofarming practices
Agriculture	ecofarm_income	RON/Year	O	A	Yearly income for a ecofarm producer
Agriculture	ecofarm_production_costs	RON/(Year*hectare)	I	A	Yearly costs per hectare in ecofarming
Agriculture	ecofarm_transition_rate	1/Year	O	F	growth rate obtained from solution logistic growth equation see Sterman (2000), page 298.
Agriculture	ecofarms_area(t)	hectare	O	S	The area cultivated under ecological farming
Agriculture	FarmToFork_Target	Dmnl	I	A	fraction ecofarming as part of Farm-To-Fork Strategy
Agriculture	FarmToFork_Target_Time	Year	I	A	target year for reaching target FarmToFork conversion to ecofarming, calculated from initial year 2020
Agriculture	forest_belts_installation_year	Year	I	F	policy setting: 0 is without forest belts, 1 = with forest belts
Agriculture	initial_area_ecofarms	hectare	I	F	The area cultivated under ecofarming for the case study area, 2019 data

Agriculture	initial_area_traditional_farms	hectare	I	A	The area cultivated under traditional farming for the case study area, 2019 data
Agriculture	irrigation	m3/(Year*hectare)	O	A	Yearly quatity of water used for irrigation
Agriculture	maximum_fertilizer_use	kg N/(Year*hectare)	I	A	Hypothetical maximum of yearly fertiliser allowed per hectare
Agriculture	maximum_irrigation	m3/(Year*hectare)	I	A	Yearly water need for the specific crop
Agriculture	total_agriculture_area	hectare	O	A	Total cultivated area
Agriculture	Total_agriculture_employment	employees	O	A	Total number of emplyees in agriculture
Agriculture	Total_agriculture_income	RON/Year	O	A	The yearly income generated by farming activity
Agriculture	Total_agriculture_N_load	ton N/Year	O	A	The quantity of Nitrogen load due to agriculture activity
Agriculture	total_crop_production	ton crop/Year	O	A	Amount of Total crops harvested
Agriculture	total_fertilizer_use	ton N/Year	O	A	Yearly amount of fertiliser used on available land
Fish farming	aquaculture_intensification_rate	1/Year	O	A	Yearly fraction of existing normal aquaculture area which is changed into intensive aquaculture.
Fish farming	Danube's_flow	l/Year	I	A	Yearly Danube's flow
Fish farming	fish_consumption	ton fish/Year	I		time series SCENARIO
Fish farming	fish_farming_labor_intensity	employees /ha	I		
Fish farming	fish_production_ratio		O	A	~ :SUPPLEMENTARY
Fish farming	impact_of_N_load_on_water_quality	Dmnl	O	A	The impact that nitrogen load from aquaculture is exerting on water quality
Fish farming	initial_area_in_use_for_intensive_aquaculture	ha	I		Available area for aquaculture, reference value 2020
Fish farming	initial_area_in_use_for_normal_aquaculture	ha	I		Actual granted area by National Authorithy for Aquculture
Fish farming	intensive_aquaculture_development	ha/Year	O		The yearly expansion of aquaculture
Fish farming	intensive_aquaculture_production	ton fish/Year	O		The total yearly amount of fish produced f
Fish farming	intensive_aquaculture_productivity	ton fish/(ha*Year)	I		
Fish farming	intensive_fish_farm_employment	employees	O		Number of employees needed for intensive farming per year
Fish farming	intensive_fish_farm_revenues	RON/Year	O		Yearly revenues generated for entrepreneurs by intesive fish farming activity
Fish farming	Intensive_Fish_Farming_Area(t)	ha	O	S	The area used for intensive fish farming
Fish farming	labor_costs_per_employee	RON/(employees*Year)	I		The cost with labor force in fish farming sector

Fish farming	maximum_allowable_N_conc	ton N/l	I		Maximum allowable concentration (MAC) for sum of inorganic nitrogen
Fish farming	maximum_area_available_for_aquaculture	Ha	I		Maximum area usable for aquaculture
Fish farming	normal_aquaculture_development	ha/Year	O		Yearly expansion of aquaculture area
Fish farming	normal_aquaculture_N_load_per_unit_area	ton N/(Year*ha)	I		The Nitrogen load generated by aquaculture
Fish farming	normal_aquaculture_production	ton fish/Year	I		Total amount of fish produced by aquaculture
Fish farming	normal_fish_farm_employment	employees	O		Number of employees needed for normal aquaculture farming per year
Fish farming	normal_fish_farm_revenues	RON/Year	O		Yearly revenues generated for entrepreneurs by normal fish farming activity
Fish farming	Normal_Fish_Farming_Area(t)	ha	O	S	The area used for normal fish farming
Fish farming	spatial_pressure_from_aquaculture_development	Dmnl	O		The spatial pressure exerted by the development of aquaculture in our case study area
Fish farming	subsidies_per_unit_area	RON/(ha*Year)	I		Amount of subsidies granted for aquaculture
Fish farming	total_aquaculture_production	ton fish/Year	O		The amount of fish produced (reference value is 3.500 Ton/Year)
Fish farming	Total_Area_in_use_for_Aquaculture	ha	O		The area in use for activities related to aquacultue
Fish farming	total_fish_farm_employment	employees	O		Number of employees involved in fish farming
Fish farming	total_fish_farm_revenues	RON/Year	O		The yearly revenues generated by fish framing
Tourism	Annual_tourist_days		O		Number of days spent by tourist in the area
Tourism	decline_rate_without_development	1/Year	I		
Tourism	duration_of_tourist_staying	Tourist Days/Tourists	I		Average number of days per tourist
Tourism	emergency_level	Dmnl	I		Fraction of carrying capacity, according to literature overwiew,
Tourism	employment_factor	employees /Tourist Days	I		Number of employees per tourist days
Tourism	fraction_of_revenues_used_for_marketing		I		Share of the gross revenue used for marketing and advertising.
Tourism	impact_tourism_attractiveness_on_decline	Dmnl	I		
Tourism	initial_marketing_budget	RON/Year	I		Initial share of revenues used for marketing
Tourism	initial_tourist_days	Tourist Days	O		Initial value of tourist days
Tourism	marketing	RON/Year	O		Yearly expenditure invested for marketing
Tourism	N_load_per_tourist_day	ton N/Tourist Days			Value to set based on waste water concentration and water use per tourist day
Tourism	Number_of_Tourists(t)	Tourists	O	S	Number of arrivals in the area

Tourism	revenues_per_tourist day	RON/Tourist Days	O		Revenues indicator related to the number of tourist days
Tourism	time_until_emergency_level_is_reached	Year	O		Calculation of timeline until reaching the critical threshold of 2120000 tourists
Tourism	total_tourism_N_load	ton N/Year	O		Tons nitrogen generated yearly from tourism activity
Tourism	tourism_attractivenes s	Dmnl	O		Attractiveness of the area. It will be low when tourism is underdeveloped, However, at a certain point crowding will be a problem for the attractiveness, though less than in the case of underdevelopment
Tourism	tourism_carrying_cap acity	Tourist Days	I		Value set for maximum tourist days that will not negativelly influence the development of te area
Tourism	tourism_decline	Tourists/Ye ar	O		Decrease in number of tourists
Tourism	tourism_developmen t	Tourists/Ye ar	O		Increase in number of tourists
Tourism	tourism_employment	employme nt	O		Number of employees in tourism sector
Tourism	tourism_pressure	Dmnl	O		The presuree exrted by tourism sector upon the development of the area
Tourism	tourism_revenues	RON/Year	O		Revenues generated by tourism sector

Annex 5f Overview of variables MAL06 Mar Menor

Table 17: Main variables in the model (Role: I: input, O: indicator); SD: S: stock, F: flow, A: auxiliary).

Topic	Name	Unit	Role	SD	Definition
Agricultural nutrients balance	agricultural nutrients input	t/Year		F	Total nitrate input to the Mar Menor lagoon
Agricultural nutrients balance	AlbujonSWPumping status	Dmnl		A	Dummy variable that allows to activate the AlbujonSWPumping scenario at a specific time period
Agricultural nutrients balance	AlbujonSWPumpingOnOff	Dmnl	I	A	Scenario of water and nutrients extraction of the Albujón ephemeral river
Agricultural nutrients balance	Annual water pumped from Albujon ephemeral channel	hm3	I	A	Amount of annual water pumped from Albujon ephemeral channel
Agricultural nutrients balance	average excess of fertilizer use	kg/ha	I	A	Average excess of Nitrogen (fertilizer) use
Agricultural nutrients balance	Average NO3 content in Albujon emphemeral channel	t/hm3	I	A	Empirical average of nitrate content in Albujon emphemeral channel
Agricultural nutrients balance	Average percentage of groundwater desalinated	Dmnl	I	A	Average percentage of groundwater desalinated when pumped
Agricultural nutrients balance	brine produced	hm3		A	Total amount of brine exported to the Mar Menor lagoon
Agricultural nutrients balance	BrineDenitrification satus	Dmnl		A	Dummy variable that allows to activate the BrineDenitrificatio scenario at a specific time period
Agricultural nutrients balance	BrineDenitrificationOnOff	Dmnl	I	A	Binary variable acting as a switch to (de)activate the brine denitrification scenario
Agricultural nutrients balance	BrineStart	Dmnl	I	A	Dummy variable that starts the production of brine in 1995

Agricultural nutrients balance	Conversion factor Kg to Ton	t/kg	I	A	Conversion factor
Agricultural nutrients balance	Conversion factor N to NO3	Dmnl	I	A	Conversion factor
Agricultural nutrients balance	empirical aver NO3 concentration in aquifer	t/hm3	I	A	Empirically measured average of NO3 concentration in the Cuaternario aquifer
Agricultural nutrients balance	Empirical brine nitrate concentration	t/hm3	I	A	Empirical brine nitrate concentration
Agricultural nutrients balance	Empirical percentage of NO3 exported to groundwater	Dmnl	I	A	Empirical percentage of nitrate exported to groundwater
Agricultural nutrients balance	Empirical percentage of nutrients reaching the MM via AQ	Dmnl	I	A	Empirical percentage of nitrate reaching the Mar Menor lagoon via aquifer
Agricultural nutrients balance	estimated NO3 input to MM from Cuaternario	t		A	Total estimated amount of nitrate input to the Mar Menor lagoon from the aquifer
Agricultural nutrients balance	excess Kg haNin	kg/ha		A	Nitrogen leached in agricultural fields per hectare
Agricultural nutrients balance	gw nitrate from brine	t		A	Total amount of nitrates from brine exported to the Mar Menor lagoon
Agricultural nutrients balance	net NO3 export via sw	t		A	Net nitrate export to the Mar Menor lagoon via surface water
Agricultural nutrients balance	tons of nitrate yearly extracted by the AlbujonSWPumping	t		A	Amount of nitrate yearly extracted by the Albujon surface water pumping plan
Agricultural nutrients balance	tons of nitrate yearly extracted by the Vertido0Pumping	t		A	Tons of nitrates extracted from the aquifer by the Vertido Cero water pumping
Agricultural nutrients balance	Tons of NO3 input per ha	t/ha		A	Nitrate leached in agricultural fields per hectare
Agricultural nutrients balance	total excess of NO3 to gw	t		A	Total amount of nitrate leached to groundwater

Agricultural nutrients balance	total excess of NO3 to sw	t		A	Total amount of nitrate leached to surface water
Agricultural nutrients balance	VCOnOff	Dmnl	I	A	Binary variable to switch on or off the Vertido Cero scenario
Agricultural nutrients balance	VCstatus	Dmnl		A	Dummy variable that allows to activate the VC scenario at a specific time period
Agricultural water balance	ActualNrWorkingWells	well		A	Number of active wells
Agricultural water balance	agricultural pressure on water resources	Dmnl	O	A	The fraction of the total agricultural water demand that is not met by the available surface water for agriculture
Agricultural water balance	agricultural surface water balance	hm3		A	Available surface water for agriculture (plus the VC water pumped) minus the total agricultural water demand
Agricultural water balance	agricultural water demand per hectare	hm3/ha		A	Average agricultural water demand per hectare and per year
Agricultural water balance	AllowedNrWells	well	I	A	This variable represents a scenario in which the number of allowed wells can be set
Agricultural water balance	AllowedNrWellsStatus	Dmnl		A	Dummy variable that allows to activate the AllowedNrWells scenario at a specific time period
Agricultural water balance	annual groundwater pumping by well	hm3/well	I	A	Average annual groundwater pumping by well
Agricultural water balance	Annual water pumped by the VC	hm3	I	A	Water extracted from the aquifer by the Vertido Cero Plan
Agricultural water balance	ATS opened	Dmnl	I	A	A switcher that opens the Tagus-Segura water transfer in 1979
Agricultural water balance	available surface water for agriculture	hm3		A	The sum of all surface water sources

Agricultural water balance	Available water from Tagus river	hm3		A	The yearly average amount of water that has been transferred or is predicted to be transferred based on CC scenarios
Agricultural water balance	available water from the TS water transfer	hm3		A	The water diverted to the Campo de Cartagena from the Tagus-Segura aqueduct
Agricultural water balance	average TS water transfer	hm3		A	The water actually transferred as long as the aqueduct is opened
Agricultural water balance	baseline for agricultural water demand per hectare	hm3/ha	I	A	Baseline value for agricultural water demand per hectare of irrigated land areas
Agricultural water balance	BAUATSOnOff	Dmnl	I	A	Scenario of business as usual water transfer from Tagus-Segura
Agricultural water balance	catchment water sources	hm3	I	A	Additional sources of surface water available for the Campo de Cartagena
Agricultural water balance	change in agricultural water demand per hectare	Dmnl	I	A	Scenario of relative change in agricultural water demand per hectare
Agricultural water balance	change in agricultural water demand per hectare status	Dmnl		A	Dummy variable that allows to activate the change in agricultural water demand per hectare scenario at a specific time period
Agricultural water balance	Change in sea water desalination amount	Dmnl	I	A	Scenario of relative change in sea water desalination amount for agriculture
Agricultural water balance	Change in sea water desalination status	Dmnl		A	Dummy variable that allows to activate the change in sea water desalination amount scenario at a specific time period
Agricultural water balance	excessive irrigated land areas due to lack of water	ha		A	Number of hectares of agricultural irrigated land areas that exceed the total irrigation capacity
Agricultural water balance	final treated gw used	hm3		A	Final amount of groundwater extracted

Agricultural water balance	Fixed CRCC share of ATS water	Dmnl	I	A	The percentage of water that is assigned to the Comunidad de Regantes del Campo de Cartagena
Agricultural water balance	gross amount of gw needed	hm3		A	Total amount of groundwater needed to meet the agricultural water demand
Agricultural water balance	gw use ratio	Dmnl		A	The fraction of groundwater needed that is actually pumped based on the number of working wells
Agricultural water balance	gw2brine ratio	Dmnl	I	A	Percentage of usable water contained in the groundwater pumped from the aquifer
Agricultural water balance	NeededNrWells	well		A	The number of wells needed in order to pump all the groundwater demanded
Agricultural water balance	net amount of gw surplus needed	hm3		A	Total amount of groundwater needed
Agricultural water balance	OFFATS	hm3		A	Dummy variable that allows for non BAU Tagus-Segura water transfer scenarios
Agricultural water balance	percentage of water gap covered by unknown water sources	Dmnl	I	A	Percentage of water gap covered by unknown water sources
Agricultural water balance	RCP45ATS	hm3	I	A	Predicted water from Tagus-Segura transferred under the RCP4.5 scenario
Agricultural water balance	RCP45ATSOnOff	Dmnl	I	A	Dummy variable that activates the RCP4.5 scenario
Agricultural water balance	RCP85ATS	hm3	I	A	Predicted water from Tagus-Segura transferred under the RCP8.5 scenario
Agricultural water balance	RCP85ATSOnOff	Dmnl	I	A	Dummy variable that activates the RCP8.5 scenario
Agricultural water balance	sea water desalination	hm3		A	Sea water desalinated that serves as an input for the agricultural water demand

Agricultural water balance	total agricultural water balance	hm3		A	Difference between the total available water for agriculture and the total agricultural water demand
Agricultural water balance	total agricultural water demand	hm3	O	A	Total agricultural water demand
Agricultural water balance	total available water for agriculture	hm3		A	The sum of the available surface water for agriculture and the groundwater pumped
Agricultural water balance	urban wastewater treatment plant effluents	hm3	I	A	Urban wastewater treatment plant effluents that serve as an input for the agricultural water demand
Agricultural water balance	water from unknown water sources	hm3		A	Amount of water used coming from unknown sources
Agricultural water balance	water gap	hm3		A	The agricultural water needed not met by the surface water sources
Agricultural water balance	yearly average of sea water desalination	hm3	I	A	Yearly average of sea water desalinated for agriculture
Coastal-rural recreation potential	coastal ecotourism activities	Dmnl	I	A	Scenario variable of relative increase in the number of coastal ecotourism activities
Coastal-rural recreation potential	coastal recreation potential	Dmnl		A	Relative coastal recreation potential value
Coastal-rural recreation potential	CoastalEcoEffect	Dmnl		S	Gradual increase in the relative coastal ecotourism effect
Coastal-rural recreation potential	CoastalEcostatus	Dmnl/Year		A	Dummy variable that allows to activate the impact of coastal ecotoruism at a specific time period
Coastal-rural recreation potential	coastalrural recreation potential	Dmnl	O	A	Relative total coastal-rural recreation potential value

Coastal-rural recreation potential	impact of coastal ecotourism	Dmnl/Year		F	Relative impact of coastal ecotourism
Coastal-rural recreation potential	impact of rural ecotourism	Dmnl/Year		F	Relative impact of rural ecotourism
Coastal-rural recreation potential	rural ecotourism activities	Dmnl	I	A	Scenario variable of relative increase in the number of rural ecotourism activities
Coastal-rural recreation potential	rural recreation potential	Dmnl		A	Relative rural recreation potential value
Coastal-rural recreation potential	RuralEcoEffect	Dmnl		S	Gradual increase in the relative rural ecotourism effect
Coastal-rural recreation potential	RuralEcostatus	Dmnl/Year		A	Dummy variable that allows to activate the impact of rural ecotoruism at a specific time period
Mar Menor degra-dation	agricultural nutrients in the MM lagoon	t		S	Total amount of nitrates in the Mar Menor lagoon
Mar Menor degra-dation	Mar Menor degradation	Dmnl	O		Relative degradation status of the Mar Menor lagoon
Mar Menor degra-dation	mitigated impact of other point source pollution	Dmnl/Year		F	Mitigated impact of other point source pollution
Mar Menor degra-dation	NO3 consumed by lagoon metabolism	t/Year		F	Amount of nutrient being processed by the Mar Menor lagoon ecosystem
Mar Menor degra-dation	other point source pollution	Dmnl	I	A	Scenario variable of the relative amount of point-source pollution sources
Mar Menor degra-dation	other point source pollution status	Dmnl		A	Dummy variable that allows to activate the other point-source pollution scenario at a specific time period

Mar Menor degra-dation	OtherPointSourcePollutionMitigationEffect	Dmnl		S	Relative value of the other point source pollution mitigation effect
Mar Menor degra-dation	Percentage of nutrients that are metabolized by the native lagoon ecosystem	Dmnl	I	A	Percentage of nitrate naturally assimilated by the lagoon metabolism
Mar Menor degra-dation	relative weight of agricultural pollution in relation to the MM	Dmnl	I	A	Relative weight of agricultural pollution in relation to the Mar Menor degradation versus other point source pollution
Sectorial develop-ment and economic profit	Agricultural revenue per hectare	EUR/ha	I	A	Agricultural revenue per hectare
Sectorial develop-ment and economic profit	agricultural water revenue per m3	EUR/m3	O	A	Agricultural water revenue per cubic meter
Sectorial develop-ment and economic profit	Average area occupied by PV facilities per Mw	ha/MW	I	A	Average area occupied by photovoltaic facilities per megawatt
Sectorial develop-ment and economic profit	Average daily water consumption per person	hm3/tourist	I	A	Average daily water consumption per person
Sectorial develop-ment and economic profit	Average number of overnights per tourist a year	day	I	A	Average number of overnights per tourist a year
Sectorial develop-ment and economic profit	Average number of stable jobs generated by irrigated agriculture per hectare	jobs/ha	I	A	Average number of stable jobs generated by irrigated agriculture per hectare

Sectorial develop-ment and economic profit	Average number of stable jobs generated by PV facilities per MW installed	jobs/MW	I	A	Average number of stable jobs generated by photovoltaic facilities per megawatt installed
Sectorial develop-ment and economic profit	change in irrigated land area	ha/Year		F	Yearly increase in irrigated land area
Sectorial develop-ment and economic profit	Daily average expenditure per tourist	EUR/(tourist *day)	I	A	Daily average expenditure per tourist
Sectorial develop-ment and economic profit	decrease in irrigated land area	ha/Year		F	Decrease in irrigated land area
Sectorial develop-ment and economic profit	Electricity price	EUR/(Kw*hour)	I	A	Electricity price
Sectorial develop-ment and economic profit	expected number of tourists	tourist		S	Total number of yearly tourists expected
Sectorial develop-ment and economic profit	hm3tom3 conversion factor	m3/hm3		A	Conversion factor
Sectorial develop-ment and economic profit	IAControl	Dmnl		A	Dummy variable that allows to activate the control of irrigated land areas scenario at a specific time period
Sectorial develop-ment and	IAControlOnOff	Dmnl	I	A	Scenario variable that limits the amount of irrigated land areas

economic profit					
Sectorial develop-ment and economic profit	Incentives for PV growth	Dmnl	I	A	Positive incentives by public administrations in relation to the development of the photovoltaic renewable energy sector
Sectorial develop-ment and economic profit	initial estimated PV MW installed	MW/Year	I	A	Initial estimated amount of photovoltaic energy power installed
Sectorial develop-ment and economic profit	Initial nr of tourists	tourist/Year	I	A	Initial number of tourists
Sectorial develop-ment and economic profit	irrigated land areas	ha	O	S	Extent of irrigated agricultural areas
Sectorial develop-ment and economic profit	maxAllowedIAs	ha	I	A	Current agricultural area with legal access to water sources
Sectorial develop-ment and economic profit	maxIAs	ha		A	Effective maximum number of irrigated agricultural areas
Sectorial develop-ment and economic profit	maxPotIAs	ha	I	A	Available space for agricultural areas
Sectorial develop-ment and economic profit	Mean number of hours per day of PV electricity production	hour/day	I	A	Mean number of hours per day of PV electricity production

Sectorial develop-ment and economic profit	MM degradation threshold for tourism	Dmnl	I	A	Mar Menor degradation threshold negatively affecting tourism
Sectorial develop-ment and economic profit	Mw2Kw conversion factor	Kw/MW	I	A	Conversion factor
Sectorial develop-ment and economic profit	Number of days per year	day	I	A	Number of days per year
Sectorial develop-ment and economic profit	number of employees in agriculture	jobs	O	A	Total number of employees in agriculture
Sectorial develop-ment and economic profit	number of employees in PV	jobs	O	A	Total number of employees in photovoltaic renewable energy facilities
Sectorial develop-ment and economic profit	number of employees in tourism	jobs	O	A	Total number of employees in tourism
Sectorial develop-ment and economic profit	number of jobs created per tourist	jobs/tourist	I	A	Average number of jobs created per tourist
Sectorial develop-ment and economic profit	observed growth rate of agriculture	Dmnl	I	A	Historical rate of agricultural growth
Sectorial develop-ment and	observed growth rate of tourism	Dmnl/Year	I	A	Historical rate of tourism growth rate

economic profit					
Sectorial develop-ment and economic profit	observed PV growth rate in MW installed	Dmnl	I	A	Historical rate of photovoltaic energy power growth
Sectorial develop-ment and economic profit	potential agricultural development	Dmnl		A	Potential growth rate for agricultural development
Sectorial develop-ment and economic profit	potential growth rate of agriculture based on water availability	Dmnl		A	The fraction of the total agricultural water demand that is met by the available surface water for agriculture
Sectorial develop-ment and economic profit	potential PV installation	MW/Year		F	Increase in renewable PV energy facilities power installed
Sectorial develop-ment and economic profit	Potential PV installed	MW	O	S	Total power of photovoltaic energy installed
Sectorial develop-ment and economic profit	potential tourist growth	tourist/Year		F	Potential yearly increase in tourists
Sectorial develop-ment and economic profit	Promotion of PV facilities OnOff	Dmnl	I	A	Scenario of positive incentives by public administrations in relation to the development of the photovoltaic renewable energy sector
Sectorial develop-ment and economic profit	Promotion of PV facilities status	Dmnl		A	Dummy variable that allows to activate the promotion of photovoltaic facilities scenario at a specific time period

Sectorial develop-ment and economic profit	PV growth rate in MW installed	Dmnl		A	Photovoltaic growth rate expressed in megawatts installed
Sectorial develop-ment and economic profit	PV revenue per hectare	EUR/ha	O	A	Photovoltaic revenue per hectare
Sectorial develop-ment and economic profit	Rate of tourism loss influenced by MM degradation status	Dmnl/Year	I	A	Observed rate of tourism loss influenced by the Mar Menor degradation status
Sectorial develop-ment and economic profit	Total area occupied by PV facilities	ha		A	Total area occupied by photovoltaic facilities
Sectorial develop-ment and economic profit	total gross economic benefit	EUR		A	Total gross economic benefit including all sectors
Sectorial develop-ment and economic profit	total number of jobs	jobs		A	Total number of jobs including all sectors
Sectorial develop-ment and economic profit	Total water demand	hm3		A	Total water demand including agriculture and tourism
Sectorial develop-ment and economic profit	total water demand by tourists	hm3	O	A	Total water demand by tourists
Sectorial develop-ment and	tourism loss	tourist/Year		F	Amount of tourist loss influenced by the Mar Menor degradation status

economic profit					
Sectorial develop-ment and economic profit	tourism water revenue per m3	EUR/m3	O	A	Tourism water revenue per cubic meter
Sectorial develop-ment and economic profit	yearly gross economic benefit of agricultural production	EUR	O	A	Yearly gross economic benefit of agricultural production
Sectorial develop-ment and economic profit	yearly gross economic benefit of PV energy production	EUR	O	A	Yearly gross economic benefit of photovoltaic energy production
Sectorial develop-ment and economic profit	yearly gross economic benefit of tourism	EUR	O	A	Yearly gross economic benefit of tourism
Social awareness and governance	EnvEdstatus	Dmnl		A	Dummy variable that allows to activate the EnvironmentalEducation scenario at a specific time period
Social awareness and governance	EnvironmentalEducation	Dmnl	I	A	Scenario variable representing the relative number of environmental education activities
Social awareness and governance	impact of EnvEd	Dmnl/Year		F	EnvironmentalEducation scenario mediated by the status variable
Social awareness and governance	social pressure on public administrations	Dmnl		A	Relative pressure exerted by an environmentally-aware society on the public administration
Social awareness	territorial bonding	Dmnl	O	S	Relative level of territorial bonding by local populations

and governance					
Sustainable land manage-ment practices	NSW retention measures effect	Dmnl		A	NSW retention measures effect mediated by the status variable
Sustainable land manage-ment practices	NSW retention measures implementation level	Dmnl	I	A	Scenario of relative precentage of implementation of nutrient, soil and water retention measures
Sustainable land manage-ment practices	NSW retention measures implementation level status	Dmnl		A	Dummy variable that allows to activate the NSW retention measures implementation level scenario at a specific time period
Sustainable land manage-ment practices	Percentage of reduction in fertilizer effect	Dmnl		A	Percentage of reduction in fertilizer excess mediated by the status variable
Sustainable land manage-ment practices	Percentage of reduction in fertilizer excess	Dmnl	I	A	Scenario of percentage of reduction in fertilizer excess
Sustainable land manage-ment practices	Percentage of reduction in fertilizer status	Dmnl		A	Dummy variable that allows to activate the Percentage_of_reduction_in_fertilizer_excess scenario at a specific time period
Sustainable land manage-ment practices	yearly effectiveness in nutrients reduction of NSW retention measures	Dmnl	I	A	Average percentage of yearly nutrients reduction of nutrients, soil and water retention measures

Annex 6a Overview of data MAL01

Climate resilience and polder management model

Ampe, A (2007) Is golfenergie voordeliger dan windenergie? Onderzoek naar een economische exploitatie van het energiepotentieel in de Noordzee. Scriptie burgerlijk ingenieur bouwkunde. Universiteit Gent.

Bekkenbestuur (2010) Handleiding voor de opmaak van peilbesluiten in de kustpolders. (https://www.integraalwaterbeleid.be/nl/bekkens/bekken-brugse-polders/gebiedsgerichte-werking/handleiding-peilbesluiten/Handleiding%20peilafspraken.pdf/view)

De Maesschalck , P., Weekers, K. (2020) De economische betekenis van toerisme in Vlaanderen Resultaten van de Vlaamse en Brussels satellietrekening toerisme 2018 Statistiek Vlaanderen Havenlaan 88, 1000 Brussel D/2020/3241/064

Debrie, E. (2017) Een grondige statistische studie van het Belgische kustklimaat Master Thesis mathematics Gent University.

Federaal Planbureau en Statbel (2020) Demografische vooruitzichten 2019-2070 Bevolking en huishoudens D/2020/7433/6.

Statistiek Vlaanderen (2018) Jouw gemeente in cijfers Oostende https://www.statistiekvlaanderen.be/sites/default/files/docs/GM-Oostende.pdf

Weekers K,.(2017) Het aantal tweede verblijven in het Vlaamse Gewest in 2016 Studiedienst van de Vlaamse Regering (SVR) (https://www.statistiekvlaanderen.be/sites/default/files/atoms/files/aantal-tweede-verblijven-vlaanderen.pdf)

White, R., Uljee, I., & Engelen, G. (2012). Integrated modelling of population, employment and land-use change with a multiple activity-based variable grid cellular automaton. International Journal of Geographical Information Science, 26(7), 1251–1280. doi - 10.1080/13658816.2011.635146.

Zwaenepoel E., Danckaert S. & Van Gijseghem D. (2016) Klimaatverandering in de polders. Kiezen voor zoet of zilt?, Departement Landbouw en Visserij, Brussel. D/2016/3241/279

Port and energy model

Ampe, A (2007) Is golfenergie voordeliger dan windenergie? Onderzoek naar een economische exploitatie van het energiepotentieel in de Noordzee. Scriptie burgerlijk ingenieur bouwkunde. Universiteit Gent.

Bekkenbestuur (2010) Handleiding voor de opmaak van peilbesluiten in de kustpolders. (https://www.integraalwaterbeleid.be/nl/bekkens/bekken-brugse-polders/gebiedsgerichte-werking/handleiding-peilbesluiten/Handleiding%20peilafspraken.pdf/view)

Belgian Offshore Platform (2019): FAQ – Economy. [Online]. Available at: https://www.belgianoffshoreplatform.be/en/faq/. [Accessed July 2nd, 2020].

Crabtree, G., Misewich, J. et al. (2010) Integrating Renewable Electricity on the Grid A Report by the APS Panel on Public Affairs. American Physical Society (APS), Washington D.C., USA, 202-662-8700.

De Maesschalck , P., Weekers, K. (2020) De economische betekenis van toerisme in Vlaanderen Resultaten van de Vlaamse en Brussels satellietrekening toerisme 2018 Statistiek Vlaanderen Havenlaan 88, 1000 Brussel D/2020/3241/064

Debrie, E. (2017) Een grondige statistische studie van het Belgische kustklimaat Master Thesis mathematics Gent University.

Degraer, S., Brabant, R., Rumes, B., (Eds.) (2013) Environmental impacts of offshore wind farms in the Belgian

part of the North Sea: Learning from the past to optimise future monitoring programmes. Royal Belgian Institute of Natural Sciences, Operational Directorate Natural Environment, Marine Ecology and Management Section. 239 pp.

Depraetere, H and Lammertyn, K (2008) Getijdenenergie: een toekomst vanuit Belgisch perspectief? Onderzoek naar de technische en economische haalbaarheid. Scriptie burgerlijk ingenieur bouwkunde Universiteit Gent

Dijkema, G., Lukszo, Z., Verkooijen, A., de Vries, L., Weijnen, M. (2009) De regelbaarheid van elektriciteitscentrales Een quickscan in opdracht van het Ministerie van Economische Zaken 22 p.

ESMAP. 2019. "Global: Expanding Offshore Wind to Emerging Markets". Washington, DC: World Bank. Accessed: 30 April 2020.

Federaal Planbureau en Statbel (2020) Demografische vooruitzichten 2019-2070 Bevolking en huishoudens D/2020/7433/6.

Frumkes, D.R. (2002) The status of the California Rigs-to-Reefs Programme and the need to limit consumptive fishing activities. ICES Journal of Marine Science 272-276. Doi:10.1006/jmsc.2002.1289.

Kruse, M. et al. (2019) Market analysis Decom Tools - Interreg North Sea Region – Project Number: 20180305091606 Eco-Innovative concepts for the end of offshore wind energy farms lifecycle.

Kruse, M. et al. (2020) Stakeholder analysis Decom Tools - Interreg North Sea Region – Project Number: 20180305091606 Eco-Innovative concepts for the end of offshore wind energy farms lifecycle.

Luengo, M. and A. Kolios, "Failure Mode Identification and End of Life Scenarios of Offshore Wind Turbines: A Review," Energies, vol. 8, pp. 8339–8354, aug 2015.

Sayer, M.D.J., Baine, M.S.P. (2002) Rigs to Reefs: A critical Evaluation of the Potential for Reef Development Using Decommissioned Rigs. Journal of the Society for Underwater Technology Vol. 25, No. 2, pp. 93-97

Statistiek Vlaanderen (2018) Jouw gemeente in cijfers Oostende https://www.statistiekvlaanderen.be/sites/default/files/docs/GM-Oostende.pdf

Sun ,H., Gao, X. and Yang, H. (2019) Investigation into offshore wind farm repowering optimization in Hong Kong International Journal of Low-Carbon Technologies 2019, 14, 302–311.

Topham,E., Gonzalez,E., McMillan, D. and João, E. (2019) Challenges of decommissioning offshore wind farms: Overview of the European experience Journal of Physics: Conference Series, Volume 1222, WindEurope Conference and Exhibition 2019 2–4 April 2019, Bilbao,Spain.

Weekers K,.(2017) Het aantal tweede verblijven in het Vlaamse Gewest in 2016 Studiedienst van de Vlaamse Regering (SVR) (https://www.statistiekvlaanderen.be/sites/default/files/atoms/files/aantal-tweede-verblijven-vlaanderen.pdf)

Wuppertal Institut (2020) „Policy Brief – Infrastructure needs of an EU industrial transformation towards deep decarbonisation", based on research project funded by EIT Climate-KIC. Task ID: TC_2.11.1_190229_P259-1B, Wuppertal/Berlin, June 2020.

Zwaenepoel E., Danckaert S. & Van Gijseghem D. (2016) Klimaatverandering in de polders. Kiezen voor zoet of zilt?, Departement Landbouw en Visserij, Brussel. D/2016/3241/279

Annex 6b Overview of data MAL02 – SW Messinia

Androni Afrodite, Ellie Eleftheriadi, 2019. Nutrients and Chlorophyll-a in coastal and lagoon waters. COASTAL deliverable, The SW Messinia case study: Environmental assessment of the freshwater and marine systems.

Berg, H., Maneas, G., Salguero Engström, A. 2018. A Comparison between Organic and Conventional Olive Farming in Messenia, Greece. Horticulturae, 4, 15. https://doi.org/10.3390/horticulturae4030015

Bousbouras, D.; Maneas, G.; Bilionis, S.; Euaggelopoulos, A. Gialova Lagoon Hydrological Study. Determining the Necessary Management Measures for Achieving a Favourable Conservation Status for Birds; Available Only in Greek; Hellenic Ornithological Society: Athens, Greece, 2011; 212p.

Enveco, 2008. Perleros, V.; Pavlakis, G. Water Resources Management Study for Pylos and Romanos Catchments; Technical Report Submitted to the Region of Peloponnese; Enveco S.A.: Athens, Greece, September 2009. (In Greek) [Google Scholar]

Hatzianestis Ioannis, Constantine Parinos, Elvira Plakidi, Stiliani Chourdaki, 2019. Organic contaminants in marine and lagoon seawater and sediments. COASTAL deliverable, The SW Messinia case study: Environmental assessment of the freshwater and marine systems.

Klein, J.; Ekstedt, K.; Walter, M.T.; Lyon, S.W. 2015 Modeling Potential Water Resource Impacts of Mediterranean Tourism in a Changing Climate. *Environ. Model. Assess.* 2015, *20*, 117–128. [Google Scholar] [CrossRef]

Koutsoubas, D, C. Dounas, C. Arvanitidis, And S. Kornilios, G. Petihakis, G. Triantafyllou, and A. Eleftheriou. 2000. "Macrobenthic Community Structure and Disturbance Assessment in Gialova Lagoon, Ionian Sea." ICES Journal of Marine Science 57 (5): 1472–80. https://doi.org/10.1006/jmsc.2000.0905.

Maneas G, Bousbouras D, Norrby V and Berg H (2020) Status and Distribution of Waterbirds in a Natura 2000 Area: The Case of Gialova Lagoon, Messinia, Greece. Front. Ecol. Evol. 8:501548. doi: 10.3389/fevo.2020.501548

Maneas, G.; Makopoulou, E.; Bousbouras, D.; Berg, H.; Manzoni, S., 2019. Anthropogenic Changes in a Mediterranean Coastal Wetland during the Last Century—The Case of Gialova Lagoon, Messinia, Greece. Water, 11, 350. https://www.mdpi.com/2073-4441/11/2/350

Maniatakou S., 2019. "Unraveling diverse values of ecosystem services: a socio-cultural valuation using the Q-methodology in Messenia, Greece". MSc Thesis in Social Ecological Resilience for Sustainable Development. Stockholm Resilience Centre, Stoclholm University, Stockholm.

Manzoni, S. Maneas G., Scaini A., Psiloglou B.E., Destouni G., and Lyon S.W. 2020. "Understanding Coastal Wetland Conditions and Futures by Closing Their Hydrologic Balance: The Case of the Gialova Lagoon, Greece." Hydrology and Earth System Sciences 24 (7): 3557–71. https://doi.org/10.5194/hess-24-3557-2020.

Pavlidou Alexandra, Eleni Rousselaki, Georgia Assimakopoulou, Panagiota Zachioti, Vassileia Fioraki, Angeliki Konstantinopoulou, 2019. 5. Nutrients and Chlorophyll-A in Coastal and Lagoon Waters. COASTAL deliverable, The SW Messinia case study: Environmental assessment of the freshwater and marine systems.
Tiller et al., 2019. COASTAL Deliverable D04: Multi-Actor Analysis of Land-Sea Dynamics.

Viaene et al., 2020. COASTAL Deliverable D13 Pilot SD Models for Coastal-Rural Interactions - Case Study Level.

Annex 6c Overview of data MAL03 – Norrström/Baltic Sea

Technical and scientific peer-reviewed publications and official reports are mainly considered for quantification of the two SD sub models in MAL3. They are also listed in the data and model inventory for MAL3 as part of the deliverable D06(D2.1) of WP2 (Kastanidi et al., 2018 – updated in 2020). Quantitative information, data and equations used for quantifying the two sub models are also reported in detail in the deliverable D07(D2.2) of WP2 (Seifollahi-Aghmiuni et al., 2020). Most of data for input and boundary variables are read from an excel file that is linked to the integrated MAL3 SD model. Variables related to change scenario analysis are structured as a slider variable in the dashboard view within the MAL3 model and user can change their values directly within the model and test their impacts on the key performance indicators discussed in Section 3.3.6 business and policy analysis in this current report. The associated resources used to extract various quantitative information for the MAL3 land-sea system modelling are listed as below:

Baresel, C., and Destouni, G. (2006) Estimating subsurface nitrogen accumulation-depletion in catchments by input-output flow analysis. Physics and Chemistry of the Earth, Parts A/B/C, 31(17), 1030-1037.

Baresel, C., and Destouni, G. (2005) Novel quantification of coupled natural and cross-sectoral water and nutrient/pollutant flows for environmental management. Environmental Science and Technology, 39, 6182-6190.

Basu, N.B., Destouni, G., Jawitz, J.W., Thompson, S.E., Loukinova, N.V., Darracq, A., Zanardo, S., Yaeger, M., Sivapalan, M., Rinaldo, A., and Rao, P.S.C. (2010) Nutrient loads exported from managed catchments reveal emergent biogeochemical stationarity. Geophysical Research Letters, 37, L23404.

Bring, A., Asokan, S.M., Jaramillo, F., Jarsjö, J., Levi, L., Pietroń, J., Prieto, C., Rogberg, P., and Destouni, G. (2015a) Implications of freshwater flux data from the CMIP5 multi-model output across a set of Northern Hemisphere drainage basins. Earth's Future, 3(6), 206–217.

Bring, A., Rogberg, P., and Destouni, G. (2015b) Variability in climate change simulations affects needed long-term riverine nutrient reductions for the Baltic Sea, Ambio, 44, S381-S391.

Cseh, M. (2009) Multi-approach comparison of nutrient flow modeling in the Norrström drainage basin. Master thesis of Environmental Engineering, Budapest University of Technology and Economics, Budapest, Hungary, and Stockholm University, Stockholm, Sweden.

Darracq, A., and Destouni, G. (2005) In-stream nitrogen attenuation: model-aggregation effects and implications for coastal nitrogen impacts. Environmental Science and Technology, 39, 3716-3722.

Darracq, A., Lindgren, G., and Destouni, G. (2008) Long-term development of phosphorus and nitrogen loads through the subsurface and surface water systems of drainage basins. Global Biogeochemistry Cycles, 22, GB3022.

Destouni, G., and Darracq, A. (2009) Nutrient cycling and N2O emissions in a changing climate: the subsurface water system role. Environmental Research Letters, 4, 035008.

Destouni, G., Fischer, I., and Prieto, C. (2017) Water quality and ecosystem management: Data driven reality check of effects in streams and lakes. Water Resources Research, 53, 6395-6404.

Destouni, G., Hannerz, F., Prieto, C., Jarsjö, J., and Shibuo, Y. (2008) Small unmonitored near-coastal catchment areas yielding large mass loading to the sea. Global Biogeochemical Cycles, 22(4), GB4003

Destouni, G., and Jarsjö, J. (2018) Zones of untreatable water pollution call for better appreciation of mitigation limits and opportunities. WIREs Water, 5(6), e1312.

Elmhagen, B., Destouni, G., Angerbjörn, A., Borgström, S., Boyd, E., Cousins, S. A. O., Dalén, L., Ehrlén, J., Ermold, M., Hambäck, P. A., Hedlund, J., Hylander, K., Jaramillo, F., Lagerholm, V. K., Lyon, S. W., Moor, H., Nykvist, B., Pasanen-Mortensen, M., Plue, J., Prieto, C., van der Velde, Y., Lindborg, R. (2015) Interacting effects of change in climate, human population, land use, and water use on biodiversity and ecosystem services. Ecology and Society, 20(1), Art. 23.

European Commission (EC) (2020) A European Green Deal: Striving to be the first climate-neutral continent. Available at: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en#policy-areas (accessed on 14 October 2020)

Hannerz, F., and Destouni, G. (2006) Spatial characterization of the Baltic Sea Drainage Basin and its unmonitored catchments, Ambio, 35, 214-219.

Helsinki Commission (HELCOM) (2018) State of the Baltic Sea – Second HELCOM holistic assessment 2011-2016. Baltic Sea Environment Proceedings 155, ISSN 0357-2994, pp. 155. Available at (accessed on 12 February 2021): https://helcom.fi/media/publications/BSEP155.pdf

Helsinki Commission (HELCOM) (2010) Ecosystem health of the Baltic Sea – Initial HELCOM holistic assessment 2003-2007. Baltic Sea Environment Proceedings 122, ISSN 0357 - 2994, pp. 68. Available at (accessed on 11 June 2021): https://helcom.fi/wp-content/uploads/2019/08/BSEP122.pdf

Helsinki Commission (HELCOM) Ministerial Meeting (2007) Baltic Sea Action Plan. Available at: https://helcom.fi/media/documents/BSAP_Final.pdf

Kastanidi, E., Panagopoulos, I., Karageorgis, A., Destouni, G., Seifollahi, S., Kalantari, Z., … and Vernier, F. (2018-updated in 2020 based on the first project review). Model and data inventory, Deliverable D06, in: H2020, C. (Ed.), WP2 Knowledge transition, T2.1 – Data and model base.

Lindgren, G.A., Destouni, G., and Darracq, A. (2007) Inland subsurface water system role for coastal nitrogen load dynamics and abatement responses, Environmental Science and Technology, 41(7), 2159-2164.

Mazi, K., Koussis, A.D., and Destouni, G. (2016) Quantifying a sustainable management space for human use of coastal groundwater under multiple change pressures. Water Resources Management, 30, 4063-4080.

Riahi, K., Van Vuuren, D.P., Kriegler, E., Edmonds, J., O'neill, B.C., Fujimori, S., ... and Tavoni, M. (2017) The shared socioeconomic pathways and their energy, land use, and greenhouse gas emissions implications: an overview. Global Environmental Change, 42, 153-168.

Seifollahi-Aghmiuni, S., Destouni, G., Kalantari, Z., Viaene, P., D'Haese, N., De Kok, J.-L., Kastanidi, E., ... and Albaladejo, J. (2020) Knowledge transition, Deliverable D07, in: H2020, C. (Ed.), WP2 Knowledge transition, T2.2 – Knowledge transition.

Swedish Agency for Marine and Water Management (Hav) (2019) Marine spatial plans for Gulf of Bothnia, Baltic Sea and Skagerrak/Kattegat. Available at: https://www.havochvatten.se/download/18.7d45de5c174e8f2dabec53f5/1602497688808/SwAM-MSP-proposals-chapters-4-12-13.pdf (accessed on 20 October 2020)

Tiller, R., De Kok, J.-L., Notebaert, B., Wouters, N., Stubbe, F., Motmans, S., Stubbe, W., … and Albaladejo, J. (2019a) Sectoral analysis of coastal and rural development, Deliverable D03, in: H2020, C. (Ed.), WP1 Multi actor analysis, T1.1 – Sectoral analysis of coastal & rural development.

Tiller, R., De Kok, J.-L., Notebaert, B., Viaene, P., Wouters, N., Depoorter, M., Stubbe, F., … and Myhre, M. (2019b) Multi-actor analysis of land-sea dynamics, Deliverable D04, in: H2020, C. (Ed.), WP1 Multi actor analysis, T1.2 – Multi-actor analysis; & T1.3 – Conceptual analysis of land-sea dynamics.

United Nation (UN) (2015) Sustainable Development Goals. Available at: https://www.un.org/sustainabledevelopment/ (accessed on 20 October 2020)

Viaene, P., De Kok, J.-L., Karageorgis, A., Panagopoulos, Y., Kastanidi, E., Destouni, G., … and Martinéz-López, J. (2020) Pilot SD models for coastal-rural interactions – Case study level, Deliverable D13, in: H2020, C. (Ed.), WP4 Systems modelling, T4.2 – SD modelling of coastal-rural interactions – case study level.

Vigouroux, G., Chen, Y., Jönsson, A., Cvetkovic, V., Destouni, G. (2020) Simulation of nutrient management and hydroclimatic effects on coastal water quality and ecological status – The Baltic Himmerfjärden Bae case. Ocean & Coastal Management, 198, 105360.

Vigouroux, G., Destouni, G., Jönsson, A., Cvetkovic, V. (2019) A scalable dynamic characterisation approach for water quality management in semi-enclosed seas and archipelagos. Marine Pollution Bulletin, 139, 311-327.

Annex 6d Overview of data MAL04 Charente

The INRAE data management plan identifies all sources of data that will be used by the stock-flow models. This inventory involves analysis and evaluation of the availability, quality and usefulness, spatial-temporal scales and periodicity of the data. Metadata files are filled by researchers and controlled by a data manager. The structure of the file stored (.csv) preserves future interoperability within the Coastal project. Strict internal rules are laid down to comply with the GDPR Directive (personal data from surveys, workshops records...). Only two people (IT specialists) have a write access to data and a small number of partners (people who need to analyse and use the data) have read-only access.

Agence Bio. (2020a). Données départementales et régionales de certification au 31 décembre de 2011 à 2019. Les Chiffres Clés. https://www.agencebio.org/wp-content/uploads/2020/07/Donnees_Dept_depuis2011_AgenceBio.zip

Agence Bio. (2020b). Données géolocalisées de certification au 31 décembre de l'année par EPCI. Les Chiffres Clés. https://www.agencebio.org/wp-content/uploads/2020/07/Donnees_EPCI_AgenceBio_2019.xlsx

Agence Bio. (2020c). Le marché BIO en France. Les Chiffres Clés. https://www.agencebio.org/wp-content/uploads/2020/07/FigTab_DPjuillet2020.xlsx

Agence de l'Eau Adour-Garonne. (2021a). Données de prélèvement. http://adour-garonne.eaufrance.fr/catalogue/72831d03-7080-416a-b6a2-a9f1b945a8bf

Agence de l'Eau Adour-Garonne. (2021b). Données de rejet des collectivités. http://adour-garonne.eaufrance.fr/catalogue/581d5f70-558c-49e4-8d77-5bd4fe974b62

Agence de l'Eau Adour-Garonne. (2021c). Station d'épuration collective. http://adour-garonne.eaufrance.fr/catalogue/42f43670-099d-11de-97dd-001517506978

Agreste. (2010). Service d'eau et d'assainiseement: une inflexion des tendances. https://www.agreste.agriculture.gouv.fr/agreste-web/download/publication/publie/Pri250/primeur250.pdf

Agreste. (2012). Recensements de la conchyliculture, 2001 - 2012. 10. https://agriculture.gouv.fr/telecharger/86410?token=7625f41477acd041e4f86cee9e195e5388705f779f4a0fb27acebcfe9fcdd8cc

Agreste. (2015). Recensement de la conchyliculture. https://www.agreste.agriculture.gouv.fr/agreste-web/disaron/ChdAgr226/detail/

Agreste. (2020). Statistique agricole annuelle (SAA) - Utilisation du territoire. https://www.agreste.agriculture.gouv.fr/agreste-web/disaron/SAANR_1/detail/

Arribard, L. (2015). Le marché du Cognac. https://www.unigrains.fr/wp-content/uploads/2017/11/2015-Marche-du-Cognac.pdf

Ballé-Béganton, J., Bailly, D., Lample, M., Mongruel, R., Prou, J., Réthoret, H., Bacher, C., Agùndez, J. A. P., Vanhoutte-Brunier, A., & Neveu, J. (2012). Building an integrated model for freshwater allocation with local managers in a coastal area. IEMSs 2012 - Managing Resources of a Limited Planet: Proceedings of the 6th Biennial Meeting of the International Environmental Modelling and Software Society, 1851–1858.

Barbier, P., Barré, M., Bodin, P., Oudot, G., & Vieira, J. (2021). Observatoire ostréicole du littoral charentais - Rapport annuel 2020. https://creaa.pagesperso-orange.fr/doc/04_rapport_suivi_estran.pdf

Bichot, F., & Gennat, A. (2018). Les eaux souterraines en Poitou-Charentes. http://sigespoc.brgm.fr/IMG/pdf/brochure_es_pch.pdf

Bordenave, P., Delmas, F., Laplana, R., & Vernier, F. (2020). Agriculture in coastal areas : environmental issues, impacts and regulation tools. https://hal.inrae.fr/hal-02594849

Charentes Toursime. (2020). Chiffres Clés 2019. https://charentestourisme.com/wp-content/uploads/2020/07/Chiffres-clés-2019-BD.pdf

Comptabilité Gestion Océan. (2020). Thème viticulture (collection d'articles). https://www.cgocean.com/Viticulture/

Comptabilité Gestion Océan. (2021). Cognac : historique des rendements autorisés. https://www.cgocean.com/Chiffres-cles/Cognac-et-viticulture/Cognac-historique-des-rendements-autorises

Département Charente Maritime. (2021). Plan digues. https://la.charente-maritime.fr/grands-projets/digues/plan-digues

Eau 17. (2020). Rapport sur le prix et la qualité du service d'eau potable 2019. http://www.eau17.fr/pdf/RPQS_AEP_2019.pdf

Etablissement Public Territorial de Bassin Charente. (2020a). Niveau des barrages. http://www.fleuve-charente.net/les-donnees-sur-leau/suivi-de-letiage/niveau-des-barrages

Etablissement Public Territorial de Bassin Charente. (2020b). Notre territoire - Le bassin versant. https://www.fleuve-charente.net/notre-territoire/le-bassin-versant

Etablissement Public Territorial de Bassin Charente. (2021a). Evolution de l'irrigation (Fiche 2.4 pour "Charente 2050"). http://www.fleuve-charente.net/wp-content/files/Charente2050/2.4_ACTIVITES_Irrigation.pdf

Etablissement Public Territorial de Bassin Charente. (2021b). Rapport de suivi du PGE Charente : Bilan de l'étiage 2020. http://www.fleuve-charente.net/wp-content/uploads/2021/02/Bilan_etiage_Charente_2020_V2.pdf

European Environment Agency. (2021). Copernicus Land Monitoring Service - Corine Land Cover. EEA. https://land.copernicus.eu/pan-european/corine-land-cover

FranceAgriMer - VISIONet. (2021). Historique des prix trimestriels moyens payés aux producteurs depuis 2005 céréales et protéagineux (SCR-CER-HISTOPRIXTRIMESTRIELS-C20-21). https://visionet.franceagrimer.fr/Pages/OpenDocument.aspx?fileurl=SeriesChronologiques%2Fproductions végétales%2Fgrandes cultures%2Fprix payés aux producteurs%2FSCR-CER-HISTOPRIXTRIMESTRIELS-C20-21.xlsx&telechargersanscomptage=oui

Frenken, K., & Gillet, V. (2012). Besoins et prélèvements d'eau pour l'irrigation par pays. http://www.fao.org/3/bc824f/bc824f.pdf

INSEE. (2020). Historique des populations légales. https://www.insee.fr/fr/statistiques/2522602

Ministère de la transition écologique. (2021). Direction interdépartementale des routes Atlantique. http://www.dir.atlantique.developpement-durable.gouv.fr/presentation-de-la-dir-atlantique-r1.html

Port Atlantique La Rochelle. (2015a). Présentation du port et de ses filières (partie 1). https://www.larochelle.port.fr/media/20150423_presentation_port_partie_1055850100_1723_23042015.pdf

Port Atlantique La Rochelle. (2015b). Présentation du port et de ses filières (partie 2). https://www.larochelle.port.fr/media/20150423_presentation_port_partie_2_fiches_filieres009207300_1726_23042015.pdf

Ruelle, P., Mailhol, J., & Itier, B. (2004). Évaluation Des Pertes Par Évaporation Lors Des Irrigations Par Aspersion En Condition De Fort Déficit Hydrique. Ingénieries Eau-Agriculture-Territoires, 38, 13–20. https://hal.archives-ouvertes.fr/hal-00472878/file/DG2004-PUB00013835.pdf

Sébille, L. (2011). Comparaison de la main d'oeuvre utilisée en agriculture biologique et conventionnelle [Université de Rennes 1]. https://hal.archives-ouvertes.fr/hal-01462578/

Vernier, F., Bordenave, P., Leccia, O., & Petit, K. (2009). SSA 10 (Pertuis sea and Charente river basin) Agriculture-Irrigation box: Definition and impact of scenarios Links with SSA10 extend model. Spicosa Meeting, 8. https://hal.inrae.fr/hal-02592517

Vernier, F., Leccia-Phelpin, O., Lescot, J. M., Minette, S., Miralles, A., Barberis, D., Scordia, C., Kuentz-Simonet, V., & Tonneau, J. P. (2017). Integrated modeling of agricultural scenarios (IMAS) to support pesticide action plans: the case of the Coulonge drinking water catchment area (SW France). Environmental Science and Pollution Research, 24(8), 6923–6950. https://doi.org/10.1007/s11356-016-7657-2

Vernier, F., Leccia, O., Lescot, J.-M., Minette, S., Miralles, A., J.P., G., PRYET, A., & Petit, K. (2016). Rapport final du projet MODCHAR2 : Modélisation des pressions agricoles et de leur impact 2013-2015 - Evaluation environnementale et économique de scénarios agricoles par modélisation intégrée (IMAS) dans le bassin versant de la Charente. https://hal.inrae.fr/hal-02606274

Voinov, A., Kolagani, N., McCall, M. K., Glynn, P. D., Kragt, M. E., Ostermann, F. O., Pierce, S. A., & Ramu, P. (2016). Modelling with stakeholders – Next generation. Environmental Modelling & Software, 77, 196–220. https://doi.org/10.1016/j.envsoft.2015.11.016

Annex 6e Overview of data MAL05 – Danube Mouth and Black Sea

Baboianu G. (2016) Danube Delta: The Transboundary Wetlands (Romania and Ukraine). In: Finlayson C., Milton G., Prentice R., Davidson N. (eds) The Wetland Book. Springer, Dordrecht.

Basiago, A., (1999). Economic, social, and environmental sustainability in development theory and urban planning practice. The Environmentalist 19, 145-161.

Collste, D., Pedercini, M. & Cornell, S.E. (2017). Policy coherence to achieve the SDGs: using integrated simulation models to assess effective policies. Sustain Sci 12, 921–931. https://doi.org/10.1007/s11625-017-0457-x.

Institutul Mational de Cercetare-Dezvoltare Martina "Grigore Antipa" (2018). Studiu privind elaborarea raportului privind starea ecologică a ecosistemului marin Marea Neagră conform cerinţelor art. 17 ale Directivei Cadru Strategia pentru mediul marin (2008/56/EC).

Ministerul Dezvoltării Regionale și Administrației Publice (MDRAP), (2016). Strategia Integrată de Dezvoltare Durabilă a Deltei Dunării.

National Institute of Statistics Database, Tempo Online, retrieved at http://statistici.insse.ro:8077/tempo-online/#/pages/tables/insse-table

Nicula, V., (2008).Ecoturism si conservarea mediului, retrieved athttp://webspace.ulbsibiu.ro/dumitru.troanca/html/resurse/Ecoturism%20%20B02%20an%201/Ecoturism%20si%20conservarea%20mediului.pdf

OECD, (2007). Promoting Pro-Poor Growth. POLICY GUIDANCE FOR DONORS.

https://www.oecd-ilibrary.org/docserver/9789264024786-en.pdf?expires=1595506959&id=id&accname=guest&checksum=1181168B0D5F1115C4F91D0AB20CE3F9.

Petrisor, A.-I., Petre, R., Meita, V. (2016). Difficulties in achieving social sustainability in a biosphere reserve. INTERNATIONAL JOURNAL OF CONSERVATION SCIENCE Volume 7, Issue 1, January-March 2016: 123-136.

Sbarcea, M., Petrisor, A-I, Petrisor, L.E., (2019) Mapping Potential Environmental Conflicts in the Danube Delta Biosphere Reserve. Scientific Annals of the Danube Delta Institute, Vol.24, https://doi.org/10.7427/DDI.24.19

Tulcea County Directorate of Statistics and Tulcea Local Promotion and Development Association Report during 2017-2019, retrieved at https://focuspress.ro/turismul-o-industrie-cu-probleme-la-tulcea/), based on an average length of stay per tourist of 2 touristic days

Vaidianu, N., Adamescu, C., Wildenberg, M., Tetelea, C. (2014). Chapter from book Fuzzy Cognitive Maps for Applied Sciences and Engineering (pp.355-374) Understanding Public Participation and Perceptions of Stakeholders for a Better Management in Danube Delta Biosphere Reserve (Romania). 10.1007/978-3-642-39739-4_19.

World Bank (2014a) REPORT 2.2 Draft Danube Delta Integrated Sustainable Development Strategy (2030), https://www.mlpda.ro/userfiles/delta_dunarii/draft_Danube_Delta_Strategy.pdf

World Bank (2014b) DIAGNOSTIC REPORT Danube Delta Integrated Sustainable Development Strategy.

Annex 6f Overview of data MAL06 Mar Menor

Álvarez-Rogel, J., Barberá, G.G., Maxwell, B., Guerrero-Brotons, M., Díaz-García, C., Martínez-Sánchez, J.J., Sallent, A., Martínez-Ródenas, J., González-Alcaraz, M.N., Jiménez-Cárceles, F.J., Tercero, C., Gómez, R., 2020. The case of Mar Menor eutrophication: State of the art and description of tested Nature-Based Solutions. Ecol. Eng. 158, 106086. doi:10.1016/j.ecoleng.2020.106086

APPA, 2018. Estudio del Impacto Macroeconómico de las Energías Renovables en España. Asociación de Empresas de Energías Renovables.

Arroyo Mompeán, P., 2018. BALANCE TURÍSTICO DELA REGIÓN DE MURCIA 2017. Instituto de Turismo de la Región de Murcia - Unidad de Estadística.

Arroyo Mompeán, P., Vegas Juez, A.M., 2019. TURISMO EN LA REGIÓN DE MURCIA - 2018. Instituto de Turismo de la Región de Murcia - Unidad de Estadística.

Ayuntamiento de Torre Pacheco, 2019. Estrategia de Desarrollo Urbano Sostenible Integrado de Torre-Pacheco. Ayuntamiento de Torre-Pacheco.

CARM, 2017. INVERSIÓN TERRITORIAL INTEGRADA (ITI) DEL MAR MENOR. Comunidad Autónoma de la Región de Murcia.

Carreño, M.F., Palazon, J.A., Martínez-López, J., 2015. 1988-2009 time-series of land-use/land-cover maps for the Mar Menor / Campo de Cartagena watershed by means of supervised classification of Landsat images. Zenodo.

CHS, 2015. PLAN HIDROLÓGICO DE LA DEMARCACIÓN DEL SEGURA 2015/21. Confederación Hidrográfica del Segura.

CHS, 2019. Colector de vertido cero al Mar Menor Norte (Expediente No. 07.330-0628/0411). Confederación Hidrográfica del Segura.

CHS, 2020. Esquema provisional de Temas Importantes (EpTI) del tercer ciclo de planificación: 2021–2027. Confederación Hidrográfica del Segura.

Comité de Asesoramiento Científico del Mar Menor, 2017. INFORME INTEGRAL SOBRE ELESTADO ECOLÓGICO DEL MAR MENOR. CARM.

ECONET, 2020a. Turismo de la Región de Murcia. CARM.

ECONET, 2020b. Evolución de la electricidad generada según fuente de generación y distintas variables. CARM.

Guaita-García, N., Martínez-Fernández, J., Barrera-Causil, C.J., Esteve-Selma, M.Á., Fitz, H.C., 2020. Local perceptions regarding a social–ecological system of the mediterranean coast: the Mar Menor (Región de Murcia, Spain). Environ. Dev. Sustain. doi:10.1007/s10668-020-00697-y

López Ortiz, I., 1999. Entre la tradición y el cambio: la respuesta de la Región de Murcia a la crisis de la agricultura tradicional. Historia agraria: Revista de agricultura e historia rural 75–113.

Morote, Á.-F., Olcina, J., Rico, A.-M., 2017. Challenges and Proposals for Socio-Ecological Sustainability of the Tagus–Segura Aqueduct (Spain) under Climate Change. Sustainability 9, 2058. doi:10.3390/su9112058

Pärn, J., Pinay, G., Mander, Ü., 2012. Indicators of nutrients transport from agricultural catchments under temperate climate: A review. Ecol. Indic. 22, 4–15. doi:10.1016/j.ecolind.2011.10.002

Pellicer-Martínez, F., Martínez-Paz, J.M., 2018. Climate change effects on the hydrology of the headwaters of the Tagus River: implications for the management of the Tagus–Segura transfer. Hydrol. Earth Syst. Sci. 22, 6473–6491. doi:10.5194/hess-22-6473-2018

TRAGSATEC, 2019. Análisis de soluciones para el vertido cero al Mar Menor proveniente del Campo de Cartagena. MITECO.

Annex 7 Calculating growth rates using a logistic growth model

Logistic growth is a common phenomenon in social-environmental systems and generated by the corresponding system archetype described in deliverable D12 (Figure 104). The difference equation for logistic growth of a variable X(t) is:

$$dX = g\,X\left(1 - \frac{X}{X_{max}}\right) \qquad (6.1)$$

where g is the growth rate and X_{max} the maximum (saturation) level.

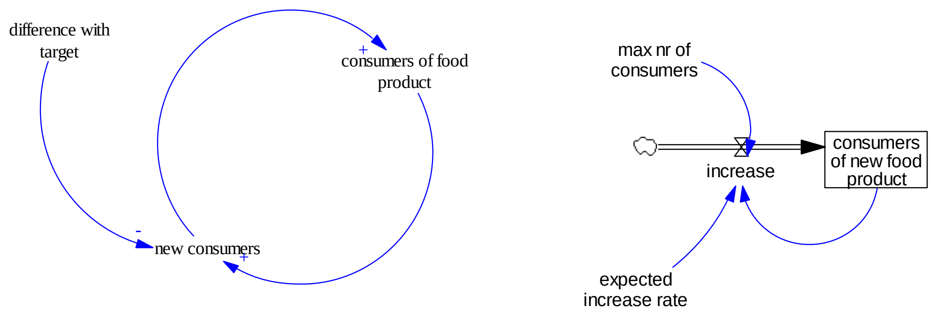


Figure 104: Examples of a causal loop and stock-flow diagram generating logistic growth (see deliverable D12)

Equation (1) can be solved analytically (Sterman, 2001) with the solution:

$$X(t) = \frac{X_{max}}{1+\left(\frac{X_{max}}{X_0}-1\right)e^{-gt}} \qquad (6.2)$$

where x_0 is the initial value of the variable. The growth rate g can be estimated from historic data (model calibration) or obtained based on expert estimate. Interactions with experts and stakeholders proved that the concept of growth rates is difficult to communicate and discuss. The logistic growth model can be explained more easily and the growth rate determined indirectly by asking for: (1) a critical threshold level defined as a fraction α of the saturation level X_{max} and (2) the time T expected for the variable to reach this threshold level. This information can then be used to derive the growth rate by solving for $X(T) = \alpha\, X_{max}$. This gives (Sterman, 2001):

$$g = \frac{1}{T}\log\left(\left(\frac{\alpha}{1-\alpha}\right) \times \left(\frac{X_{max}-X_0}{X_0}\right)\right) \qquad (6.3)$$

This approach was used to calculate the transition growth rate for ecofarming and the tourism development growth rate for the Romanian MAL (see Section 3.5). In the case of the ecofarming model the critical level was defined as a fraction α of the total area available for farming X_{tot} i.e. replacing α by αX_{tot} in Equation 6.3.