Deliverable 7.4. Report on the evaluation of scenarios of changed soil environmental footprint for a range of policy scenarios

Authors: Luis Garrote, David Santillán, Ana Iglesias (UPM) & ISS

Report number: t.b.a.

Deliverable: D7.4

Report type: Deliverable

Issue date: 27 Dec 2019

Project partner: UPM

www.iSQAPER-project.eu

DOCUMENT SUMMARY	
Project Information	
Project Title	Interactive Soil Quality Assessment in Europe and China for Agricultural Productivity and Environmental Resilience
Project Acronym	iSQAPER
Call identifier	The EU Framework Programme for Research and Innovation Horizon 2020: SFS-4-2014 Soil quality and function
Grant agreement no:	635750
Starting date	1-5-2015
End date	30-4-2020
Project duration	60 months
Web site address	www.isqaper-project.eu
Project coordination	Wageningen University
EU project representative&coordinator	Prof. Dr. C.J. Ritsema
Project Scientific Coordinator	Dr. L. Fleskens
EU project officer	Ms Adelma di Biasio
Deliverable Information	
Deliverable title	Report on the evaluation of scenarios of changed soil environmental footprint for a range of policy scenarios
Author	Ana Iglesias
Author email	ana.iglesias@upm.es
Delivery Number	D7.4
Work package	WP7
WP lead	UPM
Nature	Deliverable
Dissemination	Project partners
Editor	L. Fleskens
Report due date	December 2019
Report publish date	January 2020
Copyright	© iSQAPER project and partners

Participants list

partici-pants	iSQAPER Participant legal name + acronym	Country
1	Wageningen University (WU)	Netherlands
2	Joint Research Center (JRC)	Italy
3	Research Institute of Organic Agriculture (FIBL)	Switzerland
4	Universität Bern (UNIBE)	Switzerland
5	University of Évora (UE)	Portugal
6	Technical University of Madrid (UPM)	Spain
7	Institute for European Environmental Policy (IEEP)	UKand Belgium
8	Foundation for Sustainable Development of the Mediterranean (MEDES)	Italy
9	ISRIC World Soil Information (ISRIC)	Netherlands
10	Stichting Dienst Landbouwkundig Onderzoek (DLO)	Netherlands
11	Institute of Agrophysics of the Polish Academy of Sciences (IA)	Poland
12	Estonian University of Life Sciences, Institute of Agricultural and Environmental Sciences (IAES)	Estonia
13	University of Ljubljana (UL)	Slovenia
14	National Research and Development Institute for Soil Science, Agrochemistry and Environmental Protection (ICPA)	Romania
15	Agrarian School of Coimbra (ESAC)	Portugal
16	University of Miguel Hernández (UMH)	Spain
17	Agricultural University Athens (AUA)	Greece
18	Institute of Agricultural Resources and Regional Planning of Chinese Academy of Agricultural Sciences (IARRP)	China
19	Institute of Soil and Water Conservation of Chinese Academy of Sciences (ISWC)	China
20	Soil and Fertilizer Institute of the Sichuan Academy of Agricultural Sciences (SFI)	China
21	CorePage (CorePage)	Netherlands
22	BothEnds (BothEnds)	Netherlands
23	University of Pannonia (UP)	Hungary
24	Institute of Soil Science of the Chinese Academy of Sciences (ISS)	China
25	Gaec de la Branchette (GB)	France

Report on the evaluation of scenarios of changed soil environmental footprint for a range of policy scenarios

Deliverable 7.4 of WP7

iSQAPER

Interactive Soil Quality Assessment in Europe and China for Agricultural Productivity and Environmental Resilience

Leading author: Luis Garrote (UPM–Universidad Politécnica de Madrid, Spain)

Co-authors:

David Santillán, Ana Iglesias (UPM, Spain)

Contributors (ISS, China)

December 2019

Table of contents

LIST OF FIGURES

LIST OF TABLES

Executive summary

The main focus of this Deliverable 7.4 to evaluate scenarios of changed soil environmental footprint for a range of policy scenarios using the model tools in Europe and China (Objective 4 of WP7). The soil environmental footprint is defined by a combination of the soil quality indicators developed in Tasks 7.1 and 7.2. The scenarios developed in Task 7.3 are then applied to the upscaling model to evaluate changes in the soil quality indicators driven by changes in agricultural management practices. Changes in soil environmental footprint are quantified in terms of the effect of management practices on soil productivity, nutrients and biodiversity.

The specific objectives of Deliverable 7.4 are: (a) to design a framework to evaluate the effect of policy scenarios (identified in Deliverable 7.3) on soil quality indicators through the upscaling model (developed in Deliverable 7.2); (b) to apply the upscaling model to obtain projections of the changes in soil quality indicators bought by the implementation of policy scenarios; and (c) to evaluate changes of soil environmental footprint resulting from changes in soil quality indicators.

The soil environmental footprint is defined by a combination of the indicators developed in Deliverables 7.1, 7.2 and 7.3. The approach is based on the upscaling model that expands the scientific results generated in iSQPAPER at the local level to a wider geographical and management context. Within the context of iSQAPER, the scenarios defined to evaluate changes in the soil environmental footprint are driven by changes in agricultural management practices. Regional changes in agricultural management practices are linked to the policy scenarios co-developed in a multi-actor framework and reported in Deliverable 7.3. The scenarios are necessarily a simplification of the complex policy processes that influences farmer choices at the local and regional levels. Changes in soil environmental footprint are quantified in terms of their effects on soil organic carbon, productivity and biodiversity.

The central actor in the analytical process is the farmer, who is managing a plot of land where a certain crop is grown under a typical farming system. This plot of land is subject to policy scenarios, determined by the combination of agro-environmental determinants at the regional level, defined within the targets of the Common Agricultural Policy, environmental policy, market conditions and socio-economic development.

Functional relations to define the effect of agricultural management practices on ecosystem services are formulated in qualitative terms.

This iSQAPER deliverable presents the results of the application of the upscaling model to policy scenarios to obtain the spatial representation of soil quality indicators in order to evaluate soil environmental footprint. The policy scenarios evaluated are:

Expected: The Expected scenario maintains the observed tendency in the implementation of beneficial agricultural management practices.

Regional Targets: This scenario assumes the same rate of implementation of agricultural management practices, but considers that policy efforts are focused on areas where soil threats are more active and soil quality indicators are poorer. The emphasis, therefore, is place on targeting the regions that where the practices would be more beneficial.

Towards 2050: This scenario assumes an intensification on the rate of implementation of agricultural management practices as a result of public policies.

Policy portfolios for each scenario include the selective implementation of certain combinations of management practices. The results for individual farming systems are grouped together to account for subgrid variability. The results for different agricultural management practices are combined to produce the effect of each policy scenario. Results of different soil quality indicators are then combined to produce descriptions of improvement of soil environmental footprint. Soil Environmental foot print scenarios are then analysed in terms of improvements with respect to the current situation.

Our results show that the expected scenario is not enough to make significant contributions towards improving the soil environmental footprint and the Towards 2050 scenario delivers important benefits. The Regional Targets scenario delivers important benefits in key challenging areas, where the effects improve greatly the soil environmental footprint. The results of this analysis inform the policy workpackage to iSQAPER (WP8).

1 Introduction

1.1 Integration of Task 7.4 in iSQAPER

The goal of WP7 is to evaluate the change in soil environmental footprint that can be brought by the application of beneficial agricultural management practices on representative farming systems of Europe and China. This objective is achieved through the application of an upscaling model that relies on work developed in WPs 2 to 8 (see Figure 1). The dynamic upscaling model was presented in Deliverable 7.2. The model was co-developed, validated and refined with stakeholders through informal consultations and in a formal workshop, reported on Deliverable 7.3.

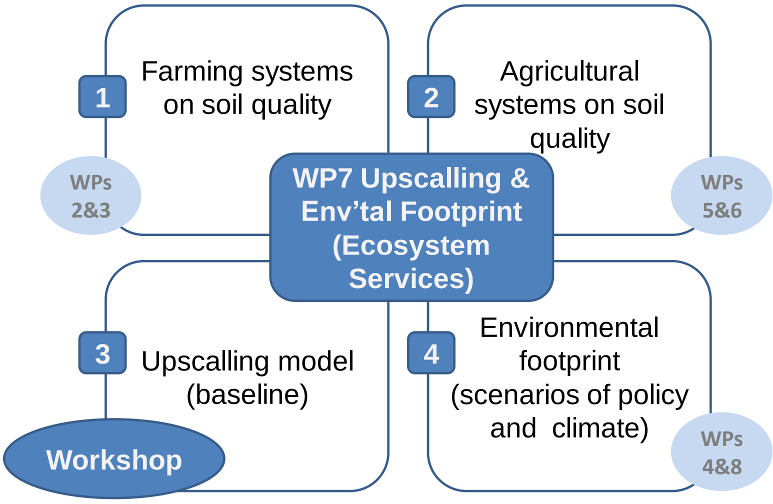


Figure 1. Approach to evaluate the environmental footprint in WP7

In Task 7.4, the upscaling model was applied to account for the implementation of agricultural management practices driven by policy and other physical, social and economic factors. Task 7.4 is mostly related to WP4 and WP8. The main output of the project, the SQAPP tool, was developed in WP4. The upscaling model is based on the concepts developed in the tool. It shares the same data model, although it applies a simplified version, dealing with a reduced set of soil quality indicators and a simplified description of measures for soil quality improvement. WP8 is devoted to policy analysis. As such, in provides insights on how public policy related so soils may induce the implementation of beneficial agricultural management practices, which in turn will improve the environmental footprint of soils in Europe and China. The science behind the upscaling model is based on results of WP3 and WP6. The model also draws information of case study sites analysed in WP5.

1.2 Objectives

This Deliverable 7.4 is framed into WP7 titled "Upscaling of practices and assessing soil environmental footprint at the level of Europe and China". The specific objectives of WP7 are:

1. Define typical farming systems in Europe and China and their effects on soil quality.
2. Identify key management practices affecting soil quality and their applicability in various farming systems in Europe and China.
3. Develop scenarios of future farm and soil management systems in Europe and China for improved productivity and enhanced soil quality.
4. Evaluate scenarios of changed soil environmental footprint for a range of policy scenarios using the model tools in Europe and China.

Deliverable 7.4 reports on the fourth specific objective. The soil environmental footprint is defined by a combination of the soil quality indicators developed in Tasks 7.1 and 7.2. The scenarios developed in Task 7.3 will be applied to the upscaling model to evaluate changes in the soil quality indicators driven by changes in agricultural management practices. Changes in soil environmental footprint are quantified in terms of the effect of management practices on soil productivity, nutrients and biodiversity. The specific objectives of Deliverable 7.4 are:

- Design a framework to evaluate the effect of policy scenarios (identified in Deliverable 7.3) on soil quality indicators through the upscaling model (developed in Deliverable 7.2).
- Apply the upscaling model to obtain projections of the changes in soil quality indicators bought by the implementation of policy scenarios.
- Evaluate changes of soil environmental footprint resulting from changes in soil quality indicators.

This iSQAPER deliverable presents the results of the application of the upscaling model to policy scenarios to obtain the spatial representation of soil quality indicators in order to evaluate soil environmental footprint. Following this introduction, Section 2 summarizes the conceptual approach of the upscaling model developed in Deliverable 7.2. Section 3 deals with the core development of the Deliverable: the conceptual framework to evaluate the effect of the set of policy scenarios identified in Deliverable 7.3. Section 4 presents the results obtained while upscaling the effect of changes in agricultural management practices to the continental level. Section 5 discusses the implications in terms of soil environmental footprint. Section 6 presents the conclusions.

2 The conceptual approach of the upscaling model

A brief summary of the conceptual approach of iSQAPER upscaling model is presented in this section. The details are fully described in Deliverable 7.2. The model is based on a geospatial database of soil quality indicators (SQI) and agricultural management practices (AMP) and on the relationships between AMP and SQI established on Deliverables 3.2 and 3.3.

2.1 Basic framework

The upscaling model intends to provide results of the scientific knowledge at the local level to a wider geographical context, to understand how agricultural management practices that mitigate soil threats also affect ecosystem services. In order to perform this task, the model accounts for the basic processes that influence agricultural management of the soil. The basic approach is illustrated on Figure 2, where the relevant processes are represented.

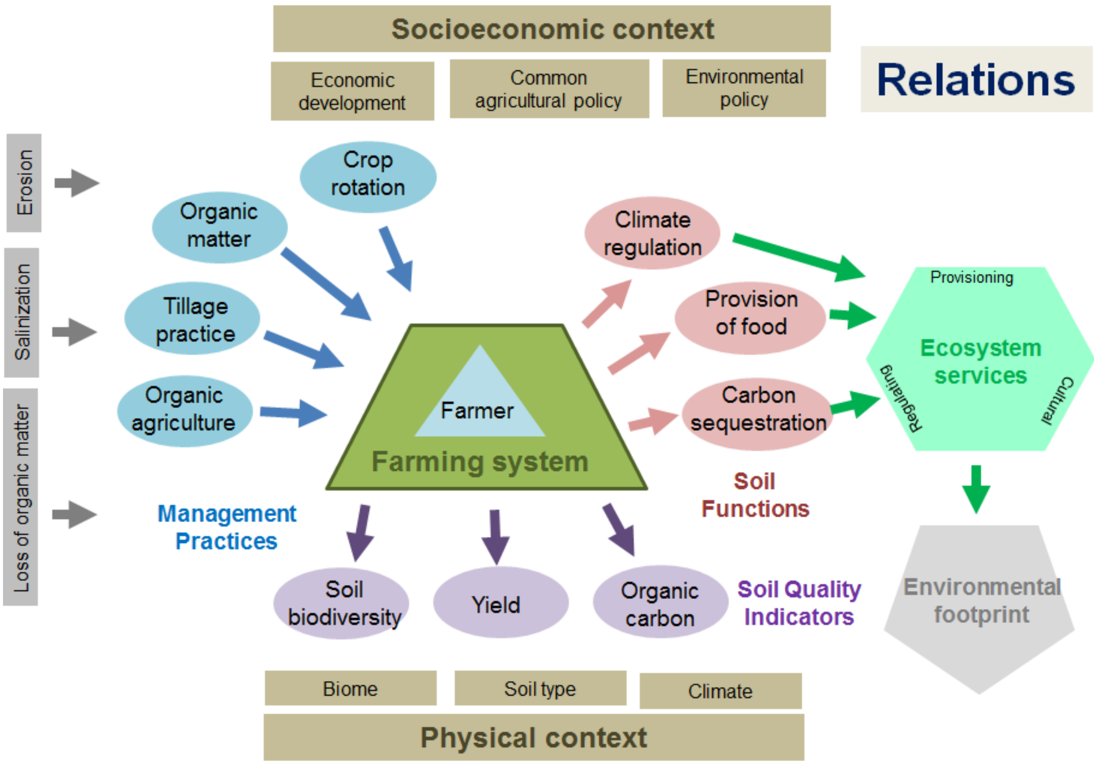


Figure 2. Overall representation of the upscaling approach

The central actor in the process is the farmer, who is managing a plot of land where a certain crop is grown under a typical farming system. This plot of land is subject to a physical context, determined by biome, soil type, climate and other factors that control biophysical processes. The farmer is also immersed in a socio-economic context that influences agricultural activity: Common Agricultural Policy, environmental policy, financial instruments, market conditions and socio-economic development determine managing decision regarding crop selection and management practices. The choice of management practices is also influenced by existing soil threats, like soil erosion, desertification, loss of organic matter and many others. The farmer intends to control local soil threats by applying suitable management practices.

Science developed in iSQAPER project determines that certain agricultural management practices may have a beneficial effect on agricultural soil conditions. These conditions are described through a set of suitable indicators, chosen because they represent the status of the soil. The analysis of Long Term Experiment (LTE) sites proves that these effects can be objectively quantified in terms of such indicators. Under the upscaling approach, policy is considered to be a driver of change, motivating farmers to adopt beneficial management practices. The upscaling model intends to quantify the global effect of policies promoting beneficial agricultural practices. In order to do so, functional relations are established between the agricultural management practices and the soil quality indicators for different farming systems. The improved values of soil quality indicators can then be used to evaluate the soil environmental footprint by accounting for soil functions that support ecosystem services. Through the upscaling model a spatial representation of soil environmental footprint may be generated under a set of policy scenarios. These upscaled maps can be used as a decision support tool for policy identification and implementation.

2.2 Linking farming systems, management practices and soil quality indicators

The dynamic models developed in WP7 aim to determine the effect of the evolving physical and socioeconomic context (climate, population, economic development, policies) on the implementation of dominant management practices that have an impact on soil quality. The complex interplay between physical, chemical and biological factors that affect soil quality needs to be simplified in order to produce global results at the continental scale. For this reason, the analysis in WP7 is focused on a limited number of essential components that are introduced in this section. The components of the upscaling model are summarized in Figure 3.

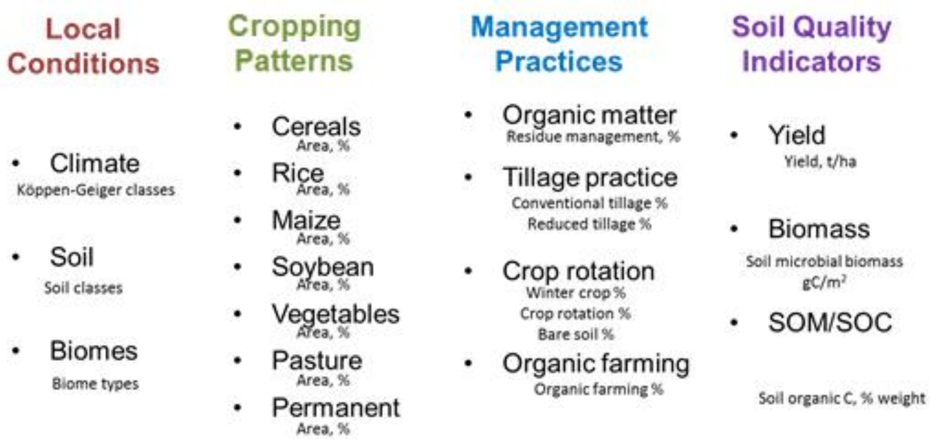


Figure 3. Main components of the iSQAPER upscaling model

2.3 Deriving functional relations for ecosystem services

Functions that relate agricultural management practices and soil quality indicators are defined from the results compiled for the LTE sites. We start from the reference values obtained in Deliverable 3.2 and published in Bai et al., 2018 and adapt them to different farming systems accounting for the variability of local conditions.

Table 1. Relevant results (response ratios) of Long Term Experiment sites, derived from Table 1 of Bai et al. (2018), shows the median values of the response ratios, together with the standard deviation of the results obtained for the relevant combinations of soil quality indicators and agricultural management practices.

Table 1. Relevant results (response ratios) of Long Term Experiment sites

	Yield		Earthworms		Soil Organic Matter	
	Median	SD	Median	SD	Median	SD
Organic matter	1.37	1.19	1.69	1.67	1.29	0.33
No tillage	0.98	0.12	1.53	0.62	1.20	0.69
Crop rotation	1.17	0.40	1.73	1.55	1.25	0.61
Organic farming	0.89	0.30	1.93	0.37	1.12	0.56

These mean values are adapted to local conditions through interaction with local stakeholders from case study sites. Experts were asked to fill a questionnaire about the impact of management practices on soil quality for the farming systems available at their case study site. Based on their responses and on the analyses carried out in WP3, the effect of the management practice for every farming system was classified into qualitative categories that modified the average response ratios obtained from LTE sites.

2.4 Spatial analysis

The objective of the upscaling model is to produce maps of improvement of soil environmental footprint under different policy scenarios. Therefore, the model needs to account for spatially-explicit representation of soil processes. The foundation of the spatial representation is the data catalogue introduced in Deliverable 7.1. The unit of computation is the model cell, which corresponds to a spatial resolution of 0.5 minutes (approximately 9 km at the Equator). Information about the grid cell includes the climate zone, the soil type, the cropping patterns within the cell (there may be several), the soil status described by the available soil quality indicators and the current degree of implementation of each category of agricultural management practice in the region. The scenario determines the additional degree of implementation of each agricultural management practice to be achieved in the time frame of the analysis. Upscaling functional relations are applied to appropriate grid cells where each agricultural management practice is considered to be implemented. This leads to a modification of the soil quality indicators, which is the initial output of the upscaling model.

In order to estimate the effect of management practices on soil quality indicators, it is essential to account for values of each point in the coarse-scale geographical analysis. The basic rationale of the upscaling model is that the influence of soil management practices will be larger on areas with relatively lower values of soil quality indicators. Assuming that the rest of conditions are equal, the fact that a local point shows a low value of the soil quality indicators may be explained by poorer soil management practices.

Local conditions were established based on the variable considered most relevant for each soil quality indicator. Yield was linked to climate zone, soil biomass was linked to biome and soil organic carbon was linked to soil type. The local variable selected for Yield is climate zone, taken from the Köppen-Geiger climate classification system. The basic variable for zonation is the World Map of Köppen-Geiger Climate Classification distributed by the University of Vienna (Rubel and Kottek, 2010). Local yield for a certain farming system is compared to the distribution of yields for the same farming system obtained from all cells in the same climatic zone. The local variable selected for Soil Organic Carbon is soil type. The basic variable for zonation is the Digital Soil Map of the World distributed by FAO (Version 3.6, completed January 2003). Local Soil Organic Carbon for a certain model cell is compared to the distribution of SOC obtained from all cells of the same soil type.

In order to account for local conditions, soil quality indices are re-scaled to standardized variables that compare local values to conditions for the same local group. The "Standardized Soil Quality Index" is defined applying the following equation:

$$SSQI = \frac{x - \mu}{\sigma}$$

Where SSQI is the standardized soil quality index for a certain local group (for instance, cereal yield in Arid (B) climate); μ is the average value of the soil quality index in all cells in the same local group and σ is the standard deviation of the soil quality index values of all cells in the same local group.

The response of soil quality indicators to the susained application of the management practice is based on the conclusions of the analysis of the LTE sites. The main value is the response ratio, RR, defined as:

$$RR = \frac{SQI_{MP}}{SQI_0}$$

Where SQI_0 is the value of the soil quality indicator in the reference condition and SQI_{MP} is the value of the soil quality indicator after the application of the management practice. The results of the long term experiments show that there is a significat uncertainty in the response ratios observed in different locations. The distributions of the response ratios were characterized in Table 1. Relevant results (response ratios) of Long Term Experiment sites through their median values and their standard deviation. These two values are taken as input for the local influence models. Local conditions are accounted through the standardized soil quality indicator.

The local influence model determines the response ratio for the individual cell as a function of the standardized soil quality indicator. The effect of the measure is considered to be larger or smaller values of the standardized soil quality indicator, according to the function definition shown in Figure 4.

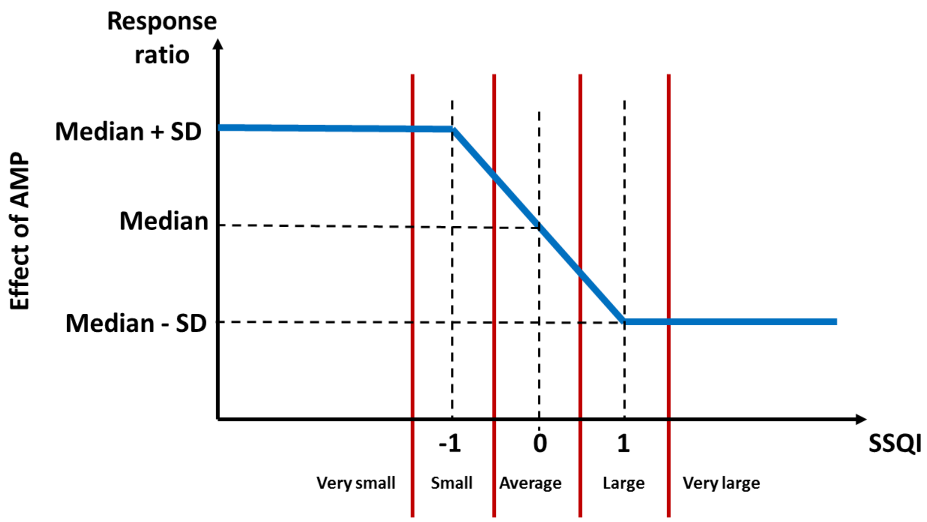


Figure 4. Function for the local influence model

2.5 Results of Deliverable 7.2

The upscaling model described above was applied in Deliverable 7.2 to obtain results of an additional implementation of 10% of the four agricultural management practices. Results were obtained for the three soil quality indicators in all seven cropping patters. A summary of those results is presented on Appendix one, where results obtained for the soil quality indicators in the different cropping patterns have been averaged using as weights the area of each cropping pattern in the cell.

3 Conceptual framework for policy analysis

The conceptual framework for the evaluation of soil environmental footprint is presented in this section. The policy scenarios defined in Deliverable 7.3 are presented first. Then, the implementation of these scenarios in the iSQAPER upscaling model is discussed. Finally, some information is provided regarding the analysis of results.

3.1 Definition of policy scenarios

The objective of this Deliverable is to evaluate the impact of policy scenarios defined in Deliverable 7.3 on soil environmental footprint in Europe and China. Policy scenarios are defined as a certain level of additional implementation of agricultural management practices. Scenarios are defined locally on the case study sites through consultation with stakeholders and taking into account the output from WP8, devoted to policy analysis. There are three characteristic scenarios:

Expected: The Expected scenario maintains the observed tendency in the implementation of beneficial agricultural management practices. It represents a policy scenario where no particular emphasis is placed on soil health protection. The rates of implementation were estimated from previous projects, like SmartSoils, that studied the level of implementation of management practices.

Towards 2050: This scenario assumes an intensification on the rate of implementation of agricultural management practices as a result of public policies. Experts in each case study site were asked to give their expectation on the desirable rate of implementation of each group of agricultural management practice at their sites. This target can be considered as a reference, in order to obtain projected values of the effect of this policy.

Regional Targets: This scenario assumes the same rate of implementation of agricultural management practices, but considers that policy efforts are focused on areas where soil threats are more active and soil quality indicators are poorer. The emphasis, therefore, is place on targeting the regions where the practices would be more beneficial.

The levels of implementation of agricultural management practices are presented in the following tables. Table 2 corresponds to the Expected scenario and Table 3 corresponds to the Towards 2050 and Regional Targets scenarios. The tables show the projected increase (in percentage) of the implementation of the agricultural management practices in the time horizon of the analysis.

Table 2. Level of implementation of agricultural management practices for the Expected scenario in Europe and China

CS	Site	Organic matter	Reduced Tillage	Crop rotation	Organic farming
1	Argentré du Plessis (FR)	1.3	0.4	1.3	0.8
2	De Peel (NL)	1.1	0.8	1.1	1.1
3	Cértima (PT)	1.3	0.8	1.3	1.1
4	SE Spain (ES)	1.3	0.8	0.8	1.6
5	Crete (GR)	1.1	1.1	0.5	1.3
6	Ljubljana (SL)	1.3	0.8	1.1	1.1
7	Zala (HU)	1.3	0.5	0.5	0.5
8	Braila (RO)	0.3	0.8	1.3	0.3
9	Trzebieszów (PL)	1.3	0.2	0.8	1.1
10	Tartuuma (EE)	0.8	1.3	0.4	0.5
11	Qijang (CN)	1.3	0.5	0.5	0.5
12	Suining (CN)	0.8	1.3	0.5	0.5
13	Zhifanggou (CN)	0.8	1.1	0.8	0.5
14	Gongzhuling (CN)	0.5	1.3	1.1	0.5

Table 3. Level of implementation of agricultural management practices for the Towards 2050 and Regional Targets scenarios in Europe and China

CS	Site	Organic matter	Reduced Tillage	Crop rotation	Organic farming
1	Argentré du Plessis (FR)	4.0	1.3	4.0	2.3
2	De Peel (NL)	3.3	2.3	3.3	3.3
3	Cértima (PT)	4.0	2.3	4.0	3.3
4	SE Spain (ES)	4.0	2.3	2.3	5.0
5	Crete (GR)	3.3	3.3	1.7	4.0
6	Ljubljana (SL)	4.0	2.3	3.3	3.3
7	Zala (HU)	4.0	1.7	1.7	1.7
8	Braila (RO)	1.0	2.7	4.0	1.0
9	Trzebieszów (PL)	4.0	0.7	2.7	3.3
10	Tartuuma (EE)	2.7	4.0	1.3	1.7
11	Qijang (CN)	4.0	1.7	1.7	1.7
12	Suining (CN)	2.7	4.0	1.7	1.7
13	Zhifanggou (CN)	2.7	3.3	2.7	1.7
14	Gongzhuling (CN)	1.7	4.0	3.3	1.7

3.2 Implementation of policy scenarios on iSQAPER upscaling model

The implementation of the policy scenarios in the iSQAPER upscaling model implies a number of steps. First, the local values at the case study sites need to be upscaled to the entire region under analysis. A simple spatial interpolation procedure has been adopted for this task. This produces a smooth map of implementation across Europe and China which accounts for regional variations.

Secondly, the implementation level has to be applied at each cell in the domain. In the iSQAPER upscaling model, the implementation of the management practices is carried out by selecting a random number of cells such that the practice is implemented in the prescribed percentage of the cultivated area for the cropping pattern under study. In the cells where the measure is implemented, we compute the values of the soil quality indicators by multiplying the current value by the response ratio, determined from local conditions as described in the previous chapter. The soil quality indicators of cells where the practice is not implemented remain unchanged, i.e., the response ratio is null. To account for the effect of the randomly chosen cells for implementation, we conduct 100.000 realizations of the raffle, and compute the mean value and standard deviation of the response ratio in every cell.

In the Regional Targets scenario, this procedure has been modified to concentrate the policy efforts on the cells that show lower values of the standardized soil quality indicator. We assume that the implementation level will be higher in areas where the value of the soil quality indicator is low, since policy will be more focused on increasing the implementation level in the regions where the action is most needed.

Finally, we need to account for the possibility of several agricultural practices applied in the same cell. The analysis at LTE sites were carried out by applying one singe agricultural management practice. If two or more practices are applied on the same plot, it can be expected that combine effect would be less than the sum of individual effects. We have accounted for this possibility in the model by computing the probability of having more than one agricultural management practice applied to a single cell under ransom selection and defining an efficiency coefficient.

The results of the implementation of the policy scenarios in the iSQAPER model are presented in the following sections.

3.2.1 Spatial distribution of implementation levels in the Expected scenario

The spatial distribution of the implementation of agricultural management practices in the Expected scenario is presented in the following figures. The implementation of organic matter is presented in Figure 5, the implementation of reduced tillage is presented in Figure 6, the implementation of crop rotation is presented in Figure 7 and the implementation of organic farming is presented in Figure 8. The figures show the projected percentage increase in application of the management practices contemplated in the scenario Expected.

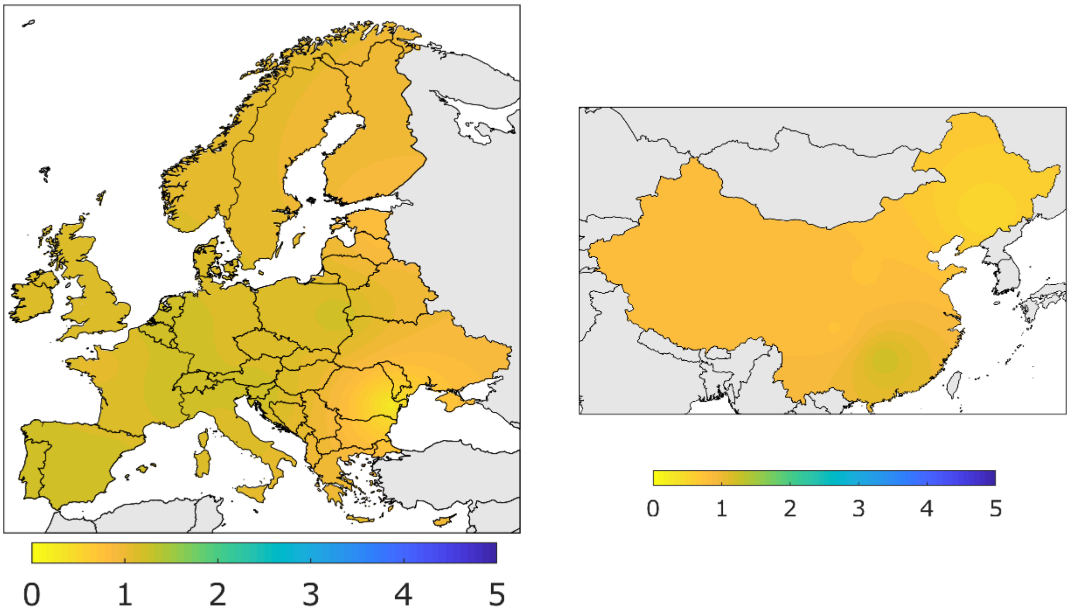


Figure 5. Spatial distribution of implementation levels for organic matter in the Expected scenario (in percentage)

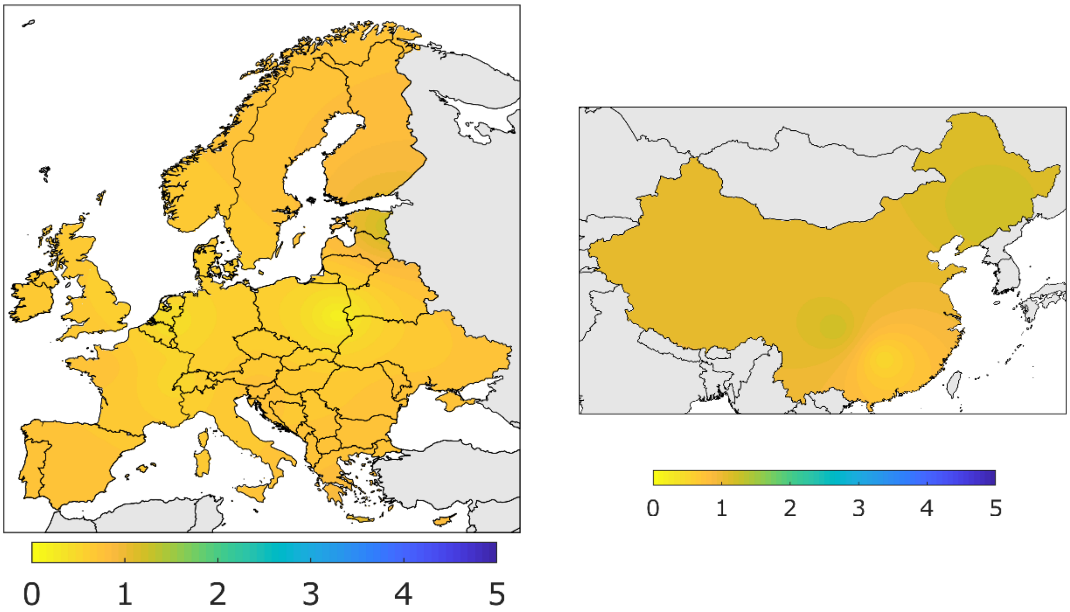


Figure 6. Spatial distribution of implementation levels for reduced tillage in the Expected scenario (in percentage)

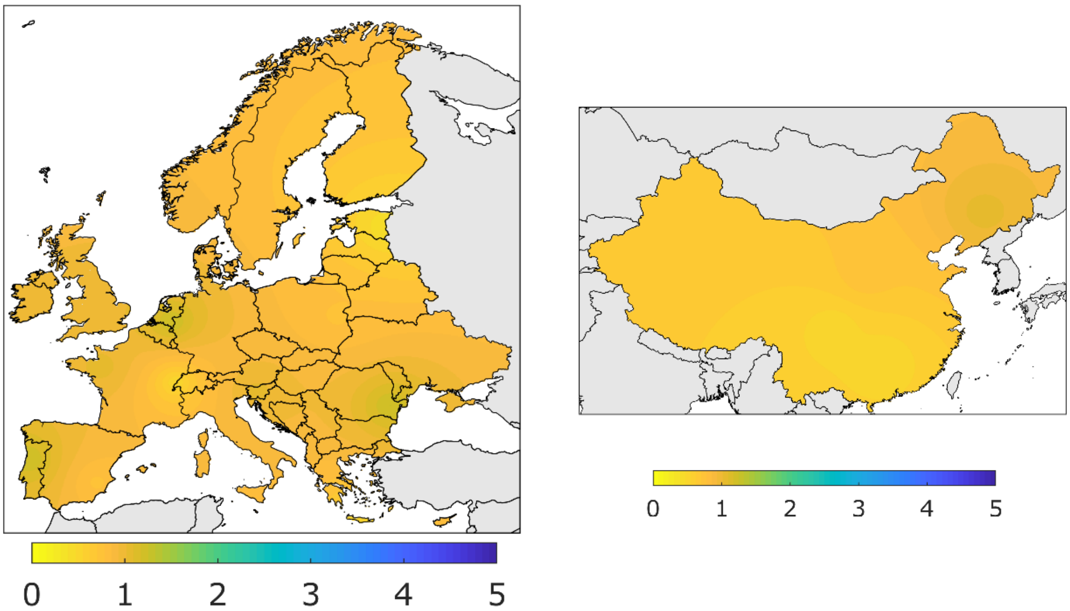
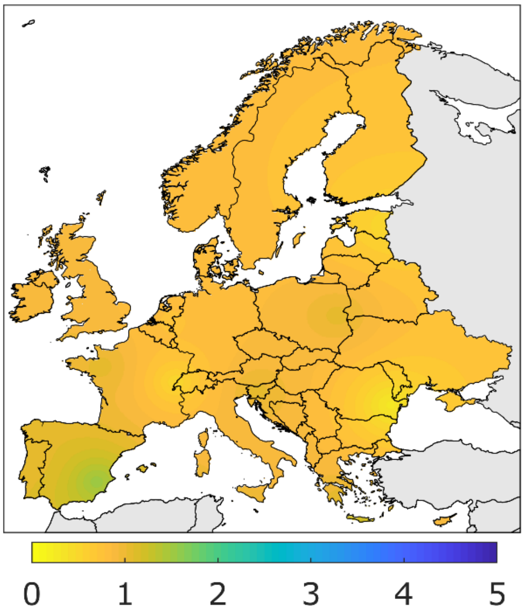


Figure 7. Spatial distribution of implementation levels for crop rotation in the Expected scenario (in percentage)



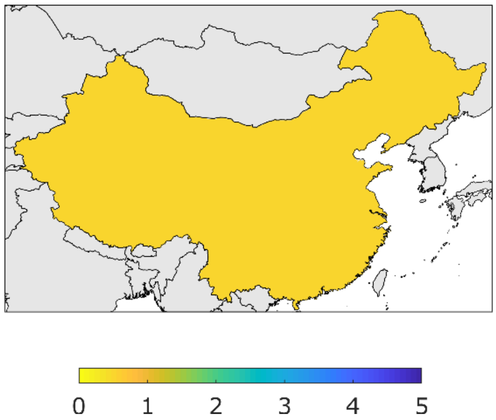


Figure 8. Spatial distribution of implementation levels for organic farming in the Expected scenario (in percentage)

3.2.2 Spatial distribution of implementation levels in the Towards 2050 and Regional Targets scenarios

The spatial distribution of the implementation of agricultural management practices in the Towards 2050 and Regional Targets scenarios is presented in the following figures. The implementation of organic matter is presented in Figure 9, the implementation of reduced tillage is presented in Figure 10, the implementation of crop rotation is presented in Figure 11 and the implementation of organic farming is presented in Figure 12. The figures show the projected percentage increase in application of the management practices contemplated in the scenarios Towards 2050 and Regional Targets.

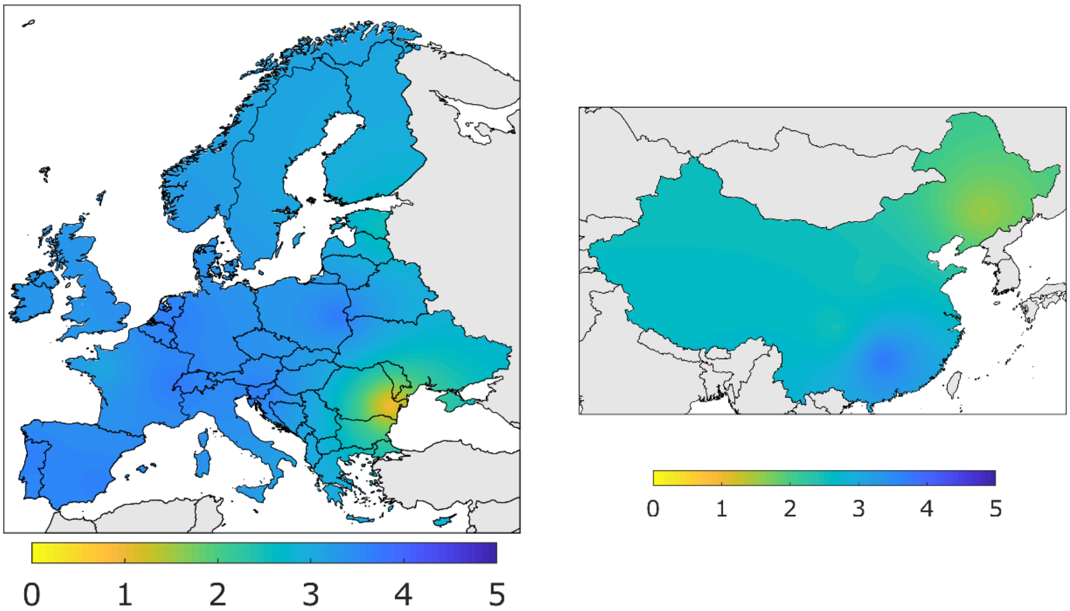


Figure 9. Spatial distribution of implementation levels for organic matter in the Expected and Regional Targets scenarios (in percentage)

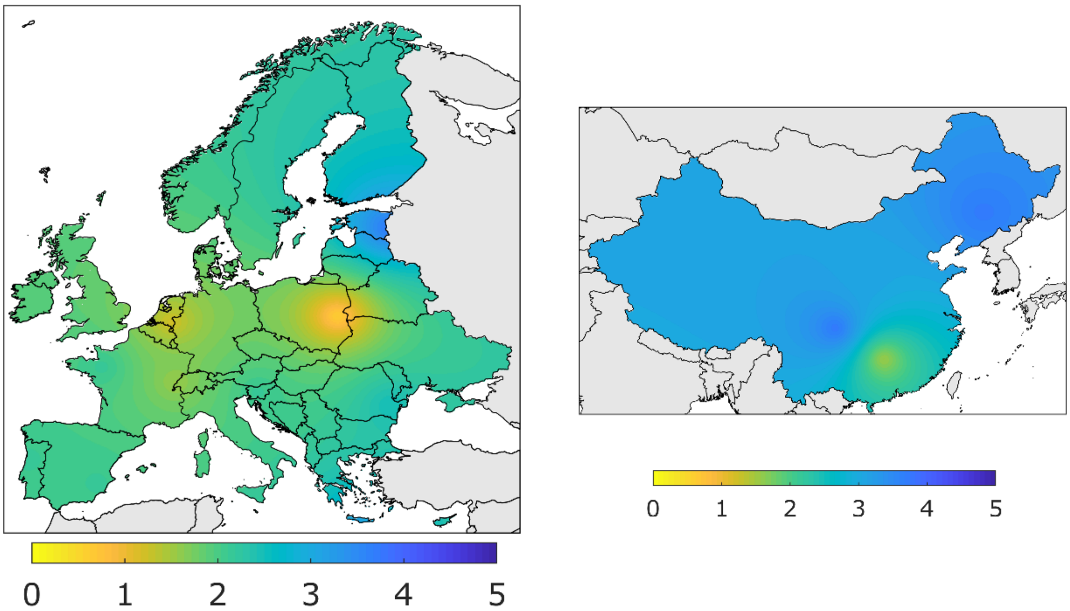


Figure 10. Spatial distribution of implementation levels for reduced tillage in the Expected and Regional Targets scenarios (in percentage)

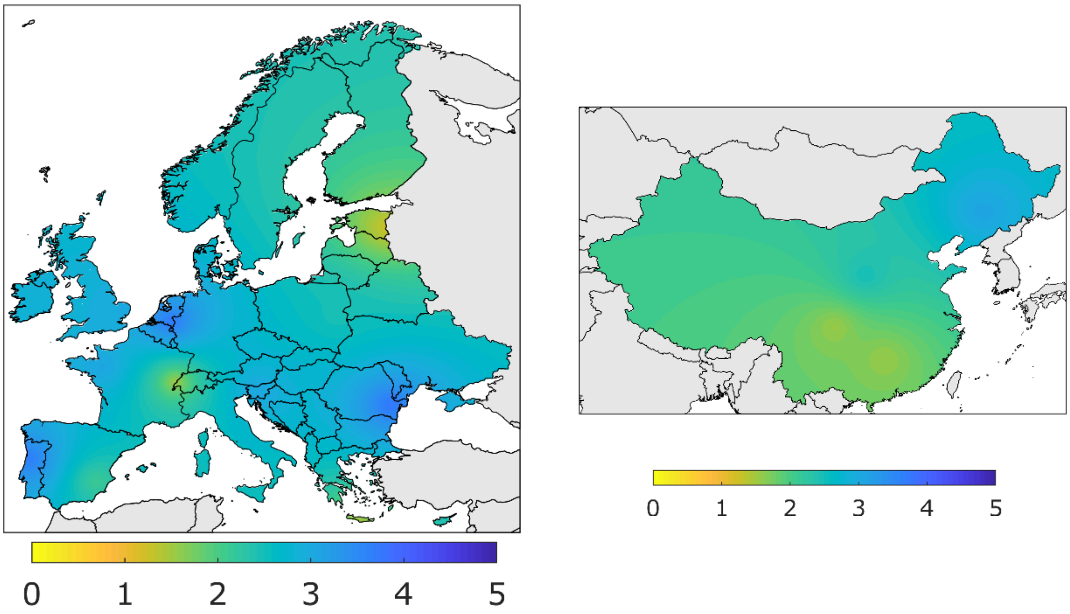


Figure 11. Spatial distribution of implementation levels for crop rotation in the Expected and Regional Targets scenarios (in percentage)

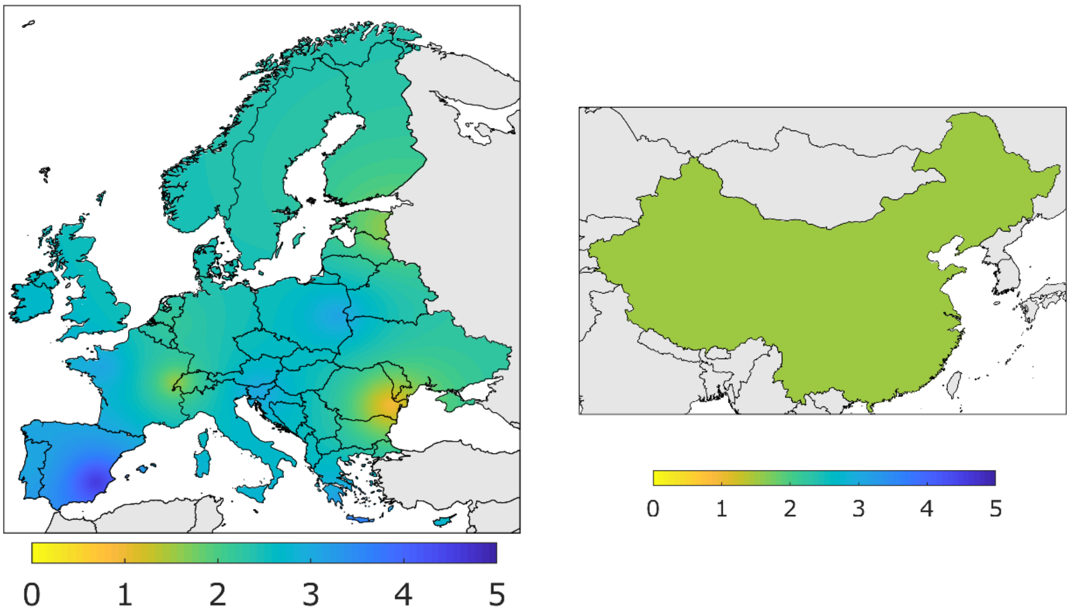


Figure 12. Spatial distribution of implementation levels for organic farming in the Expected and Regional Targets scenarios (in percentage)

3.3 Agroclimatic regions

The results are analysed in agro-climatic regions relevant for policy making. These regions were defined by combining the information on physical factors, such as climate classes, soil types or biomes and socio-economic factors, such as administrative organization.

The adopted agro-climatic regions for policy analysis in Europe and China are shown in Figure 13.

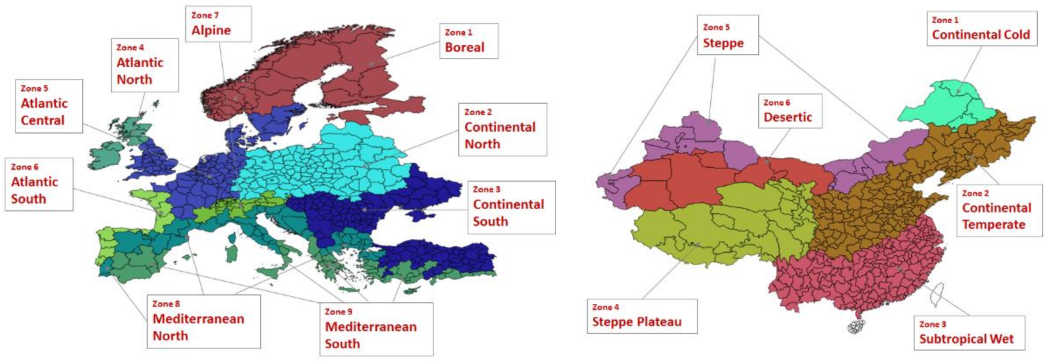


Figure 13. Agro-climatic regions adopted for upscaling in Europe(left) and China (right)

The codes used to identify farming systems and agro-climatic regions are shown in Table 4.

Table 4. Codes used in the visualization of results

Region EU	Code	Region CH	Code
Boreal	Bor	Continental-Cold	CnC
Continental-North	CoN	Continental-Temperate	CnT
Continental-South	CoS	Subtropical-Wet	StW
Atlantic-North	AtN	Steppe-Plateau	StP
Atlantic-Central	AtC	Steppe	Stp
Atlantic-South	AtS	Desertic	Des
Alpine	Alp		
Mediterranean-North	MdN		
Mediterranean-South	MdS		

4 Effect of scenarios on soil ecosystem services in Europe and China

The results of the application of the iSQAPER upscaling model to the three scenarios identified in Deliverable 7.3 are presented in this section. The results are formulated in terms of projected increased values of the three soil ecosystem services selected for analysis: crop yield, soil organic content and soil biodiversity. The three ecosystem services are related to basic soil environmental functions and are the basis for evaluating the changed environmental footprint.

For each scenario, a global overview of the results is presented first, showing maps of the projected increase of soil ecosystem services under the corresponding scenario. Secondly, the analysis is focused on the differential effect on agroclimatic regions of Europe and China. Finally, the variability of soil response to agricultural management practices is presented through box plots for the different agroclimatic regions.

4.1 Effect of Expected scenario

The Expected scenario is characterized by the maintenance of the observed tendency in the implementation of beneficial agricultural management practices.

4.1.1 Spatial effect of Expected scenario

The following figures present the spatial distribution of the effects of the Expected scenario on soil ecosystem services. The effects on crop yield are presented in Figure 14, the effects on soil organic matter are presented in Figure 15 and the effects on soil biodiversity are presented in Figure 16. The figures show the projected percentage increase in soil quality indicators as a result of the application of the additional management practices contemplated in the Expected scenario.

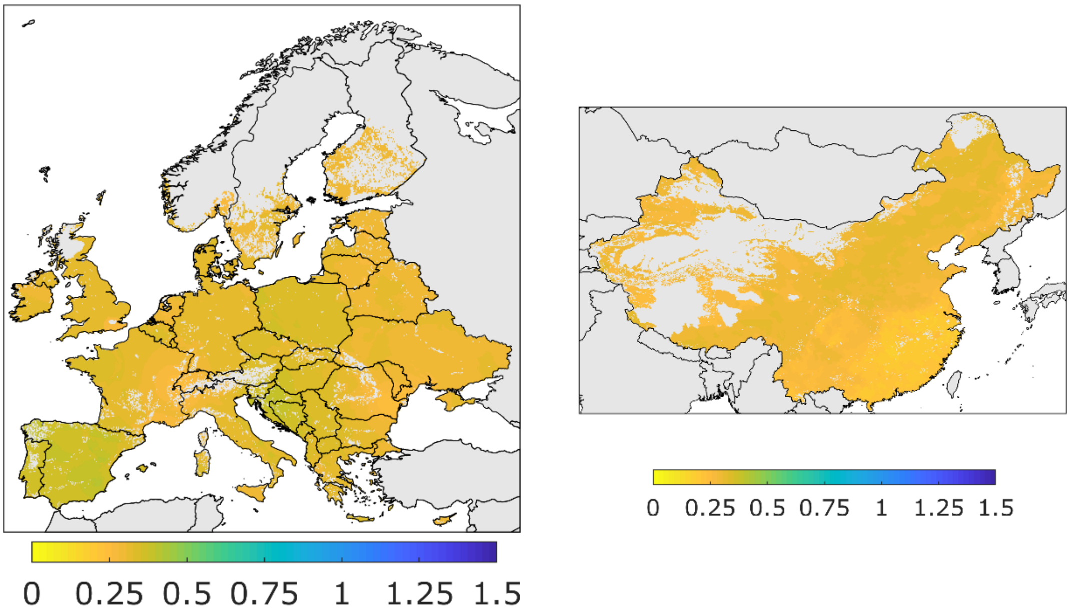


Figure 14. Projected effect of Expected scenario on mean increase in crop yield (in percentage)

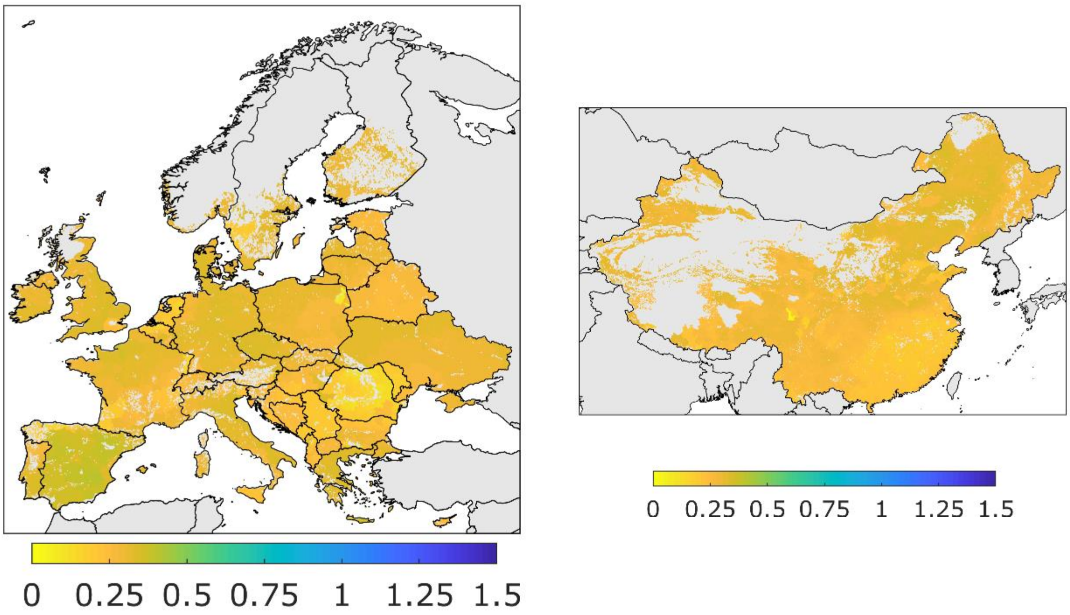


Figure 15. Projected effect of Expected scenario on mean increase in soil organic matter (in percentage)

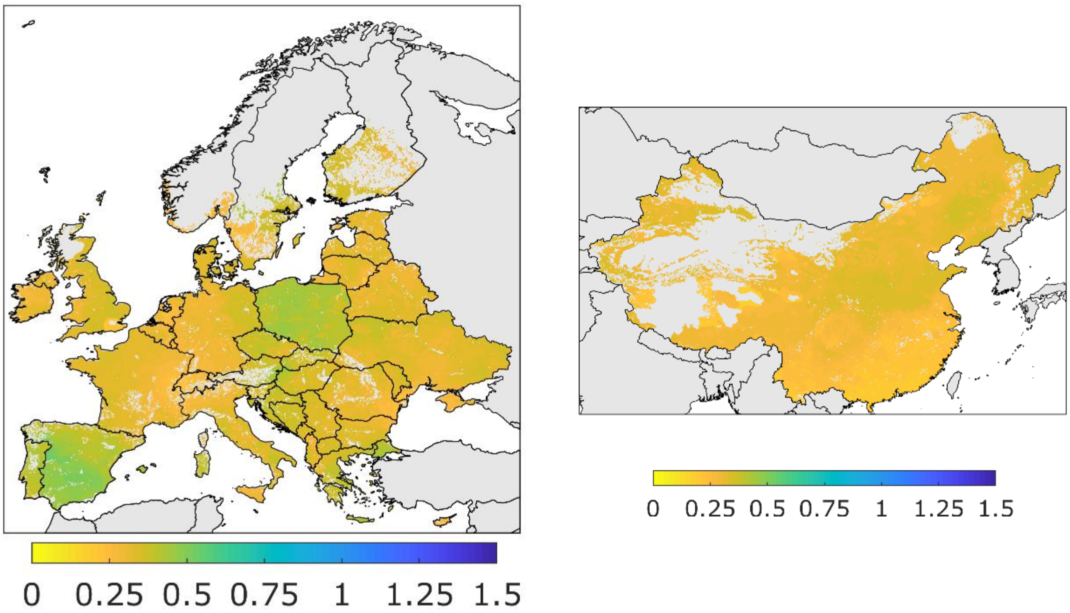


Figure 16. Projected effect of Expected scenario on mean increase in soil biodiversity (in percentage)

The results show a moderate increase of soil ecosystem services, with average increases between 0.27% for soil organic matter in China and 0.34% average increase for soil biodiversity in Europe. The increase of yield ranges from 0.23% to 0.40% in Europe, with an average value of 0.32%. The increase of yield in China ranges from 0.14% to 0.33%, with average of 0.27%. The spatial variability of soil organic matter is larger, ranging from an increase of 0.02% to 0.41% in Europe and 0.03% to 0.35% in China. Average values are 0.29% increase in Europe and 0.27% increase in China. Soil biodiversity shows the larger response to agricultural management practices. Average values are an increase of 0.34% in Europe and an increase of 0.28 in China. Values in Europe range from 0.20% to 0.54% and from 0.16% to 0.37% in China.

4.1.2 Effect of Expected scenario on agroclimatic regions

The compared values of average results of the upscaling of the Expected scenario in the agroclimatic regions of Europe and China are shown in Figure 17. Figure 17 shows that average impact is slightly above 0.30% in Europe and below 0.30% in China. Average response is an increase of 0.31% in Europe and 0.28% in China. The ecosystem service that is more sensitive to the implementation of agricultural management practices is soil biodiversity, followed by crop yield and soil organic matter.

The variability across agroclimatic regions is relatively low. The region that shows the greatest response in Europe is Mediterranean-South, with an average increase of 0.36% for the three ecosystem services. The European region that shows the least response is the Alpine region, with an average increase of 0.28%. In China, the largest response corresponds to the Continental-Cold region, with 0.31% increase. The least response is shown by the Subtropical-Wet region, with an increase of 0.23%.

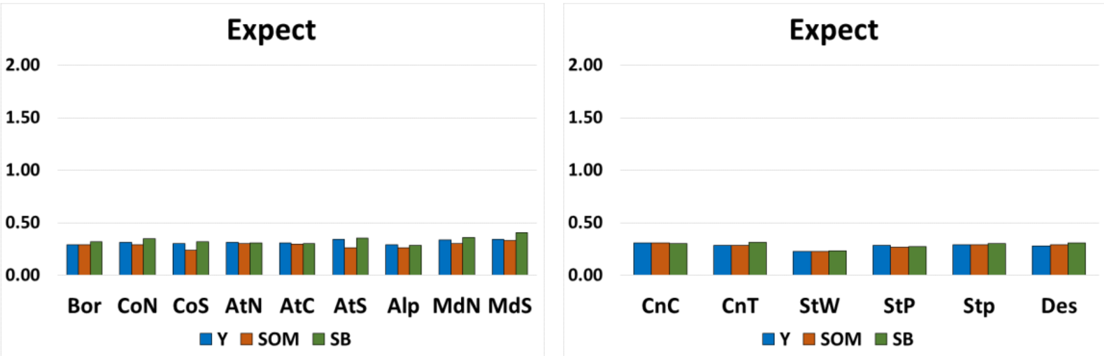


Figure 17. Effect of Expected scenario on soil ecosystem services in agroclimatic regions of Europe (left) and China (right)

The largest response in Europe for the Expected scenario corresponds to Mediterranean-South for soil biodiversity, with mean increase of 0.41%. The region that shows the smallest response is Continental-South for soil organic matter, with mean increase of 0.24% for soil organic matter. In China, the largest response corresponds to the Continental-Temperate region, with mean increase of 0.31% for soil biodiversity. The least response is shown by the Subtropical-Wet region, with a mean increase of 0.23% for crop yield and soil organic matter.

4.1.3 Variability of the effect of Expected scenario

The variability of the results of the upscaling for the Expected scenario is shown in Figure 18 and Figure 19. Both figures show box and whisker plots of the values of soil quality indicators in agroclimatic regions of Europe (Figure 18) and China (Figure 19). Boxes show the values of the mean plus and minus one standard deviation and whiskers show the maximum and minimum values obtained for the region. The ecosystem service that shows larger variability in Europe is soil organic matter, with average standard deviation of 0.05%. In China, the largest variability corresponds to soil biodiversity, with a standard deviation of 0.04%. Crop yield shows the least variability in Europe and China with average standard deviations of 0.03% and 0.04% respectively. Soil organic matter also shows the largest dispersion, particularly regarding minimum values.

Europe

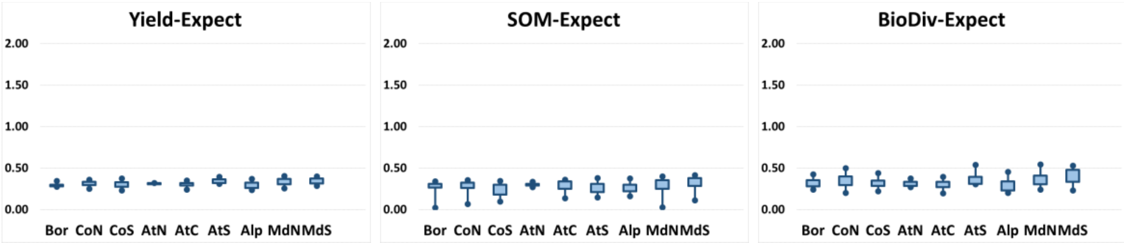


Figure 18. Variability of the results of the Expected scenario for agroclimatic regions in Europe: Yield (left), soil organic matter (centre) and soil biodiversity (right).

Results for Europe, presented in Figure 18, indicate that Mediterranean-North and Mediterranean-South are the regions where variability is largest, with average standard deviations of 0.05% for the three ecosystem services. Atlantic-North is the region with least variability with average standard deviation of 0.01%. The largest individual variability corresponds to Mediterranean-South for soil biodiversity, with standard deviation of 0.07%. The regions that show least variability are Boreal and Atlantic-North, both for yield, with standard deviation of 0.01%.

China

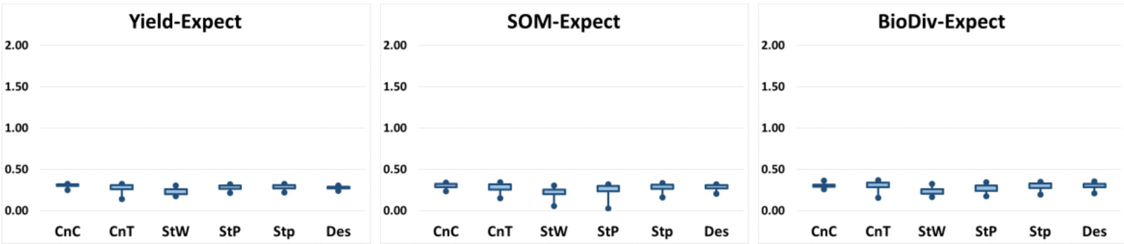


Figure 19. Variability of the results of the Expected scenario for agroclimatic regions in China: Yield (left), soil organic matter (centre) and soil biodiversity (right)

The regions where variability is largest in China are Subtropical-Wet and Steppe-Plateau, with average standard deviations of 0.03% for the three ecosystem services. Continental-Temperate is the region with least variability with average standard deviation of 0.01%. The region with the largest individual variabilities are Subtropical-Wet for soil organic matter and Steppe for soil organic matter and soil biodiversity, all with standard deviations of 0.03%. Continental-Temperate is the region that shows least variability with standard deviation of 0.01% for crop yield. Overall variabilities are similar in Europe and China, with average standard deviations for the three soil ecosystem services of 0.04%.

4.2 Effect of Towards 2050 scenario

The Towards 2050 scenario is characterized by an intensification of the rate of implementation of agricultural management practices induced by public policies. According to stakeholders from the case studies, the desirable rate of implementation is around three times the rate of implementation assumed in the Expected scenario.

4.2.1 Spatial effect of Towards 2050 scenario

The spatial distribution of the effects of the Towards 2050 scenario on soil ecosystem services is presented in the following figures. The effects on crop yield are presented in Figure 20, the effects on soil organic matter are presented in Figure 21 and the effects on soil biodiversity are presented in Figure 22. The figures show the projected percentage increase in soil quality indicators resulting from the application of the management practices contemplated in the scenario Towards 2050.

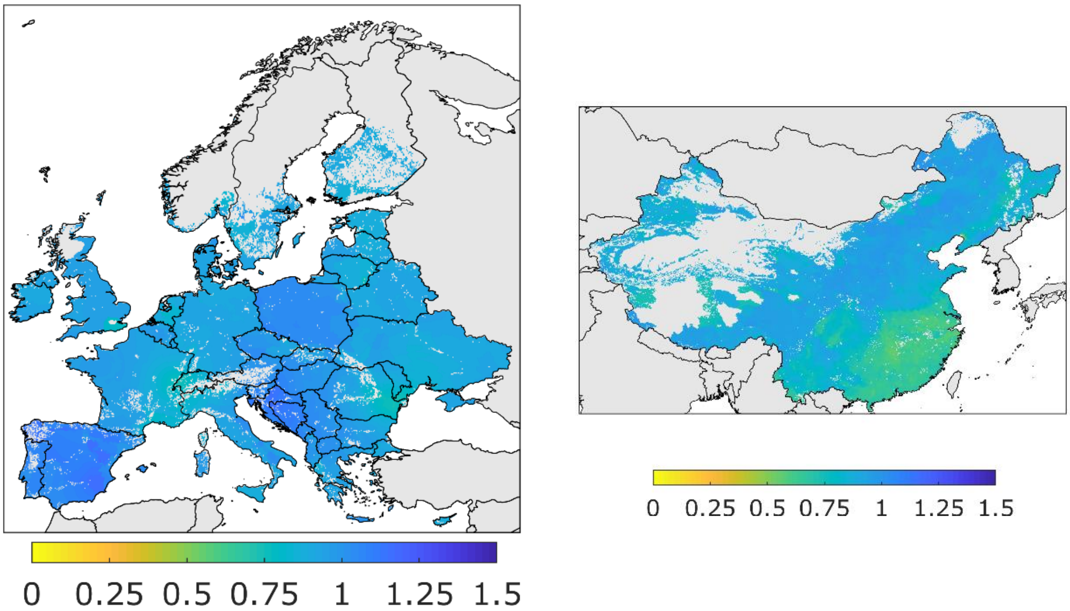


Figure 20. Projected effect of Towards 2050 scenario on mean increase in crop yield (in percentage)

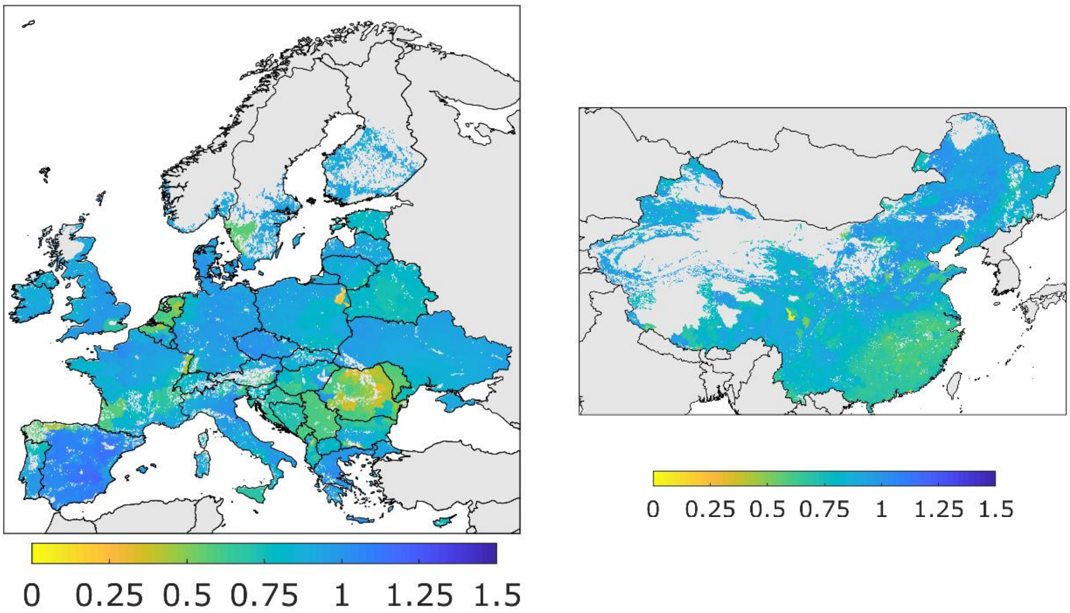


Figure 21. Projected effect of Towards 2050 scenario on mean increase in soil organic matter (in percentage)

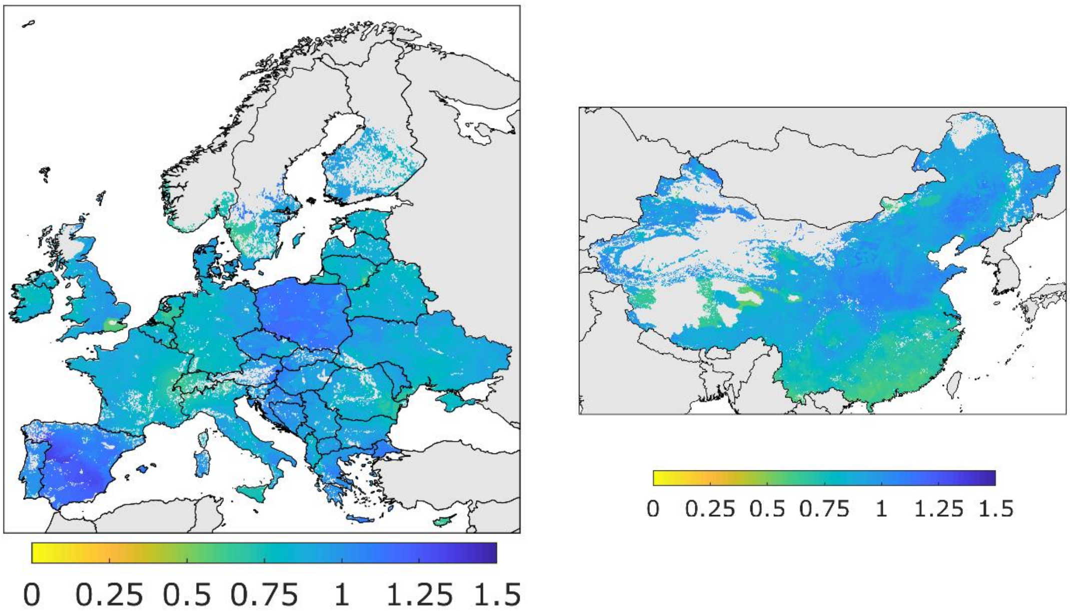


Figure 22. Projected effect of Towards 2050 scenario on mean increase in soil biodiversity (in percentage)

The results show a significant increase of soil ecosystem services, with average increases between 0.84% for soil organic matter in China and 0.99% average increase for soil biodiversity in Europe. The increase of yield ranges from 0.72% to 1.18% in Europe, with an average value of 0.95%. The increase of yield in China ranges from 0.45% to 1.01%, with average of 0.85%. The spatial variability of soil organic matter is larger, ranging from an increase of 0.07% to 1.21% in Europe and 0.08% to 1.05% in China. Average values are 0.86% increase in Europe and 0.84% increase in China. Soil biodiversity shows the larger response to agricultural management practices. Average values are an increase of 0.99% in Europe and an increase of 0.88 in China. Values in Europe range from 0.60% to 1.47% and from 0.49% to 1.13% in China.

4.2.2 Effect on agroclimatic regions

The compared values of average results of the upscaling of the Towards 2050 scenario in the agroclimatic regions of Europe and China are shown in Figure 23. Average impact is slightly below 1%. The threshold of 1% is exceeded in Europe by Mediterranean-South in yield and soil biodiversity and by Mediterranean-North, Atlantic-South and Continental-North in soil biodiversity. Average response is an increase of 0.93% in Europe and 0.86% in China. The ecosystem service that is more sensitive to the implementation of agricultural management practices is soil biodiversity, followed by crop yield and soil organic matter.

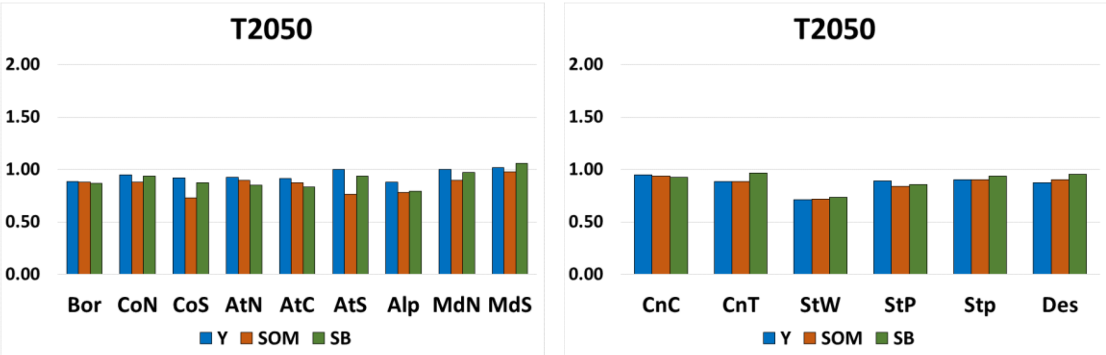


Figure 23. Effect of Towards 2050 scenario on soil ecosystem services in agroclimatic regions of Europe (left) and China (right)

The variability across agroclimatic regions is larger than in the other scenarios. The region that shows the greatest response in Europe is Mediterranean-South, with an average increase of 1.05% for the three ecosystem services. The European region that shows the least response is the Alpine region, with an average increase of 0.84%. In China, the largest response corresponds to the Continental-Cold region, with 0.94% increase. The least response is shown by the Subtropical-Wet region, with an increase of 0.72%.

4.2.3 Variability of the effect of Towards 2050 scenario

The variability of the results of the upscaling for the Towards 2050 scenario is shown in Figure 24 and Figure 25. Both figures show box and whisker plots of the values of soil quality indicators in agroclimatic regions of Europe (Figure 24) and China (Figure 25). Boxes show the values of the mean plus and minus one standard deviation and whiskers show the maximum and minimum values obtained for the region. The ecosystem service that shows larger variability in Europe is soil organic matter, with average standard deviation of 0.15%. In China, the largest variability corresponds to soil biodiversity, with a standard deviation of 0.13%. Crop yield shows the least variability in Europe and China with average standard deviations of 0.08% and 0.11%

respectively. Soil organic matter also shows the largest dispersion, particularly regarding minimum values.

Europe

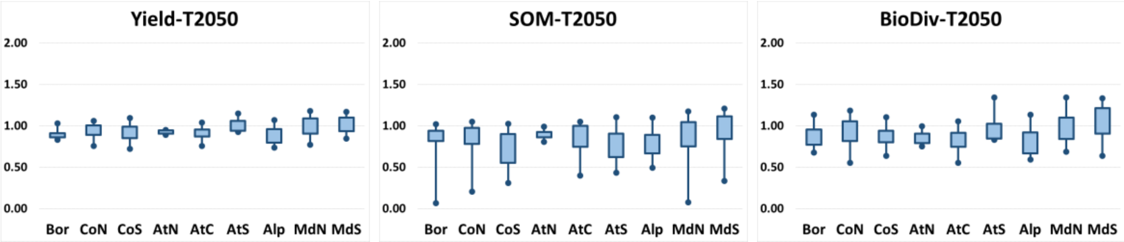


Figure 24. Variability of the results of the Towards 2050 scenario for agroclimatic regions in Europe: Yield (left), soil organic matter (centre) and soil biodiversity (right)

Results for Europe, presented in Figure 24, indicate that Mediterranean-North and Mediterranean-South are the regions where variability is largest, with average standard deviations of 0.13% for the three ecosystem services. Atlantic-North is the region with least variability with average standard deviation of 0.04%. The largest individual variability corresponds to Continental-South for soil organic matter, with standard deviation of 0.17%. The regions that show least variability are Boreal and Atlantic-North, both for yield, with standard deviation of 0.02%.

China

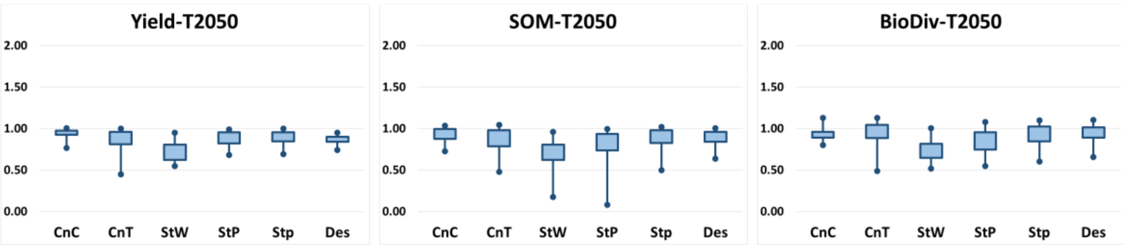


Figure 25. Variability of the results of the Towards 2050 scenario for agroclimatic regions in China: Yield (left), soil organic matter (centre) and soil biodiversity (right)

The regions where variability is largest in China are Subtropical-Wet and Steppe-Plateau, with average standard deviations of 0.09% for the three ecosystem services. Continental-Temperate is the region with least variability with average standard deviation of 0.04%. The region with the largest individual variabilities are Subtropical-Wet for soil organic matter and Steppe for soil organic matter and soil biodiversity, all with standard deviations of 0.10%. Continental-Temperate is the region that shows least variability with standard deviation of 0.03% for crop yield. Overall variabilities are similar in Europe and China, with average standard deviations for the three soil ecosystem services of 0.12%.

4.3 Effect of Regional Targets scenario

The Regional Targets scenario is characterized by the same rate of implementation of agricultural management practices as Towards 2050, but considering that policy efforts are focused on areas where soil threats are more active and soil quality indicators are poorer.

4.3.1 Spatial effect of Regional Targets scenario

The spatial distribution of the effects of the Regional Targets scenario on soil ecosystem services is presented in the following figures. The effects on crop yield are presented in Figure 26, the effects on soil organic matter are presented in Figure 27 and the effects on soil biodiversity are presented in Figure 28. The figures show the projected increase in soil quality indicators (in percentage with respect to current values) resulting from the application of the additional management practices contemplated in the Regional Targets scenario.

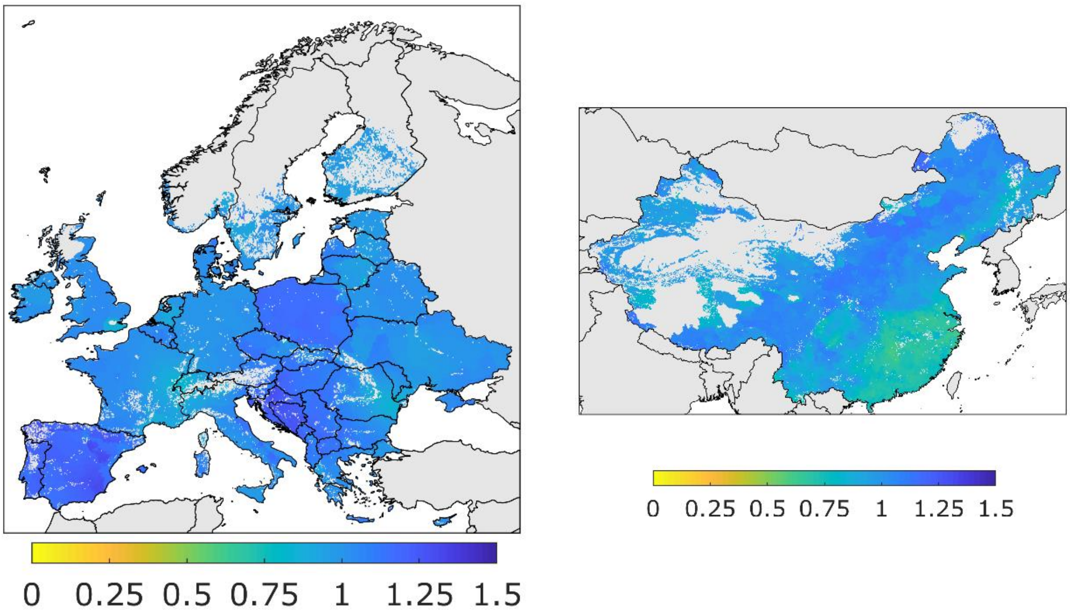


Figure 26. Projected effect of Regional Targets scenario on mean increase in crop yield (in percentage)

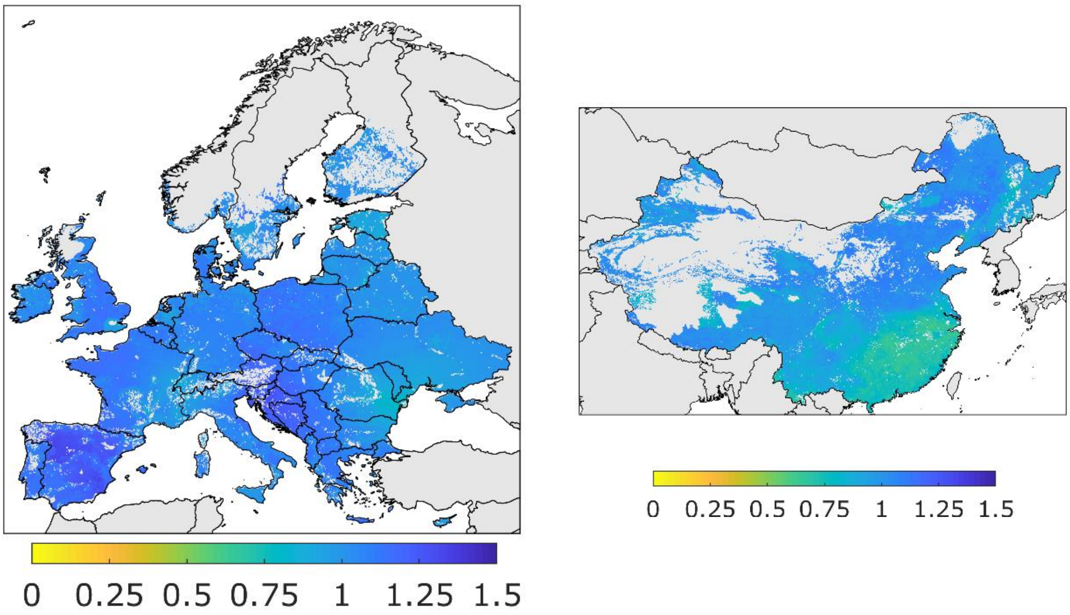


Figure 27. Projected effect of Regional Targets scenario on mean increase in soil organic matter (in percentage)

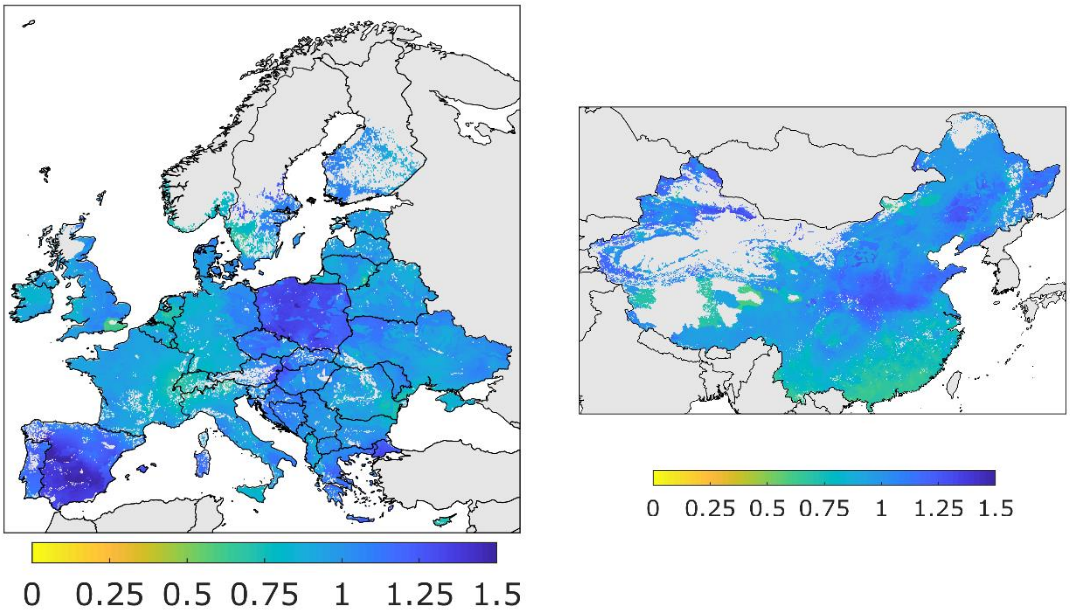


Figure 28. Projected effect of Regional Targets scenario on mean increase in soil biodiversity (in percentage)

The results show an effect on soil ecosystem services significantly better than in the case of the Towards 2050 scenario, with average increases between 0.94% for soil organic matter in China and 1.06% average increase for soil organic matter in Europe. The increase of yield ranges from 0.79% to 1.33% in Europe, with an average value of 1.05%. The average increase of crop yield in China is 0.95%, ranging from 0.49% to 1.30%. The effect on soil organic matter ranges from an increase of 0.74% to 1.35% in Europe and 0.53% to 1.16% in China. Average values are 1.16% increase in Europe and 0.94% increase in China. The average values of the effect on soil biodiversity are an increase of 1.01% in Europe and an increase of 0.97 in China. Values in Europe range from 0.58% to 1.58% and from 0.52% to 1.40% in China.

4.3.2 Effect on agroclimatic regions

The compared values of average results of the upscaling of the Regional Targets scenario in the agroclimatic regions of Europe and China are shown in Figure 29. The average impact is 1.04% for Europe and 0.95% for China. The ecosystem service that is more sensitive to the implementation of agricultural management practices is soil organic matter in Europe and soil biodiversity in China. Conversely, the ecosystem services that show the least sensitivity are soil biodiversity in Europe and soil organic matter in China.

As in the case of the Expected scenario, different agroclimatic regions show relatively low variability. The region that shows the greatest average response in Europe is Mediterranean-South, with an average increase of 1.15% for the three ecosystem services. The European region that shows the least response is the Alpine region, with an average increase of 0.95%. In China, the largest average response corresponds to the Continental-Cold region, with 1.03% increase. The least response is shown by the Subtropical-Wet region, with an increase of 0.80%.

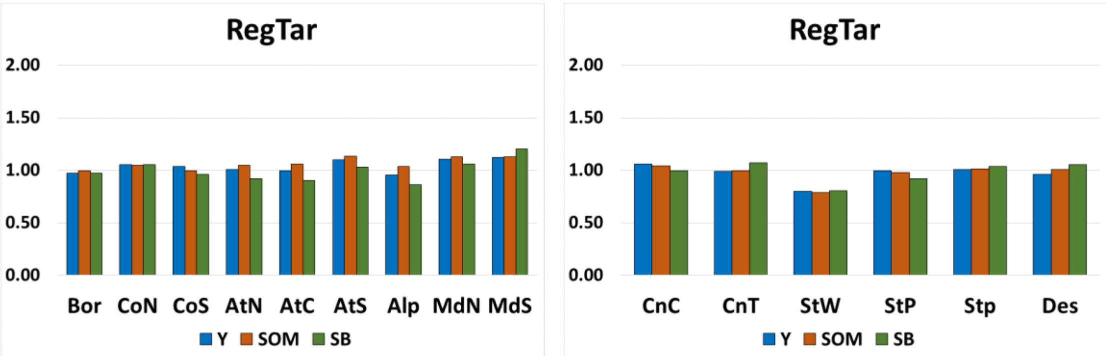


Figure 29. Effect of Regional Targets scenario on soil ecosystem services in agroclimatic regions of Europe (left) and China (right)

The largest response in Europe for the Expected scenario corresponds to Mediterranean-South for soil biodiversity, with mean increase of 1.20%. The region that shows the smallest response is the Alpine region for soil biodiversity, with mean increase of 0.86%. In China, the largest individual response corresponds to the Continental-Temperate region, with mean increase of 1.07% for soil biodiversity. The least response is shown by the Subtropical-Wet region, with a mean increase of 0.79% for soil organic matter.

4.3.3 Variability of the effect of Regional Targets scenario

The variability of the results of the upscaling for the Regional Targets scenario is shown in Figure 30 and Figure 31. Both figures show box and whisker plots of the values of soil quality indicators in agroclimatic regions of Europe (Figure 30) and China (Figure 31). Boxes show the values of the mean plus and minus one standard deviation and whiskers show the maximum and minimum values obtained for the region. The ecosystem service that shows larger variability in Europe is soil biodiversity with average standard deviation of 0.16%. In China, the largest variability corresponds to soil biodiversity, with a standard deviation of 0.15%. Crop yield and soil organic matter show the least variability in Europe, with average standard deviation of 0.09% for both. In China, the least variability is shown by soil organic matter, with average standard deviation of 0.12%. The dispersion is significantly reduced with respect to the Expected scenario, with much higher minimum values, particularly regarding soil organic matter.

Europe

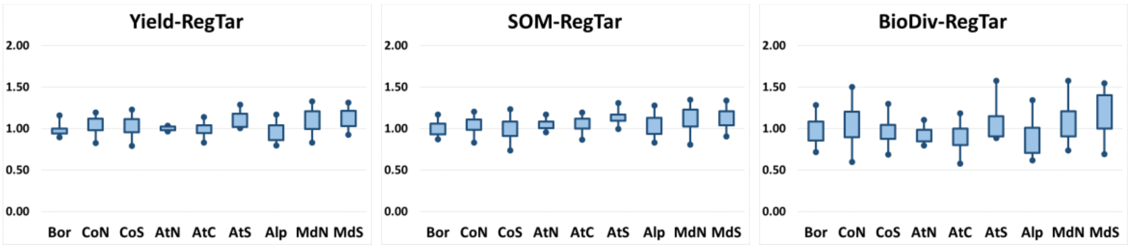


Figure 30. Variability of the results of the Regional Targets scenario for agroclimatic regions in Europe: Yield (left), soil organic matter (centre) and soil biodiversity (right)

Mediterranean-South is the region where variability is largest in Europe, with average standard deviation of 0.13% for the three ecosystem services. Atlantic-North is the region with least variability with average standard deviation of 0.04%. The largest individual variability corresponds to Mediterranean-South for soil biodiversity, with standard deviation of 0.20%. The region that shows least variability is Atlantic-North for crop yield, with standard deviation of 0.02%.

China

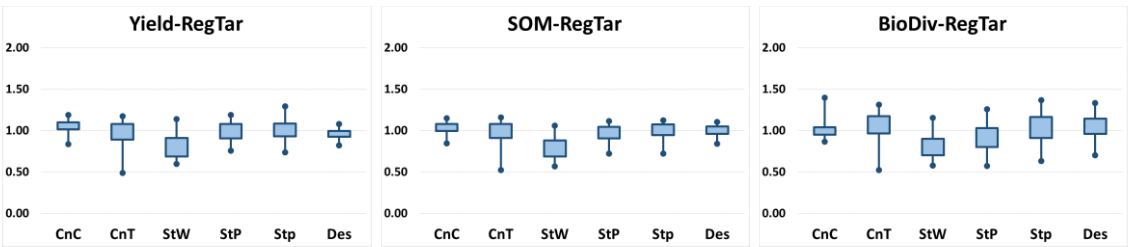


Figure 31. Variability of the results of the Regional Targets scenario for agroclimatic regions in China: Yield (left), soil organic matter (centre) and soil biodiversity (right)

The region where variability is largest in China is Steppe-Plateau, with average standard deviation of 0.10% for the three ecosystem services. Continental-Temperate is the region with least variability with average standard deviation of 0.04%. The region with the largest individual variability is the Desertic region for soil biodiversity, with standard deviation of 0.13%. Continental-Temperate is the region that shows least variability with standard deviation of 0.04% for all three ecosystem services. Overall variabilities are slightly smaller in Europe that in China, with average standard deviations for the three soil ecosystem services of 0.11% in Europe and 0.13% in China.

4.4 Summary and conclusions

The results obtained for the three scenarios are compared in this section. **Error! Reference source not found.**Table 5 presents the global overview, showing the average results obtained for the three soil ecosystem services in the three scenarios for Europe and China. The same results are visualized in Figure 32.

Table 5. Average results for the three soil ecosystem services in the three scenarios for Europe (left) and China (right)

	Yield		Soil Organic Matter		Biodiversity	
	Europe	China	Europe	China	Europe	China
Expected	0.32	0.27	0.29	0.27	0.34	0.28
Towards 2050	0.95	0.85	0.86	0.84	0.91	0.88
Regional Targets	1.05	0.95	1.06	0.94	1.01	0.97

The average response in Europe is an increase of soil ecosystem services of 0.31% for Baseline, 0.91% for Towards 2050 and 1.04% for Regional Targets. In China, the average response is an increase of 0.28% for Baseline, 0.86% for Towards 2050 and 0.95% for Regional Targets. Overall, the response to policy in China is between 0.05% and 0.09% less than in Europe.

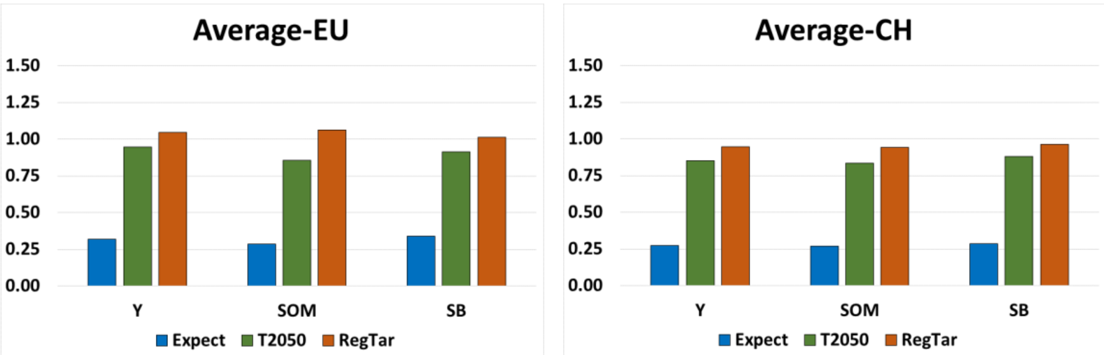


Figure 32. Average results for the three soil ecosystem services in the three scenarios for Europe (left) and China (right)

Figure 33 compares the results obtained in the Regional Targets and Towards 2050 scenarios to those obtained in the Expected scenario. The Towards 2050 and Regional Targets scenarios imply approximately three times the implementation levels of those in the Expected scenario (on average 3.1 times in Europe and 3.2 times in China).

The straight lines in Figure 33 mark the projected effects of those implementation levels. However, the increase of soil ecosystem services are less than the projected ratios: 2.88 times in Europe and 3.1 times in China. The average efficiency is 93% in Europe and 97% in China. This is because, as implementation levels grow, the probability of having a model cell with implementation of more than one agricultural management practice also grows. In this case, intervention efficiency decreases, since the combined effect of two management practices is less than the sum of both effects considered separately. As seen in Figure 33, the soil ecosystem service that is more sensitive to both effects is soil biodiversity. The Regional Targets scenario implies the same level of implementation as the Towards 2050 scenario, but the intervention is focused on the areas where soil quality is poor. This produces a better response, with an average improvement of 11.50% in Europe and 11.23% in China.

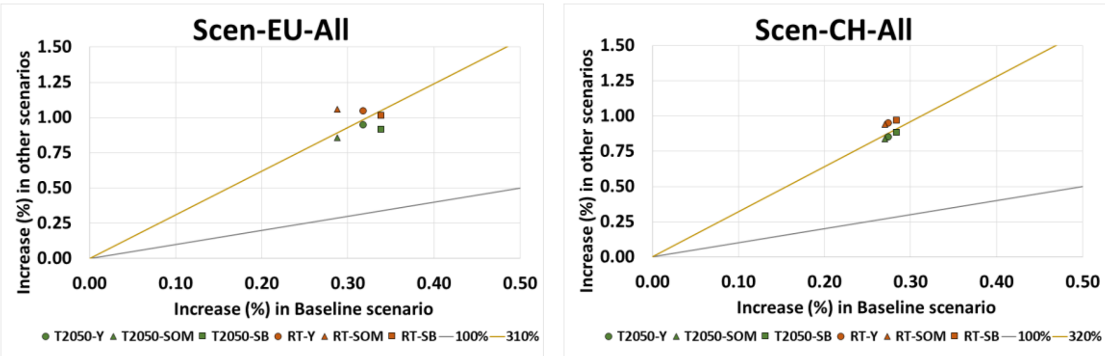


Figure 33. Comparison of average response in Regional Targets and Towards 2050 scenarios with respect to Expected scenario: Europe (left) and China (right)

Figure 34 and Figure 34Figure 35 present the comparison of the results obtained in the Towards 2050 and Regional Targets scenarios to those obtained in the Expected scenario for individual agroclimatic regions in Europe (Figure 34) and China (Figure 35). The regional effect of focussing the intervention on the less quality soils is more distinct in soil organic matter, where the increases corresponding to the Regional Targets scenario are well above those for the projected ration corresponding to the implementation level. This effect is stronger in Europe than in China.

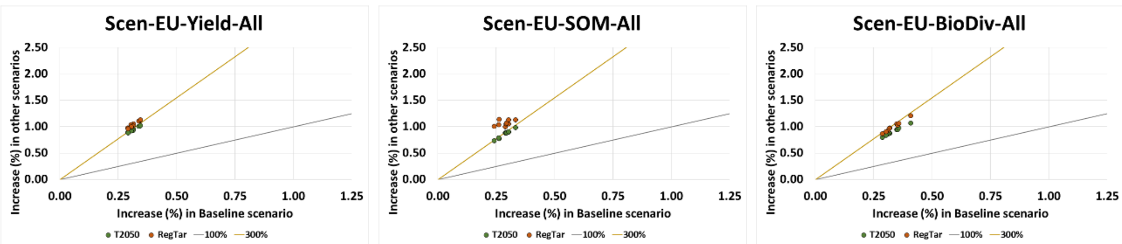


Figure 34. Comparison of average response in Regional Targets and Towards 2050 scenarios with respect to Expected scenario for agroclimatic regions in Europe: Yield (left), soil organic matter (centre) and soil biodiversity (right)

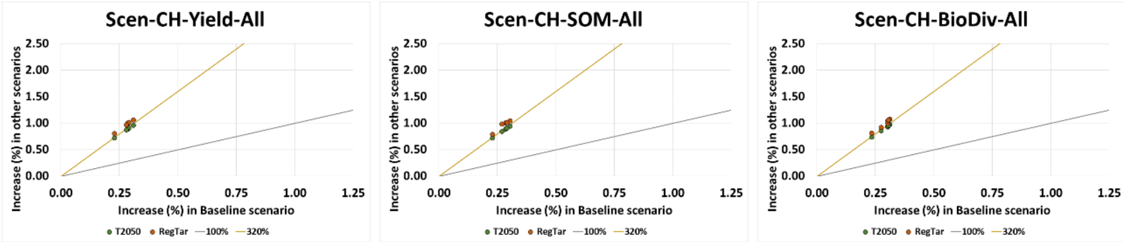


Figure 35. Comparison of average response in Regional Targets and Towards 2050 scenarios with respect to Expected scenario for agroclimatic regions in China: Yield (left), soil organic matter (centre) and soil biodiversity (right)

5 Analysis of the soil environmental footprint

The evaluation of the changed environmental footprint of soil under the scenarios analysed is based on the enhancement of the soil environmental functions associated to the three ecosystem services studied in the previous section. The results of the analysis are presented in this section.

The methodology for evaluating the soil environmental footprint is presented first. Then, the global results are presented, showing maps of the projected change in soil environmental footprint under the corresponding scenario. Secondly, the analysis is focused on the differential effect on agroclimatic regions of Europe and China. Thirdly, the variability of soil environmental footprint response to agricultural management practices is presented through box plots for the different agroclimatic regions. Finally, some conclusions are drawn.

5.1 Methodology for the evaluation of the soil environmental footprint

The iSQAPER upscaling model provides the projected increase in soil ecosystem services as a response to increased implementation of beneficial agricultural management practices. This increase leads to improvement of soil ecosystem functions, like food provision or carbon storage, and thus improves the environmental footprint of the soil.

A simple geometric interpretation of soil environmental footprint has been devised in order to obtain a global picture of how the combined effect of the three ecosystem services improves the environmental footprint of the soil. The interpretation is based on the schematic view of Figure 36. The projected increases of soil ecosystem services are represented in a radar chart showing the increased values for the three ecosystem services under consideration. The environmental footprint is considered to be proportional to the area of the resulting triangle.

The area of the triangle can be easily calculated. If the improvements of soil ecosystem functions are x_1, x_2 and x_3, the area of the triangle is given by the expression:

$$A = \frac{x_1 x_2}{2}\sin(120º) + \frac{x_1 x_3}{2}\sin(120º) + \frac{x_2 x_3}{2}\sin(120º) = \frac{\sin(120º)}{2}(x_1 x_2 + x_1 x_3 + x_2 x_3)$$

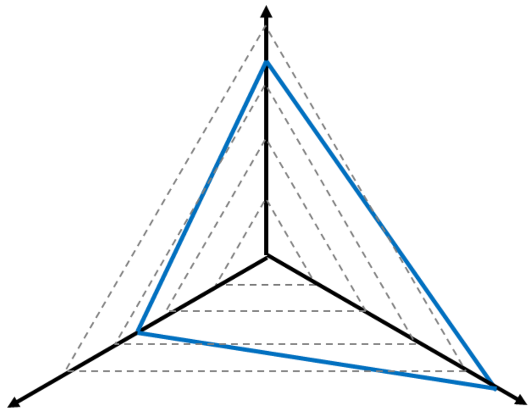


Figure 36. Schematic representation of the evaluation of the changes in soil environmental footprint.

This simple geometric interpretation accounts for the combined effect of all three pairs of ecosystem services. As a reference, an increase of 1% in all three ecosystem services would lead to an improvement of soil environmental footprint of 1.3 and an increase of 2% would lead to an improvement of 5.2. It should be noted that, under this interpretation, soil environmental footprint has a positive connotation because it is linked to soil ecosystem services: the larger the contribution of soil to ecosystem services, the larger its environmental footprint. In other interpretations, environmental footprint has a negative connotation because it is linked to the consumption of environmental resources.

5.2 Evaluation of the improved soil environmental footprint

The methodology to quantify soil environmental footprint was applied to the results of the iSQAPER upscaling model for the three scenarios considered. The results are presented in this section.

5.2.1 Spatial distribution of the soil environmental footprint

The following figures present the spatial distribution of the effects of the scenarios on soil environmental footprint. The effects of the Expected scenario are presented in Figure 37, the effects of the Towards 2050 scenario are presented in Figure 38 and the effects of the Regional Targets scenario are presented in Figure 39. The figures show the projected improvement of the soil environmental footprint with the methodology described above.

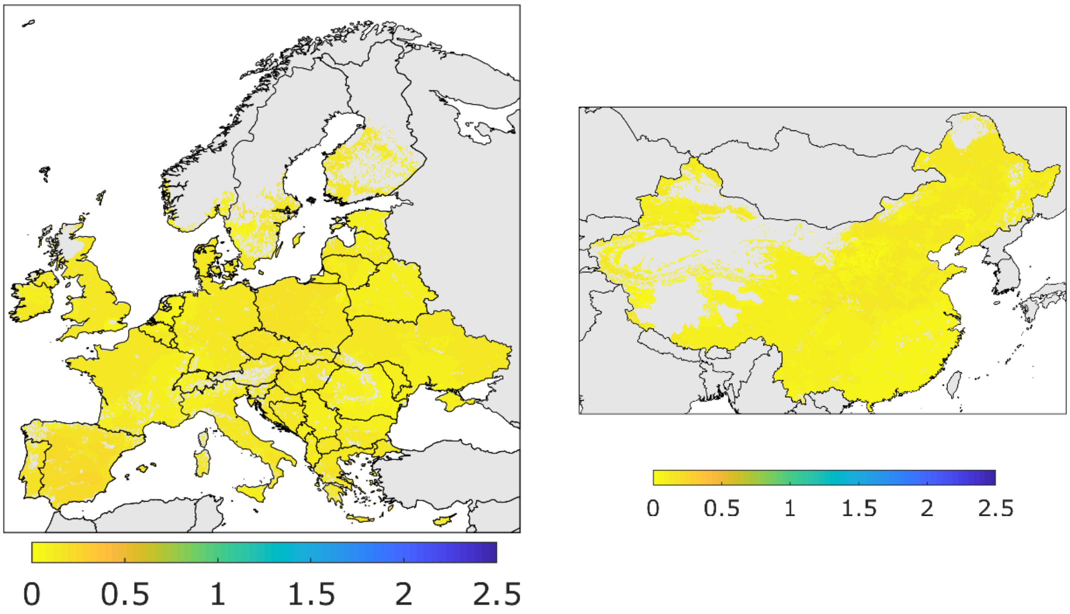


Figure 37. Projected effect of Expected scenario on soil environmental footprint

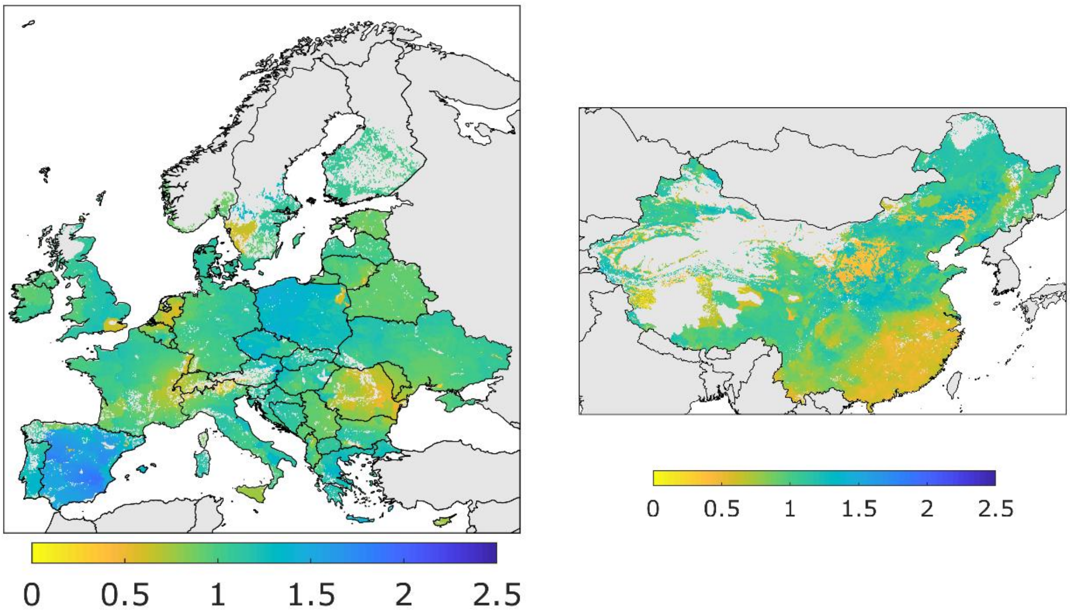


Figure 38. Projected effect of Towards 2050 scenario on soil environmental footprint

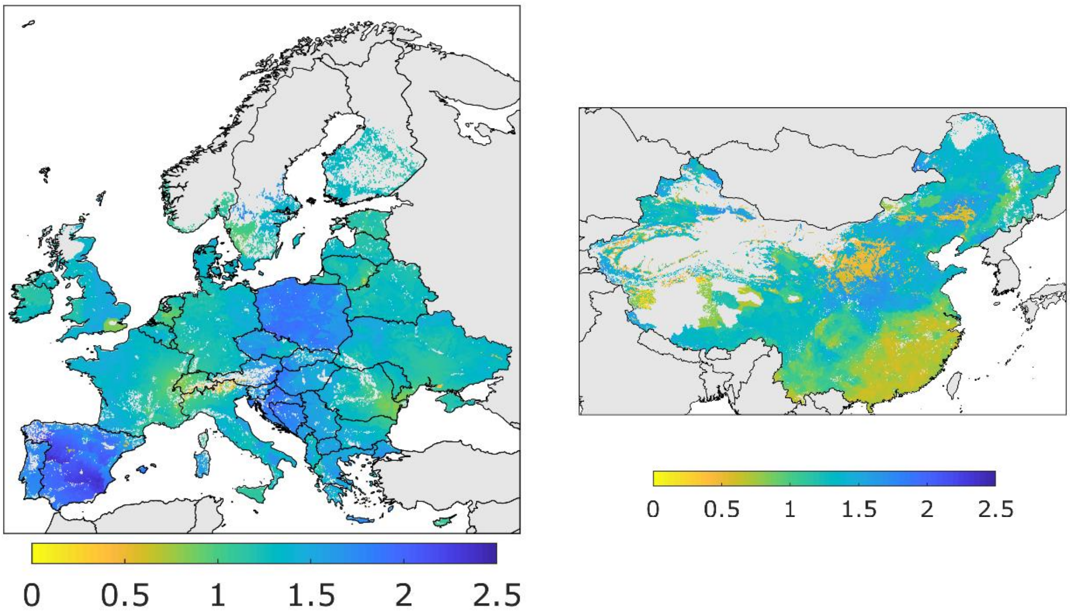


Figure 39. Projected effect of Regional Targets scenario on soil environmental footprint

The results show a significant improvement of soil environmental footprint, with average values between 0.10 for the Expected scenario in China and 1.41 average value for the Regional Targets scenario in Europe. The improvement in the Expected scenario ranges from 0.02 to 0.25 in Europe, with an average value of 0.13. The improvement in the Expected scenario in China ranges from 0.02 to 0.15, with average of 0.10. The Towards 2050 scenario provides a much better improvement. Average values are 1.07 in Europe and 0.92 in China. Values in Europe range from 0.14 to 1.94 and from 0.15 to 1.41 in China. The Regional Targets scenario shows the best improvement of soil environmental footprint, ranging from a value of 0.24 to 2.44 in Europe and 0.18 to 1.91 in China. Average values are 1.41 in Europe and 1.13 in China.

5.2.2 Effect on soil environmental footprint by agroclimatic regions

The compared values of average results of the improved soil environmental footprint in the agroclimatic regions of Europe and China are shown in Figure 40. Figure 40 shows that the Towards 2050 and Regional Targets provide a much better improvement of soil environmental footprint than Baseline, with the Regional Targets scenarios showing the best results.

The region that shows the greatest improvement of soil environmental footprint in Europe is Mediterranean-South, with an average value of 0.97 for the three scenarios. The European region that shows the least improvement is the Alpine region, with an average value of 0.67. In China, the largest improvement corresponds to the Continental-Cold region, with an average value of 0.88. The least improvement is shown by the Subtropical-Wet region, with an average value of 0.53.

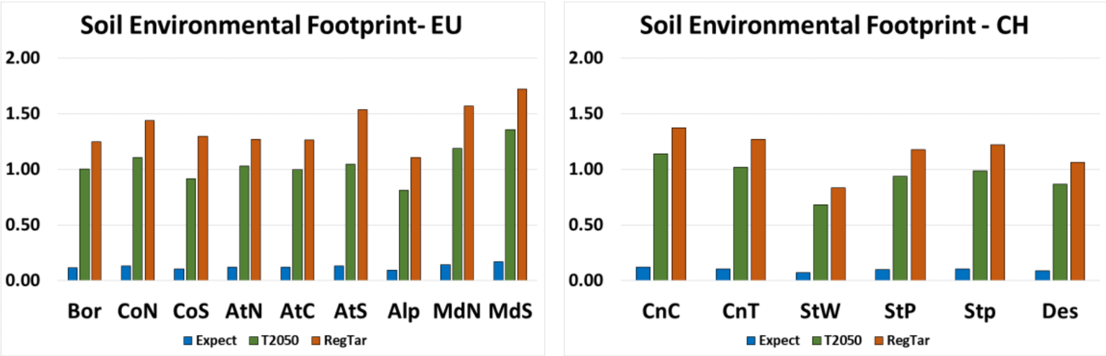


Figure 40. Improved soil environmental footprint in agroclimatic regions of Europe (left) and China (right)

The largest improvement in Europe for an individual region corresponds to Mediterranean-South for the Regional Targets scenario, with mean value of 1.72. The region that shows the smallest improvement is the Alpine region in the Expected scenario, with mean improvement of 0.10. In China, the largest improvement corresponds to the Continental-Cold region, with mean value of 1.38 for the Regional Targets scenario. The least improvement is shown by the Subtropical-Wet region, with a mean value of 0.07 for the Expected scenario.

5.2.3 Variability of the effect on soil environmental footprint

The variability of the results of the evaluation of soil environmental footprint for different scenarios is shown in Figure 41 and Figure 42. Both figures show box and whisker plots of the values of soil quality indicators in agroclimatic regions of Europe (Figure 41) and China (Figure 42). Boxes show the values of the mean plus and minus one standard deviation and whiskers show the maximum and minimum values obtained for the region. The scenario that shows larger standard deviation in Europe is Regional Targets, with 0.29, which implies a coefficient of variation of 0.20, but the scenario with largest variability is Expected, with a standard deviation of 0.03 and a coefficient of variation of 0.30. In China, the largest standard deviation corresponds also to the Regional Targets scenario, with a value of 0.34, and a coefficient of variation of 0.30. The Expected scenario shows the least standard deviations in Europe and China with average values of 0.03, which correspond to coefficients of variation of 0.24. The Regional Targets scenario shows the largest dispersion, particularly regarding maximum values.

Europe

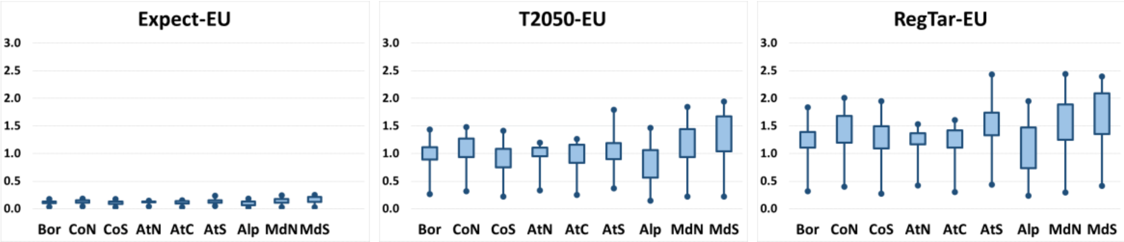


Figure 41. Variability of the results of the soil environmental footprint for agroclimatic regions in Europe: Expected (left), Regional Targets (centre) and Towards 2050 (right).

Results for Europe, presented in Figure 41, show that the region with largest standard deviation is Mediterranean-South, with an average value of 0.24 for the three scenarios. However, the largest variability is shown by the Alpine region, with an average standard deviation of 0.22 and a coefficient of variation of 0.32. Boreal is the region with least variability with average standard deviation of 0.09 and a coefficient of variation of 0.11. The largest individual variability corresponds to the Alpine Region for the Regional Targets scenario, with standard deviation of 0.37 and coefficient of variation of 0.33. The largest standard deviation is shown by Mediterranean-South, with a value of 0.37 for the Regional Targets scenario. The region that shows least variability is Atlantic North for the Regional Targets scenario, with standard deviation of 0.01 and a coefficient of variation of 0.08.

China

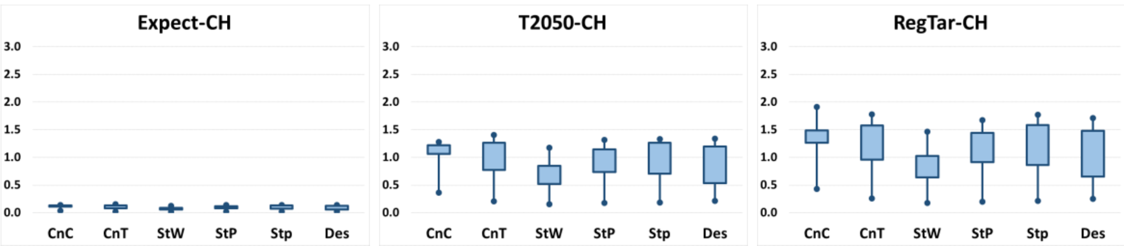


Figure 42. Variability of the results of the soil environmental footprint for agroclimatic regions in China: Expected (left), Regional Targets (centre) and Towards 2050 (right)

The region where average standard deviations is largest in China is Desertic, with average value of 0.26 for the three scenarios. The largest average variability is also shown by Desertic, with an average coefficient of variation of 0.39. Continental-Cold is the region with least variability with average standard deviation of 0.07 and coefficient of variation of 0.08. The region with the largest individual variability is Desertic for Regional Targets scenario, with standard deviation of 0.42 and coefficient of variation of 0.39. Continental-Cold is the region that shows least variability with standard deviation of 0.08 and coefficient of variation of 0.07 for the Regional Targets scenario. Overall, there is more variability in China than in Europe, with coefficients of variation of 0.21 in Europe and 0.29 in China.

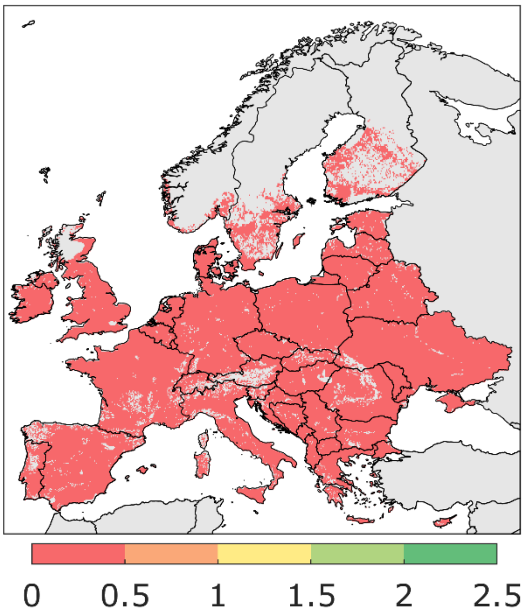
5.3 Qualitative values of improved soil environmental footprint

The results of improved soil environmental footprint obtained for the three scenarios are presented in this section using a qualitative scale. The scale in qualitative categories is shown in **Error! Reference source not found.**Table 6. The numerical values of soil environmental footprint have been divided in five qualitative categories. The column on the right shows the average value of the increase of soil ecosystem services, in percentage, which corresponds to the boundaries of the range.

Table 6. Qualitative values used in the classification of soil environmental footprint

Qualitative category	Range of numerical values	Average increase of soil ecosystem services (%)
Very low	0-0.5	From 0 to 0.71
Low	0.5-1	From 0.71 to 1.0
Moderate	1-1.5	From 1.0 to 1.22
High	1.5-2	From 1.22 to 1.41
Very high	2-2.5	From 1.41 to 1.58

The following figures present the spatial distribution of the results of the classification of soil environmental footprint. The results for the Expected scenario are presented in Figure 43, the results for the Regional Targets scenario are presented in Figure 44 and the results for the Towards 2050 scenario are presented in Figure 45. The figures show the qualitative categories of the projected improvement of the soil environmental footprint for Europe and China.



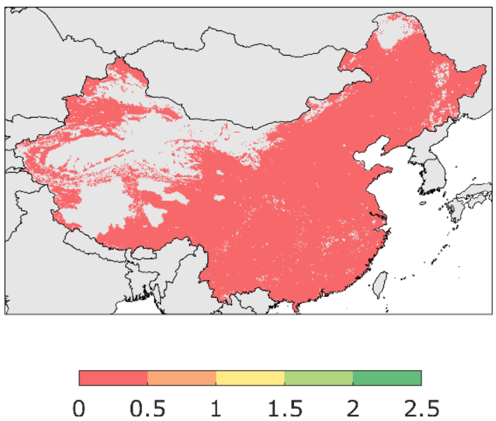


Figure 43. Qualitative classification of improved soil environmental footprint for the Expected scenario

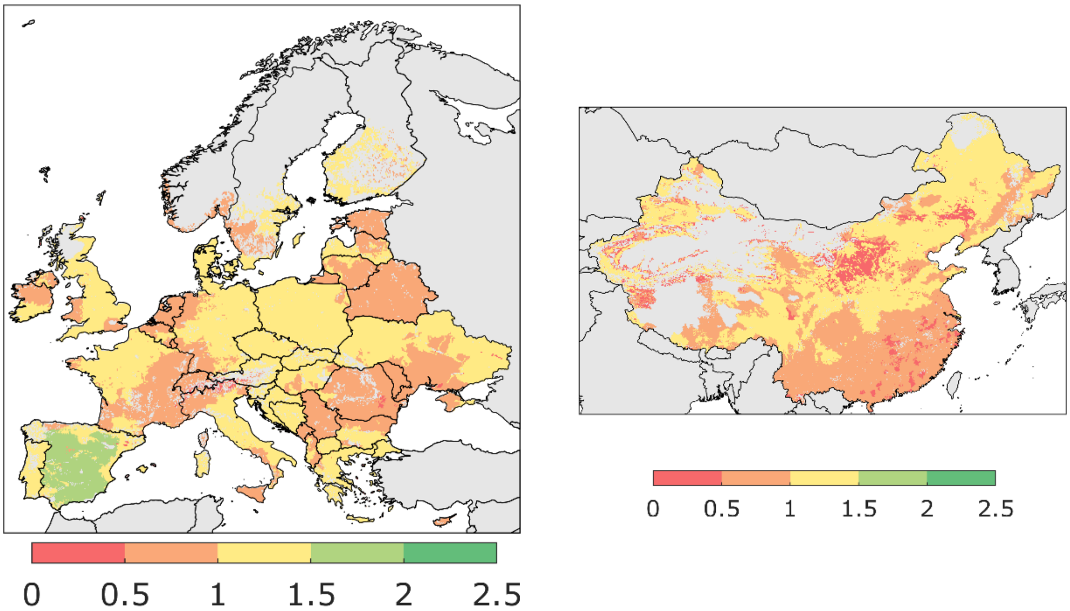


Figure 44. Qualitative classification of improved soil environmental footprint for the Regional Targets scenario

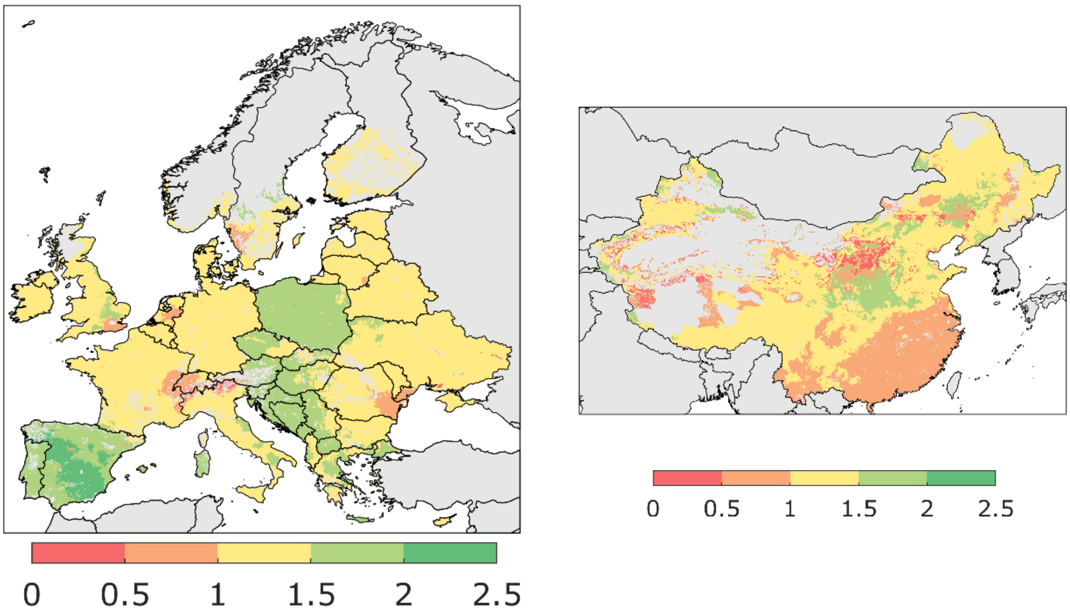


Figure 45. Qualitative classification of improved soil environmental footprint for the Towards 2050 scenario

The figures allow the comparison of the improvement of soil environmental footprint in the three scenarios. For the Expected scenario the improvement of the soil environmental footprint is very low. The Towards 2050 scenario shows a much better improvement of soil environmental footprint. In Europe, high values are located in the Iberian Peninsula. The regions of low values are centred in Eastern France, the Netherlands, Belarus and the Baltic countries, and Romania. In China, the low values are located in the Southeast. For the Regional Targets scenario, there are no low values in Europe. High values are located in the Iberian Peninsula and in a band going from Poland to the former Yugoslavian countries. There are a few patches of very high values in the Iberian Peninsula. In China, the dominant value is moderate, although there is a large region to the Southeast with low values and some patches of high values distributed over the Continental-Temperate region.

5.4 Summary and conclusions

The results of improved soil environmental footprint obtained for the three scenarios are compared in this section. **Error! Reference source not found.**Table 7 presents the global overview, showing the average results obtained for the three scenarios in Europe and China. The same results are visualized in Figure 46.

Table 7. Average results for improved soil environmental footprint in the three scenarios for Europe and China

	Europe	China
Expected	0.13	0.10
Towards 2050	1.07	0.92
Regional Targets	1.41	1.13

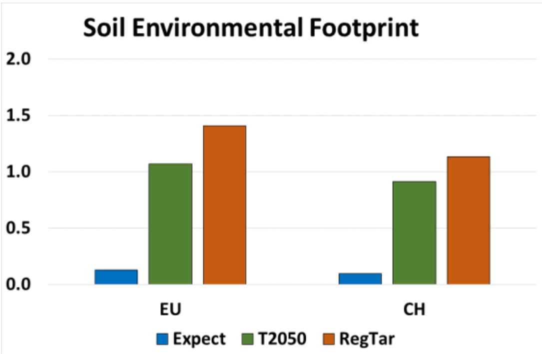


Figure 46. Average results for improved soil environmental footprint in the three scenarios for Europe and China

The average response in Europe is an improvement of soil environmental footprint of 0.13 for the Expected scenario. This corresponds to an average increase of 0.36% of each ecosystem service. The average improvement for the Towards 2050 scenario is 1.07, which corresponds to an average improvement of ecosystem services of 1.03%. In the case of the Regional Targets scenario, the improvement of soil environmental footprint is 1.41, which corresponds to an average improvement of soil ecosystem services of 1.19%. In China, the average improvement of soil environmental footprint for the Expected scenario is 0.10, with an average improvement of 0.32% of soil ecosystem services. For the Towards 2050 scenario, the improvement is 0.92, corresponding to an average increase of 0.96% of soil ecosystem services. In the Regional Targets scenario, the improvement of soil ecosystem services is 1.13, which corresponds to an average increase of 1.06% in soil ecosystem services. Overall, the improvement of soil environmental footprint in China is around 9% less than in Europe for the scenarios under consideration. The comparative results are visualized in Figure 47, where the triangles corresponding to the average values of soil ecosystem services are shown for the three scenarios in Europe and China. In both cases the triangles corresponding to the Towards 2050 and Regional Targets scenarios are much larger than the Baseline, with Regional Targets clearly larger than Towards 2050.

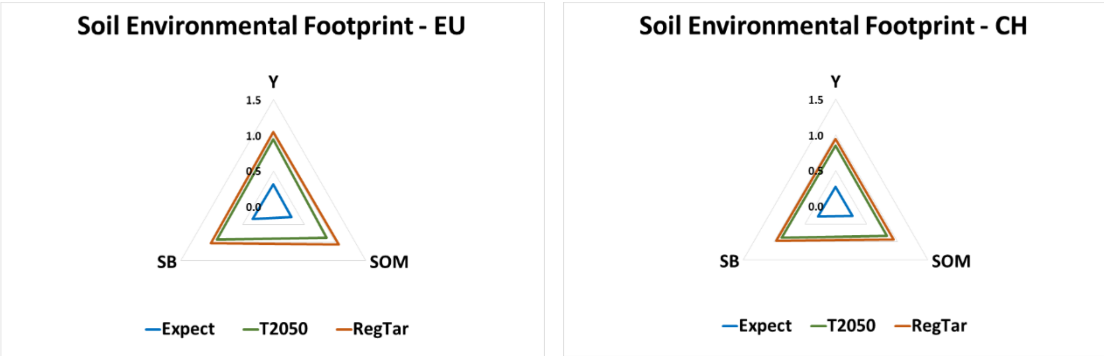


Figure 47. Triangles of soil environmental footprint for the three scenarios in Europe (left) and China (right)

Figure 48 compares the results of improved environmental footprint obtained in the Towards 2050 and Regional Targets scenarios to those obtained in the Expected scenario. The Towards 2050 scenario implies around three times the implementation levels of those in the Expected scenario. However, the increase of soil environmental footprint is close to ten times. The average improvement is 829% better in Europe and 959% better in China. This due to the combined effect of the three ecosystem services, which reinforce each other under the proposed methodology for evaluation. The Regional Targets implies the same level of implementation as the Towards 2050, but the intervention is focused on the areas where soil quality is poor. This produces a significantly better response, with an average improvement of soil environmental footprint of 1090% in Europe and 1187% in China.

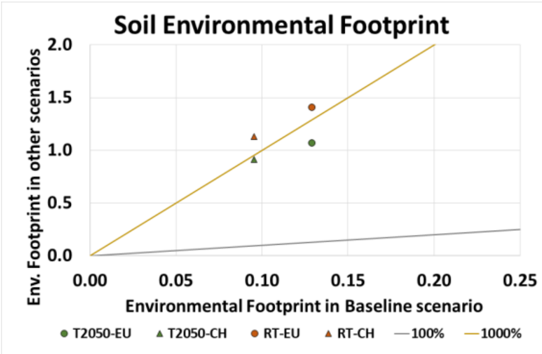


Figure 48. Comparison of improved soil environmental footprint in Regional Targets and Towards 2050 scenarios with respect to Expected scenario

Figure 49 presents the comparison of the results for improved soil environmental footprint obtained in the Towards 2050 and Regional Targets scenarios to those obtained in the Expected scenario for individual agroclimatic regions in Europe and China. The Towards 2050 scenario corresponds to three times the implementation level of the Expected scenario. This leads to a response that is close to the 1000% line. In fact, the slopes of the fitted regression lines in the Towards 2050 scenario are 7.08 for Europe and 8.95 for China. The regional effect of focussing the intervention on the less quality soils is apparent for all regions, because the points corresponding to the Regional Targets scenarios are all above the line corresponding to 1000% of the Expected scenario. The slopes of the fitted regression lines are 8.35 for Europe and 10.87 for China

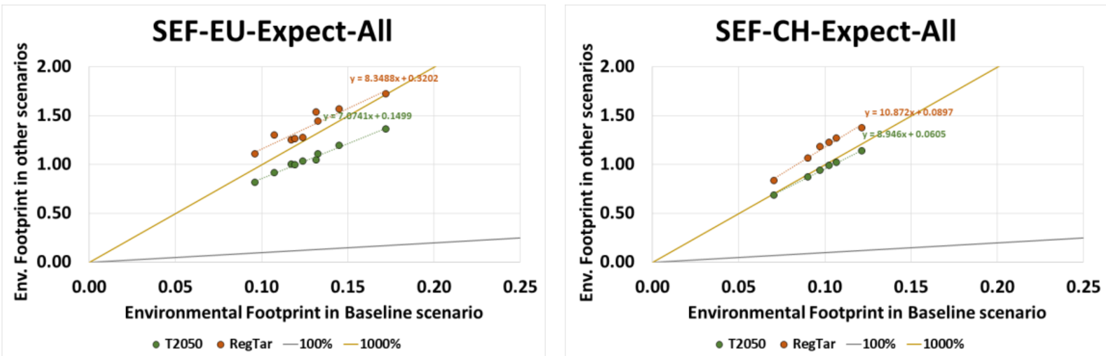


Figure 49. Comparison of improved soil environmental footprint in Regional Targets and Towards 2050 scenarios with respect to Expected scenario for agroclimatic regions in Europe (left) and China (right)

6 Conclusions

6.1 Gaps in knowledge

Limitations of analysis are derived from the modelling tools and datasets used (detailed in Deliverables 7.1 and 7.2). The upscaling model is a generalization of results obtained in long-term experiment sites. These scientific experiments concentrated on specific management practices, crops and soil quality variables under local conditions. The results were generalized to the four classes of management practices, seven farming systems and three soil quality indicators adopted in model conceptualization. Although this process was validated by case study sites, it is a significant extrapolation and results should be viewed with caution. The model is also based on a set of assumptions regarding the differential effect of management practices under local conditions. Although these assumptions are based on evidence, there is no specific information regarding the quantitative values of the differential effect.

There are also limitations derived from the definition of regional scenarios in the multi-actor framework (detailed in Deliverable 7.3). The information on the rate of implementation of agricultural management practices is fragmentary and the desirable rate of implementation is the result of subjective judgement by participating actors. Several assumptions were made on the quantification of the policy scenarios in terms of implemented agricultural management practices. These assumptions influence the results obtained.

Finally, a particular method was chosen to aggregate information on the three soil quality indicators in one single value for soil environmental footprint. This method is based on a geometric construction that does not account for the relative weight of each indicator. It also produces a value that scales as the square of individual indicator values.

6.2 Further work

The results will be used to define the policy recommendations at the regional level (WP8).

7 References

Bai Z, Caspari T, Ruiperez Gonzalez M et al. (2018): Effects of agricultural management practices on soil quality: A review of long-term experiments for Europe and China. Agriculture, Ecosystems and Environment 265, 1-7.

Bünemann EK,Bongiorno G, Bai Z et al. (2018): Soil quality – A critical review. Soil Biology and Biochemistry 120, 105-125.

Rubel, F., and M. Kottek (2010): Observed and projected climate shifts 1901-2100 depicted by world maps of the Köppen-Geiger climate classification. Meteorol. Z., 19, 135-141.

Appendix. Detailed spatial results of the effect of key management practices in soil quality indicators

Figures 50 to 61 present the detailed spatial results of the effect of 10% increase in the implementation of key management practices in soil quality indicators. Values are obtained aggregating the results of Deliverable 7.2 for individual crops.

7.1 Effect of projection of nutrient management

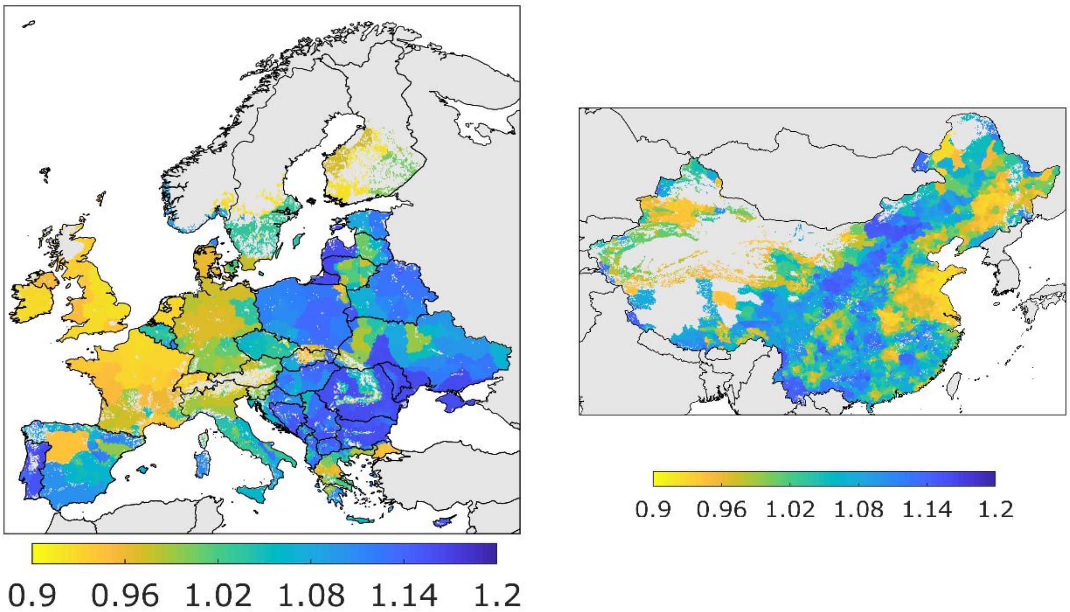


Figure 50. Projected effect of organic matter addition on mean increase in crop yield

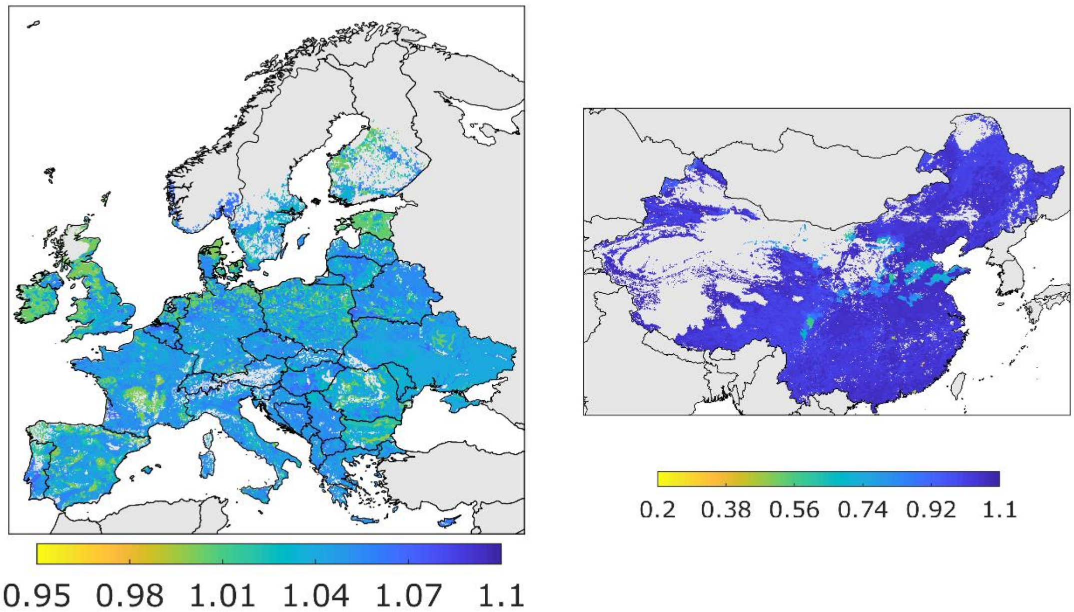


Figure 51. Projected effect of organic matter addition on mean increase in soil organic matter

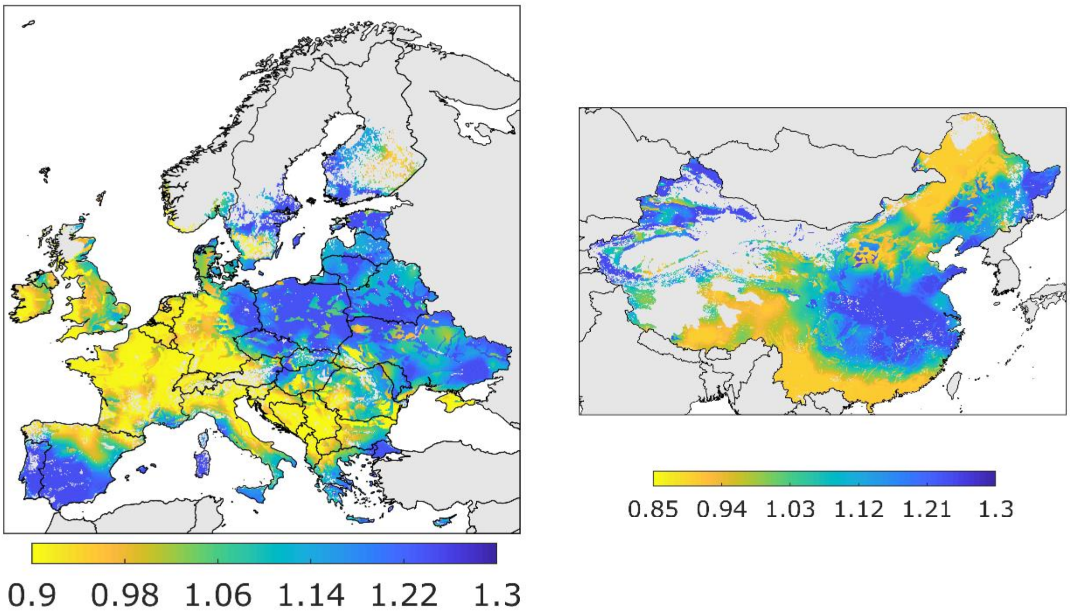


Figure 52. Projected effect of organic matter addition on mean increase in global soil biodiversity

7.2 Projection of tillage practices

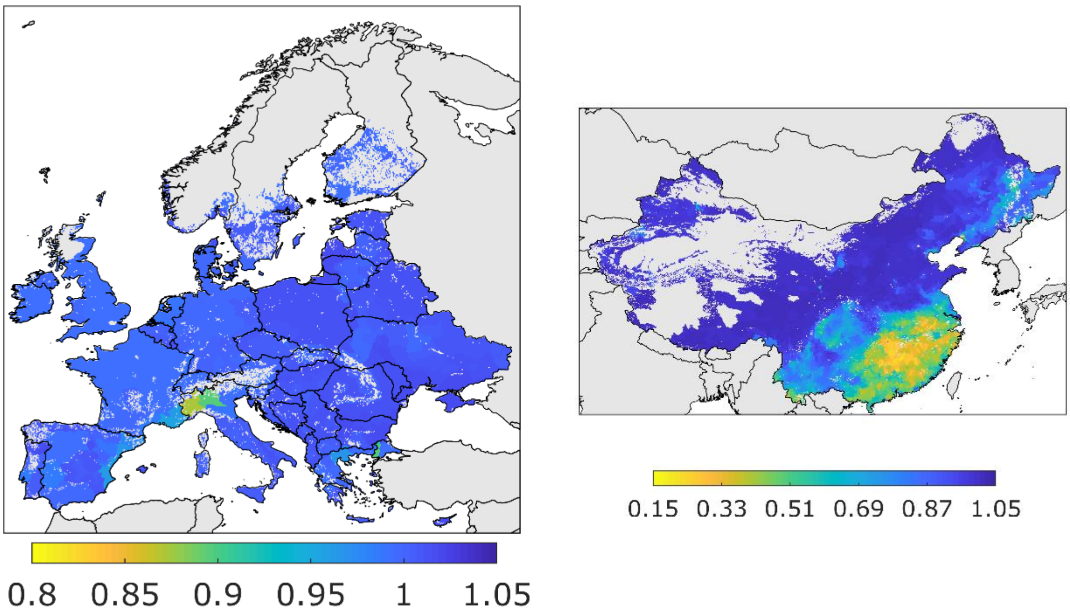


Figure 53. Projected effect of tillage practice on mean increase in crop yield

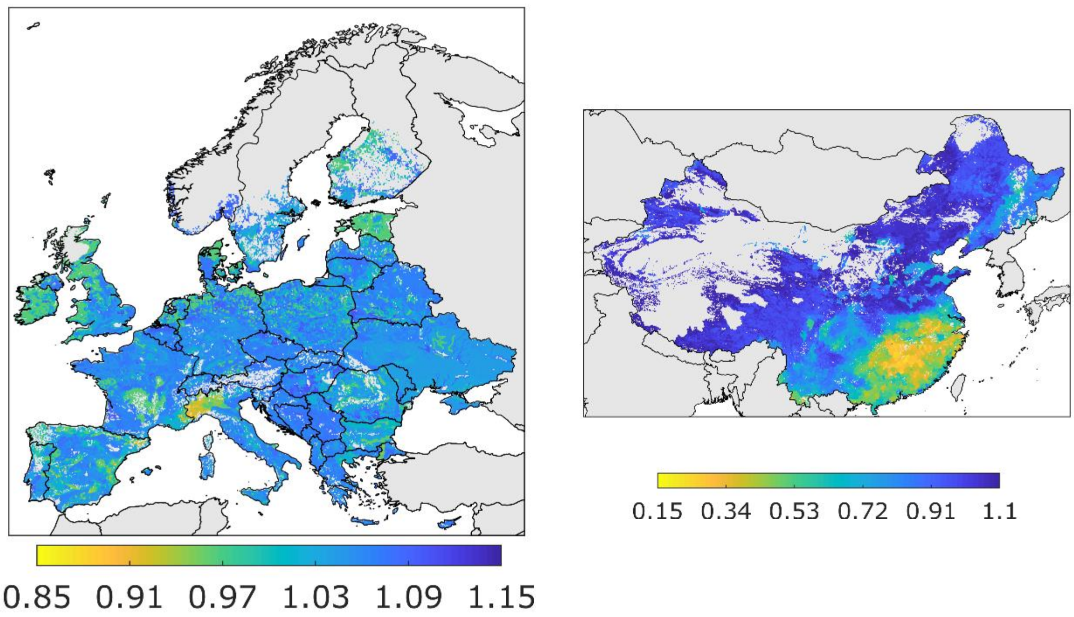


Figure 54. Projected effect of tillage practice on mean increase in soil organic matter

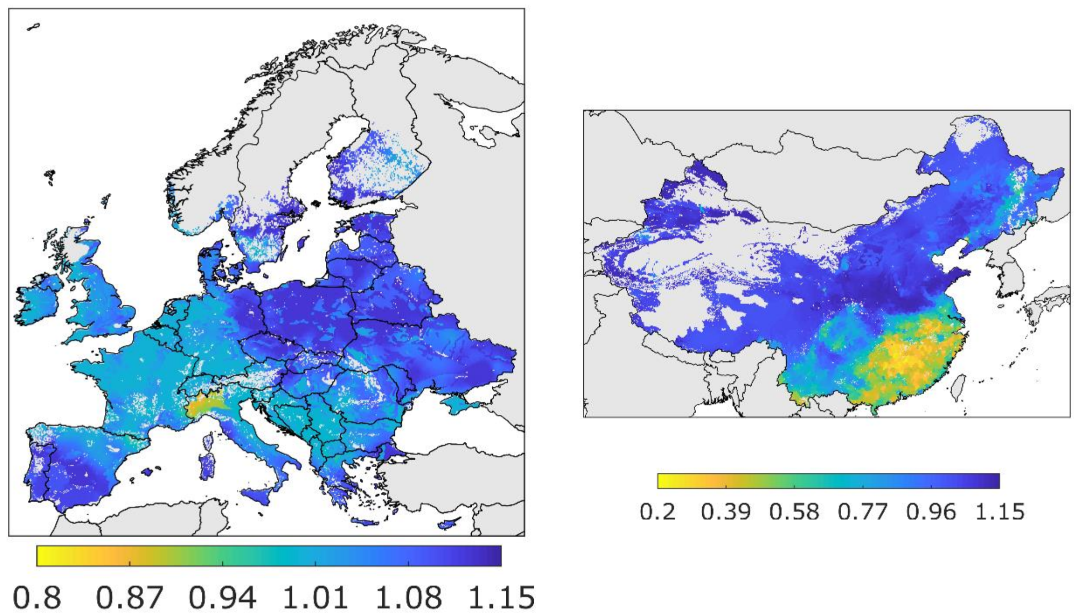


Figure 55. Projected effect of tillage practice on mean increase in global soil biodiversity

7.3 Projection of crop rotation

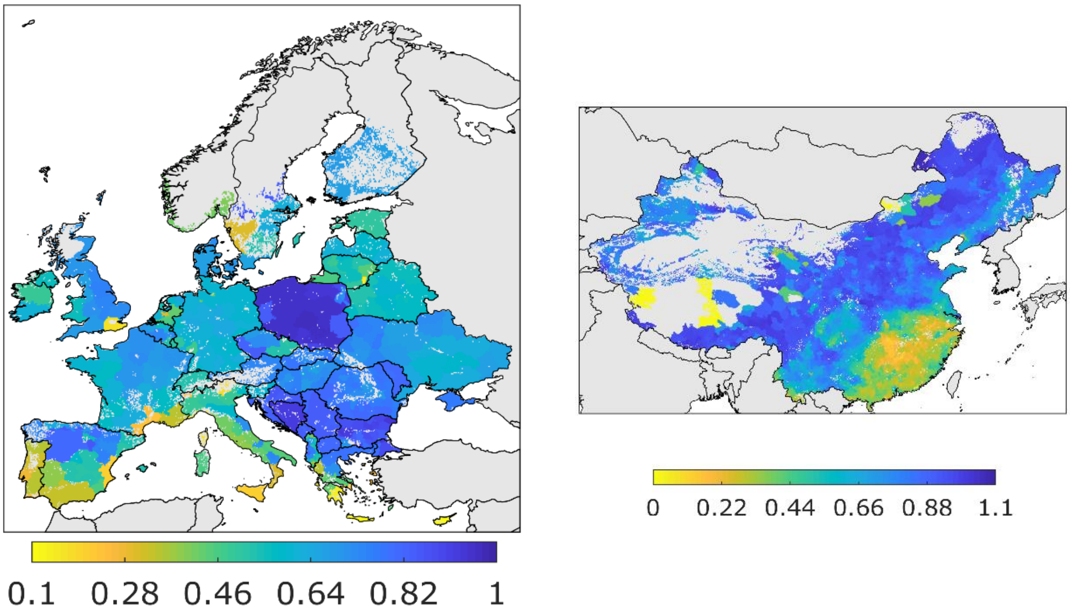


Figure 56. Projected effect of crop rotation on mean incease in crop yield

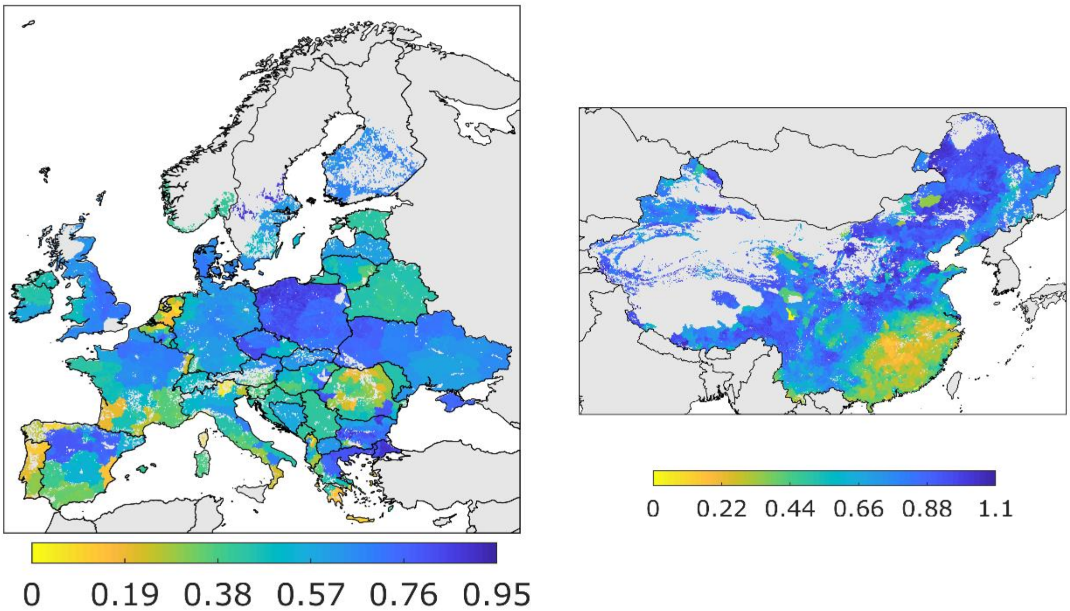


Figure 57. Projected effect of crop rotation on mean increase in soil organic matter

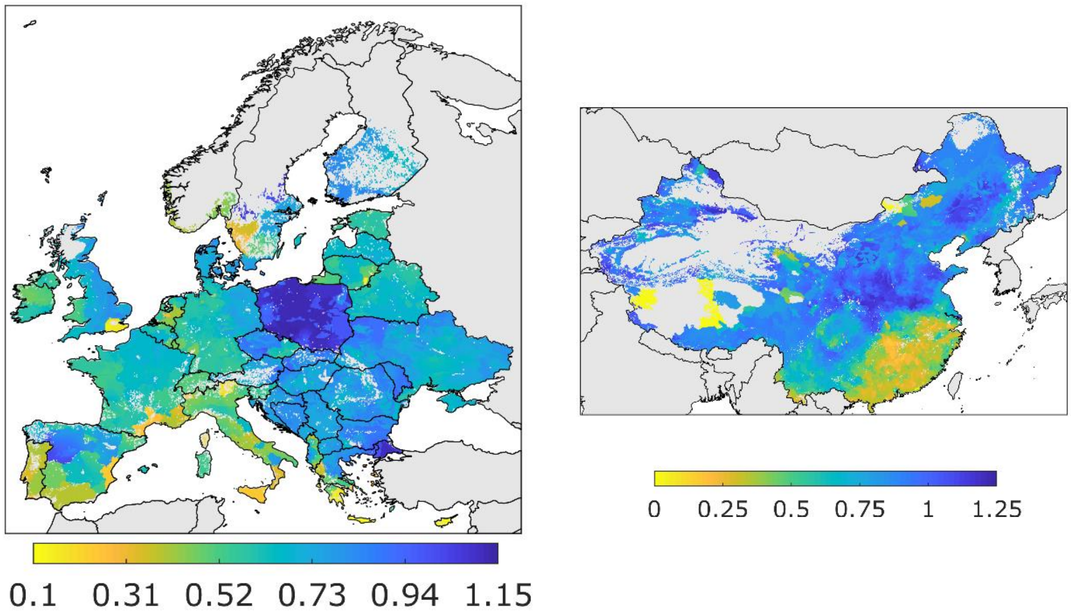


Figure 58. Projected effect of crop rotation on mean increase in global soil biodiversity

7.4 Projection of organic farming

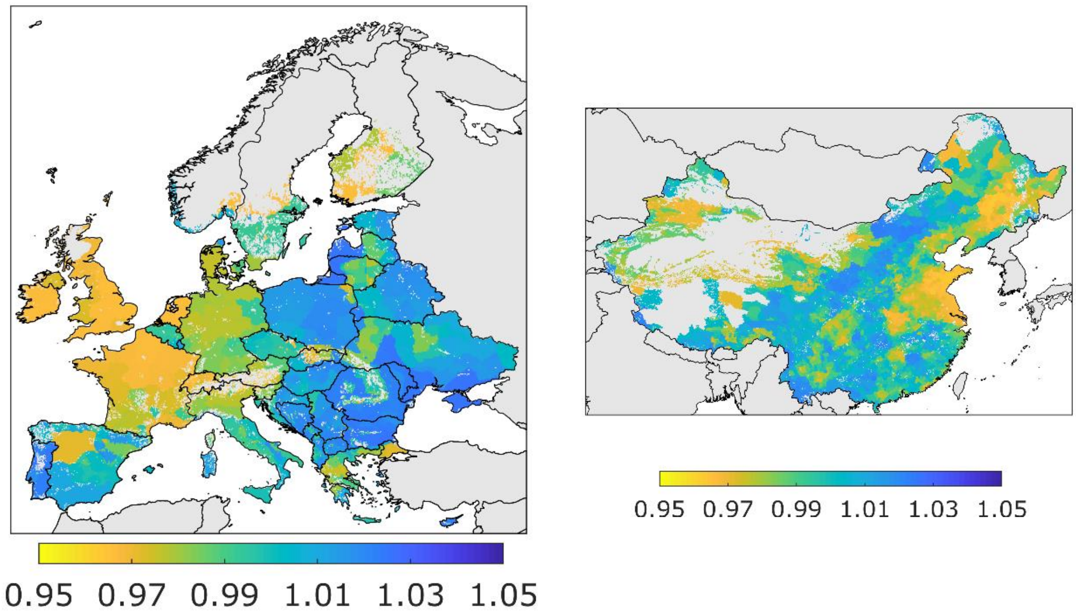


Figure 59. Projected effect of organic farming on mean increase in crop yield

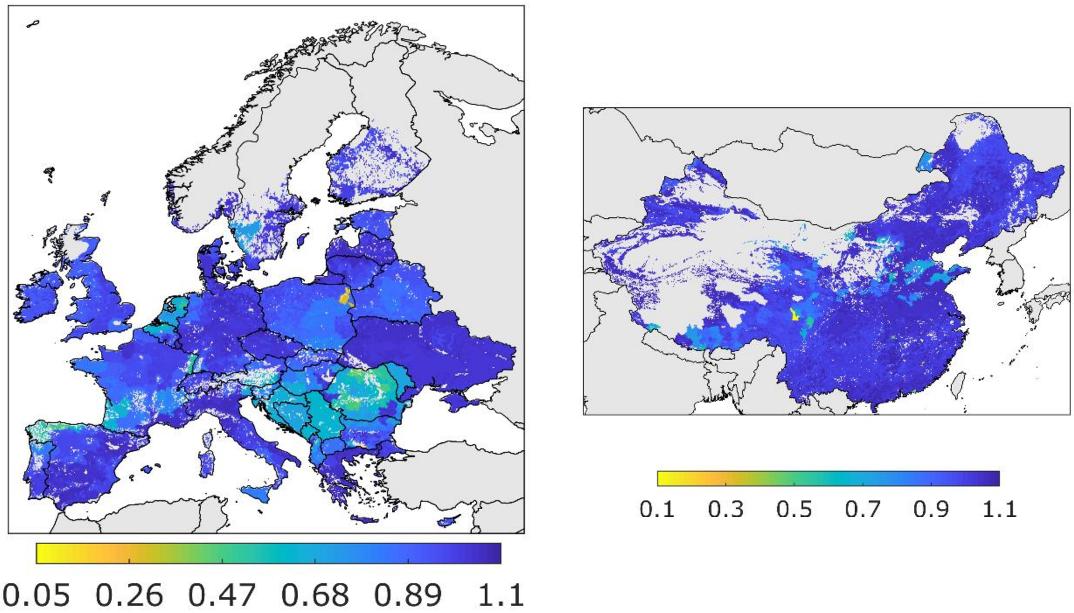


Figure 60. Projected effect of organic farming on mean increase in soil organic matter

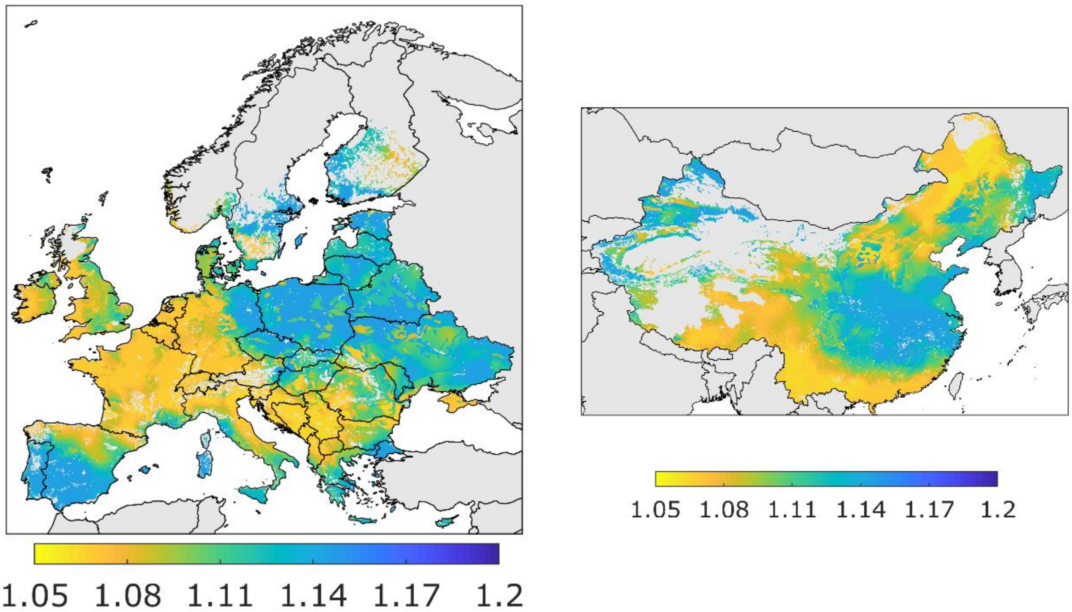


Figure 61. Projected effect of organic farming on mean increase in global soil biodiversity