COASTAL
Collaborative Land-Sea Integration Platform

Deliverable D20
Business & Policy Robustness

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COASTAL: Collaborative Land and Sea Integration Platform - Co-creating evidence-based business roadmaps and policy solutions for enhancing coastal-rural collaboration and synergies in Europe focusing on economic growth, spatial planning and environmental protection. Project timeframe: 01/05/2018 - 30/04/2022

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ABBREVIATIONS

CAP - Common Agricultural Policy

DG AGI - Directorate-General for Agriculture and Rural Development

DG-EMPL - Directorate-General for Employment, Social Affairs and Inclusion

DG-ENER - Directorate-General for Energy

DG ENV - Directorate General for Environment

DG-GROW - Directorate-General for Internal Market, Industry, Entrepreneurship, and SMEs

DG MARE - Directorate-General for Maritime Affairs and Fisheries

DG REGIO - Directorate-General for Regional Policy and Urban Affairs

EIP-AGRI – European Innovation Partnership for Agricultural productivity and Sustainability

ENRD - EU Network for Rural Development

KPI – Key Performance Indicator

M – month

MA – multi-actor

MAL – Multi-Actor Lab

MS – Milestone

MSFD – Marine Strategy Framework Directive

RD – rural development

SAB – Scientific Advisory Board

SD – System Dynamics

SDG – Sustainable Development Goal

WFD – Water Framework Directive

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1. INTRODUCTION

1.1. Purpose

In this report we examine the effectiveness of policy and business actions to direct European coastal areas towards a more sustainable future. Key to this research was the co-creation of the system-dynamics models reflecting stakeholders' views and understandings of the coastal areas under scope. In these models different sectors are represented, such as tourism, agriculture and fisheries, that were identified by the Multi-Actor Labs as being key to the future development of these regions. The models allow us to examine the dynamic response of the coastal-rural systems to different combinations of policy actions and scenarios (cfr. COASTAL deliverable D19), interactions within and between these sectors, and can be used to assess the impact of actions on key policy indicators (KPIs). For example, agriculture can be made more climate resilient by introducing crops that are less water demanding. The environmental and economic boundary conditions for such a change need to be considered from a long-term, systems perspective in the context of EU policy frameworks, in particular the EU Green Deal. In COASTAL deliverable D19 different scenarios were presented to address the role of social-economic and environmental uncertainties in a coherent manner. These scenarios comprise societal evolutions external to the modelled coastal systems of which the outcomes are very uncertain. Climate change is an example, but also certain water management and tourism development strategies, for instance, were among the changes put forward by coastal actors as evolutions they have (almost) no grip on. This report describes how and to what extent these external uncertainties can influence the modelled systems' behaviour. This was done using KPIs linked to critical assets of each of the coastal regions.

The concept of **robustness** of policy and business interventions plays a central role in the analyses described in this report. Here robustness is mathematically defined as the ability of actions or combined set of actions to maintain the system in a sustainable state, regardless of the exogenous conditions (described in the scenarios). This systemic sustainability implies that key (policy or business) indicators or KPIs remain within the desirable range, generally defined by a minimum and maximum value. Actions which fail to keep the system in this range at a certain point in time cannot be considered to be robust. It is also important to distinguish this robustness – the ability to withstand conditions – from resilience – the ability to recover from these conditions. We search for an answer to the question whether it's possible to intervene in the modelled coastal systems in such a way that each of the KPIs remains within sustainable ranges under each of the scenarios. Or phrased otherwise: can we point out sets of actions that allow us to develop towards the sustainable coastal area aspired for by stakeholders no matter the direction and severity of external evolutions? If such a set of actions does not exist And if this is not possible, can we already shed some light on the consequences this may have for these regions? The answers to these questions for the MALs can be found throughout this report and are summarized in the last, concluding chapter.

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1.2. Methodology

The analysis by the MALs has been carried out following a similar approach. An exception is the robustness analysis for the Belgian MAL (Oudlandpolder model) which is explained in Chapter 2. The general approach for assessing the robustness of business and policy actions is based on the following steps:

a. Inventory of actions: first, each MAL was asked to provide an inventory of the input variables used in their models and linked to the policy recommendations, with a brief description. These model variables are different from the scenario variables presented in deliverable D19. For example, 'the amount of water that can be withdrawn for irrigation' is such an input variable. The model variable or parameter is then linked to specific actions. For the previous example, this can then, for instance, be 'regulative actions increasing or decreasing the amount of water that can be used for irrigation'. In principle four different sets of measures were prepared. Each of these sets is made up of all the input variables. In the remaining part of this chapter an overview is given of the evolution of each of these entry variables under these different sets of measures.

b. Dynamics of model input variables: the impact of changes at the level of the input variables separately was already examined for the scenarios described in deliverable D19. Therefore the MALs were asked to design 3 to 4 sets of measures with all input variables allowed to change over their range simultaneously. The dynamics of the input variables for each set of measures was determined with the model and described in time graphs.

c. Assessment of impacts on KPIs: here the MALs were asked to describe the differences between the dynamic patterns of key variables – comparable to the work for the scenarios. The KPIs were identical to those used in deliverable D19, the difference being that the dynamics of these KPIs was examined for combinations of scenarios and sets of actions. The purpose was to assess the sensitivity for changes in measures relative to the impact of developments outside the system (as described by the scenarios).

d. General assessment: conclusions for each set of measures separately. Comparison of the KPI patterns with patterns presented in D19. Importance of taking actions within the region in the context of uncertain external conditions. General reflections beyond the individual KPIs, including take home messages for stakeholders and recommendations.

A detailed description with examples of the robustness analysis for the six MALs is provided in the following chapters. Data will be made available through the Knowledge Exchange Platform (https://coastal-xchange.eu/) and COASTAL data repository (https://zenodo.org/communities/773782-coastal/).

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2. ROBUSTNESS ANALYSIS OF POLICY AND BUSINESS ACTIONS FOR THE OUDLANDPOLDER, BELGIAN COASTAL ZONE

2.1. INTRODUCTION

This particular model differs from the models developed for the other MALs in that some of the model external drivers which could have been considered as policy inputs are an integral part of the model calculation. To be more specific, the polder water level management is an integral part of the model as the model itself calculates the amount of water that needs to be added or removed from the system to ensure that the water levels for agriculture and nature in the polder are consistent with the seasonal target levels. This implies that the modelled water system is with respect to its state variable, the polder water level, inherently robust. A robustness analysis can therefore not be based on the polder water level with this model. However, to maintain the polder water levels at an optimum value the model will remove or add water to the system. A too low polder water level which corresponds to water shortage is solved by taking water from the canal or some other source while too high polder water levels and thus excess water will be discharged to the sea. As water surplus and shortage occur at different times, water management involving intermediate storage through creek ridge infiltration is also envisioned as a solution in the polder. These water exchanges and th intermediate storage to creek ridges are clearly also subject to physical and other limitations, such as amount of water available in the canal, storage capacity available for creek ridge infiltration, possibility for discharge to the sea which presumes a level difference between the polder and sea water level to be gravitationally possible and/or additional pumping capacity. The robustness analysis will therefore be based on the water exchanged and not the polder water level.

As pointed out in D19 the model is in its current state not able to correctly describe the water dynamics in the Oudland polder with a daily timestep. This is due to the fact that the model does not adequately account for differences in the dynamics of the slowly responding but large groundwater component and the fast but in terms of water volume much smaller surface water component. As a consequence from the discussion with the stakeholders it was concluded that the dynamics of this model are not suitable to represent the daily dynamics of the water retention and buffering in the polder. The model results should thus be considered carefully keeping in mind these limitations. It was therefore decided for the assessment of the robustness to consider a coarser temporal resolution of a year when presenting the results and to base the analysis mainly on changes instead of absolute daily values.

To conclude, when using the model to determine the robustness of the proposed measures we need to take into account that 1) we should not focus on the polder water level itself but on the amount of water exchanged with the system boundaries in our analysis and 2) we should look at differences and trends in yearly values instead of the absolute daily values calculated by the model. While from a hydrodynamic point of view (e.g. flash floods) the latter may be of limited value, for the purpose of a long-term system analysis over a period of 80 years this still fits the bill.

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2.2. PRESENTATION OF THE MEASURES FOR THE OUDLANDPOLDER

In the context of COASTAL, we choose to focus in our System Dynamics (SD) model on a selection of land planning and management challenges that will most probably have an impact on the Oudland polder's water management system. An overview of the water management model for the Oudland polder is presented in Figure 1. In the figure the main state variables considered are shown as blue boxes: water level for agriculture and nature and water storage in the creek ridge buffer. Climate change affects the precipitation, water demand (evapotranspiration) and how much water needs to be discharged to the sea while the land use will determine the fraction of land allocated to respectively farming and nature. Policy actions, coloured red in Figure 1, are then water outtake from the canal, water discharge to sea, pumping between the agricultural and nature compartments and intermediate storage in creek ridge buffers.

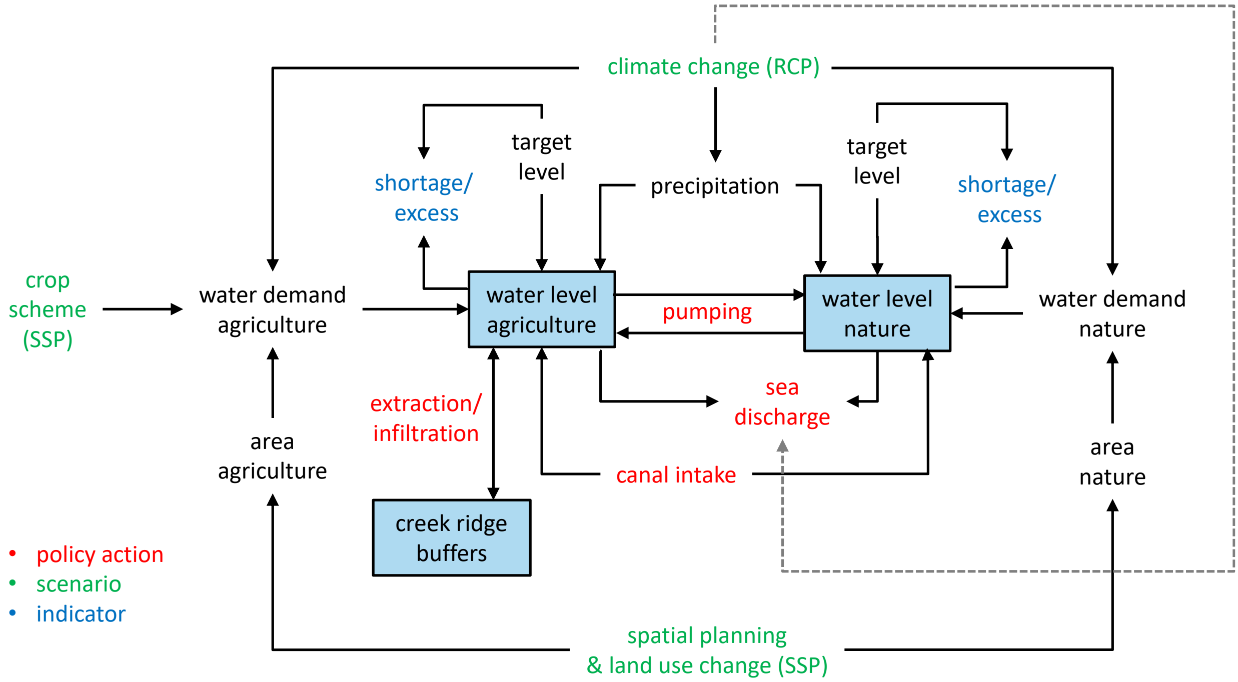

Figure 1: Schematic overview of the water management model for the Oudland polder.

The model was developed together with the Flemish Land Agency (VLM) to obtain high-level, systemic understanding of the mid- and long-term impacts of water management actions on the average water level for the Oudland polder in Belgium in the framework of the new Spatial Implementation Plan. The model considers separate compartments for agriculture and nature, and considers scenarios for climate change, land use and crop schemes. Water levels in the agriculture and nature compartment are optimized based on monthly target levels and day-to-day decisions on water management actions such as canal or waste water treatment plant effluent intake, sea discharge and creek ridge extraction or infiltration. The model uses a time horizon of 80 years (2020-2100) and a time step of 1 day, to align with the practice of water management decisions such as the opening of sluices. The model uses diverse data related to land use cover change, climate change, meteorology, water management, and crop farming including the Royal Meteorological Institute (KMI) of Belgium for meteorological parameters and the FAO for crop factors to derive reference evapotranspiration. Operational water management parameters such as desired levels and thresholds for gravitational sea discharge were discussed with and provided by the VLM. Driving scenarios are based on the Shared-Social Economic Pathways (for crop schemes and land use patterns, see https://doi.org/10.5281/zenodo.7081500), the VITO RuimteModel for land use change (see https://vito.be/en/product/geodynamix-spatial-modelling-tools), RCP-based projections for temperature, potential evapotranspiration and precipitation, and related sea level projections (Fox-Kemper, B., et al., 2021).

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The model was developed with the VenSim PLP software (https://vensim.com/) and can be accessed through https://zenodo.org/deposit/7082571.

From Figure 1 we can also deduce that the measures for the Oudland polder will target the following variables in the model :

1. Water outtake from the canal
2. Water discharge to the sea
3. Pumping between agriculture and nature in the polder
4. Creek ridge infiltration

The last two measures, pumping between agriculture and nature and creek ridge infiltration were both implemented in the model but will not be considered in what follows. Creek ridge infiltration is seen as a solution for storing water during periods with water excess for use during periods where there is a water shortage. With pumping between nature and agriculture, water will be moved between these two compartments instead of discharging it to the sea. This exchange is based on whether either of these compartments has a water demand which can (partially) be met by a surplus in the other compartment. Both the creek ridge infiltration and pumping between agriculture and nature imply an intra-annual and even intra-month redistribution of water. As the results at a time scale of less than a year are not considered reliable we therefore don't consider these two measures in our analysis.

The context in which these water management measures are implemented is determined by the Shared Socio-economic Pathways (SSPs) complemented with Representative Concentration Pathways (RCPs). Details are provided in D'Haese et al. (2022).

For the climate scenarios input was prepared for 4 different RCP scenarios: RCP2.6, RCP 4.5 RCP 6.0 and RCP 8.5. The following variables are considered in the model:

1. Precipitation: climate change will mainly affect the distribution over the year. With climate change less rainfall is expected during summer and more during wintertime. The more severe the climate scenario is, the more pronounced this phenomenon is expected to be.
2. Evapotranspiration: water loss for the area through evaporation and plant transpiration. Higher temperatures during summertime will result in more water loss through evapotranspiration.
3. Sea level rise: for gravitational water discharge from the Oudlandpolder to be possible the water levels in the polder during (part of) the day need to be higher than the sea water level. When the opportunity for gravitational discharge is too small or even non-existent, water will need to be discharged using pumps.

The evolution of these climate variables for the RCP2.6 and RCP8.5 which are respectively considered as a minimum (RCP2.6) and maximum (RCP8.5) scenario, is depicted in Figure 2. From Figure 2 it is clear that more severe climate change (RCP8.5 vs RCP2.6) will result in more precipitation during wintertime and less precipitation but higher temperatures and thus more evapotranspiration during summertime. The sea level will also rise more with more severe climate change.

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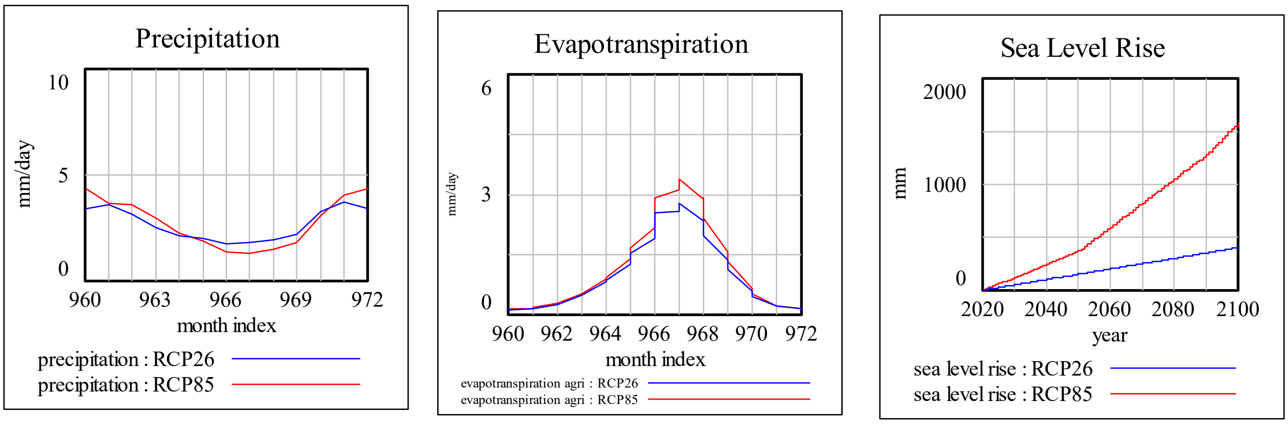

Figure 2: Precipitation and evapotranspiration distribution for the 12 months of 2100 and sea level rise from 2020 to 2100 for the minimal (RCP2.6) and maximal (RCP8.5) climate scenario's considered in the model.

Besides the climate, the land use detemines the context in which the measures are implemented. For the land use 4 scenarios were calculated using the VITO Ruimtemodel:

- Full sustainability (SSP1): RCP2.6 + Anti-Urban Sprawl (AUS)
  This scenario takes account of a population growth of 63,771 residents in 2013 to 80,574 residents in 2050 (rise of 21%). Most of this growth can be attributed to the towns/cities and the large coastal municipalities.

- Not choosing is losing (SSP2): RCP4.5 + Business As Usual (BAU)
  This scenario assumes a population growth of 63,771 residents in 2013 to 73,612 residents in 2050 (rise of 11%).

- Structural inequality (SSP4): RCP6.0 + Growth As Usual (GAU)
  This scenario takes account of a population growth of 63,771 residents in 2013 to 74,522 residents in 2050 (rise of 12%). As a result of the ability to eat into more and more new open spaces, a relatively large proportion of this population growth can be ascribed to smaller municipalities such as Zuienkerke.

- Technological optimism (SSP5): RCP8.5 + Flanders Spatial Policy (FSPP)
  Technological optimism (SSP5) – Flanders Spatial Policy Plan: This scenario is also linked to population growth: from 63,771 residents in 2013 to 88,419 residents in 2050 (rise of 33%). This population rise is largely situated in the larger towns/cities.

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The land use maps for these scenario's are shown in Figure 3.

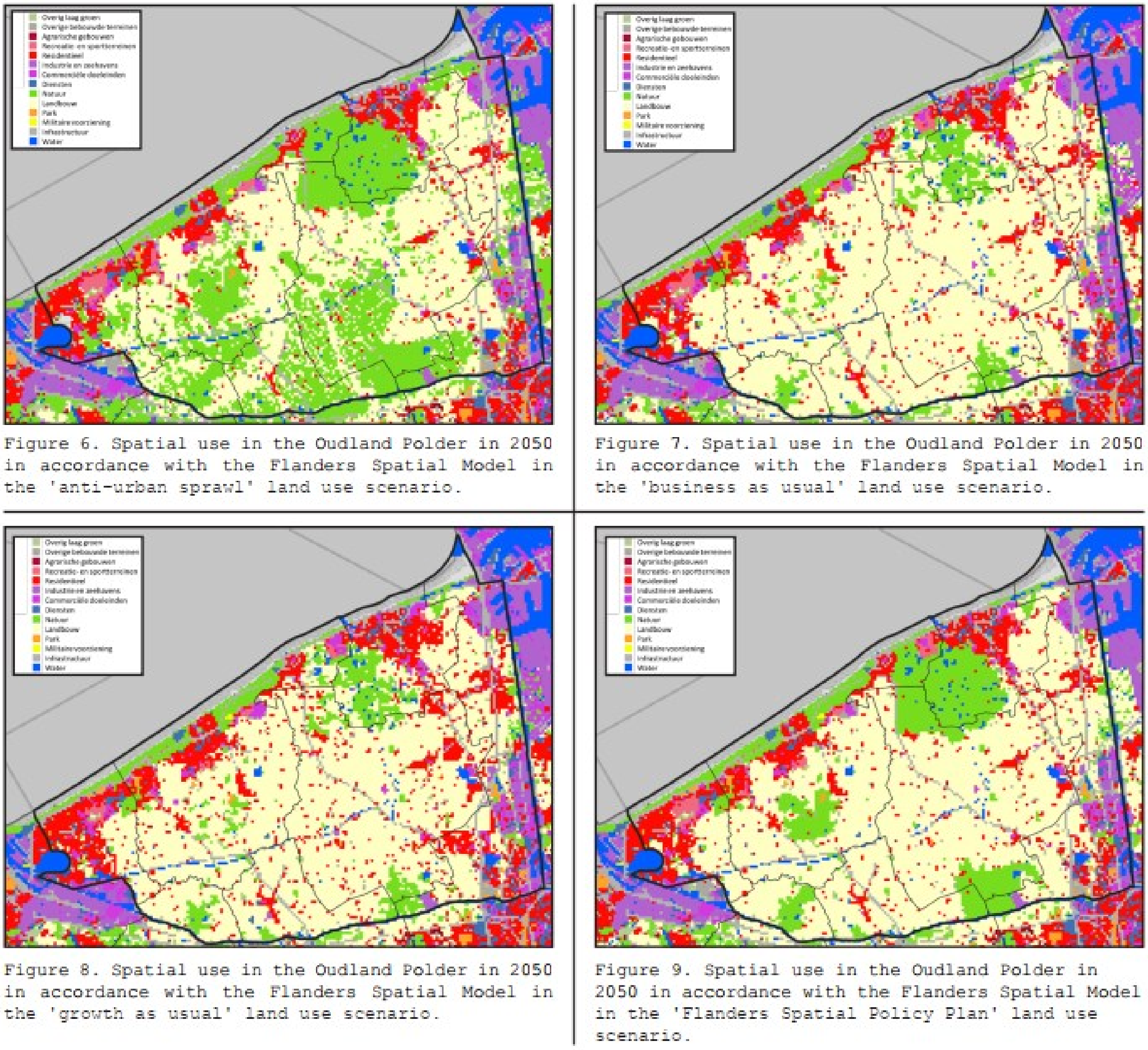

Figure 3: Land use by 2050 as calculated with the VITO RuimteModel (see Policy Recommendations available on Zenodo: https://doi.org/10.5281/zenodo.7081821) (D'Haese et al. ,2022).

A final important input considered is the choice of crops on the agricultural areas. These are related to the choice of SSP in the model. The following crop schemes are considered :

• Crop SSP1: SSP1 is characterised by a drastic swing in the nutritional pattern in rich regions like Flanders. There will be a switch to a largely vegetable-based diet. In this vegetation scenario, it is therefore assumed that more and more of the creek ridge grounds will be used for vegetable cultivation as we approach 2050. (The vegetables on which the analyses will calculated are peas and sprouts.)

• Crop SSP2: SSP2 stands for 'business as usual'. Continuing to walk the path set out upon in previous years. This scenario maintains the same cultivation distribution as could be found in the Oudland Polder in 2020.

• Crop SSP4: SSP4 is characterised by rising structural inequality. This scenario therefore follows the rationale that the high-quality agricultural grounds on the creek ridges will increasingly end up in the hands of large

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agro-industrial players targeting the international market. The proportion of agricultural commodities, in these analyses considered to be wheat, will thereby substantially increase by 2050.

• Crop SSP5: SSP5 is a development path that is characterised by technological development and regional specialisation. Given the proximity of the Ghent and Antwerp port industrial cluster, this cultivation scenario thereby presupposes strong growth in the biobased economy, and therefore a constantly rising demand for vegetable carbohydrates. Consequently, a major proportion of the agricultural area is used for the cultivation of sugar beets in this cultivation scenario.

In Figure 4we present the distribution over the different crop/vegetation types considerd for the different SSPs.

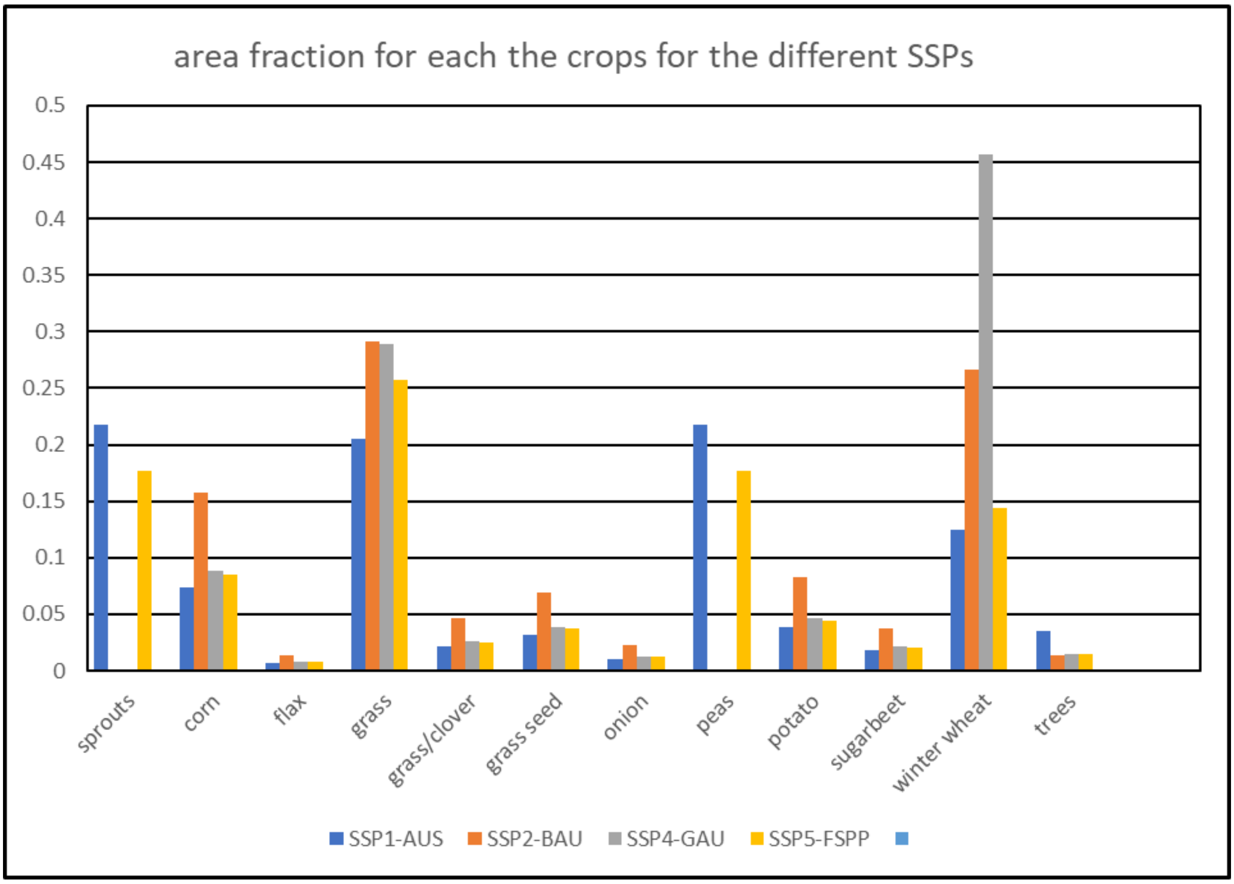

Figure 4: Area fraction assigned to each of the 12 vegetation types and the 4 SSPs considered.

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2.3. ASSESSMENT OF THE DYNAMIC PATTERNS

2.3.1. Introduction

In this chapter we'll discusss the effect of the major variables that impact the model recharge to and the discharge from the polder. As presented in **Error! Reference source not found.** these are the climate, the land u se and vegetation in the polder. All these effects will be assessed assuming that an infinite amount of water is available for recharge and water can always be discharged regardless of whether the required discharge exceeds the capacity of the gravitational discharge to the sea. By then considering the required amounts of water to what is today available in terms of recharge from the canal and discharge to the sea the severity of the impact can be estimated.

2.3.2. Long term impact of climate change

To assess robustness of the water management with climate change we will consider the water exchanged in for both RCP2.6 and RCP8.5. These two climate scenarios are the two extreme scenarios in our case. The effect of changing the climate scenario from RCP2.6 to RCP8.5 is shown (Figure 5) for the case where the land use change is set to 'Flanders spatial policy plan' (FSPP/SSP5) which is in between the business/growth as usual and anti-urban sprawl plans and with the same crop scheme SSP2-BAU.

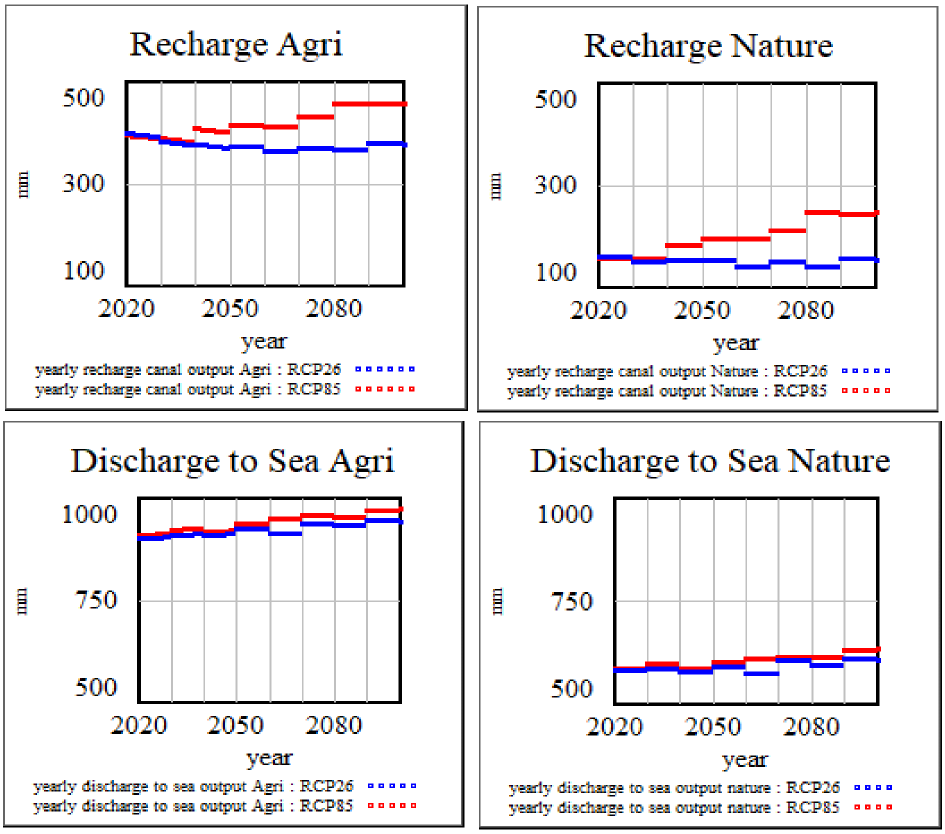

Figure 5: Discharge and recharge for the agricultural and natural areas for the RCP2.6 and RCP8.5 scenarios for the Oudlandpolder for the period 2020 – 2100 with FSPP land use and SSP2-BAU crop.

In Table 1**Error! Reference source not found.** the changes from 2020 to 2100 in the water amounts exchanged both to (recharge) as from (discharge) the Oudlandpolder as calculated by the model. It can be observed that change in water needed to sustain the water level in the natural areas will be bigger than the change in water needed for agriculture areas. The total amounts of water needed for agriculture are however much larger, the ratio between de requirements in the agricultural area to the one in the natural area decreases from 2.2 times in 2020 to 1.8 time in 2100. Also for the discharge to sea the amounts that would ideally need to be discharged from the agricultural areas are much larger than for the natural areas. Contrary, to the recharge however the increase in discharge to the sea from 2020 to 2100 will be larger for the areas use for farming than those that are destined for nature.

Table 1: Yearly amounts of water exchanged with the Oudland polder (mm/year) to ensure that the water level is kept at the optimal level in both 2020 and 2100 for the RCP8.5 scenario.

		2020	2100	change
Recharge to polder	Agriculture	405	458	53
	Nature	181	246	65
Discharge to sea	Agriculture	918	975	57
	Nature	584	633	48

The above can also be presented in terms of water volumes. The Oudlandpolder has a surface area of 125 km^2 of which around 80% is used for farming and 20% for nature. 1 mm of water then corresponds to 125,000 m^3 of water for the Oudland polder and an additional input of 53 mm and 65 mm for respectively agriculture and nature by the end of the century would mean that an additional amount of 7 million m^3 of water is required on top of what is needed now. To put this additional volume in perspective: in 2020, according to VLM data, about 3 million m^3 of waste water treatment plant water (WWTP)was used for the Oudland polder which is less than half of what would be additionally needed in the Polder by the end of the century. For the discharge to the sea the changes of 57 mm and 48 mm by the end of 2100 for respectively agriculture and nature correspond to an additional discharge of 7 million m^3. Antea (2018) in waterbalance study of the area estimate the discharge to see at around 1.5 m^3/s. Assuming that water is mainly discharged during winter time, the additional discharge corresponds to 0.9 m^3/s.

In Table 2 the difference in yearly recharge and discharge of the polder for the climate scenarios in 2100 is shown. Curbing climate change will clearly make a big difference.

Table 2: Yearly amount of water exchanged with the Oudland polder (mm/year) to ensure that the water level is kept at the optimal level in 2100. Difference between the RCP2.6 andRP8.5 scenarios for 2100.

	RCP2.6	RCP8.5	RCP8.5 – RCP2.6
Recharge to polder	331	415	84
Discharge to sea	875	906	31

From Figure 5 it can be seen that the main demands in terms of water recharge and discharge are those of the agricultural areas. This is not unexpected and can be related to the bipolar nature of the water demand by the agiculture: in winter, early spring and autumn (harvest) water needs to be removed so that the fields are trafficable while during summer water is needed by the crops. In the next chapters we'll therefore also mainly focus on the results for agriculture as the water management for agriculture will determine the dimensioning for the additional recharge and discharge.

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Finally, the decrease in recharge seen in for both agriculture and nature for the RCP2.6 climate scenario is due to the choice of landuse and cropping scheme in the agricultre. For a different land use and cropping scheme where the evaporation demand is lower this will not be the case. This is illustrate in Figure 6 where we selected a crop scheme that requires more water (SSP4). The decrease then becomes an increase. This ilustrates that the results for the two climate scenario's discussed above have to be seen in the light of the specific landuse and crop scenario. It also means that for the RCP8.5 even bigger changes are possible if the RCP8.5 is evaluated for other land use and cropping scenarios.

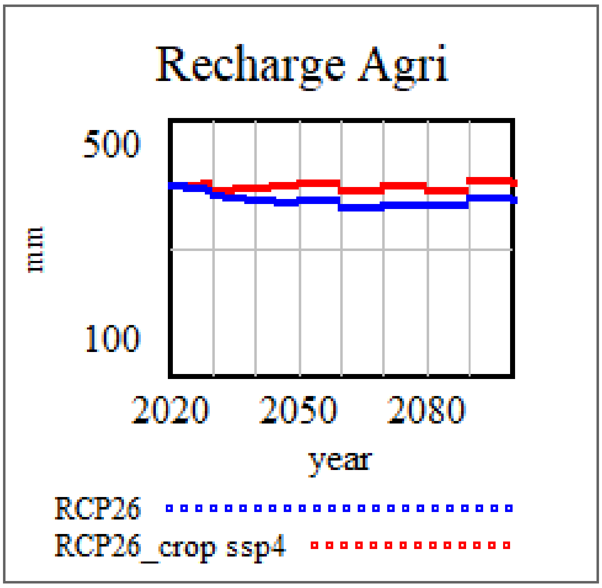

Figure 6: Recharge from the canal for agriculture for the RCP26 scenario considering both an average cropping scenario (blue) and a cropping scenario that required more water (red).

2.3.3. Effect of landuse change

The water management is to a large extend determined by the land use. For agriculture the polder water level will be lowered outside the growing season to drain water away from the fields so that tillage and harvest are possible while during summertime water levels ar raised to supply water to the crops on the fields. In natural areas on the other hand the water level is kept almost constant. Spatial planning in which the area designated to nature and/or agriculture is changed will therefore clearly affect the amount of water that needs to be supplied and/or removed from from the area.

For the land use change the anti urban sprawl (AUS) and the Growth As Usual (GAU) present the two extremes (see Figure 3). As RCP8.5 is our most exrteme climate scenario we consider this as our climate scenario for which we want to assess recharge and discharge changes with the landuse scenarios AUS and GAU. For the part of the area used for agriculture the crop scheme Business As Usual (BAU) was as this an intermediate crop scheme scenario.

The difference in recharge required and discharge to sea for the AUS and GAU land use scenarios is shown in Figure 7 and the values themselves (mm/year) are listed in Table 3.

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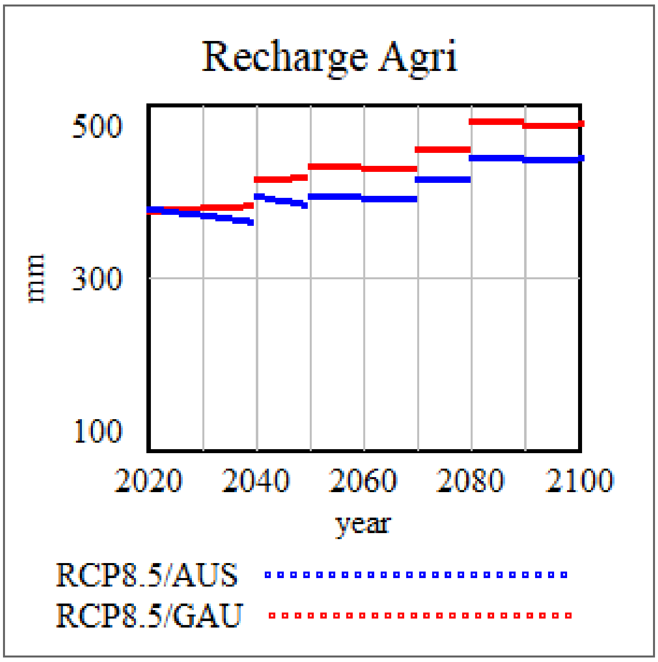

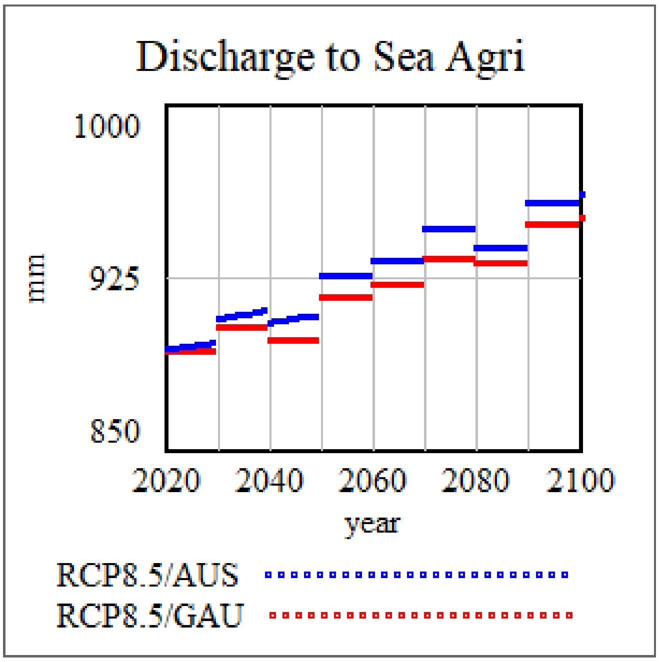

Figure 7: Discharge and recharge (mm/year) for the agricultural area in the Oudlandpolder for the anti-urban sprawl (AUS) and Growth as Usual (GAU) for the RCP8.5 climate and Business As Usual crop scenarios

For GAU, where the water demand by the crops is higher, the additional recharge for GAU compared to AUS amounts to 32 mm/year which is the equivalent of 3.2 million m^3/year which is more than the water available from the WWTP in 2022. For the discharge to sea it is noticeable that the sustainable land use option will result in a slightly larger discharge to sea than for GAU, the land use scenario requiring more water. It is also exactly the latter that explains this result: as GAU uses more water than AUS there is less water to discharge.

Table 3: Yearly amount of water exchanged with the Oudland polder (mm/year) to ensure that the water level is kept at the optimal level in 2100. Difference between the AUS and GAU crop scenarios when considered for the RCP8.5 climate scenario and Business As Usual crop scenario.

	AUS	GAU	GAU – AUS
Recharge to polder	391	423	32
Discharge to sea	879	875	-4

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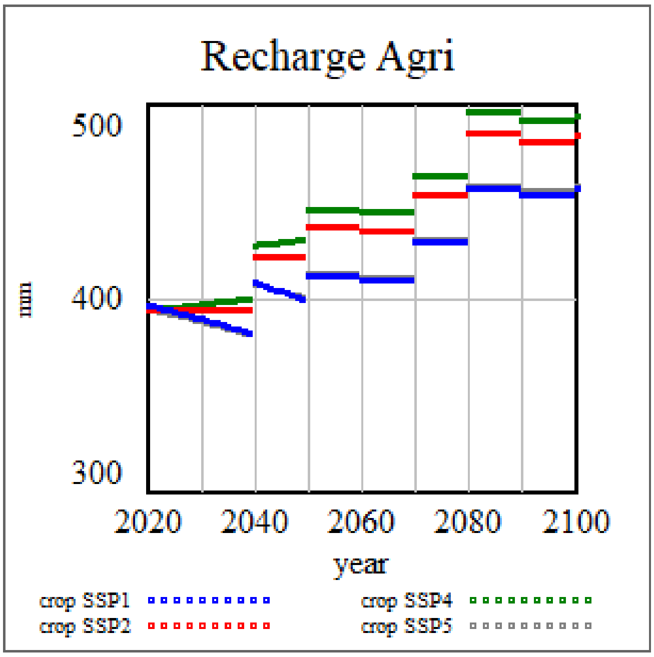
2.3.4. Effect of crop choice

As a final factor the effect of the cropp scheme was investigated. Also for these tests the climate scenario was set to RCP8.5 as this represents the worse case climate scenario in our model. For the landuse scenario we selected the'Flanders spatial policy plan' (FSPP/SSP5). The resulting differences in recharge and discharge are shown in Figure 8 and Table 4. The SSP4 scenario with high water demand in summer time clearly constrasts with the SSP1 scenario that requires 31 mm/year less water. These 31 mm/year correspond to the water available from the WWTP in 2020. As also noticed in the previous chapter the higher water demand for the SSP4 also results in a lower need for discharging water to the sea: 11 mm/year more needs to be discharged for SSP1 than for SSP4.



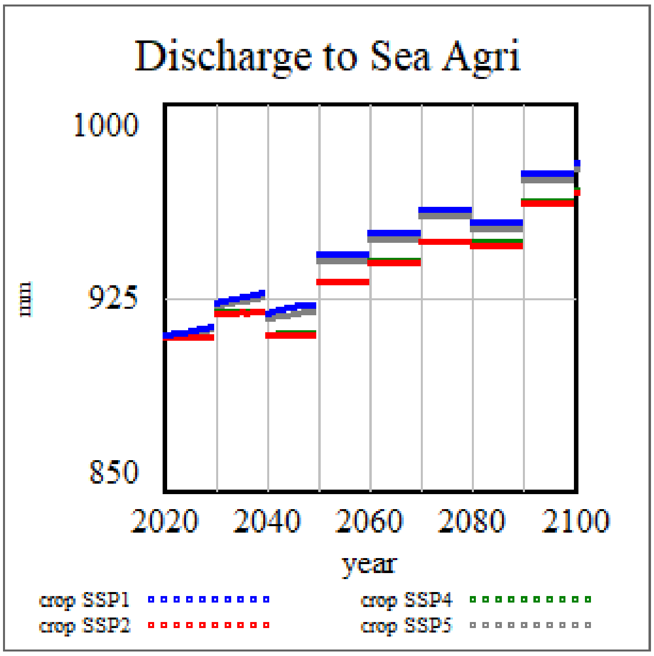


Figure 8: Discharge and recharge (mm/year) for the agricultural area in the Oudlandpolder for the different crop scenarios in the model for the RCP8.5 climate and the FSPP land use scenarios.

Table 4: Water exchanged (mm/year) in 2100 for the different cropping schemes when applied with the RCP8.5 climate an FSPP land use scenarios.

	Recharge	discharge
Crop SSP1	401	896
Crop SSP2	424	887
Crop SSP4	432	888
Crop SSP5	403	894

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2.4. CONCLUSIONS

Water management in the polder aims at keeping the poldert water level at certain target levels values. Normally, for this model the polder water level would therefore have been the ideal candidate as an indicator to assess the model robustness. However, in our model the polder water level is optimised by the model itself and can not be used to assess model robustness. In the optimisation process, the model will calculate how much water needs to be added or removed to the polder to keep the polder water level at the optimal target value. Instead of looking at the polder water level we have therefore assessed to what extend the different elements that affect the polder water level will change the water recharge and discharge from the polder.

As the short term dynamics of the model were found to be to deficient, the focus in our analysis is based on yearly values resulting from the daily calculations of the model . This is also in line with the long term horizon of our model spanning 80 years. Using yearly values off course will have some limitations. For one, our analysis will not be of any use for assessing flash floods but that in the end is not the purpose of our system dynamics and other models have been developed for that.

In our analysis we have focused on the three elements affecting the water management requirements most in the model: the climate, the land use and the crop scheme. All these three elements interact and the net result on the water recharge and discharge will depend on the combined effect these three have. The most important observations that can be made from our analysis are:

- Climate change will have the largest impact of the three elements both on the extra recharge required for the polder and the water that needs to be discharged from the polder to the sea.

- By selecting a land use and/or crop scenario that consumes less water, the increase in recharge can be reduced but at the same time this decrease in the amount of water required for recharge could go hand in hand with an increase in the amount of water that needs to be discharged to sea. So decreasing water use might result in more water having to be discharged to sea. We on purpose wrote 'could' and 'might' in the previous sentences as improving the short term dynamics of the model by considering the buffering effect of the slow but large groundwater compartment in the polder might result in a different conclusion.

- The extra recharge required in the extreme scenarios considered is signficant. The additional volume required is of the same order and in case of the climate scenarios larger than the water volume from the waste water treatment plant that was supplied to the polder in 2022.

- The discharge is maybe even more troublesome as rising sea levels wll make it more and more difficult and maybe even impossible to discharge water from the polder gravitationally. The model also does not consider salt water intrusion. Salinification of the aquifer will also worsen with the rising sealevel and will need to be counteracted by additional water inputs.

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3. ROBUSTNESS ANALYSIS OF POLICY AND BUSINESS ACTIONS DESIGNED FOR SOUTH-WEST MESSINIA

3.1. PRESENTATION OF THE MEASURES FOR SW MESSINIA

In D19 we show the effect of external socioeconomic changes in the area without any local measures. In this deliverable we will see the effect of the proposed policy measures and actions identified in the Business Road Map (COASTAL D11) and whether these are sufficient in maintaining a sustainable pathway for the SW Messinia.

The vision developed by the stakeholders of MAL2 is based on the ideal concept of achieving a sustainable and balanced interaction with the environment, through processes that are dynamic and allow the system to be resilient to external and internal pressures as well as shocks. In order to address the system's resilience and robustness to the different Shared Socioeconomic Pathways (SSPs) (O'Neill, Brian C., et al. " 2014) it was decided that climatic changes would be kept to an agreed minimum, hence all scenarios presented in D19 and also here are under RCP2.6. In order to develop strategic policy guidelines and business solutions supporting the pathway towards a resilient future it is important to be able to measure the system's vulnerability to shocks, identify possible tipping points and analyse the robustness of the system under different conditions. With this in mind the scenarios and storylines presented in D19 show the trajectory of the area under no local changes, i.e. no effort in implementing the sustainability vision of the local community.

Thus the question still remains how would the progress of implementing the vision would be affected under the different SSPs which are translated as different external pressures, as explained in D19? And also are the changes proposed by the local population enough to support a sustainable pathway under any possible future?

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 products*". It was agreed that sustainability and the achievement of acquiring this brand name is dependent upon

1) The adoption of integrated farming practices
2) The restoration and enhancement of wetland ecosystem services in Gialova Lagoon wetland
3) The promotion of thematic tourism as a sustainable alternative to beach tourism.

The set of measures corresponding to achieving this is described in detail in the BRM (COASTAL D11) and are summarised in (Figure 9 Summary of the BRM actions included in the BRMFigure 9 Summary of the BRM actions included in the BRM

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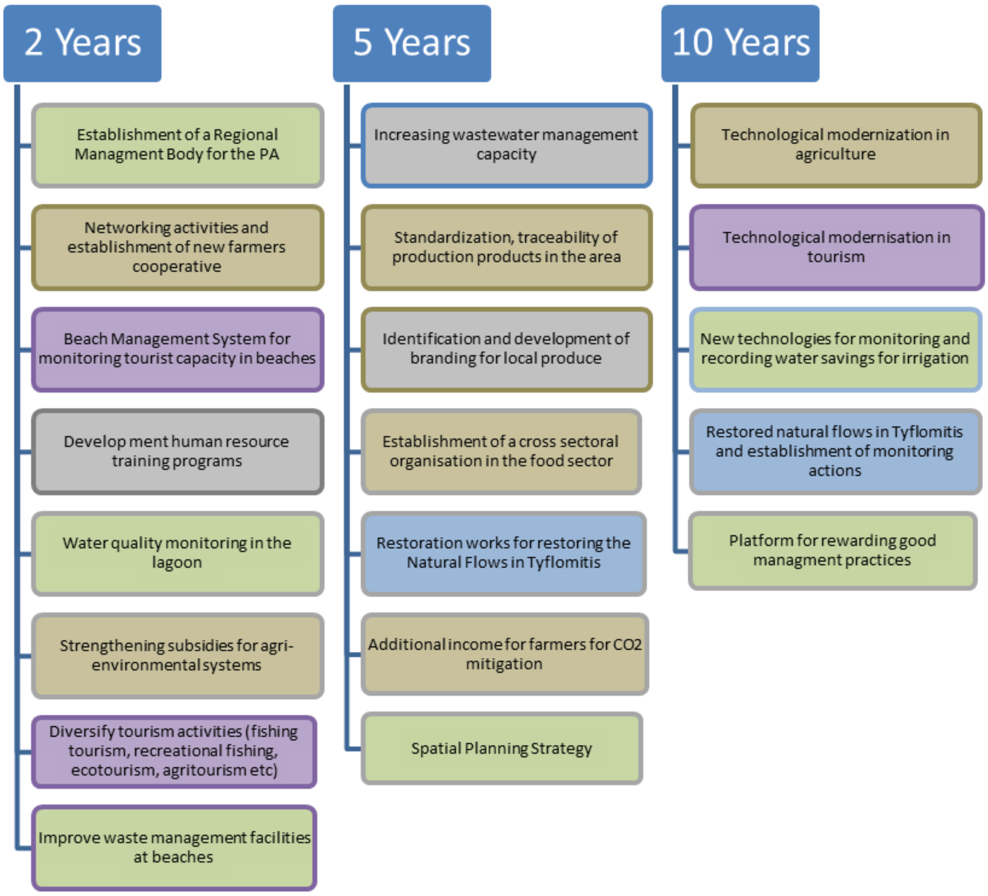

Figure 9 Summary of the BRM actions included in the BRM

Based on the stakeholder discussions, prior to quantifying the scenarios, we developed three scenario storylines in relation to the implementation of the vision and the Business Road Map (BRM): The storylines describe how the conditions in the area would be formed under the different socioeconomic pathways, and how would these changes affect the implementation of the proposed BRM actions. As the stakeholders participating in the MAL have agreed to take actions under all possible futures we assume that certain aspects of the BRM will be implemented. However, the implementation of the BRM actions will be affected resulting in slower or less effective implementation of certain actions.

Scenario 1: Following a Sustainable Pathway (SP)

Under this scenario it is assumed that societies will become more collaborative, in recognition that common goals can only be achieved through integrated partnerships. As a result this is the scenario where a ***full and fast implementation of the BRM*** is achieved.

Storyline

Actors throughout the area will work together to achieve the land sea synergies. This future will facilitate the implementation of the BRM and will enhance the transition towards organic agriculture. Policies are supportive to sustainable and collaborative practices offering financial support and promoting inclusive governance. Equitable practices and high agency build trust and understanding among farmers. Coupled with the increasing support for agriculture and the establishment of a spatial plan for the area the trend of land use change and acquirement of secondary houses is contained. Water demand, for irrigation and municipal use is decreased due to the awareness campaigns and network improvement actions as well as the efficient usage both in agriculture and in tourist facilities. Wetland restoration actions are implemented with high priority, and as the aquatic habitats are gradually improved the benefits for the local society are multiple (nature conservation, fishing, eco-tourism development).

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Scenario 2: Improving Current trends (ICP)

Under this scenario it is assumed that the partners will be invested in the vision. Still, they will tend to follow their own work plans, working haphazardly towards the BRM implementation. Hence, ***certain aspects of the BRM will not be implemented effectively***.

Storyline

There is reduced level of agency and equity. The success is much more dependent on outside drivers such as policies and supporting subsidies.The partnership is more vulnerable and weak to attract new partners, hence the transition is being slowed down and organic farming transition is not achieved. The lack of spatial planning policies remains and the interest to build secondary houses and tourist accommodation continues to be a driver for land use change. However, others will become interested in the natural assets of the area. Eco-tourism and agro-tourism activities will become popular but without reaching their full potential. Wetland restoration actions are implemented with medium priority, and there is a risk of collapse. Eventually, the challenges are tackled and the wetland is managed to support nature conservation, sustainable fishing, and eco-tourism activities. To be able to simulate this effect we have assumed that the BRM will be implemented at 50% effectiveness

Scenario 3: Quick Development in a Fragmented Territory (QDFT).

Under this scenario the implementation of the vision depends upon a dominant partner who holds the vision, mission and strategy of the partnership. Hence, there are ***difficulties to implement certain actions in an equitable and inclusive manner***. Still, as the dominant partner is interested in green development, the restoration of the lagoon as well as eco-tourism activities will be implemented.

Storyline

Tourist growth rates are expected to remain high, without any control on new infrastructure development. Under these conditions there is a collapse risk in the lagoon, as well as increased the alteration to the landscape attractiveness. Public payments to the agriculture and food systems are drastically reduced to conform to liberalized and integrated markets hence there is a reduction in the overall policy support for small scale farmers. Together with reduced interest for collaboration, the farmers' cooperative cannot attract members hence reducing the rate of transition to integrated and organic agriculture. Additionally, as farmers receive reduced support from policies they will have increased interest in selling their land, which coupled with the lack of spatial planning policies will result in an increased rate of land use change. Wetland restoration actions are implemented with medium priority, which depending on climatic changes could lead to a temporal or long term collapse of the lagoon fisheries. Eventually, the challenges are tackled and the wetland is managed to support nature conservation, sustainable fishing, and eco-tourism activities. Under this scenario the actions described in the BRM are only partially implemented. To be able to simulate this effect we have assumed that the BRM will be implemented at 30% effectiveness.

For the purpose of this research three groups of actions were prepared, corresponding to the 3 major courses identified in the vision.

i) Actions influencing the future on the agricultural sector and in particular the transition from conventional to integrated to organic olive oil farming
ii) Actions influencing the restoration and enhancement of Ecosystem Services in the Lagoon.
iii) Actions influencing the transition to alternative tourism.

In the table below an overview is given of each of the variables and parameters, where systemic interventions enter the SD-model for Messinia. The first column gives the variables' names. What these variables stand for, can be read in the second column. The third column, finally, gives an overview of the policy and/or business actions that may in reality (indirectly) change the variable's state. A given input variable can represent several actions described in the BRM, and a given BRM action can be represented by several input variables

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Table 5 Variables in the model that reflect actions introduced with the BRM

Name entry variable or parameter	Description	Type of real actions reflected in variable
Policy Adoption (Natura)	adoption of multi –level governance system as a management decision support system to achieve a satisfactory conservation status in the wetland	Establishment of a Regional Managment Body for the PA that will be responsible for implementing the management plan
Transition factors	A range of activities concentrating in assisting farmers into adopting integrated and organic practices.	Networking activities and establishment of new farmers cooperative Development human resource training programs Strengthening subsidies for agri-environmental systems Technological modernization in agriculture
Waste generation awareness	A range of activities to reduce the quantities of litter and improve waste management	Improve waste management facilities at beaches
Surface freshwater input	A number of technical interventions to restore the flow of surface waters into the wetland/lagoon, in order to solve the problem of increased salinity	Interventions for restoring the Natural Flows in Tyflomitis and Xerolagados
Land Use Change	the rate of Land Use Change	Spatial Planning Strategy
Water supply network (improvement)	Investments for replacing the water supply network and reduce losses. The action is linked to groundwater abstractions from Tyflomitis aquifer.	Water practice changes
Water demand (per capita)	water consumption by the local population	Water practice changes
Water demand (per tourist)	water consumption by tourists	Water practice changes

Each storyline' quantification is made up of all the entry variables and parameters listed in the table above. Yet, under each of these sets of measures these variables and parameters are linked to different data ranges, and hence referring to business and/or policy actions that intervene more or less seriously in the modeled coastal system. Overall, given the descriptive storylines of the possible pathways we assumed that:

i) Under scenario 1 we will have a full implementation of the proposed actions
ii) Under scenario 2 the proposed actions will be implemented at a value range of 50% and
iii) Under scenario 3 the proposed actions will be implemented at a value range of 30%

These values were chosen to reflect the effect of the different future conditions (SSPs) as described in COASTAL D19

Table 6 The evolution of the variables reflecting the BRM actions and policy measures

Variable	**Description**	**Unit**	**2010 value**	**2020 value**	**SP (2050)**	**ICP (2050)**	**QDFT (2050)**
Policy Adoption (Natura)	This variable ranges from 0 (no environmental management) to 1 (full implementation of the Natura2000 framework)	Dmnl	0,1	0,1	1	0,7	0,48
Surface freshwater inputs to lagoon	The volume of freshwater inputs which feeds the lagoon. This variable depicts the volume of water that is needed annually to	m^3/ Year	176446	184645	677178	1211271	1379112

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	first restore and then regulate the lagoon salinity.						
Water supply network (improvement)	This variable ranges from 0 (*no improvements*) to 0,37 (*total network replacement*)	Dmnl	0	0	0,3	0,15	0,1
Water demand (per capita)	Daily average water consumption by the local population	m^3/ person	0,25	0,25	0,23	0,25	0,27
Water demand (per tourist)	Daily average water consumption by tourists	m^3/ person	0,5	0,5	0,45	0,5	0,55
Transition factors	This value ranges from 0 (*lack of support to farmers*) to 1 (*full support to farmers*)	Dmnl	0,11	0,13	0,99	0,47	0,38
Land Use Change	the value ranges from 1 to 0	Dmnl	1	1	0,28	0,64	0,76
Waste generation awareness	Daily waste generation by locals and visitors	Kg/ person	0,86	0,86	0,5	0,68	0,74

Policy Adoption (Natura)

In 2021, the Special Environmental Study for the protected areas (PAs) of the case study has been validated (the initial study was implemented in 200&) and the environmental management of the PAs have been assigned to an already operating Management Body. Hence, it is assumed that the implementation of environmental management actions within the protected areas of the case study will proceed within the coming years. Nonetheless, the progress of the implemented actions is dependent on the year of implementation and thus the efficacy is expected to be different under each scenario.

***Following a Sustainable Pathway (SP)*:** the implementation of actions (conservation, awareness) is progressing fast reaching the value 1 by 2030.

Improving Current trends (ICP): the current delays in implementation continue and we assume that by 2030 the value of this parameter is at 0,54.

Quick Development in a Fragmented Territory (QDFT): the progress of actions is low and we assume that by 2030, the value of this parameter is at 0,37.

Surface freshwater inputs to lagoon

To increase the volume of surface freshwater inputs to lagoon, the implementation of technical interventions for restoring the natural flows is needed. Within the model, this can be achieved once the ***Policy adoption (Natura)*** variable reaches the value 0,4 and continues as the value increases.

***Following a Sustainable Pathway (SP)*:** the technical work for the restoration of natural flows starts already in 2023 with the aim to regulate the salinity within the lagoon.

Improving Current trends (ICP): the technical work for the restoration of natural flows starts in 2025.

Quick Development in a Fragmented Territory (GDFT): the technical work for the restoration of natural flows starts already in 2034.

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Water supply network (improvement)

***Following a Sustainable Pathway (SP)*:** the whole network is upgraded. We assume that the value of the parameter reaches its highest value (0.3) by 2026, and remains the same for the coming decades.

Improving Current trends (ICP): only part of the network is upgraded. We assume that the value of the parameter reaches its highest value (0.15) by 2026, and remains the same for the coming decades.

Quick Development in a Fragmented Territory (GDFT): We assume that the value of the parameter reaches its highest value (0.1) by 2026, and remains the same for the coming decades.

Water demand (per capita/tourist)

***Following a Sustainable Pathway (SP)*:** water demand is gradually decreased. We assume that by 2050, the water demand per capita will be decreased by more than 8% while the water demand will be decreased by more than 10%.

Improving Current trends (ICP): Water demand follows the current trends which, within the model it is set at 0,25 m3/day per capita and at 0,5 m^3/day per tourist.

Quick Development in a Fragmented Territory (GDFT): water demand is gradually increased. We assume that by 2050, the water demand per capita will be increased by more than 8% while the water demand will be increased by more than 10%.

Transition factors

***Following a Sustainable Pathway (SP)*:** the support to local farmers is strong. Already by 2026, the value of this variable is increased by more than 140% (0,72) and reaches the maximum (1) by 2050.

Improving Current trends (ICP): the support to local farmers is improved. By 2026, the value of this variable is increased by more than 100% (0,4). After 2026, the increase is small and by 2050 it reaches the value of 0.47.

Quick Development in a Fragmented Territory (GDFT): the support to local farmers is improved. By 2026, the value of this variable is increased by 88% (0,31). After 2026, the increase is small and by 2050 it reaches the value of 0.38.

Land Use Change (rate)

The values of the variable Land Use Change (LUC) are directly linked to the implementation of spatial planning strategy that limits the development of new built up land. The issue of built up land has been discussed as part of D19 scenarios as well. However, as the adoption of a spatial planning strategy has been included in the BRM further measures are being realised as part of the BRM.

***Following a Sustainable Pathway (SP)*:** The LUC is much decreased reaching a value of 0,28 by year 2050, which is 72% lower than the 2020 value.

Improving Current trends (ICP): Under this scenario, by 2050 the LUC rate is decreased by almost 36% when compared to the 2020 value.

Quick Development in a Fragmented Territory (GDFT): Under this scenario, by 2050 the LUC rate is decreased by almost 24% when compared to the 2020 value.

Waste generation

***Following a Sustainable Pathway (SP)*:** waste generation is much decreased reaching a daily value of 0,5 Kg/person by 2026.

Improving Current trends (ICP): waste generation is mildly decreased reaching a daily value of 0,68 Kg/person by 2026.

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Quick Development in a Fragmented Territory (GDFT): waste generation is decreased reaching a daily value of 0,74 Kg/person by 2026.

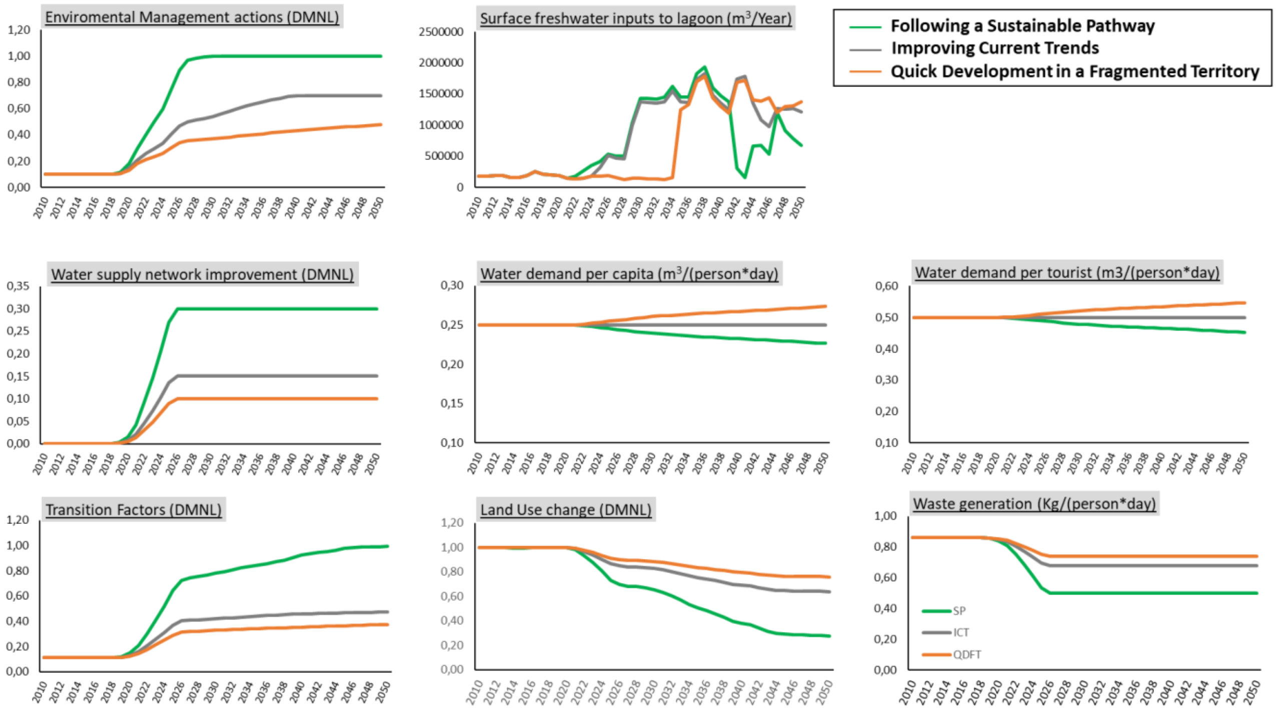

Figure 1: Dynamic patterns of variables in the model that reflect actions introduced with the BRM.

The data corresponding to these entry variables can be found here: (https://zenodo.org/communities/773782-coastal/?page=1&size=20).

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3.2. ASSESSMENT OF THE DYNAMIC PATTERNS OF KEY POLICY INDICATORS

This chapter discusses the impact that these scenarios have on the modelled Social – Ecological System of land sea interactions in SW Messinia. Table 5 lists the KPIs (model output variables) chosen to reflect the impact of each of these scenarios in the area and assess the robustness of the solutions towards future uncertainties. The KPIs, were chosen to reflect EU and national policies and targets for agriculture and biodiversity.

This chapter discusses the impact that each of the sets of measures presented in the previous chapter has on the modelled system under different scenarios for Messinia. In order to make these results easily comparable with the outcomes presented earlier on, that is in the chapter investigating the impact of external societal evolutions named 'Comparison of the dynamic patterns of key model variables', the same logic is followed here. This means that the same KPIs are used here to structure the analyses. And also the model runs were done making use of the same scenarios. An overview is given here of the main insights coming out of our analyses.

Table 7 Key Policy Indicators selected to assess the impact of the scenarios on the sustainability of SW Messinia

KPI	Description	SD model variables
Cooperative strength	Index based on the percentage of farmers that participate in a business cooperative	Cooperative strength
Orchards treated with SF practices	Area under integrated or/and organic farming practices	Orchards treated with SF practices
Olive-oil branding	An index showing the ability to branding	Local olive oil production branding
Application of chemical fertilizers	percentage of orchards treated with chemical fertilizers.	Application of chemical fertilizers
irrigation demand	the volume of water per square meter of irrigated land	water volume per irrigation effort per m2 (irrigation)
GDP from agriculture	the annual GDP from olive-oil sales	GDP from olive-oil production
cultivation costs	the mean annual average of costs (excluding gasoline/diesel costs)	production costs
Groundwater Abstractions	the volume of annual groundwater abstractions (drinking water and irrigation) from Tyflomitis	T abstractions
Tyflomitis groundwater volume	the volume of the groundwater aquifer which is supplying fresh water inputs to the wetland	Tyflomitis (T) inland groundwater aquifer (irrigation, municipal use)
Groundwater available for restoration	the excess of groundwater which is naturally discharged via springs	T discharge to T ditch (groundwater upwelling to springs)

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Mean Annual Salinity	the salinity of the lagoon (wetland)	Mean Annual Salinity (MAS)
Fish Catch	the potential fish catch from the lagoon	fish catch
Wetland vegetation (freshwater species)	index linked to conditions for the survival of fresh water vegetation species	wetland vegetation (fresh-water species)
collapse risk	an index which depicts the risk of collapse due to hyperhaline conditions	lagoon collapse risk
Birds Conservation Index	An index which is linked to fish availability and status of the wetland habitats	Birds' conservation index
Habitats conservation index	An index which is linked to the status of the wetland and coastal habitats	Habitats conservation index
Build-up land	Build up land changes per year	Build-up land
Expected tourists	Annual tourist arrivals	expected tourists
Alternative tourism potential	An index which depicts the potential of alternative forms of tourism link to agriculture and nature	Alternative tourism index
Landscape character	An index reflecting the intensity of land uses calculated assigning spatial cover of different land covers and land uses	Landscape character index

As the sustainability of the region is considered to be a dynamic process which is related to the collective choices in interacting with the environment within the social-ecological system of SW Messinia, the KPIs are presented here in groups of actions connected to one of three targets identified with the stakeholders as part of the vision for a sustainable Messinia.

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GROUP 1 Actions influencing the future on the agricultural sector and in particular the transition from conventional to sustainable (integrated or/and organic) olive oil farming

The target of this group of actions in to increase the economic performance of the orchards, while minimizing environmental impact (N load and groundwater abstraction KPIs).

1) What is considered sustainable and robust in Messinia for this group of KPIs?

The model outcomes suggest that, the percentage of farmers in cooperation is crucial to reaching these targets. As well as those agreed by the Common Agricultural Policy, and the green deal. As an outcome it is suggested that this cooperation is vital for the robustness and sustainability of the sector. It is difficult to identify specific thresholds for most of these KPIs, but with regards to the adoption of sustainable (integrated and organic) farming practices the target of 25 % organic by 2030 seems reachable only under scenario 1.

2) What is the impact of the three trajectories on this group of KPIs?

Under all scenarios there is a trend towards the goals set for the agricultural sector, however only through the complete implementation the rate of change is sufficient to achieve the Green Deal targets for sustainable food production.

KPI 1: Cooperative strength

The participation of farmers in cooperative schemes is considered a cornerstone for the development of the sector as through the collaboration the local farmers can overcome current challenges. The higher the percentage the more sustainable and robust are the cooperatives. Currently, it is estimated that the value of this KPI is at 0.15. By 2050, the value of this KPI is expected to follow the below trends:

(SP) **:**	0.70,	increased by 367%
(ICP) :	0.24	increased by 60%
(GDFT) :	0.18,	increased by 20%

KPI 2 Orchards treated with SF practices

The adoption of sustainable farming practices by the local olive-oil producers is crucial for the development of the sector and it is related to several environmental benefits (e.g. less nutrients to water resources). Currently, it is estimated that the value of this KPI is at 1785 hectares. By 2050, the value of this KPI is expected to follow the below trends:

(SP) **:**	7125,	increased by 299%
(ICP) :	2579,	increased by 45%
(GDFT) :	2226,	increased by 25%

KPI 3 Olive oil branding

Within the model, this parameter is linked with the strength of the cooperatives and the production of olive-oil based on sustainable practices. It is also an indicator of the of potential of olive oil to be sold bottled rather than bulk. Bulk sales of olive oil were one of the main issues reported by the olive oil producers. Currently, it is estimated that the value of this KPI is at 0.16. By 2050, the value of this KPI is expected to follow the below trends:

(SP) **:**	0.56,	increased by 269%
(ICP) :	0.24,	increased by 50%
(GDFT) :	0.19,	increased by 19%

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KPI4 Application of chemical fertilizers

This KPI is linked to environmental benefits and it is linked to reductions in N loads as the farmers adopt more sustainable farming practices. Currently, it is estimated that the value of this KPI is at 88. By 2050, the value of this KPI is expected to follow the below trends:

(SP) **:** 50, decreased by 43%

(ICP) : 82, decreased by 7%

(GDFT) : 84, decreased by 5%

KPI5 Irrigation demand

The water uses within the case study are dependent on groundwater resources, and the resilience of the system is much dependent on the optimization of irrigation patterns. Currently, it is estimated that the value of this KPI is at 0.0134 m^3/m^2 per irrigation effort. By 2050, the value of this KPI is expected to follow the below trends:

(SP) **:** 0.0108, decreased by 19%

(ICP) : 0.0135, increased by 1%

(GDFT) : 0.0137, increased by 2%

KPI 6 GDP from agriculture

This KPI is important for the local farmers who want to see their income to increase. Currently, it is estimated that the value of this KPI is at 54482633 euro/ Year. By 2050, the value of this KPI is expected to follow the below trends:

(SP) **:** 104764417, increased by 92%

(ICP) : 59185000, increased by 9%

(GDFT) : 55467508, increased by 2%

KPI 7 Cultivation costs

This KPI is important for the local farmers who want to see their costs to decrease. Currently, it is estimated that the value of this KPI is at 1378 euro/ Hectare. By 2050, the value of this KPI is expected to follow the below trends:

(SP) **:** 1147, decreased by 17%

(ICP) : 1338, decreased by 3%

(GDFT) : 1360, decreased by 1%

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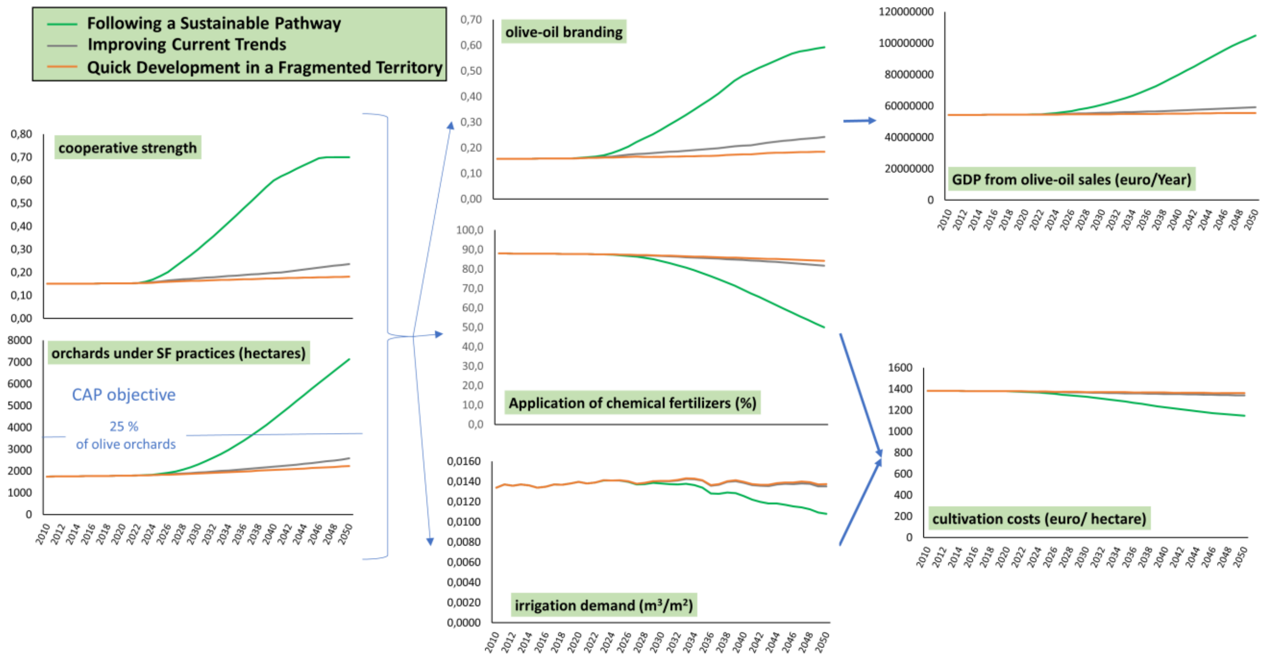

Figure 2: Dynamic patterns of KPIs associated with the agricultural sector

3) Given the impact of external uncertainties, to what degree can dedicated interventions bring this group of KPIs within a sustainable and robust state

Comparing to the trends under the different SSP scenarios presented in COASTAL deliverable D19 it is evident that the implementation of the BRM has a positive impact on the required transformation for the sustainability of agriculture. The implementation for the BRM further enhances the positive changes promoted by the sustainability scenario and improves on the trends for scenarios 2 (ICT) and 3 (QDFT). However, the agricultural sector is very much reliant on external policy related decisions, hence without the support it is difficult for the sector to achieve its required targets. This reliance is related to the small land size, which increases the cost of transformative actions. Thus interventions focusing on enhancing collaboration between small scale farmers could increase the robustness and sustainability of the sector.

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GROUP 2 Actions influencing the restoration and enhancement of Ecosystem Services in the Gialova Lagoon wetland.

A challenge for the region is how to balance societal and conservation needs, and suggest salinity restoration solutions with a broader acceptance by the society.

1) What is considered sustainable and robust in Messinia for this group of KPIs?

The permanent stock of Tyflomitis groundwater aquifer is at 6.500.000 m^3. Hence, to avoid over-exploitation, groundwater abstractions should be regulated in a way that ensure a volume above 7.000.000 m^3.

With regards to the wetland, a sustainable and robust status can be achieved if MAS is regulated at 25 g/Lt.

2) What is the impact of the three trajectories on this group of KPIs?

Under all scenarios there is a trend towards the goals set for the agricultural sector, however only through the complete implementation the rate of change is sufficient to achieve the Green Deal targets for sustainable food production.

KPI8 Groundwater Abstractions (Tyflomitis aquifer)

The water uses within the case study are dependent on groundwater resources, and the resilience of the system is much dependent on the optimization of irrigation and water supply patterns. Currently, it is estimated that the value of this KPI is at 1232200 m^3/ Year. By 2050, the value of this KPI is expected to follow the below trends:

***(SP)* :** 902628, decreased by 27%

(ICP) : 1189836, decreased by 3%

(GDFT) : 1304787, increased by 6%

KPI 9 Tyflomitis groundwater aquifer

This KPI is important for the local society/ economy (water supply and irrigation) and for the conservation of surface and transitional water resources. Currently, it is estimated that the value of this KPI is at 7760327 m^3/ Year. By 2050, the value of this KPI is expected to follow the below trends:

***(SP)* :** 7716415, decreased by 0,6%

(ICP) : 7438822, decreased by 4,1%

(GDFT) : 7328022, decreased by 5,6%

KPI 10 Groundwater available for restoration

For as long as the volume (mean annual) of the groundwater aquifer remains above sustainable levels, there is enough freshwater for supplying the wetland. Currently, it is estimated that the value of this KPI is at 923227 m^3/ Year. By 2050, the value of this KPI is expected to follow the below trends:

***(SP)* :** 851490, decreased by 8%

(ICP) : 657175, decreased by 29%

(GDFT) : 579616, decreased by 37%

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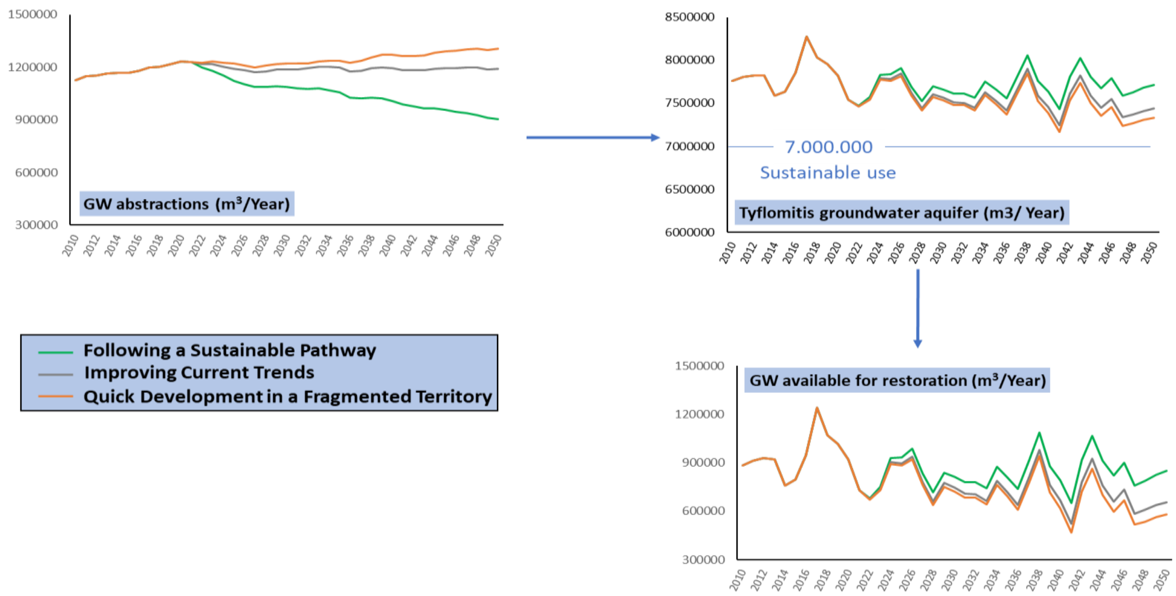

Figure 10 Dynamic patterns of KPIs associated with groundwater resources availability

KPI 11 Mean Annual Salinity

This KPI is crucial for all biota within the wetland and associated ecosystem services. Currently, it is estimated that the value of this KPI is at 32 g/ Lt, while the optimum mean annual salinity is estimated at 25g/ Lt. By 2050, the value of this KPI is expected to follow the below trends:

***(SP)* :** 25,0, decreased by 22%

(ICP) : 25,0, decreased by 22%

(GDFT) : 32,4, increased by 1%

KPI 12 Fish Catch

This KPI is important for the local fishers. Currently, it is estimated that the value of this KPI is at 7566 Kg/ Year. By 2050, the value of this KPI is expected to follow the below trends:

***(SP)* :** 11980, increased by 58%

(ICP) : 11976, increased by 58%

(GDFT) : 7509, decreased by 1%

KPI 13 Wetland vegetation (freshwater species)

This KPI is used to depict the conditions which are favorable for freshwater species. Currently, it is estimated that the value of this KPI is at 0.13. By 2050, the value of this KPI is expected to follow the below trends:

***(SP)* :** 0.70, increased by 438%

(ICP) : 0.70, increased by 438%

(GDFT) : 0.15, increased by 15%

KPI 14 Collapse risk

This KPI is important for the local fishers, but also for the whole region as a possible collapse could impose health issues and would impact the recognition of the area. Currently, it is estimated that the value of this KPI is at 0.71. By 2050, the value of this KPI is expected to follow the below trends:

***(SP)* :** 0.08, decreased by 88%

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(ICP) : 0.08, decreased by 88%

(GDFT) : 0.66, decreased by 7%

KPI 15 Birds Conservation Index

This KPI depicts how future management actions could be of benefit for birds' conservation. Currently, it is estimated that the value of this KPI is at 0,60. By 2050, the value of this KPI is expected to follow the below trends:

***(SP)* :** 0,83, increased by 38%

(ICP) : 0,83, increased by 38%

(GDFT) : 0,59, decreased by 2%

KPI 16 Habitats Conservation Index

This KPI depicts how future management actions could be of benefit for coastal (sand dunes) and wetland habitats. Currently, it is estimated that the value of this KPI is at 0,48. By 2050, the value of this KPI is expected to follow the below trends:

***(SP)* :** 0,87, increased by 81%

(ICP) : 0,75, increased by 56%

(GDFT) : 0,57, increased by 19%

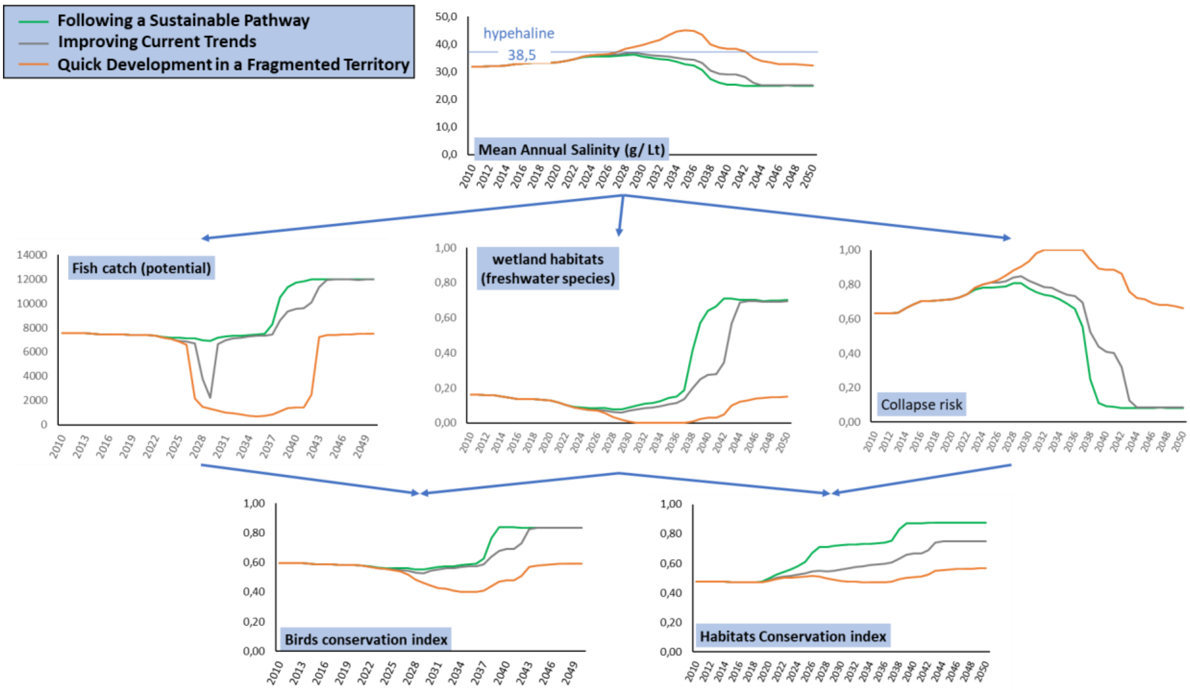

Figure 11 Dynamic Patterns of KPIs associated with wetland restoration

3) Given the impact of external uncertainties, to what degree can dedicated interventions bring this group of KPIs within a sustainable and robust state.

Under specific climate scenarios, an external uncertainty, which affects this group of KPIs is the timing of implementation of the BRM, with regards to the restoration works. Under these circumstances, a delay in restoration efforts could result to a lagoon collapse, which will lead to extended fish mortality, and loss of associated provisional and cultural ecosystem services.

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To improve groundwater savings, it is suggested that the municipality invests in renewing the water supply network to minimize water losses. In addition, it is suggested that the farmers optimize their irrigation patterns based on new technologies (weather forecast, humidity sensors, irrigation based on tree needs, etc.).

The model suggests that under current climatic conditions it is possible to restore and optimize salinity values by restoring the natural flows. For as long as the volume (mean annual) of the groundwater aquifer remains above sustainable levels, there is enough freshwater for supplying the wetland. However, since the wetland is already at a critical stage any delay in implementation could be proven catastrophic for the system, and to reduce the risk of a collapse it is important to act the soonest possible.

GROUP 3 Actions influencing the promotion of thematic tourism as a sustainable alternative to beach tourism

The main target of this group of measures was to increase the alternative tourism activities in area while maintaining a minimum impact on the coastal and rural environment of the area.

1) What is considered sustainable and robust in Messinia for this group of KPIs?

Looking at the KPI – Alternative tourism potential, this is increased under all conditions, hence it can be said that the actions are sufficient to achieve the shift towards more sustainable forms of tourism, in relation to the environmental impact of the sector. However, only in the case of Scenario 1, which would include a full implementation of the measures included in the BRM the number of tourists is kept at a level below the social comfort level., which could affect the characterisation of sustainable destination according to the ETIS toolkit (DG Enterprise and Industry, 2013).

2) What is the impact of the three trajectories on this KPI?

KPI's related to the robustness of the tourism sector show an upward trend under all scenarios. However, those related to the landscape identity and the social comfort thresholds regarding the appropriation of resources by tourists show significant improvement only under scenario 1.

Similarly, the habitats and bird conservation indexes also seem to be improving, although there is a delay in the improvement under scenario 3 (QDFT), which is linked to the collapse of the fish catch in the lagoon, due to the creation of a hyperhaline environment.

KPI 17 Build-up Land

This KPI is important for monitoring the impact of land use change in the area.. Currently, it is estimated that the value of this KPI is at 560 hectares. By 2050, the value of this KPI is expected to follow the below trends:

(SP) **:** 864 , increased by 54%

(ICP) : 995, increased by 78%

(GDFT) : 1021, increased by 82%

KPI 18 Expected tourists

This KPI is important for indicating pressure on the environmental and social resources of the region and its communities. The value is compared to an agreed total threshold of local community comfort level of 150,000 visitors. The number has been estimated based on the discussion with workshop participants and stakeholders about the number of tourists during peak times, and assuming a seasonal concentration of arrivals. Currently, it is estimated that the value of this KPI is at 103234 m^3/ Year. By 2050, the value of this KPI is expected to follow the below trends:

(SP) **:** 129771, increased by 26%

(ICP) : 178439, increased by 73%

(GDFT) : 198559, increased by 92%

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KPI 19 Alternative tourism potential

This KPI is important for indicating the aggregated potential for activities of ecotourism, agrotourism and pescatourism. Currently, it is estimated that the value of this KPI is at 0,33. By 2050, the value of this KPI is expected to follow the below trends:

***(SP)* :** 0,78, increased by 92%

(ICP) : 0,53, increased by 61%

(GDFT) : 0,41, increased by 24%

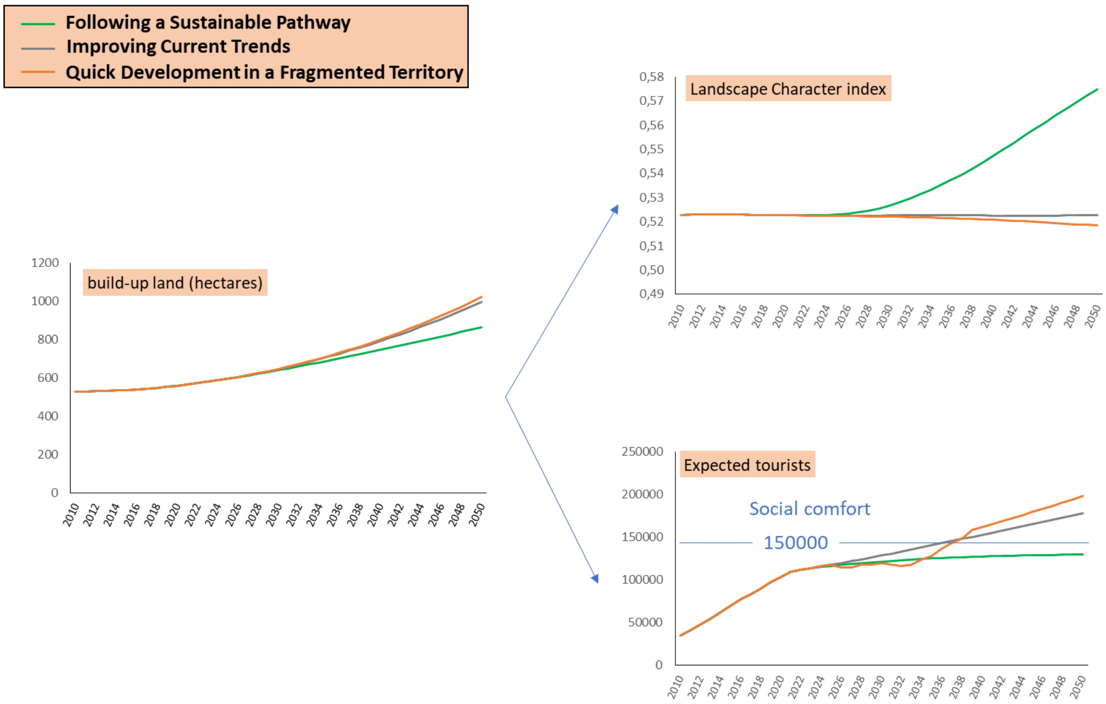
KPI 20 Landscape Character

This KPI is important to assess the impact of land use changes on the landscape identity of the area, which is being used as a branding potential to attract more agrotourism and ecotourism activities. Currently, it is estimated that the value of this KPI is at 0,523. By 2050, the value of this KPI is expected to follow the below trends:

***(SP)* :** 0,575, increased by 10%

(ICP) : 0,523,

(GDFT) : 0,518, decreased by 1%



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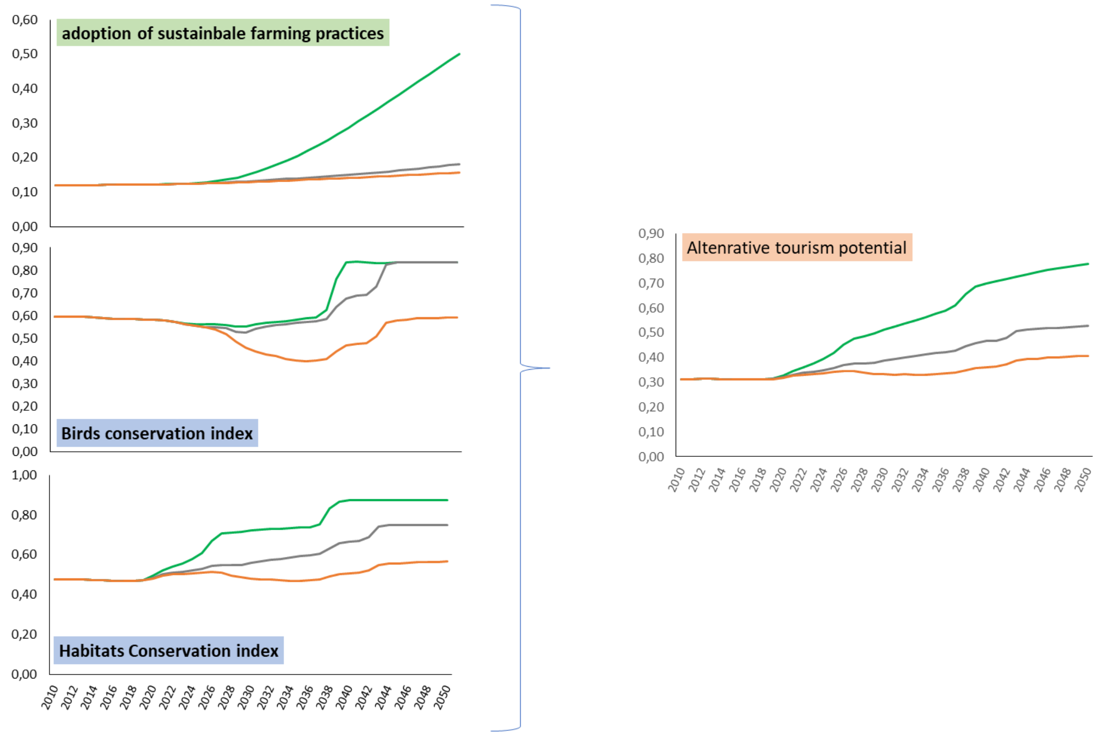

Figure 12 Dynamic patterns of KPIs associated with tourism

3) Given the impact of external uncertainties, to what degree can dedicated interventions bring this group of KPIs within a sustainable and robust state

As discussed in the previous sections, the external uncertainties and policy support affect mainly the future of the agricultural sector and the ability to transition to an integrated and organic agriculture. With regards to tourism a possible impact would result from a lagoon collapse which could impose health issues and would impact the recognition of the area. The tourism sector acts as the receiver of the benefits of the shift in agriculture, whereas it has the ability to perform sustainably internally, and even bounce back after an initial drop due to the previously mentioned collapse in the lagoon. As a measure perhaps the most important action would be the adoption of a spatial management plan regulating the uncontrollable development of new units.

3.3. CONCLUSION

Given the impact of climate and ecological changes, economic growth and other external uncertainties, to what degree can dedicated interventions bring this within a sustainable and robust state?

The targeted scenario (Aplizar, and Bovarnick, 2013) approach that was followed throughout the scenario development process (COASTAL D19), started from the stakeholders vision of what future they want for their area and ended with the modelling of their proposed actions under specific climatic (RCP2.6) and different socioeconomic (SSP1, SSP2, SSP4 and SSP5) uncertainties. The outcomes of this scenario analysis indicate that the actions included in the BRM (Figure 9 of this report or COASTAL D11 for more information) are on the sustainability pathway. The comparison of current values to those of 2050, under all scenarios, shows that even if the proposed actions are partially implemented, there would be improvements in all selected KPIs. Nonetheless an important exception is the possibility of a collapse in the lagoon. If the measures of restoration

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are not implemented on time, the risk of collapse is high even under climatic scenario RCP2.6. As a result it is important to note that the level of engagement to the BRM is fundamental if the region is to reach the targets set by the Green Deal (eg. 25% increase of sustainable farming) and Biodiversity strategies (eg. restoring natural flow of rivers and wetlands), as it is clearly shown in the spider diagram Figure 13.

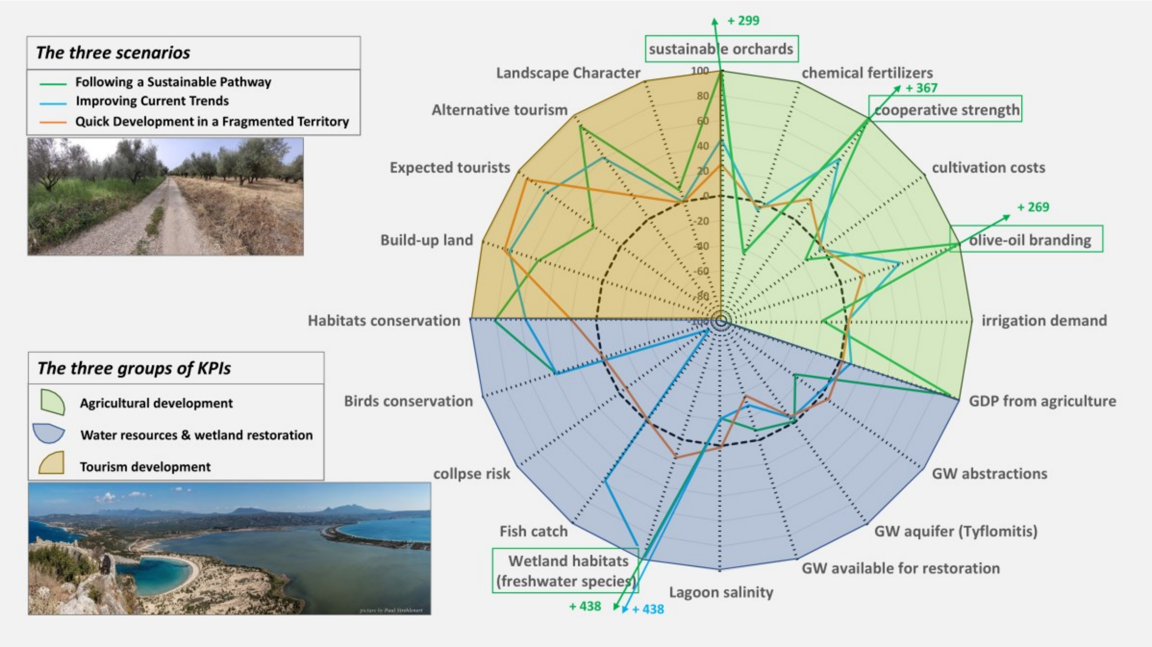

Figure 13 Spider Diagram KPIs for SW Messinia case study area

KEY Messages to local stakeholders:

- **Quick implementation of the restoration works to prevent a possible lagoon collapse**
  In recognition that the wetland has been gradually transformed from brackish to saline, and at the moment is at a critical state (Maneas, et al 2019, Maneas et al 2020, Manzoni et al, 2020, Bray et al 2022, COASTAL D33).

- **Dedicated support to encourage the cooperation between farmers to enhance sustainable farming**
  In recognition that current farming practices and the lack of trust among farmers, coupled with the lack of policy support for small scale farming, hinder the sustainable development of the sector (COASTAL D03).

- **Spatial plan for regulating uncontrollable development of new hotel units**
  In recognition that there is an increasing trend of land use change over the last 20 years (COASTAL D14), and in order to avoid coastal zone degradation (as this has happened in other touristic areas around Greece) and limit the risk of agricultural abandonment.

The experience gained from the Greek case study could be used as an example other rural coastal areas in Greece and the Mediterranean which face similar challenges.

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4. ROBUSTNESS ANALYSIS OF POLICY AND BUSINESS ACTIONS DESIGNED FOR THE NORRSTRÖM – BALTIC REGION

4.1. PRESENTATION OF THE MEASURES FOR THE NORRSTRÖM – BALTIC REGION

The table below gives an overview of each of the variables and parameters representing effects of systemic interventions in the system dynamics (SD) model for the Norrström - Baltic region. The first column gives the names of the variables. The second column describes what these variables represent. The third column, finally, gives an overview of the policy and/or business actions that may (indirectly) change the state of the variable.

<table>
<tr><th>Name entry variable or parameter</th><th>Description</th><th>Type of real actions reflected in variable</th></tr>
<tr><td>Concentration of nitrogen (N) in subsurface waters (SSW)</td><td>Average nitrogen concentration level in subsurface waters</td><td rowspan="4">Reduction of total nitrogen and phosphorus concentrations in SSW and SW by mitigation (removal/capture and possible reuse) of nutrients released from dominant diffuse legacy sources that still remain in soil, groundwater and sediments from different types of earlier nutrient inputs (agricultural leakage, municipal and industrial wastewater discharges). Such legacy releases can be captured, e.g., by restoration/ construction of wetlands and construction of reactive barriers that are effectively placed and distributed over each hydrological catchment. These actions also relate to possible changes in socio-economic drivers (improved knowledge transfer between sectors, creation of nutrient market making nutrient recovery and reuse worthwhile, shift of the Swedish municipal water (quality) management monopoly).</td></tr>
<tr><td>Concentration of phosphorus (P) in SSW</td><td>Average phosphorus concentration level in subsurface waters</td></tr>
<tr><td>Concentration of N in surface waters (SW)</td><td>Average nitrogen concentration level in surface waters</td></tr>
<tr><td>Concentration of P in SW</td><td>Average phosphorus concentration level in surface waters</td></tr>
<tr><td>"Concentration of N-agriculture to SSW"</td><td>Nitrogen concentration in flow from agricultural lands to subsurface water</td><td rowspan="4">Reduction in nutrient concentrations that leach and are drained from currently active agriculture to soil and subsurface water, and through drainage systems also to directly to surface waters. This may be achieved by improved/optimized fertilization practices and drainage facilities, following an integrated risk assessment of nutrient application practices and related leaching and drainage from agricultural land to and through soil and drainage pipes and ditches.</td></tr>
<tr><td>"Concentration of P-agriculture to SSW"</td><td>Phosphorus concentration in flow from agricultural lands to subsurface water</td></tr>
<tr><td>"Concentration of N-agriculture to SW"</td><td>Nitrogen concentration in flow from agricultural lands to surface water</td></tr>
<tr><td>"Concentration of P-agriculture to SW"</td><td>Phosphorus concentration in flow from agricultural lands to surface water</td></tr>
<tr><td>"Concentration of N in WWTP-output"</td><td>Average nitrogen concentration levels in discharges from wastewater treatment plants (WWTP) into surface waters</td><td rowspan="2">Reduction in nutrient concentrations discharged from currently active WWTPs and unconnected wastewater facilities. This may be achieved by improved nutrient removal in WWTPs and recovery in smart water and sanitation systems, related to technological advancements and, more widely, e.g., creation of a nutrient market that makes such recovery and reuse worthwhile.</td></tr>
<tr><td>"Concentration of P in WWTP-output"</td><td>Average phosphorous concentration levels in discharges from WWTP into SW</td></tr>
</table>

For the purpose of this research 3 sets of measures were prepared. Each of these sets is made up of all the entry variables and parameters listed in the table above. Yet, under each of these sets of measures these variables and parameters are linked to different data ranges, and hence referring to business and/or policy actions that intervene more or less seriously in the modelled coastal system. The studied sets of measures

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relate to different Business Road Map (BRM) alternatives prioritized by stakeholders in the Norrström-Baltic (MAL3) case and are:

- **Current management**: Base case with no change in nutrient concentrations for nitrogen (N) and phosphorous (P) (same results as for the base case scenario in D19).
- **Agricultural measures**: Considers the example of 25% reduction in nutrient concentrations leaching from currently active agriculture with associated reduction in agricultural nutrient contributions to subsurface water (SSW) and surface water (SW) nutrient concentrations. Such reductions may result, e.g., from improved/optimized agricultural fertilization practices and drainage facilities, and restoration/construction of wetlands that can capture local nutrient leakage. This set of measures relates to the stakeholder-prioritized BRM alternative "Integrated risk assessment of nutrient losses from agricultural soils to surface waters".
- **WWTP measures**: Considers the example of 25% reduction of nutrient concentrations in discharges from currently active municipal and industrial wastewater treatment plants (WWTPs) and unconnected wastewater facilities with associated reduction in their contributions to SW nutrient concentrations. Such reductions may result, e.g., from improved nutrient removal in WWTPs and recovery in smart water and sanitation systems, related to technological advancements and, more widely, e.g., creation of a nutrient market that makes such capture and reuse worthwhile. This set of measures relates to the stakeholder-prioritized BRM alternatives "Nutrient recovery in wastewater treatment plants" and "Smart water and sanitation systems".
- **Legacy measures**: Considers the example of 25% reduction in total SSW and SW nutrient concentrations. Such reductions may result from catchment-wide mitigation (removal/capture and possible reuse) of nutrients released from diffuse wide-spread legacy sources that still remain in soil, groundwater and sediments from different types of earlier nutrient inputs (past agricultural leakage, municipal and industrial wastewater discharges). Such mitigation may be achieved, e.g., by restoration/construction of wetlands and construction of reactive barriers that are well-placed and distributed to effectively capture considerable parts of the overall legacy nutrient releases throughout each hydrological catchment. This set of measures also relates to possible changes in socio-economic drivers, such as creation of a nutrient market that can make capture and reuse of nutrients worthwhile, along with improved knowledge transfer between sectors and some shift in the municipal water (quality) management monopoly that current applies in Sweden. With regard to the stakeholder-prioritized BRM alternatives, it relates to: "Improved knowledge transfer between sectors" that may drive better system understanding with more efficient nutrient mitigation measures taken and well/optimally placed in each hydrological catchment for targeting and mitigating the diffuse legacy sources that have been found to be dominant in the Norrström-Baltic (MAL3) case (Chen et al., 2021) as in other parts of the world (Basu et al., 2022); and "Change of municipal monopoly" that may enhance collaboration and communication between different municipalities within the same hydrological catchment toward more overarching efficiency and circular principles on whole catchment-scale.

For consistency, a similar approach to that of the D19 SSP scenarios has been used here, with the parameter values shifting from their base case values to their values considered to prevail by year 2060 under the studied new added/enhanced sets of measures. Consistent 25% reduction examples have been considered for the different parameter values in each of these studied set of measures. This has been done: (a) for direct comparability of what similar reduction levels in the different studied sets of measures imply for total nutrient loads to the coast and, thus, for effectiveness in combating coastal eutrophication; and (b) due to major uncertainties in setting actual parameter values for the different sets of measures, as these values ultimately depend on essential undecided factors, such as actual management effort and policy incentives, along with natural spatiotemporal variability not accounted for in the lumped system dynamics modelling. In the

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remaining part of this chapter an overview is given of the evolution of each of these variables and parameters under these different sets of measures.

Entry parameters 1 and 2: Concentrations of N and P in SSW

The base case values used in the "Current management" set of measures are also used as initial values in the other sets of measures. The values for the latter shift to their new, enhanced management levels by year 2060, when they are considered to be ultimately reached for each studied set of measures. At that new, enhanced management state, the parameter values: (i) for the agricultural set of measures are the new concentration levels that result from the system dynamics model for the considered 25% decrease in nutrient leakage from agricultural land to SSW; (ii) for the WWTP set of measures remain unchanged as the WWTPs discharge predominantly to SW and thus do not considerably change SSW concentration levels; and (iii) for the legacy set of measures are decreased in total by the considered 25%.

Values for the base case (current management) and initial conditions for the other sets of measures:

- SSW N concentration: $5.3852.10^{-3}$ $kg.m^{-3}$
- SSW P concentration: $1.048.10^{-4}$ $kg.m^{-3}$

Resulting managed values for the agricultural set of measures:

- SSW N concentration: $5.2683.10^{-3}$ $kg.m^{-3}$
- SSW P concentration: $1.025.10^{-4}$ $kg.m^{-3}$

Resulting managed values for the WWTP set of measures:

- SSW N concentration: $5.3852.10^{-3}$ $kg.m^{-3}$
- SSW P concentration: $1.048.10^{-4}$ $kg.m^{-3}$

Resulting managed values for the legacy set of measures:

- SSW N concentration: $4.0389.10^{-3}$ $kg.m^{-3}$
- SSW P concentration: $7.86.10^{-5}$ $kg.m^{-3}$

Entry parameters 3 and 4: Concentrations of N and P in SW

The base case values used in the "Current management" set of measures are also used as initial values in the other sets of measures. The values for the latter shift to their new, managed levels in year 2060, when the managed equilibrium is considered to be reached for each studied set of measures. At that new, enhanced management state, the parameter values: (i) for the agricultural set of measures are the concentration levels that result from the system dynamics model for the considered 25% decrease in nutrient leakage from agricultural land to SW; (ii) for the WWTP set of measures are the concentration levels that result from the system dynamics model for the considered 25% decrease of WWTP discharges to SW; and (iii) for the legacy set of measures are decreased in total by the considered 25%.

Values for the base case (current management) and initial conditions for the other sets of measures:

- SW N concentration: $1.43.10^{-3}$ $kg.m^{-3}$
- SW P concentration: $4.0.10^{-5}$ $kg.m^{-3}$

Resulting managed values for the agricultural set of measures:

- SW N concentration: $1.4223.10^{-3}$ $kg.m^{-3}$
- SW P concentration: $3.98.10^{-5}$ $kg.m^{-3}$

Resulting managed values for the WWTP set of measures:

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- SW N concentration: $1.3912.10^{-3}$ $kg.m^{-3}$
- SW P concentration: $3.89.10^{-5}$ $kg.m^{-3}$

Resulting managed values for the legacy set of measures:

- SW N concentration: $1.0725.10^{-3}$ $kg.m^{-3}$
- SW P concentration: $3.0.10^{-5}$ $kg.m^{-3}$

Entry parameters 5 and 6: Concentrations of N and P leakage from agriculture to SSW

The base case values used in the "Current management" set of measures are also used as initial values in the other sets of measures. The values for the latter shift to their new, managed levels in year 2060, when the managed equilibrium is considered to be reached for each studied set of measures. At that new, managed equilibrium state, the parameter values: (i) for the agricultural set of measures are decreased by the considered 25% reduction in nutrient leakage from agricultural land to SSW; (ii) for the WWTP set of measures remain unchanged, as this set does not include any agricultural measures; and (iii) for the legacy set of measures remain unchanged, as this set does not include measures for currently active agricultural leakage.

Values for the base case (current management) and initial conditions for the other sets of measures:

- N-agriculture to SSW concentration: $5.3852.10^{-3}$ $kg.m^{-3}$
- P-agriculture to SSW concentration: $1.048.10^{-4}$ $kg.m^{-3}$

Resulting managed values for the agricultural set of measures:

- N-agriculture to SSW concentration: $4.0389.10^{-3}$ $kg.m^{-3}$
- P-agriculture to SSW concentration: $7.86.10^{-5}$ $kg.m^{-3}$

Unchanged values for the WWTP set of measures:

- N-agriculture to SSW concentration: $5.3852.10^{-3}$ $kg.m^{-3}$
- P-agriculture to SSW concentration: $1.048.10^{-4}$ $kg.m^{-3}$

Unchanged values for the legacy set of measures:

- N-agriculture to SSW concentration: $5.3852.10^{-3}$ $kg.m^{-3}$
- P-agriculture to SSW concentration: $1.048.10^{-4}$ $kg.m^{-3}$

Entry parameters 7 and 8: Concentrations of N and P leakage from agriculture to SW

The base case values used in the "Current management" set of measures are also used as initial values in the other simulated sets of measures. The values for the latter shift to their new, managed levels in year 2060, when the managed equilibrium is considered to be reached for each studied set of measures. At that new, managed equilibrium state, the parameter values: (i) for the agricultural set of measures are decreased by the considered 25% reduction in nutrient leakage from agricultural land to SW; (ii) for the WWTP set of measures remain unchanged, as this set does not include agricultural measures; and (iii) for the legacy set of measures remain unchanged, as this set does not include measures for currently active agricultural leakage.

Values for the base case (current management) and initial conditions for the other sets of measures:

- N-agriculture to SW concentration: $1.43.10^{-3}$ $kg.m^{-3}$
- P-agriculture to SW concentration: $4.0.10^{-5}$ $kg.m^{-3}$

Resulting managed values for the agricultural set of measures:

- N-agriculture to SW concentration: $1.0725.10^{-3}$ $kg.m^{-3}$
- P-agriculture to SW concentration: $3.0.10^{-5}$ $kg.m^{-3}$

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Unchanged values for the WWTP set of measures:

- N-agriculture to SW concentration: $1.43.10^{-3}$ $kg.m^{-3}$
- P-agriculture to SW concentration: $4.0.10^{-5}$ $kg.m^{-3}$

Unchanged values for the legacy set of measures:

- N-agriculture to SW concentration: $1.43.10^{-3}$ $kg.m^{-3}$
- P-agriculture to SW concentration: $4.0.10^{-5}$ $kg.m^{-3}$

Entry parameters 9 and 10: Concentrations of N and P in WWTP discharges to SW

The base case values used in the "Current management" set of measures are also used as initial values in the other simulated sets of measures. The values for the latter shift to their new, managed levels in year 2060, when the managed equilibrium is considered to be reached for each studied set of measures. At that new, managed equilibrium state, the parameter values: (i) for the agricultural set of measures remain unchanged, as this set does not include any wastewater measures; (ii) for the WWTP set of measures are decreased by the considered 25% reduction in wastewater discharge concentrations to SW; and (iii) for the legacy set of measures remain unchanged, as this set does not include measures for currently active wastewater discharges.

Values for the base case (current management) and initial conditions for the other sets of measures:

- WWPT-discharge N concentration: $9.2.10^{-3}$ $kg.m^{-3}$
- WWPT- discharge P concentration: $2.7.10^{-4}$ $kg.m^{-3}$

Unchanged values for the agricultural set of measures:

- WWPT- discharge N concentration: $9.2.10^{-3}$ $kg.m^{-3}$
- WWPT- discharge P concentration: $2.7.10^{-4}$ $kg.m^{-3}$

Resulting managed values for the WWTP set of measures:

- WWPT- discharge N concentration: $6.9.10^{-3}$ $kg.m^{-3}$
- WWPT- discharge P concentration: $2.025.10^{-4}$ $kg.m^{-3}$

Unchanged values for the legacy set of measures:

- WWPT- discharge N concentration: $9.2.10^{-3}$ $kg.m^{-3}$
- WWPT- discharge P concentration: $2.7.10^{-4}$ $kg.m^{-3}$

The data corresponding to these entry variables can be found here:
https://doi.org/10.5281/zenodo.6855357.

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4.2. ASSESSMENT OF DYNAMIC PATTERNS FOR POLICY INDICATORS

This chapter discusses the impact that each of the sets of measures presented in the previous chapter has on the modelled system under different scenarios for the Norrström – Baltic coastal region. In order to make these results easily comparable with earlier presented outcomes, the same logic is followed here as in the chapter 'Comparison of the dynamic patterns of key model variables' on the impact of external evolution scenarios (D19). This means that the model simulations consider the same scenarios and the analysis is structured according to the same KPIs as in D19, except for the KPIs relating to water availability (for socio-economic sectors and natural sub-systems, and related salinity intrusion risk), as these are not influenced by any of the stakeholder-prioritized sets of measures investigated here and are therefore unchanged from D19. An overview is given here of the main insights emerging from this analysis.

KPI 1: Net waterborne TN and TP inputs to and loads from socio-economic sectors

What is considered sustainable and robust in the Norrström – Baltic coastal region?

This KPI relates to total nitrogen (TN) and phosphorous (TP) inputs to and loads from currently active socio-economic sectors, i.e., excluding the nutrient releases from diffuse legacy sources that still remain in soil, groundwater and sediments from earlier sector inputs; the legacy sources are included in the modelling through the SSW and SW concentration parameter values that these sources are dominant contributors to (Chen et al., 2021). As the main coastal eutrophication problem and its targeted solution for the Norrström-Baltic coastal region relate to the combined contributions from the different active sectors as well as from the legacy sources to the total coastal nutrient loads, a long-term sustainable state is not defined for each sector-specific aspect of this KPI. With regard to current sector emissions of nutrients, however, this KPI is especially relevant for agriculture, as the main current nutrient emitter, and WWTPs, as the second and third largest nitrogen and phosphorus emitter, respectively. In general, this KPI can quantify sustainability improvements in terms of how the different studied sets of added/enhanced management measures can reduce the nutrient inputs to and loads from the different active sectors in comparison with the inputs/loads prevailing under current management conditions (base case, Figure 1) for each external climate (RCP) and socio-economic (SSP) scenario combination considered (different colored bars in Figure 1). Since current coastal loads of nutrients are in total too high (lead to severe eutrophication that requires load mitigation solutions), and agricultural leakage and wastewater discharges are major current nutrient emitters, a minimum requirement for robust sustainability improvement in the Norrström-Baltic case can be stated as: reduction of the agricultural and wastewater contributions to the total coastal nutrient loads for all considered climate and socio-economic scenarios. Policy-wise, this KPI relates directly to the EU Water Framework Directive (EU WFD) regulation of inland and coastal water quality and ecological status, as well as to the Green Deal goal of cleaner waters.

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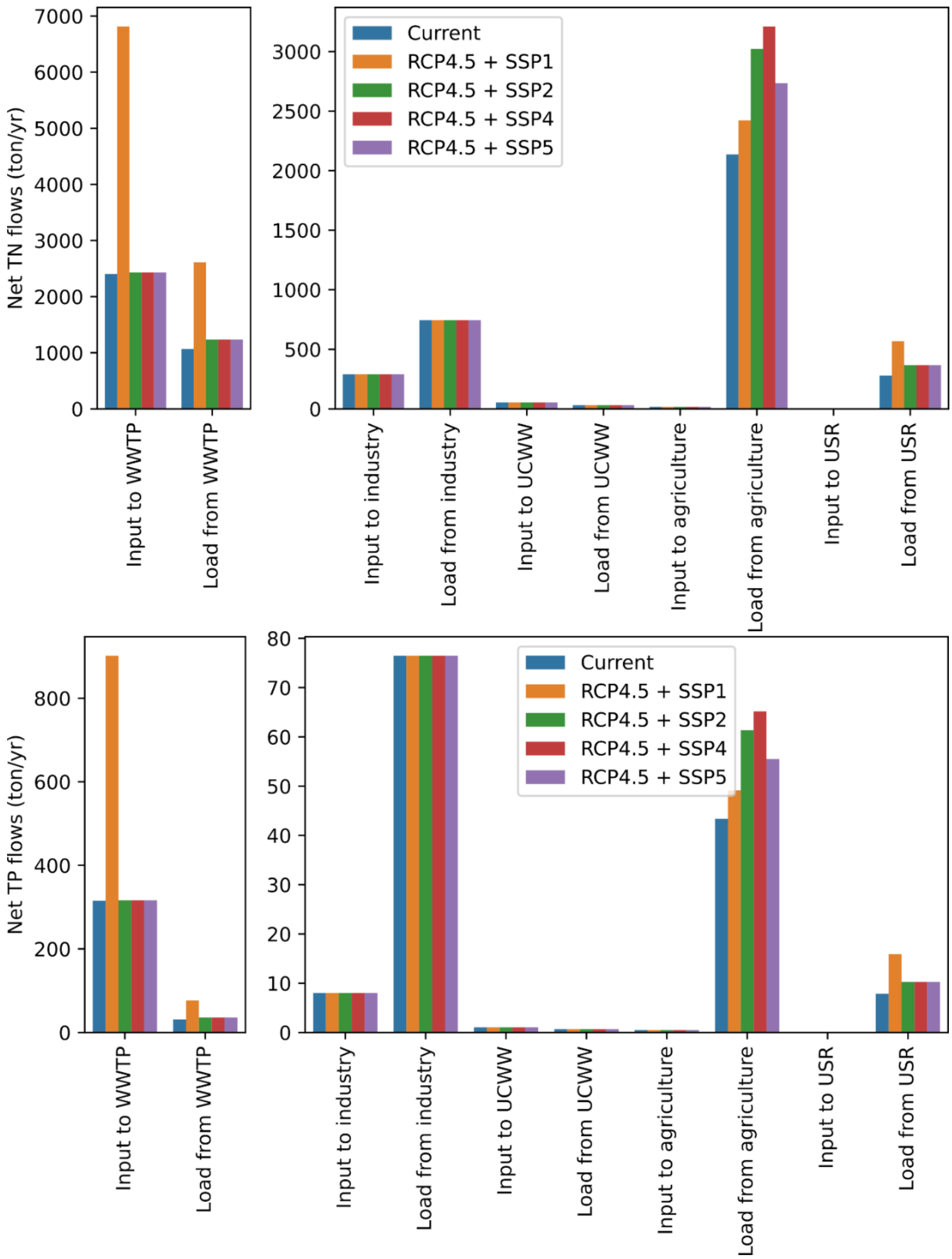

Figure 14: Scenario results for sector water quality KPIs in 2060 under current management conditions (base case, same results as in D19) for the Norrström-Baltic coastal region. The KPIs represent net inputs to and loads from different socio-economic sectors for total nitrogen (TN, top graph) and total phosphorus (TP, bottom graph). The sectors include wastewater treatment plants (WWTP), industry, unconnected coastal wastewater (UCWW), agriculture, and urban surface runoff (USR). Note the difference in scale between left and right panels.

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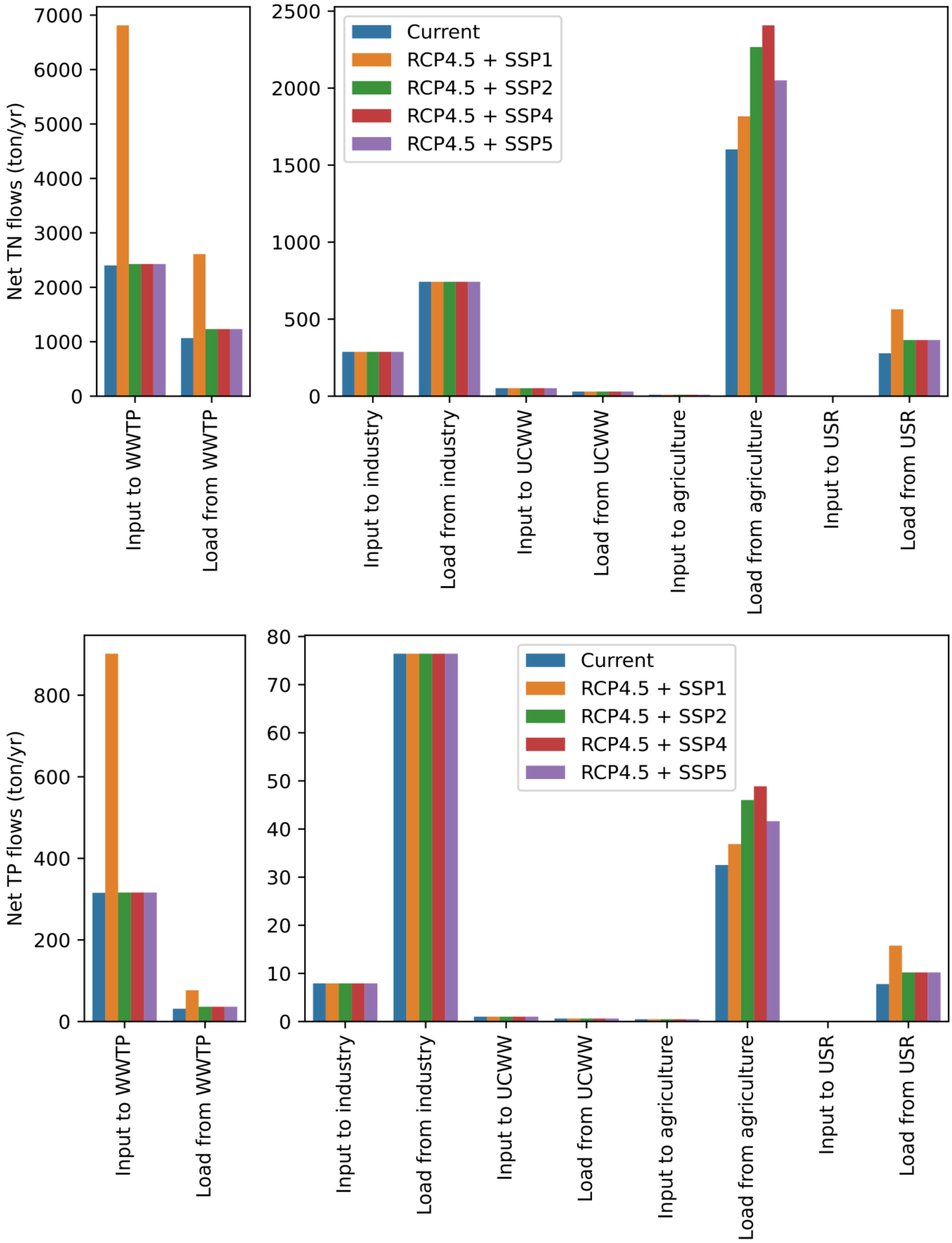

Figure 15: Scenario results for sector water quality KPIs in 2060 under the agricultural set of measures for the Norrström-Baltic coastal region. The KPIs represent net inputs to and loads from different socio-economic sectors for total nitrogen (TN, top graph) and total phosphorus (TP, bottom graph). The sectors include wastewater treatment plants (WWTP), industry, unconnected coastal wastewater (UCWW), agriculture, and urban surface runoff (USR). Note the difference in scale between left and right panels.

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What is the impact of the agricultural set of measures on this KPI?

The agricultural set of measures targets nutrient concentrations leaching from agriculture to the natural surface and subsurface water systems. It yields considerable reductions of nutrient loads from the agricultural sector (by 500-800 ton/year for nitrogen and 11-16 ton/year for phosphorus) for each considered RCP-SSP scenario (compare same-colored bars for agricultural loads in Figures 1 and 2), while the other sectoral nutrient loads remain largely unchanged. For each such scenario, the agricultural set of measures can thus improve agricultural sector sustainability with respect to nutrient load emissions.

However, the base case nutrient loads from the agricultural sector under current management conditions (blue bars for agricultural loads, Figure 1) are widely considered unsustainable and, even with implementation of the enhanced set of agricultural measures, these load levels are exceeded under scenarios RCP4.5+SSP2, SSP4, and SSP5 (see related scenario bars for agricultural loads in Figure 2). Thereby, it can be concluded that even a significant management effort to decrease nutrient loads from currently active agriculture does not robustly improve the sustainability of this sector.

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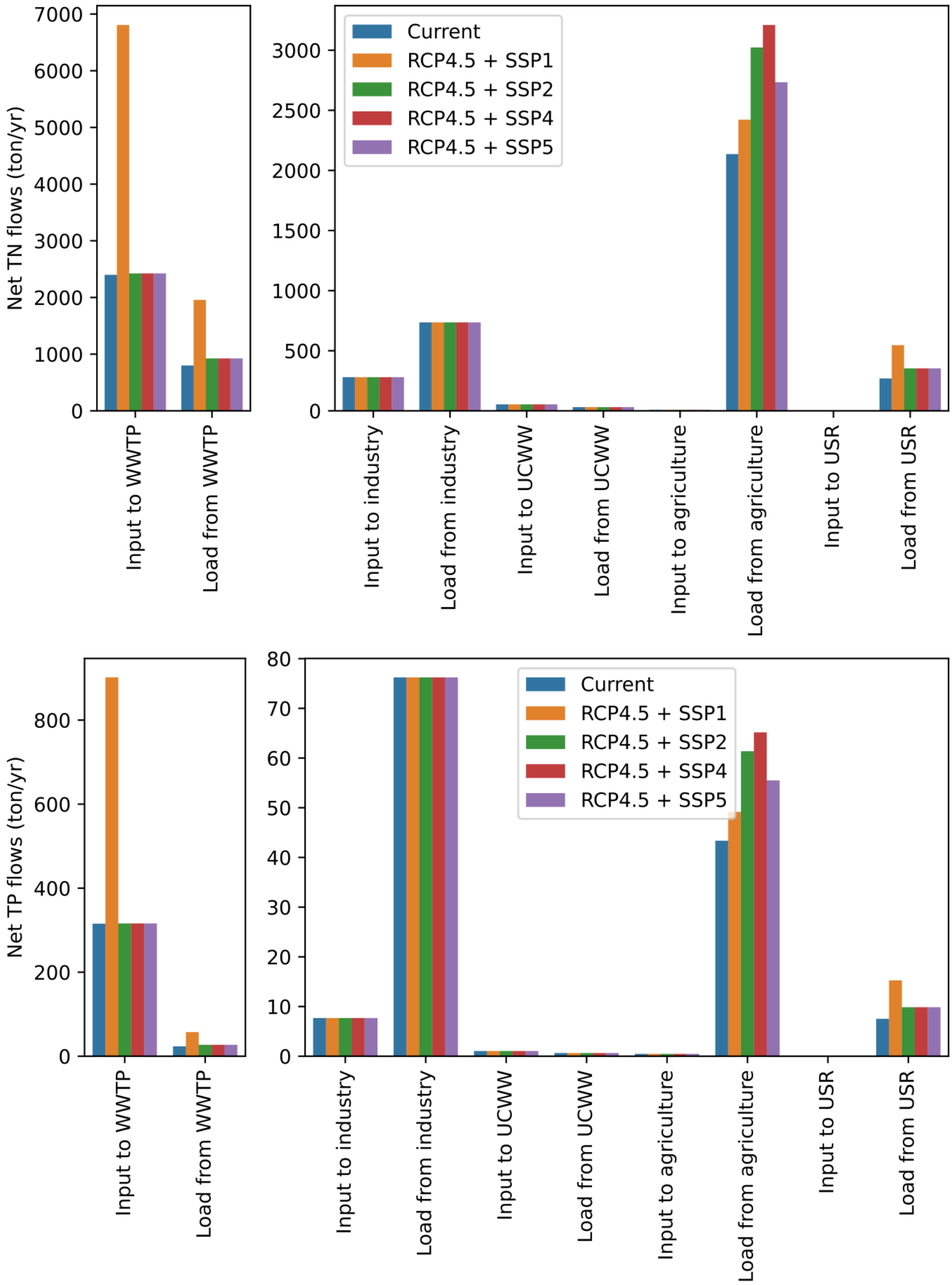

Figure 16: Scenario results for sector water quality KPIs in 2060 under the WWTP set of measures for the Norrström-Baltic coastal region. The KPIs represent net inputs to and loads from different socio-economic sectors for total nitrogen (TN, top graph) and total phosphorus (TP, bottom graph). The sectors include wastewater treatment plants (WWTP), industry, unconnected coastal wastewater (UCWW), agriculture, and urban surface runoff (USR). Note the difference in scale between left and right panels.

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What is the impact of the WWTP set of measures on this KPI?

The WWPT set of measures targets nutrient concentrations discharging from wastewater treatment plants and unconnected coastal wastewater to the natural surface and coastal water systems. It yields considerable reductions of the nutrient loads from the wastewater sector (by 270-660 ton/year for nitrogen and 8-19 ton/year for phosphorus) for each considered RCP-SSP scenario (compare same-colored bars for WWTP loads in Figures 1 and 2), while the other sectoral nutrient loads remain largely unchanged. For each such scenario, the WWTP set of measures can thus improve wastewater handling sustainability with respect to associated nutrient load emissions.

The base case nutrient loads from wastewater discharges under current management conditions (blue bars for WWTP loads, Figure 1) are substantially reduced compared to 50 years ago in the Norrström-Baltic coastal region (Reusch et al., 2018). However, the sector still discharges considerable nutrient loads to the natural surface and coastal water systems (second and third largest nitrogen and phosphorus emitter, respectively) and, even with implementation of the enhanced set of WWTP measures, these load levels are exceeded under scenario RCP4.5+SSP1 (see related scenario bars for WWTP loads in Figure 3). Thereby, it can be concluded that even a significant management effort to decrease WWTP nutrient loads by removing more nutrients from wastewater does not robustly improve the sustainability of this sector.

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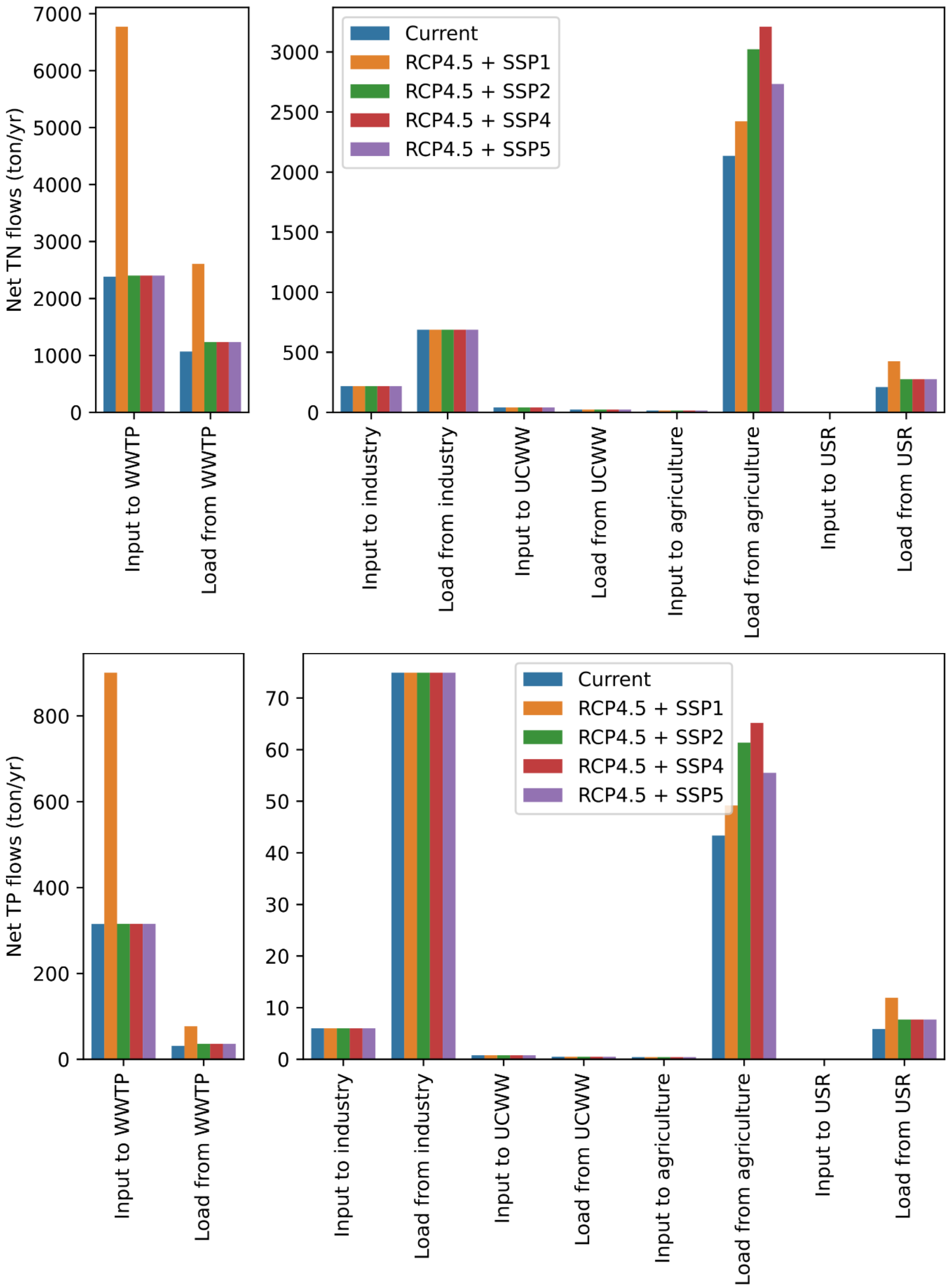

Figure 17: Scenario results for sector water quality KPIs in 2060 under the legacy set of measures for the Norrström-Baltic SD model. The KPIs represent net inputs to and loads from different socio-economic sectors for total nitrogen (TN, top graph) and total phosphorus (TP, bottom graph). The sectors include wastewater treatment plants (WWTP), industry, unconnected coastal wastewater (UCWW), agriculture, and urban surface runoff (USR). Note the difference in scale between left and right panels.

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What is the impact of the legacy set of measures on this KPI?

The legacy set of measures targets mitigation of nutrient releases from diffuse legacy sources directly in the natural subsurface water system and sediments of surface waters. As such, these measures are located downgradient/downstream of currently active sector sources at the land surface and have thus very limited effects on the loads leaking/discharging from those active sector sources (compare same-colored bars for the various sector loads in Figures 1 and 4). Thereby, the legacy set of measures cannot improve sustainability of any currently active socio-economic sector, as quantified by the sector KPI 1, but targets instead direct improvement of natural water system sustainability as quantified by KPI 2 that is discussed further in the following.

In general, legacy measures need to be combined with measures targeting currently active agricultural leakage and WWTP discharges in order to achieve relatively fast water quality improvements (by direct mitigation of ongoing legacy source releases) that are also maintained in the long-term (by mitigating currently active source emissions and thereby hinder them from adding to and building up future legacy sources).

Given the impact of climate and ecological changes, economic growth and other external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

None of the investigated sets of measures can separately and robustly improve the sustainability of any socio-economic sector, even assuming substantial reductions in sector-related nutrient concentrations that determine KPI 1. However, the legacy set of measures can directly and relatively quickly capture and reduce even unsustainable resulting nutrient loads from the various active socio-economic sector sources to downgradient/downstream waters, along with the releases from the diffuse legacy sources that have been built up over time in soil, groundwater and sediments from earlier sectoral nutrient inputs. Meanwhile, in combination with the legacy set of measures, the agricultural and WWTP sets of measures can then stop/reduce further legacy source build-up and thereby eventually lead to sustainable long-term reduction of nutrient concentrations and loads. Further SD model development and use are needed to also investigate the time frames and effectiveness of such measure combinations. Moreover, the implementation of such combined measures also requires enhanced inter-sectoral and inter-municipality communication and collaborations, as well as efficient recycling and reuse of nutrients in order to substantially and robustly improve sustainability of societal nutrient loads.

KPI 2: Net waterborne TN and TP inputs to and loads from natural water systems

What is considered sustainable and robust in the Norrström – Baltic coastal region?

This KPI relates to nutrient inputs to and loads from the natural inland surface and subsurface water systems to the coastal waters. A sustainable state of this KPI for the Norrström-Baltic coastal region may be considered as achievement of the good or higher water quality and ecological status required by the EU WFD, in addition to the nutrient load reductions targeted in the international agreement of the HELCOM Baltic Sea Action Plan (BSAP; HELCOM, 2007) for combatting Baltic Sea eutrophication. With regard to the latter, KPI 3 that is discussed further below is specifically focused on quantifying achievement of the BSAP targets, while the focus of KPI 2 discussed here is more on the EU WFD requirements of good or higher quality and ecological status that is still far from reached in the inland and coastal waters of the Norrström-Baltic coastal region (Destouni et al., 2017). In general, KPI 2 can quantify sustainability improvement in terms of how the different studied sets of added/enhanced management measures can reduce the loads of nutrients to and from the natural inland water systems and further to the coast in comparison with the inputs/loads prevailing under current management conditions (base case, Figure 5) for each considered RCP-SSP scenario (different colored bars in Figure 5). Policy-wise, this KPI also relates to the EU Marine Strategy Framework Directive (MSFD) and, as mentioned above, to the BSAP as an international agreement for its implementation in the Baltic Sea region.

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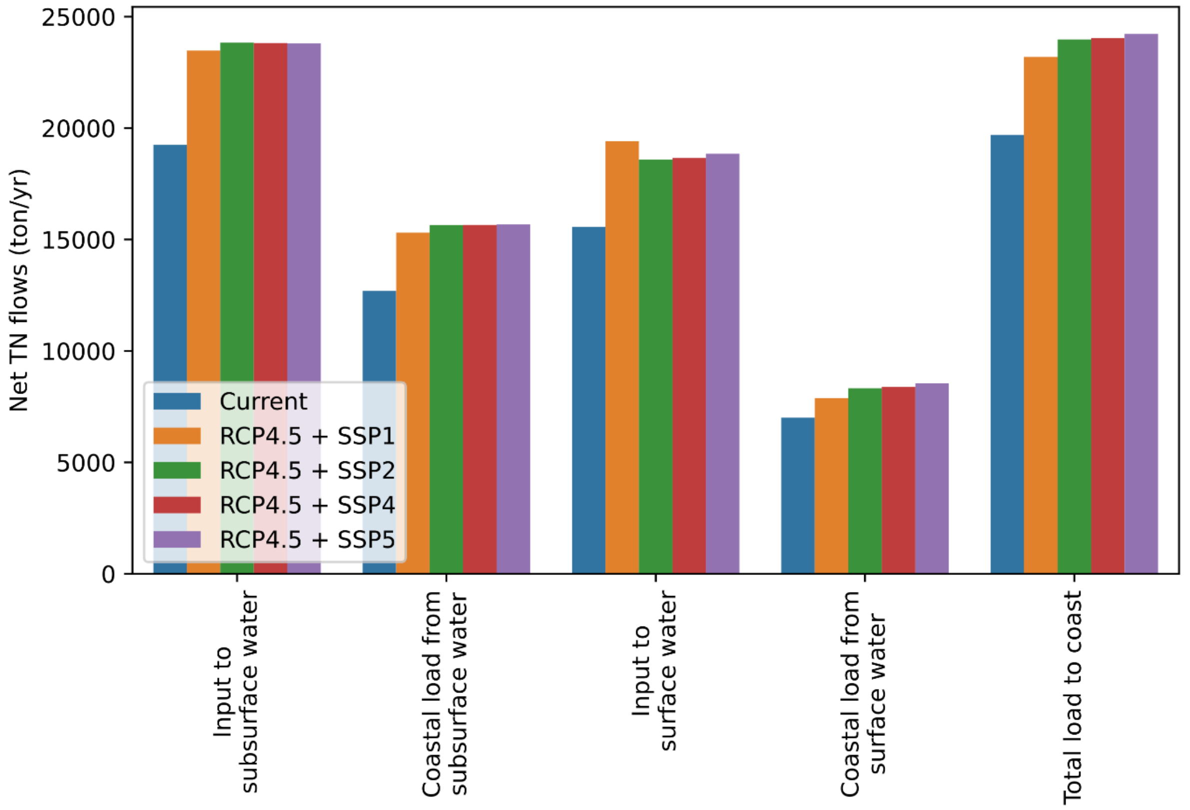

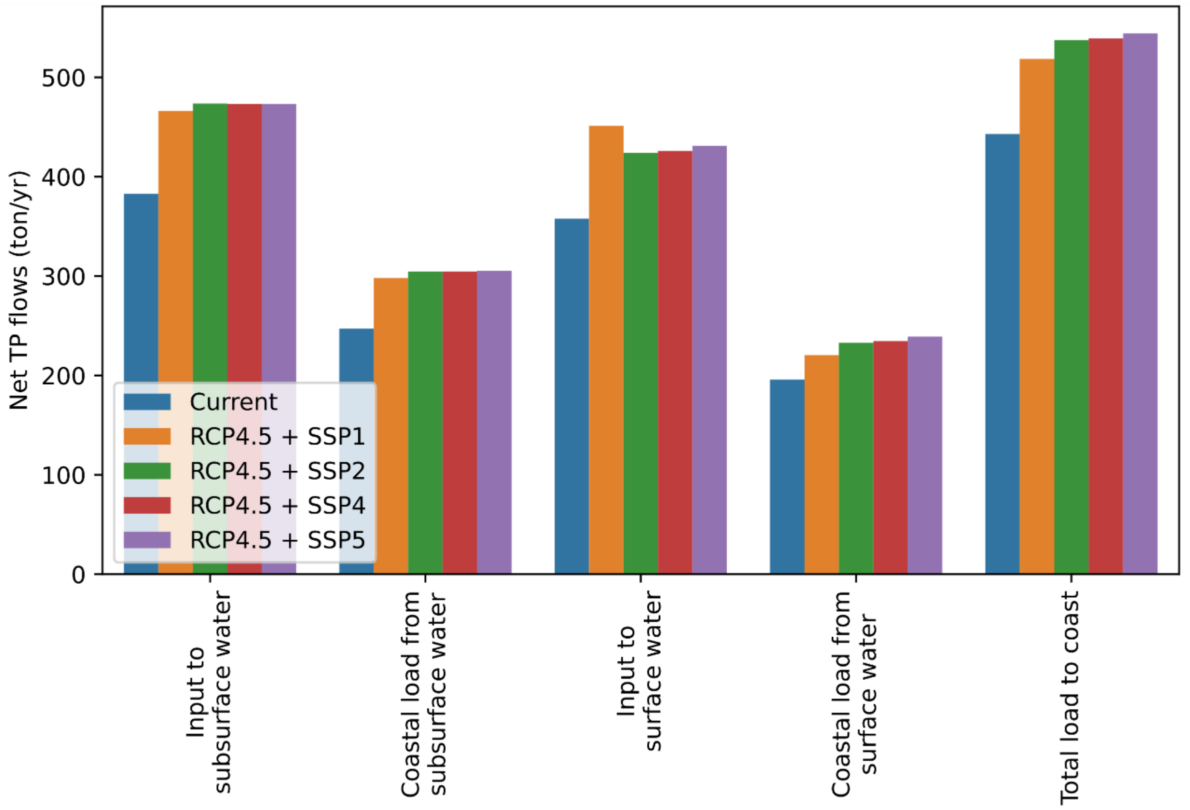

Figure 18: Scenario results of water quality KPIs for natural water systems in 2060 under current management conditions (base case, same results as in D19) for the Norrström-Baltic coastal region. The KPIs represent net inputs to the natural water systems and loads from them to the coast for total nitrogen (TN, top graph) and total phosphorus (TP, bottom graph).

What is the impact of the agricultural set of measures on this KPI?

The agricultural set of measures yields reductions in nutrient inputs to subsurface waters of around 5% and further to surface waters of around 2%. These reductions in turn decrease TN and TP loads to coastal waters by 310-490 ton/year and 6-8 ton/year, respectively, for each RCP-SSP scenario (compare same-colored bars for agricultural loads in Figures 5 and 6). For each considered scenario, the agricultural set of measures thus only marginally improves sustainability with regard to nutrient inputs/loads to/from the natural inland and coastal water systems.

The base case nutrient inputs to and loads from the natural inland water systems and further to the coast under current management conditions (blue bars, Figure 5) are widely considered unsustainable (HELCOM, 2007). Even with implementation of the enhanced set of agricultural measures, these load levels are exceeded under all considered climate and socio-economic scenarios (Figure 6). Thereby, it can be concluded that even a significant management effort to decrease nutrient loads from currently active agriculture does not robustly improve sustainability for the natural water systems.

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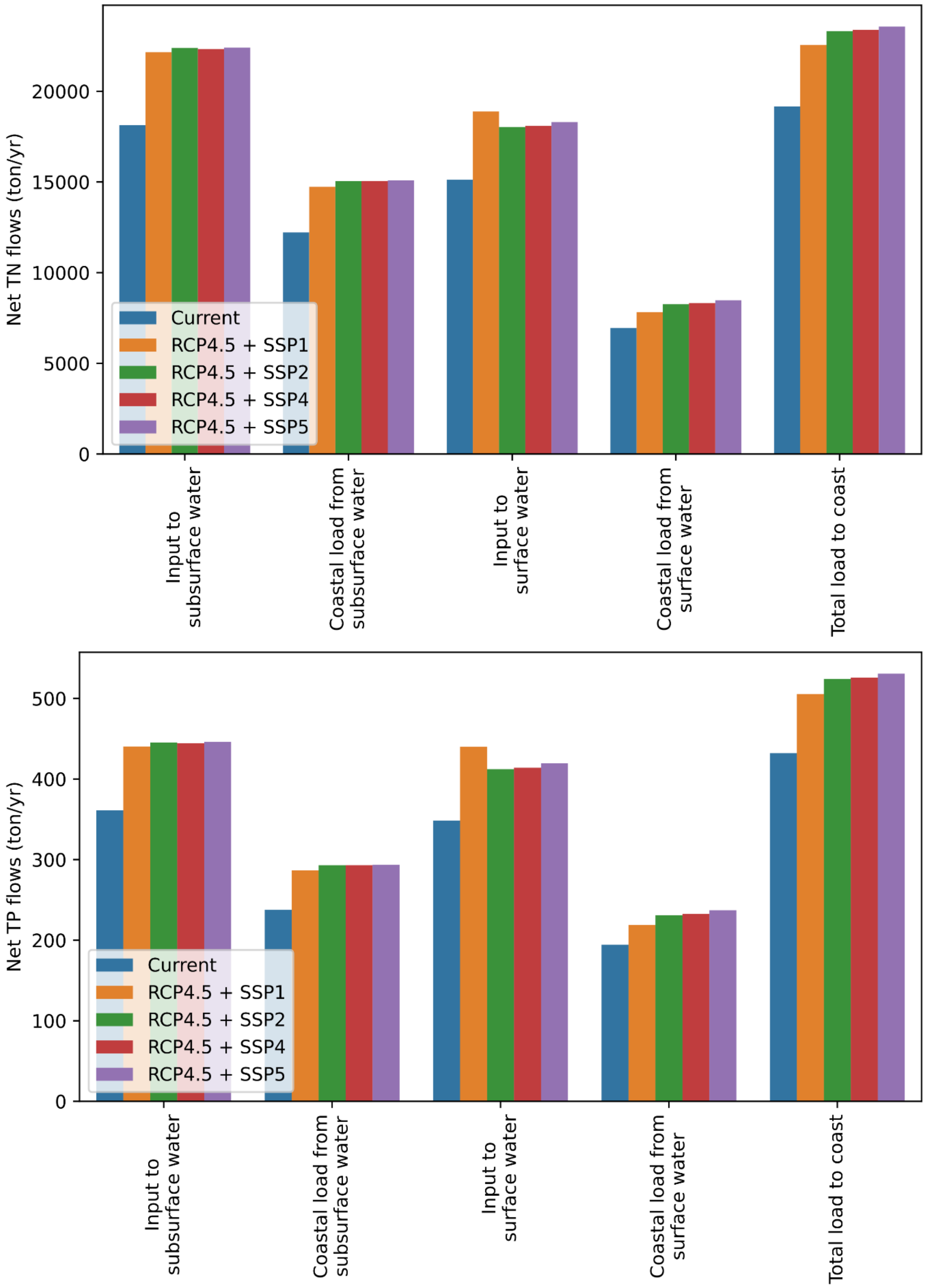

Figure 19: Scenario results of water quality KPIs for natural water systems in 2060 under the agricultural set of measures for the Norrström-Baltic coastal region. The KPIs represent net inputs to the natural water systems and loads from them to the coast for total nitrogen (TN, top graph) and total phosphorus (TP, bottom graph).

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What is the impact of the WWTP set of measures on this KPI?

The WWTP set of measures reduces nutrient inputs to surface waters by less than 5%, with no reduction of nutrient inputs to subsurface waters. This in turn results in reduced nitrogen and phosphorus loads to coastal waters by 190-210 ton/year and 6 ton/year, respectively, for each considered RCP-SSP scenario (compare same-colored bars in Figures 5 and 7). For each such scenario, the WWTP set of measures thus only marginally improves sustainability with regard to nutrient inputs/loads to/from the natural inland and coastal water systems.

The already unstainable base case nutrient inputs/loads under current management conditions (blue bars, Figure 5) are exceeded by their respective counterparts under the WWTP set of measures for all considered climate and socio-economic scenarios (Figure 7). Thereby, it can be concluded that even a significant management effort to decrease nutrient loads from currently active wastewater discharges does not robustly improve sustainability for the natural water systems.

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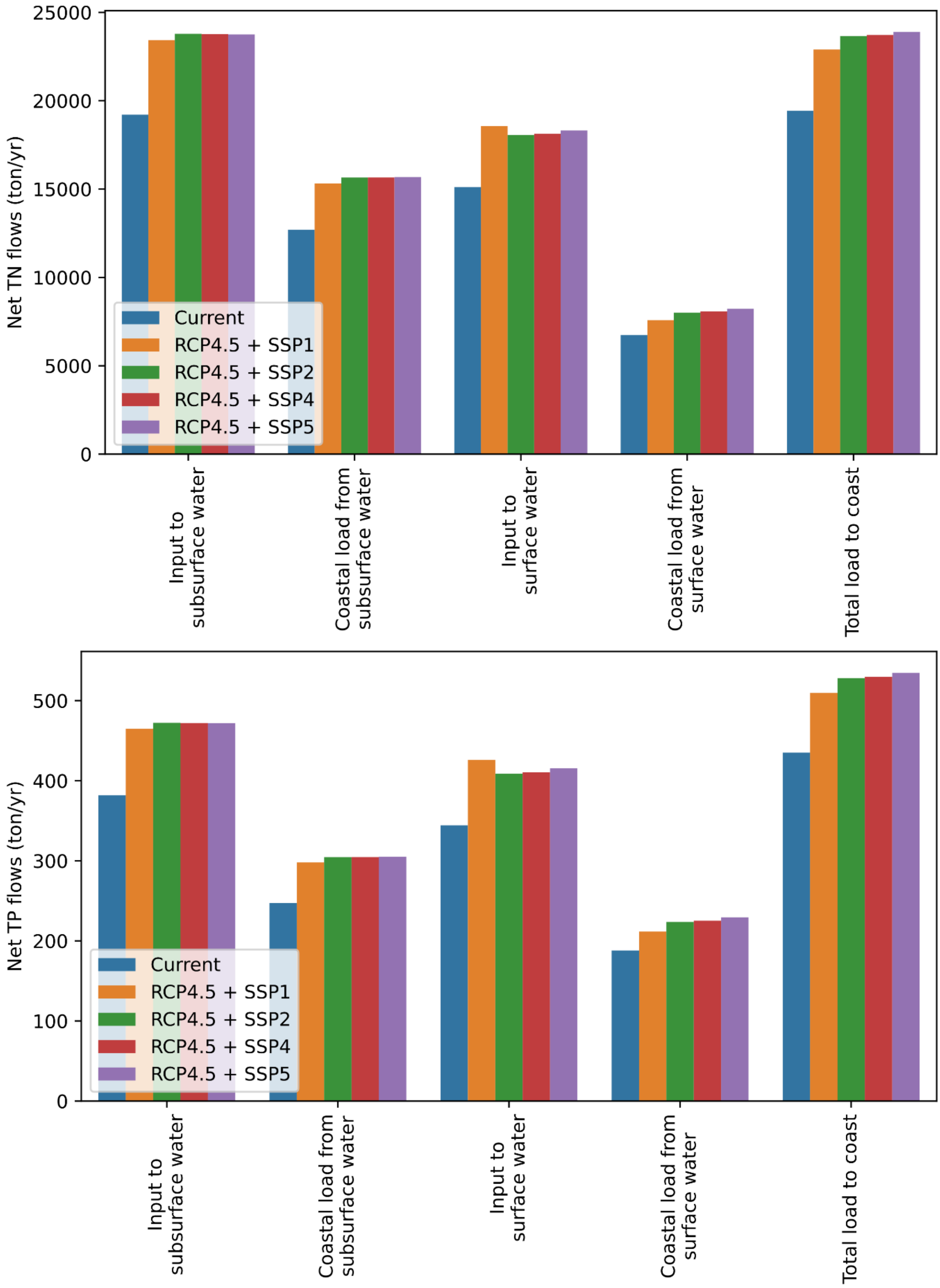

Figure 20: Scenario results of water quality KPIs for natural water systems in 2060 under the WWTP set of measures for the Norrström-Baltic coastal region. The KPIs represent net inputs to the natural water systems and loads from them to the coast for total nitrogen (TN, top graph) and total phosphorus (TP, bottom graph).

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What is the impact of the legacy set of measures on this KPI?

The legacy set of measures yields the greatest reductions of nutrient inputs to surface and subsurface waters, up to 23%. This in turn reduces nitrogen and phosphorus loads to coastal waters by 4900-6100 ton/year and 110-140 ton/year, respectively, for each RCP-SSP scenario (compare same-colored bars in Figures 5 and 8). For each such scenario, the legacy set of measures thus considerably improves natural water system sustainability in terms of nutrient inputs and loads.

The base case nutrient inputs/loads under current management conditions (blue bars, Figure 5) are higher than their respective counterparts under the legacy set of measures for all climate and socio-economic scenarios except for the input of phosphorus to surface waters under RCP4.5+SSP1, which is just 2 ton/year (<1%) higher (Figure 8). Thereby, it can be concluded that the legacy set of measures can considerably and robustly improve sustainability for the natural water systems.

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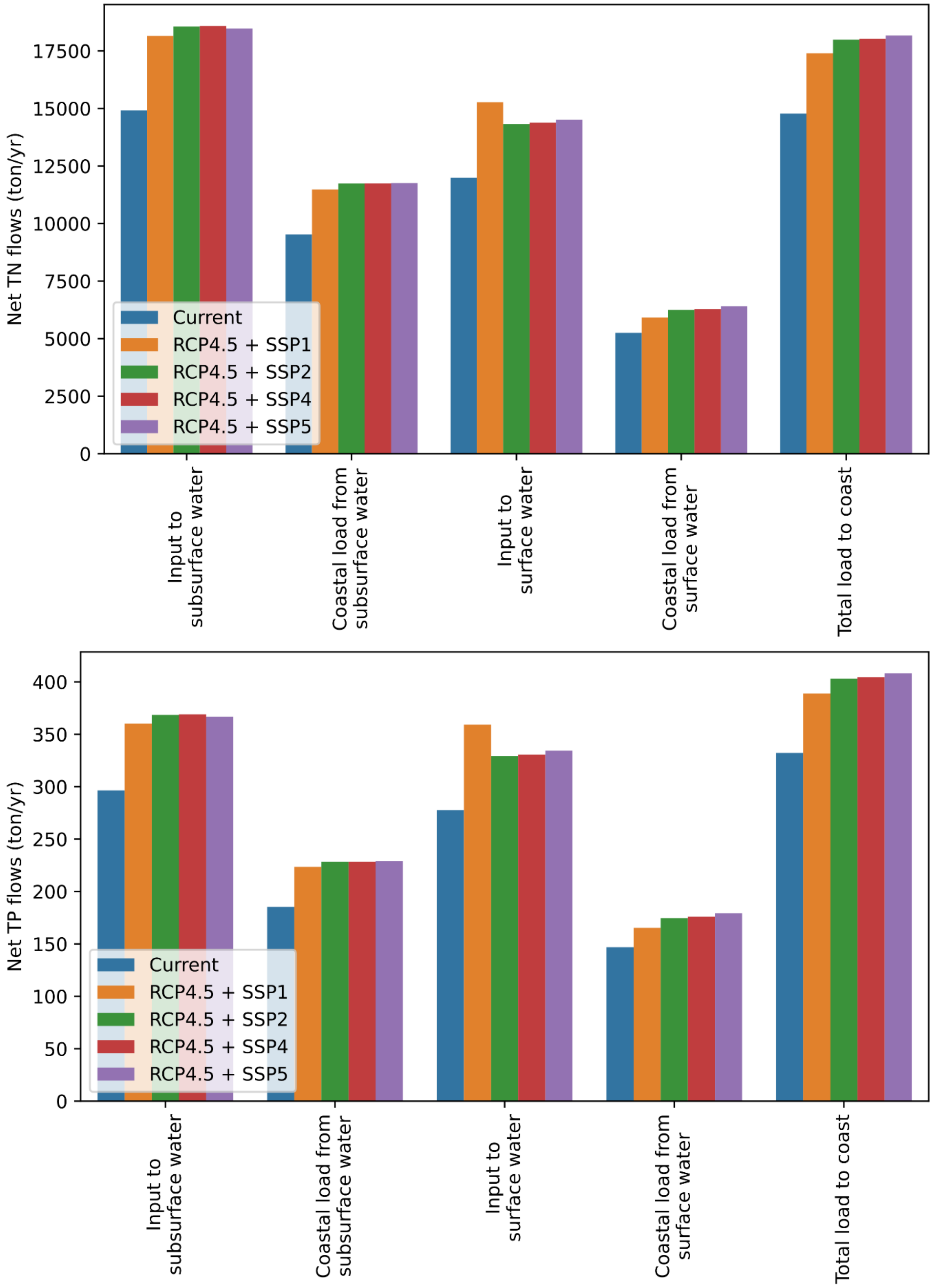

Figure 21: SSP scenario results of KPIs for water quality in 2060 under the legacy set of measures from the Norrström-Baltic SD model. The KPI represents net input to and loads to the coast from the natural water sub-systems for total nitrogen (TN, top graph) and total phosphorus (TP, bottom graph).

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Given the impact of climate and ecological changes, economic growth and other external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

As the diffuse legacy sources are dominant in the Norrström-Baltic coastal region (Chen et al., 2021), only the legacy set of measures can directly start decreasing total nutrient concentrations in subsurface and surface waters sufficiently for achieving considerable and robust sustainability improvements with regard to nutrient inputs/loads to/from the natural inland and coastal water systems. In isolation, the agricultural and WWTP measures that target only a particular socio-economic sector do not yield substantial such improvements if the legacy sources are left to still remain and uphold high nutrient concentrations with their continuous releases. This is due the shifts that are increasingly reported to have occurred in nutrient pollution of natural waters in different parts of the world, from being dominated by well-known active point sources in the past to currently being dominated by legacy and other diffuse sources (Le Moal et al., 2019; Basu et al., 2022). Therefore, tackling the nutrient pollution and eutrophication problems requires legacy measures to be taken, well-placed and distributed over the contributing hydrological catchment to each targeted inland and coastal water body. Such measures may include, e.g., restoration/construction and relevant placement of wetlands and reactive barriers for downgradient/downstream capture – and possible recovery and reuse - of the nutrient loads from diffuse legacy as well as currently active sources in each catchment. These measures can also lead to a more adaptive management that handles and performs better under different types of upstream source uncertainties. However, extensive downgradient/downstream measures also require better communication and cooperation between the municipalities and the socio-economic sectors and various agencies involved (such as water management, environmental, agricultural agencies), which in turn require some policy changes, as noted in the sectoral KPI 1 section.

KPI 3: Policy and management indicators for water quality

What is considered sustainable and robust in the Norrström – Baltic region?

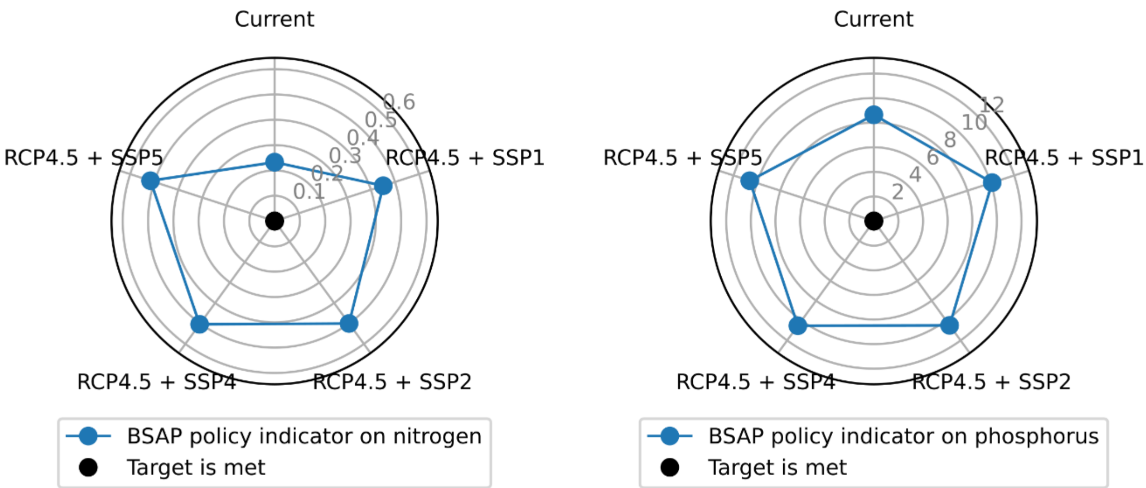

Figure 22: Scenario results of water quality KPIs in 2060 under the under current management conditions (base case, same results as in D19) for the Norrström-Baltic coastal region. These policy-related KPIs quantify the achievement (KPI values equal or less than zero) or non-achievement (KPI values greater than zero) of the Baltic Sea Action Plan (BSAP) mitigation targets for coastal nitrogen load (right panel) and coastal phosphorus load (left panel).

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For this KPI, the state is considered sustainable when the reductions in coastal nutrient load meet the reduction levels required by the HELCOM BSAP (HELCOM, 2007) for the Baltic Proper marine basin, as calculated to apply to the Norrström-Baltic coastal region (MAL3) that is a main Swedish contributor to that marine basin. The BSAP nutrient reduction targets are defined for present climate and socio-economic conditions, and even further reductions may be needed under future such conditions (Bring et al., 2015). A minimum requirement for a robust sustainable state for this KPI 3 can be stated as: achievement of the BSAP nutrient reduction targets under all considered climate and socio-economic scenarios.

This KPI thus relates to the international HELCOM BSAP agreement, and thereby also to the regional implementation of the EU MSFD. This KPI also includes and depends on possibilities to capture/reuse nutrient loads from inland waters downgradient/downstream by the coast itself. As such, it is further related to Blue Economy initiatives, e.g., of mussel and seaweed farming that can be used to reduce nutrient concentrations in coastal waters while producing valuable goods (Kotta et al. 2020).

What is the impact of the agricultural set of measures on this KPI?

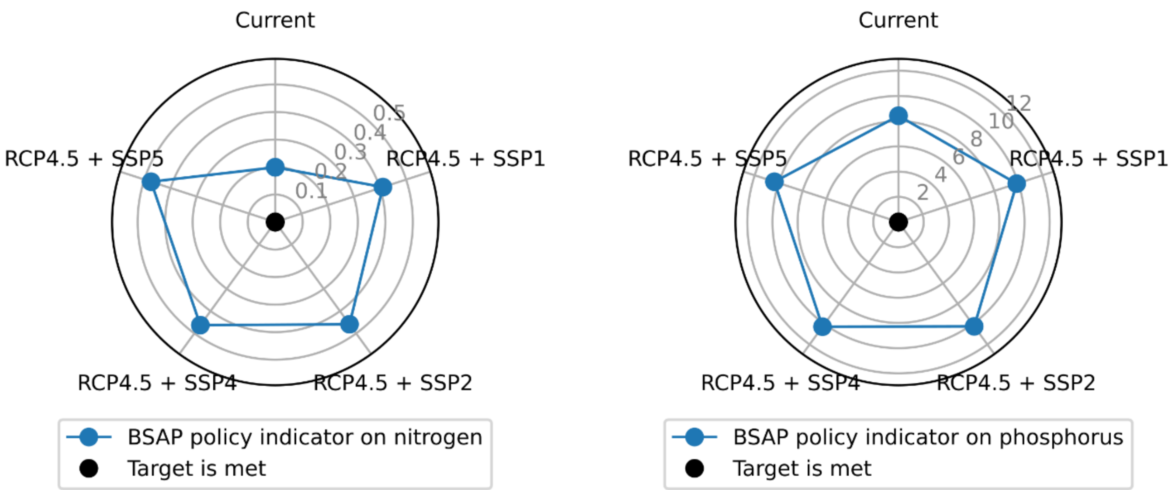

Figure 23: Scenario results of water quality KPIs in 2060 under the agricultural set of measures for the Norrström-Baltic coastal region. These policy-related KPIs quantify the achievement (KPI values equal to or less than zero) or non-achievement (KPI values greater zero) of the Baltic Sea Action Plan (BSAP) mitigation targets for coastal nitrogen load (right panel) and coastal phosphorus load (left panel).

The agricultural set of measures does not yield a sustainable state for these KPIs under any considered climate and socio-economic scenario. These KPIs depend directly on the total nitrogen and phosphorus loads to the coast. Thereby, as for the net waterborne TN and TP inputs/loads to/from natural water systems, the agricultural set of measures improves sustainability in terms of BSAP target achievement indicator only marginally and not robustly (compare Figure 9 for the base case of current management conditions and Figure 10 for the corresponding outcomes under the agricultural set of measures).

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What is the impact of the WWTP set of measures on this KPI?

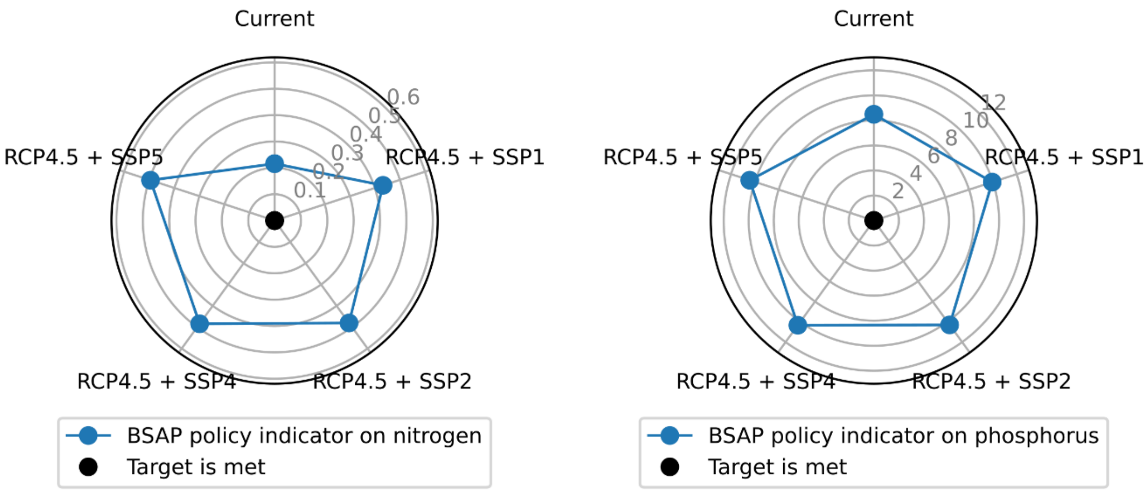

Figure 24: Scenario results of water quality KPIs in 2060 under the WWTP set of measures for the Norrström-Baltic coastal region. These policy-related KPIs quantify the achievement (KPI values equal to or less than zero) or non-achievement (KPI values greater zero) of the Baltic Sea Action Plan (BSAP) mitigation targets for coastal nitrogen load (right panel) and coastal phosphorus load (left panel).

The WWTP set of measures does not yield a sustainable state for these KPIs under any considered climate and socio-economic scenario. These KPIs depend directly on the total nitrogen and phosphorus loads to the coast. Thereby, as for the net waterborne TN and TP inputs/loads to/from the natural water systems, the WWTP set of measures improves sustainability in terms of BSAP target achievement on nitrogen and phosphorus only marginally and not robustly (compare Figure 9 for the base case of current management conditions and Figure 11 for the corresponding outcomes under the WWTP set of measures).

What is the impact of the legacy set of measures on this KPI?

The legacy set of measures can facilitate achievement of the BSAP target for nitrogen and thus reach a sustainable state for this KPI under current climate and socio-economic conditions (Figure 12). This set of measures also improves sustainability in terms of BSAP target achievement for nitrogen and phosphorus for each considered climate and socio-economic scenario (compare Figure 9 for the base case of current management conditions and Figure 12 for the corresponding outcomes under the legacy set of measures). Moreover, the legacy set of measures robustly improves the sustainability of both KPIs (respective KPI values lower than the base case values under current management), but does not fully achieve an ultimate (robust) sustainable state, as the load reduction targets are not met under any other climate and socio-economic scenario than the base case (current climate and socio-economic conditions) scenario under the legacy set of measures for nitrogen.

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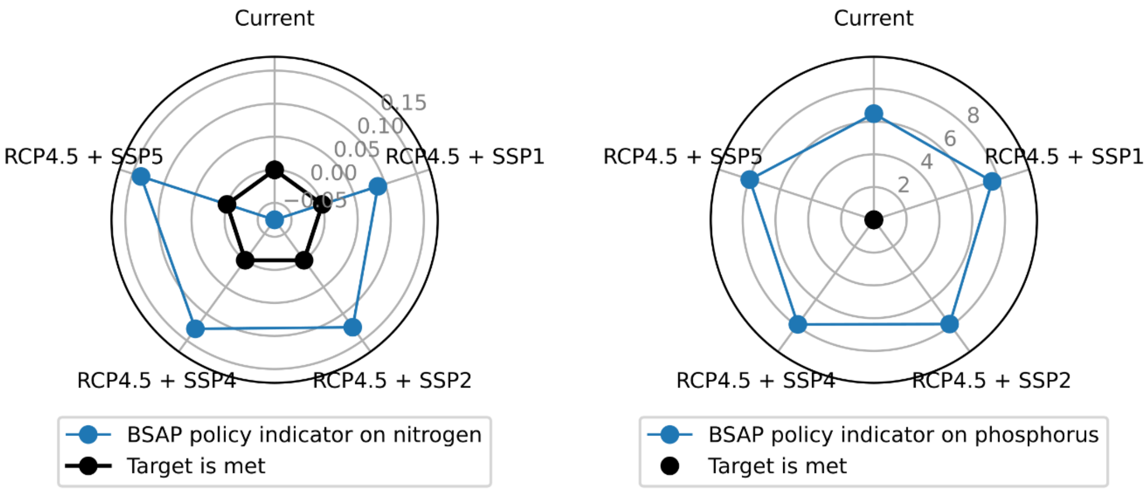

Figure 25: Scenario results of water quality KPIs in 2060 under the legacy set of measures for the Norrström-Baltic coastal region. These policy-related KPIs quantify the achievement (KPI values equal to or less than zero) or non-achievement (KPI values greater zero) of the Baltic Sea Action Plan (BSAP) mitigation targets for coastal nitrogen load (right panel) and coastal phosphorus load (left panel).

Given the impact of climate and ecological changes, economic growth and other external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

In consistency with the results for KPI 2 for the net waterborne TN and TP inputs/loads to/from the natural water systems, the KPI 3 results also show that only the legacy set of measures can substantially and robustly improve sustainability in terms of BSAP target achievement for nitrogen and phosphorus (Figure 13). For the BSAP reduction target for nitrogen, the state is substantially improved with nitrogen load reduction close to the sustainable state across all considered RCP-SSP scenarios. For the BSAP reduction for on phosphorus, the state is also improved, but remains relatively far from the sustainable state across all RCP-SSP scenarios. This implies that even greater phosphorus load reductions than the considered example of 25% are needed from the legacy set of measures to robustly reach a sustainable state. To that end, additional nutrient load capture and reuse measures can be used directly at the coast, such as mussel and seaweed farming and geoengineering solutions targeting legacy nutrients directly in the coastal sediments. These types of measures have not been considered as parts of the legacy set of measures in the present SD modelling investigations, as they do not influence nutrient concentrations in inland subsurface and surface waters, but may follow if enhanced incentives are introduced for circular principles and practices to be applied for nutrient recovery and reuse in policy and business road maps.

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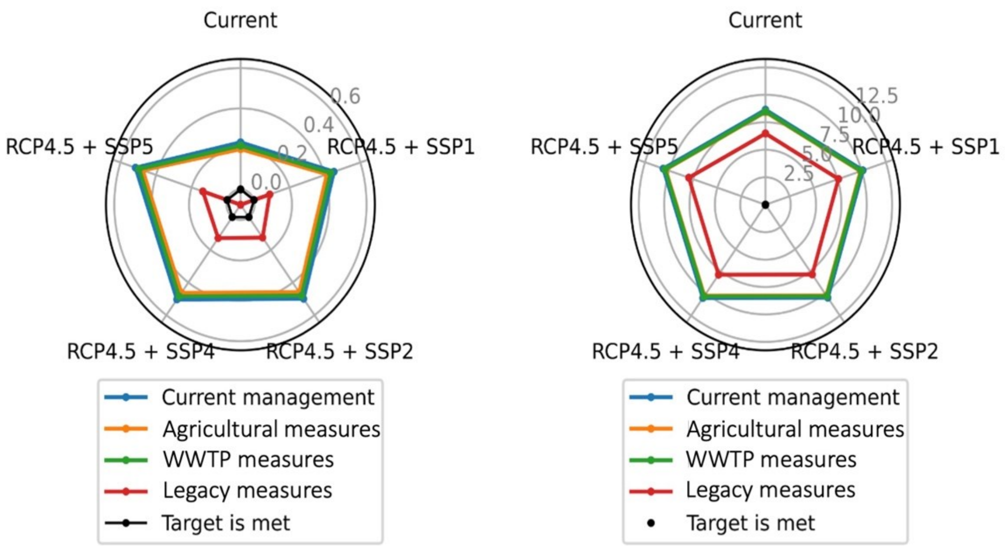

Figure 26: SSP scenario results of KPIs for water quality in 2060 under the various sets management measures from the Norrström-Baltic SD model. Policy-related KPIs showing the achievement (KPI values inferior to zero) or non-achievement (KPI values strictly superior to zero) of the Baltic Sea Action Plan (BSAP) mitigation targets for coastal nitrogen load (right panel) and coastal phosphorus load (left panel).

4.3. CONCLUSIONS

Our SD model simulation results show that measures targeting only currently active sectoral nutrient load reductions, in particular for the predominant active sources of agricultural nutrient leakage and wastewater discharges, yield only limited, insufficient reductions of ongoing nutrient loads from each of these active socio-economic sectors and in total to natural inland and coastal water systems that do not robustly reach sustainable KPI states. In contrast, the legacy set of measures that targets downgradient/downstream capture (and possible reuse) of ongoing dominant nutrient releases from legacy sources in soil, groundwater and sediments can achieve substantial and robust sustainability improvements. These apply directly to the net total waterborne TN and TP inputs/loads to/from natural inland and coastal water systems and can lead to robust sustainability improvements toward achievement of the BSAP nutrient reduction targets – and, depending on RCP-SSP scenario, even reach a sustainable state of the related KPI 3 for nitrogen load reduction that meets the associated BSAP target. These results are consistent with and follow from other, independent reports of dominant diffuse legacy sources that are distributed throughout the land catchments of the MAL3 coastal waters, for both nitrogen and phosphorus. Addressing and mitigating the continuous nutrient releases from these sources, by a legacy set of measures, is thus key to achieving sustainable good water quality and ecological status in the inland and coastal waters of MAL3.

However, the active nutrient source inputs today determine the legacy source conditions of the future. For long-term sustainability and reduction of uncertainty and risk associated with future source evolution, the legacy set of measures should also be combined with the agricultural and WWTP sets of measures in order to stop/reduce further legacy source build-up for the future. By also implementing the agricultural and WWTP sets of measures, in addition to legacy measures, sustainable future nutrient concentrations and loads may

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eventually be maintainable without the necessity to also continue all additional measures in the legacy set. Further SD model developments and simulations are needed to investigate the time frames for such possible shifts in future needs for and effectiveness of various combinations of measures. In general, the implementation of combined measures also requires enhanced inter-sectoral and inter-municipality communication and collaborations, as well as new incentives for implementation of efficient nutrient circularity principles (recycling, reuse) in order to substantially and robustly improve sustainability of societal nutrient loads.

Policy changes needed to incentivize such combined measures would be particularly valuable for phosphorus, which is becoming an increasingly scarce resource, for example through mining of phosphorus legacy reserves in soils and sediments, and productive re-use of sludge-based fertilizers from wastewater treatment plants. Establishment of a nutrient market could drive these types of measure combinations, but discussion with MAL3 partners and stakeholders indicate that this might not be directly feasible at the regional scale of the whole Baltic Sea and its entire land catchment, as needed for total BSAP target achievement.

Moreover, also at the scales of local coastal regions, taking extensive combined measures requires better cooperation between different municipalities and various socio-economic sectors within the total land catchment of each coastal region, along with overarching national agencies that are, e.g., responsible for water, environmental and agricultural policy and management. Such communication and collaboration improvements will likely also need some substantial changes in policy (e.g., shift of the municipal water management monopoly in Sweden) and business practices (e.g., improved information transfer between sectors) of relevance for water, nutrient and environmental management. These changes may drive more sustainable and efficient management, including also more recycling and reuse, of nutrients in each socio-economic sector, as well as of total loads to the natural inland and coastal water systems. Moreover, implementation of a wider range of combined measures, with improved communication and collaboration practices, can also lead to more adaptive nutrient management that can perform better under the various types of uncertainties associated with future scenario, source and load evolutions, and their modelling.

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5. ROBUSTNESS ANALYSIS OF POLICY AND BUSINESS ACTIONS DESIGNED FOR THE CHARENTE RIVER BASIN AND ITS COASTAL ZONE

5.1. Presentation of the measures for the charente river basin and its coastal zone

In this last part of the report, we elaborate on this work and analyse the benefits of different sets of policy and business actions under each of the scenarios (external uncertainties) presented in D19.

Together, the MAL4 team, partners and stakeholders designed three trajectories for the future of the territory:

- Trajectory 1 ("Towards a desirable future") implies a full implementation of the BRM towards the desirable future co-built with the stakeholders. We will interpret the assessed impacts of this trajectory as the advantages and disadvantages of implementing the BRM.
- In Trajectory 2 ("Improving current trends"), collaborative and participative solutions are implemented but to a lower extent than in the first trajectory. We will interpret the assessed impacts of this trajectory as the advantages and disadvantages of continuing current actions or slightly improving them.
- Trajectory 3 ("Towards a fragmented territory") exacerbates different forms of inequality, due to the existence of multiple socioeconomic models, which leads to social tensions. We will interpret the assessed impacts of this trajectory as the advantages and disadvantages of acting without favouring sustainability.

Each trajectory includes two components:

- A qualitative component, which is a narrative describing a possible future evolution of the territory (see below).
- A quantitative component, called set of measures, in which we give different values to the model's input variables that correspond to actions underlying the implementation of the trajectory.

Note that all the sets of measures (trajectories) concern the same actions/input variables but set at different levels. In addition, we assess the effect of implementing the BRM's actions per sector and compare it with the current trends trajectory and with the effect of implementing the whole BRM. We consider four groups of actions:

- Water management: the actions influencing the sharing, use and quality maintenance of water in all sectors ("Management of water as a land-sea continuum" in the BRM, cf. Annex I). Notably, water storage and abstraction permits for agriculture are included in this group.
- Shellfish farming: the actions directly influencing the production of shellfish ("Towards a sustainable shellfish industry rooted in the territory" in the BRM, cf. Annex I).
- Agriculture: the actions influencing the transition towards agroecology and the conduct of farming systems ("Towards a 100% agroecological territory" in the BRM, cf. Annex I).
- Infrastructure & population: the actions influencing the territory's demography (residents and tourism) and investments in infrastructure, notably their spatial distribution ("Towards a harmonious and diversified territory" in the BRM, cf. Annex I).

We discuss the results of this sectoral analysis only for the pertinent KPIs.

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5.2. Qualitative components of the trajectories

5.2.1. Trajectory 1: towards a desirable future (implementation of the BRM)

This trajectory relates to the “desirable future”, designed in collaboration with stakeholders during our workshops, and to be achieved somewhere between 2040 and 2050. It involves widespread societal change, wherein stakeholders across the territory work in synergy to achieve a sea-land continuum. By using a mosaic for the space and its associated activities, as well as applying governance strategies at finer temporal and spatial scales, it is possible to make the territory more resilient in the face of economic and climate change. The partition of space into urbanised, agricultural and protected natural areas has been revised: natural areas increased in urbanised areas to create new spaces where people can interact with their environment in a sustainable way. The size of the homogeneous areas is adapted to the health of the biosystem. This small-scale mosaic of landscapes and activities can be managed to produce biodiversity corridors.

By including local stakeholders in a network, and encouraging a more effective dialogue and knowledge sharing, it is possible for all those involved to achieve a clearer view of development across the area.

It also includes large-scale investment, along with support for local development. This means that public services (including digital services) and infrastructure are available across the territory, preserving its rural and coastal fabric, and allowing local residents to continue to work while remaining in the area. These developments are accompanied by legal and economic innovative changes, with decentralised sources of water and energy making the territory even more independent and resilient. Soils have been reclaimed from artificial development, transport is as low impact as possible, energy production is decentralised, and rainwater management is also decentralised.

Another key aspect of the “desirable future” trajectory is the way in which shellfish farming develops: it is locally focused, creates jobs, and provides quality produce. At the same time, densities and transition zones are better managed, with regulations suitable to the area, and a collective, properly-designed system of water management. This would enable growth and flesh rates to be as good as in other European regions and would avoid the exodus of local businesses.

In addition, mass tourism is restricted, while alternative forms of tourism flourish. Tourism has evolved under two constraints: the management of the accommodation capacity of sites, which allows the management of tourist densities in a given area and the distribution of this accommodation capacity over time, which sets the conditions for seasonality.

Some areas of the coast are given up to the sea, and areas of marshland serve as buffer zones. Ports and windfarms share coastal waters with other activities. Again here, the participative and inclusive aspect of local policies have allowed a better integration of these activities in the coastal area.

Further inland, farming succeeds in transitioning to a greener model, with new rural policies focusing on employment, local development, and the environment. Farming systems become more diverse, less water and pesticide-intensive, and satisfy the organic farming standards (including for vines).

Irrigation is properly managed, and centred on crops with high added value. Mixed crop systems have been introduced (not all varieties are irrigated). With reasonably-sized plots, and a modernized landscape (using hedges and buffer zones), producers have access to new markets, thanks to shorter supply chains and a

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proliferation of medium-sized businesses. All of this helps the rural fabric of the area, and ensures a dynamic population.

Water is managed and treated as a common good for the entire territory. Water quality, as defined by all local stakeholders, improves drastically, with biodiversity being protected. The territory as a whole consumes less water, and so the development of water storage is not necessary beyond current plans.

Public policy considers the environment, sustainable development, and the land-sea continuum in a much more integrated way. It also limits global warming at 1.5 °C, and pushes for faster ecological transition for domestic and economic activities.

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5.2.2. Trajectory 2: improving current trends

In this trajectory, despite attempts to manage urban development through annual action plans (e.g. SRADDET by Région Nouvelle-Aquitaine, 2019), the population tends to be concentrated on the coastline, and is generally centred on existing built-up areas. Tourism continues to develop based on the current model, with heavy demand in coastal areas, and limited development of alternative forms of tourism (e.g. "green tourism", fishing tourism, etc.). The tourist sites are increasingly crowded and traffic is very difficult. Housing prices have risen sharply due to demographic pressure and competition for space, preventing locals and seasonal workers from finding accommodation close to their work. Population density and soil artificialisation lead to recurrent pollution of coastal waters.

The development of collaborative and participative solutions is less extensive than in the "desirable" scenario, and little is done to ensure cohesiveness within the territory. The paradigm change, i.e. a switch from a sectoral approach to a territorial approach, has not yet been achieved, and sea-land synergies have not developed as imagined in the original roadmap. Public policy continues to be based on a "silo approach", with less widespread action to slow the effects of climate change and encourage sustainable development (regulations, investment, regional action plans, etc.). While population densities are not extremely high, economic activities and populations are not particularly spread out either.

The transition towards organic farming is slower and less effective, and the territory is unable to achieve 100% organic farming, or certified sustainable farming, as in the desirable scenario. A certain proportion of farming activity remains conventional, and there is still some irrigation of vineyards. Livestock breeding continues in natural grassy areas, as part of an organic process, or under a particular quality label.

Managing water as a common good remains an objective, with a number of parallel models, notably one based on multi-stakeholder management and another on privatisation, which generates a certain amount of friction. The issue of the availability of drinking water is beginning to arise. Locally-focused shellfish farming continues within the territory, but oysters are still seen as an invasive species. There are no changes to areas dedicated to shellfish farming, and a Europe-wide model is favoured in cases where water quality is not of a high standard. Shellfish purification is becoming a major cost and its increase is leading to the relocation of farms and social tensions with inland stakeholders who are blamed for polluting waters.

Despite individual efforts to save water, water demand rises with population and climate change, and quantity issues remain. Water storage develops according to current plans but access is not ensured to all.

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5.2.3. Trajectory 3: towards a fragmented territory

Trajectory 3 exacerbates different forms of inequality, due to the existence of multiple models, which in turn lead to social tensions. Economic growth is stunted. There have been important technological developments, particularly in high-tech fields. Wealth and income are increasingly concentrated in certain areas. Because of this, population density is at its highest on the coastline and in built-up areas, with economic activity being concentrated in much the same way. Urban planning prioritises housing density through the construction of buildings as agricultural and natural areas are protected by regulations.

Tourism has developed extensively along the coastline, with wide-ranging consequences for infrastructure and water resources. Inhabitants are divided into zones depending on their income, and access to services is far from equal. Public policies are more focused on promoting competitiveness and market growth than on sustainable development. Large retailers include agro-ecological products in their business model.

Development of renewable energy sources is limited, with continued dependence on fossil fuels. The ecological transition is only in its very beginnings, and climate change produces many undesirable effects, which are not addressed in a uniform way, with mitigation measures instead depending on location and the profitability of the activities.

Retiring farmers have often not been replaced, meaning that an unequal production system has developed, focused on large-scale farms, which, although conforming to organic farming standards, are far from sustainable in terms of employment, protection of the rural fabric, and their impact on the environment (e.g. adaptation, biodiversity, etc.). Access to water is not equal, and tends to be the preserve of those with the means to pay. Irrigated crops have a high added value, but there has been limited development of mixed crop systems (irrigated/non irrigated).

A certain proportion of vineyards is irrigated. Water storage infrastructure is partly privately funded by wealthy groups for their own purpose and more developed than in the green scenario. The objective of water being treated as a common good for the whole territory has yet to be achieved as part of the water management strategy. Problems of water quality have not been resolved, biodiversity is under threat, and the fragmentation of the territory as a whole has led to wide-reaching structural and spatial changes in the hydrological layout of the watershed. The scarcity of fresh water leads to the rise of salt water in the coastal aquifers. The effects of climate change lead to a deficit in freshwater and a salinization of estuaries Locally-focused shellfish farming has continued in some areas of the territory (largely dependent on financial support), but many farms have been abandoned and some areas are silted up. The coastal marshes lose their brackish character and their identity as a transition zone. A more European-focused form of shellfish farming has begun to take its place. Shellfish farming loose its position as a symbol of this transitional coastal zone.

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5.3. Quantitative components of the trajectories

Table 8 gives an overview of the SD model's input variables that represent possible actions in the modelled territory. A given input variable can represent several actions described in the BRM, and a given BRM action can be represented by several input variables (cf. tables in Annex II).

Table 8 : Input variables in the system dynamics model that are linked to real actions. The colours correspond to the sectors of activity: blue for water management, yellow for shellfish farming, green for agriculture, pink for population and tourism, and grey for infrastructure.

Input variable	Description	Example of real action reflected in variable (from the BRM)
abstraction permits for irrigation	The amount of water set by regulations that can be withdrawn for irrigation.	Improve the collective and cross-sectoral management of water as a common good (sharing issue) through enlarged consultations and possibly new management rules.
reservoirs capacity	The volume of water that is stored in reservoirs during winter to irrigate cultures during summer.	Further include and consider users in the collective management of water storage for agriculture (in particular downstream users).
share of irrigation demand that can access reservoirs	Share of the demand for irrigation water that can get access to the reservoirs.	Further include and consider all water users in the collective management of water storage for agriculture (in particular downstream users).
reused share from WWTP [coastal/rural]	Share of costal /rural wastewater that is reused for irrigation.	Use wastewater for different activities, diminish water use in all activities and improve water efficiency.
capacity [coastal/rural] WWTP people eq	Wastewater treatment capacity in the coastal/rural area.	Adapt infrastructure to achieve sustainable exploitation of the water resource (WWTP capacity, water network, housing, etc.).
authorised oyster farms area	The total area that can be dedicated to oyster farming by regulations.	Adjust areas, ideally extending them, and densities to achieve a product quality compatible with the market demand.
share of floating bags	Two types of bag can be used for growing oysters: floating bags (new) or tables (traditional). The variable represents the proportion of floating ones.	Develop and use new farming technologies to produce higher quality products and reduce environmental impacts.
oyster density per bag year 3	Number of oysters grown per bag during the third production year (main growth year).	Negotiate a common total stock of farmed oysters to efficiently and sustainably exploit the trophic capacity of the system (guarantee of a flesh content satisfying the constraints of the label).

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mortality rate year [1 to 3]	Mortality of oysters during the first/second/third production year.	Collect and spread producers' and scientific knowledge about how the water quality, the input of freshwater and the trophic resource affect shellfish production in the marshes, in the estuary and at sea.
agroecological share of food consumption	Share of agroecological products in the domestic consumption of agricultural products, measured in euros.	Continue the sensitization of consumers and support the commercialisation of agroecological products.
agroecological share of supply chain	Share of the operators involved in the supply of agricultural products that are certified for agroecological products.	Create new supply chains and increase commercial alliances to jointly promote products "from the territory".
employment per 100ha [conventional/ agroecological]	Number of people needed to conduct 100 hectares of conventional/agroecological farming.	Improve the attractiveness of rural areas with more services, infrastructure, job opportunities, etc.
agroecological share of vines	Share of the vineyards area under agroecology.	Reach 100% of agroecological vineyards.
change rate of total agricultural area	Change rate of the total UAA, expressed as a decrease rate since it will most likely keep diminishing. All losses are attributed to conventional agriculture.	Maintain the agricultural area and a dynamic rural fabric thanks to a structure that monitors land acquisition.
agricultural workers replacement rate	The rate at which new farmers take the place of retiring ones	Promote the installation of young farmers and the transmission of farms, through new legal and employment structures and new installation incentives.
tourists demand growth per year	Yearly growth of the number of nights that tourists want to spend in total over a year.	Regulate the tourism offer (facilities, infrastructure) to limit mass tourism.
coastal share of residents	Share of the residents who live on the coast.	Find incentives to maintain a residential population balanced throughout the territory.
coastal share of tourists	Share of the tourists who stay on the coast.	Foster new forms of tourism (rural, alternative, seasonal, etc.) less concentrated during the summer period and on the coastal zone.

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water use per person	Water consumption per person per month (same for residents and tourists).	Further sensitize citizens to water savings.
urban yearly expansion	Yearly expansion of urban areas, as reported and planned in Nouvelle-Aquitaine's regional land management and territorial development plan (SRADDET by Région Nouvelle-Aquitaine, 2019).	Limit land artificialisation.
coastal share of urban expansion	Share of the urban expansion occurring in the coastal area.	Improve land use planning policies to better manage competition for space between multiple activities in the coastal zone.

For each of the three studied trajectories, we assigned, in collaboration with the stakeholders, a different value to all the input variables listed in Table 8. This allows representing business and/or policy actions that intervene more or less in the modelled land-sea system. The values chosen for each variable are their possible future values. In the model, the value of a given input variable is set via an increasing or decreasing curve starting at its current value (2020) and reaching the proposed value by a year that depends on whether the variable corresponds to short, mid or long-term actions in the BRM (cf. table in Annex II): 2025 for short-term, 2030 for mid-term, 2035 for long-term. When we had no clear idea about the possible evolution of a variable, we assumed a linear change over time. The input variables then remain constant after their term. As a result, from 2035, all the actions have been implemented and effective in the model. Since we simulate the model until 2050 with some external drivers that keep changing after 2035 (population, climate), this allows observing how the system should behave once the actions have been implemented.

The remaining part of this chapter describes the evolution of each input variable under each trajectory.

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5.3.1. Water input variables

Table 9 summarizes the studied trajectories for the water sector while Table 10 presents the values of the related input variables and Figure 27 their evolution over time.

Table 9 : Synthesis of the three territorial trajectories for water.

Trajectory 1 Towards a desirable future	Trajectory 2 Improving current trends	Trajectory 3 Towards a fragmented territory
Water is managed as a common good on the basis of enlarged consultations with the objective to meet all needs. The territory as a whole consumes less water. Water storage develops according to current plans and access is guaranteed to all. Water quality, as defined by all stakeholders, improves drastically, with biodiversity being protected.	Water management is not adapted to deal with territory-level issue. Despite individual efforts to save water, water demand rises with population and climate change. Water storage develops according to current plans but access is not ensured to all. Water quality remains low.	Water is no longer treated as a common good for the whole territory and demand remains high. Access to water is not equal and tends to be the privilege of those who can afford to pay for it, leading to the development of private access water storage. Quantity and quality issues are frequent.

Table 10 : Value per territorial trajectory of the input variables for water.

Variable	Description	Unit	2000 value	2020 value	Towards a desirable future	Improving current trends	Towards a fragmented territory
abstraction permits for irrigation	The amount of water set by regulations that can be withdrawn for irrigation.	Mm3/ year	100	45	35	45	55
reservoirs capacity	The volume of water that is stored in reservoirs during winter to irrigate cultures during summer.	Mm3/ year	7	7	25	25	35
share of irrigation demand that can access reservoirs	Share of the demand for irrigation water that can get access to the reservoirs.	%	1	1	1	0.7	0.4
reused share from WWTP coastal	Share of costal wastewater that is reused for irrigation.	%	0	0.1	0.3	0.2	0.1

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reused share from WWTP rural	Share of rural wastewater that is reused for irrigation.	%	0	0.1	0.3	0.2	0.1
capacity coastal WWTP people eq	Wastewater treatment capacity in the coastal area.	people-eq.	400000	400000	600000	500000	400000
capacity rural WWTP people eq	Wastewater treatment capacity in the rural area.	people-eq.	200000	200000	300000	250000	200000

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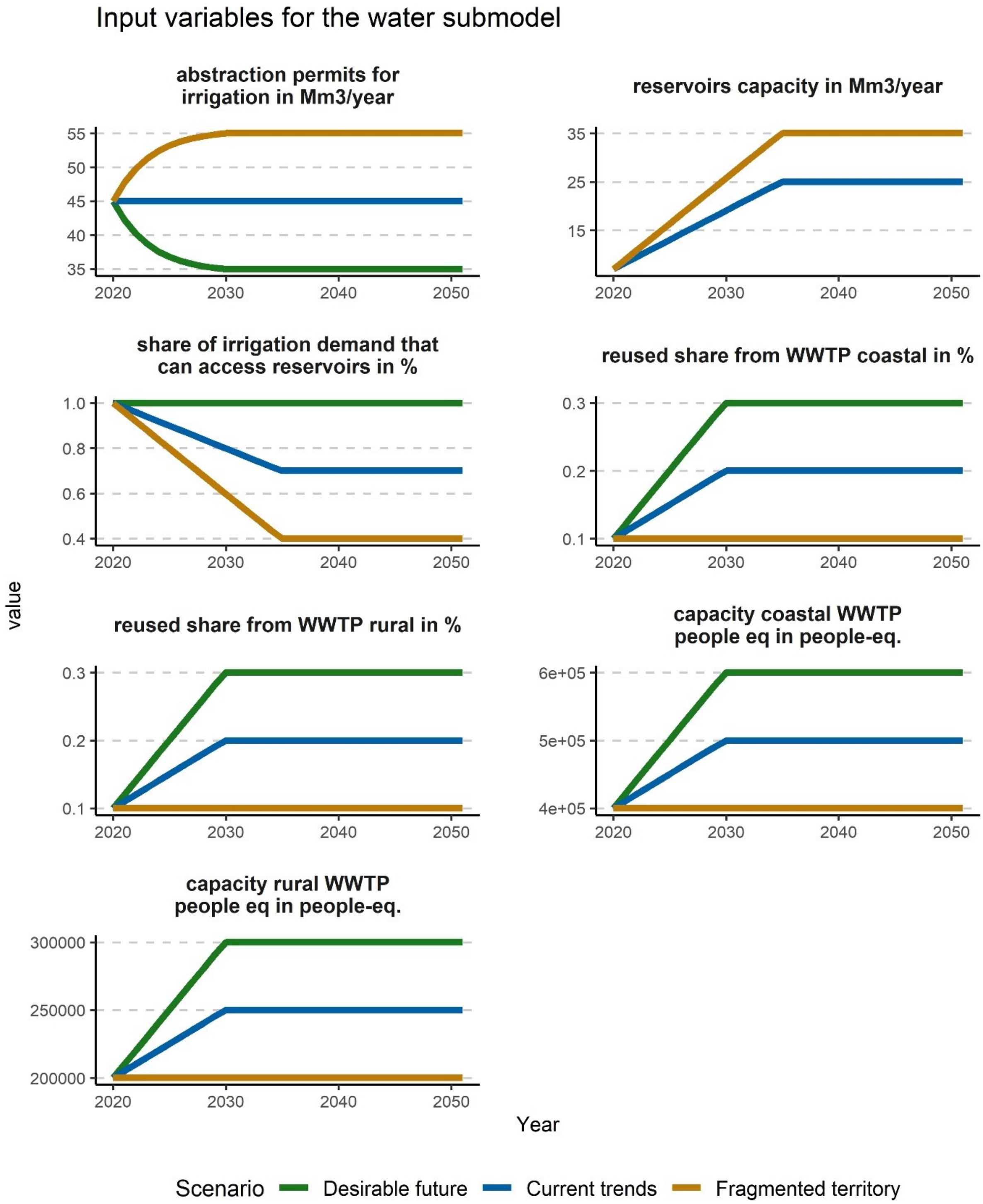

Figure 27 : Dynamic trends of the input variables for the water sector, as entered in the SD model.

5.3.1.1. abstraction permits for irrigation

Trajectory 1: agriculture moves towards a model that demands less water and there are strong regulations to preserve and restore the water resources. Therefore, we assume that the abstraction permits will be lower than currently (35 Mm^3/yr).

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Trajectory 2: current trends continue, with less water-demanding agricultural systems. Overall, permits remain at their current level (45 Mm^3/yr).

Trajectory 3: the water demand for irrigation remain high, as the development of mixed systems is limited. Combined with a lower protection of ecosystems, this will lead to an increase in abstraction permits for irrigation (55 Mm^3/yr), with a higher capacity of water storage.

5.3.1.2. reservoirs capacity

Trajectory 1: the territory as a whole consumes less water and manages it as a common good. With a lower water demand, water storage does not develop beyond current plans (25 Mm^3).

Trajectory 2: water storage develops according to current plans (25 Mm^3) with a difference in access due to an inadequate management (cf. next variable).

Trajectory 3: water is not managed as a common good and is privatized by those with the means to pay (large wealthy farms). Hence, water storage develops widely (35 Mm^3).

*5.3.1.3. s*hare of irrigation demand that can access reservoirs

Trajectory 1: irrigation demand is well regulated and the collective management of water resource ensures access to all farmers (100% of water demand has access).

Trajectory 2: the collective management of water is not achieved and access to water storage is not guaranteed to all (70% of demand has access).

Trajectory 3: Access to water is unequal and limited to big farms or companies who can afford to store water (40% of demand has access).

5.3.1.4. reused share from WWTP coastal/rural

Trajectory 1: legal and economic innovative changes, with decentralised sources of water and energy, make the territory's infrastructure more adapted and resilient. The reuse of wastewater is encouraged (30% is reused).

Trajectory 2: despite efforts to save water and reuse it, investments are not very high and the reuse from WWTP reaches 20%.

Trajectory 3: the lack of public incentives and adapted regulations make the share of reused wastewater low (10%).

5.3.1.5. capacity coastal WWTP people eq

Trajectory 1: the likely increase in population in the coastal zone is taken into account with adapted WWTP capacity (600000 people-eq.) to support a sustainable development.

Trajectory 2: the investment in infrastructure follow current trends and there is no incentive to allocate public funding on a reinforced capacity (500000 people-eq., slightly under-dimensioned like currently).

Trajectory 3: the lack of public incentives and adapted regulation make the WWTP capacity under-dimensioned (400000 people-eq.).

5.3.1.6. capacity rural WWTP people eq

Trajectory 1: the development of infrastructure in the whole territory is adapted to the population, less concentrated on the coastline. Therefore the rural wastewater treatment capacity is reinforced (300000 people-eq.).

Trajectory 2: despite a more concentrated population in the coastal zone, efforts are made to grow the rural capacity (250000 people-eq.).

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Trajectory 3: investments in wastewater treatment occur mainly in cities and the coastal zone where population is concentrated. The rural capacity remains low (200000 people-eq.).

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5.3.2. Shellfish farming input variables

Table 11 summarizes the studied trajectories for the shellfish farming sector while Table 12 presents the values of the related input variables and Figure 28 their evolution over time.

Table 11 : Synthesis of the three territorial trajectories for shellfish farming.

Trajectory 1 **Towards a desirable future**	**Trajectory 2** **Improving current trends**	**Trajectory 3** **Towards a fragmented territory**
Areas increases and best practices are shared among producers. With an improved water quality, shellfish farming is locally focused, creates jobs and provides quality products.	Areas dedicated to shellfish farming do not change. A Europe-wide model is favoured when water quality is not high enough.	Because of water quality issues, locally-focused shellfish farming continues in some areas of the territory but many farms have been abandoned and some areas are silted up.

Table 12 : Value per territorial trajectory of the input variables for shellfish farming.

Variable	**Description**	**Unit**	**2000 value**	**2020 value**	**Towards a desirable future**	**Improving current trends**	**Towards a fragmented territory**
authorised oyster farms area	The total area that can be dedicated to oyster farming by regulations.	ha	597	597	650	597	550
share of floating bags	Two types of bag can be used for growing oysters: floating bags (new) or tables (traditional). The variable represents the proportion of floating ones.	%	0	0	0.5	0.25	0.5
oyster density per bag year 3	Number of oysters grown per bag during the third production year (main growth year).	oysters/bag	180	180	160	180	200
mortality rate year 1	Mortality of oysters during the first production year.	%/year	0.4	0.55	0.48	0.55	0.67
mortality rate year 2	Mortality of oysters during the second production year.	%/year	0.15	0.13	0.06	0.13	0.25
mortality rate year 3	Mortality of oysters during the third production year.	%/year	0.05	0.15	0.13	0.15	0.18

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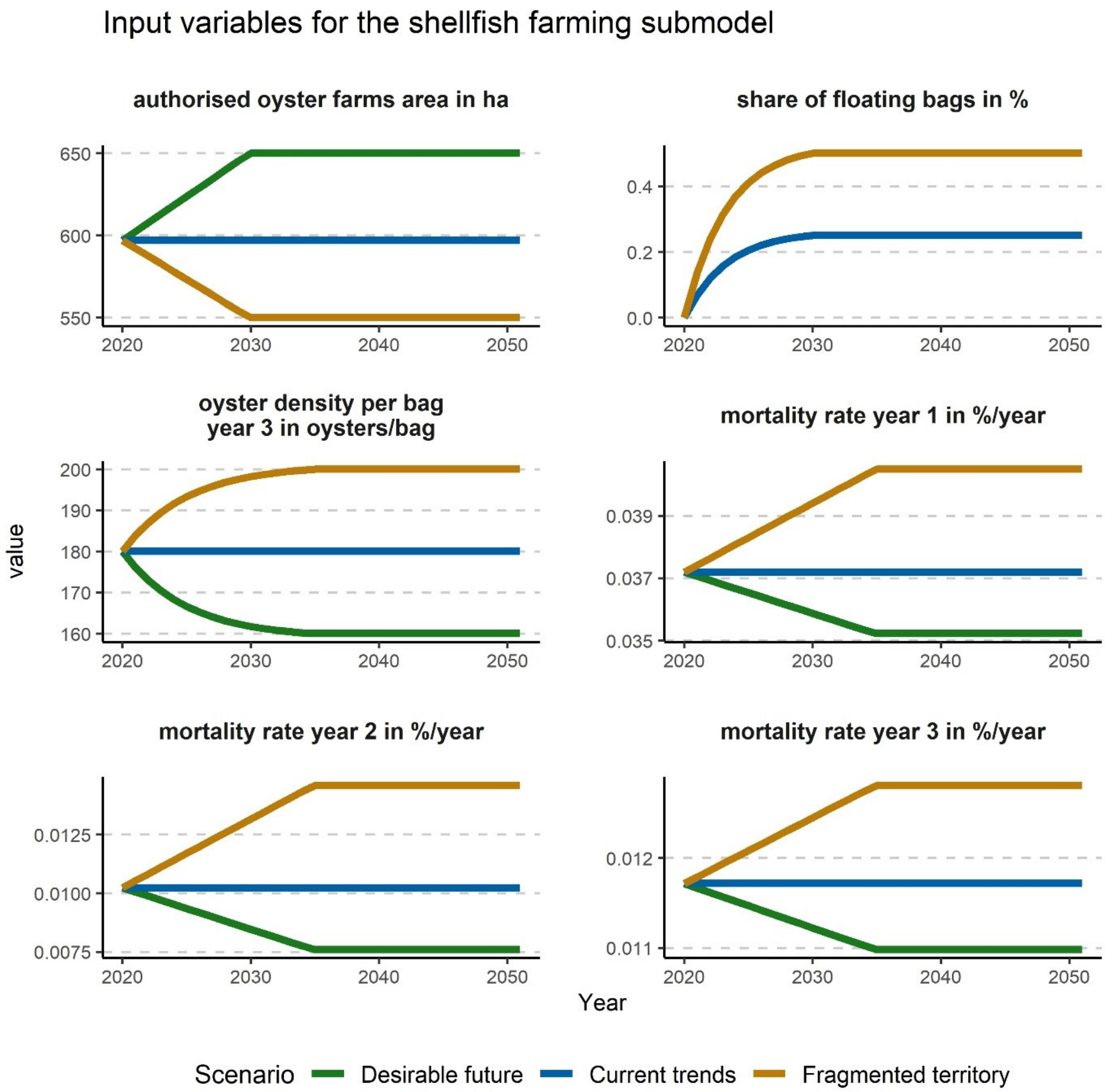

Figure 28 : Dynamic trends of the input variables for the shellfish farming sector, as entered in the SD model.

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5.3.2.1. authorised oyster farms area

Trajectory 1: because the production is less dense and innovative and sustainable practices are introduced, as well as new regulations suitable to the area, shellfish farming areas can thus increase (to 650 ha) while preserving the environment and in particular coastal water resources.

Trajectory 2: following the current trend, there are no changes to areas (597 ha) dedicated to shellfish farming.

Trajectory 3: some traditional shellfish farming areas are abandoned and oyster farms areas decrease (550 ha), due to a damaged environment and to the development of Europeanised shellfish farming and off ground breeding.

5.3.2.2. share of floating bags

Trajectory 1: the development of this new technique is moderate (50%) as some small-scale producers maintain their traditional technique.

Trajectory 2: the technique does not widely spread (25%), following a business as usual logic.

Trajectory 3: the technique spreads (50%) as large-scale producers, who have the capacity to invest in new technologies, concentrate most of the activity.

5.3.2.3. oyster density per bag year 3

Trajectory 1: a lower density of production (160 oysters/bag) is favoured to produce higher quality oysters.

Trajectory 2: the current densities are kept (180 oysters/bag).

Trajectory 3: more intensive shellfish farming will lead to an increase of production density (200 oysters/bag).

5.3.2.4. mortality rate year 1 to 3

Trajectory 1: the mortality rates are low due to a higher water quality, lower densities and a sustainable management of the activity based on the sharing of empirical knowledge and new technologies.

Trajectory 2: both small-scale and intensive shellfish farming share the farming areas and water quality issues remain. The mortality rates stay at their current level.

Trajectory 3: the European-focused form of shellfish farming dominates, with only intensive production in the region. There is no sustainable management of water resources and the water quality is deteriorated. Therefore, the mortality rates are high.

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5.3.3. Agriculture input variables

Table 13 summarizes the studied trajectories for agriculture while Table 14 presents the values of the related input variables and Figure 29 their evolution over time.

Table 13 : Synthesis of the three territorial trajectories for agriculture.

Trajectory 1 Towards a desirable future	Trajectory 2 Improving current trends	Trajectory 3 Towards a fragmented territory
New rural policies focus on employment, local development, and the environment. Farming succeeds in transitioning to an agroecological model.	Current policies continue but are not sufficient to solve all the existing rural development issues. The transition towards agroecological farming continues but is slower and less effective.	Policies do not particularly support rural development and the agroecological transition. An unequal production system develops, focused on large-scale farms. Although conventional practices become greener to some extent, environmental issues expand.

Table 14 : Value per territorial trajectory of the input variables for agriculture.

Variable	Description	Unit	2000 value	2020 value	Towards a desirable future	Improving current trends	Towards a fragmented territory
agroecological share of food consumption	Share of agroecological products in the domestic consumption of agricultural products, measured in euros.	%	0.01	0.063	0.8	0.4	0.1
agroecological share of supply chain	Share of the operators involved in the supply of agricultural products that are certified for agroecological products.	%	0.1	0.57	1	0.8	0.6
employment per 100ha conventional	Number of people needed to conduct 100 hectares of conventional farming.	FTE*/ 100ha	2.5	2.5	2.5	2.5	2
employment per 100ha agroecological	Number of people needed to conduct 100 hectares of agroecological farming.	FTE/ 100ha	3.25	3.25	3.25	2.75	2.25
agroecological share of vines	Share of the vineyards area under agroecology.	%	0	0.015	1	0.75	0.5
agricultural workers replacement rate	The rate at which new farmers take the place of retiring ones.	%/year	0.66	0.66	0.75	0.5	0.25

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* FTE: full-time equivalent

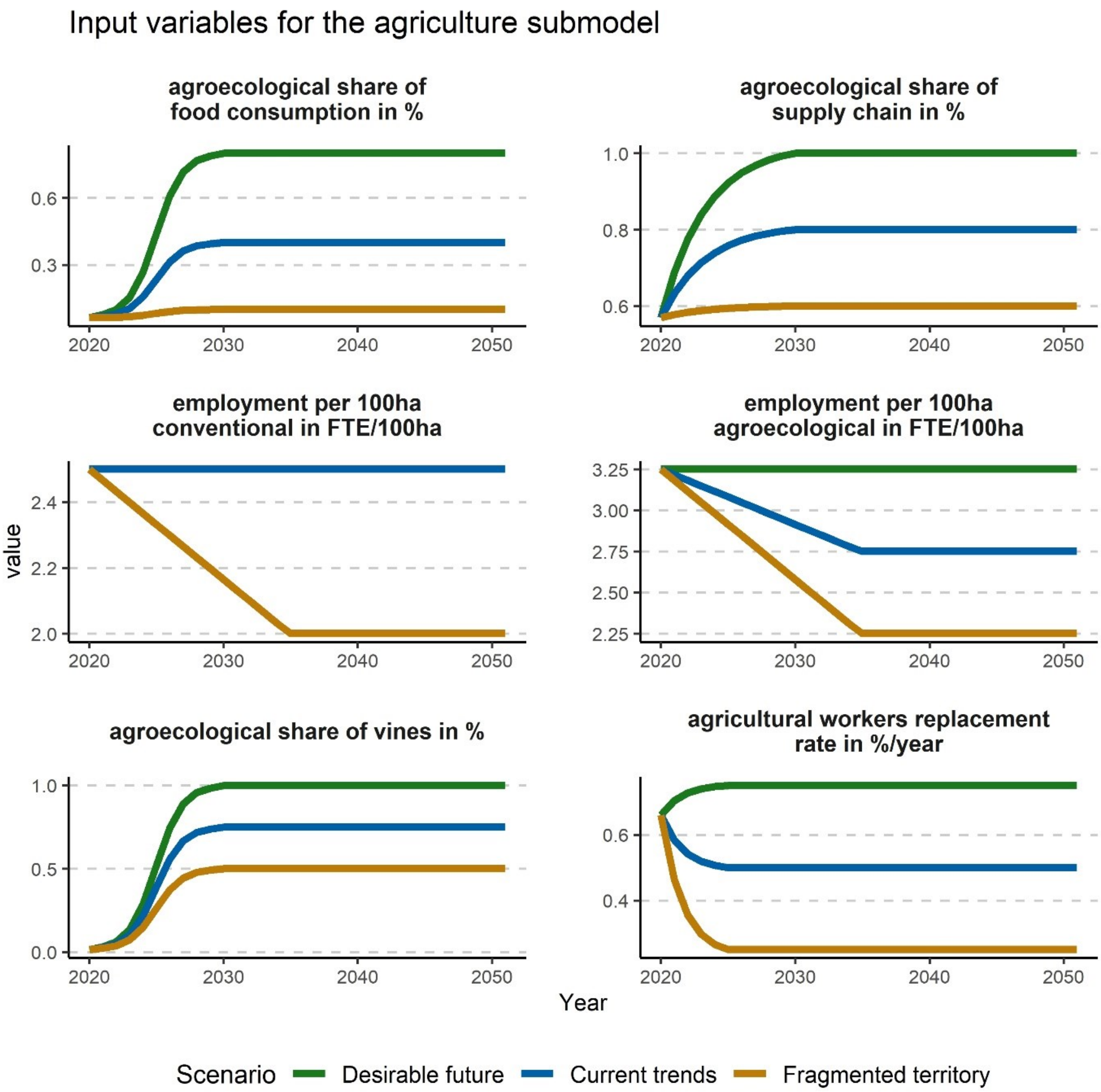

Figure 29 : Dynamic trends of the input variables for agriculture, as entered in the SD model.

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5.3.3.1. agroecological share of food consumption

Trajectory 1: new supply chains develop aside the diversification of agricultural production and the consumer demand for agroecological products reaches a very high level in a highly aware population (80%).

Trajectory 2: the demand for agroecological products reaches a high but lower level (40%), in anticipation of current trends.

Trajectory 3: sustainable agriculture does not develop much and agroecological products remain a niche. The demand quickly stagnates at a low level (10%).

5.3.3.2. agroecological share of supply chain

In general, we assume that the development of short supply chains, which is necessary to some extent for the development of agroecology, will follow consumer demand.

Trajectory 1: diversification of crops implies diversification of commercial outlets, both for food and non-food products. Both long and short supply chains for agroecological products develop. Ultimately, 100 % of the food supply chain is certified agroecological products.

Trajectory 2: with a lower demand and less emphasis on short distribution circuits, only 80% of the food supply chain is certified in the end.

Trajectory 3: a production system focused on large-scale farms, which do not sell though short supply chains, dominates. The agroecological share of the supply chain stagnates at 60%.

5.3.3.3. employment per 100ha conventional/agroecological

Trajectory 1: agroecology is highly developed, with the maintenance of small and medium size farms, and therefore labour needs remain the same (3.25 FTE/100ha). Same for conventional agriculture that does not improve a lot in technological terms since it becomes marginal (2.5 FTE/100ha).

Trajectory 2: agroecology, which develops less and in larger farms, becomes a bit more mechanized and requires less labour (2.75 FTE/100ha). Conventional farming remains the same as it loses importance and so investments (2.5 FTE/100ha).

Trajectory 3: the development of large scale, more intensive and specialised farms, for both agroecological and conventional farming, enables a lower workforce need. For agroecology, it decreases to 2.25 FTE/100ha, and for conventional farming to 2 FTE/100ha.

5.3.3.4. agroecological share of vines

Trajectory 1: all the farmers adopt labelled or agroecological practices in 100% of the vineyards area.

Trajectory 2: a part of vineyards is still managed in a conventional and pesticides consuming way, the agroecological share is 75%.

Trajectory 3: with few policy or economic incentives, only 50% of vineyards implement agroecological practices.

5.3.3.5. agricultural workers replacement rate

Trajectory 1: various actions facilitate access to land, making rural jobs more attractive to young people or professionals. Therefore, the replacement rate increases to 75 %/year.

Trajectory 2: replacing the agricultural workforce is a major challenge for the territory. Without strong additional efforts, the replacement rate decreases to 50 %/year following current trends.

Trajectory 3: agriculture is focused on large-scale high productivity farms, making agriculture less attractive for young people and decreasing the needed workforce. Hence, the replacement rate diminishes to 25 %/year.

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5.3.4. Population & tourism input variables

Table 15 summarizes the studied trajectories for population and tourism while Table 16 presents the values of the related input variables and Figure 30 their evolution over time.

Table 15 : Synthesis of the three territorial trajectories for population and tourism.

Trajectory 1 Towards a desirable future	Trajectory 2 Improving current trends	Trajectory 3 Towards a fragmented territory
Public services and infrastructure are available across the territory, preserving its social fabric in the rural and coastal areas. This allows local residents to continue to live and work in the area. Mass tourism is restricted, while alternative forms of tourism flourish.	The population tends to be concentrated on the coastline and around existing built-up areas. Tourism develops based on the current model, with heavy demand in coastal areas, and limited development of alternative forms.	The population density is at its highest on the coastline and in built-up areas. Tourism develops extensively along the coastline, with wide-ranging consequences for infrastructure and water resources

Table 16 : Value per territorial trajectory of the input variables for population and tourism.

Variable	Description	Unit	2000 value	2020 value	Towards a desirable future	Improving current trends	Towards a fragmented territory
tourists demand growth per year	Yearly growth of the number of nights that tourists want to spend in total over a year.	nights/ year	14000	40000	40000	50000	60000
coastal share of residents	Share of the residents who live on the coast.	%	0.7	0.7	0.6	0.7	0.8
coastal share of tourists	Share of the tourists who stay on the coast.	%	0.8	0.8	0.6	0.7	0.8
water use per person	Water consumption per person per month (same for residents and tourists).	m3/ (month x person)	5	5	4	4.5	5

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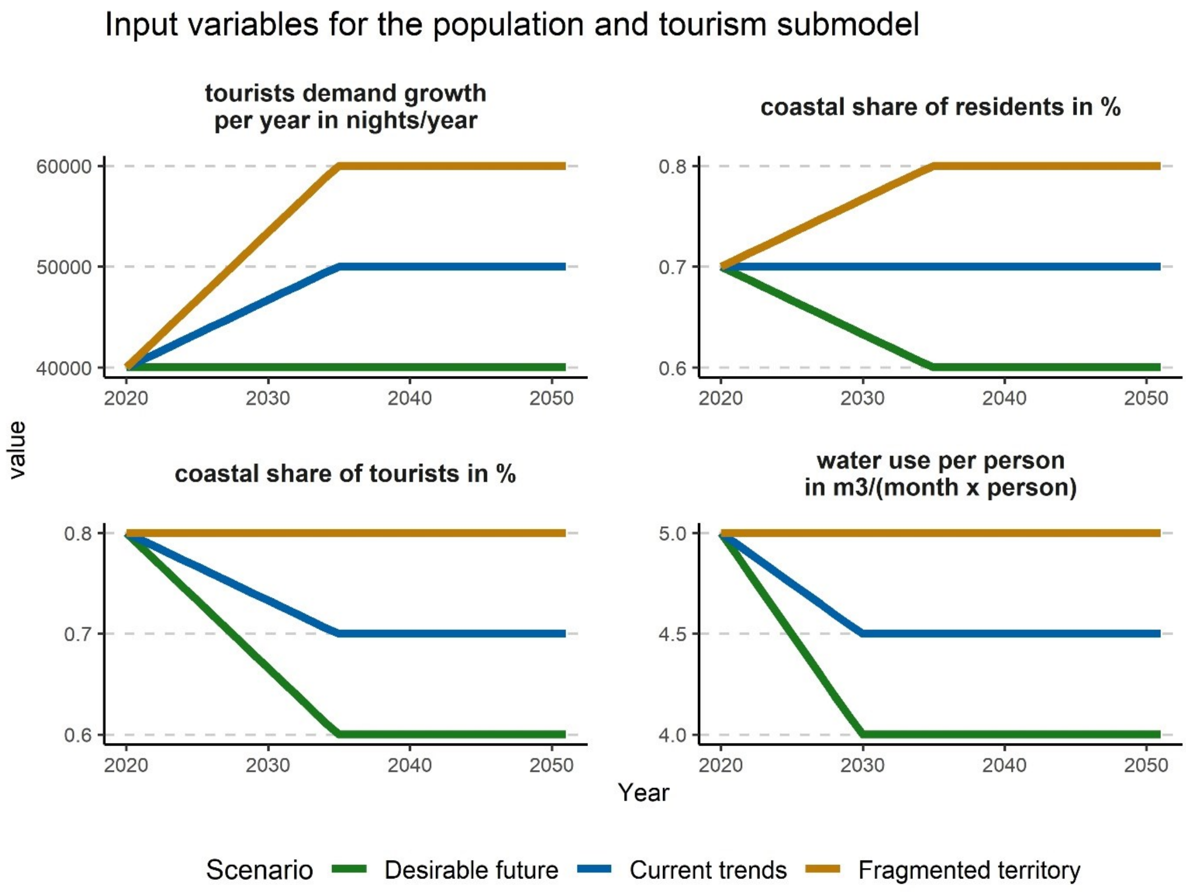

Figure 30 : Dynamic trends of the input variables for population and tourism, as entered in the SD model.

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5.3.4.1. tourists demand growth per year

In all the scenarios, tourism increases.

Trajectory 1: tourism's growth is efficiently managed (limited to current +40000 nights/year) as sustainable and alternative tourism (rural, green, biking, etc.) are favoured.

Trajectory 2: tourism, oriented towards sustainability but still mostly seen as a source of income, slightly increases (+50000 nights/year).

Trajectory 3: mass tourism strongly develops (+60000 nights/year) while alternative tourism is barely maintained.

5.3.4.2. coastal share of residents/tourists

The shares of residents living and tourists staying on the coastal zone should follow the same dynamics. Hence, we assign them the same values in the scenarios.

Trajectory 1: the populations of residents and tourists, and activities too, are more or less harmoniously distributed over the territory, considering that the coastal zone will always be favoured (60%) through heliotropism notably.

Trajectory 2: the population remains concentrated on the coastal area (70%), still more accessible and attractive.

Trajectory 3: the residents and tourists, as well as activities, concentrate on the coastal zone (80%) because of the lack of infrastructure in the rural area.

5.3.4.3. water use per person

Trajectory 1: with highly aware citizens and local policies more focused more on water savings, domestic water use per person decreases to 4 Mm^3/month.

Trajectory 2: without particular efforts, water use per person keeps decreasing to 4.5 Mm^3/month.

Trajectory 3: without further sensitization of the citizens, water use per person stagnates at 5 Mm^3/month.

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5.3.5. Infrastructure input variables

Table 17 summarizes the studied trajectories for infrastructure while Table 18 presents the values of the related input variables and Figure 31 their evolution over time.

Table 17 : Synthesis of the three territorial trajectories for infrastructure.

Trajectory 1 Towards a desirable future	Trajectory 2 Improving current trends	Trajectory 3 Towards a fragmented territory
The partition of space into urbanised, agricultural and protected natural areas has been revised: natural areas increased in urbanised areas and infrastructure is available across the territory. The rural fabric has been preserved.	Despite attempts to manage urban development through annual action plans, the population tends to be concentrated on the coastline, and is generally centred around existing built-up areas.	Population density is at its highest on the coastline and in built-up areas. Urban planning prioritises housing density through the construction of buildings as agricultural and natural areas are protected by regulations. Infrastructure and services are spread in a very unequal way throughout the territory.

Table 18 : Value per territorial trajectory of the input variables for infrastructure.

Variable	Description	Unit	2000 value	2020 value	Towards a desirable future	Improving current trends	Towards a fragmented territory
urban yearly expansion	Yearly expansion of urban areas, as reported and planned in Nouvelle-Aquitaine's regional land management and territorial development plan (SRADDET by Région Nouvelle-Aquitaine, 2019).	ha	425	425	212	318	425
coastal share of urban expansion	Share of the urban expansion occurring in the coastal area.	ha	0.7	0.7	0.5	0.6	0.7

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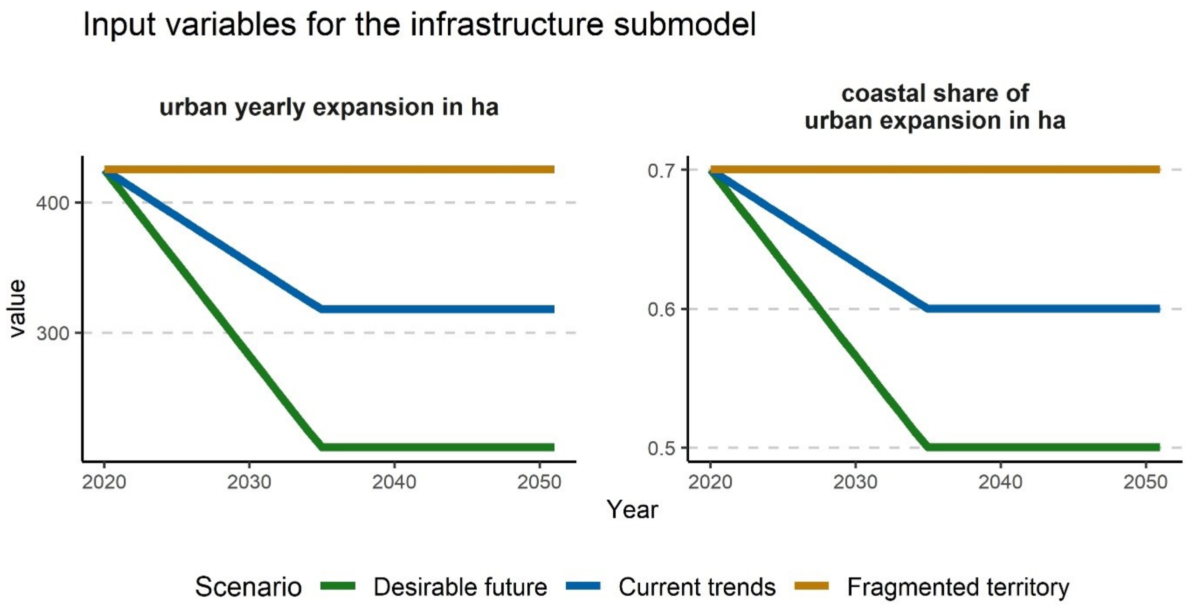

Figure 31 : Dynamic trends of the input variables for infrastructure, as entered in the SD model.

5.3.5.1. urban yearly expansion

Trajectory 1: urban expansion follows the sustainable trajectory defined by the SRADDET (regional land management plan by Région Nouvelle-Aquitaine, 2019) and is divided by two by 2030 (to 212 ha/year).

Trajectory 2: the SRADDET (Région Nouvelle-Aquitaine, 2019) plan is not fully effective and urban expansion decreases by 25% (to 318 ha/year).

Trajectory 3: the regulation of urban expansion fails, it stagnates at its current level (425 ha/year).

5.3.5.2. coastal share of urban expansion

Trajectory 1: with the aim to adapt to sea level rise and restore the social fabric, urban expansion is equally split between the coastal and rural areas (50% coastal share).

Trajectory 2: urban areas still expand in majority in the coastal area, even if the share declines as the coastal area becomes saturated (to 60%).

Trajectory 3: the coastal share of urban expansion remains at its current level (70%), without regard for potential risks and damages.

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5.4. Assessment of the dynamic patterns of key policy indicators

This chapter discusses the impact that the trajectories presented in the previous chapter ("Towards a desirable future", "Improving current trends" and "Towards a fragmented territory") have on the modelled Charente River basin. Table 19 lists the KPIs (model output variables) chosen with the stakeholders to assess the effect of the trajectories. For each KPI, we defined, with the stakeholders, a sustainable value range in order to evaluate whether the trajectories lead to a sustainable state of the system or not.

Each trajectory is simulated under different external scenarios (external drivers: agricultural prices and climate), as explained in the "Scenarios and transition pathways for the Charente River basin" chapter. We have two sets of scenarios available (cf. dedicated chapter): one with RCP climate scenarios and one with smooth versions of these scenarios. Here, we use the smooth ones in the main text (clearer to read) and provide the results obtained with the RCP ones in Annex III, except for some specific KPIs that depend on extreme events and for which RCP results are more relevant (identified in dedicated chapter). We consider the external scenario with constant rainfall and temperature and a ratio of agroecological to conventional prices that reaches 1.5 as reference to draw the curves in the following results. Areas around these reference curves depict the range of the other external scenarios' effect. Note that these areas are always drawn but are hardly visible for the KPIs that are not much sensitive to external changes (identified in the dedicated chapter). Note also that using the smooth scenarios, we pass from 2019 with very high above-average rainfall (last observed year) to 2020 with a smooth average rainfall (first scenario year). This yields for some KPIs a peak in 2020 that may seem odd but is in fact normal. This peak is not obvious when using the RCP scenarios (cf. Annex III).

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Table 19 : Key policy indicators (KPIs) for the Charente River basin – COASTAL MAL4.
The colours correspond to the sectors of activity: blue for water management, yellow for shellfish farming, green for agriculture, pink for population and tourism, and grey for infrastructure.

KPI	Description	SD model variables
Water streams flow	The water streams flow, considered here at the most downstream measuring station in Beillant, must be over a certain threshold (low-water target flow) needed for the good functioning of aquatic ecosystems and for the sustainability of the resource. It is constantly monitored and restrictions on water use, notably for irrigation, are triggered when it is below the threshold.	water streams flow
Water use	Water use is a main driver of water depletion with climate change.	total water use irrigation water use domestic water use industrial water use
Water deficit	The agricultural actors identified the availability of water for irrigation as a limiting factor of their production, as well as a driver of changes in practices. The availability of water for domestic uses has to be guaranteed.	irrigation water deficit domestic water deficit
Oysters production performance	The performance of oysters production is assessed with three indicators: The quality index of an oyster is equal to the ratio of its flesh weight to its total weight. Oyster farmers aim to increase this ratio since rich in flesh oysters are more demanded and sold at a higher price. Total sales, which depend in part on the quality of oysters, are quantified in tons. The sustainable transition of the territory should at least maintain, if not improve, economic development, measured here through gross margin.	oysters quality index total sales oysters gross margin of shellfish farming
Spats capture	Oyster farmers know the quantity of spats that they have to capture to meet production targets. The spats that cannot be captured are purchased in nurseries. The objective of farmers, notably small-scale ones, is to capture as many spats as possible because they can be labelled (local production). Still, the purchase of spats is to some extent always necessary in order to cope with high mortality episodes.	spats capture

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Employment in shellfish farming	The sustainable transition of the territory should at least maintain, if not improve, economic development, measured here through employment.	employment in shellfish farming
Share of the UAA under agroecological farming	Agricultural policies aim to foster a more sustainable agriculture, represented here by agroecological systems. In this sense, increasing the share of the UAA under agroecological farming is a target of the territory's desired development.	share of the UAA under agroecological farming
Agricultural inputs	Uses of nitrogen and pesticides are indicators of pressure on water quality. They are considered as indirect proxies of water quality.	nitrogen use agriculture pesticides use agriculture
Agricultural yields	The transition towards less intensive agroecological practices will necessarily diminish yields. While this trade-off has to be accepted and accompanied by a change in consumption, yields should not diminish too much in order to maintain local food production capacities.	[cereals/oleaginous/ proteaginous] yield animal husbandry capacity
Composition of agricultural production	The transition to more sustainable farming systems should also aim for a more diversified production, supporting a healthier and less impacting diet. Meat production is also meant to transit towards less intensive systems producing less (reduced part in diets) but of higher quality (healthier).	[cereals/oleaginous/ proteaginous] yield [conventional/ agroecological] animal husbandry capacity [conventional/ agroecological]
Gross margin of agriculture	The sustainable transition of the territory should at least maintain, if not improve, economic development, measured here through gross margin.	gross margin of agriculture
Employment in agriculture	The sustainable transition of the territory should at least maintain, if not improve, economic development, measured here through employment.	employment in agriculture
Population	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. Their distribution between the coastal and rural areas is also tracked, with the aim to have a more harmonious distribution that will diminish pressures in the saturated coastal zone and will foster the development of the rural area.	total population coastal residents coastal tourists rural residents rural tourists
Infrastructure development	The development of infrastructures supporting the functioning of the territory will be necessary. Land artificialization should however be as low as possible	coastal urban rural urban storage need [conventional/

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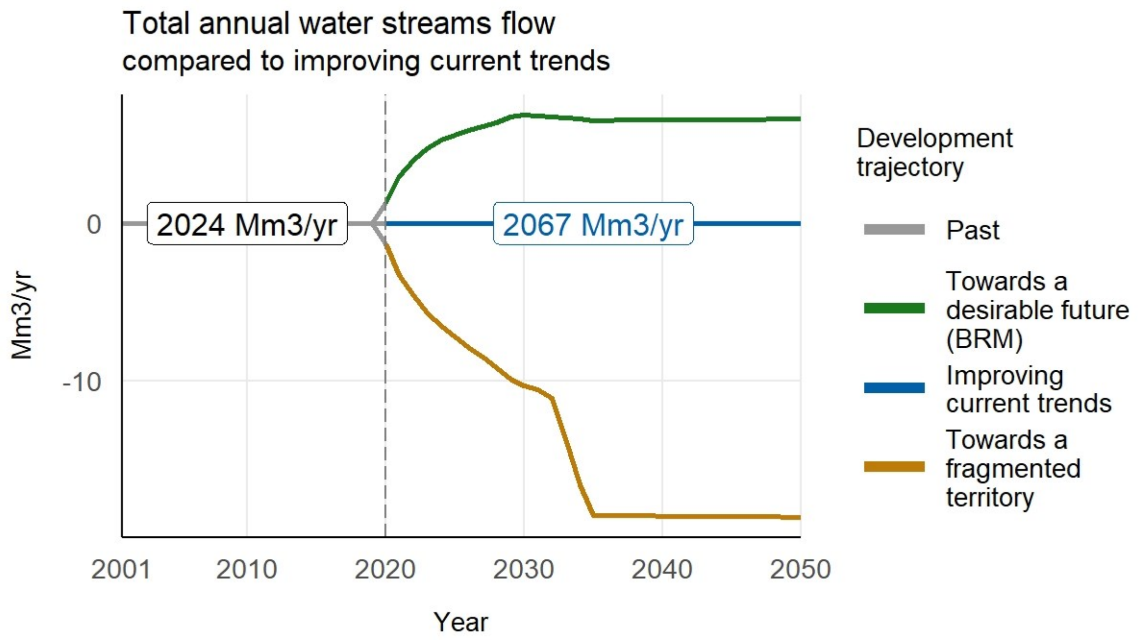
	in order to preserve ecosystems and ecological continuities. The necessary adaptation of infrastructure will also have a cost that diverse actors will have to assume in order to support the territory's sustainable development.	agroecological] roads congestion
Attractiveness of the territory	The ability of the territory to offer actors the conditions that convince them to locate their projects on the territory rather than on another. It depends on multiple social, economic and environmental factors.	attractiveness of the territory

5.4.1. KPI – Water streams flow

What is a sustainable state in the Charente river basin and its coastal zone?

According to the European Water Framework Directive (European Commission, 2000), the water streams flow should remain above its Low-Water Target Flow (LWTF), which is 10 m3/s for the Charente River. For the total annual flow, the Charente 2050 study (EPTB Charente, 2022) claims that 50 Mm^3 lack in the hydro-system to ensure the sustainability of the socio-ecosystem.

What is the impact of the trajectories on this KPI?



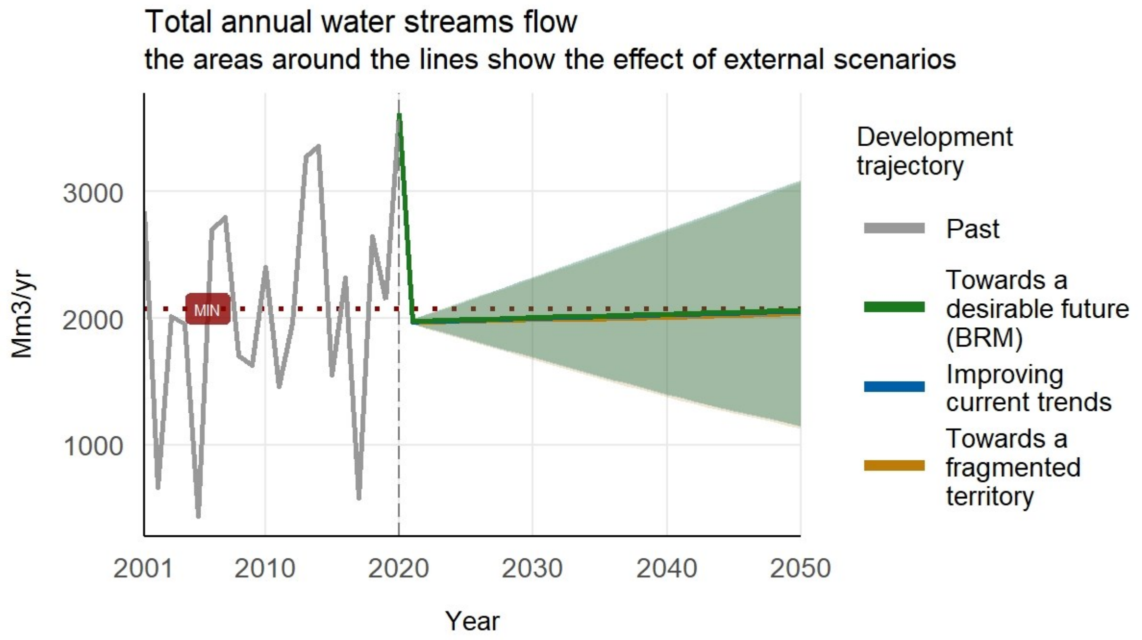


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Figure 32 : Effect of the territorial development trajectories on the total annual water streams flow. Top: compared to the trajectory improving current trends; the boxes show the mean absolute values over the past and the future for the current trends trajectory. Bottom: absolute value with the effect of external uncertainties.

The results show that implementing the BRM is beneficial for both the total annual water streams flow (Figure 32) and the minimum yearly flow (Figure 33), given that improving current trends already generates a substantial gain compared to the current situation.

For the annual flow, the extra gain induced by the BRM (+6 Mm3 compared to improving current trends) allows getting close to the objective of Charente 2050 (+49 Mm3 compared to the current level).

Concerning the minimum yearly flow, the gain is less substantial. Note here that the results of Figure 33 were obtained using the RCP climate scenarios to observe extreme events, notably years with low rainfall. On average over the years (dark bars), the BRM induces a gain of +0.27 m3/s when compared to improving current trends (2.5% of the LWTF) and of +0.55 m3/s when compared to going towards a fragmented territory (5% of the LWTF). For the lowest yearly minimum over the years (light bars), the gains are smaller: +0.07 m3/s (<1% of the LWTF) and +0.17 m3/s (1.7% of the LWTF). Still, these gain are not negligible given how close the current situation is to the LWTF.

Under all trajectories, the average minimum yearly flow is higher than currently. This is due to the development of water storage that permits diminishing abstractions during summer. However, the lowest yearly minimum is always lower than currently. This is due to years with extremely low rainfall in the RCP scenarios.

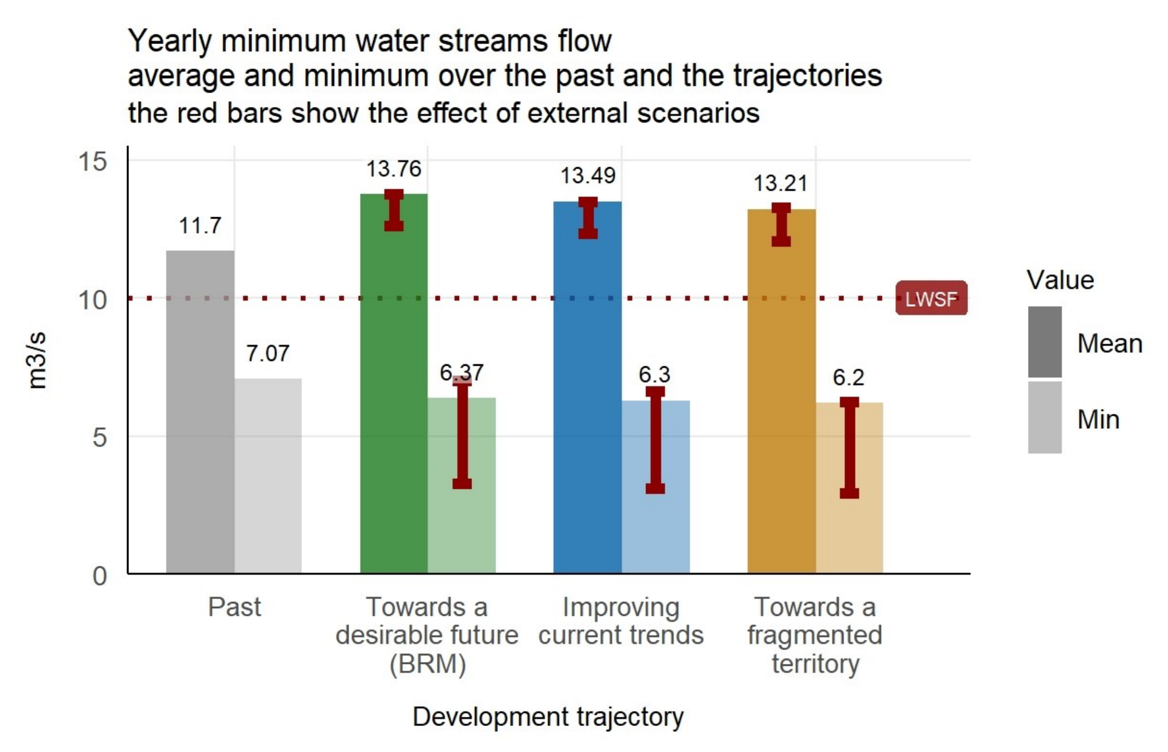

Figure 33 : Effect of the territorial development trajectories on the yearly minimum water streams flow (results obtained using the RCP climate scenarios). The red bars show the effect of external scenarios.

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Given the impact of external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

The yearly total and minimum flow are both sensitive to external uncertainties, mostly to rainfall. The possible effect of changing climate is larger than the possible effect of actions. Acting however remains useful as the expected gains of implementing the BRM can make the system, currently close to threshold values, balance towards sustainability. While maintaining the system on good average dynamics seems possible, extreme events will not be avoidable and adapting to these will be necessary.

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What is the impact of the sectoral groups of actions?

Here, we look at the yearly total water stream flow (Figure 27Figure 34), but note that the same trends are observed for the yearly minimum flow. As shown, actions related to water management, which include the regulation of irrigation for agriculture, influence the water streams flow the most and generate most of the BRM's gain. Actions related to infrastructure (wastewater reuse) and population (individual savings) also improve the water streams flow. Then, interestingly, we observe that actions enhancing the agroecological transition are slightly detrimental. In addition, the BRM's gain is lower than the summed gain of individual actions. These two results are explained by the fact that when agriculture transits towards less water-demanding systems, and even more when the whole BRM is implemented, more water is available in the system since less is consumed. As a result, deficits are less frequent (cf. KPI Water deficit) and consumption is never limited. Overall, this creates a state where water is more reasonably consumed, and so more water can be consumed than when implementing actions on their own (hence the BRM is lower than the sum of actions) or when irrigation stresses the resource (hence the negative effect of agroecological transition). Saving water together thus allows using more water together (synergistic effect).

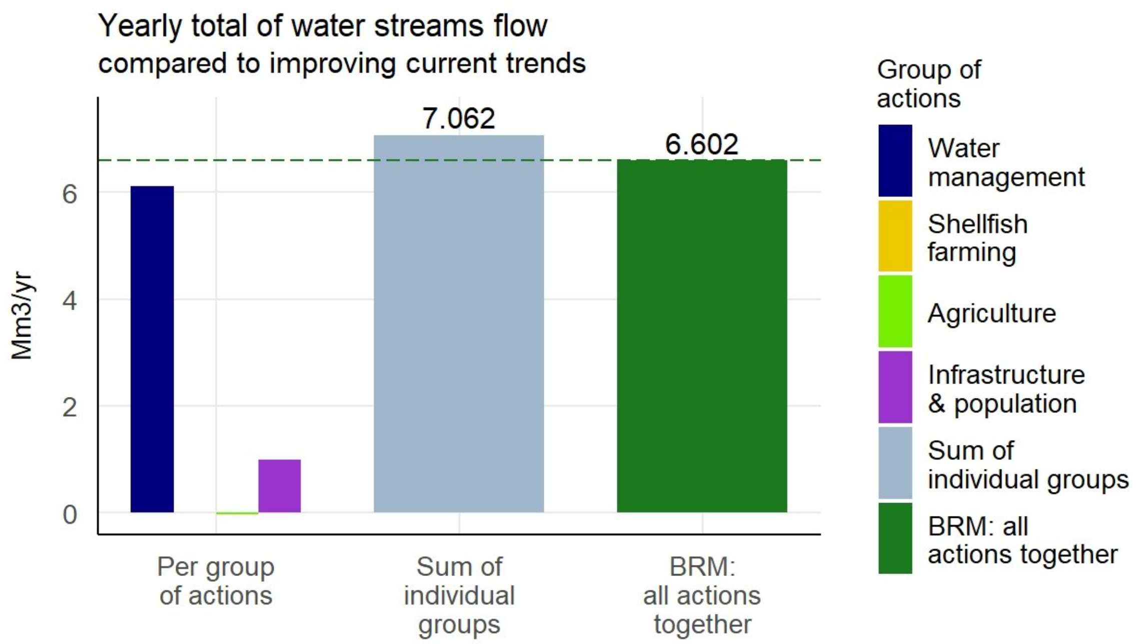

Figure 34 : Effect of the sectoral groups of actions on the total annual water streams flow, compared to the 'Improving current trends' trajectory. The sum of individual actions is the sum of the effects of applying each sectoral group independently. The BRM corresponds to the effect of applying all the actions together.

5.5. KPI – Water use

What is a sustainable state in the Charente river basin and its coastal zone?

Water use is sustainable if the linked water streams flow remains above the LWTF (cf. Water streams flow KPI) and there are no deficits for users. This indicator serves to show the concrete reality of water use underlying the identified sustainable situations. Still it should be lower than currently. The Charente 2050 study (EPTB Charente, 2022) estimated the need to diminish the yearly extraction of water by 50 Mm^3/year by 2050. For individual uses, we set the sustainable state at the current level.

What is the impact of the trajectories on this KPI?

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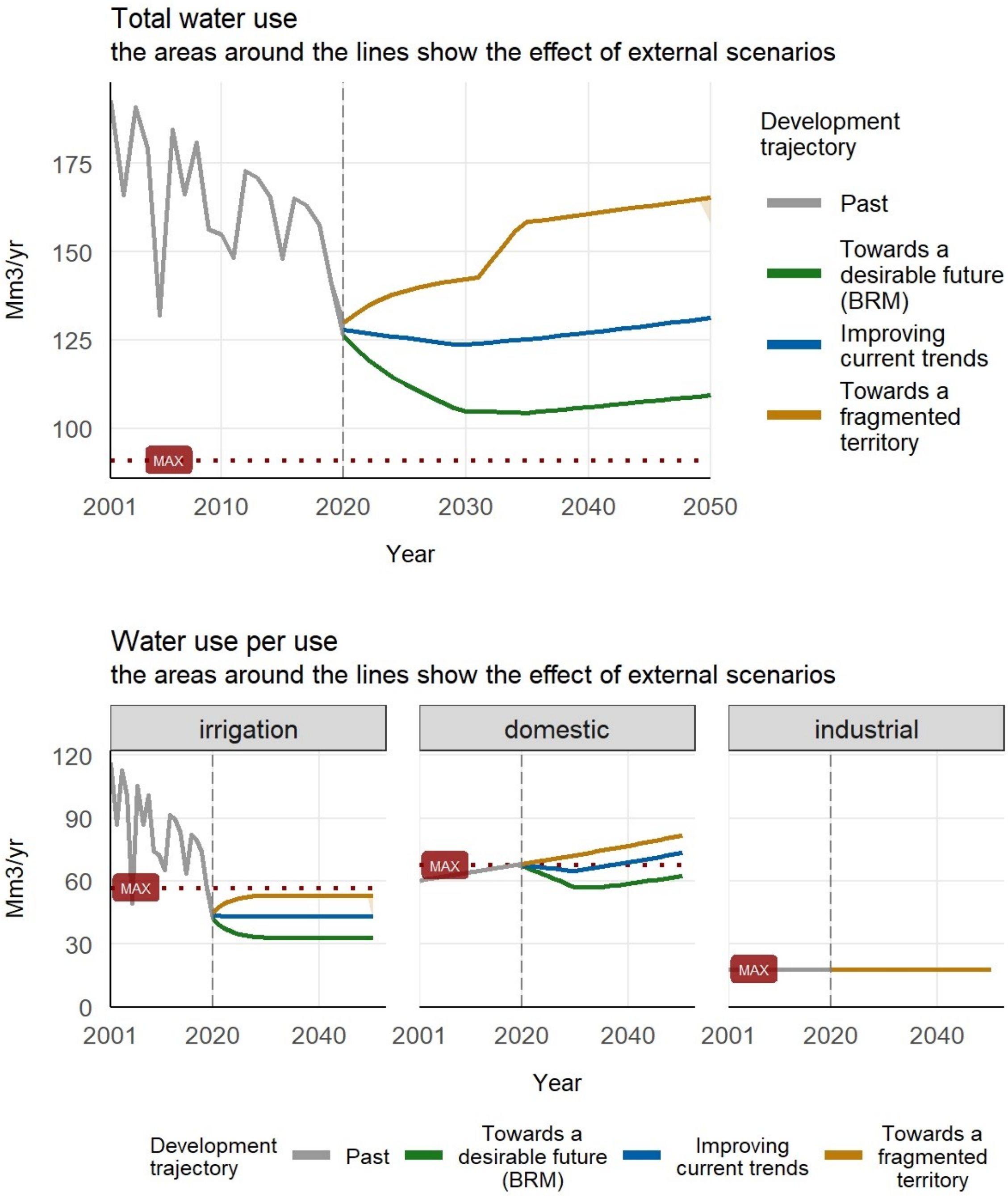

Figure 35 : Effect of the territorial development trajectories on water use (top: total, bottom: per use).

Implementing the BRM induces substantial water savings, with around 20 Mm^3/year saved by 2050 when compared to improving current trends and 55 Mm^3/year saved when compared to going towards a fragmented territory (top of Figure 35). Although water use does not go below the sustainable limit with the BRM, it is almost the case for extractions (real objective) as around 12 Mm^3/year of wastewater are reused in this trajectory (not illustrated) and accounted for in water use (illustrated here). Therefore, only the BRM allows getting close to the objective of the Charente 2050 study (EPTB Charente, 2022). Considering the trends of water use per use over the long term (bottom of Figure 35), the expected savings will come from both irrigation and domestic uses (no substantial savings from industries were envisioned by stakeholders as they

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already made important efforts and don't use much water). However, in order to maintain a sustainable level of water use over the long term and avoid the constant growth observed in the results, it will be difficult to diminish irrigation beyond the low level reached with the BRM. Therefore, further domestic savings or innovative technologies for industry may be needed at some point if population keeps growing.

Given the impact of external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

In the present results, obtained with the smooth climate scenarios, water use is not sensitive to external scenarios as it is driven by regulations and there are no extreme drought events in the climate scenarios. It is slightly different in the results obtained with the RCP scenarios (cf. Annex III), where water use is limited in some periods of deficit (cf. next KPI water deficit). In any case, climate change will only induce a decrease of water use and so actions are both useful and necessary to achieve a sustainable and robust level of water use. Note that we do not raise the question of a minimum sustainable level of consumption, although it is important to maintain water use high enough for meeting basic needs at least. Still, in the current situation, the territory is far from not using enough water and this issue is one to keep in mind for later, once overconsumption has been solved.

5.5.1. KPI – Water deficit

What is a sustainable state in the Charente river basin and its coastal zone?

The irrigation deficit should be lower than currently, to ensure a more efficient production, although it will always remain positive. The deficit for domestic uses should remain equal to zero.

What is the impact of the trajectories on this KPI?

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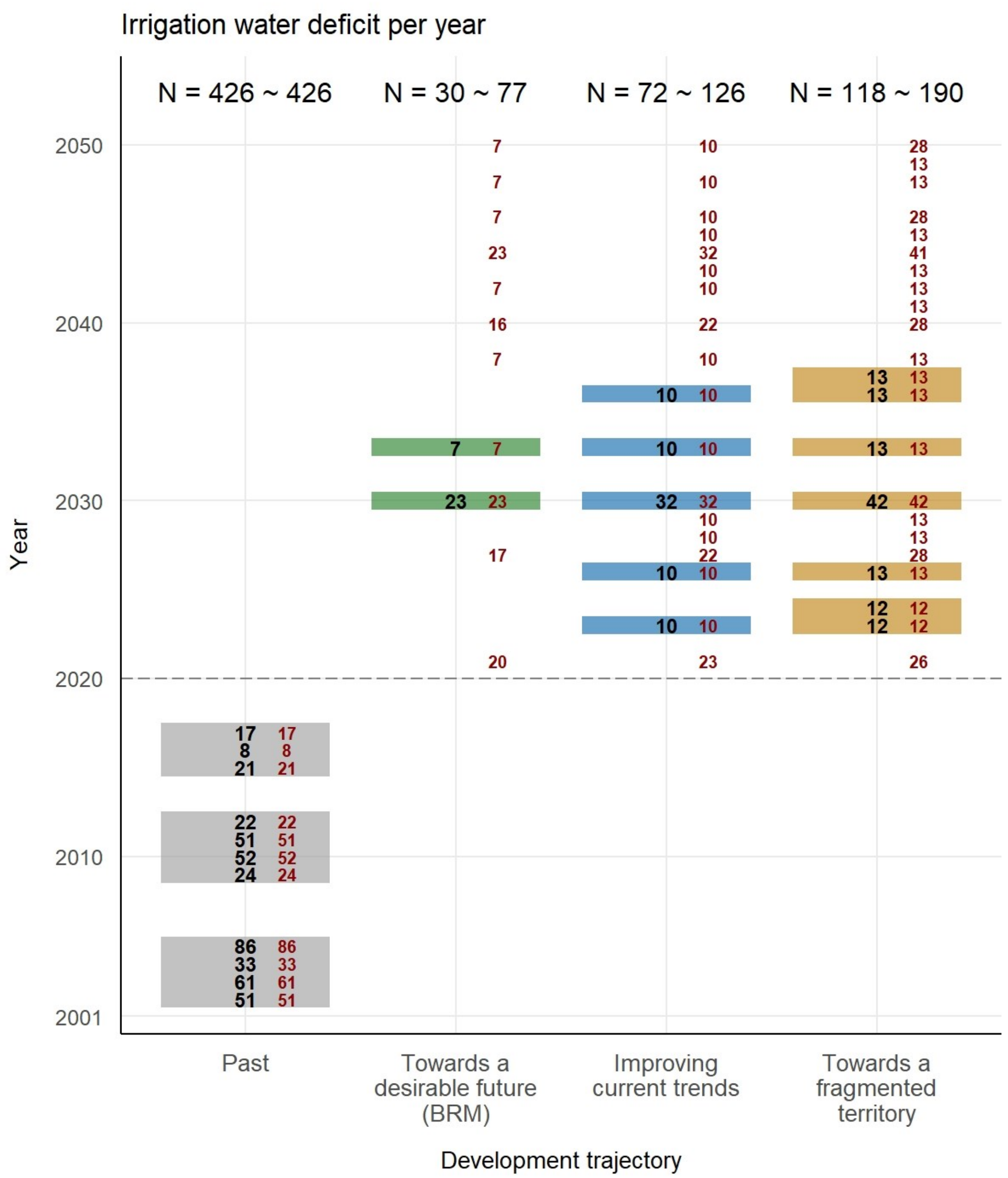

Figure 36 : Effect of the territorial development trajectories on irrigation water deficit (results obtained using the RCP climate scenarios). A coloured bar (colours correspond to the trajectories) indicates a deficit during the year on the y axis. The black numbers in the bars indicate the yearly deficit. For instance, there will be a deficit of 23 Mm^3 in 2030 when implementing the BRM. The red numbers indicate the maximum deficit observed across the climate scenarios. The N on top are the ranges across the climate scenarios of the total deficits over the years.

A first result, not illustrated, is that no deficit for domestic uses is observed under any trajectory and external scenario. That is mostly due to the model's structure, where domestic uses have the priority over irrigation as currently. Hence, if this priority is removed, which is not impossible if irrigation has to be maintained at a certain level to ensure agricultural production, then domestic deficits may appear.

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Concerning irrigation, although water deficits will always occur, implementing the BRM leads to rarer and less important episodes (Figure 36). A more important development of low-irrigation agricultural systems (lower demand) and a better management of the water resource, thus more available, explain this benefit. Deficits disappear over the long term with the development of reservoirs for water storage. These appear as beneficial in the model, by design, as they make water available for irrigation and preserve the low-water flow during summer (cf. first KPI). Note however that these results do not touch other issues linked with their development, such as access to the resource or long term effects on the water cycle (a detailed hydrological model is needed for this purpose).

Given the impact of external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

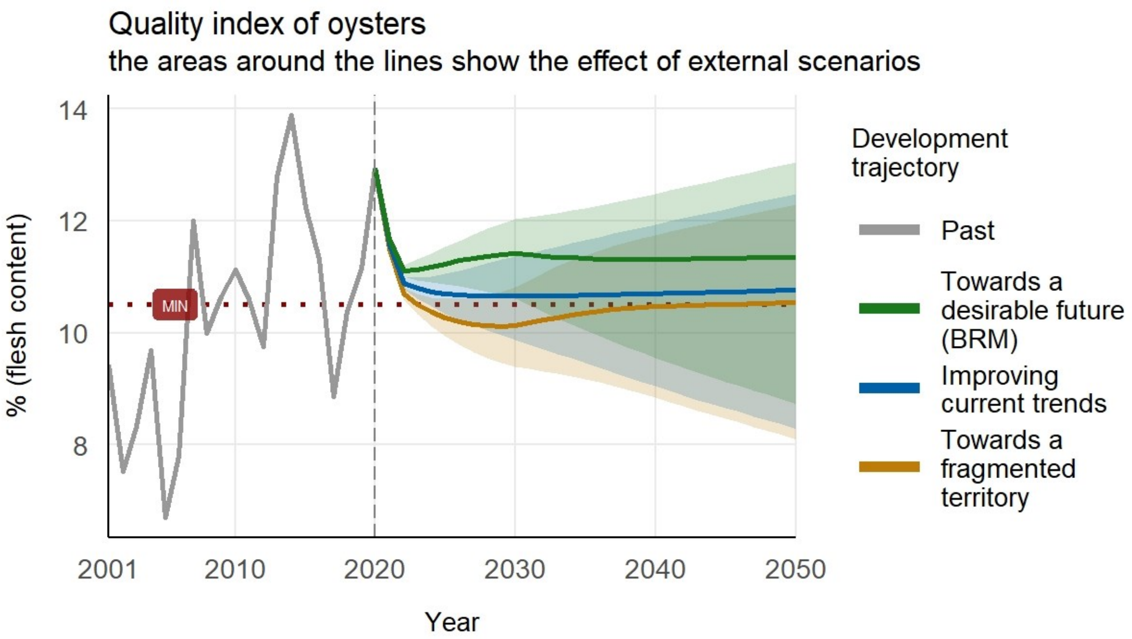
The ranges of the total deficits (N in Figure 36) show that external uncertainties (mostly climate here) sensibly influence the magnitude of irrigation deficits. The red numbers in Figure 36 show that they also significantly influence their occurrence. Still, the BRM remains the trajectory with the lowest total deficit under all climate scenarios (its maximum is almost equal to the lowest deficit of improving current trends). It also induces less frequent episodes, with more years that remain without deficit under all scenarios. Therefore, actions can play an important role in guaranteeing the availability of water for irrigation and other uses.

5.5.2. KPI – Oysters production performance

What is a sustainable state in the Charente river basin and its coastal zone?

The oysters' quality index should be > 10.5% (flesh content) for oysters to be of high quality. Although sales should be as high as possible for a given quality, it may be more profitable (gross margin) and sustainable to produce less of higher quality. Still, both sales and gross margin should increase in order to completely relocate the activity inside the territory.

What is the impact of the trajectories on this KPI?



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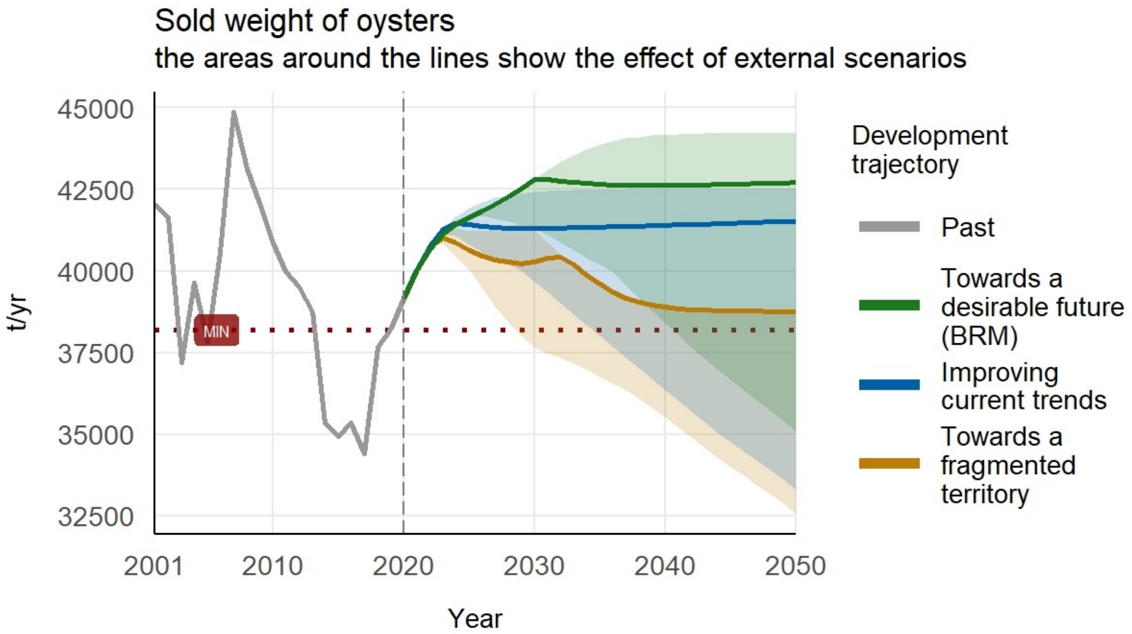

Figure 37 : Effect of the territorial development trajectories on the quality index of oysters (top) and sales (bottom).

Implementing the BRM, with notably more space for farms and lower densities, allows producing higher quality oysters (top of Figure 37) that sell better (bottom of Figure 37), which generates a higher gross margin (Figure 38). The gain in quality is significant (higher than the high quality threshold) when compared to the two other trajectories that lead to a similar quality, right above the high quality threshold. Sales increase to and remain at a high level under the BRM and when improving current trends, while they drastically diminish in the fragmented territory. Gross margin stays above its current level only when the BRM is implemented. That is because the high quality of the production allows selling oysters at a higher price that under the improved current trends.

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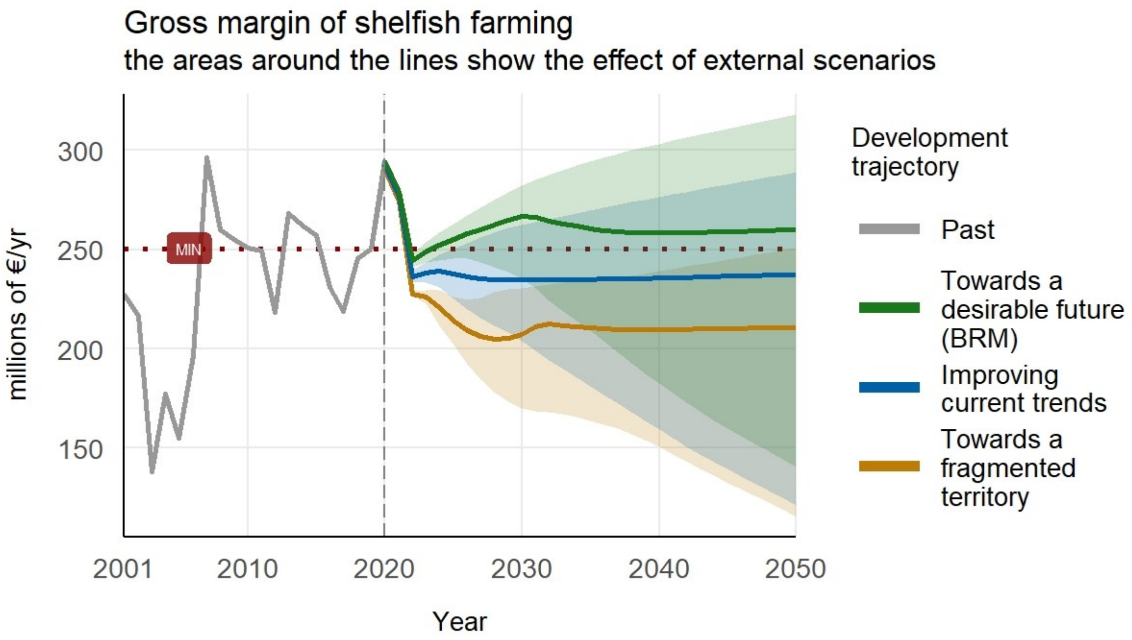

Figure 38 : Effect of the territorial development trajectories on the gross margin of shellfish farming.

Given the impact of external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

The performance of oysters' production appears very sensitive to external scenarios, mostly climate change and its effect on the water streams flow, which has to be high to carry enough trophic resource for oysters' growth. Depending on future climate, all three indicators can go below their minimum sustainable threshold under all the trajectories, sometimes reaching very low levels even with the BRM. While actions remain effective and can help maintaining a significant part of the activity in the area, the activity will most likely stay dependent on the evolution of climate. Note that the observed sensitivity may come from our model, the modelling of oysters' quality being quite uncertain by lack of knowledge and data. Hence, our conclusions may be too drastic and actions may be more useful than assessed.

What is the impact of the sectoral groups of actions?

Looking at the gross margin of shellfish farming (Figure 39), actions from the sector itself are those influencing it the most. Still, actions from water management, regulating water use and therefore the water streams flow, and actions from the population and infrastructure, diminishing water use, can also affect gross margin positively. Note that actions from agriculture, diminishing agricultural inputs and improving water quality (cf. KPI Agricultural inputs), may also be very effective, but we could not model the relation between water quality and oysters production. Hence, shellfish production does depend on other activities and will benefit from improving collaborations and synergies between them. Comparing the summed effect of the groups of actions with the implementation of the BRM (all actions together), the BRM is a bit less effective. This shows that the potential of oysters production is limited (limited capacity of the system) and shellfish production systems (areas and densities) should thus be optimised to be efficient under expected future conditions. A model like ours can help such endeavour.

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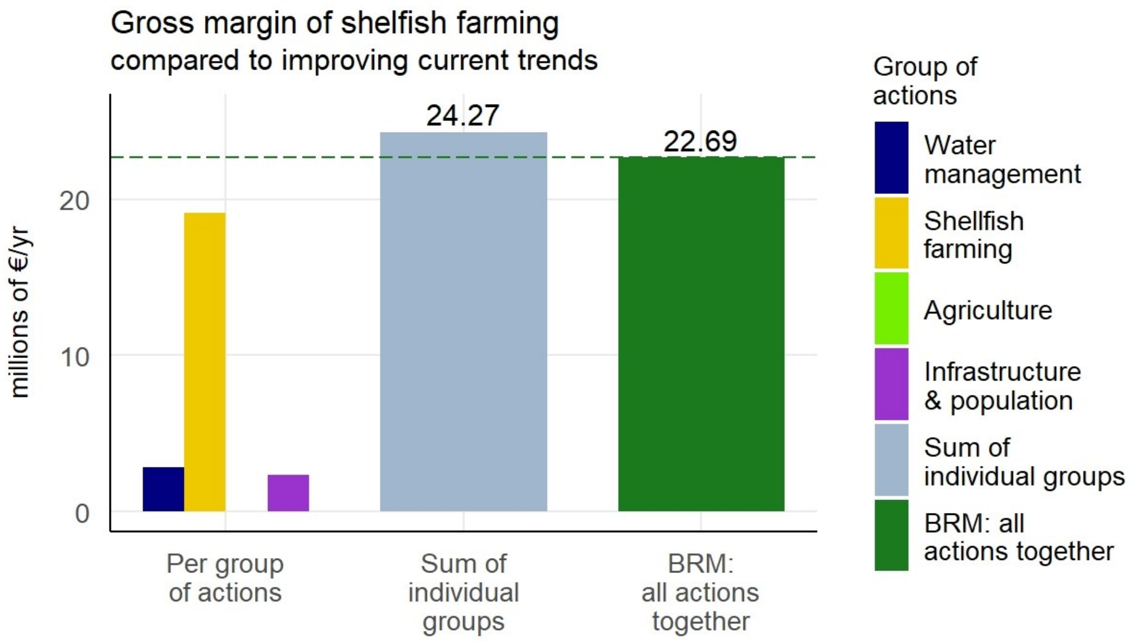

Figure 39 : Effect of the sectoral groups of actions on the gross margin of shellfish farming, compared to the 'Improving current trends' trajectory. The sum of individual actions is the sum of the effects of applying each sectoral group independently. The BRM corresponds to the effect of applying all the actions together.

5.5.3. KPI – Spats capture

What is a sustainable state in the Charente river basin and its coastal zone?

The sustainability of spats capture depends on various criteria and so defining a sustainable state is complicated. What we can say is that the capture of spats should at least remain at its current level to achieve a completely local production cycle.

What is the impact of the trajectories on this KPI?

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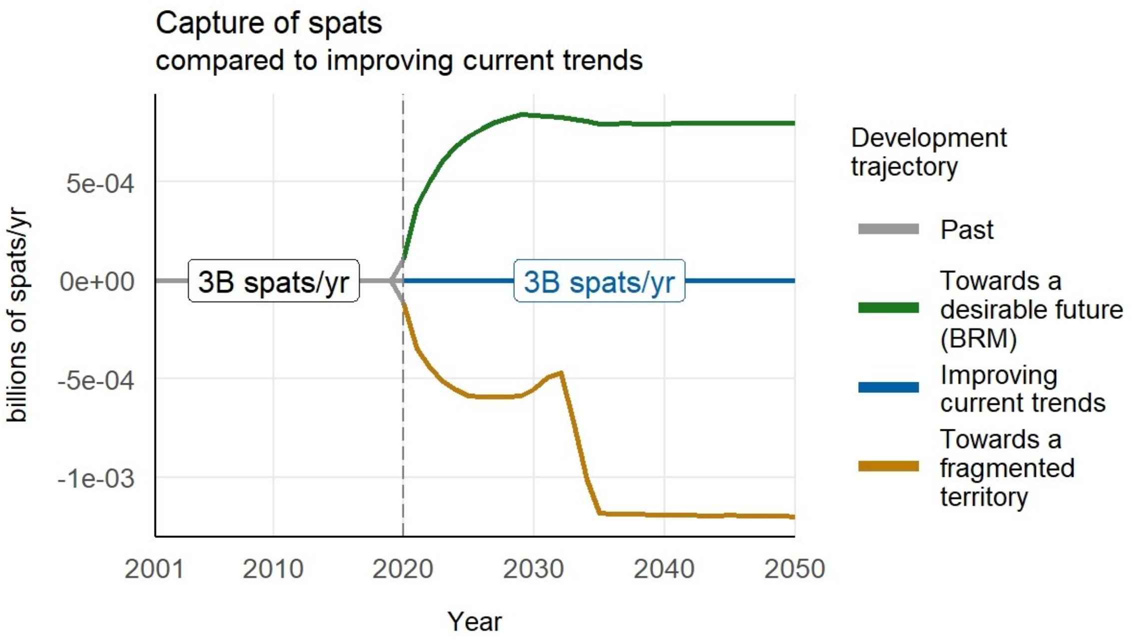

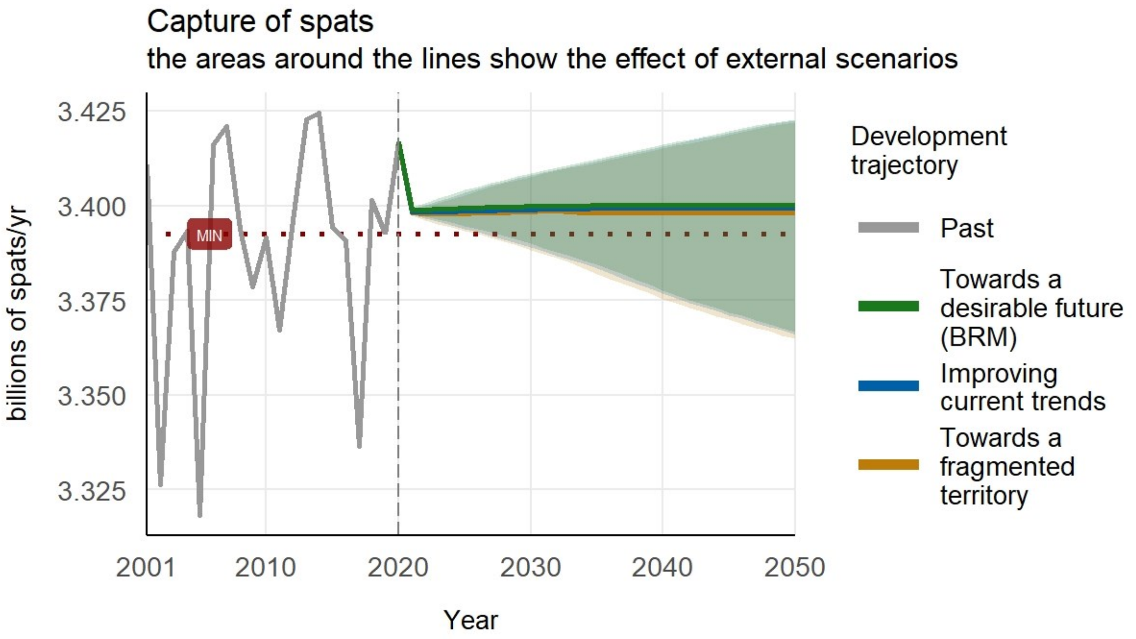

Figure 40 : Effect of the territorial development trajectories on the capture of spats. Top: compared to the trajectory improving current trends; the boxes show the mean absolute values over the past and the future for the current trends trajectory. Bottom: absolute value with the effect of external uncertainties.

Implementing the BRM improves the capture of spats (top of Figure 40) as it improves the water streams flow, which favours the birth of spats (trophic resource and salinity). The observed gain is however very small compared to total captures. Here we note that our modelling of spats capture is quite uncertain, as observations lack, and so the magnitude of effects that we observe may be inaccurate. The relative effect (BRM as best trajectory) is however likely.

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Given the impact of external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

The capture of spats is much more sensitive to external uncertainties than to actions, but not so much in absolute (bottom of Figure 40). Climate change may decrease captures bellow their current level under all the territorial trajectories. Hence actions should not help much in preserving the capture of spats, at least according to our model. This is half an issue since, in fact, the capture of spats depends on complex conditions and is a natural process that shellfish farmers can hardly control.

5.5.4. KPI – Employment in shellfish farming

What is a sustainable state in the Charente river basin and its coastal zone?

Employment in shellfish farming should be at least equal to its current level, and if possible increase, as a component of the territory's attractiveness.

What is the impact of the trajectories on this KPI?

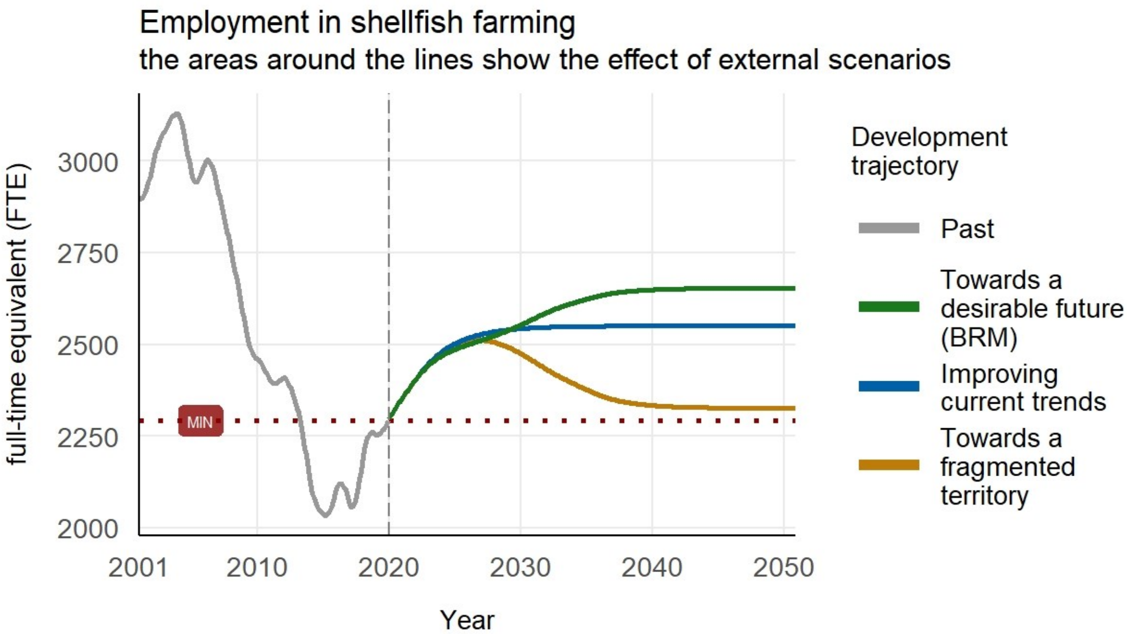

Figure 41 : Effect of the territorial development trajectories on employment in shellfish farming.

The implementation of the BRM permits an increased production of shellfish and therefore increases the sector's employment capacity (Figure 41). In this regard, employment is proportional to the produced weight in the model, without considering sales as a constraint. It may thus be that the employment capacity measured here is in fact not possible if economic benefits are insufficient. Similarly, the model does not take into account the part of the jobs that may be displaced with the production if it cannot continue locally. Therefore, implementing the BRM, which also yields a higher gross margin and overall better conditions to maintain local production, may be more preferable than observed here.

Given the impact of external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

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Since employment in shellfish farming depends only on the produced amount, which does not depend on external uncertainties in the model, it depends only on actions. These can bring the KPI within a sustainable state.

5.5.5. KPI – Share of the UAA under agroecological farming

What is a sustainable state in the Charente river basin and its coastal zone?

According to our previous study Modchar (Vernier et al, 2016 and 2017), the agroecological share of the UAA should be superior or equal to 50% for having strong effects on the water resource. This objective is higher than the 25% increase promoted in the Farm to Fork strategy (European Commission, 2022).

What is the impact of the trajectories on this KPI?

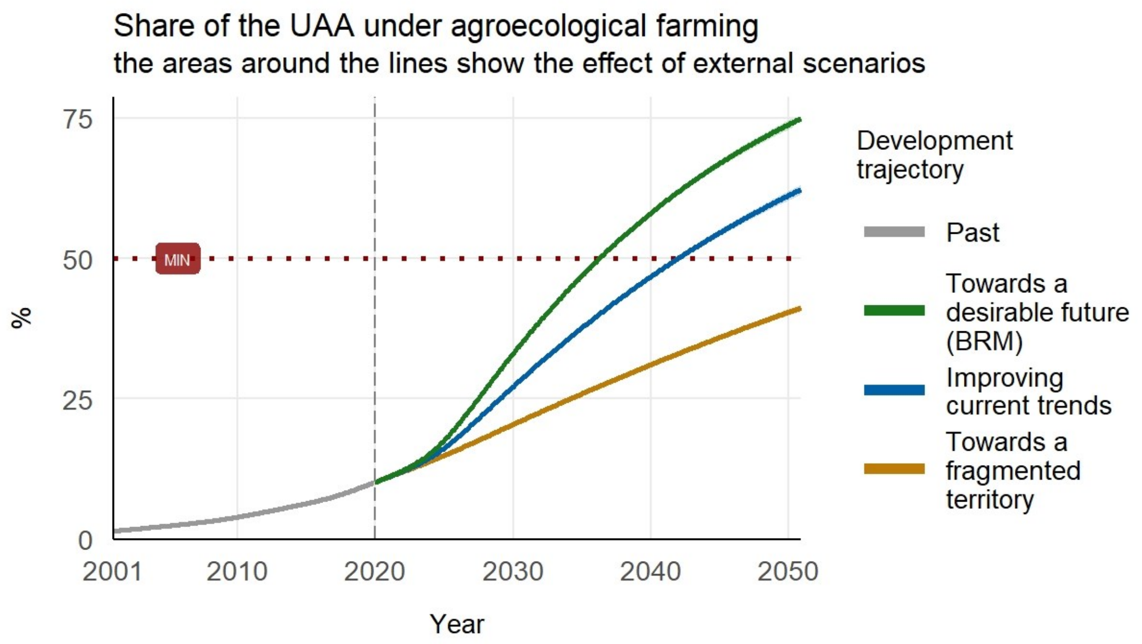

Figure 42 : Effect of the territorial development trajectories on the share of the UAA (used agricultural area) under agroecological farming.

The BRM trajectory is the only one that reaches a very high share of agroecology in the UAA (75%, Figure 42), as envisioned by the stakeholders in their desirable future to enhance the resilience and sustainability of the territory and of agriculture in particular. Given that the model's structure hardly permits to reach 100% (claimed objective of the BRM) by design, we may assume that a higher share can be reached if the conditions develop very favourably (labelled farming prices, development of local supply chains and processing units, climate change). Improving current trends leads to a significant share of agroecology, which is an encouraging result as several BRM actions are already in progress in the area and just need a further push. The trajectory towards a fragmented territory doesn't meet the sustainable objective, showing that actions are required to encourage the sustainable transition of agriculture.

Given the impact of external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

The transition of agricultural is almost not sensitive to external uncertainties (there are very thin not visible areas around the curves in Figure 42), although the availability of water and incomes are considered as factors

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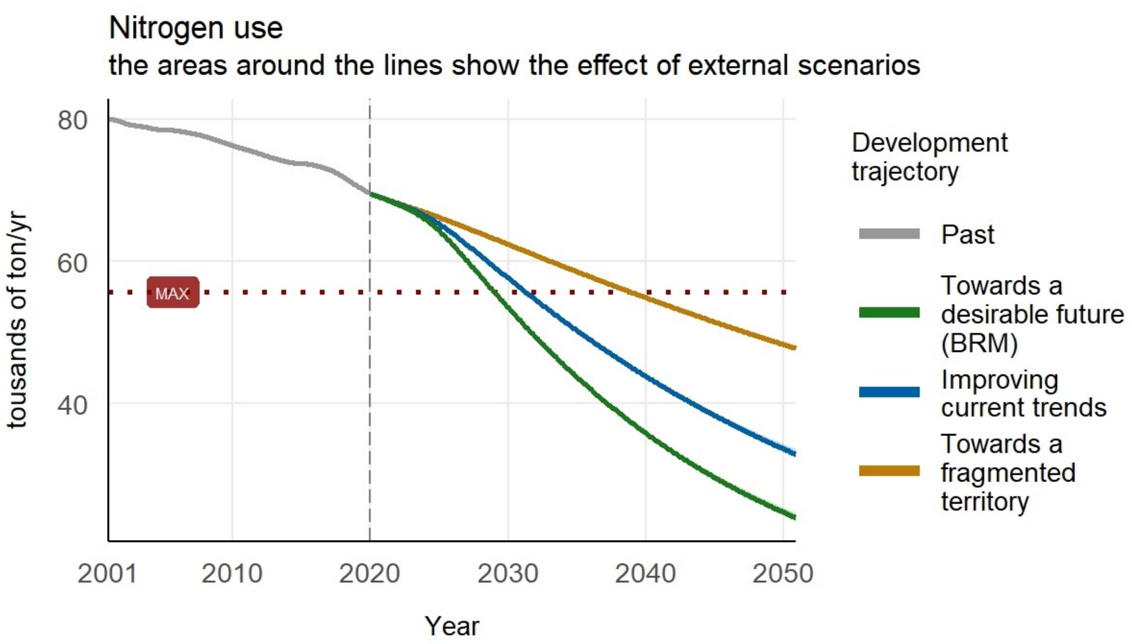
of transition in the model. That is because along the transition towards agroecology, which occurs in all the trajectories, the availability of water become less relevant as production systems require less water. Concerning incomes, they always remain higher for agroecology, even when assuming a decreasing difference between conventional and agroecological prices. Overall, the model shows that further developing dedicated supply chains, promoting the consumption of agroecological products and supporting the installation of young farmers are the most effective means to reach a sustainable agriculture. Conducting these actions in a proactive way will lead to a robust state as external drivers, as explained above, will be less relevant when agroecology becomes the main model of production and consumption.

5.5.6. KPI – Agricultural inputs

What is a sustainable state in the Charente river basin and its coastal zone?

According to the European Green deal's Farm to Fork strategy (European Commission, 2022), France should diminish its use of nitrogen by 20% and of pesticides by 50% when compared to 2015-2017.

What is the impact of the trajectories on this KPI?



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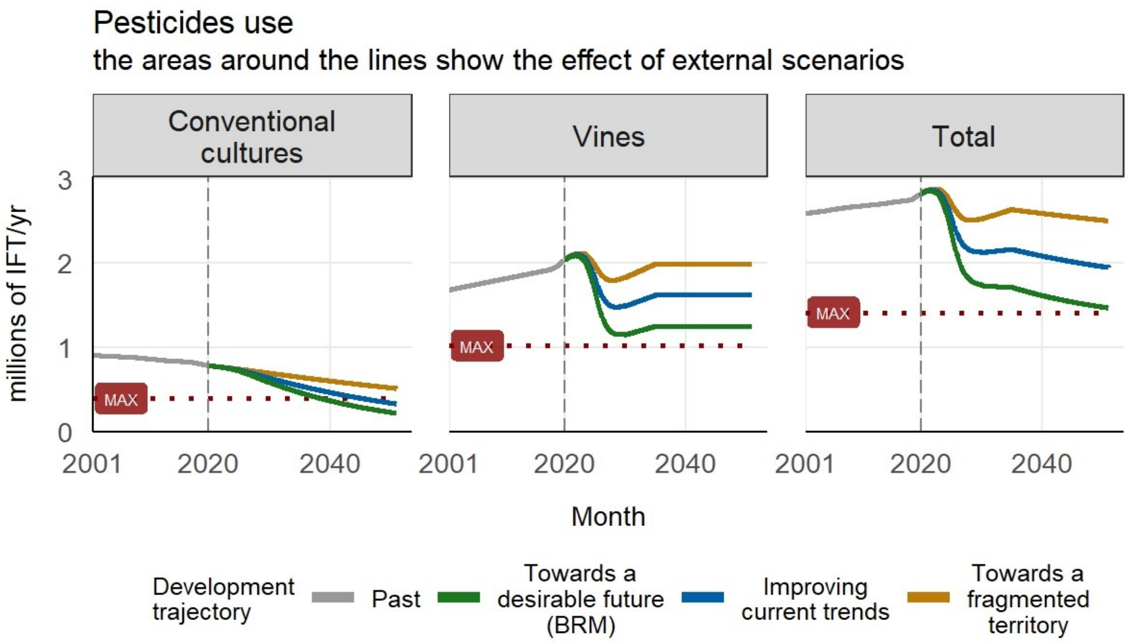

Figure 43 : Effect of the territorial development trajectories on the use of agricultural inputs (top: nitrogen, bottom: pesticides)

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The BRM trajectory implies the development of a sustainable agriculture on 75% of the UAA and thus leads to the most important decrease in the use of inputs (fertilizers and pesticides in Figure 43). At the opposite, in the trajectory towards a fragmented territory, conventional and intensive agriculture is maintained at a higher level and the use of inputs remain at a high and unsustainable level, although it decreases. Improving current trends, like the BRM, reaches a sustainable level for nitrogen. For pesticides, it does too but by a little. Vines being a large contributor to pesticides, their transition to agroecology is important for the territory's sustainability (people's and ecosystems' health).

Given the impact of external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

The use of agricultural inputs being proportional to the agroecological share of the UAA in the model (previous KPI), we draw the same conclusions: it does not appear as sensitive to external drivers and actions are necessary and effective to reach a sustainable and robust state of the system.

5.5.7. KPI – Agricultural yields

What is a sustainable state in the Charente river basin and its coastal zone?

Defining a sustainable level for yields is too complicated for several reasons. Yields should diminish, because of environmental criteria and the necessity to transit to a less productive agroecological system. Still, they should not diminish too much to keep feeding people and maintain agriculture as a socio-economic activity. In addition, agricultural production has to be considered within the open global system, as almost half of the region's production is exported. Finally, as the composition of agricultural production and food consumption should change, setting comparable levels for different cultures is difficult. Overall, the sustainable state should be between the current level (too high maximum) and the capacity to feed people (necessary minimum), which we could not quantify.

What is the impact of the trajectories on this KPI?

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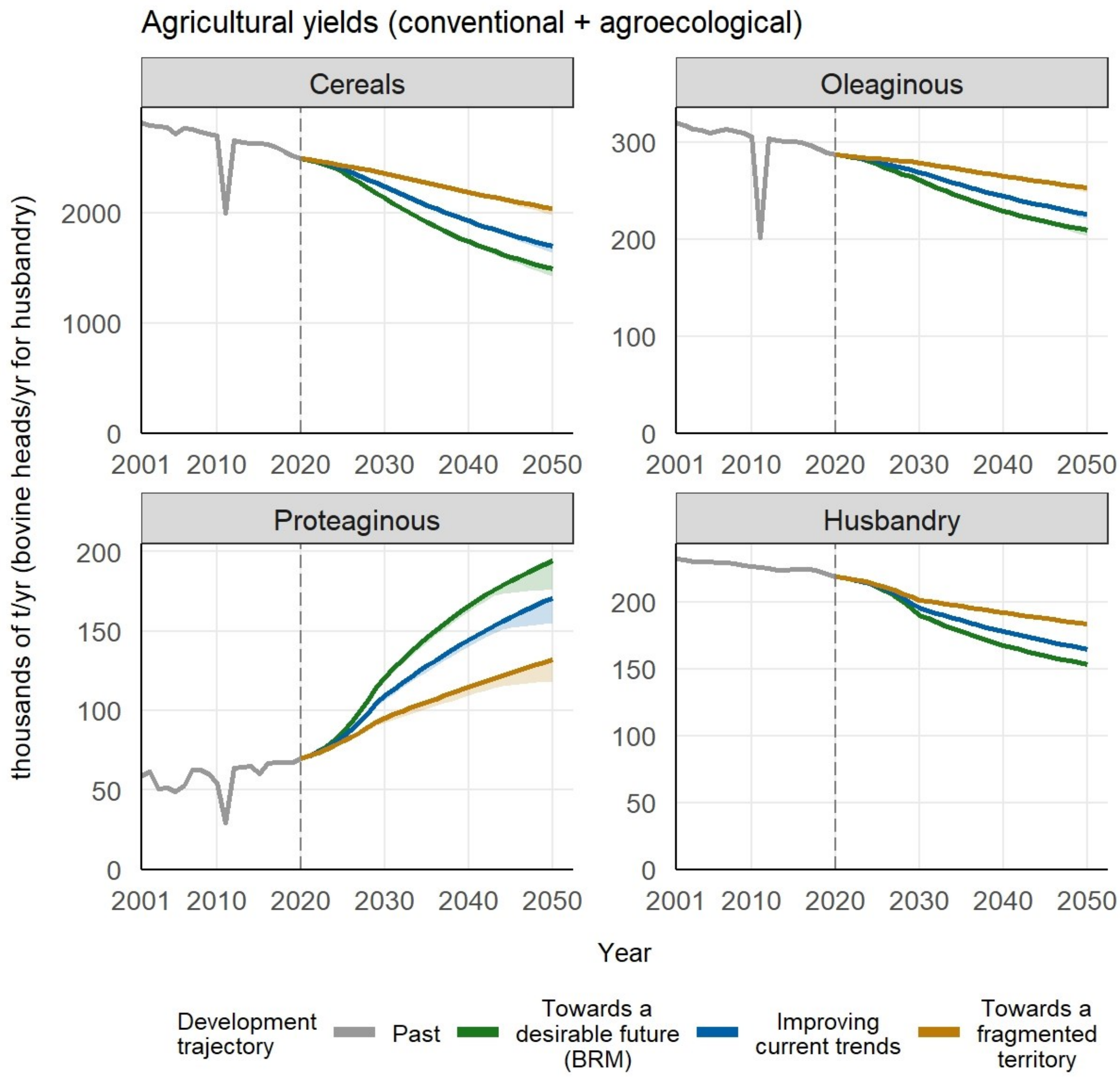

Figure 44 : Effect of the territorial development trajectories on agricultural yields.

The agroecological model is characterized by lower yields, due to less intensive practices, and a different composition of the UAA, more diversified with more proteins. Hence, the production of cereals and oleaginous crops diminishes as the agroecological share of the UAA increases, with the implementation of the BRM, while the production of protein crops increases (Figure 45). Agroecological livestock farming also leads to a lower production (less stock density with more respectful practices for animal welfare). But it could be a condition to maintain livestock farming in the territory. Overall, we conclude that only the two trajectories implementing the BRM and improving current trends could lead to a more sustainable agriculture, as production is not diversified enough and remains intensive when going towards a fragmented territory.

Given the impact of external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

Yields become sensitive to external drivers (climate here) in the long term and in the most extreme cases, when rainfall is low and evapotranspiration is high. They appear a bit more sensitive when considering the RCP climate scenarios (cf. Annex III). In line with the conclusions about water deficits (previous KPI), acting to

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promote the agroecological transition will lead to a more sustainable and robust system where yields may be lower but more constant and the agriculture more resilient.

5.5.8. KPI – Composition of agricultural production

What is a sustainable state in the Charente river basin and its coastal zone?

The composition of agricultural production should be more balanced than currently, with notably more proteaginous (cf. Farm to Fork strategy by European Commission, 2022). Animal husbandry should diminish, becoming less intensive, but remain at a sufficient level to maintain the activity and meet the local demand.

What is the impact of the trajectories on this KPI?

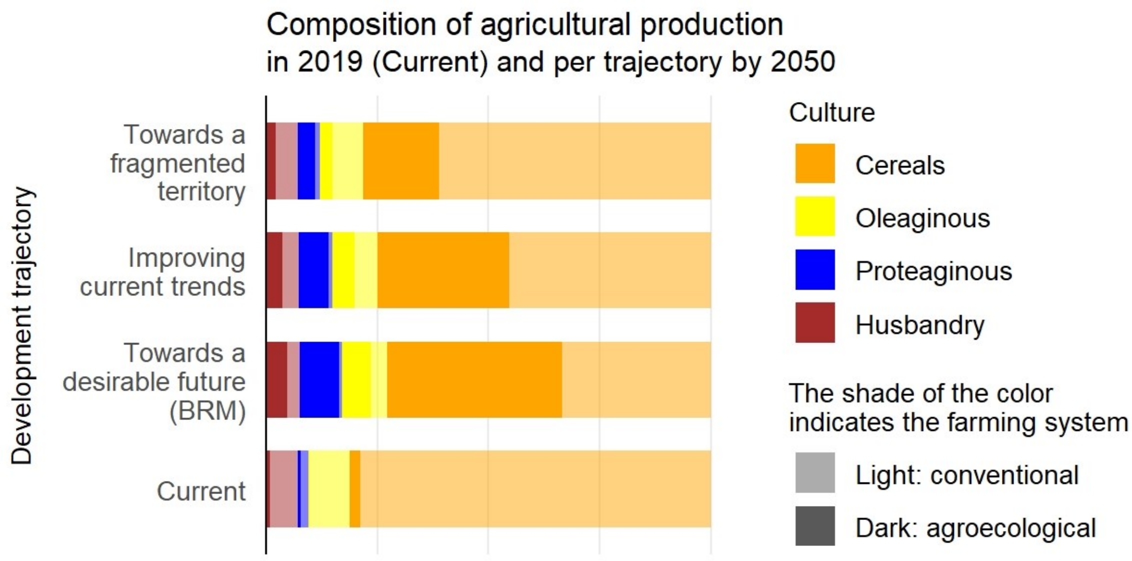

Figure 45 : Effect of the territorial development trajectories on the composition of agricultural production.

The BRM trajectory enables the highest share of agro-ecological cereals and protein, as well as a more diversified overall composition between cereals, oleaginous and proteaginous crops, .i.e., a more sustainable and resilient agriculture. Improving current trends allows for the development of agro-ecological protein crops and cereals, but to a lesser extent. The fragmented territory trajectory maintains more conventional and intensive crops and practices, yielding a less diversified composition.

Given the impact of external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

External uncertainties were not considered for this KPI. The conclusions about agricultural yields (previous KPI) apply.

5.5.9. KPI – Gross margin of agriculture

What is a sustainable state in the Charente river basin and its coastal zone?

Agricultural gross margin should at least remain at its current level for the economic sustainability of the activity, necessary to maintain agriculture in the territory.

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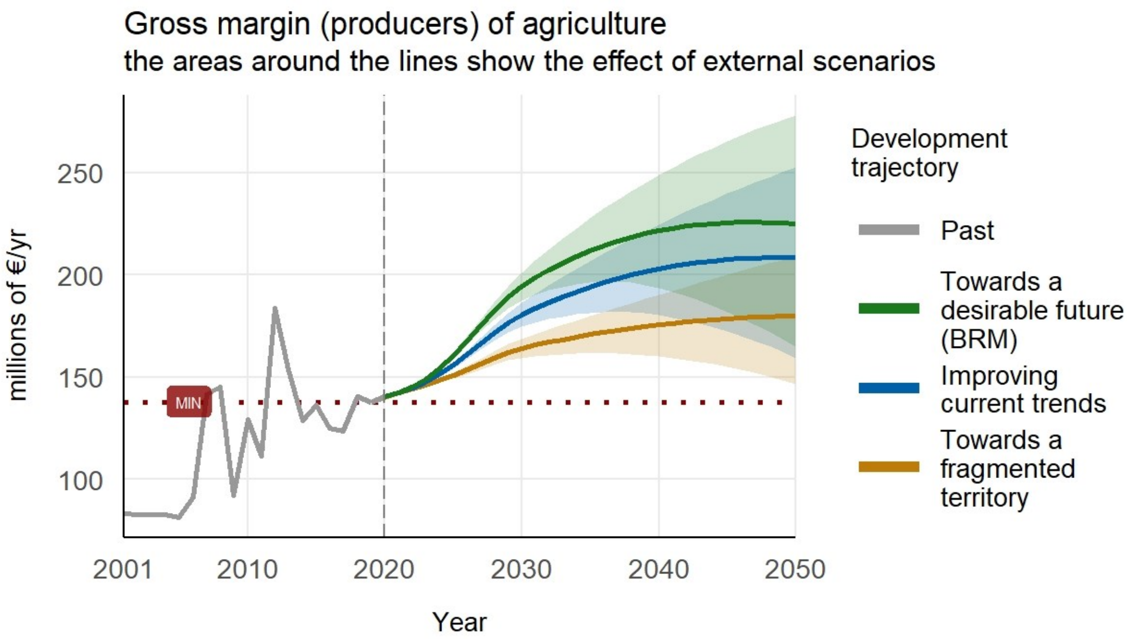
What is the impact of the trajectories on this KPI?



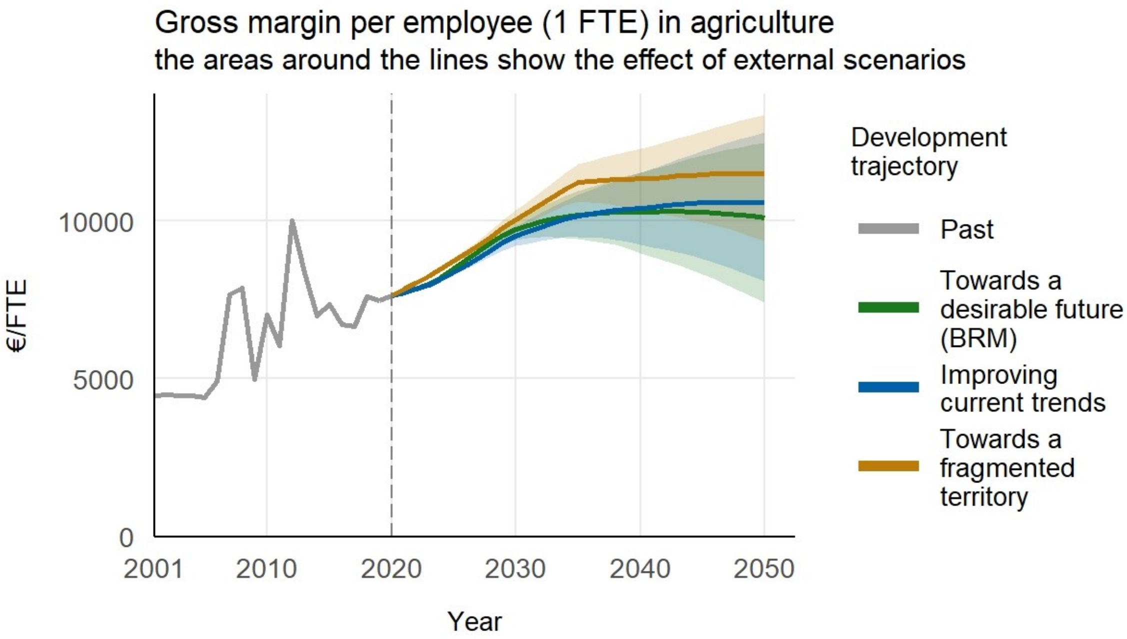


Figure 46 : Effect of the territorial development trajectories on the gross margin of agriculture, on top in total and in bottom per employee.

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The BRM allows the most significant increase in agriculture gross margin, globally, much better than the two others trajectories. However, as the BRM trajectory leads to the creation of the largest number of jobs, in contrast to the fragmented trajectory, which sees the concentration of farms and value chains and a larger part of intensive agriculture in the territory, the margin per employee of the latter remains the highest.

Given the impact of external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

Areas around the lines intersect much, indicating a significant influence of external uncertainties (climate change and market prices). Despite of that, the BRM is backed by the results and acting should have a significant effect.

What is the impact of the sectoral groups of actions?

Figure 47 shows that gross margin of agriculture depends mostly on actions from the sector itself. Yet, actions improving water management can also play a role. Comparing the BRM to the summed effect of the groups of actions, the BRM generates a small extra benefit, indicating a possible synergistic effect between the transformation of agriculture and the improvement of water management. More water can be consumed by a less-demanding system with an adapted management process (cf. discussion about the impact of the sectoral groups of actions on the water streams flow KPI).

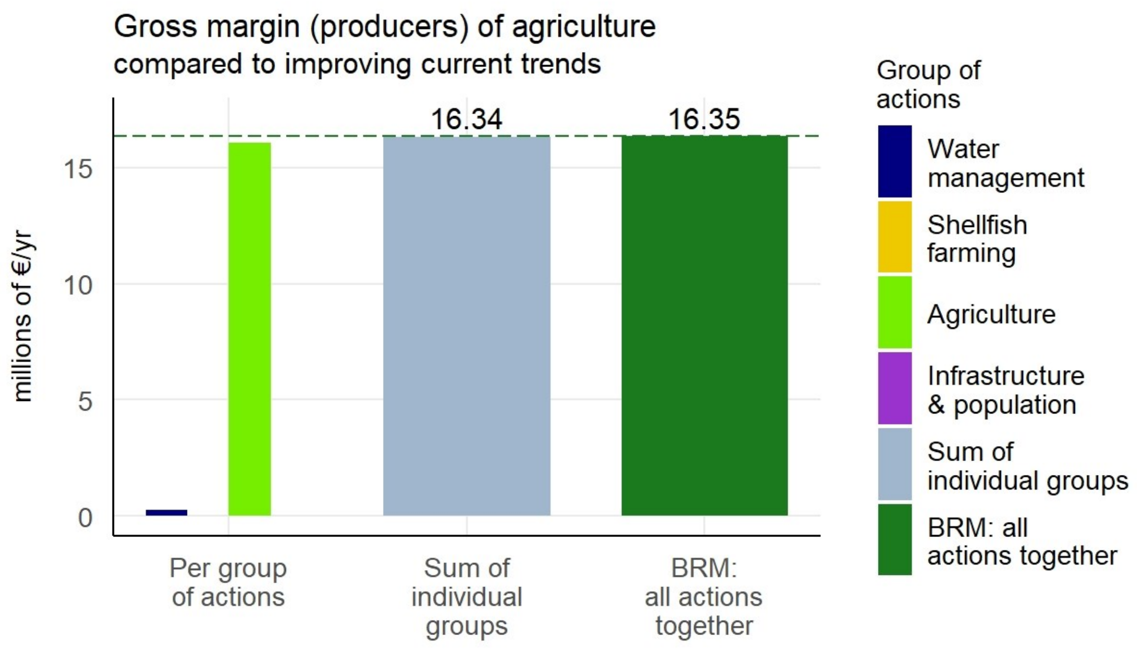

Figure 47 : Effect of the sectoral groups of actions on the gross margin of agriculture, compared to the 'Improving current trends' trajectory. The sum of individual actions is the sum of the effects of applying each sectoral group independently. The BRM corresponds to the effect of applying all the actions together.

5.5.10. KPI – Employment in agriculture

What is a sustainable state in the Charente river basin and its coastal zone?

Employment in agriculture should be at least equal to its current level, and if possible increase, as a component of the territory's attractiveness.

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What is the impact of the trajectories on this KPI?

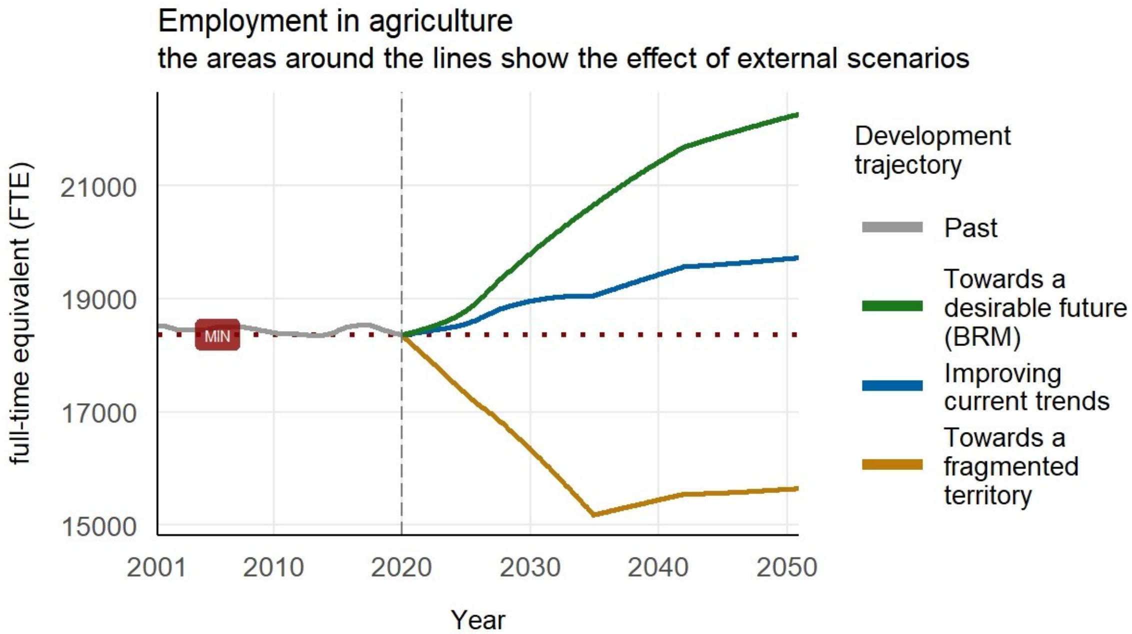

Figure 48 : Effect of the territorial development trajectories on employment in agriculture.

The BRM allows maintaining and creating the greatest number of jobs (Figure 48). This is due to the higher agroecological transition, with agroecology requiring more hands than conventional agriculture, and the maintenance of a rural fabric and the associated processing units on the territory. In the trajectory improving current trends, the share of conventional agriculture remains more important, limiting job creation, while the fragmented territory favours the concentration of supply chains and farms, maximizing profits at the expense of employment.

Given the impact of external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

Employment in agriculture being proportional to the agroecological share of the UAA in the model (previous KPI), we draw the same conclusions: it does not appear as sensitive to external drivers and actions are necessary and effective to reach a sustainable and robust state of the system.

5.5.11. KPI – Population

What is a sustainable state in the Charente river basin and its coastal zone?

The territory's population (residents and tourists) should be better distributed between the rural and coastal areas to maintain the social fabric. It should also not increase too much to avoid mass effects.

What is the impact of the trajectories on this KPI?

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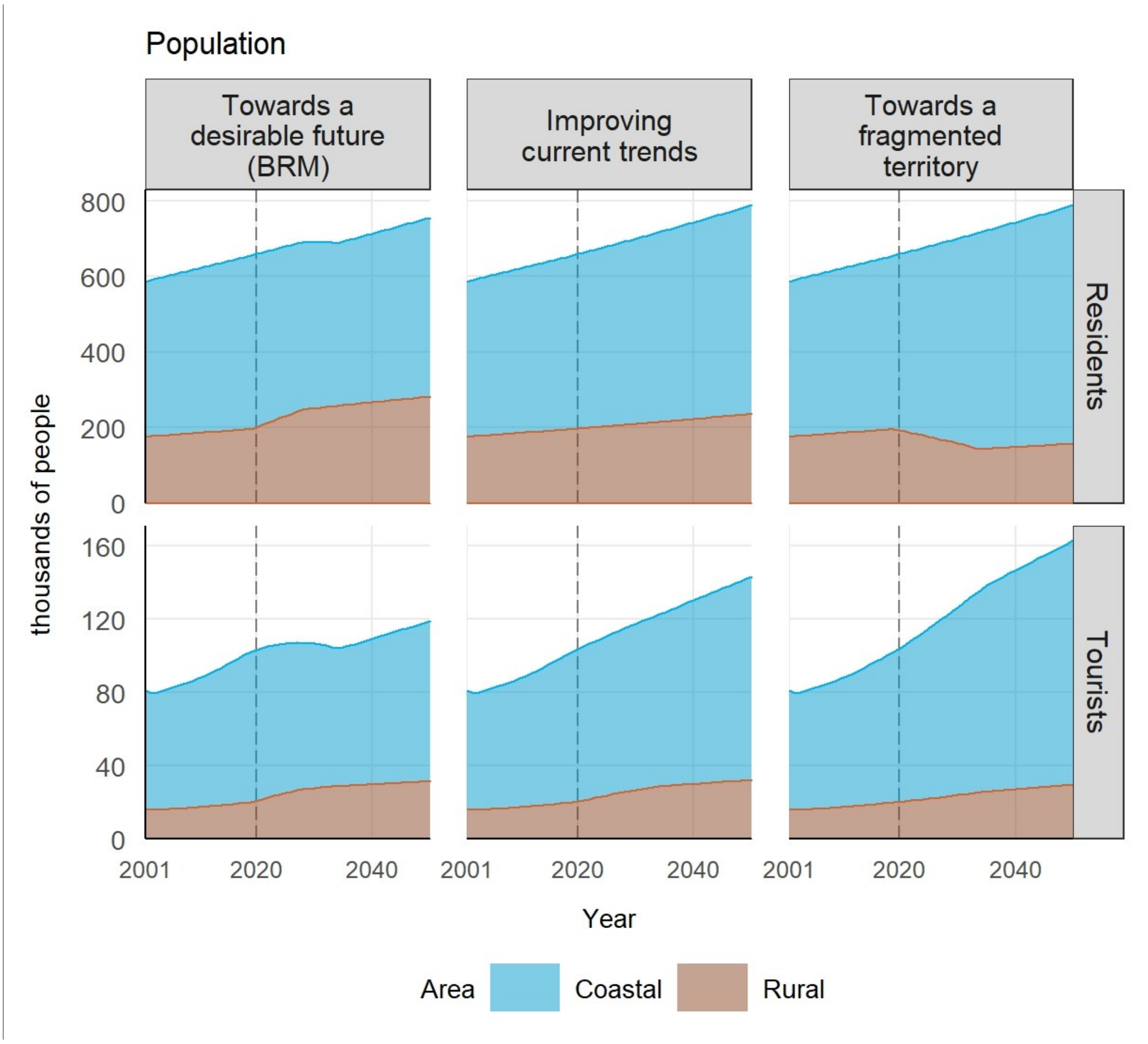

Figure 49 : Effect of the development trajectories on the populations of residents and tourists and their distribution between the coastal and rural areas.

The population is likely to increase in all the prospective studies (SRADDET – Région Nouvelle-Aquitaine, 2019; Charente 2050 - EPTB Charente, 2022; etc.). The population on the coast will increase in all trajectories, however the balance between rural and coastal fabric is different. The BRM best allows preserving residency and activity in the rural areas, as well as the development of alternative tourism outside the coastal zone. The fragmented trajectory is the most detrimental because it concentrates the population on the coast and favours mass tourism.

Given the impact of external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

By design of the model, this KPI is not sensitive to external drivers.

5.5.12. KPI – Infrastructure development

What is a sustainable state in the Charente river basin and its coastal zone?

Although infrastructure has to expand to meet new needs, it should be as limited as possible to avoid the artificialization of natural ecosystems. Roads congestion should be limited. Storage needs are quantified to assess the necessary adaptation of infrastructure and are not related to sustainability.

What is the impact of the trajectories on this KPI?

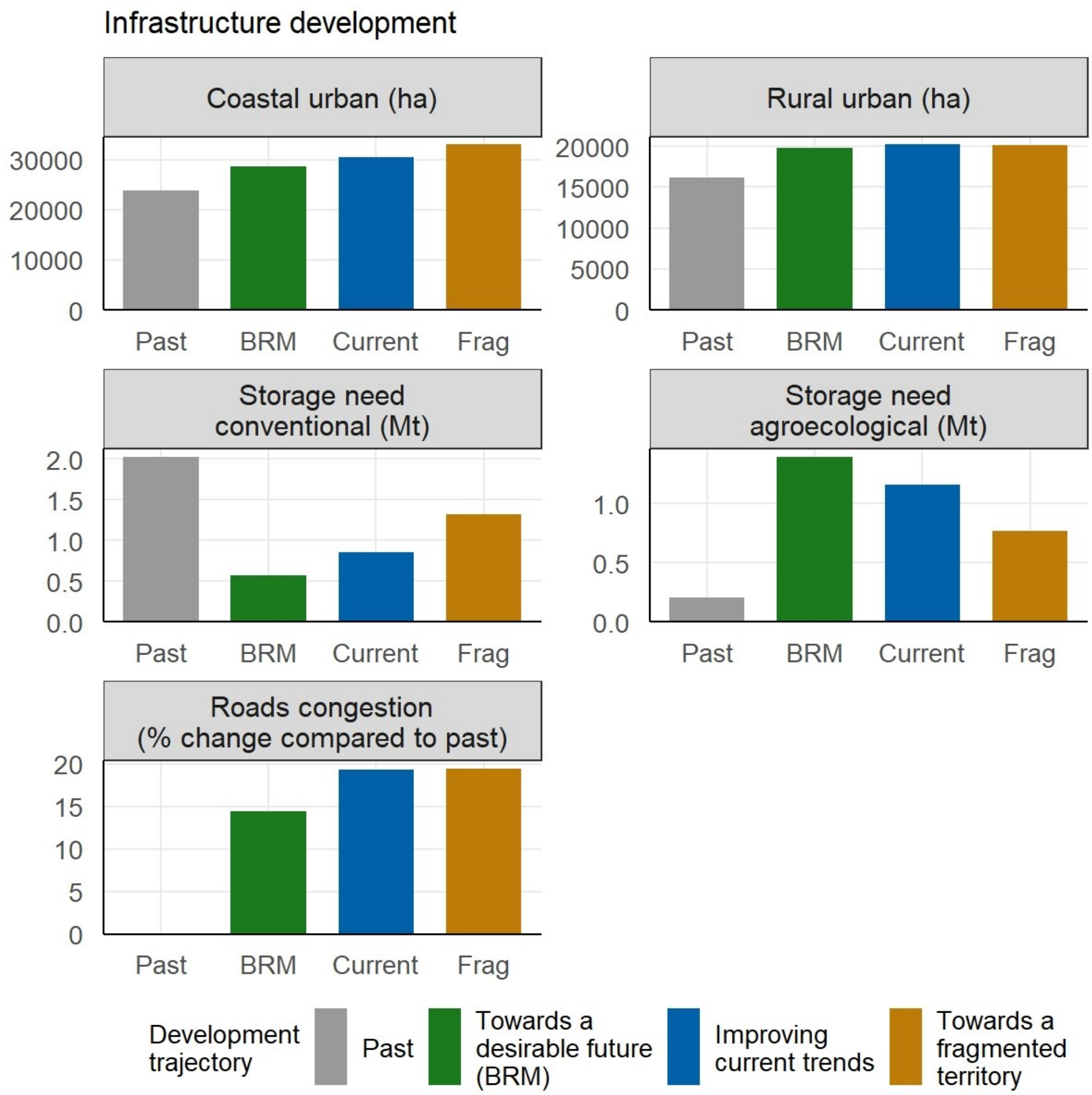

Figure 50 : Effect of the territorial development trajectories on the development of infrastructure.

The trajectory towards a desirable future implies a lower development of urban areas, limiting land artificialization. Urban expansion is more limited on the coastline in the BRM with the aim to spread investments, preserving the rural fabric and allowing people to live and work in a better environment throughout the territory. Because population is lower in the BRM trajectory (cf. population KPI), the road congestion indicator is at its lowest. The BRM trajectory implies the most rapid and intense expansion of agroecology and therefore the storage infrastructure will require more adaptation.

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Given the impact of external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

By design of the model, this KPI is not sensitive to external drivers.

5.5.13. KPI – Attractiveness of the territory

What is a sustainable state in the Charente river basin and its coastal zone?

The attractiveness of the territory should increase and be as high as possible.

What is the impact of the trajectories on this KPI?

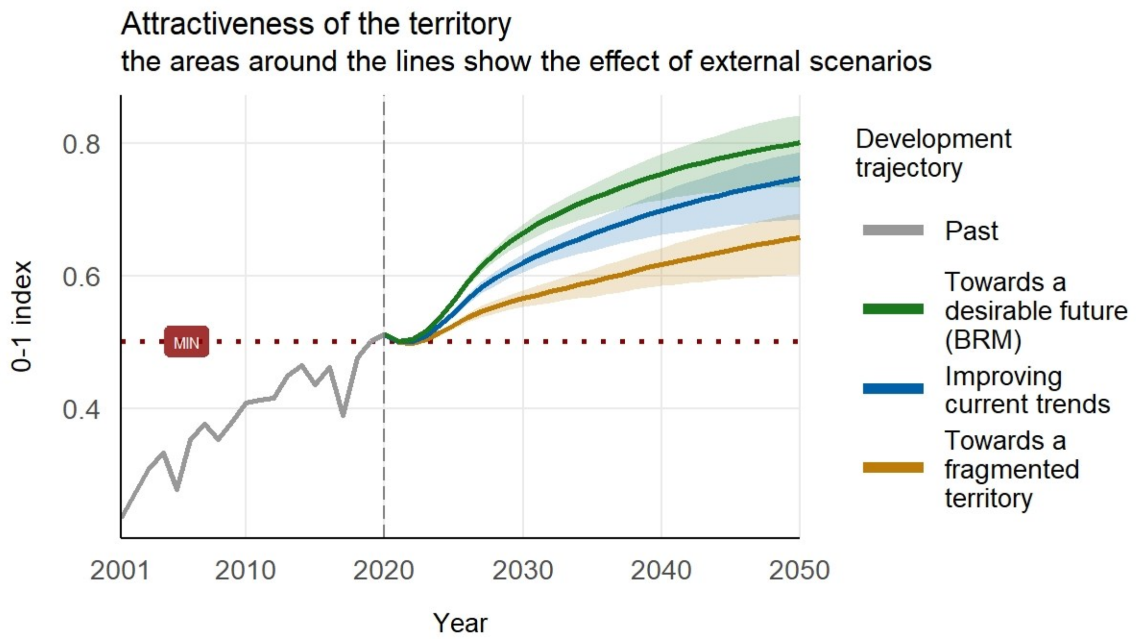

Figure 51 : Effect of the territorial development trajectories on the attractiveness of the territory (theoretical index).

The indicator of the attractiveness of the territory combines a large number of relevant variables. All the trajectories enhance this attractiveness, with the implementation of the BRM that allows reaching the best score when (0.8, cf. Figure 51). The trajectory towards a fragmented territory differs significantly from the other two with the lowest attractiveness score at the end of the simulation, even when taking into account external uncertainties. The BRM seems effective overall to sustainably enhance coastal-rural synergies and the global attractiveness.

Given the impact of external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

External uncertainties matter but do not influence so much this KPI. The implementation of the BRM brings this KPI within a sustainable and robust state, as the score is constantly increasing and reaches a high value at the end. There are intersects with the trajectory improving current trends, but they occur when external drivers are at their worst for the BRM and at their best for the current trends.

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What is the impact of the sectoral groups of actions?

The actions aiming to reach a sustainable agriculture in the territory are key actions to improve the attractiveness of the territory (Figure 52). Actions focused on water management and shellfish farming can also play a role. Here, we note that the structure of the indicator (its calculation) is not perfect and may be too sensitive to some specific actions. More interestingly, comparing the effect of the BRM with the summed effect of the groups of actions, the BRM yields a slightly more attractive territory. While this difference may be insignificant, it shows that implementing actions together in collaboration can have a synergistic effect. The extent of such synergies is then difficult to quantify, but at least it seems they do exist and should thus be aimed for.

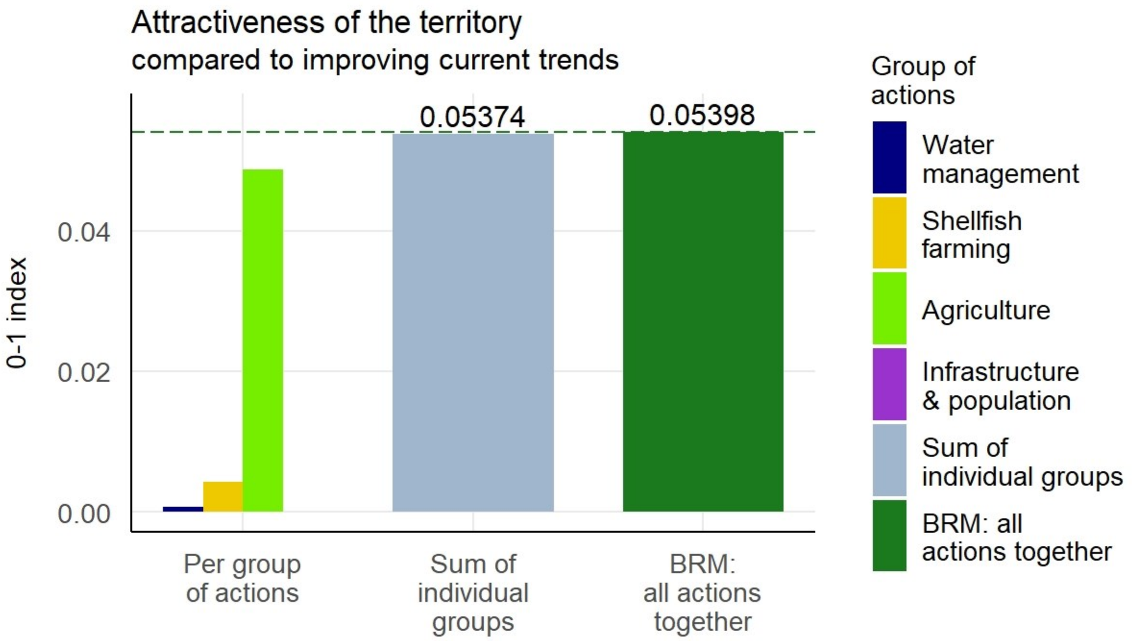

Figure 52 : Effect of the sectoral groups of actions on the attractiveness of the territory, compared to the 'Improving current trends' trajectory. The sum of individual actions is the sum of the effects of applying each sectoral group independently. The BRM corresponds to the effect of applying all the actions together.

5.6. Conclusions

System dynamics modelling has demonstrated value to help decision-makers understand and predict the dynamic behaviour of complex systems in support to effective policy actions. The land-sea model developed in the context of the COASTAL project's MAL4 simulates the interactions between the main coastal activities (shellfish farming, tourism), the main rural activity (agriculture), water resources (quantity, quality), the population and infrastructure. Simulation results were able to feed intra- and extra-sectoral discussions between stakeholders, in a global approach towards a more sustainable and attractive territory. Several group of actions have been defined in the BRM in order to enhance coastal-rural synergies, develop sustainable agriculture and shellfish farming in the area, avoid mass tourism, maintain the social fabric and protect water resources and ecosystems.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773782.

The results of simulating the territorial development trajectories defined with local stakeholders show that implementing the BRM towards a desirable future is the best trajectory for almost all KPIs (Figure 53 and Table 20), allowing to meet the goal of an harmonious, attractive and resilient territory. A clear trade-off appears between agricultural production and the other indicators of interest. For several KPIs, the BRM is the sole trajectory that reaches a sustainable state (or overpasses it largely) under different climate scenarios (water streams flow, water use, quality index of oysters, pesticides use). Improving current trends could help but the final situation would be less sustainable, which calls for innovative actions. In any case, when looking at the trajectory going towards a fragmented territory, acting appears as necessary and inevitable, since the territory could also easily go towards an undesired and unsustainable state. Considering the speed at which the BRM becomes sustainable for some KPIs, many actions have to be implemented as soon as possible (short term ones) before mid-term and long-term actions can be effective. Summarizing the findings per KPI, we can establish the following main messages for local actors and decision-makers:

- Manage water resources as a common good, join the effort of rural and coastal stakeholders to decrease the total water use and improve water quality.
- Develop quickly a more sustainable agriculture, knowing that yields will decrease but that global margin can be maintained and the use of nutrients and pesticides will diminish. To do this, changes are required in cultivated crops, agricultural practices and systems and irrigation techniques.
- Use new techniques and new leasing grounds to exploit the improved coastal waters quality and develop a shellfish farming activity completely rooted in the territory.
- Adapt policy to regulate the spatial and temporal distribution of residents and tourists.
- Upscale and adapt infrastructure to better meet the needs of a growing population more spread over the territory.

Beyond the results, implementing concertation structures and defining new consensual indicators appear as essential to enhance coastal-rural concertation and improve local policies (cf. policy recommendations in BRM deliverable).

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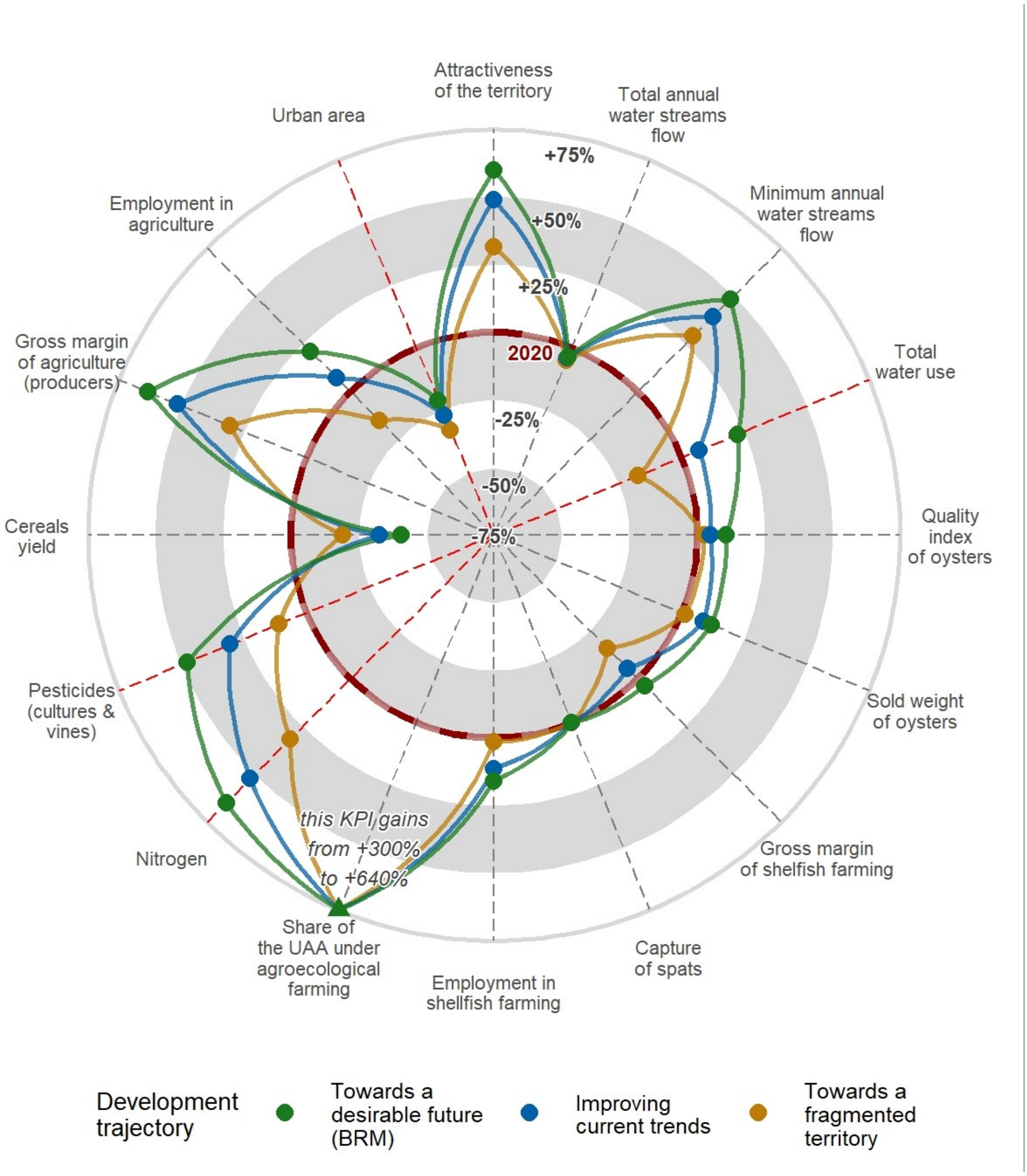

Figure 53 : Radar graph summarizing the effect of the territorial development trajectories on all the KPIs. The value of the KPIs are reported as a relative change when compared to their value in 2020. The red axis are inverted so the best scenario is on the outside for all the KPIs.

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Table 20 : Summary of the BRM's effect across the KPIs and in relation to external uncertainties.

KPI	Is the BRM the best trajectory?	The best under all external scenarios?	Is the BRM sustainable?	Sustainable under all external scenarios?	Is the KPI more sensitive to actions than to external scenarios?
Water streams flow	YES	YES	YES	YES	NO
Water use	YES	YES	YES	YES	YES
Water deficit	YES	YES	YES	NO	NO
Oysters production performance	YES	NO	YES	NO	~
Spats capture	YES	NO	YES	NO	NO
Employment in shellfish farming	YES	YES	YES	YES	YES
Share of the UAA under agroecology	YES	YES	YES	YES	YES
Agricultural inputs	YES	YES	YES	YES	YES
Agricultural yields	NO	NO	~	NO	YES
Composition of agricultural production	YES	YES	YES	YES	YES
Gross margin of agriculture	~	~	YES	YES	~
Employment in agriculture	YES	YES	YES	YES	YES
Population	YES	na	na	na	na
Infrastructure development	YES	na	na	na	na

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Attractiveness of the territory	YES	YES	YES	YES	YES

5.7. References

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5.8. Annex I – Groups of actions in the BRM

The actions present in this table are those represented in the model and in the studied trajectories. The BRM includes other actions not simulated. The complete BRM can be consulted in its own deliverable and on the COASTAL knowledge exchange platform online.

Group of actions	Actions	SD model's input variables
Management of water as a land sea continuum	Further sensitize citizens to water savings	water use per person

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Management of water as a land sea continuum	Improve the collective and cross-sectoral management of water as a common good (sharing issue) through enlarged consultations and possibly new management rules	abstraction permits for irrigation reservoirs capacity share of irrigation demand that can access reservoirs
Management of water as a land sea continuum	Better coordinate and integrate existing policies together (water framework directive, maritime strategy directive, SAGEs, territories plans...)	abstraction permits for irrigation reservoirs capacity share of irrigation demand that can access reservoirs
Management of water as a land sea continuum	Use wastewater for different activities, diminish water use in all activities and improve water efficiency	reused share from WWTP coastal reused share from WWTP rural
Management of water as a land sea continuum	Adapt infrastructure to achieve sustainable exploitation of the water resource (WWTP capacity, water network, housing, etc.)	capacity rural WWTP people eq capacity coastal WWTP people eq
Towards a sustainable shellfish industry rooted in the territory	Collect and spread producers' and scientific knowledge about how the water quality, the input of freshwater and the trophic resource affect shellfish production in the marshes, in the estuary and at sea	mortality rate year 1 mortality rate year 2 mortality rate year 3
Towards a sustainable shellfish industry rooted in the territory	Restore the multifunctionality of the dammed and free salt marshes and the link between inland watersheds and the coastal zone on the basis of a concertation procedure	mortality rate year 1 mortality rate year 2 mortality rate year 3
Towards a sustainable shellfish industry rooted in the territory	Give more importance to empirical knowledge gathered from the producers in the management of the activity	mortality rate year 1 mortality rate year 2 mortality rate year 3
Towards a sustainable shellfish industry rooted in the territory	Adjust areas, ideally extending them, and densities to achieve a product quality compatible with the market demand	authorised oyster farms area oyster density per bag year 3
Towards a sustainable shellfish industry rooted in the territory	Ensure a good maintenance of concessions and a limited impact of oyster farming equipment on sandy or muddy bio-systems to restore interface areas and abandoned oyster beds	authorised oyster farms area mortality rate year 1 mortality rate year 2 mortality rate year 3

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Towards a sustainable shellfish industry rooted in the territory	Develop and use new farming technologies to produce higher quality products and reduce environmental impacts	share of floating bags mortality rate year 1 mortality rate year 2 mortality rate year 3

Towards a sustainable shellfish industry rooted in the territory	Negotiate a common total stock of farmed oysters to efficiently and sustainably exploit the trophic capacity of the system (guarantee of a flesh content satisfying the constraints of the label)	oyster density per bag year 3
Towards a sustainable shellfish industry rooted in the territory	Manage the common total stock according to a constant monitoring of the trophic resource and the feedback from professionals in the field	oyster density per bag year 3
Towards a 100% agroecological territory	Continue the sensitization of consumers and support the commercialisation of agroecological products	agroecological share of food consumption
Towards a 100% agroecological territory	Financially support the conversion to agroecology and the creation of dedicated supply chains, and provide details about the new promising opportunities (new crops, etc.) and the new organisation of the sector (relocation of processing units, etc.)	agroecological share of supply chain
Towards a 100% agroecological territory	Promote the installation of young farmers and the transmission of farms, through new legal and employment structures and new installation incentives	agricultural workers replacement rate
Towards a 100% agroecological territory	Further include and consider all water users in the collective management of water storage for agriculture (in particular downstream users)	reservoirs capacity share of irrigation demand that can access reservoirs
Towards a 100% agroecological territory	Reach 100% of agroecological vineyards	agroecological share of vines
Towards a 100% agroecological territory	Implement new agroecological systems with reasonably sized plots in a modernised landscape (new crops, irrigation techniques, agroforestry, etc.)	employment per 100ha conventional employment per 100ha agroecological
Towards a 100% agroecological territory	Create new supply chains and increase commercial alliances to jointly promote products "from the territory"	agroecological share of food consumption agroecological share of supply chain

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Towards a 100% agroecological territory	Maintain the agricultural area and a dynamic rural fabric thanks to a structure that monitors land acquisition	agricultural workers replacement rate
Towards a harmonious and diversified territory	Foster new forms of tourism (rural, alternative, seasonal, etc.) less concentrated during the summer period and on the coastal zone	coastal share of tourists urban yearly expansion coastal share of urban expansion
Towards a harmonious and diversified territory	Regulate the tourism offer (facilities, infrastructure) to limit mass tourism	tourists demand growth per year coastal share of tourists urban yearly expansion coastal share of urban expansion
Towards a harmonious and diversified territory	Avoid gentrification to preserve the possibility for all inhabitants (all social categories) to live and work in the territory	employment per 100 ha conventional employment per 100ha agroecological agricultural workers replacement rate
Towards a harmonious and diversified territory	Improve the attractiveness of rural areas with more services, infrastructure, job opportunities, etc.	employment per 100 ha conventional employment per 100ha agroecological agricultural workers replacement rate coastal share of tourists coastal share of residents
Towards a harmonious and diversified territory	Find incentives to maintain a residential population balanced throughout the territory	coastal share of residents urban yearly expansion coastal share of urban expansion
Towards a harmonious and diversified territory	Improve land use planning policies to better manage competition for space between multiple activities in the coastal zone	urban yearly expansion coastal share of urban expansion
Towards a harmonious and diversified territory	Limit land artificialisation	urban yearly expansion coastal share of urban expansion
Towards a harmonious and diversified territory	Ensure supplies, space, opportunities and outlets over the territory for all private and individual activities	coastal share of tourists coastal share of residents urban yearly expansion coastal share of urban expansion

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5.9. Annex II – Input variables vs. Business roadmap

Variable	BRM actions	BRM term			Variable term
		Short	Mid	Long	
abstraction permits for irrigation	Improve the collective and cross-sectoral management of water as a common good (sharing issue) through enlarged consultations and possibly new management rules		X		MID
	Better coordinate and integrate existing policies together (water framework directive, maritime strategy directive, SAGEs, territories plans...)		X		
reservoirs capacity	Further include and consider users in the collective management of water storage for agriculture (in particular downstream users)	X			LONG
	Improve the collective and cross-sectoral management of water as a common good (sharing issue) through enlarged consultations and possibly new management rules		X		
	Better coordinate and integrate existing policies together (water framework directive, maritime strategy directive, SAGEs, territories plans...)		X		
share of irrigation demand that can access reservoirs	Further include and consider all water users in the collective management of water storage for agriculture (in particular downstream users)	X			LONG
	Improve the collective and cross-sectoral management of water as a common good (sharing issue) through enlarged consultations and possibly new management rules		X		
reused share from WWTP coastal	Use wastewater for different activities, diminish water use in all activities and improve water efficiency		X		MID
reused share from WWTP rural	Use wastewater for different activities, diminish water use in all activities and improve water efficiency		X		MID
capacity coastal WWTP people eq	Adapt infrastructure to achieve sustainable exploitation of the water resource (WWTP capacity, water network, housing, etc.)		X		MID
capacity rural WWTP people eq	Adapt infrastructure to achieve sustainable exploitation of the water resource (WWTP capacity, water network, housing, etc.)		X		MID
authorised oyster farms area	Adjust areas, ideally extending them, and densities to achieve a product quality compatible with the market demand		X		MID
	Ensure a good maintenance of concessions and a limited impact of oyster farming equipment on sandy or muddy bio-systems to restore interface areas and abandoned oyster beds		X		

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share of floating bags	Develop and use new farming technologies to produce higher quality products and reduce environmental impacts		X		MID
oyster density per bag year 3	Adjust areas, ideally extending them, and densities to achieve a product quality compatible with the market demand		X		LONG
	Negotiate a common total stock of farmed oysters to efficiently and sustainably exploit the trophic capacity of the system (guarantee of a flesh content satisfying the constraints of the label)			X	
	Manage the common total stock according to a constant monitoring of the trophic resource and the feedback from professionals in the field			X	
mortality rate year [1 to 3]	Collect and spread producers' and scientific knowledge about how the water quality, the input of freshwater and the trophic resource affect shellfish production in the marshes, in the estuary and at sea	X			LONG
	Restore the multifunctionality of the dammed and free salt marshes and the link between inland watersheds and the coastal zone on the basis of a concertation procedure	X			
	Give more importance to empirical knowledge gathered from the producers in the management of the activity		X		
	Ensure a good maintenance of concessions and a limited impact of oyster farming equipment on sandy or muddy bio-systems to restore interface areas and abandoned oyster beds		X		
	Develop and use new farming technologies to produce higher quality products and reduce environmental impacts		X		
agroecological share of food consumption	Continue the sensitization of consumers and support the commercialisation of agroecological products	X			MID
	Create new supply chains and increase commercial alliances to jointly promote products "from the territory"		X		
agroecological share of supply chain	Financially support the conversion to agroecology and the creation of dedicated supply chains, and provide details about the new promising opportunities (new crops, etc.) and the new organisation of the sector (relocation of processing units, etc.)	X			MID
	Create new supply chains and increase commercial alliances to jointly promote products "from the territory"		X		
employment per 100ha	Implement new agroecological systems with reasonably-sized plots in a modernised landscape (new crops, irrigation techniques, agroforestry, etc.)		X		LONG

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[conventional/ agroecological]	Improve the attractiveness of rural areas with more services, infrastructure, job opportunities, etc.		X		
	Avoid gentrification to preserve the possibility for all inhabitants (all social categories) to live and work in the territory		X		
agroecological share of vines	Reach 100% of agroecological vineyards		X		MID
agricultural workers replacement rate	Promote the installation of young farmers and the transmission of farms, through new legal and employment structures and new installation incentives	X			SHORT the underlying mid-term actions concern less the action and will allow maintaining the short-term result
	Improve the attractiveness of rural areas with more services, infrastructure, job opportunities, etc.		X		
	Avoid gentrification to preserve the possibility for all inhabitants (all social categories) to live and work in the territory		X		
tourists demand growth per year	Regulate the tourism offer (facilities, infrastructure) to limit mass tourism		X		LONG
coastal share of residents	Find incentives to maintain a residential population balanced throughout the territory		X		LONG
	Improve the attractiveness of rural areas with more services, infrastructure, job opportunities, etc.		X		
	Ensure supplies, space, opportunities and outlets over the territory for all private and individual activities			X	
coastal share of tourists	Foster new forms of tourism (rural, alternative, seasonal, etc.) less concentrated during the summer period and on the coastal zone	X			LONG
	Regulate the tourism offer (facilities, infrastructure) to limit mass tourism Improve the attractiveness of rural areas with more services, infrastructure, job opportunities, etc.		X		
	Ensure supplies, space, opportunities and outlets over the territory for all private and individual activities			X	
water use per person	Further sensitize citizens to water savings	X			MID
urban yearly expansion	Foster new forms of tourism (rural, alternative, seasonal, etc.) less concentrated during the summer period and on the coastal zone	X			LONG
	Regulate the tourism offer (facilities, infrastructure) to limit mass tourism		X		

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	Find incentives to maintain a residential population balanced throughout the territory		X		
	Limit land artificialization		X		
	Improve land use planning policies to better manage competition for space between multiple activities in the coastal zone		X		
	Ensure supplies, space, opportunities and outlets over the territory for all private and individual activities			X	
coastal share of urban expansion	Foster new forms of tourism (rural, alternative, seasonal, etc.) less concentrated during the summer period and on the coastal zone	X			LONG
	Regulate the tourism offer (facilities, infrastructure) to limit mass tourism		X		
	Find incentives to maintain a residential population balanced throughout the territory		X		
	Limit land artificialization		X		
	Improve land use planning policies to better manage competition for space between multiple activities in the coastal zone		X		
	Ensure supplies, space, opportunities and outlets over the territory for all private and individual activities			X	

5.10. Annex II – Results obtained with the RCP climate scenarios

The results are reported per KPI without legend (cf. the corresponding KPI for explanations).

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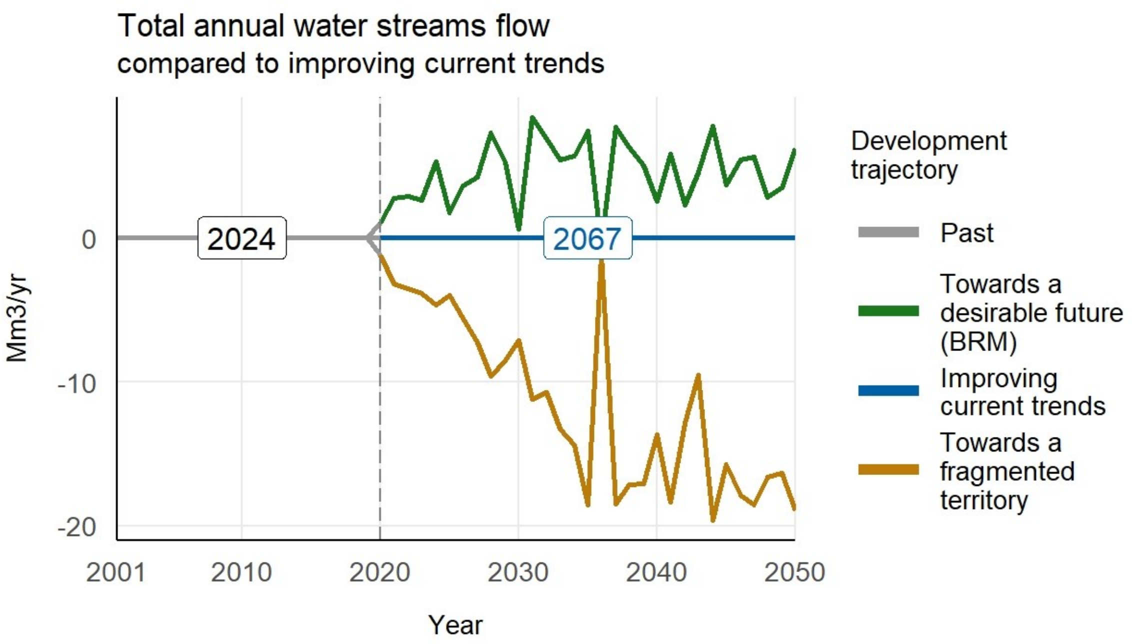
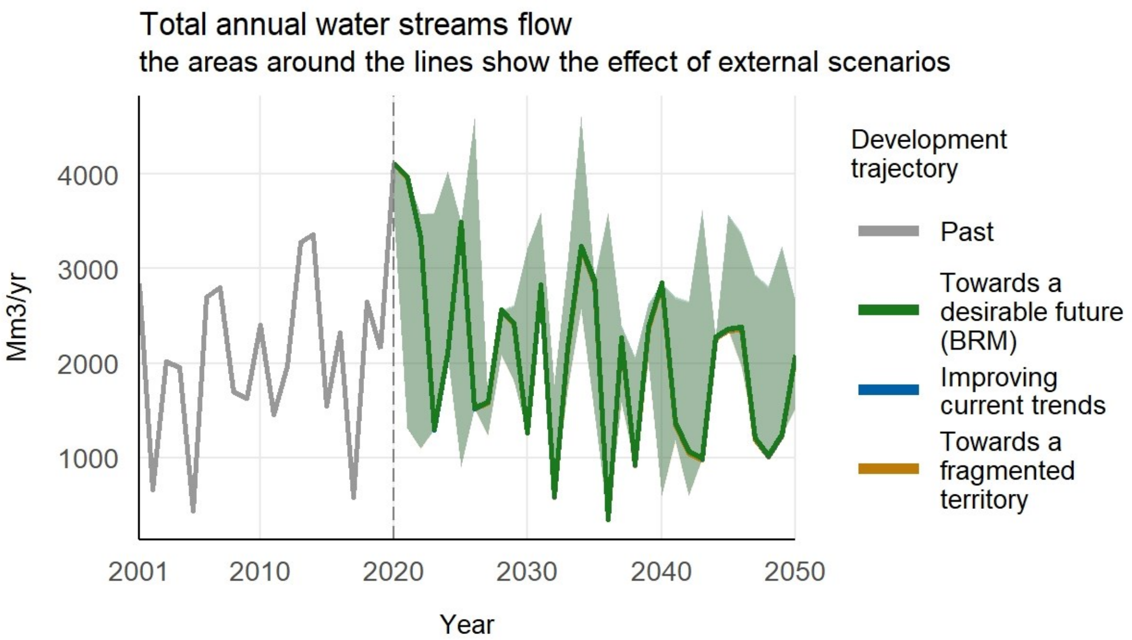
5.10.1. Water streams flow





Minimum water streams flow: used in main text.

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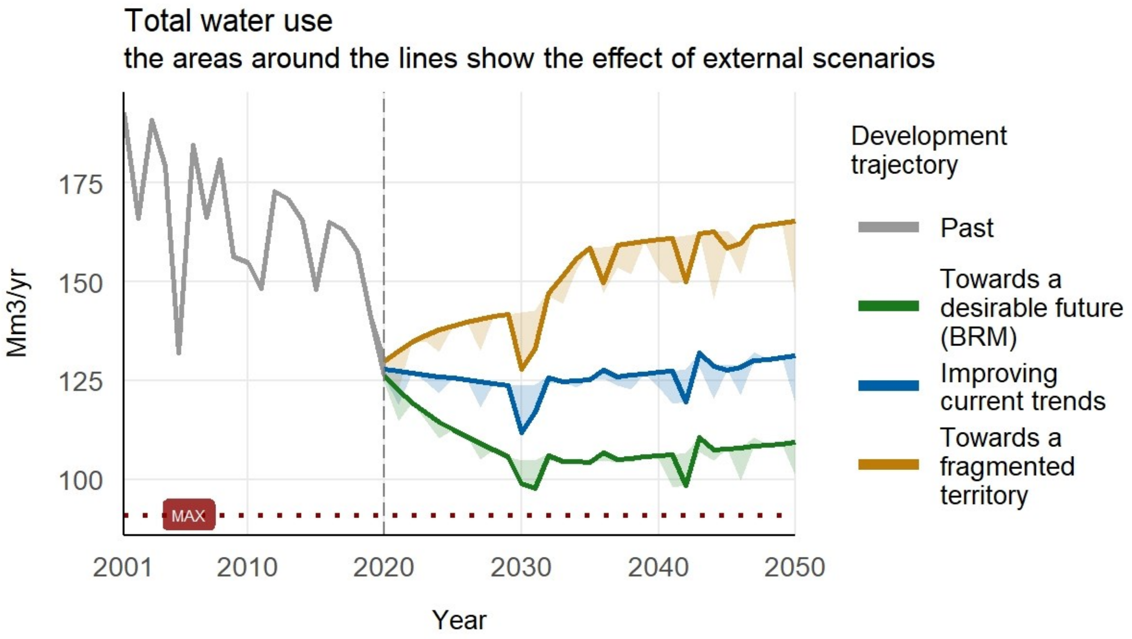
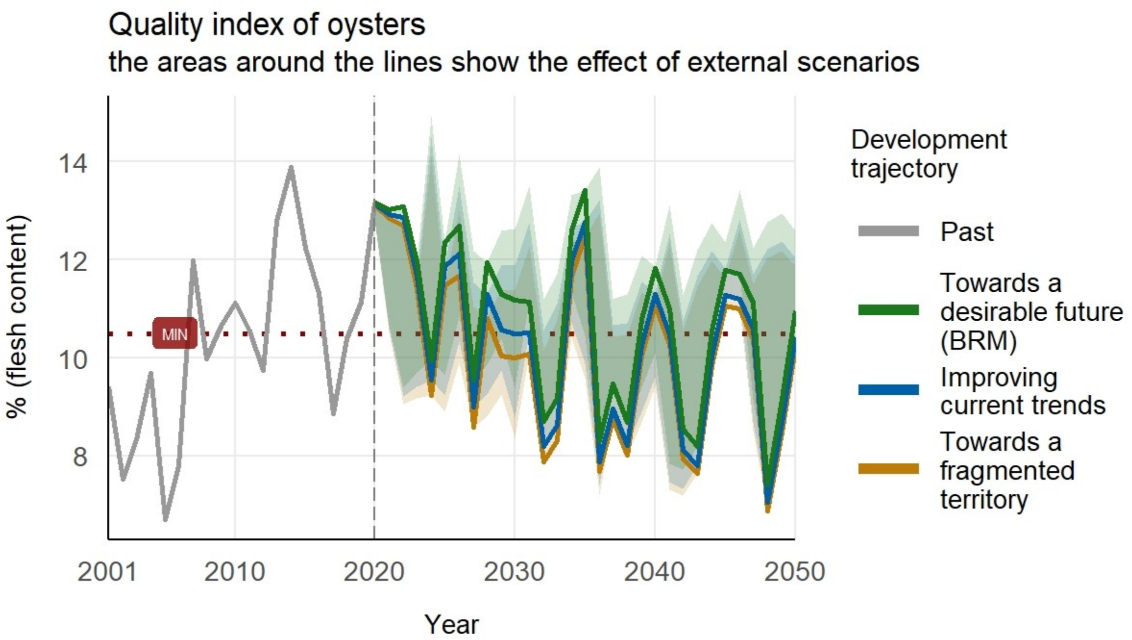
5.10.2. Water use



5.10.3. Water deficit

Used in main text.

5.10.4. Oysters production performance



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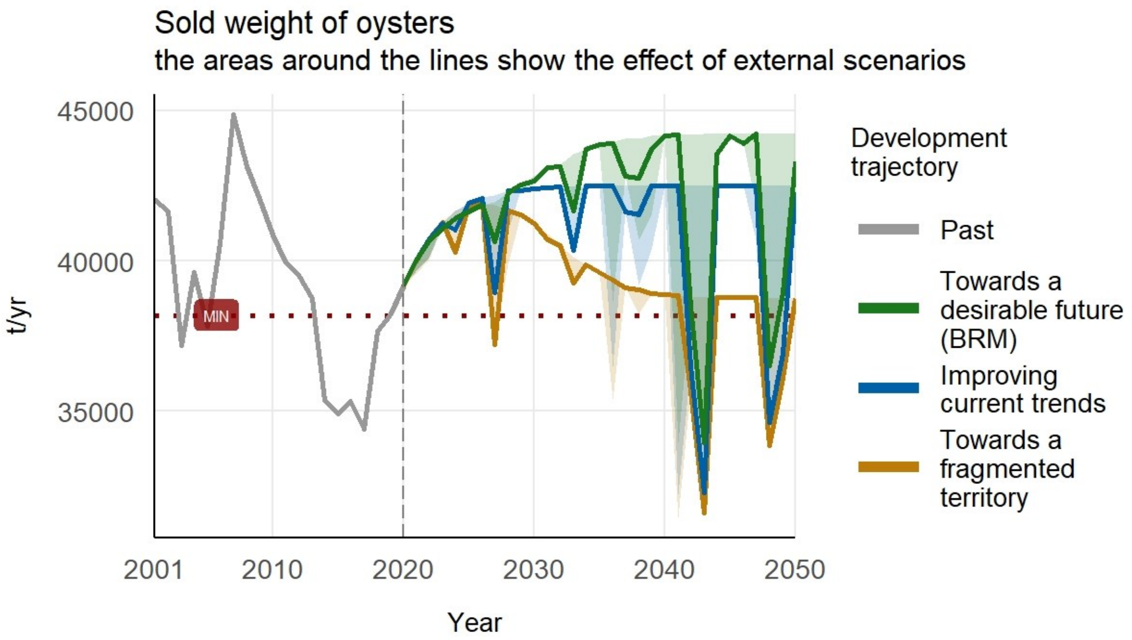

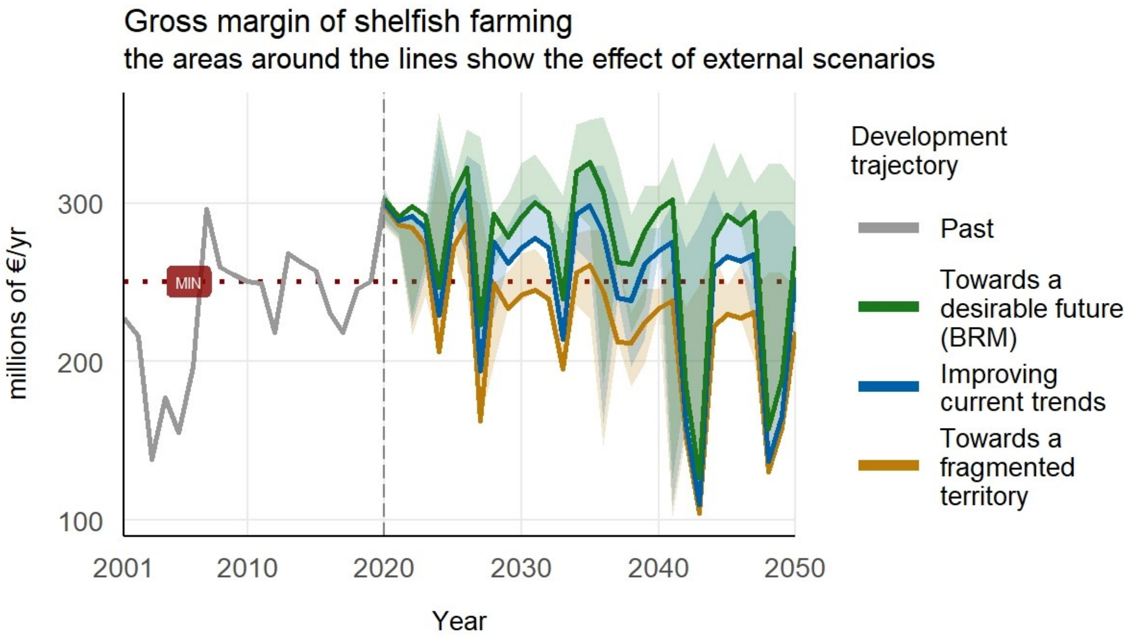

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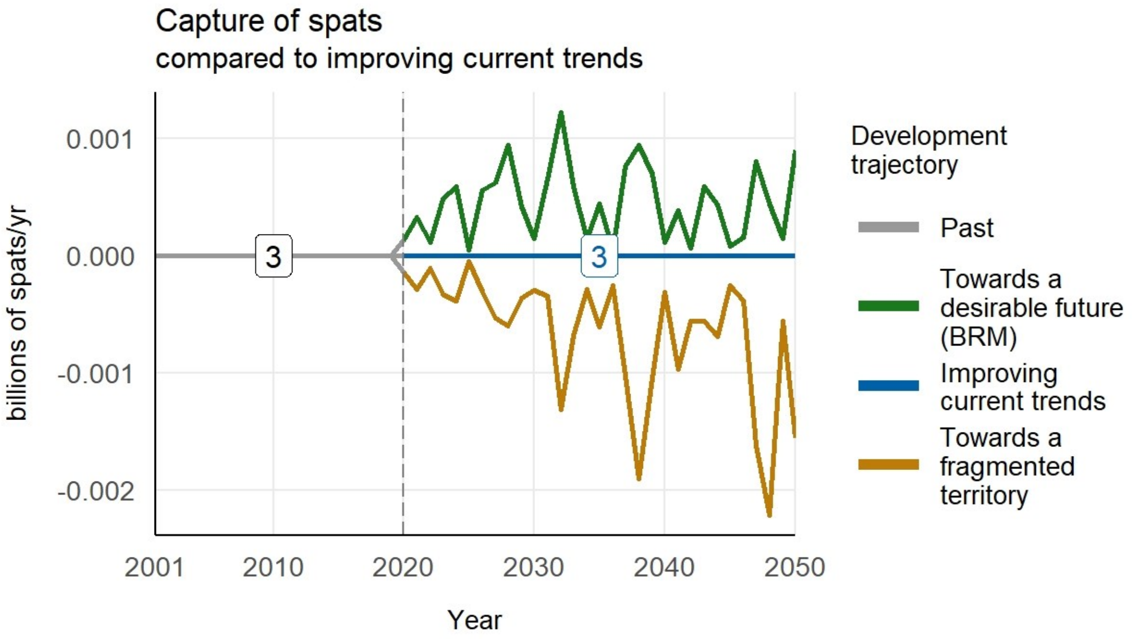
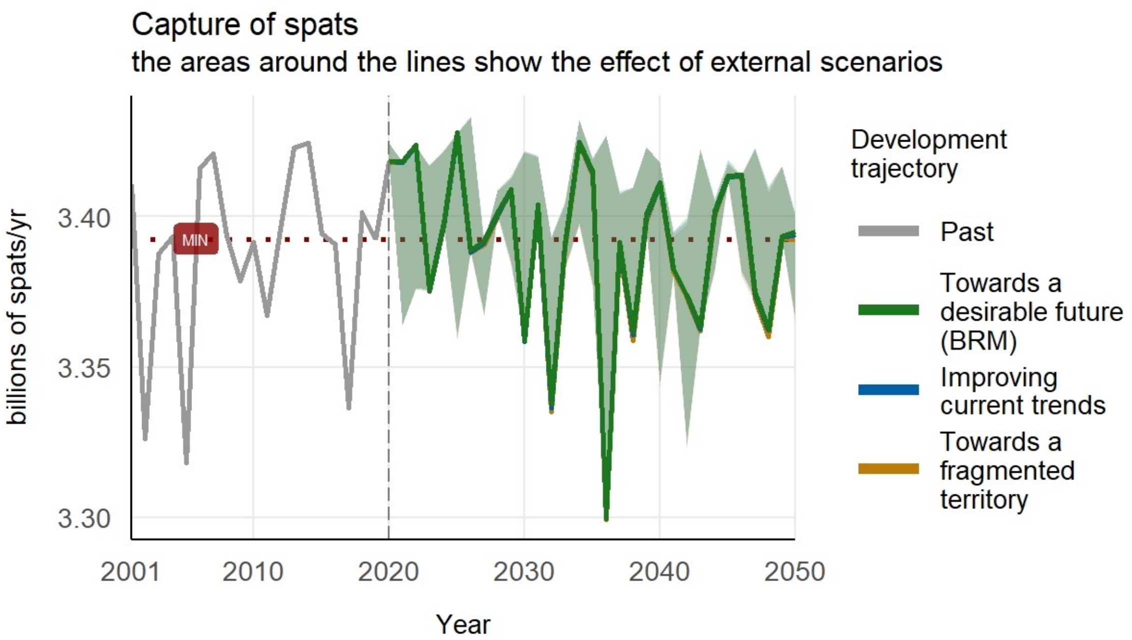
5.10.5. Spats capture





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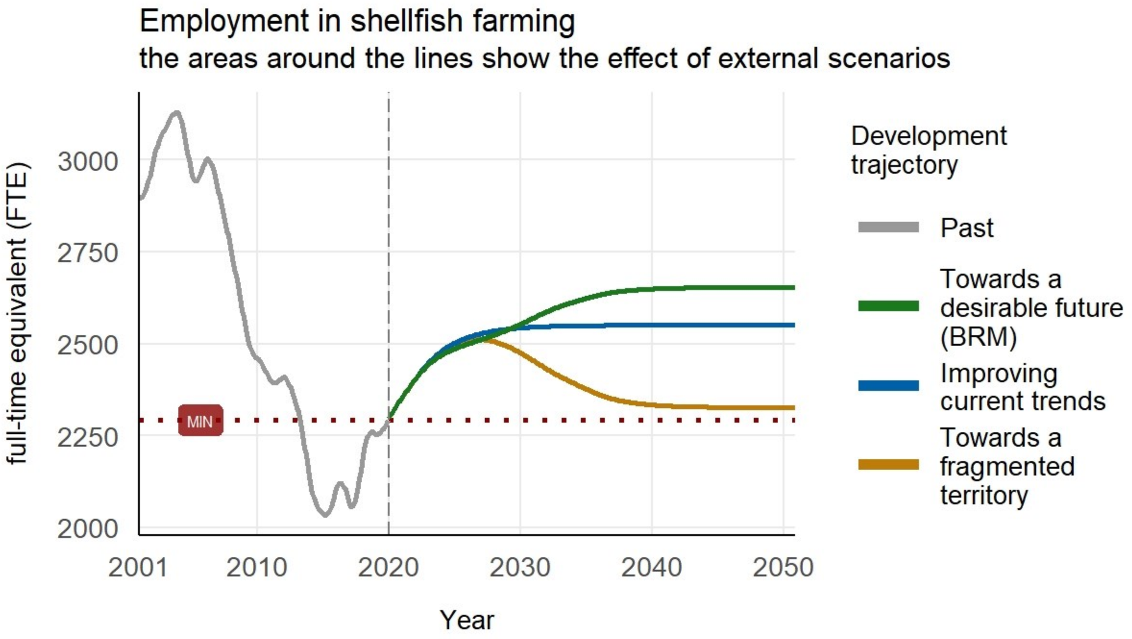
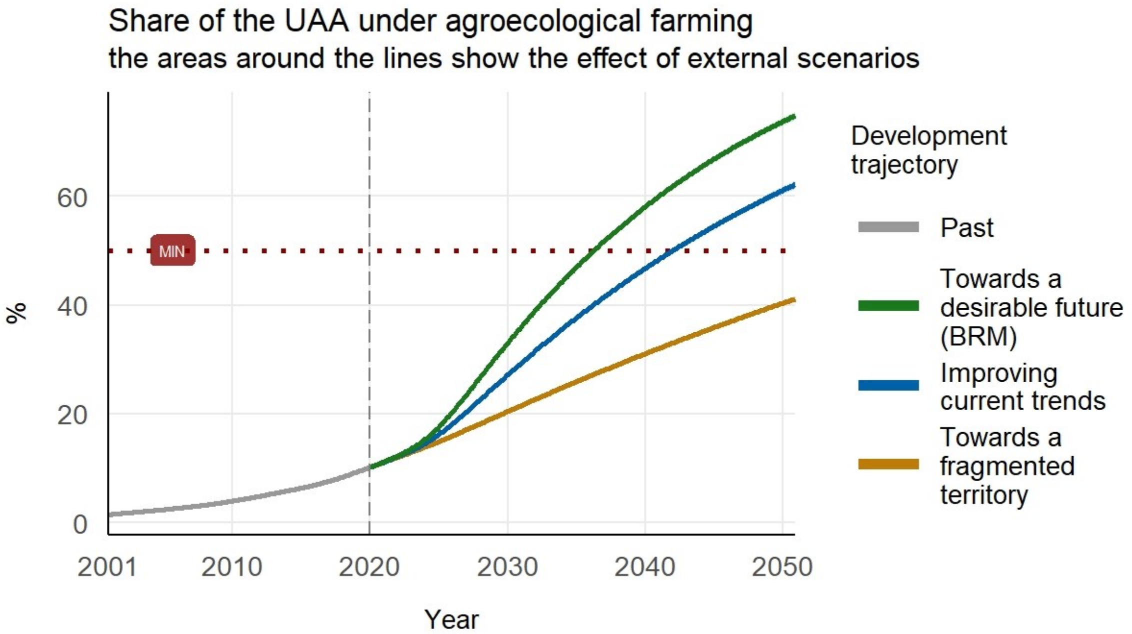
5.10.6. Employment in shellfish farming



5.10.7. Share of the UAA under agroecological farming



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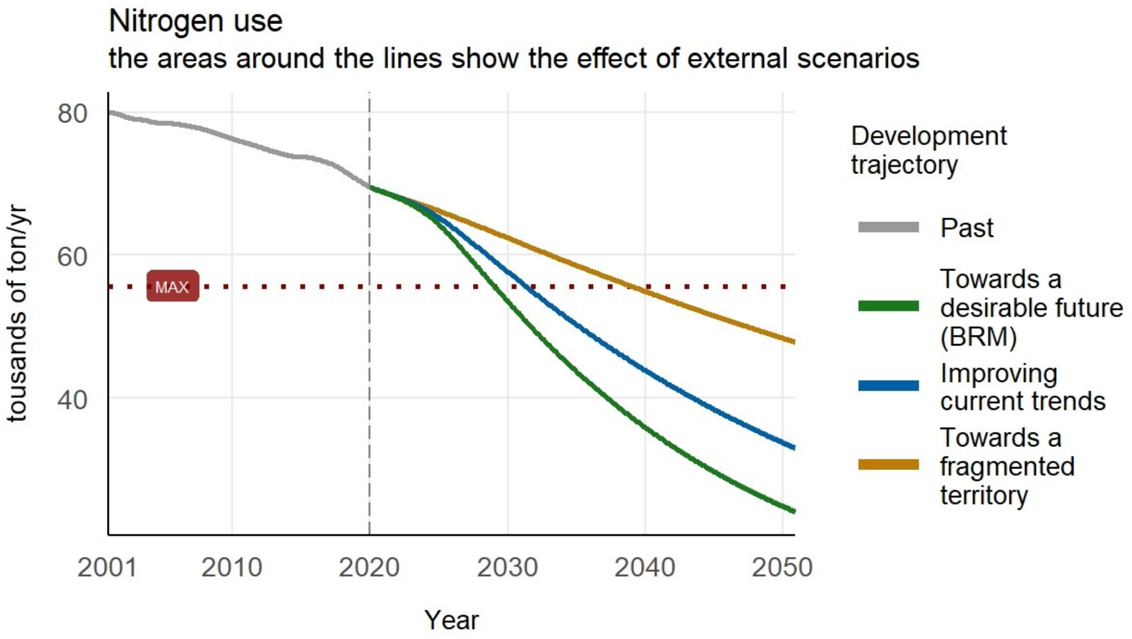
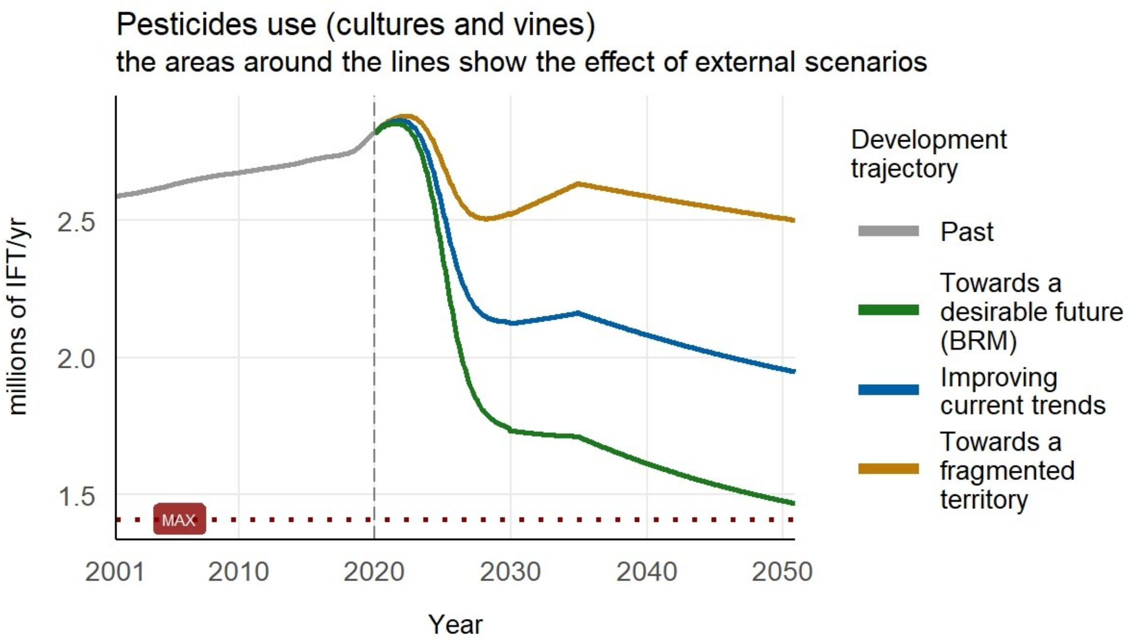
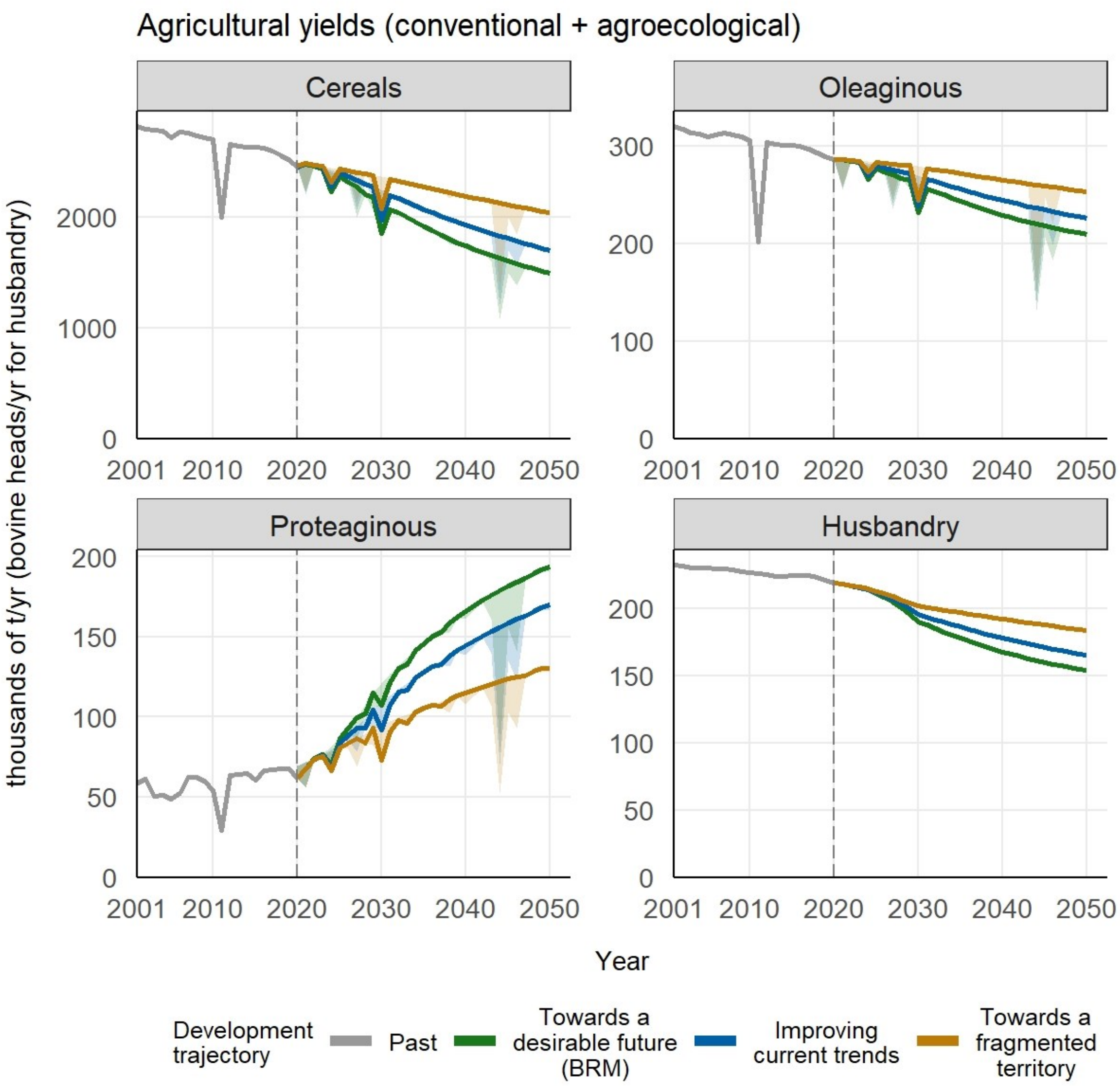
5.10.8. Agricultural inputs





This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773782.

5.10.9. Agricultural yields



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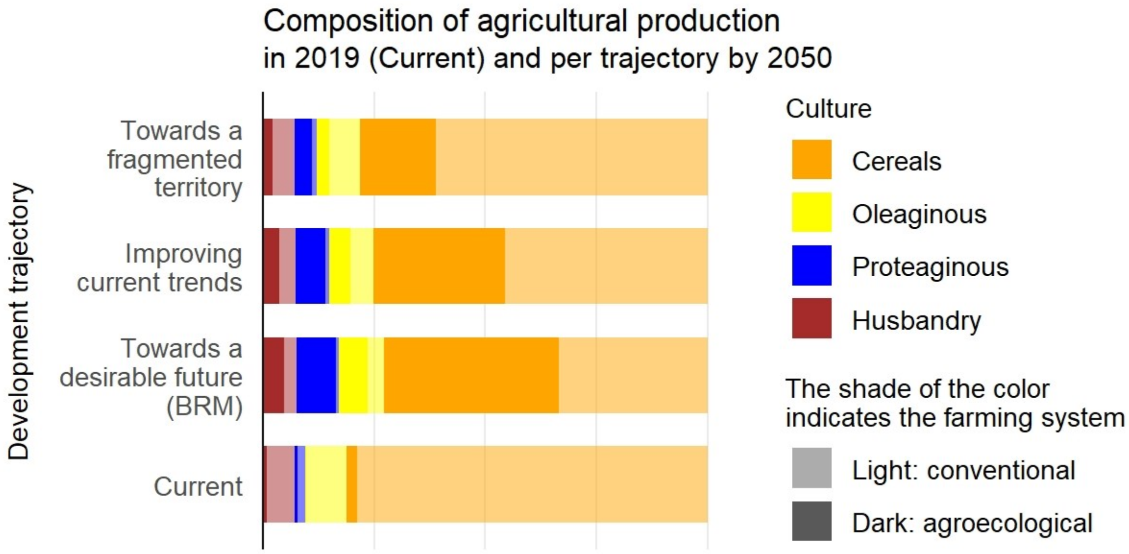
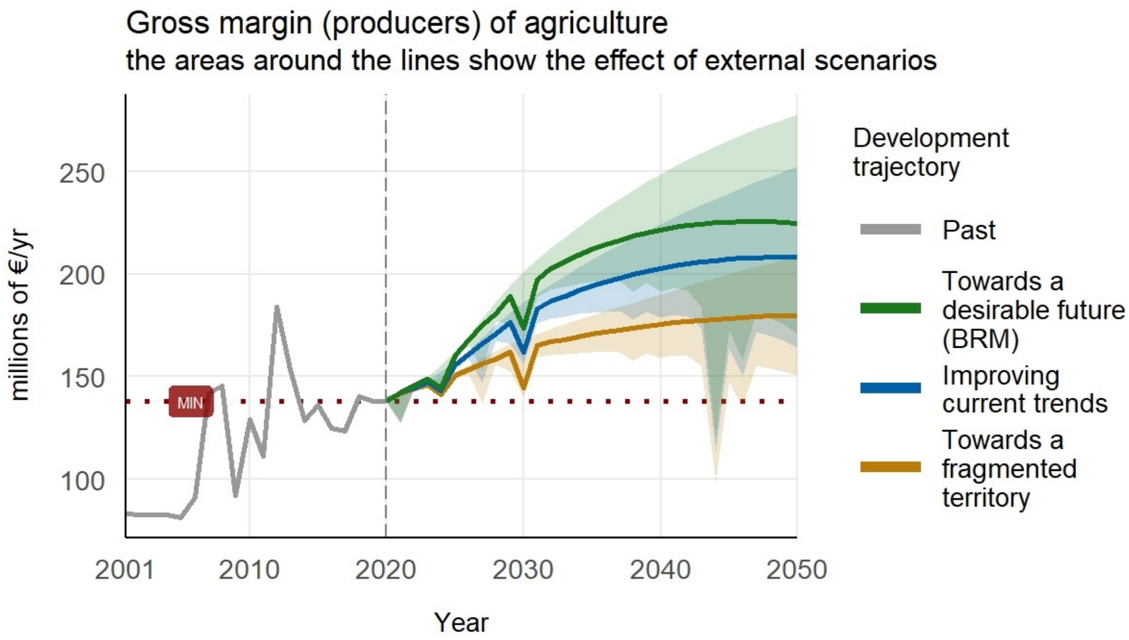
5.10.10. Composition of agricultural production



5.10.11. Gross margin of agriculture



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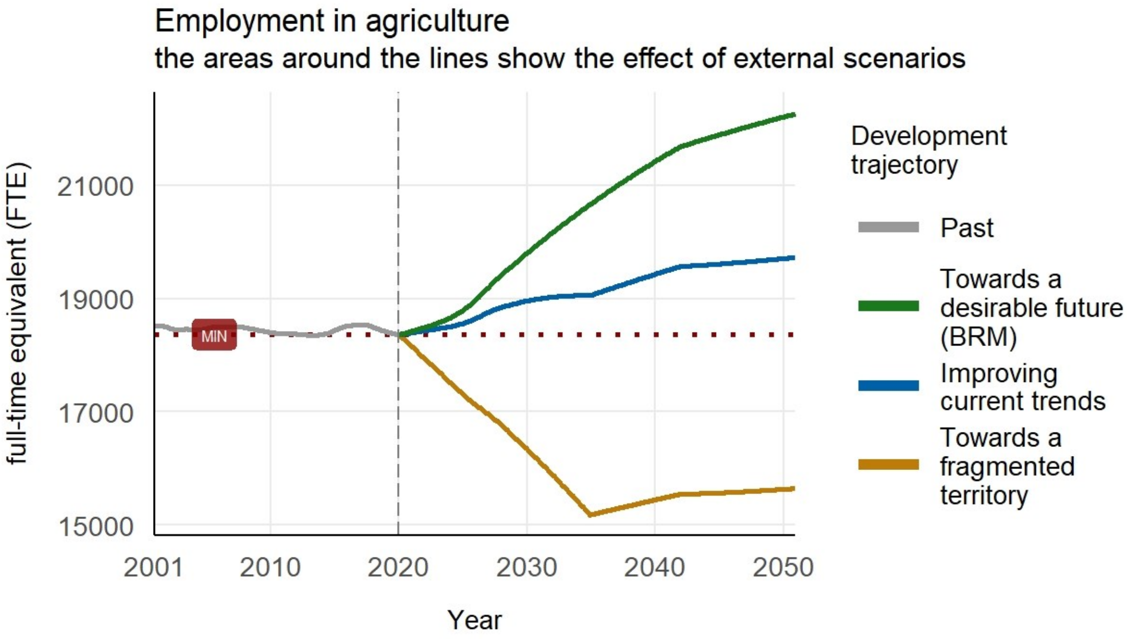
5.10.12. Employment in agriculture



5.10.13. Population

Irrelevant (cf. KPI).

5.10.14. Infrastructure development

Irrelevant (cf. KPI).

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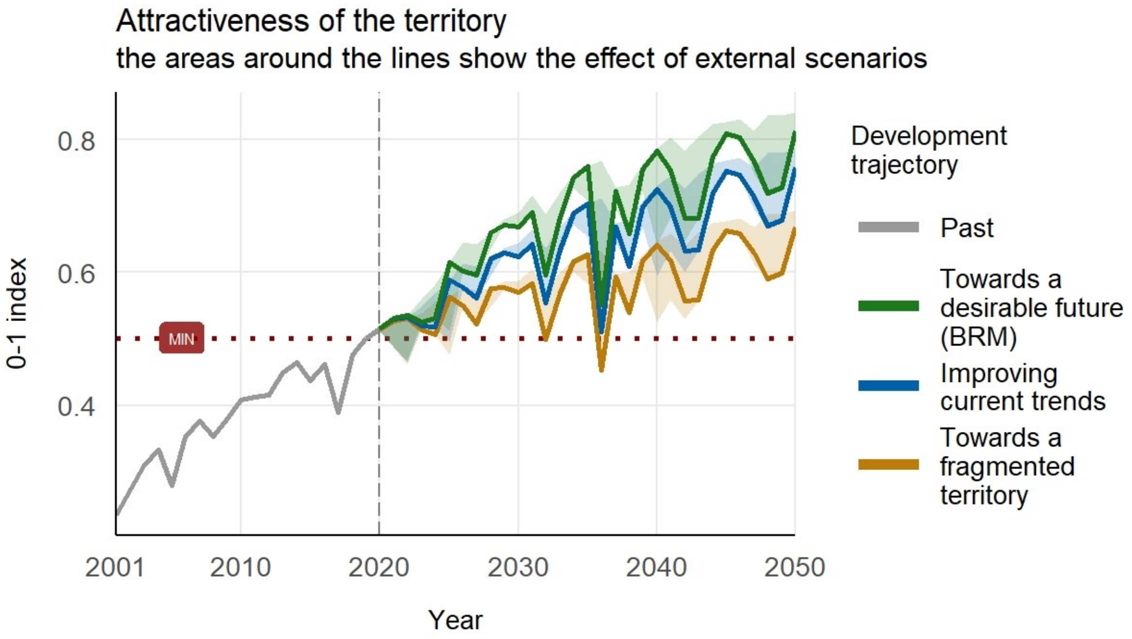
5.10.15. Attractiveness of the territory



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6. ROBUSTNESS ANALYSIS OF POLICY AND BUSINESS ACTIONS DESIGNED FOR THE DANUBE'S MOUTHS – BLACK SEA

6.1. INTRODUCTION

This report is part of a publication covering research investigating the effectiveness of policy and business actions to encourage European coastal areas to develop in a more sustainable direction. Key to this research was the participatory co-creation of System-Dynamics models reflecting stakeholders' views and understandings of the coastal areas under the scope. In these models, different sectors, which were identified by stakeholders as being key to the future development of these regions, are represented, as well as their interactions. The models help to understand the dynamic patterns and interactions within and between these sectors, such as the interactions between inland agricultural practices, coastal fishery actions and the developments within inland and coastal water systems and can be used to assess the impact of actions targeting this dynamic behaviour.

In the previous part of this publication different scenarios were presented (cfr. COASTAL Deliverable 19). These scenarios comprised evolutions external to the modelled coastal systems of which the outcomes are very uncertain. Climate change is an example, but also certain water management and tourism development strategies, for instance, were among the changes put forward by coastal actors as evolutions they have (almost) no grip on. In this part of the report, we showed how and to what extent these external uncertainties can influence the modelled systems' behaviour. This was done based on key performance indicators (KPIs) linked to critical assets of each of the coastal regions.

In this last part of the report, we elaborate on this work and analyse the added value of different sets of policy and business actions under each of the scenarios. We search for an answer to the question of whether it's possible to intervene in the modelled coastal systems in such a way that each of the KPIs remains within a sustainable range under each of the scenarios. Or phrased otherwise, can we point out selected sets of policy actions that allow us to develop towards the sustainable coastal area aspired for by stakeholders no matter the direction and severity of external evolutions? Can we identify this kind of robust set of actions? And if we can't, can we already shed some light on the consequences this may have for the sustainable development of these regions?

The answers to these questions for the Danube's Mouths – Black Sea area can be found throughout this report and are summarized in the last, concluding chapter. Both parts of this report, which are referred to in this introduction, are also compiled into one of the report's issues that are dedicated to this Romanian coastal region. This issue is online accessible via this link (D19_MAL05_Danube's Mouths_Black Sea_06052022.pdf).

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6.2. PRESENTATION OF THE MEASURES FOR THE DANUBE's MOUTHS – BLACK SEA case

In the table below an overview is given of each of the variables and parameters, in case the policy control is a switch in the model, where systemic interventions enter the SD-model for the Danube's Mouths – Black Sea. The first column gives the variables' names. What these variables stand for, can be read in the second column. The third column, finally, gives an overview of the policy and/or business actions that may in reality (indirectly) change the variable's state.

Name entry variable or parameter	Description	Type of real actions reflected in the variable
1. Intensive Aquaculture productivity	The quantity of fish produced per ha per year	Increase the farmed fish quantity due to feed practice, technology and commercial species Decrease the fish farmed quantity due to the transition to the ecological farming
2. Intensive Aquaculture N load	The nitrogen load per ton of fish produced per ha per year	Increase the nitrogen load from aquaculture due to feed practice and farmed species Decrease the nitrogen load due to the transition to the ecological farming and nitrogen management measures
3. Farm to fork target time	The number of years until the Farm to fork strategy target is reached	Decrease the number of years until the targeted share of the traditional agriculture area will be converted to ecological farming system. This can be achieved by support measures for farmers (i.e. proper compensatory payments, subsidies, market policies. etc.) Increase the number of years until targeted share of the traditional agriculture area will be converted to ecological farming system due to improper policy measures for encouraging conversion to ecological farming system;
4. Minimal eco farm yield	The minimal level of the ecofarm production at hectare per year	Increasing the minimal quantity of ecofarm production for one hectare, per year by encouraging investments in innovative technological measures Decrease the minimal quantity of ecofarm production for one hectare, per year, due to improper use of agricultural practices
5. Tourism carrying capacity	The number of tourists that can be present at the same time in the Danube Delta without affecting the environment. In this model, we refer especially to the natural-ecological dimension of carrying capacity.	Increase tourism carrying capacity through sustainable development by successfully applying certain management tools at a regulatory, economic, and organizational level. Decrease tourism carrying capacity due to environmental degradation.
6. Fraction used for marketing	The percent in gross revenue obtained following the tourism activity, used for marketing and advertising, in order to promote the Danube's Delta area.	Increase the fraction of tourism revenues used for different tourism marketing strategies to promote slow tourism programs and to increase the number of awareness public relations campaigns among tourists, national and local tour operators and the local community. Increase the fraction of tourism revenues used for different tourism marketing strategies in order to generate more income among the tourism sector and sustain a fast experience for the area's visitors. Decrease the fraction used from tourism revenues used for different tourism marketing strategies in order to sustain the slow-down tourism experience and to balance the nature conservation of the area with the local development.

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5. Load N per day (tourism)	The nitrogen load per tourist day produced per year	Increase the nitrogen load from tourism due to the frequent visitation that negatively impacts the Danube's Delta area. Decrease the nitrogen load due to the transition to the sustainable tourism and nitrogen management measures

For this research 4 sets of measures were prepared. Each of these sets is made up of all the entry variables and parameters listed in the table above. Yet, under each of these sets of measures these variables and parameters are linked to different changes, hence referring to business and/or policy actions that intervene more or less seriously in the modelled coastal system. In the remaining part of this chapter, an overview is given of the evolution of each of these variables and parameters under these different sets of measures.

Table 1 – Measures (1-4) applied to different variables for robustness analysis – MAL5

	Variable	UM	Range	Measure 1	Measure 2	Measure 3	Measure 4
1	Intensive Aquaculture productivity (fish)	t/ha	3-12	3	4	8	12
				-25%	0%	+100%	+200%
2	Intensive Aquaculture N load (Nitrogen)	t/ha	0.9 – 2.70	0.68	0.90	1.80	2.70
				-25%	0%	+100%	+200%
3	Farm to fork target time	year	8 - 12	8	10	10	12
				-20%	0%	0%	+20%
4	Minimal ecofarm yield	ton crop/ (Year*hectare)	0.9 – 2	2	1	2	0.9
				+100%	0%	+100%	-10%
5	Carrying capacity	tourist days	1060000 – 3000000	1060000	2120000	2292915	3000000
				-50%	0%	+8.16%	+41.5%
6	Fraction used for marketing (tourism)	DML	0.07 – 0.1	0.07	0.08	0.09	0.1
				-12.5%	0%	+12.5%	+12.5%
7	Load N per day (tourism)	ton N/ (Tourist Days*Year)	0.00008 – 0.00013	0.00008	0.0001	0.00012	0.00013
				-20%	0%	+20%	+30%

1. Intensive Aquaculture productivity

Domestic fish in Romania represented less than 20% of the internal consumption (2016-2019) owning the 18th place in the EU with 12 798 t (0.93% of total EU production). The difference arose from imports. Thus, for 2019, it was estimated that the national consumption is over 120 000 t representing approx. 195 million euros. This shortfall in 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 low production were:

- the fishing facilities in the public and private domain of the state and managed by NAFA were not fully granted, and those in the perimeter of the Danube Delta Biosphere Reserve were exploited only 57%.

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- reduced productivity per hectare, obtained in aquaculture farms, very close to the level of fish productivity in 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 – estimated as 80%.

Consequently, we modelled the transition of the normal to intensive aquaculture and more granted areas by the national authorities. We propose four types of actions to change productivity for intensive aquaculture by increasing the fish farming area and using key technologies facilitating intensification including nutritionally complete pelleted feeds, fertilizers, improved animal strains, veterinary medicines, and mechanical aeration and water exchange (Henriksson et al., 2018) (Fig. 1).

Evolution in the first set of measures: The productivity is lower, 3t/ha.

Evolution in the second set of measures: The productivity is unchanged, 4t/ha.

Evolution in the third set of measures: The productivity is double, 8t/ha.

Evolution in the fourth set of measures: The productivity is triple and maximum according to literature, 12t/ha (Figure 1).

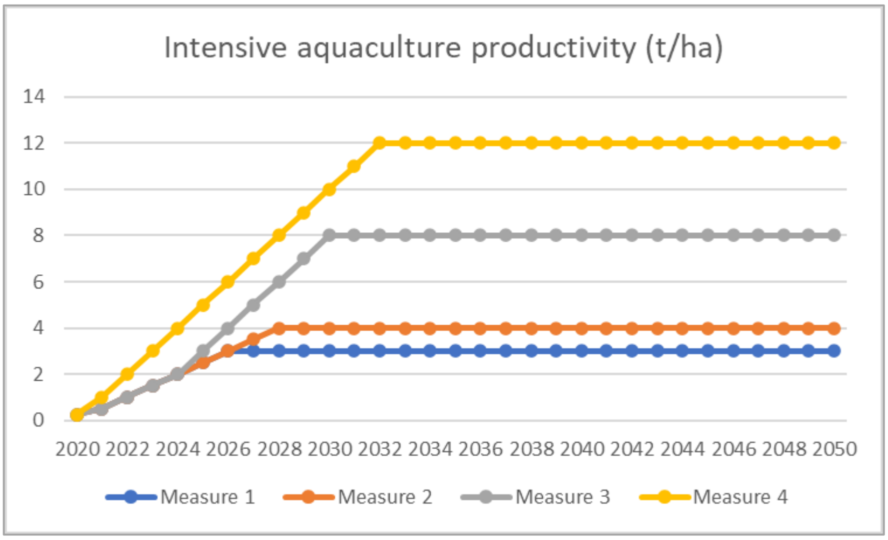

Figure 1 – Intensive aquaculture productivity under different measures

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2. Intensive Aquaculture N load

The primary solution for managing the environmental impacts of aquaculture is the management of feed. Feed and feeding systems can effectively reduce wastes resulting from the fish feed through proper management of the inputs into the culture systems. d'Orbcastel et al. (2009) reported that a reduction in feed conversion ratio (FCR) by 30% in a fish farm will bring about a 20% reduction in environmental impact from the fish culture system. To reduce waste from aquaculture, it is important to know the nutritional requirements of the species (based on age, health, and other conditions); fish biomass and size uniformity; feed quality and proper feed management and application to prevent waste (Dauda et al, 2019).

The main impact of aquaculture derived from the emissions into the surface waters from the regular feeding of the fish population from traditional farms unless additional purification measures are taken, insufficiently treated water discharge from intensive and super-intensive farms which, no matter how good the recirculation technology, also need a supply of water from outside the system and therefore discharges, wastewater resulting from processing activities discharged into effluents without passing through a treatment system, intensive use of old, unverified engines with oil or fuel losses during fishing and transfer of catch to premium centres – sales, accidental pollution in the area of berths and docks where fishing vessels moor, improper operation of existing treatment plants at fish farms, catch processing and processing centres, improper management of sludge from these wastewater treatment plants (by-products of the wastewater treatment process)(Ministerul Mediului, 2021)(Fig.2).

Evolution in the first set of measures: The nitrogen load is gradually lowered due to the lower productivity, 0,68t/ha.

Evolution in the second set of measures: The nitrogen load is unchanged, 0.9t/ha.

Evolution in the third set of measures: The nitrogen load is gradually increasing to double, 1.8t/ha.

Evolution in the fourth set of measures: The nitrogen load is gradually increasing to triple, 2.7t/ha (Figure 2).

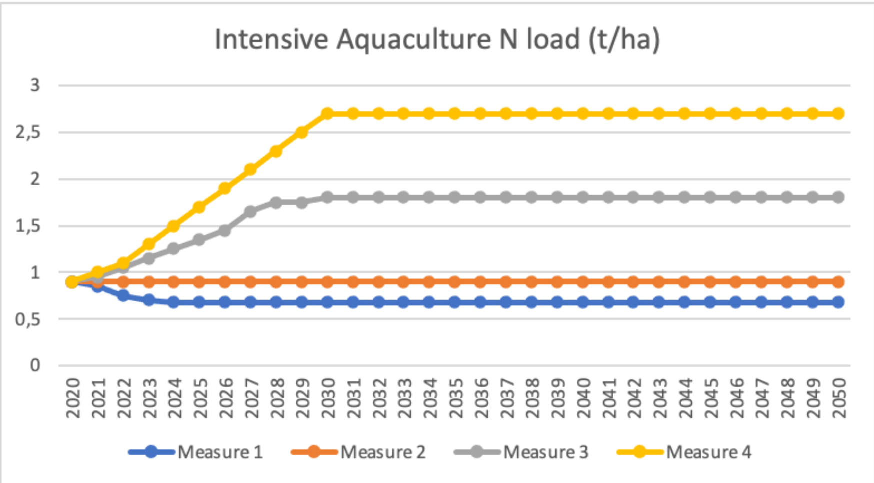

Figure 2 – Intensive aquaculture N (nitrogen) load under different measures

The data corresponding to these entry variables can be found here:
https://zenodo.org/record/6984907#.Y01WG3ZByUk

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3. Farm to fork target time

This parameter was introduced in early model design (year 2020) and is currently set to a value of 10 years, to be in line with the EU Farm to Fork strategy, which specifies targets to be reached for conversion to systems of ecological agriculture until the year 2030. The variability of the parameter has in mind the encouragement of the transition to this system of agriculture through the application of appropriate public policies.
Of course, the pessimistic option (measure 4) of not fulfilling the time target established by the European strategy was also considered.
Given the fact that the Farm to Fork deadline is approaching fast (already 8 years' time) and that extensive impact analysis is not yet available, stakeholders pointed out that solution-oriented policies must be built rapidly, based on the existing data, and having technological innovation for increasing yields as their foundation.
Therefore, the feasibility of reaching this target (in the specific timeline and the specified organic farming share) will depend on the support provided to innovative practices, techniques and products brought to light. However, sufficient time must be given for viable alternatives from innovation to become effectively available to primary producers.

Evolution in the first set of measures: The Farm to fork target decreased by 20%, in 8 years.

Evolution in the second set of measures: The Farm to fork target remains constant, for 10 years.

Evolution in the third set of measures: The Farm to fork target remains constant, for 10 years.

Evolution in the fourth set of measures: The Farm to fork target increased by 20%, in 12 years (Figure 3).

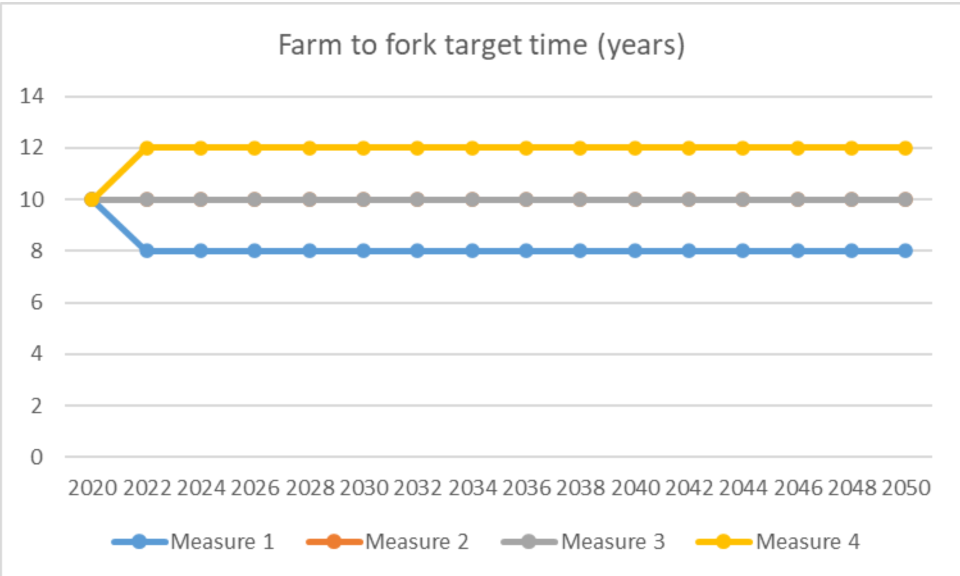

Figure 3 – Farm to fork target time under different measures

The data corresponding to these entry variables can be found here: (to be inserted: link to the data repository). https://zenodo.org/record/6984907#.Y01WG3ZByUk

4. Minimal eco farm yield

The agriculture sub model is designed and calculated considering the hypothetical situation of cultivating a single agricultural crop on the entire area of the study region, namely the wheat crop.

Both for economic reasons and for environmental protection requirements, a correct management and use of fertilizers is required. Assessment of the need for organic and mineral fertilizers with NPK is based on the calculation of economically optimal doses (DOE). This assessment is performed based on formula that takes into consideration various factors, such as:

- the specific consumption of crops.
- the expected harvest size.
- the condition of providing nutrients to the soil, established by its periodic agrochemical analysis.
- the inputs of usable nutrients from organic fertilizers, from the preceding crops, and the autumn crops and the input of mineral nitrogen from the soil profile (Nmin).
- the economic situation in which the plant production activity takes place, given by the ratio between the selling price of the product and the procurement cost of the fertilizer.

Once again, it is to be highlighted that reaching EU goals of transition to greener economy is only achievable with intensive policy support towards innovation to be able to counteract the current predicted production losses potentially resulting with current production technologies. For this reason, we chose to model the variability of “Minimal eco farm yield” under the four chosen measures.

It should be specified that the current value of “Minimal ecofarm yield” considers the pessimistic scenario, indicating a minimal possible quantity of agricultural production for both organic and traditional agriculture.
By studying the effects of the variability of this parameter, the aim is to encourage the policy driven measures that enable ways to contribute to change in a practical and realistic manner such as the use of: New Breeding Techniques to improve farming resilience naturally through better genetic material; appropriate crop varieties; agricultural practices (crop rotation, no tillage, carbon farming); low risk substances – to replace means to combat pest and disease while losing synthetic molecules; that help to increase production per hectare.
It was already demonstrated in practical experience reported in scientific literature that, having few means available to control the limiting factors of production, in ecological agriculture, along with the choice of resistant varieties, it is also necessary to strictly observe the specific agrotechnical rules.
Farmers must be aware that the use of fertilizers to achieve profitable production must be based on realistic forecasts, which consider the local pedoclimatic conditions, the productive potential of the crops and the technological level of the agricultural unit. A special emphasis, especially in areas with high vulnerability to water pollution with nitrates of agricultural origin, is currently placed on the management of organic and mineral fertilizers with nitrogen, considering the particularly complex behavior of this nutrient in the soil and the ease with which it can be lost in the form of nitrates by entrainment with infiltration waters and surface runoff
Of course, the fertilizers should be used rationally, according to annual fertilization plans based either on national standards set by regulatory framework or a proper soil analysis.

Evolution in the first set of measures: The minimal eco farm yield is double, 2 ton crop/(Year*hectare).

Evolution in the second set of measures: The minimal eco farm yield remains constant, 1 ton crop/(Year*hectare).

Evolution in the third set of measures: The minimal eco farm yield is double, 2 ton crop/(Year*hectare).

Evolution in the fourth set of measures: The minimal eco farm yield decreased by 10%, 0.9 ton crop/(Year*hectare) (Figure 4).

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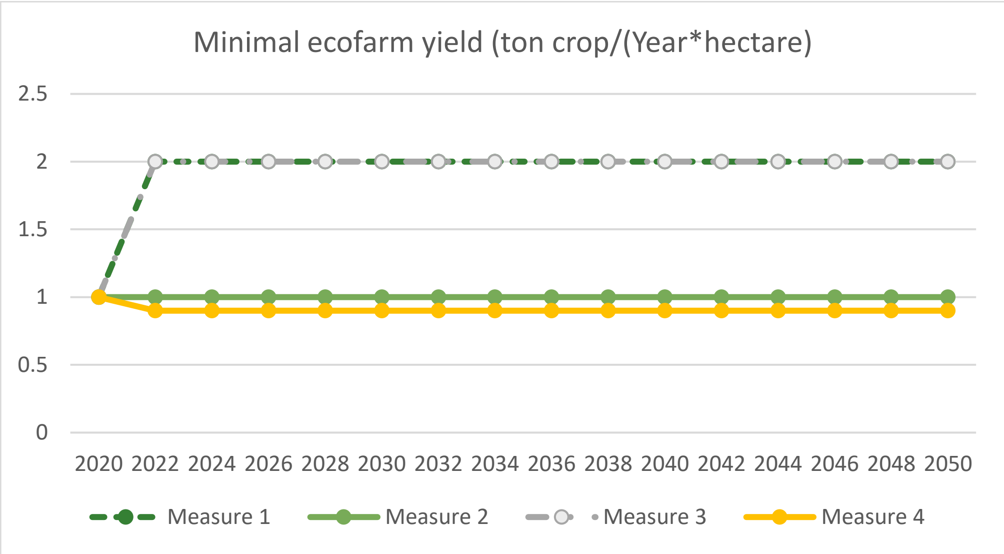

Figure 4 – Minimal ecofarm yield under different measures

The data corresponding to these entry variables can be found here: https://zenodo.org/record/6984907#.Y01WG3ZByUk

5. Tourism carrying capacity

Regarding the tourism model, one of the main objectives is to determine how far the rural tourism of the Danube Delta area can be developed without damaging the balance with the environment. Setting the value of the" tourism carrying capacity" variable plays an important role in this goal, to determine the critical point which concerns tourism development. Middleton and Chamberlain (1997) define Tourism Carrying Capacity as „... the level of human activity an area can accommodate without the area deteriorating, the resident community being adversely affected or the quality of visitors' experience declining". The World Tourism Organization defines Tourism Carrying Capacity as „the maximum number of people that may visit a tourist destination at the same time, without causing unacceptable and irreversible destruction of the physical, *economic*, socio-cultural *environment* or a decrease in the quality of visitors' satisfaction". In our model, we are focusing on the ecological and economic dimensions of carrying capacity.

According to the National Statistical Institute data, for Tulcea county, in 2021, the accommodation capacity reached 1 048 722 tourist days, and the number of tourist days was 280 935, which represents 27% of total accommodation capacity. Most of the tourists who choose Danube's Delta as a holiday destination are Romanian, the foreign tourists represent 4.11% of the total number, compared to the data registered at the national level, with 9.96% of foreign tourists in total number, both national and foreign visitors.

According to the specialized literature, and following the meetings held with the stakeholders in the field of tourism, the following conclusions can be drawn, succinctly, regarding the tourism activity in Danube's Delta:

- Tourism development should be focused on environmental conservation and good practices;

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- The budget for applying different marketing strategies should be allocated in eco-tourism direction, in order to promote Danube's Delta as a touristic destination;
- The local green economy based on sustainable consumption and production by valorizing the locally available resources, such as land, fish stock workforce, and natural & cultural heritage should be developed.

Following the previous mentions, we modelled the transition from conventional tourism to slower tourism, in Danube's Delta, using the tourism carrying capacity as a variable. We propose four types of actions to adjust carrying capacity to promote a slow-down tourism experience, by respecting all the conservation zones (approx. 50 900 ha). These types of actions could bring balance between nature conservation and local development, increase visitor's satisfaction and increase the competitiveness of Danube's Delta area through sustainable development. (Association of Ecotourism in Romania Report, 2014).

Evolution in the first set of measures: Promoting the slow-down experience of customers in the tourism sector, to balance nature conservation with the local area development. According to this measure, the carrying capacity is lower, but the tourists will stay longer. Carrying capacity is set at 1,060,000 tourist days.

Evolution in the second set of measures: The carrying capacity is unchanged and remains at 2,120,000 tourist days, taking into account taking into consideration that the tourism sector development in Tulcea county area continues in the same manner as usual.

Evolution in the third set of measures: The carrying capacity is set depending on the number of accommodation units with the ecological profile. Through specific development strategies, the extension of the duration of tourist stay will be encouraged. The carrying capacity is set at 2,292,915 tourist days.

Evolution in the fourth set of measures: The carrying capacity is higher, due to promotion strategies for a fast experience in the tourism sector. According to this measure, the carrying capacity is higher, but the tourists will stay less in Danube's Delta. Carrying capacity is set at 3,000,000 tourist days (Figure 5).

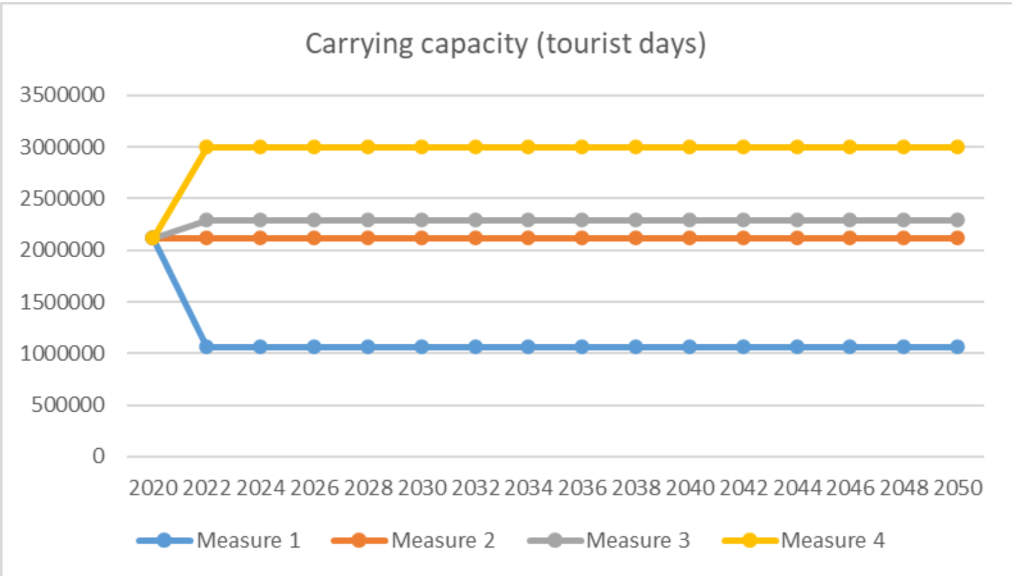

Figure 5 – Carrying capacity under different measures

The data corresponding to these entry variables can be found here: https://zenodo.org/record/6984907#.Y01WG3ZByUk

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6. Fraction of revenues used for marketing (tourism)

"Tourism marketing refers to the organized, combined efforts of the national tourist bodies and/or the businesses in the tourism sector of an international, national or local area to achieve growth in tourism by maximizing the satisfaction of tourists. In doing so, the tourist bodies and businesses expect to receive profits." (Milano S., 2019).

Regarding the fraction of tourism revenues used for marketing, according to The U.S. Small Business Administration, it is recommended to spend 7 to 8 % of the gross revenues.

According to the National Strategy for Ecoturism Development (2019), in Danube's Delta area territory ecotourism programs and activities are often promoted, such as bird watching or canoeing, boat trips, discovering traditional occupations and architecture, nature observation programs, and gastronomic tours. According to this strategy, ecotourism programs in Romania are offered for sale through local tour operators, who usually collaborate with tour operators from abroad.

In 2021, a budget of 6.7 mil lei (the equivalent of 1.4 mil euros) was allocated for the Marketing and Promotion Program (implemented by The Ministry of Economy, Entrepreneurship and Tourism). According to a statistical source, this value represents 3% of tourism revenues, at the national level.

Following the previous mentions, we modelled the transition from conventional tourism to a 'greener' tourism, in Danube's Delta, using the fraction of revenues used for marketing as a parameter.

Evolution in the first set of measures: The fraction of revenues used for marketing decreased to 7%. For this measure, several changes in the tourism services strategies are needed, and the tourism in Danube's Delta will be promoted to a niche public segment, characterized by a higher level of education and income and with increased awareness about the importance of balance between the nature and local development and how should they involve in this matter.

Evolution in the second set of measures: The fraction of revenues used for marketing is unchanged and remains at 8%. Taking into account the literature overview considerations, it is recommended to spend 7 to 8% of the gross revenue on marketing activities and advertising. Within this measure, all forms of tourism (leisure, ecological, rural, gastronomic, cultural and other forms) in the Danube Delta area are promoted, a situation that is more appropriate for the current situation.

Evolution in the third set of measures: The fraction of revenues used for increasing marketing activities to 9%, due to ecological tourism intensive promotion in the Danube's Delta and to increase the number of foreign visitors in the area.

Evolution in the fourth set of measures: The fraction of revenues used for increasing marketing activities to 10%, due to slow down tourism experience intensive promotion in the Danube's Delta. Also, the marketing budget will be used for public relations campaigns, to increase the local community and effective or potential tourists' awareness about the importance of their behaviour as consumers or as good civic education example (Figure 6).

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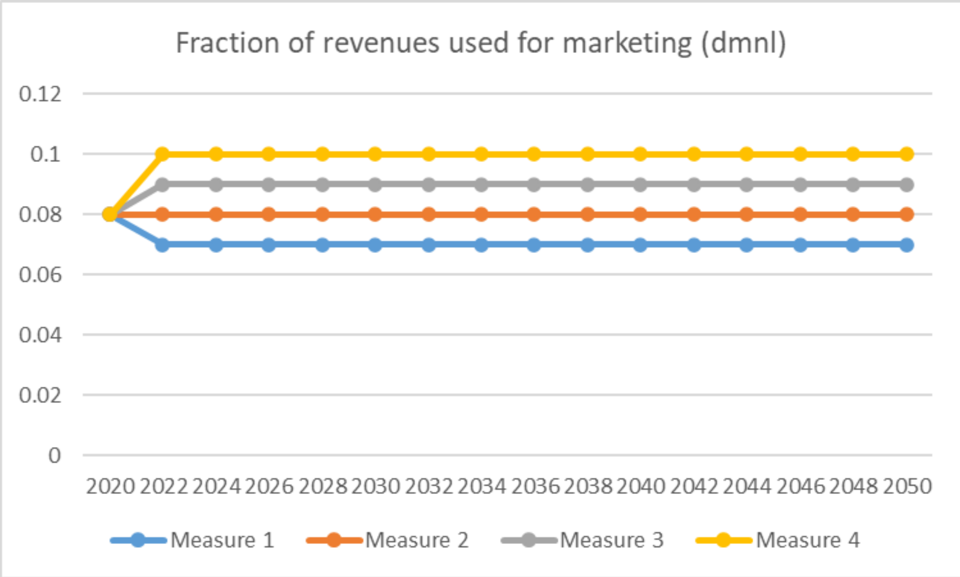

Figure 6 – Fraction of revenues used for marketing (%) under different measures

The data corresponding to these entry variables can be found here: https://zenodo.org/record/6984907#.Y01WG3ZByUk

7. Load N per day (tourism)

According to the literature overview, tourism has also an important influence on water quality, in addition to agriculture and aquaculture. In this model, we observed that water quality also influences the efficiency of the tourism industry in Danube's Delta. An increased number of tourists generates a negative impact on the area's attractiveness, which affects all involved parties' wellness: economic agents, local entrepreneurs, visitors, inhabitants and the Danube's Delta ecosystem. This was the first identified and discussed causal loop with invited stakeholders at the meetings held within the project.

In our case, water quality is the main variable that leads to all the important economic activities that characterized Danube's Delta development: aquaculture, agriculture and tourism.

The tourism N load is derived from the daily nitrogen load per person, reported on the annual tourist days.

One of the main threats to tourism activities development is the inclination to overconsumption. Tourism consequently produces a substantial amount of waste and pollution. In some places, tourists produce up to twice as much waste as residents, because they experience fast tourism, they don't stay in Danube's Delta for a long period. At present, the average length of their stay is 2.2 days/tourist.

Following the previous mentions, we modelled the transition from conventional tourism to a 'greener' tourism, in Danube's Delta, using the tourism N load as a modelled variable.

Evolution in the first set of measures: The nitrogen load is gradually lowered due to the lower carrying capacity, 0,00008 t/tourist day/year.

Evolution in the second set of measures: The nitrogen load is unchanged, 0.0001 t/ tourist day/year.

Evolution in the third set of measures: The nitrogen load is gradually increased by 20%, 0.0001 t/ tourist day/year.

Evolution in the fourth set of measures: The nitrogen load is gradually increased by 40%, 0.00013 t/ tourist day/year (Figure 7).

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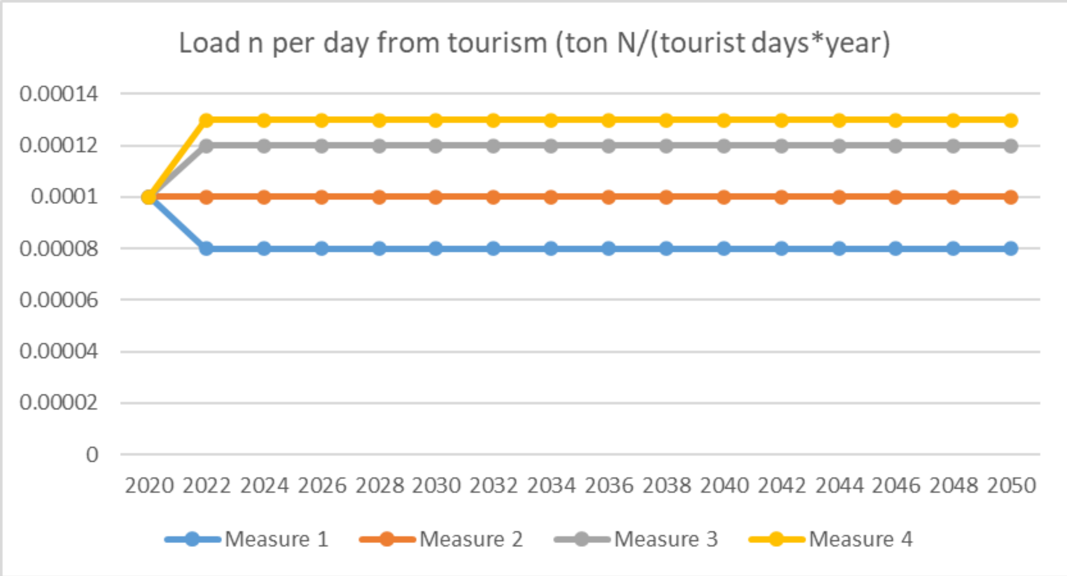

Figure 7 – Nitrogen (N) load per day (tourism) under different measures

The data corresponding to these entry variables can be found here: https://zenodo.org/record/6984907#.Y01WG3ZByUk

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6.3. ASSESSMENT OF THE DYNAMIC PATTERNS OF KEY POLICY INDICATORS

This chapter discusses the impact that each of the sets of measures presented in the previous chapter has on the modelled system under different scenarios for the Danube delta. To make these results easily comparable with the outcomes presented earlier on, that is in the chapter investigating the impact of external societal evolutions named 'Comparison of the dynamic patterns of key model variables, the same logic is followed here. This means that the same KPIs are used here to structure the analyses. Also the model runs were done making use of the same scenarios. An overview is given here of the main insights coming out of our analyses.

From the 12 KPI discussed in D19, Fish farming area and fish consumption are not subject to change under measures regarding the changes in productivity and nitrogen loads.

KPI 1: Intensive fish farming area

What is considered sustainable and robust in the Danube Mouths – Black Sea region?

The European Green Deal and the Farm to Fork Strategy underline the potential of farmed seafood as a source of protein for food and feed with a low-carbon footprint which has an important role to play in helping to build a sustainable food system. The Farm to Fork Strategy also sets specific targets for aquaculture, in particular the reduction of sales of antimicrobials and a significant increase in organic aquaculture [1]. In our case, this approach requires at least 2 major measures - increasing the area for intensive aquaculture by transitioning from normal but also by allocating areas for aquaculture and intensifying it by using modern food and technologies to contribute to the proposed targets. The implementation of the measures involves actions such as space allocation planning - land and water, coordinated with the marine area of the Danube Delta. Coordinated spatial planning should encompass freshwater as well as land-based aquaculture (Recirculating Aquaculture Systems, RAS) and marine aquaculture, including transitional (brackish) waters, in front of the Danube's Mouths among other activities, while preserving the aquatic ecosystem.

According to the previous deliverable, the moderate intensive fish farming (4 t/ha) area depends on aquaculture intensification rate and development according to different scenarios. Scenarios 1 and 2 show the same pattern with a steady increase reaching in 2050, 11 % and 66 % of the total surface (NAFA,2021). Scenarios 3 and 4 have almost the same endpoint, representing 87% and 97% with a different rate of increase, which is very sharp for scenario 4 when the maximum is reached in the first 5 years. Consequently, scenario 2 is considered the most sustainable and robust for the sustainable development of the area (Figure 8).

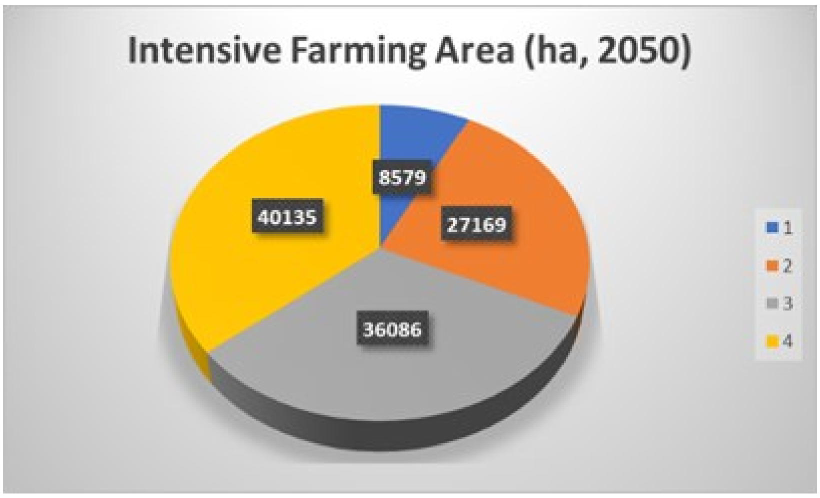

Figure 8 – System Dynamics model's 4 scenarios - Intensive Farming Area – 2050, Danube's Mouths – Black Sea

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As the farming area is limited and the measures are not applied to it, no changes were observed for all measures and scenarios. According to deliverable 19, the moderate intensive fish farming (4 t/ha) (measure 2) area depends on aquaculture intensification rate and development according to SSPs. Scenarios 1 and 2 show the same pattern with a steady increase reaching in 2050, 11 % and 66 % of the total surface (NAFA,2021). Scenarios 3 and 4 have almost the same endpoint, representing 87% and 97% with a different rate of increase, which is very sharp for scenario 4 when the maximum is reached in the first 5 years.

KPI 2: Total aquaculture production

What is considered sustainable and robust in the Danube Mouths – Black Sea region?

The aquaculture sector is still far from reaching its full potential in terms of growth and meeting the increasing demand for more sustainable seafood. The EU imports over 70% of the seafood that it consumes [1]. The potential for the development of the fisheries sector in Romania (over 100 000 t) is seen as a complement to domestic production over consumption. In this case, the quantity of fish obtained at different productivities (Table 1) differs significantly depending on the scenario even for the same measure.

For freshwater aquaculture predators (e.g., birds in the Danube Delta) and drought also pose a challenge in terms of profitability. Producers and market organisations, as well as control and combatting fraud, are also important tools to ensure the resilience and competitiveness of the EU aquaculture sector. Finally, the sector can also be made more competitive by further diversifying EU aquaculture production and adding value to aquaculture products.

What is the impact of the first set of measures on this KPI?

Total aquaculture production is growing the fastest and is peaking in scenario 3 in which highly unequal investments in human capital, combined with increasing disparities in economic opportunity and political power, led to increasing inequalities and stratification across the country. Therefore, considering scenario 2 as the most envisaged and sustainable for the studied area, this measure implies a low production that would not help enough to the economic development of the area (Figure 9).

What is the impact of the second set of measures on this KPI?

The second measure leads to a steady increase in production in all scenarios. Their application involves the development of the supply chain in scenario 2 and the diversification of fish products by developing the processing industry in the other two scenarios (3 and 4) in which production exceeds approximately 50% of the estimated need (Figure 9).

What is the impact of the third set of measures on this KPI?

Doubling productivity compared to the previous measure returns values by about 10% more than the estimated need even in scenario 1. This result contrasts with the conditions in scenario 1 in which fish consumption is lower, and the industrialization of the area as well. In scenario 2, the closest to the vision of stakeholders and governors for the Danube Delta, production is 50% more than the estimated need. Consequently, the application of this measure involves investments in “green” and “blue” technology, processing, and the supply chain (Figure 9).

What is the impact of the fourth set of measures on this KPI?

Measure 4 involves achieving maximum productivity. In this case, the intensification is also at its maximum and is considered an inapplicable measure. However, although in scenario 1 the production is at acceptable levels, the other measures that would imply its application do not match the description of scenario 1 (Figure 9).

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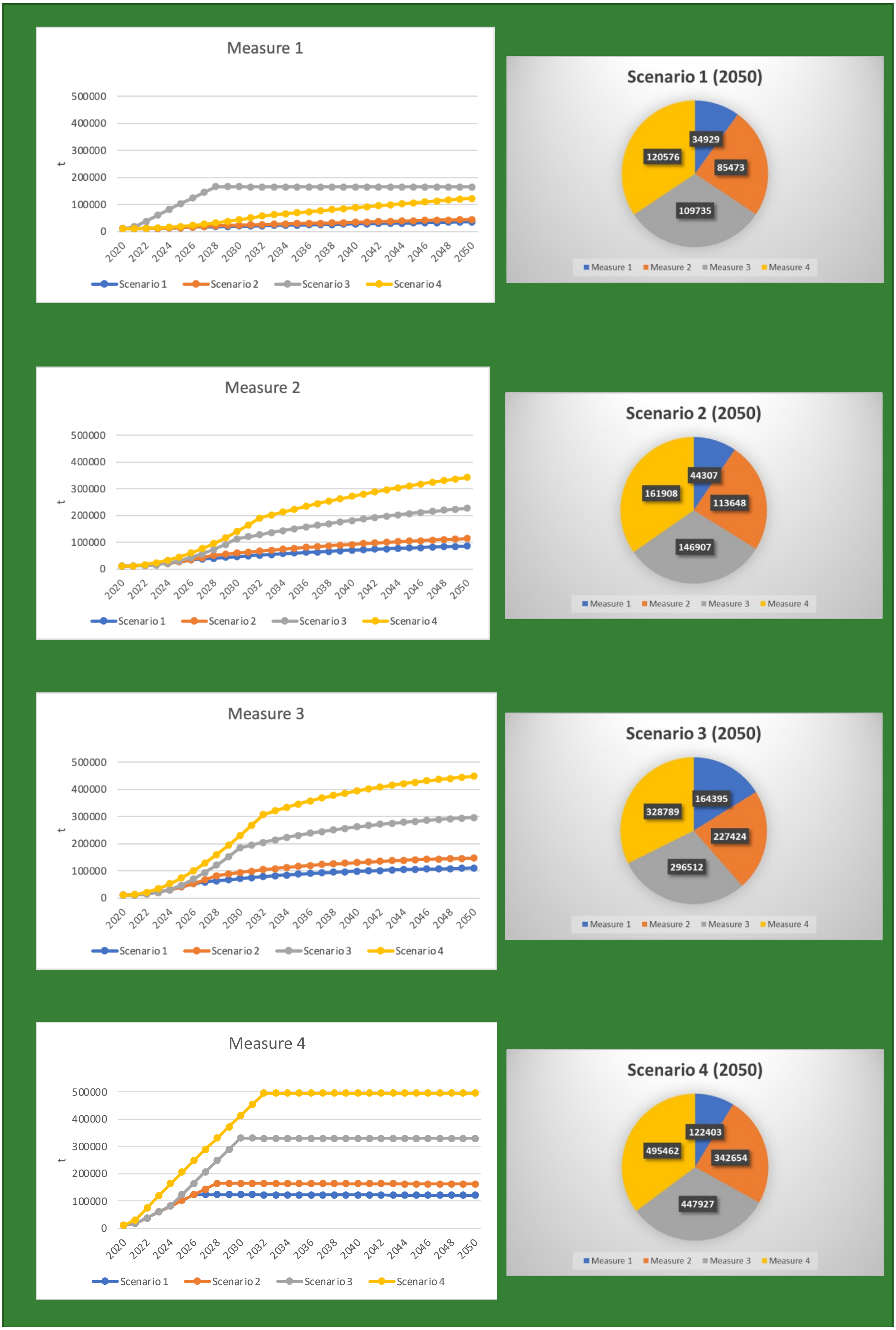

Figure 9 – Total aquaculture production under different measures and scenarios (2050) – MAL5 – Danube 's Mouths – Black Sea (Danube Delta)

Given the impact of climate and ecological changes, economic growth and other external uncertainties, to what degree can dedicated interventions bring this KPI to a sustainable and robust state?

The overlap of the different measures regarding the productivity and implicitly the production from aquaculture with the scenarios designed for the development of the area, including RCP1.5, highlighted very different results from measure to measure and for each scenario (Figure 9). As we pointed out in deliverable 19, scenario 2 was foreseen by the stakeholders and, therefore, we consider it the most sustainable. Regarding the potential of aquaculture, both the development of marine areas and farms on land recirculating aquaculture systems (RAS) and the capitalization of chlorophyll from micro and macroalgae were mentioned. Thus, strengthening the productivity and profitability of aquaculture based on environmental performance (increasing the intensive aquaculture productivity and monitoring the impact of the nitrogen load from aquaculture) are considered essential and diverse types of actions were mentioned in the elaborated business road map (e.g. Extending the ecological certification of fish farmed and other products from fish in conjunction with the creation of a local brand of traditional products from the Danube Delta).

KPI 3: Fish consumption

What is considered sustainable and robust in the Danube Mouths – Black Sea region?

Although currently there is an internal consumption of over 100,000 t the scenarios have considered the decrease of the population through migration or natural ways none reaches a consumption of over 100,000 t (Figure 10).

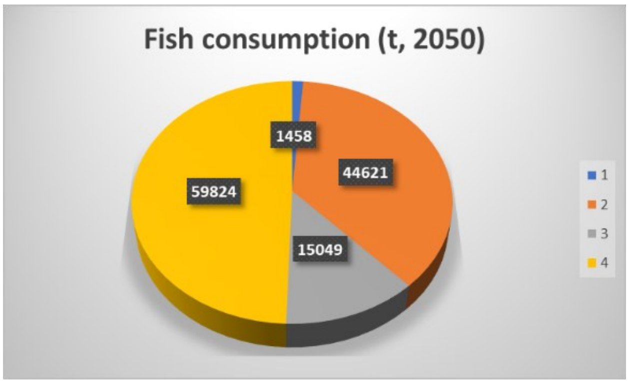

Figure 10 – System Dynamics model's 4 scenarios – Fish consumption – 2050, Danube's Mouths – Black Sea

What is the impact of the measures on this KPI?

There is no impact of measures on this KPI.

Given the impact of climate and ecological changes, economic growth and other external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

Although there is no direct impact on fish consumption, increasing productivity and diversifying production and processing as water quality improves are basic preconditions for increasing fish consumption within sustainable limits.

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KPI 4: Impact of nitrogen load from aquaculture

Aquaculture, like other human activities, should operate within ecological limits to minimize environmental degradation, as the environment provides 'ecosystem services' vital to human welfare and society's ultimate survival as well as to that of farmed fish (Bosma & Verdegem, 2011; Luo et al., 2018). The intensive management of aquaculture is an essential step in the comprehensive management, improvement of production efficiency and promotion of advanced production technology. Thus, improved aquaculture practices for sustainable intensification such as modern polyculture systems, recirculating aquaculture systems, and integrated multi-trophic aquaculture are likely to become increasingly important (Luo et al., 2018). Promising advanced production technologies, such as strengthening biological nitrogen fixation and denitrification processes, modern biological breeding technology, feed balanced nutritional technology, water quality treatment and regulation technology, and disease prevention and control technology, are also effective ways to contribute to the sustainability of modern aquaculture (Luo et al., 2018). Furthermore, apart from aquaculture activities, other human social and economic activities, such as diet habits also result in changes in nutrient cycling (especially nitrogen). Therefore, a reasonable and balanced dietary structure is encouraged (Luo et al., 2018).

What is considered sustainable and robust in the Danube Mouths – Black Sea region?

The indicator is calculated as the "grey water" footprint (Hoekstra et al.,2011) of aquaculture which is an indicator of the degree of freshwater pollution that can be associated with fish farming (Hoekstra et al.,2011). It is calculated as the total aquaculture N load divided by the Danube flow and maximum nitrogen acceptable concentration from nowadays' national legislation (Ord.161/2006). Based on the formula, the indicator must be sub unitary for compliance with the legislation in force, a situation considered sustainable for the Danube Delta. It starts from the current state (2020) which, according to the model, indicates estimates of values over 3 times higher than the maximum allowable value.

What is the impact of the first set of measures on this KPI?

For measure 1, the greatest impact is found in scenarios 3 and 4. Although this measure involves a lower production than the one considered sustainable, the impact of nitrogen input from aquaculture is manifested in all cases, with the minimum amplitude in scenario 1.

What is the impact of the second set of measures on this KPI?

Scenario 2 and measure 2 were considered in terms of fish production as the most sustainable solution. However, nitrogen intake exceeds 5 times the maximum allowable values, so removal measures are essential. The greatest impact is found in scenarios 3 and 4, also.

What is the impact of the third set of measures on this KPI?

Measure 3 produces a significant impact in all scenarios, but the lowest in scenario 2. Therefore, if such big productivity is desired, the possible scenario to be followed should be a "modified" scenario 2 with an increased concern about the environmental policies focused on reducing pollution, with a rapid impact to preserve the Danube Delta's ecosystems.

What is the impact of the fourth set of measures on this KPI?

Measure 4 is the most unsatisfactory in terms of degrading the water quality and it is not recommended (Figure 11).

Given the impact of climate and ecological changes, economic growth and other external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

With more than 800,000 km^2 or 10% of Continental Europe, the Danube River Basin extends into the territories of 19 countries. It is considered the most international river basin in the World with 14 countries that have more than 2000 km^2 (ICPDR, 2022). Nutrients are an important issue throughout the Danube basin (ICPDR,

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2015). In the study area, although in most cases the Danube is mentioned as the main source of nutrients as a river carrier, rarely is mentioned the intake of nutrients from human activities in the area, is considered insignificant. This does not mean that development does not have to consider the intake of nutrients (nitrogen, in this case) from aquaculture, agriculture or tourism because it brings the Danube from its basin anyway.

The impact of aquaculture intensification in the Danube Delta exists in all scenarios and all measures from 3.35 to 71.95 meaning that for a constant average flow of the Danube the increases in nitrogen concentrations in intensive aquaculture are 3 to about 72 higher (Figure 6). Thus, the intensification of aquaculture cannot take place without measures to reduce nitrogen emissions of different magnitude according to the scenario and the chosen measure.

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Figure 11 – Impact of nitrogen (N) from aquaculture under different measures and scenarios (2050) – MAL5 – Danube 's Mouths – Black Sea (Danube Delta)

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KPI 5: Annual tourist days

What is considered sustainable and robust in the Danube Mouths – Black Sea region?

Danube's Delta is currently one of the most visited tourist destinations in Romania, especially for foreign tourists. At the global level, due to the Covid-19 pandemic, the tourism industry suffered significant losses, but Danube's Delta area was a particular case. Even if between 2021 and 2022 the number of foreign tourists who arrived in Danube's Delta considerably decreased, this was covered by the domestic tourists, which registered a constant increase. This situation could be explained by Danube's Delta characteristics. The Danube's Delta hosts extraordinary biodiversity and provides important environmental services.

During the COASTAL project, we presented multiple specific features of this region and reasons why the Danube Delta is so valuable and important at the national level, but also, at the global level.

Decision makers' strategies for the sustainable development of the area are multiple, with different specific objectives, but finally, they all reach a common destination: how far can be Danube's Delta developed without damaging the environment? This is a question also for the annual tourists' days. How many tourists could come to Danube's Delta to ensure the balance between the local development and nature?

There is not necessarily a quantitively answer to this question, we couldn't say a certain number of annual tourist days that keeps Danube's Delta environment safe.

Ensure Danube's Delta sustainability implies not a certain number of annual tourist days, but a certain behaviour of the tourists staying in Danube's Delta. It is important to keep and increase the awareness regarding acceptable behaviour according to the destinations' local characteristics. This is important for tourists, the local community, local tour operators and policymakers.

Currently, is preferred a slow-down tourist experience implementation, which implies a longer duration of tourists' stay and a lower resource consumption rate.

Figure 12 – System Dynamics model's 4 scenarios – Annual Tourist Days – 2050, Danube's Mouths – Black Sea

What is the impact of the first set of measures on this KPI?

This measure has an impact in all the four scenarios and the greatest impact is found in scenarios 3 and 4. Although this measure involves a lower carrying capacity, in this scenario the duration of tourist stay is longer, due to the main purpose, to facilitate the transition between the current situation regarding the tourism sector and a slow touristic experience (Figure 12).

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What is the impact of the second set of measures on this KPI?

For the second measure, the carrying capacity is set at the current values, according to the National Statistics database, considering an average duration of tourist stay of 2.2 days in Danube's Delta, which corresponds with a fast tourism experience. However, applying this measure, the highest level of this KPI is reached in Scenario 4 (Figure 13).

What is the impact of the third set of measures on this KPI?

According to this measure, carrying capacity and the fraction of tourism revenues used for tourism undergoes minor modifications from the previous measure, so the impact on this KPI is not very different from the previous situation. However, measure 3 has a higher impact in Scenario 4 (Figure 13).

What is the impact of the fourth set of measures on this KPI?

Measure 4 operates with the highest level of the fraction of tourism revenues used for marketing parameters and carrying capacity. This is the main consideration that boosts the number increases significantly the range of annual tourist days but affects the environment of Danube's Delta and water quality (Figure 13).

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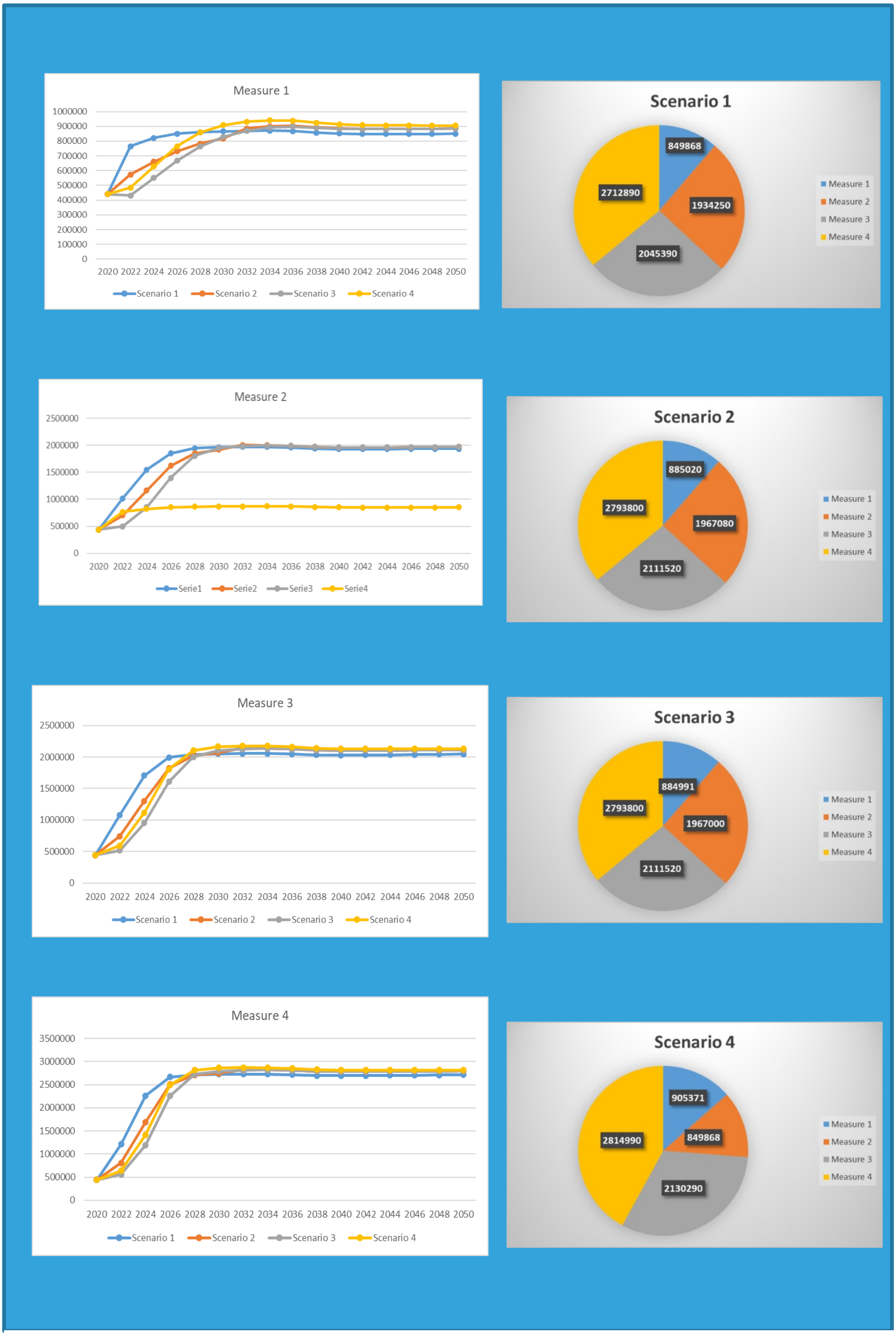

Figure 13 – Annual tourist days under different measures and scenarios (2050) – MAL5 – Danube's Mouths – Black Sea (Danube Delta)

Given the impact of climate and ecological changes, economic growth and other external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

As in the case of the other economic activities practiced in the Danube's Delta (agriculture, aquaculture), it is desired to find satisfactory solutions taking into account the economic development of these market segments but without harming the environment. A higher number of annual tourist days contributes to the economic development of the area, but this does not ensure the sustainable development of the area. A sudden increase in this KPI value could negatively impact the area's attractiveness and improper use of the marketing budget. Considering this, the marketing budget allocation could be straightened to increase awareness of the public through campaigns, addressed to a certain target audience, such as the local community, foreign and national tourists, opinion leaders, and local economic agents.

KPI 6: Tourism revenues

What is considered sustainable and robust in the Danube Mouths – Black Sea region?

According to recent statistical data, the share of tourism activities in the national GDP does not exceed 5%. In Romania, the share of this sector in GDP decreased from 6% to 3% in 2020, because of the Covid-19 pandemic. At the global level, the average tourism share in GDP was over 10% in 2019 but decreased to 5.5% last year (World Travel Tourism & Council data, 2020) for the same reason.

During the COASTAL project, we tried to show why the tourism industry should be developed sustainably, especially if we refer to vulnerable touristic areas, such as Danube's Delta. The changing trends registered in consumer behaviour, both in terms of tourism services and agri-food products, the Covid-19 pandemic and the changes observed in population mindset and lifestyle make invaluable touristic destinations like Danube's Delta a pillar regarding increasing income level, following the sustainable development of the area. During the workshops that took place during the COASTAL project, stakeholders from the tourism field and experts mentioned that the main barrier to tourism revenues increase is the lack of infrastructure, labour workforce and the inefficient promotion of the Danube's Delta area.

The tourism model shows that the tourism revenues are directly connected with the annual tourist days (through the formula) and the fraction of revenues used for marketing has a major impact on the tourism development, very important for the area's attractiveness.

For sure, one of the main objectives regarding the tourism revenues is to reach a higher level, but in a way that facilitates the development of slow down experience for tourists that are coming to the Danube's Delta. Following this path is the optimal choice for finding the balance between local development and environmental protection, which is very important.

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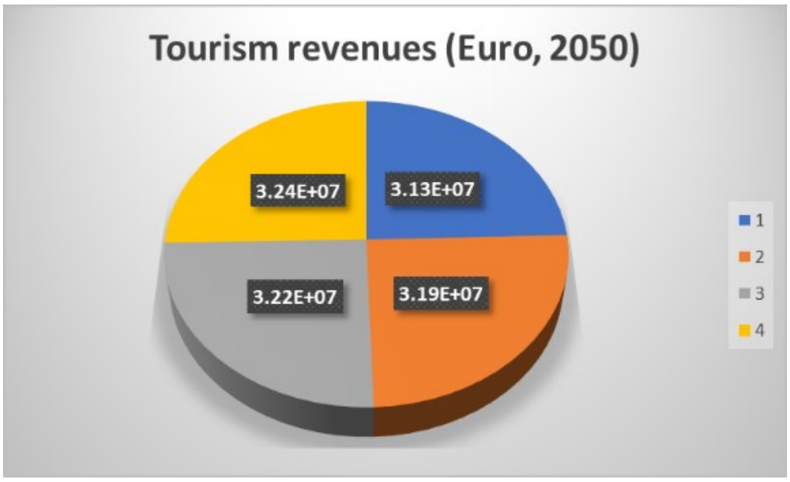

Figure 14 – System Dynamics model's 4 scenarios – Tourism – 2050, Danube's Mouths – Black Sea

What is the impact of the first set of measures on this KPI?

For measure 1, the greatest impact is found in scenarios 4 and 3. Although this measure involves a lower carrying capacity, in this scenario the duration of tourist stay is longer, due to the main purpose, to facilitate the transition between the current situation regarding the tourism sector and a slow touristic experience. Within measure 1, the tourism attractiveness is preserved, so in long term, the level of tourism revenues is higher, compared with the other measures (Figure 15).

What is the impact of the second set of measures on this KPI?

Measure 2 ensures a fast increase of the tourism income level in the first interval, followed by a constant trend, which shows that not always setting a higher value for carrying capacity produces economic growth in this industry. More tourists at the same time and place might affect the attractiveness and the environment, which is then reflected in the tourism revenues KPI (Figure 15).

What is the impact of the third set of measures on this KPI?

For measure 3, we set a superior value for the carrying capacity parameter and also for the fraction of tourism revenues used for marketing and we obtain a higher level of this KPI in scenarios 4 and 3. However, the higher level of this KPI is reached in the first interval, then it remains constant, in all 4 scenarios (Figure 15).

What is the impact of the fourth set of measures on this KPI?

According to measure 4, the higher level of carrying capacity and fraction of tourism revenues used for marketing is set, which has a similar impact in all the four scenarios, with a subtle change in scenario 4. This is also the measure that mostly affects the environment of Danube's Delta and water quality (Figure 15).

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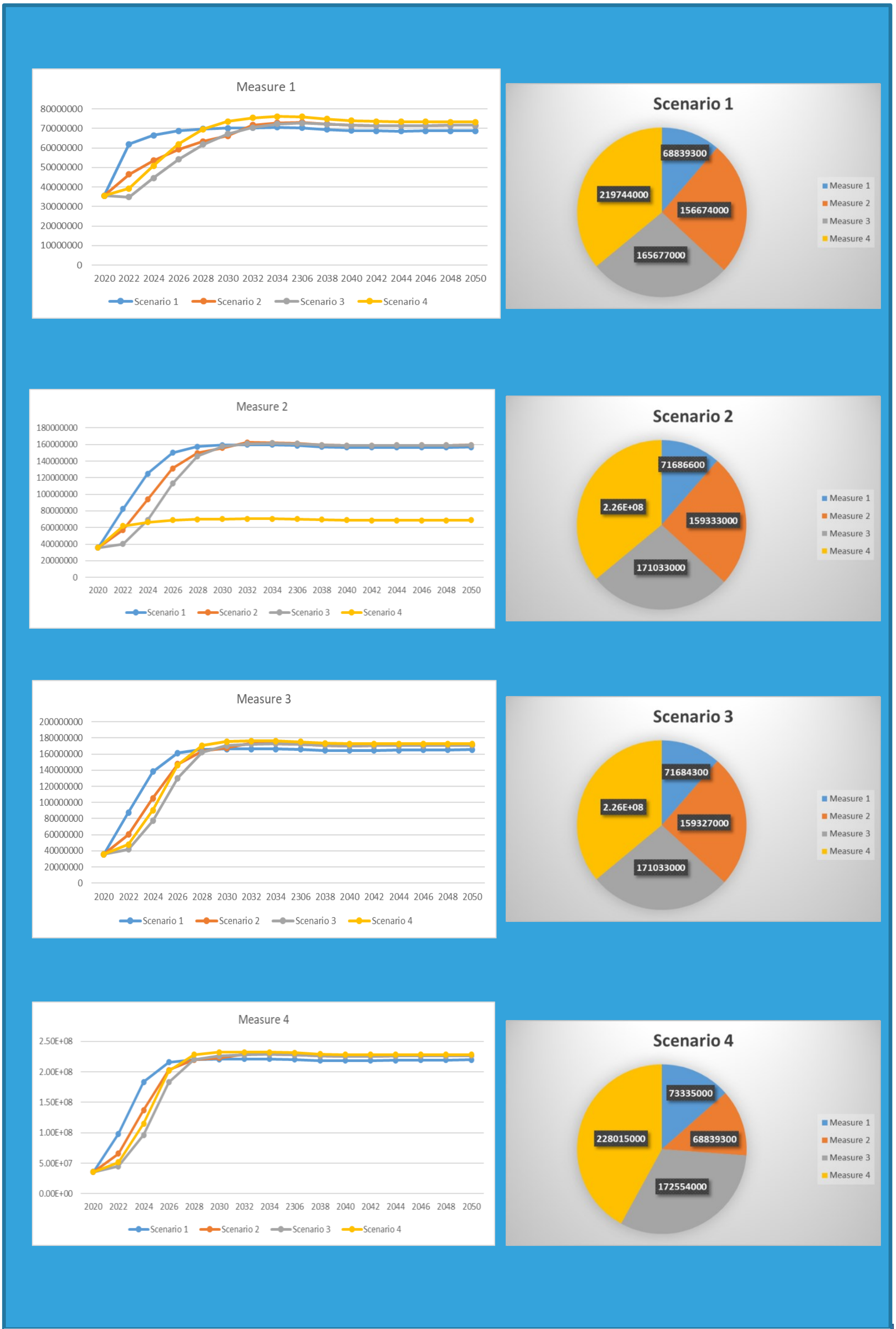

Figure 15 – Tourism revenues under different measures and scenarios (2050)– MAL5 – Danube 's Mouths – Black Sea (Danube Delta)

Given the impact of climate and ecological changes, economic growth and other external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

Following the previous analysis, regarding the tourism revenues, we can state that measure 1 brings the most satisfactory conditions regarding the balance between the level of income obtained through tourism activity and the protection of the environment. Encouraging the slow-down tourism experience in Danube's Delta area could bring higher levels of revenues, not by increasing the number of tourists that are visiting the area of interest, but by prolonging their touristic experience.

KPI 7: Tourism pressure

What is considered sustainable and robust in the Danube Mouths – Black Sea region?

The main pressures regarding the delta eco-systems are exerted by the changes both in the upstream conditions (retained sediments, increased pollution) and in the delta itself (Romanian Cultural Institute Journal, 2022). According to IUCN (World Heritage Outlook), *water pollution, illegal fishing, changes in the hydrological regime, infrastructure development and disturbance by unsuitable tourism activities, as well as the associated intensification of navigation routes, all represent high threats to the integrity of the Danube Delta*.

In our model, the main threat is reaching the critical threshold regarding the annual tourist day reported to the carrying capacity level. According to these algorithms, is considered sustainable that annual tourist days have a slower growth rate than the growth rate of the carrying capacity variable. Keeping like this these parameters over the long term, we can obtain a lower tourism pressure.

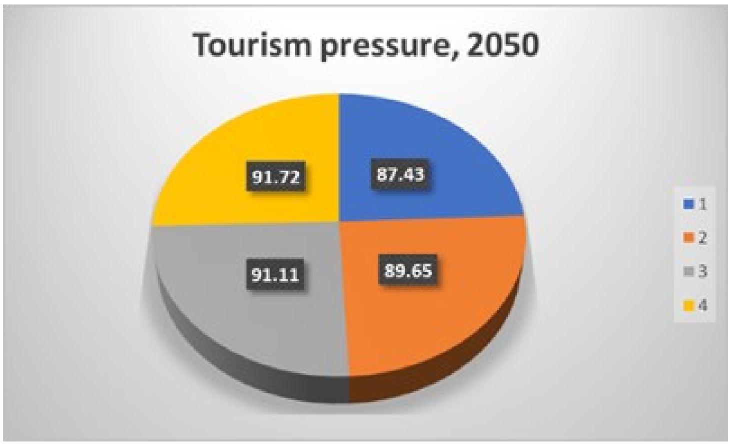

Figure 16– System Dynamics model's 4 scenarios – Tourism pressure – 2050, Danube's Mouths – Black Sea

What is the impact of the first set of measures on this KPI?

For measure 1, the highest impact is in scenario 2, because in this scenario tourism pressure records the most significant decrease. Also, it can be observed that applying this measure in all scenarios this parameter registers a decrease in comparison with the values registered in the Business As Usual (BAU) scenario (Figure 17).

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What is the impact of the second set of measures on this KPI?

For measure 2, it can be observed that in all four scenarios the tourism pressure remains constant. This situation is the most like what is currently happening in the area of the case study, the Danube's Delta (Figure 17).

What is the impact of the third set of measures on this KPI?

The third set of measures leads to a tourism pressure increase, in all four scenarios, compared to the second set. The lowest increase of this KPI value is registered in Scenario 1 (with 0.97%), followed by Scenario 2 and Scenario 3 (Figure 17).

What is the impact of the fourth set of measures on this KPI?

According to measure 4 which has a similar impact in all the four scenarios, the tourism pressure registers an increase in all the situations, due to the tourism area intensification. This is also the measure that mostly affects the environment of Danube's Delta and water quality (Figure 17).

Given the impact of climate and ecological changes, economic growth and other external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

To ensure the Danube Delta's longevity and sustainability for a long-time horizon, from a tourism perspective, a few changes in the industry development are necessary, in the sense of facilitating the transition from conventional tourism to greener, ecological tourism. Also, increasing awareness regarding the vital importance of preserving the environment and determining the specific ways in which it can be protected is a factor that authorities should take into consideration. This statement should be applied not only to tourists but also to the local rural communities, economic agents and all the actors involved in Danube's Delta tourism activity. The tourism industry development should go in a "slow-down tourism experience" direction to decrease the "tourism pressure" present level.

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Figure 17 – Tourism pressure under different measures and scenarios (2050)– MAL5 – Danube 's Mouths – Black Sea (Danube Delta)

KPI 8: Impact of nitrogen load from tourism on water quality

What is considered sustainable and robust in the Danube Mouths – Black Sea region?

According to The International Commission for the Protection of the Danube River (ICPDR), among the major problems affecting aquatic ecosystems in the Danube River Basin, are mentioned excessive nutrient loads (particularly nitrogen and phosphorous) and accidental pollution from industrial and mining facilities. The total nitrogen load upstream of the Danube Delta transported by the Danube River is estimated to be between 537,000 t/y and 551,000 t/y. This data covers the period 1992-1996 and should only be taken as a rough indicator of the current size of the nitrogen load. Due to several threats derived from economic growth and regional development of the Danube's regions, most Danube countries are working to reduce emissions of nitrogen and other nutrients from municipal wastewater treatment plants.

According to ICPDR (2016), in Danube's Delta, construction of urban wastewater treatment plants and upgrades to wastewater treatment technologies have contributed to a significant decrease in surface water pollution. By 2015, wastewater collection and treatment infrastructure were improved at almost 900 agglomerations.

In our model, we also focused on the impact of nitrogen load from three main economic activities: aquaculture, agriculture, and tourism. Due to the tourism industry particularities, we can conclude that the main issue is the tourist's environmental footprint and the activity of hotels, restaurants, or other providers of related services.

A sustainable future for Danube's Delta area involves practising slow tourism, which implies decreasing the consumption rate and a less harmful impact on the environment. In our modelling activity, we set different values for several quantitative variables such as marketing budget or carrying capacity, to facilitate the transition from the current situation in Danube's Delta to a "slower" form of tourism.

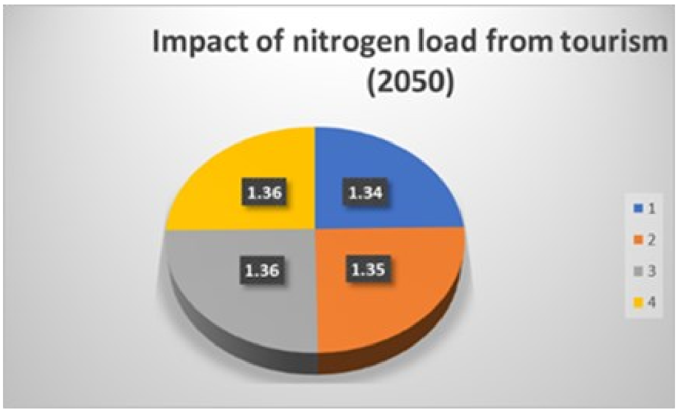

Figure 18– System Dynamics model's 4 scenarios – Impact of nitrogen load form tourism – 2050, Danube's Mouths – Black Sea

What is the impact of the first set of measures on this KPI?

For the first set of measures applied for the Impact of nitrogen load from tourism, we set a lower value for 'load N per day' parameter (with 20%), due to the promotion slowing down of Danube's Delta area and a lower value of 'carrying capacity parameter (with 50%). Thereby these types of measures a lower impact of nitrogen load from tourism is registered, in all the four scenarios, compared with the values obtained in BAU (Business

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As Usual) scenario, with a 2% average, The lowest impact of nitrogen load from tourism is registered in Scenario 2 (0.916), and the highest level in Scenario 4 (0.927) (Figure 19).

What is the impact of the second set of measures on this KPI?

The second set of measures applied for this KPI was designed according to the present situation in Danube's Delta area and the estimated evolution of each parameter, based on the currently available data. Consequently, there's no significant changes regarding the impact of nitrogen load from tourism (Figure 19).

What is the impact of the third set of measures on this KPI?

For the third set of measures, we set a higher value for the "load from N per day" parameter (with 20%), which implies a higher impact of nitrogen load from tourism in all scenarios, with a 25% average increase. The model results reflect a higher level of this KPI in Scenario 4, a lower level in Scenario 1 and a similar level in Scenario 2 and 3 (Figure 19).

What is the impact of the fourth set of measures on this KPI?

Regarding the last set of measures, we set the highest level "load from N per day" parameter, with a 30% increase, compared with the starting value (0.0001). Thus, after running the model, we obtain the highest impact of nitrogen load from tourism in Scenario 4 and the lowest impact in Scenario 3. Close values are obtained in Scenario 1 and Scenario 2. This is also the measure that mostly affects the environment of Danube's Delta and water quality (Figure 19).

Given the impact of climate and ecological changes, economic growth and other external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

The lowest impact of nitrogen load from tourism leads to a more sustainable and robust area of Danube's Delta, which would still allow tourists to come and enjoy this beautiful area with a high degree of uniqueness, in Europe and beyond. According to this, is important to keep under observation and control some parameters, such as "load N per tourist day", and keep these variables as low as possible value. This goal could be achieved by applying measures that lead to the "slow-down tourism experience" encouragement and promotion and facilitates the transition between the actual form of tourism in Danube's Delta to a more ecological, greener form of tourism. It is also important to make efforts to change the actual consumption behaviour of tourist services to a more educated and respectful manner regarding the "natural treasure" that the environment offers to us unconditionally.

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Figure 19 – Impact of nitrogen load from tourism on water quality under different measures and scenarios (2050) – MAL5 – Danube 's Mouths – Black Sea (Danube Delta)

KPI 9: Eco farm production

What is considered sustainable and robust in the Danube Mouths – Black Sea region?

Under the Green Deal's Farm to Fork strategy, the European Commission has set a target of 'at least 25% of the EU's agricultural land under organic farming. F2F does not only target the public sector but also the private sector. It includes different orientation actions. Sustainable food must be promoted and should be a priority at EU and national level. In addition to informing and educating the consumer, we need promotion.

Aiming to achieve the 25% target, The Commission has set out a comprehensive organic action plan for the European Union. One of the three axes of this plan is concentrated on "improving the contribution of organic farming to sustainability".

It is also specifying that Organic crops achieve lower yield compared with the conventional crops and therefore closing the yield gap is essential to ensure the economic viability, especial for those crops for which the yield gap is still relatively high.

What is the impact of the first set of measures on this KPI?

As explained above, the parameters with influence on this KPI are "farm to fork target time" and "minimal ecofarm yield". For the first set of measures applied, namely reaching F2F target by 20 percent earlier while increasing minimal yield by 100%, the highest level of the total ecofarm production is reached under scenario 1. Scenario 2 shows an increasing trend of the total production as well under organic system. As expected, Scenario 4 shows a decreasing trend, reaching values close to zero beginning with 2045.

What is the impact of the second set of measures on this KPI?

Applying the second set of measures (practically no new interventions on F2F target time and minimal yield) the highest level for this KPI was obtained in Scenario 1 and Scenario 2 and the lowest level of total ecofarm production in Scenario 4. Although the trend is like measure one, it is to be observed that this path will result in overall lover productions.

What is the impact of the third set of measures on this KPI?

The third set of measures generates the most significant impact in Scenario 1 and 2. Under Scenario 3 the total production obtained in organic farming is almost constant, this being the most beneficial measure for Scenario 3, while in Scenario 4 the total production obtained in organic farming will decrease. Of all measures, this one generates the lightest decrease of the total ecofarming production in Scenario 4.

What is the impact of the fourth set of measures on this KPI?

The same trend is maintained in the fourth set of measures as described above. Of all the presented sets of measures, Measure 4 leads to a significant decrease in the level of ecofarm production. The most impacted situation is for Scenario 4, with lowest values under the four set of measures.

Given the impact of climate and ecological changes, economic growth and other external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

The parameters with influence on Eco farm production are "farm to fork target time" and "minimal ecofarm yield". As explained earlier, to reach sustainability (economic, social, and environmental) it is expected to obtain an increased Total ecofarm production. This situation is exactly what is happening for all scenarios under measures 1-3. Under measure 4, when the reaching the target is done slower than expected, and the yields are even more decreased (no interventions in innovation), the calculated value will constantly decrease. The most promising scenario for 2050 seems to be scenario 2. This was earlier described in D19 as being Middle of the Road (Medium challenges to mitigation and adaptation) Measure 1 and 3 are the ones generating the highest increase of this KPI, as compared to with the dynamic patterns presented before in D19 (corresponding to measure 2). However, this KPI should further be analysed as correlated to total traditional production (Figure 20).

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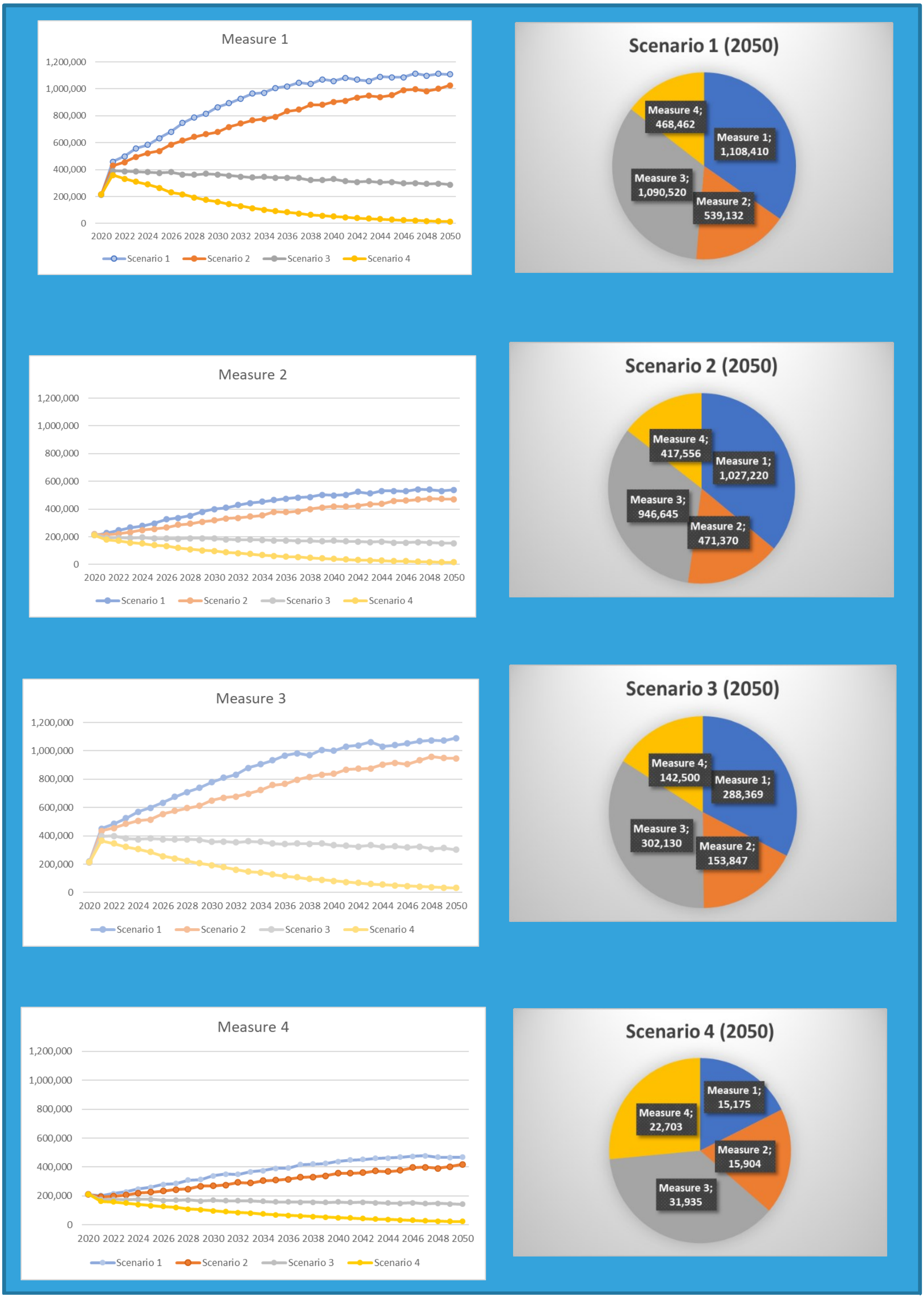

Figure 20 – Ecofarm production (ton/year) under different measures and scenarios (2050) – MAL5 – Danube 's Mouths – Black Sea (Danube Delta)

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KPI 10: Traditional farm production

What is considered sustainable and robust in the Danube Mouths – Black Sea region?

For a sustainable and robust production in MAL05 case study region, the conventional farm production should be always considered as compared to ecological farm production. The rationale is that overall agro-food production should be at least constant. Therefore, a decrease of total farm production should always be correlated with an increase of production provided in ecological system

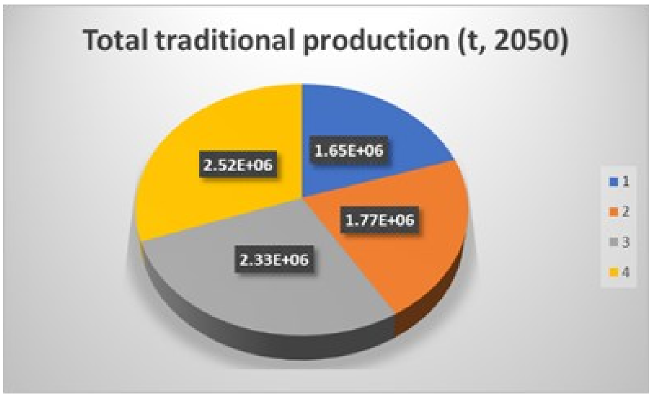

Figure 21 – System Dynamics model's 4 scenarios – Total traditional production – 2050, Danube's Mouths – Black Sea

What is the impact of the first set of measures on this KPI?

The first set of measures generates the highest level of total traditional production, in Scenario 4, the lowest level in Scenario 1 and appropriated values of this KPI resulted in Scenario 2 and Scenario 3. Measure 1 encourages farmers to produce less in the conventional agriculture system and more in the eco-farming system.

What is the impact of the second set of measures on this KPI?

Measure 2 set the associated parameters with this KPI at a level that matches the most with the current situation, in the agriculture sector in Danube's Delta area. By applying this set of measures, we obtain the highest level of total traditional farm production in Scenario 4 and the lowest level of this KPI in Scenario 1 (Figure 21). Scenario1 is more propitious with ecofarming production.

What is the impact of the third set of measures on this KPI?

The third set of measures presents similar characteristics to the above measure and by applying Measure 3 we obtain a similar impact, with subtle growth changes in the KPI values for scenarios 3 and 4.

What is the impact of the fourth set of measures on this KPI?

The last set of measure applied generates an increase of traditional farm production in Scenario 3 and 4 and decrease the level of this KPI in all the other Scenarios.

Given the impact of climate and ecological changes, economic growth and other external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

Surely ensuring food security should be one of the development priorities in any region, not only in the case of the Danube region. The transition to a green economy must consider multiple factors. The total production of farms in the conventional system must be analysed in close relationship with that of ecological farms, so that this transition does not definitively alter the ability of a region to contribute to the supply of food to the population.

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As can be observed from the figure below, not acting (Measure 2) will lead to a decrease of total agricultural production in the green scenarios (S1 and 2). Considering the entire model built for MAL05, Scenario 3 is sustainable from the point of view of the environment (Figure 22).

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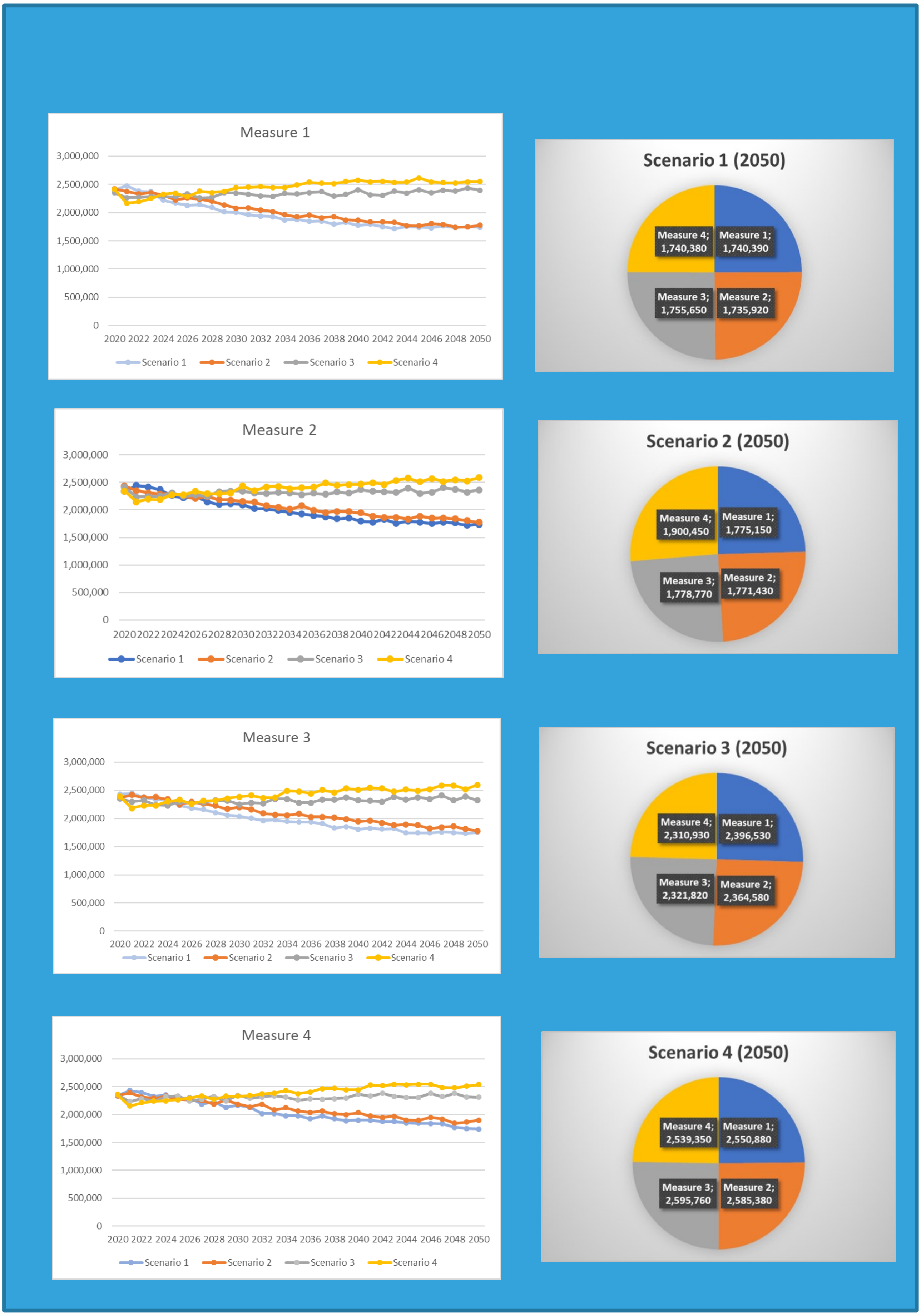

Figure 22– Traditional farm production (ton/year) under different measures and scenarios (2050) – MAL5 – Danube 's Mouths – Black Sea (Danube Delta)

KPI 11: Total agriculture income

What is considered sustainable and robust in the Danube Mouths – Black Sea region?

Of course, securing farmers' incomes is a preferable goal of any strategy in the agricultural field. Any intervention towards the development of the region must contribute to the consolidation of the stability of production and the food market, and to the reduction of disparities and fluctuations in agricultural incomes, these interventions translate into measures such as income support, through direct payments to ensure the stability of farmers' incomes or through payments for agriculture with low environmental impact and for the protection of the rural environment.

Organically certified products can have a higher profit margin. There is a price difference compared to products obtained in conventional agriculture.

What is the impact of the first set of measures on this KPI?

By applying the first set of measures, the highest level of the total agriculture income is obtained in Scenario 1 and the lowest level of this KPI in Scenario 4.

Moreover, Measure 1, Scenario 1 generates the highest income for agriculture in all measures and scenarios.

Under scenario 3, this measure will bring up medium values for the agricultural income, of all measures and scenarios.

What is the impact of the second set of measures on this KPI?

The second set of measures generates the highest level of total agriculture income in Scenario 4 and the lowest level of agriculture income in Scenario 1.

What is the impact of the third set of measures on this KPI?

This measure generates the second highest impact of al measures and scenarios under scenario 1.

Under scenario 3, third measure will bring up medium values for the agricultural income, of all measures and scenarios.

What is the impact of the fourth set of measures on this KPI?

For this set of measures is very interesting the evolution of the Total agriculture income in scenario 1. While at the beginning of the projection the income is decreasing fast, after 2 years, the income is steadily increasing. From economic point of view, the most convenient scenario for this measure remains S4, which is however destined to high challenges to mitigation, low challenges to adaptation.

Measure 4, Scenario 1 generates the lowest income of all measures and scenarios.

Given the impact of climate and ecological changes, economic growth and other external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

This KPI is exclusively reflecting economic sustainability. Securing a fair income for farmers is a key point of all national strategic plans for agriculture and rural development across Europe, and Romania is no exception to that.

It is obvious that measure 1, with intensive interventions for increasing agricultural yields will bring the most beneficial development. The income is increasing considerable in the green scenarios S1 and S2.

Measure 1 and 3 under scenarios 1 and 2 will bring the upper limit of the agricultural income up to the year 2050.

Measures 2-4 with no interventions or slow transition are the most undesirable, as for the greener scenarios (S1-S2) the income will decrease in the first part of the projected period, and then is increasing steadily, however reaching the initial level after 8 to 15 years.

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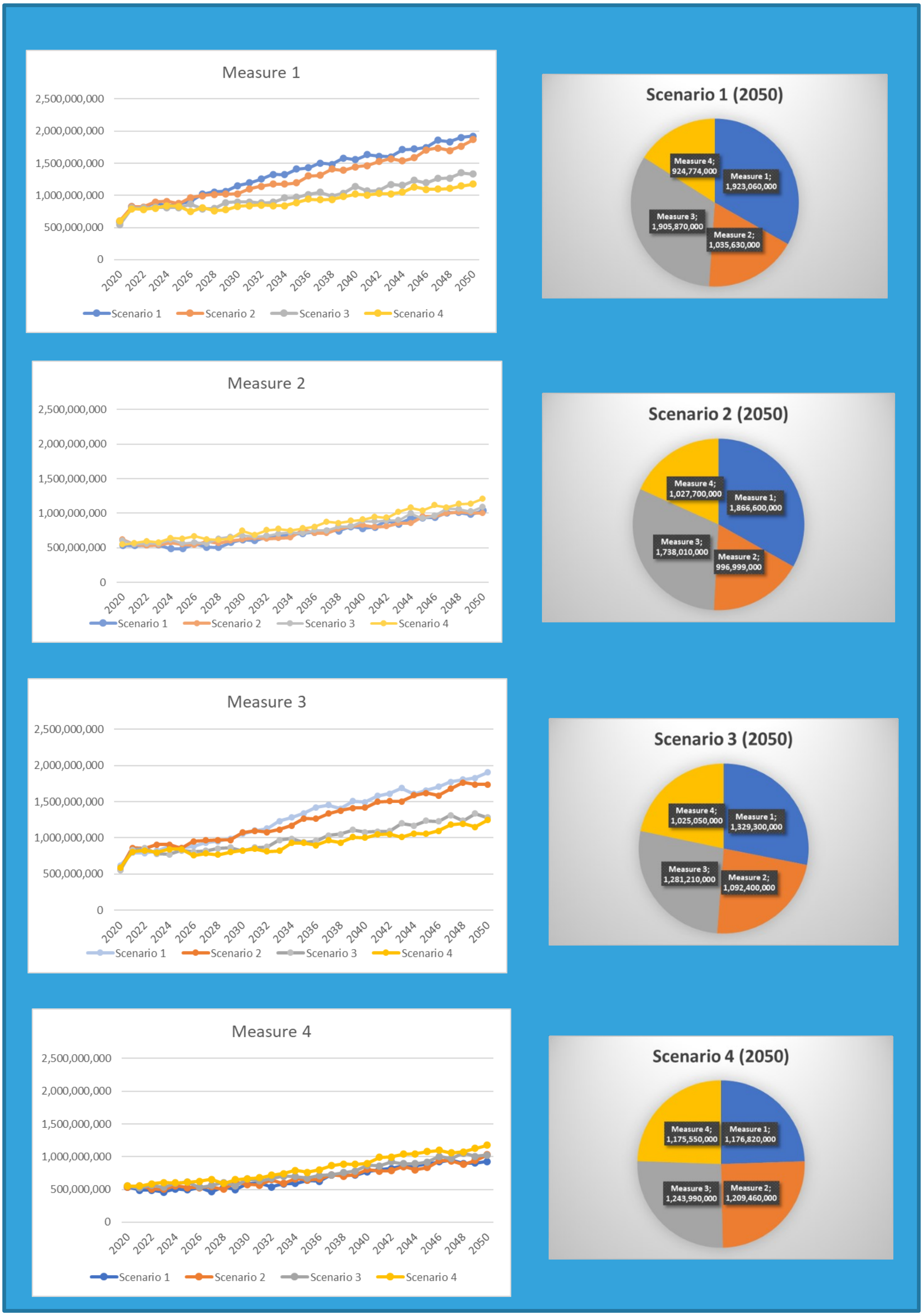


Figure 23 – Total agriculture income RON/Year under different measures and scenarios (2050) – MAL5 – Danube 's Mouths – Black Sea (Danube Delta)

KPI 12: Fraction ecofarms

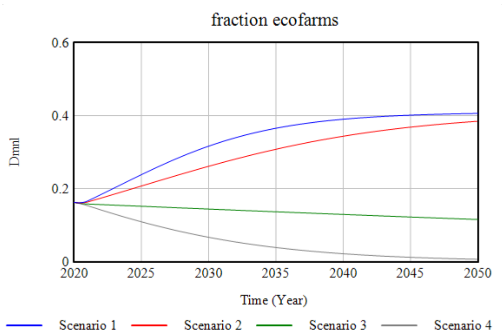
What is considered sustainable and robust in the Danube Mouths – Black Sea region?

Farm to fork strategy has proposed reducing the use of chemical fertilizers by 20% by 2030. And by then, the area of agricultural land with organic production should increase to 25%. Organic farming currently occupies 3.2% of agricultural land In Romania. Tulcea county owns a specific regime, as most of its area is under Natura 2000 area, and only organic farming is allowed. A share of 16% of the agricultural area was cultivated under organic farming in 2020.

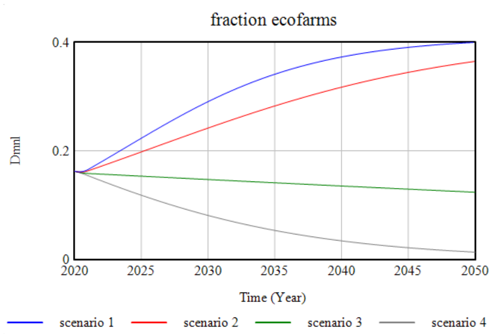
In the system dynamics developed under Coastal activities, this variable was set accordingly, to reach 25% of total agriculture area by 2030 in a green transition scenario. If dealing with a SSP5 Fossil-fuelled Development – Taking the Highway (High challenges to mitigation, low challenges to adaptation), Scenario 4 (Deliverable 19), the share of organic farming is steadily decreasing towards zero by 2050, as no measures are taken for encouraging transition to sustainable agricultural practices.

However, this KPI is not impacted under the measured modelled in D20, the small fluctuations of the trend can be attributed to the random function of the precipitation variable within the model (Figure 24).

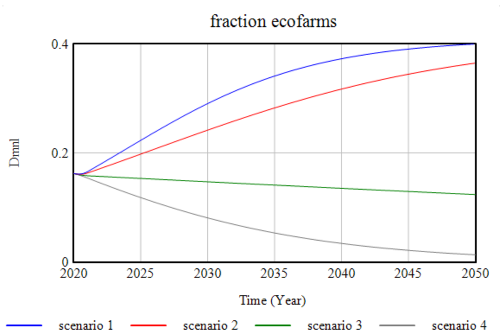
Fraction ecofarms



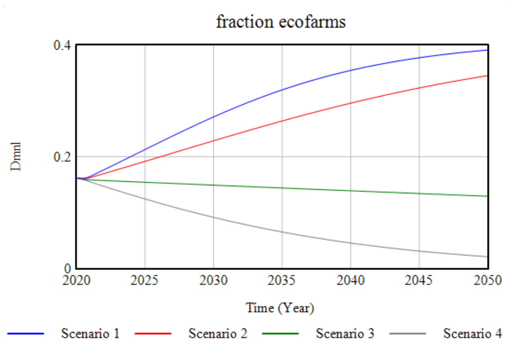
Measure 1



Measure 2



Measure 3



Measure 4

Figure 24 – Fraction ecofarms under different measures and scenarios (2050) – MAL5 – Danube 's Mouths – Black Sea (Danube Delta)

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KPI 13: Impact of nitrogen load from agriculture

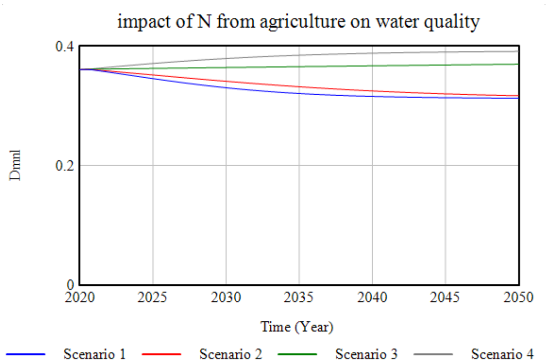
What is considered sustainable and robust in the Danube Mouths – Black Sea region?

Synthetic nitrogen, an important component of conventional fertilizers, helps to produce higher yields to feed a growing world population. However, when crops do not fully utilize nitrogen, it may negatively impact downstream water quality. This excess nitrogen can contribute to the increased formation of ground-level ozone, higher amounts of climate-changing greenhouse gases, and thinning of the protective ozone layer high in the Earth's atmosphere.

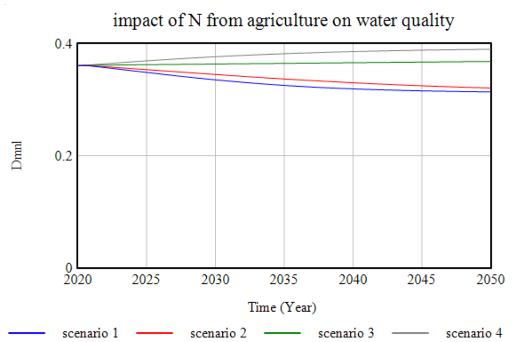
The Danube Delta region has a special regime from the point of view of agricultural technologies practised, being a protected area. That is why this region has the highest percentage in the country of areas cultivated in an ecological system. Studying the officially available data regarding nitrogen load, we concluded that there is a low influence of agriculture on Danube water quality. The amounts of nitrogen used in the region, reported in the INS statistics, are below the maximum limits allowed,

However, this KPI is not impacted under the measured modelled in D20, the small fluctuations of the trend can be attributed to the random function of the precipitation variable within the model (Figure 25).

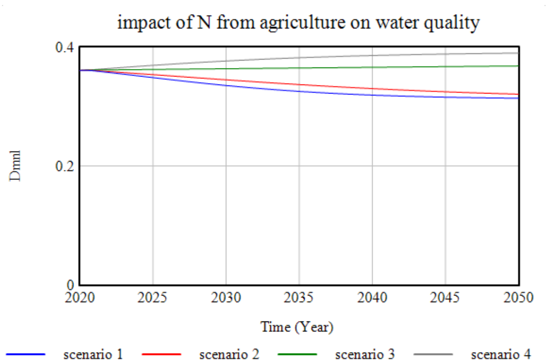
Impact of nitrogen load from agriculture



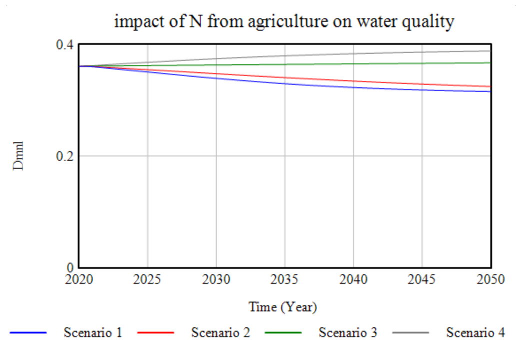
Measure 1



Measure 2



Measure 3



Measure 4

Figure 25 – Fraction ecofarms under different measures and scenarios (2050) – MAL5 – Danube 's Mouths – Black Sea (Danube Delta)

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KPI 14: Water Quality

What is considered sustainable and robust in the Danube Mouths – Black Sea region?

The Seventh Environment Action Programme (7th EAP) includes the goal of the Water Framework Directive (WFD) that good status should be achieved, enhanced, or maintained in transitional, coastal, and fresh waters. Achieving good ecological status in surface waters is a critical aspect of this. The quality of Europe's surface waters has improved over recent decades thanks to higher standards of wastewater treatment, for example, and reductions in agricultural inputs of nitrogen and phosphorus. Pollution from agriculture and urban and industrial wastewater nevertheless remains significant. Hydromorphological pressures — mainly from hydropower, navigation, agriculture, flood protection and urban development resulting in altered habitats — also affect many surface water bodies (EEA, 2018). Based on the second River Basin Management Plans (RBMPs) from 2015, around 40 % of surface waters in the EU (rivers, lakes, and transitional and coastal waters) have achieved good ecological status. Overall, the second RBMPs show a limited change in ecological status compared with the first RBMPs from 2009; for most water bodies the ecological status remained similar in both sets of RBMPs. The objective of achieving good status of waters wa not met by 2020 given the large proportion of surface waters still failing to meet good ecological status. Consequently, full implementation of the management measures under the Water Framework Directive, in combination with full implementation of other relevant directives (e.g., Urban Wastewater, Nitrates Directive) is needed to restore the ecological status of surface waters (EEA, 2018).

If we take each stakeholder separately there are several levels of sustainability in terms of water quality in the Danube Delta - the Black Sea. However, system dynamics modelling considers the cumulative impact of the main activities (aquaculture, agriculture, and tourism) on water quality and the contribution of each sector. In the current modelling, the water quality is obtained as the sum of each sector's impact correlated with the national legislation on the quality of surface waters.

What is the impact of the first set of measures on this KPI?

Under all measures 1 (Table 1), water quality degrades the fastest in scenario 4 and the least in scenario 1, which is an expected result. But what could not be observed without modelling is the slope with which this degradation occurs in the first 3-4 years, which makes this combination the most undesirable in the Danube Delta (Figure 26).

What is the impact of the second set of measures on this KPI?

The cumulative measures 2 (Table 1) have the biggest impact on the water quality in scenarios 2 and 3, while less was observed in scenario 4 (Figure 26).

What is the impact of the third set of measures on this KPI?

Under all measures 3 (Table 1), water quality degrades the fastest in scenario 4 and the least in scenario 1, which is an expected result. But what could not be observed without modelling is the slope with which this degradation occurs in the first 3-4 years, which makes this combination the most undesirable in the Danube Delta (Figure 26).

What is the impact of the fourth set of measures on this KPI?

Under all measures 4 (Table 1), water quality degrades the fastest in scenario 4 and the least in scenario 1, which is an expected result. But what could not be observed without modelling is the slope with which this degradation occurs in the first 3-4 years, which makes this combination the most undesirable in the Danube Delta (Figure 26).

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Given the impact of climate and ecological changes, economic growth and other external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

Taking into account the specificity of the activity as well as the modelling of aquaculture intensification, the greatest impact on water quality comes from nitrogen discharges from aquaculture, followed by tourism. The transition to ecofarming will bring beneficial impact on water quality.

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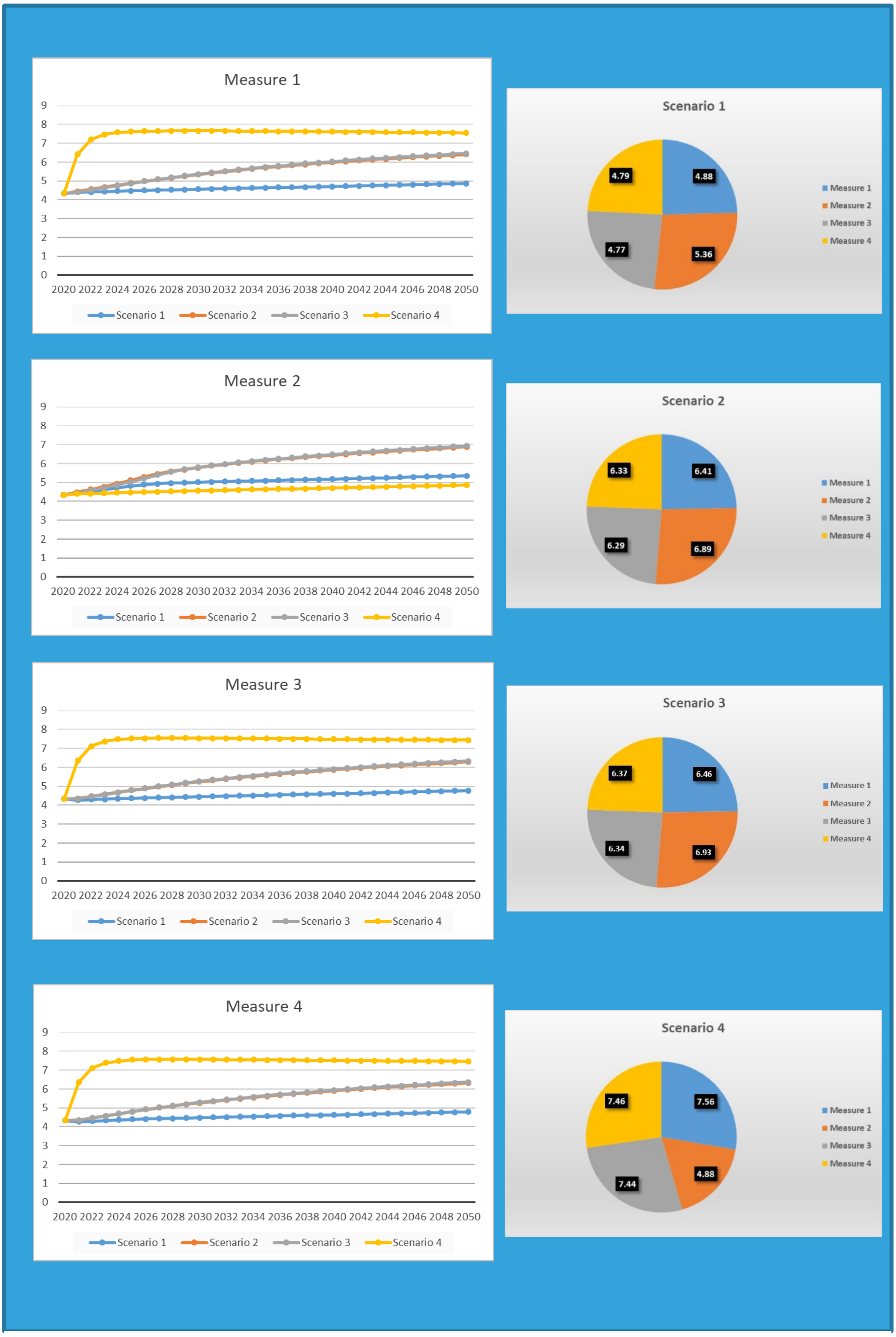

Figure 26 – Water quality under different measures and scenarios (2050)– MAL5 – Danube 's Mouths – Black Sea (Danube Delta)

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6.4. CONCLUSIONS

The Danube Delta represents both the largest remaining natural wetland and the second largest river delta in Europe, being one of Europe's most valuable habitats for wetland wildlife with 16 strictly protected areas. Unfortunately, according to our stakeholders, the governance and excessive bureaucracy are disturbing the economic activity and social areas avoiding 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 the causes, effects, and impacts of the pollution on the Black Sea and even on the surrounding neighborhood. The agriculture is for subsistence and the area is very poorly developed. On the contrary, due to the Danube Delta protected area, there is an increased pressure downward in the coastal zone for seasonal tourism (only three-four months/year). Thus, there is an artificial population "growth" which is not sustained by "real" economic development. On the other hand, domestic fish in Romania represented less than 20% of the internal consumption (2016-2019). This shortfall in 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). The main causes of low production were: the fishing facilities in the public and private domain 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 in 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 – estimated as 80%.

Each activity has its national strategy which is added to the development strategy of the Danube Delta itself. The integration of the impacts that the development of the activity has can be achieved through the COASTAL model.

The modelling for the Romanian MAL focused on three stock-flow models: one model for transition to ecological agriculture, the second for intensifying aquaculture and a third one for practicing slow tourism in the Danube Delta. Whilst the three models differ in problem scope, they are linked to the project's main objective by the impact of developing each activity on the water quality and were designed as strategic policy tools with a long-time horizon of decades to address the sustainable development of the Danube Delta which is a dual challenge - to protect its unique natural and cultural assets and meeting the aspirations of the inhabitants to improve their living conditions and seek better economic opportunities.

The aquaculture model operates with two stock variables (normal fish farming area and intensive farming fish area) and designs the impact that increasing productivity in the fish farm sector has on water quality to examine the impact of intensifying aquaculture by increasing productivity and allocated areas on water quality. The agriculture model considers the increasing farmers' welfare through their cooperation particularly sharing their assets and integrated production that ensures sustainable agriculture by adjusting agricultural practices and the use of alternatives over time, considering new knowledge and new methods. The pollution from agriculture is decreased by the implementation of a bioeconomy which is meant to reduce the dependence on natural resources, transform manufacturing, promote sustainable production of renewable resources from land, fisheries and aquaculture and their conversion into food, feed, fiber, bio-based products and bioenergy while growing new jobs and industries. In the agriculture model, we can observe how the evolution of conversion rate (set depending on the Farm to fork strategy), from traditional farms to organic farms, affects the water quality. The model for agriculture is designed for specific field crops, but it can be also adapted to other crops, depending on the needs of the beneficiary

The tourism model considers that the increase in tourism causes the main consequence of increased pollution which leads to biodiversity loss. Once the biodiversity has degraded, the area is no more a tourist attraction. This model operates with two stock variables such as traditional farms area and eco farms area. The tourism

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model starts from the premise that economic activity can be developed, but until a certain point, because once the area is damaged, the attractiveness of the area decreases progressively, and the income as well. This model focused on one stock variable, the number of tourists, which influenced tourism development, but also the tourism decline.

The integrated model was designed to examine the cumulative impacts of individual sectoral development in different socio-economic and climate change scenarios and environment management interventions.

The aquaculture itself may be adversely impacted by sources of pollution, such as agricultural, industrial, and domestic effluents, from the external environment. Therefore, a dedicated monitoring programme must manage and monitor trends in point source pollution and diffuse agricultural pollution sources. Taking nitrogen (N) pollution as an example, problems such as N fertilizer surplus in agriculture, industrial N emissions (such as those from the chemical, meat, textiles, and food processing industries), and N wastewater discharge from residents require attention and corresponding actions.

In the case of aquaculture, the increase in the intensification and the allocation of the land lead to the increase of the total production up to 5-6 times the quantity to ensure internal consumption. Equally, the impact of N on water quality is huge, so drastic measures are needed to remove it.

In the case of tourism, we can state that changing certain parameters, such as the marketing budget, tourism carrying capacity, or the duration of tourist stay (Deliverable D19) can facilitate the transition from the actual form of tourism practiced in Danube's Delta area to a slow tourism experience. In the short and medium time, this type of measure will generate lower values for the number of tourists that comes to Danube's Delta and there will be some decreases in the level of the tourism revenues, but this is one of the most efficient solutions, to delay the negative impact that tourism activity exerts on the environment and water quality. But if the tourism activity will be developed in the current way, in long term the tourism attractiveness of Danube's Delta area will more and more decrease, as well as the number of tourists, and this has obvious repercussions on the incomes obtained in this industry, on Danube's Delta community, from tourists and resident's perspective.

In the case of agriculture, applying measures that facilitate the transition from conventional agriculture to ecological farming will generate a positive impact on the water quality and the ecosystem of the Danube Delta. However, the intensive practice of eco-farming generates lower incomes, at the agriculture sector level, because of a lower yield per hectare obtained in the case of ecological farming.

Therefore, one of the main added values of the tool is that it covers a science-policy niche and can help the debate on the long-term impacts of integrated sectoral activities development and give support for decisions making process in various national and international environments, such as ministerial thematic groups, European initiatives, and strategic plans design.

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7. ROBUSTNESS ANALYSIS OF POLICY AND BUSINESS ACTIONS DESIGNED FOR THE MAR MENOR

7.1. PRESENTATION OF THE SOLUTIONS FOR THE MAR MENOR AND ITS COASTAL ZONE

Table 1 provides an overview of each of the variables and parameters – in case the policy control is a switch in the model – where systemic interventions enter the SD-model for the Mar Menor. The first column gives the variables' names. What these variables stand for, can be read in the second column. The third column, finally, gives an overview of the policy and/or business actions that may in reality (indirectly) change the variable's state.

Table 1: Overview of the 14 model variables used to simulate the impacts of policy and business solutions selected by stakeholders as part of the BRM.

Name entry variable or parameter	Description	Type of real actions reflected in variable
A. **IAControlOnOff**	Implement control of allowed irrigated areas with official water access rights	Actual implementation of state control of irrigated areas and closure of those that do not have water access rights, converting them to rainfed agriculture or natural vegetation.
B. **Environmental Education**	Promotion of environmental education activities	Develop and implement environmental education and awareness activities for the population
C. **AllowedNrWells**	Implement control of illegal wells extracting water from the aquifer	Actual implementation of control of water extraction wells from the aquifer and closure of wells without permission
D. **VCOnOff**	Groundwater pumping and treatment to reduce discharge from the aquifer to the Mar Menor	Pumping and treatment of groundwater to be used for irrigation (ca. 12hm3/year)
E. **Promotion of PV facilities OnOff**	Promotion of photovoltaic facilities	Promote the implementation of small and medium photovoltaic (less than 10 megawatts) and agrovoltaic renewable energy facilities
F. **AlbujonSWPumpingOnOff**	Surface water pumping from the Albujón ephemeral stream	Implementation of surface water pumping and treatment from the Albujón ephemeral stream (ca. 2hm3/year)
G. **Change in sea water desalination amount**	Increase in sea water desalination amount	Increase in sea water desalination amount to increase water availability (twice the Business as usual value by default in the model)
H. **Other point source pollution**	Control of other point sources of pollution to the lagoon	Improve wastewater management and treatment in urban and tourist areas

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I. **Coastal ecotourism activities**	Promotion of coastal ecotourism activities	A series of activities to promote coastal ecotourism such as activities in protected wetlands and salt pans by means of land stewardship and restoration projects; Promotion of non-motorized water sports; Increased control of illegal anchorages; Training and capacity building of workers in the tourist sector; Creation of a circular route and biking path around the Mar Menor lagoon; Restoration of buildings and infrastructures in urban centers
J. **Rural ecotourism activities**	Promotion of rural ecotourism activities	A series of activities to promote rural ecotourism, for example through the creation of green corridors for recreational purposes connecting sites of interest by sustainable transport; Restoration and promotion of cultural heritage; Training and capacity building of workers in the tourist sector; Promotion of agrotourism (accommodation, tasting and sale of local products, etc.); Promotion of music festivals; Promotion of inland sports activities (soccer fields, horse riding, golf courses, etc.)
K. **BrineDenitrificationOnOff**	Denitrification of brine wastes from groundwater treated for irrigation	Denitrification and management of brine wastes to prevent dumping in the lagoon
L. **NSW retention measures implementation level**	Implementation of nutrients, soil, and water retention measures	Implementation of nutrients, soil and water retention measures such as cover crops, crop rotations, and crop diversification techniques for a more sustainable production with less inputs and causing less runoff and erosion; plowing parallel to contour lines; implementation of field hedges; limit the number of harvests or rotations per year.
M. **Percentage of reduction in fertilizer excess**	Reduction in fertilizer excess	Promotion of organic farming (implementing a quality and sustainability brand in the Campo de Cartagena watershed); Reduction in the use of fertilizers; capacity building of workers in the agricultural sector related to fertilizer use
N. **Change in agricultural water demand per hectare**	Decrease in agricultural water demand per hectare	Optimize the water use efficiency (10% reduction in water demand) through modernization of irrigation techniques and less water demanding crops

The data corresponding to these entry variables can be found here: (to be inserted: link to the data repository).

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7.2. COMBINING AND OPTIMIZING SETS OF SOLUTIONS

In the context of this research, 14 business and policy solutions were taken into consideration that together represent the Business Roadmap that was co-developed with stakeholders during the project. To get a better view on the effectiveness of different combinations of these solutions, and the type of solutions that should be given priority, an optimization analysis was performed relative to 5 representative KPIs covering environmental, social and economic aspects. This analysis also serves to identify which of the solutions are indispensable and which ones to prioritize in case resources are limited. We give an overview here of the methodology followed for this analysis.

The model was used to find an optimal set of solutions by performing a large number of model runs (n = 16,383) based on all possible combinations of the proposed solutions (n = 14). To this end, five output variables were first selected as key performance indicators (KPIs) related to several social, economic and environmental aspects: i.e. agricultural pressure on water resources, agricultural nutrients in the MM lagoon, coastal-rural recreation potential, territorial bonding, and total number of jobs. Then, the final values of these KPIs in year 2070 under each combination of potential solutions were used as input for a multiple-criteria decision analysis (MCDA) using the TOPSIS method (Hwang et al., 1993), in which we tried to minimize the value of the first two KPI and maximize the value of the other three KPI. To exclude combinations of solutions that reached high TOPSIS scores but showed very low performance on single KPIs, as a second step in the identification of optimal solutions, normalized values of the KPIs for all combinations of policy solutions (from zero to one) representing worst and best scenario values, respectively, were used to filter out the policy solution combinations that did not reach an above/below 0.5 threshold in any of the KPIs in 2070. Results were finally analyzed by ranking the TOPSIS score obtained by the different combination of solutions tested.

The optimization procedure identified the set of best combinations of policy solutions that were considered optimal for an increasing number of potential solutions implemented. The minimum number of solutions that was needed to achieve a minimum required sustainability status for all 5 considered KPI was 6 solutions (Figure 1). The optimal score was obtained at 11 solutions. Implementing more than these 11 solutions did not result in a higher TOPSIS score (up to 14) and no differences in the relative values of the different KPIs were observed, so this set of 11 solutions could be considered optimal.

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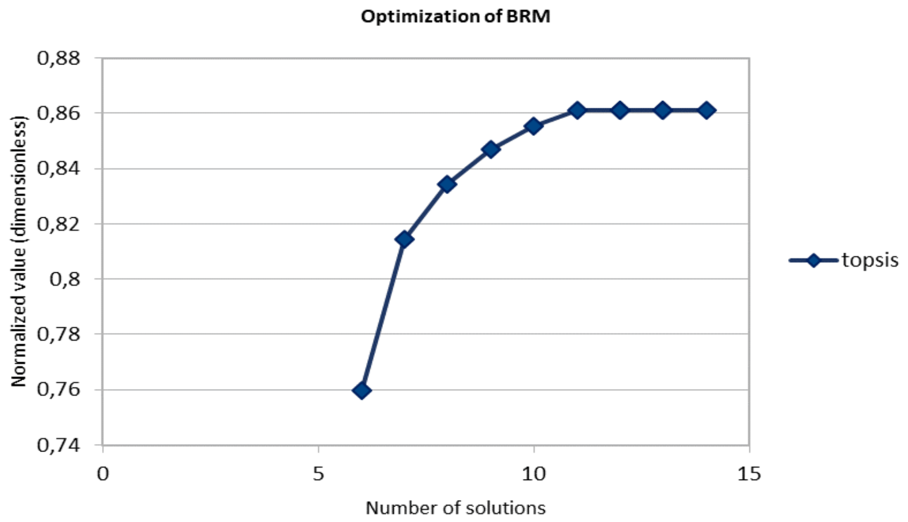

Figure 1: Outcome of the optimization of the 14 solutions of the BRM.

The combination of 6 solutions to achieve the minimal required sustainability status on five selected KPIs is formed by the following solutions (between brackets reference to full description Table 1):

- Control of irrigated land areas (A)
- Promotion of Environmental Education (B)
- Promotion of photovoltaic facilities (E)
- Promotion of coastal ecotourism activities (I)
- Promotion of rural ecotourism activities (J)
- Percentage of reduction in fertilizer excess (M).

The 11 solutions required to achieve an optimal sustainability status on the five selected KPIs is formed by the same 6 solutions as above and in addition:

- Ground water pumping and treatment (D)
- Increased sea water desalination (G)
- Control of other point sources of pollution (H)
- Brine denitrification (K)
- Reduction in agricultural water demand per hectare (N).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773782.

7.3. ASSESSMENT OF THE DYNAMIC PATTERNS OF KEY POLICY INDICATORS

This chapter discusses the impact of implementation of the Business Roadmap (BRM) consisting of the 14 solutions selected by stakeholders on selected KPIs under different scenarios of external drivers for the Mar Menor. The aim of this evaluation is to assess the robustness of the BRM to external socioeconomic and climate system drivers. In order to make these results easily comparable with the outcomes presented in Deliverable 19, the same logic is followed here. This means that the same KPIs are used here to structure the analyses, and the same scenarios of external drivers were used as described in Deliverable 19. Here we give an overview of the main insights of this analysis.

KPI 1: Brine Produced

What is considered sustainable and robust in the Mar Menor region?

The amount of brine produced depends in the SD model, among other things, on the average percentage of groundwater that becomes desalinated and the amount of groundwater needed for agriculture. Since the aquifer is polluted with salt and 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) thereby producing brine, which is discarded by farmers and, in the absence of an operational recollection system, drained to the Mar Menor lagoon. The brine contains salt and high concentrations of nitrogen, thereby contributing to eutrophication of the lagoon.

Since 1995 the amount of brine produced has increased linearly, reaching the amount of 15Hm^3 in 2021. Establishing exact sustainability thresholds for this KPI requires detailed data on the concentration of nutrients in the brine and the amount of nutrients (nitrogen) the Mar Menor lagoon is capable to metabolize without disturbing its ecology, certainly well below the amount of brine that has been receiving in the past. Since nitrogen and other nutrients (phosphorus) do not enter the lagoon only through brine production, but also through other processes like surface runoff and groundwater recharge, it is difficult to define an absolute sustainability threshold. Therefore, we have decided to establish the following sustainability thresholds for this KPI:

- The highest sustainability status reached when the amount of brine produced is 0 hm^3,
- The lowest sustainability status is considered to be at half of the difference between the current value of this KPI and its highest sustainability value achieved in any of the scenarios and at any time when implementing the Business Roadmap of 14 solutions.

Therefore, for this KPI a sustainability situation would be considered when the amount of brine produced ranges between 0 hm^3, corresponding to levels before 1995, and 9,12hm^3, corresponding to levels before 2007.

Reducing the amount of brine produced, together with the implementation of brine management and brine denitrification treatment to avoid the discharge of nutrient rich brine into the Mar Menor lagoon will help increasing the ecological status of the lagoon, which is also very important to align with objectives of the Water Framework Directive.

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What is the impact of the set of measures on this KPI?

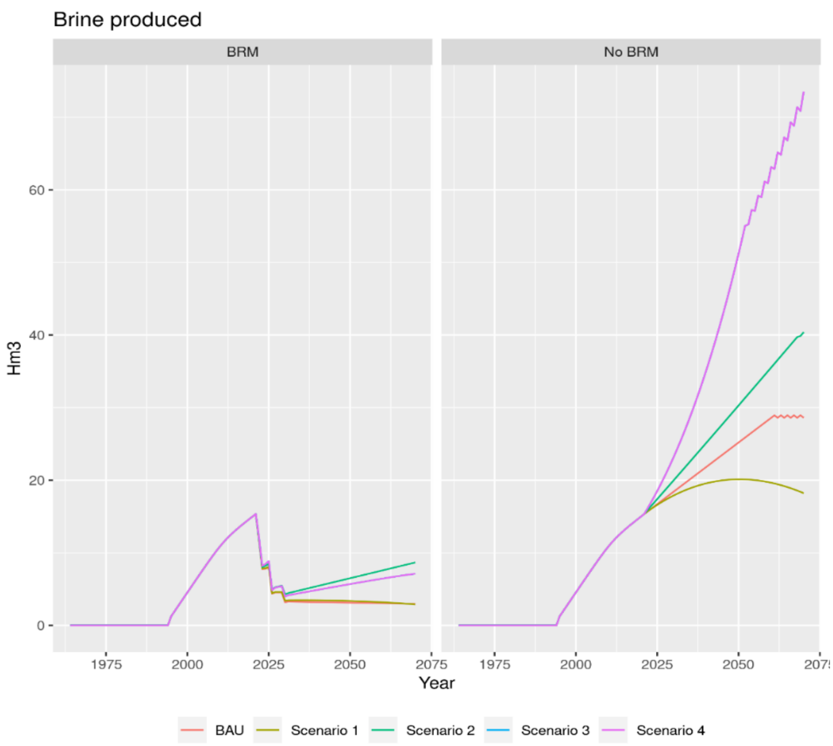

Figure 2: Impact of implementation of the BRM on KPI 'brine produced' under 5 different scenarios.

If the Business Roadmap of 14 solutions is implemented the amount of brine produced is expected to experience a sudden reduction by 2025 under all different Scenarios. Under Scenarios 2, 3 and 4, the amount of brine produced would see a slight but steady increase from 2030 onwards, while under the BAU scenario and Scenario 1, this KPI would experience a constant and mild decrease after 2030. All Scenarios are favorable for reducing the amount of brine being produced in the short term if the Business Roadmap is implemented, but only under Scenario 1 and the BAU scenario the amount of brine produced is expected to decrease for the longer term.

Considering that a sustainable amount of brine produced ranges from 0hm^3 to 9,12hm^3, it should be highlighted that the implementation of the BRM would maintain this KPI in a sustainable status over time and under any Scenario until 2070.

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Given the impact of climate and ecological changes, economic growth and other external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

If the BRM is not implemented, the amount of brine produced would suffer a steady increase under Scenarios 3 and 4, that would triple by 2050 the amount of brine produced in 2021. Under Scenario 2 this KPI shows a softer increase compared to Scenario 3 and 4, but still reaching the unsustainable amount of $40Hm^3$ of brine produced by 2070.

Under the BAU Scenario, the amount of brine produced would reach a maximum value of around $28Hm^3$ by 2060.

Scenario 1 shows the lowest amount of brine produced of all the Scenarios without BRM, reaching a peak of about $20Hm^3$ around 2050, and slowly decreasing afterwards overtime.

If the Business Roadmap is not implemented, the amount of brine produced will continue to increase for the long term in all Scenarios although at different rates. If no actions are taken to reduce the amount of brine produced, all scenarios would have a great impact on this KPI, being Scenario 1 the most favorable for this KPI although no Scenario would bring this KPI below the maximum sustainable range of $9.12hm^3$.

KPI 2: Agricultural Nutrients in the Mar Menor lagoon

What is considered sustainable and robust in the Mar Menor region?

The amount of agricultural nutrients in the Mar Menor lagoon in the SD model is the result of a balance between the nitrate consumed by the lagoon metabolism and the agricultural nutrient input (influenced by, among other things, the amount of brine produced, the average excess of fertilizer use, the yearly effectiveness in nutrient reduction, soil and water retention measures, etc.).

Since 1970 nutrient accumulation in the Mar Menor lagoon has increased linearly until 1995, when the trend changed to increase exponentially, coinciding with the start of brine production, until current times. In less than 50 years, human activities have transformed the Mar Menor lagoon into a green soup accounting for over 28.000 tons of nitrates accumulated in 2021.

Like for the brine produced, establishing exact sustainability thresholds for this KPI would require detailed data on the amount of nutrients that the Mar Menor lagoon is capable to metabolize maintaining a good ecological status and inputs from other sources. This amount would certainly be much lower than the amount of agricultural nutrients that is currently discharged into the Mar Menor lagoon.

In absence of this data, we decided to establish the following sustainability thresholds for this KPI:

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- The highest sustainability status is set up when the amount of agricultural nutrients accumulated in the Mar Menor lagoon is null.
- The lowest sustainability status is established at half of the difference between the current value of this KPI and its highest sustainability value achieved in any of the scenarios and at any time when implementing the Business Roadmap.

Therefore, for this KPI a sustainability situation would be considered when the amount of agricultural nutrients accumulated in the Mar Menor lagoon ranges between 0 tons and 14.069 tones, corresponding to levels before year 2005.

Reducing the amount of nutrients accumulated in the Mar Menor lagoon will help to increase the ecological and chemical status of the Mar Menor Lagoon, aligning with main objectives reflected in the Water Framework Directive. Furthermore, reducing agricultural nutrient losses and the use of fertilizers will align with major targets of the European Green Deal as described in the Farm to Fork strategy aiming to reduce the use of fertilizers with 20% by 2030.

What is the impact of the set of measures on this KPI?

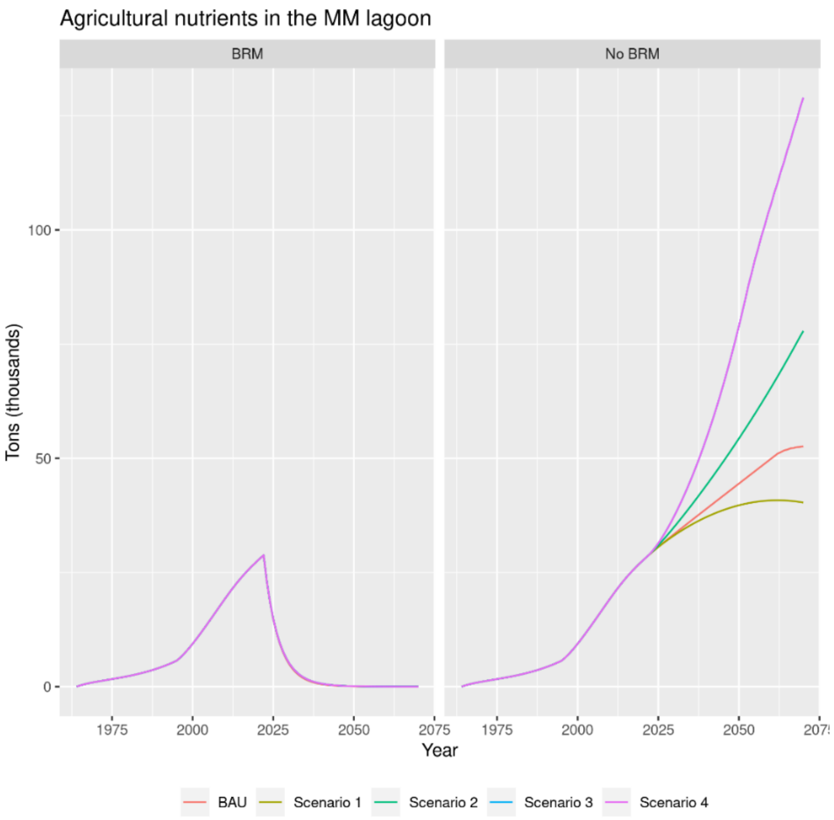

Figure 3: Impact of implementation of the BRM on KPI ‘agricultural nutrients in the Mar Menor under 5 different scenarios.

If the BRM is implemented, regardless of the Scenario, a drastic reduction of agricultural nutrients in the Mar Menor lagoon is expected to occur immediately after the implementation of the BRM, reaching minimum levels by 2035, and remaining stable for the long term. If the BRM is implemented no differentiating effects are expected for the different Scenarios.

Considering that a sustainable amount of agricultural nutrients in the Mar Menor lagoon ranges from 0 tons to 14.069 tons, it should be highlighted that the implementation of the BRM would help to decrease the current amount of agricultural nutrients in the Mar Menor lagoon to a sustainable status in few years after its implementation, and to maintain this KPI in a sustainable status over time under any Scenario taking place.

Given the impact of climate and ecological changes, economic growth and other external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

If no measures are taken, under the BAU scenario this KPI is expected to experience a linear increase of about 500 tons of nutrients per year accumulated in the Mar Menor lagoon for the next 50 years, reaching over 40.000 tons by 2050 and almost doubling the current amount by 2070.

Considering Scenarios 2, 3 and 4, the trend followed by this KPI is expected to worsen to different degrees. Under Scenario 2 the accumulation of nutrients in the MM lagoon takes a linear but steeper trend compared to the BAU scenario, increasing by 1000 tons per year. Under Scenarios 3 and 4 nutrient accumulation increases exponentially, doubling the current amount by 2050 and being four times greater by 2070. Scenario 1 shows the lowest value of nutrient accumulation of all Scenarios, peaking around 2050, and decreasing afterwards.

If the BRM is not implemented to lower the amount of nutrient inputs to the Mar Menor lagoon, the effects of the different scenarios on this KPI are expected to be remarkable, and no Scenario would keep this KPI below the sustainability threshold.

KPI 3: Irrigated land areas

What is considered sustainable and robust in the Mar Menor region?

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The high amount of groundwater extraction, together with the opening of the Tagus-Segura water transfer in the 80´s, are in the SD model the main drivers of the expansion of irrigated agricultural areas. Water demand is driven by the expansion of irrigated land areas, which is determined to a large extent by the water available for irrigation. Since 1970 irrigated land areas have continuously expanded, occupying about 60.000ha in 2021, exerting increasing pressure on the scarce water resources.

According to the current area that have water access rights, about 41.562 ha, we have established the sustainability status for this KPI in any value ranging between 0 and the current area with legal water access rights.

What is the impact of the set of measures on this KPI?

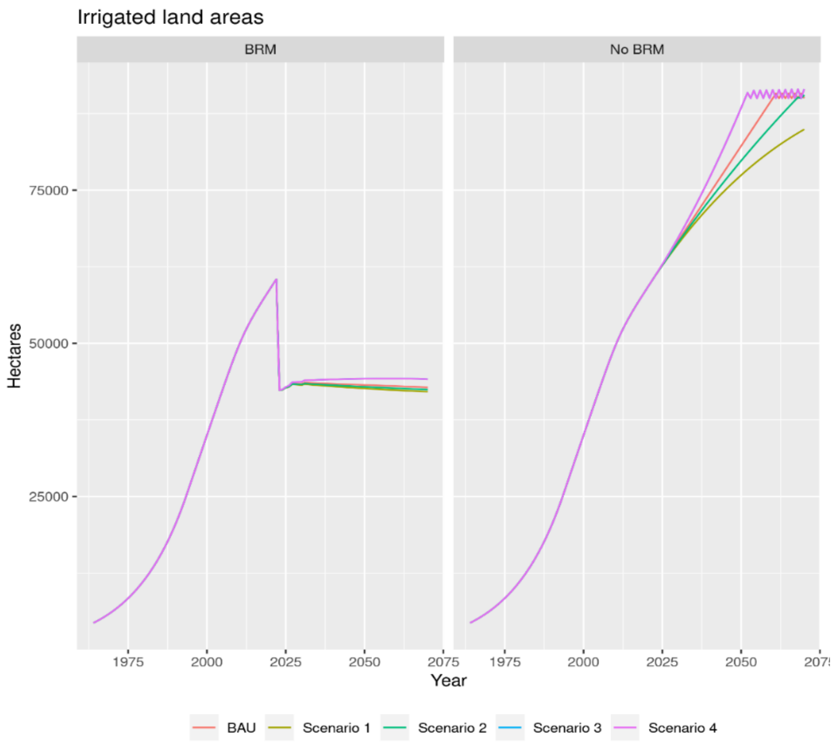

Figure 4: Impact of implementation of the BRM on KPI 'irrigated land areas' under 5 different scenarios.

The implementation of the BRM, independently of the Scenario taking place would result in a drastic reduction of the number of hectares under irrigation, mostly on the area without water rights, moving from 60.000ha to the current area with legal access to water sources of about 41.562 ha.

In addition to ensuring that irrigated areas conform to those legally permitted and maintain a sustainability status over time, if the Business Roadmap is implemented, the effects of the different Scenarios on this key performance indicator are expected to be minimal.

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Given the impact of climate and ecological changes, economic growth and other external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

If the BRM is not implemented no Scenario is favorable for limiting the land area under irrigation to what is legally stipulated. Therefore, this KPI would never reach a sustainability status if no actions are taken.

Particularly, under Scenarios 3 and 4 this KPI is expected to suffer a linear increase until reaching a peak shortly after 2050 when all arable land in the Campo de Cartagena watershed, that covers about 90,000ha, would become irrigated.

Under the BAU Scenario this KPI shows a similar pattern as under Scenarios 3 and 4, although presenting a time delay of some years to reach the maximum potential value of 90,000ha. Under Scenarios 1 and 2 this delay is more pronounced, mainly for Scenario 1.

KPI 4: Agricultural pressure on water resources

What is considered sustainable and robust in the Mar Menor region?

The pressure on water resources from agricultural water use in the SD model is a ratio between the agricultural water demand that is not fulfilled by available *surface water* and the total agricultural water demand. The available surface water depends on, among other things, catchment water sources, urban wastewater treatment plant effluents, yearly average sea water desalination and the amount of water transferred from the Tagus river. The agricultural water demand is a product of the area of irrigated farmland and cropland water requirements. The agricultural pressure on water resources indicates the dependency on groundwater resources.

Since 2000, agricultural pressure on water resources has experienced a steep and steady increase until nowadays. This has resulted in a distinct overexploitation of deeper confined aquifers. At the same time however, the unconfined Quaternary aquifer has seen an increase in its water level since the introduction of large scale irrigation with external water resources from the Tagus-Segura water transfer (Jiménez-Martínez et al., 2016). Establishing sustainability thresholds for this KPI would entail detailed quantification of the exact water balance of groundwater resources, for which insufficient data are available and comprehend a high level of uncertainty. As such, we have considered the following sustainability thresholds for this KPI:

- The highest sustainability status is set up when agricultural pressure on water resources is null (no dependence on groundwater).
- The lowest sustainability status is considered at half of the difference between the current value of this KPI and its highest sustainability value achieved in any of the scenarios and at any time when implementing the Business Roadmap.

For this KPI a sustainability situation would be considered when agricultural pressure on water resources ranges between 0.38, corresponding to levels before year 2004, and 0, which has not yet been achieved since there is data available.

Diminishing agricultural pressure on water resources is in line with the promotion of good water management by using only the portion of the overall recharge not needed by the ecology of the area, as stipulated by the Water Framework Directive. Increasing the sustainability of this KPI also aligns with the objectives promoted by the Green Deal on reducing the environmental footprint of farming systems.

What is the impact of the set of measures on this KPI?

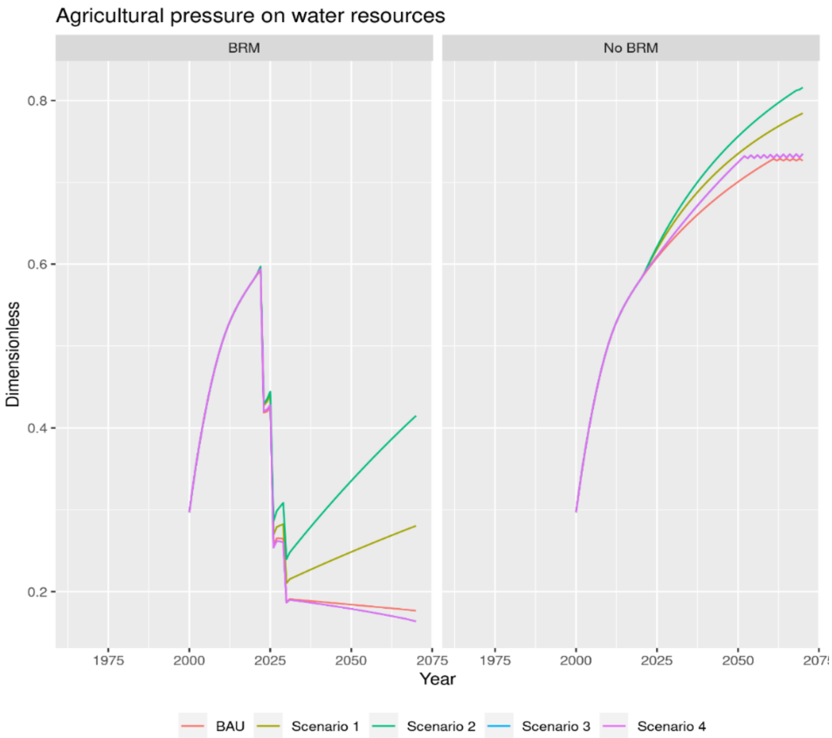

Figure 5: Impact of implementation of the BRM on KPI ‘agricultural pressure on water resources’ under 5 different scenarios.

The implementation of the BRM would have a direct effect by drastically reducing the agricultural pressure on water resources until 2030. After 2030, each Scenario displays a different trend. Under the BAU scenario, agricultural pressure on water resources keeps diminishing softly but steadily over time. Under Scenarios 3 and 4, agricultural pressure on water resources shows a similar trend as in the BAU scenario although with a slight better performance, mostly after 2050. Under Scenarios 1 and 2, the implementation of the BRM shows a reduction of the agricultural pressure on water resources until year 2030, increasing afterwards and for the long term in both scenarios, although being much higher under Scenario 2. The difference between Scenario 2 and the BAU scenario is due to decreasing water availability from the Tagus-Segura transfer under climate change conditions.

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Nevertheless, the highest values reached by this KPI under Scenarios 1 and 2 if the BRM is implemented are expected to be much lower than current values. If the Business Roadmap is applied, all Scenarios are favorable for reducing the agricultural pressure on water resources, although the BAU scenario and Scenarios 3 and 4 show a more favorable performance in this KPI for the medium and long term.

Considering that a sustainable agricultural pressure on water resources would be achieved when this KPI ranges from 0 to 0,38, it should be highlighted that the implementation of the BRM would maintain this KPI in a sustainable status over time under any Scenario, with the exception of Scenario 2 from 2060 onwards.

Given the impact of climate and ecological changes, economic growth and other external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

If the BRM is not implemented none of the scenarios are favorable for reducing the agricultural pressure on water resources, although this KPI performs slightly different under each scenario. Under Scenarios 3 and 4 this KPI shows a gradual increase until 2050, when it reaches a peak and stagnates afterwards. The same pattern is found under the BAU scenario, though with a delay of few years. Under Scenarios 2 and 1, agricultural pressure on water resources will reach the highest and second highest values respectively, both following a gradual increase for the long term that eventually ends up higher than under the other three Scenarios.

Without extra measures taken within the system to lower the agricultural pressure on water resources no scenario is favorable for this KPI. It should be noted that this KPI will never reach a sustainability status if the BRM is not implemented regardless of the Scenario taking place.

KPI 5: Photovoltaic energy facilities installed

What is considered sustainable and robust in the Mar Menor region?

The number of photovoltaic energy facilities installed (represented as Megawatts installed), depends among other things on the observed photovoltaic energy growth rate. The model only considers values starting in 2020 as there is no data for this variable previous to that date.

Establishing sustainability thresholds for this KPI would entail to define not only what situation can be considered sustainable, but also which situation can be considered desirable for the Campo de Cartagena watershed and the different sectors of the area. Many factors may determine the sustainable situation for this KPI, including cultural aspects linked to farming traditions and heritage, the design and type of photovoltaic installations, landscape aesthetics, tradeoffs between MW generated and crop production, number of jobs lost and generated, etc. Therefore, we decided to use the following sustainability thresholds for this KPI:

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- The lowest sustainability status is set at the current amount of photovoltaic Megawatts installed.
- The highest sustainability status is established at half of the difference between the current value of this KPI and its highest value achieved in any of the scenarios and at any time when implementing the Business Roadmap.

Following this logic, for this KPI a sustainability situation would be considered when potential PV installed ranges between 231 MW and 1935 MW.

Increasing the amount of photovoltaic energy facilities installed and Megawatts generated aligns with the EU Green Deal objective to move towards clean, *renewable* wind-water-*solar* (WWS) *energy*, efficiency, and storage by 2030.

What is the impact of the set of measures on this KPI?

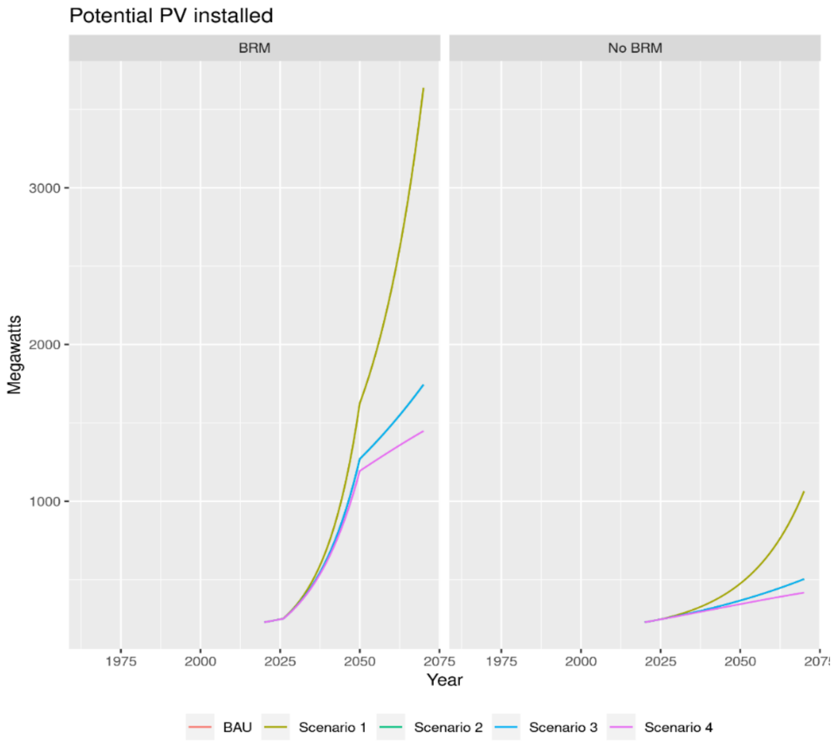

Figure 6: Impact of implementation of the BRM on KPI 'photovoltaic energy installed' under 5 different scenarios.

If the BRM is implemented, the PV installed will see a similar exponential increase under all different Scenarios until 2050. From 2050 onwards this KPI shows different trends under the different Scenarios. Under Scenario 1, the PV installed would reach over 1600 MW by 2050, and this amount would increase roughly by 1000 MW

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every 10 years. Under Scenario 4, this KPI reaches about 1200 MW by 2050 reaching a maximum of about 1500 Megawatts installed by 2070. Under the BAU Scenario, and under Scenarios 2 and 3, this KPI follows the same trend until 2050 reaching over 1300 MW. From 2050 to 2070 the increase slows down and this KPI reaches a maximum of 1750 Megawatts installed by 2070.

Considering that a sustainable situation is achieved when this KPI ranges from 231 MW to about 1935MW, it should be highlighted that the implementation of the BRM would maintain this KPI in a sustainable status over time under any Scenario, with the exception of Scenario 1, in which this KPI would surpass the amount of MW installed considered sustainable from 2054 onwards.

Given the impact of climate and ecological changes, economic growth and other external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

If the BRM is not implemented, this KPI would increase over time but at a slower rate compared to implementing the actions integrated in the BRM. If no actions are taken, under Scenario 1 the potential PV installed would increase to 500 MW by 2050, reaching 1000 MW by 2070, this means, thirty years later than if the BRM is implemented. Under Scenario 4 this KPI shows a rather small linear increase barely reaching 500 MW by 2070. Under the BAU scenario, and under Scenarios 2 and 3, this KPI follows the same trend, reaching slightly higher values of MW installed than those expected under Scenario 4.

If the Business Roadmap is not implemented, this KPI is expected to be in a sustainable situation under any of the Scenarios; nevertheless, its performance would be lower compared to the implementation of the BRM. Furthermore, Scenario 1 would be the most favorable for this KPI if no further stimulating actions are taken.

KPI 6: Total number of jobs

What is considered sustainable and robust in the Mar Menor region?

The total number of jobs depends in the SD model on the number of jobs created in the photovoltaic, agricultural and tourism sector. The model shows results starting from the year 2000, which is the earliest date from which we have tourism data. For the photovoltaic sector, our data only go back to the year 2020. Before the year 2000, the model therefore only considers the number of jobs in the agricultural sector.

For this KPI a sustainability situation would be considered when the total number of jobs equals or exceeds 54872 jobs, the number of jobs in 2021.

What is the impact of the set of measures on this KPI?

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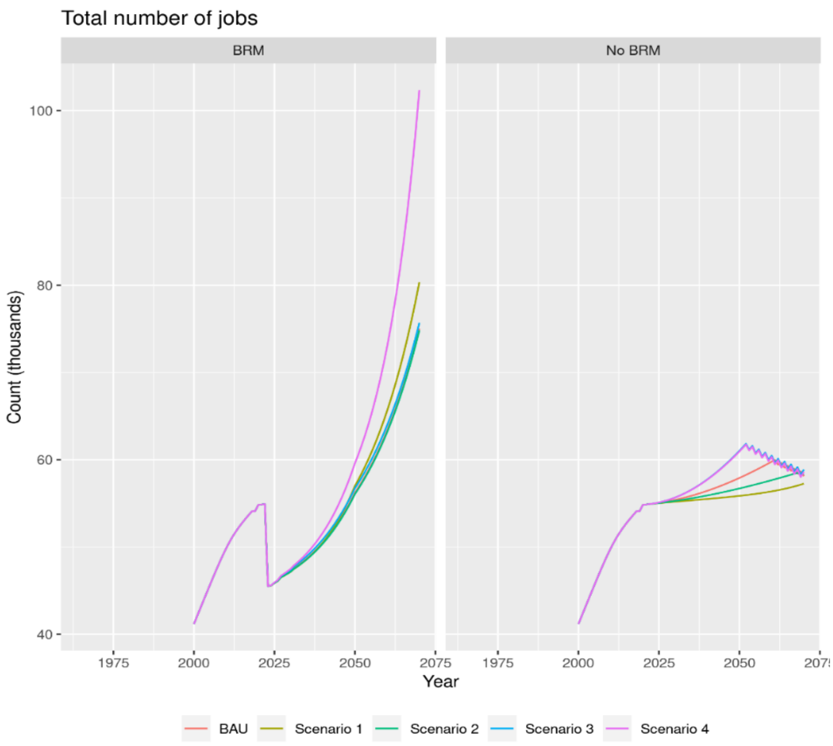

Figure 7: Impact of implementation of the BRM on KPI 'Total number of jobs' under 5 different scenarios.

If the BRM is implemented, the total number of jobs is expected to suffer a sudden decrease of about 10.000 jobs right after the implementation of the Business Roadmap and under any Scenario taking place. This initial reduction in number of jobs is the immediate effect of the reduction in irrigated areas for agriculture. However, the number of jobs is expected to increase exponentially from 2023 onwards under any Scenario taking place although with some years of difference between them, roughly reaching the same number of jobs as in 2021 by 2040, and reaching between 50.000 and 60.000 jobs by 2050.

If the Business Roadmap is implemented, this KPI would take several years to achieve a sustainable situation, although there is lot of uncertainty involved. Nevertheless, this KPI is expected to show a greater performance for the medium and longer term compared to if no actions are taken.

Given the impact of climate and ecological changes, economic growth and other external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

If no actions are taken, this KPI would show almost identical results under Scenarios 3 and 4, that is to say, a first a steep increase in the total number of jobs reaching a peak short after 2050, when more than 62.000 jobs would be created, and gradually decreasing from 2050 onwards. Under the BAU Scenario this KPI follows a similar trend as under Scenarios 3 and 4 but with a slight time delay. Under Scenarios 1 y 2 the total number of jobs increases slowly but steadily over time, reaching a total number of about 58.000 jobs by 2070.

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If the BRM is not implemented, this KPI would be in a sustainable situation over time and under any scenario taking places, although its performance in the medium and long term would be suboptimal compared to if the BRM is implemented.

KPI 7: Total gross economic benefit

What is considered sustainable and robust in the Mar Menor region?

The total gross economic benefit depends on the yearly gross economic benefit of the photovoltaic, agricultural and tourism sectors. Several variables therefore play an indirect role, such as agricultural revenue per hectare, electricity price, mean number of hours per day of photovoltaic electricity production and observed growth rate of tourism.

Since 2000, the total gross economic benefit of the Campo de Cartagena watershed and the Mar Menor lagoon area has increase yearly until 2016. In that year, the Mar Menor degradation for the first time became very visible for the larger public, since the water turned into a ‘green soup’ with strong implications for tourism attractiveness. Since then, the total gross economic benefit reached a peak, and has remained almost steady until 2021. The poor environmental status of the Mar Menor lagoon, highly visible during green soup and later anoxia events leading to the death of millions of individuals of marine fauna and flora, has become a major driver constraining the economic growth in the area.

For this KPI, a sustainable situation would be considered when the total gross economic benefit equals or exceeds 1,647 million of Euros, the maximum total economic benefit generated for this KPI in the region that was reached in 2018.

What is the impact of the set of measures on this KPI?

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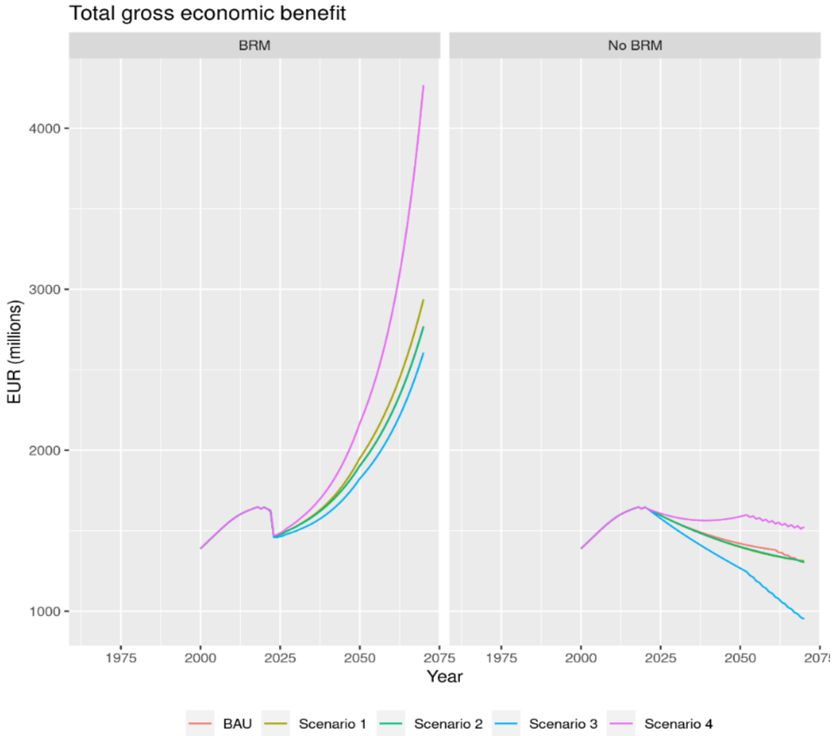

Figure 7: Impact of implementation of the BRM on KPI 'Total gross economic benefit' under 5 different scenarios.

While the implementation of the BRM is expected to result in an initial decline of the total gross economic benefit, it is expected to have a highly positive effect on this KPI under any Scenario in the medium and long term. Under Scenario 4 this KPI shows the highest total economic benefit, accounting for almost 2000 million of Euros some years before 2050. Under the other scenarios, this KPI is expected to show a similar trend under, only with some years of delay.

Considering a sustainable situation for this KPI, if the Business Roadmap is implemented, it would take between 15 and 20 years, depending on the scenario, for this KPI to achieve a sustainable situation. Notwithstanding, it is expected that the implementation of the BRM would maintain this KPI in a sustainable situation in the medium and long term regardless of the Scenario taking place.

Given the impact of climate and ecological changes, economic growth and other external uncertainties, to what degree can dedicated interventions bring this KPI within a sustainable and robust state?

If the Business Roadmap is not implemented, the total gross economic benefit is expected to decrease under all Scenarios, although with contrasting trajectories. Under Scenario 4, the total gross economic benefit would decrease until 2035, when it would start increasing slightly until 2050, and continue decreasing afterwards. Under Scenario 3, this KPI is expected to display a linear decrease, showing the lowest total gross economic benefit values compared to any other Scenarios. This KPI displays a similar decreasing trend over time under the BAU Scenario and Scenarios 1 and 2.

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If the BRM is not implemented, it is expected that this KPI would never reach a sustainable situation under any of the Scenarios taking place. Scenario 4 would be the most favorable for this KPI if no further measures are taken.

7.4. CONCLUSIONS

The analysis of the impacts of implementation of the Business Roadmap, consisting of the 14 solutions proposed by stakeholders, highlights a range of important impacts and benefits supporting more sustainable development of the Mar Menor and Campo de Cartagena socio-ecosystem. The results also show that solutions to reach restoration of the socio-ecosystem need time, investment and joint efforts. The main conclusions regarding implementation of the BRM are as follows:

1. The agricultural pressure on water resources, the amount of brine produced, and the amount of agricultural nutrients discharged in the Mar Menor lagoon, would all strongly decrease. This will contribute significantly to reduce the environmental degradation of the Mar Menor lagoon in the short, medium and long term.

2. Although, the implementation of the BRM is expected to entail an initial reduction on the total number of jobs and the total gross economic benefit, a highly positive impact is expected on both key performance indicators for the medium and long term, ensuring the social and economic long term sustainability of the region.

3. The resiliency of the different sectors to external socioeconomic, political and climate change drivers increase with implementation of the BRM, since most KPIs will maintain within sustainable boundaries, which is not achieved without implementation of the BRM. This proofs the robustness of the BRM to external political, socioeconomic and climatic drivers of change.

4. Important coastal-rural synergies are established based on the positive impact of a good environmental status of the lagoon on tourism potential that is achieved through a transition to more sustainable agriculture and promoting alternative income from photovoltaic energy and promotion of rural and coastal ecotourism activities. This is fundamental to ensure the sustainable development of the Mar Menor lagoon and Campo de Cartagena watershed.

5. An in depth analysis of the partial solutions of the BRM shows that a minimum of six specific solutions is needed to reach thresholds for sustainable economic, environmental and social development. The optimum value of sustainable development is reached at eleven of the fourteen solutions of the BRM. This analysis is relevant to prioritize solutions in case of limited available resources for their implementation.

If the Business Roadmap is not implemented:

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1. It is expected that most key performance indicators will not reach sustainable thresholds in the short, medium or long term. Therefore, the Campo de Cartagena watershed and Mar Menor lagoon are expected to fail accomplishing main objectives contemplated in the EU legislation (e.g. Water Framework Directive and the European Green Deal), or in the targets specified in the National and Regional legislation.

2. External factors such as climate change and international socio-economic and political developments, as reflected in the evaluated scenarios based on Shared Socioeconomic Pathways (SSP), are expected to have a much greater impact on the environmental, social and economic sustainability of the region than if the business roadmap is implemented. This means that implementation of the BRM makes the sustainable development of the socio-ecosystem of the Mar Menor and surrounding Campo de Cartagena more robust.

7.5. REFERENCES

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8. DISCUSSION

The design and testing of **evidence-based** policy recommendations for coastal-rural synergy was a key objective of the project. Policy recommendations and business models were developed based on a combination of stakeholder engagement (to identify and prioritize problems, solutions and opportunities), systems modelling (to analyze and compare the impacts of different policies and business actions) and scenario analysis (to examine the role of uncertainty on these impacts). Here **policy robustness** is understood to be the ability of an action to achieve the desired outcome regardless of the exogenous conditions affecting the coastal-rural system. The uncertain climate and socio-economic conditions have been captured in the scenarios which are described in WP5 deliverable D19 (D'Haese et al, 2022)[1]. This robustness criterion is not an absolute measure but should be considered against the acceptable range for key indicators although, at least in some cases, the minimum and maximum of the range may be identical. For example, in the case of the Belgian MAL the water levels are maintained at their target levels to meet both the seasonal fluctuations in demand for agriculture and nature as well as the long-term impact of climate change.

Cross-cutting the scenarios (deliverable D19), road maps (deliverable D11) and KPIs (deliverable D19 and this deliverable) four situations can be observed when examining the outcomes of the robustness analysis for the MALs:

a) In response to changes in the uncertain conditions the KPIs generally remain within the acceptable range for a specific action or set of actions (strategy);
b) In response to changes in the uncertain conditions not all KPIs remain within the acceptable range for a specific set action or set of actions (strategy);
c) The response of the KPIs to changes in the uncertain conditions is limited in significance when compared to the differences between the actions or strategies;
d) The response of the KPIs to uncertain conditions is significant but more complex and depends on, for example, the time line or specific combination of actions and scenarios.

For the Belgian Multi-Actor Lab, as explained in Chapter 2, policy robustness (maintaining target levels for all scenarios) is intrinsic to the modelled water system with self-controlled interventions to water shortages and excesses. Nevertheless, the model can generate potential conditions with an impact surpassing the limitations of the water interventions, thereby demonstrating the limitations of the policy robustness for this water system, in particular due to climate change.

For the SW Messinia region (Chapter 3) the proposed actions, even if partially applied, were concluded to be robust, at least in terms of the trends towards sustainability. An important exception was made for the eventuality of a lagoon collapse (Fig. 3) which affects not only the ecosystem but also local tourism. Clearly,

[1] D'Haese N, De Kok JL, Notebaert B, Viaene P, Destouni G, Vigouroux G, Maneas G, Kastanidi E, Karageorgis A, Venrier F, Othoniel B, Lescot JM, Lazar L, Pop R, Rodino S, Martínez-López J and De Vente J. (Octobre, 2022)Deliverable D19 Scenarios exploring land-sea interactions in six European coastal areas. https://h2020-coastal.eu

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the system is not robust for this event and proper actions should be put into place to prevent the occurrence of a collapse or at least reduce the consequences.

For the Baltic (Section 4.3, Fig. 13) situation a applies: the legacy measures clearly surpass other actions in terms of policy robustness – i.e. improving the target levels closer to the acceptable range for all scenarios. However, we also observe that the differences for these KPIs between different scenarios are small compared to the differences between the action sets (legacy vs. other).

For the Charente region (Chapter 5) the outcomes of the robustness analysis were summarized in a radar plot (Fig. 27) and Table 13. The BRM "desirable future" was identified as robust strategy, outperforming the alternative sets of actions. For this example, the robustness analysis helped identifying a more resilient strategy.

For the Danube Multi-Actor Lab (Section 6.3, Fig. 19) we notice that the nitrogen load, a key KPI, responds more strongly to a change from measure 1 to 3 than for the four scenarios. This corresponds to situation c and is observed for most MALs.

For the Mar Menor region (Chapter 7) the Business Road Map consist of 14 solutions, which can implemented partially. The analysis shows that the robustness of the BRM increases with: (1) the number of solutions implemented and (2) the developing implementation of solutions over time. In other words: policy robustness should also be considered as a dynamic and sub-optimal concept.

The robustness analysis was carried out in three steps: (1) modelling the impacts of different measures or sets of measures (BRMs) on selected KPIs for different scenarios, (2) defining an acceptable, sustainable range for the KPIs and (3) cross comparison of sets of actions in terms of achievement of outcomes in the acceptable range. The radar plots used by several MALs can be useful for obtaining an overview of the policy robustness – cutting across combinations of BRMs, KPIs and/or scenarios.

Finally, we conclude robustness analyses can help distinguish promising BRMs from less robust alternatives strategies but the effort needed to implement the steps can be considerable, depending on the complexity of the model and number of scenarios and KPIs. Future projects should therefore address robustness at an early stage of the modelling process and models. Model documentation should include aggregated indicators measuring the robustness of the set of actions in effect in specific simulations.

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