Report on key management practices affecting soil quality and their applicability in various farming systems

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Report on key management practices affecting soil quality and their applicability in various farming systems

Deliverable 7.2 of WP7

iSQAPER

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

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Table of contents

LIST OF FIGURES

LIST OF TABLES

Executive summary

The main focus of this Deliverable 7.2 is to understand at the continental scale, how agricultural management practices that mitigate soil threats also affect other ecosystem services in different farming systems in Europe and China. The approach is to design an upscaling model that expands the scientific results generated in iSQPAPER at the local level to a wider geographical and management context. The upscaling model is necessarily a simplification of the complex processes that influence and are influenced by soil management at the local level.

The central actor in the modelling 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 soil type, climate, water availability 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.

Functional relations to define the effect of agricultural management practices on ecosystem services are formulated in qualitative terms. In order to test the results with potential changes in policy, here we estimate the effect of implementing 10% additional improved agricultural management practices in each agro-climatic region. In Deliverable 7.4 we will explore the effect of different regional policy scenarios.

Our results show that even with an additional 10% implementation, the effect of improved management is significant in most European and China regions and all the crops considered in this study.

1 Introduction

1.1 Integration of Task WP7.2 in iSQAPER

The main objective of WP7 is to upscale the effect of agricultural management practices on representative farming systems to evaluate the soil environmental footprint in 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).WP2 provides the spatial frame of reference through the identification of detailed agro-climatic zones. WP3 describes how soil type, climatic zone, topography and crop and land management interact to affect indicators of soil quality. These two WPs provide the input for the analysis of farming systems and soil quality indicators performed on Task 7.1 (see Deliverable 7.1).

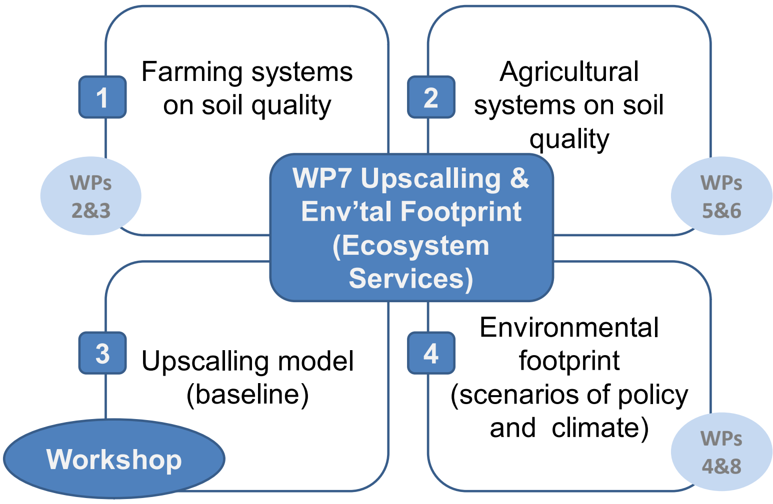


Figure 1. Approach to evaluate the environmental footprint in WP7

Task 5.2 is focused on the effect of agricultural management practices on soil quality. It is mainly based on work performed on WP5 and WP6. WP5 relates agricultural management practices to soil quality status in selected case study sites and identifies innovative practices. In WP6, the proposed measures to improve soil quality are tested, evaluated and demonstrated. Task 5.2 compiles this knowledge to identify the key management practices included in the upscaling model and discusses their applicability in the farming systems identified in Task 2.3. This is achieved through the development of empirical functional relations derived from knowledge compiled in the iSQAPER project.

The dynamic upscaling model will be co-developed, validated and refined with stakeholders through informal consultations and in a formal workshop (Task 7.3). The upscaling model will be applied to account for the changes in farming systems and management practices driven by policy and other physical, social and economic factors to produce a range of future scenarios of soil quality and soil environmental footprint in Task 7.4.

1.2 Objectives

This Deliverable 7.2 is framed into WP7 titled "Upscaling of practices and assessing soil environmental footprint at the level of Europe and China". The main objectives of WP7 are:

Objective 1. Upscale agricultural management practices in representative farming systems at the level of Europe and China.
Objective 2. Assess the impact of future agricultural scenarios on the soil environmental footprint at the level of Europe and China.

Deliverable 7.2defines the procedure to upscale the applicability of agricultural management practices to the continental level based on the previous analyses of farming systems and the assessment of the potential of management practices for improving soil quality. The methodology combines a bottom-up approach, assimilating knowledge compiled and generated in other WPs of iSQAPER and a top-down approach, processing available geospatial information on soil quality indicators and agricultural management practices. The specific objectives of Deliverable 7.2 are:

- Compile knowledge generated in iSQAPER about the long-term effect of agricultural management practices on relevant soil quality indicators
- Formulate qualitative functional relationships that can be included in a dynamical model to estimate soil quality status in future scenarios
- Design a framework to upscale the applicability of agricultural management practices to the continental level

This iSQAPER deliverable presents the upscaling model to translate project results into spatial representation of soil quality status under several future scenarios in order to evaluate soil environmental footprint. Following this introduction, Section 2 presents and overview of the conceptual approach of the proposed upscaling model. Section 3 deals with the core development of the Deliverable: the functional relations that relate agricultural management practices to soil quality for different farming systems. Section 4 presents the dynamic approach to upscale the effect of agricultural management practices to the continental level. Section 5 discusses limitations of the analysis and describes future work. This methodology will be used to link future drivers of change to the status of soil environmental footprint in future scenarios. This approach will be validated in Task 7.3, where the iSQAPER upscaling model will be co-designed. In Task 7.4 soil environmental footprint will be evaluated under a range of policy scenarios. Section 6 presents the conclusions.

2 The approach to upscale the effect of key management practices

The basis for iSQAPER scaling model is defined in Deliverable 7.1. 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. In this section we provide a general overview of the upscaling model, although it is not fully developed yet, because some the components will be developed in further work on Deliverables 7.3 and 7.4.

2.1 From local results to the continental scale

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 other ecosystem services. In order to perform this task, the model accounts for the basic processes that influence agricultural management of the soil. These processes are extremely complex at the physical, chemical, biological and socioeconomic levels and therefore they need to be simplified to become manageable. The basic approach is illustrated on Figure 2, where the relevant processes are represented.

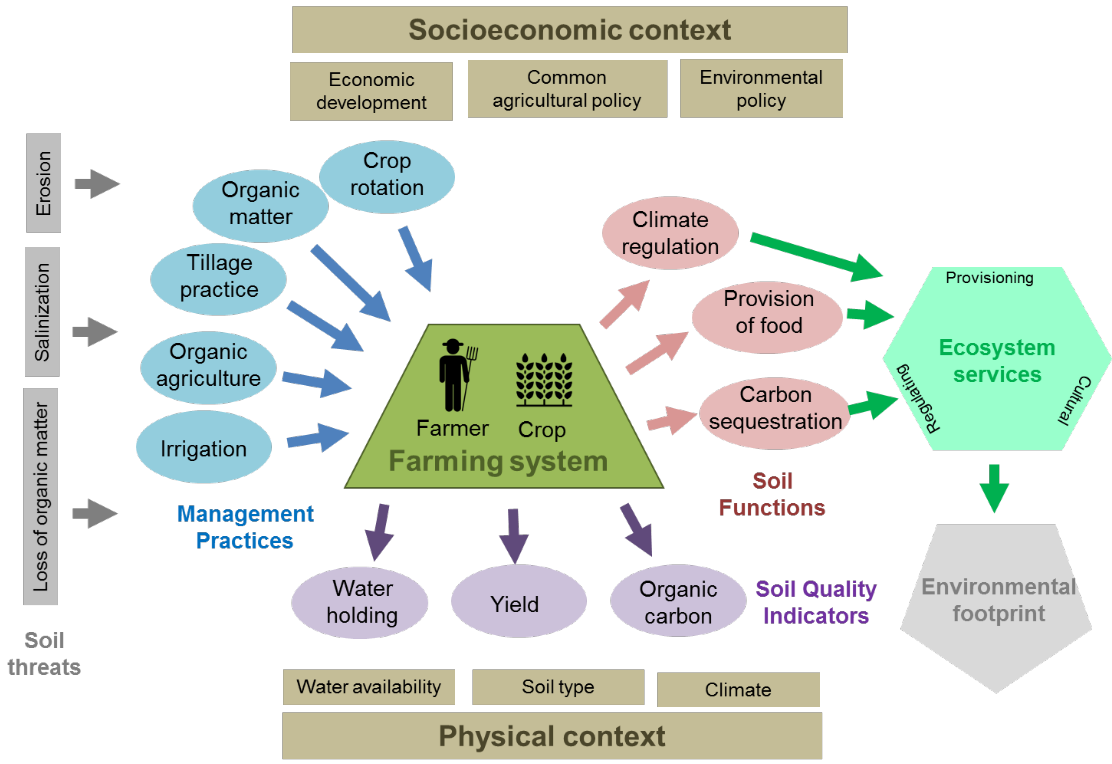


Figure 2. Overall representation of the upscaling approach

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 soil type, climate, water availability 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. For instance, the soil quality indicator "Yield" is linked to the soil function of provision of food, a basic ecosystem service for the soils. 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. They are grouped in the three main categories described below.

Farming Systems

- Cereals
- Rice
- Maize
- Soybean
- Vegetables
- Pasture
- Permanent

Management Practices

- Organic matter
- No tillage
- Crop rotation
- Organic farming

Soil Quality Indicators

- Yield
- Water holding capacity
- SOM/SOC

Figure 3. Main components of the iSQAPER upscaling model

2.2.1 Farming systems

Farming systems are complex and include multiple dimensions that cannot be easily mapped due to these complexities and data limitations. In iSQAPER, for upscaling of results farming systems were therefore represented by the typical cropping patterns (Deliverable 2.5). Seven cropping patterns were considered for the upscaling model of iSQAPER. These types represent a large fraction of the food produced globally and have been chosen to balance model complexity and representability. The categories are the following:

Cereals: Extensive cereals, like wheat, barley, oats or rye, grown in temperate regions, usually rain fed, although they might require supplemental irrigation in some locations. Farming practices usually rely on machinery for harvesting. The use of herbicides and fertilizer is frequent.

Rice: Intensive rice wetland cultivation, with or without irrigation. Farming practices range from subsistence agriculture in small and fragmented fields to fairly advanced high-tech cultivation found in some areas of Europe.

Maize: Arable land devoted to maize cultivation.

Soybean: Arable land devoted to soybean cultivation

Vegetables: Vegetable crops: legumes (beans, peas), root vegetables (carrot, potato, onion, beet), leafy greens (spinach, cabbage, cauliflower, broccoli) and fruit-bearing (tomato, cucumber, pumpkin, zucchini, eggplant). These are grown with a diversity of cultivation techniques: open field, plastic tunnels, glasshouses with or without heating, allowing production in different seasons.

Pasture: Grass-based livestock systems for meat and dairy production.

Permanent crops: Crops that are produced from plants that last for many seasons. It includes olive production for oil or table olives, fruit trees (apples, pears, citrus), vineyard, nuts (walnut, almonds) among others.

2.2.1 Agricultural management practices

Four categories of management practices have been adopted for upscaling in iSQAPER. They are the same categories published in (Bai et al., 2018) to evaluate their effect on different soil quality indicators. They have been chosen to assimilate the results of the analyses performed on the LTE sites. The categories are the following:

Organic matter addition: Addition of organic matter through different techniques, such as selection of a high-residue crop rotation that leaves surface residue or roots in the soil or application of livestock manure.

No tillage or reduced tillage: Grow crops without disturbing the soil through tillage or apply tillage without inversion at a reduced depth.

Crop rotation: Growing of different species of crops in a crop rotation scheme.

Organic agriculture: Combination of different management techniques to avoid synthetic substances. It includes fertilizers of organic origin such as compost or animal manure, crop rotation, companion planting, biological pest control, mixed cropping or fostering of insect predators.

2.2.2 Soil Quality Indicators

Three soil quality indicators have been selected for the iSQAPER upscaling model. The selection was based on the indicators identified in (Bai et al., 2018), but reducing the number for considerations of simplicity, relevance and data availability. The indicators selected for upscaling are the following:

Yield: Yield is selected because it is the most relevant factor for the farmer and is also linked to basic soil functions and ecosystem services. Spatially disaggregated yield information is available for many crops.

Soil organic carbon: SOC is selected because it is directly linked to soil productivity and to climate change mitigation. This quantity may be estimated from proxy data included in soil databases.

3 Quantification of soil ecosystem services at the continental scale

3.1 Soil quality indicators and ecosystem services considered

One of the key aspects of the iSQAPER model is the identification and quantification of the functional relations established between soil threats, agricultural management practices, soil quality indicators, soil functions and soil ecosystem services. These relationships may be very complex, as recognized by Bünemann et al. (2018) in their review of soil quality, conducted in the framework of iSQAPER project. Every soil threat affects several soil functions, which are in turn linked to several ecosystem services. This complexity needs to be simplified for establishing the effect of agricultural management practices in different farming systems at the continental scale.

The approach followed in the upscaling model has been to include functional relations that are essential to establish the linkage between policy choices and soil ecosystem services and that can be supported by the science developed within the iSQAPER project. Scientific analyses are based on the input provided by the case study sites and on the elaboration of data collected in the LTEs over a long period of time. These studies focused mainly on the relationship between agricultural management practices and soil quality indicators. These functional relations are based on science and are readily available within the project, and therefore they have been selected to build the upscaling model.

The nature of the functional relations is outlined in Figure 4. For each farming system, the long-term evolution of soil quality indicators in determined by local conditions and the management practices adopted for farming. As shown in the LTEs, sustained application of beneficial practices has a measurable impact on soil quality indicators that may be quantified, at least to a first approximation.

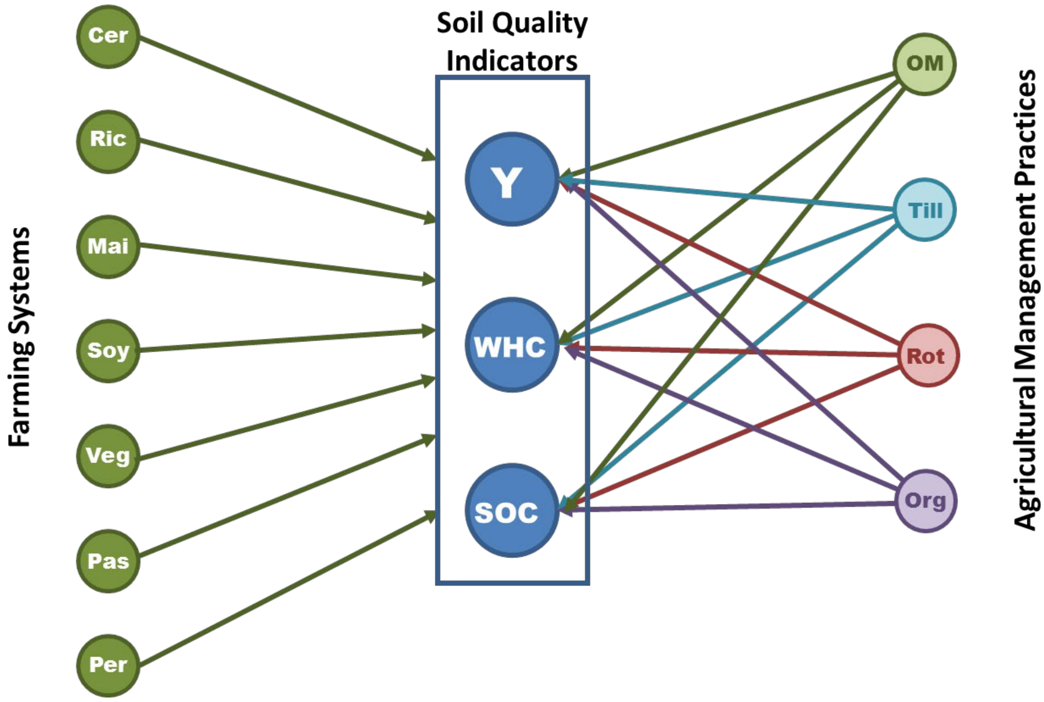


Figure 4. Main functional relations in the upscaling model that define soil ecosystem services represented by soil quality indicators

3.2 Linking scientific results at the local level to the evaluation at the continental scale

The selected indicators that represent the effect of agricultural management practices in soil ecosystem services were detailed in Deliverable 7.1. To quantify their effect, our approach is to upscale the scientific results at the local level to the evaluation at the continental scale.

Bai et al. (2018) evaluated paired response ratios for different soil quality indicators and management practices. In total, 354 paired observations were analysed. The results were reported in Bai et al. (2018). The table shown in Figure 5, taken from Bai et al. (2018), summarizes the results, showing the number of pairs compiled and relevant parameters of the distribution (mean, median, standard deviation, skewness, quartiles, maximum and minimum. The indicators with more data are Yield and SOM, while Earthworms shows the least data availability.

Table 1 and Figure 5 of Bai et al. (2018), showing descriptive statistics for impact of selected management practices on specific soil quality indicators (response ratios, dimensionless).

Table 1. Descriptive statistics for impact of sectoral management practices on soil quality (Bai et al., 2018)

Table 1
Descriptive statistics for impact of selected management practices on specific soil quality indicators (response ratios, dimensionless).

Paired Management Practices	Indicators	Response Ratio								
		Mean	Q1[a]	Median	Q3[b]	Minimum	Maximum	SD[c]	Skewness	N[d]
Organic matter addition versus no organic matter input	Yield	1.67	1.12	1.37	1.66	0.95	7.72	1.19	3.79	54
	SOM[e]	1.39	1.15	1.29	1.50	1.00	2.51	0.33	1.36	63
	pH	1.03	0.99	1.01	1.05	0.95	1.25	0.07	1.37	38
	Earthworms(numbers)	2.45	1.44	1.69	2.79	1.25	5.57	1.67	0.96	6
	Aggregate stability	1.42	1.09	1.23	1.67	0.91	2.38	0.48	0.82	16
No tillage versus tillage	Yield	0.99	0.94	0.98	1.01	0.74	1.40	0.12	1.30	50
	SOM	1.46	1.10	1.20	1.57	0.93	3.85	0.69	2.27	18
	pH	1.02	1.01	1.02	1.03	1.00	1.03	0.02	0.00	2
	Earthworms(numbers)	1.53	1.22	1.53	1.84	0.91	2.15	0.62	0.00	3
	Aggregate stability	1.45	1.09	1.12	1.30	0.82	3.86	0.92	1.91	9
Crop rotation versus mono-cultivation	Yield	1.31	1.13	1.17	1.28	0.98	2.57	0.40	2.26	14
	SOM	1.41	1.00	1.25	1.49	0.89	3.00	0.61	1.45	15
	pH	1.01	0.98	1.01	1.04	0.97	1.04	0.04	−0.07	4
	Earthworms(numbers)	1.73	1.18	1.73	2.27	0.63	2.82	1.55	0.00	2
	Aggregate stability	1.45	0.90	0.97	1.53	0.77	3.10	1.10	0.73	4
Organic versus conventional agriculture	Yield	0.96	0.75	0.89	1.09	0.54	1.66	0.30	0.81	13
	SOM	1.31	1.01	1.12	1.18	0.98	3.06	0.56	2.00	22
	pH	1.00	0.98	1.00	1.02	0.92	1.06	0.04	−0.25	12
	Earthworms(numbers)	1.75	1.63	1.93	1.97	1.32	2.00	0.37	−0.37	3
	Aggregate stability	1.31	1.19	1.34	1.40	0.99	1.61	0.22	−0.11	6

[a] Q1, first quartile.
[b] Q3, third quartile.
[c] SD, standard deviation.
[d] N, number of observations.
[e] SOM, soil organic matter.

The results were also graphically represented as “flower petals”, as shown in Figure 5. The median impact for each management practice is represented in polar coordinates. Values greater than one indicate positive effects, with a colour code to identify the intensity of the impact: orange, median ≤1; light green, 1 < median<1.5; and dark green, median>1.5.

Results obtained in the LTE sites are the core of the functional relations proposed in the upscaling model. They provide a solid description of the long-term influence of agricultural management practices on soil quality indicators, based on a large number of experimental measurements. They also analysed other factors, like the expected dispersion of results for various local conditions, that are relevant for implementing the upscaling model.

However, the upscaling model requires further information to account for different farming systems or agro-climatic zones. This additional information was derived from iSQAPER case study sites through personal interviews during the Second General Assembly held in Tartu in June 2018 and through a questionnaire that was distributed to iSQAPER partners. The objective of the interaction with case studies was twofold: validation of the general framework of the upscaling model and identification of singularities for each farming system under the local conditions of each case study site. The initial input provided during the interviews was incorporated to the upscaling functional relations, which were later validated through the questionnaire.

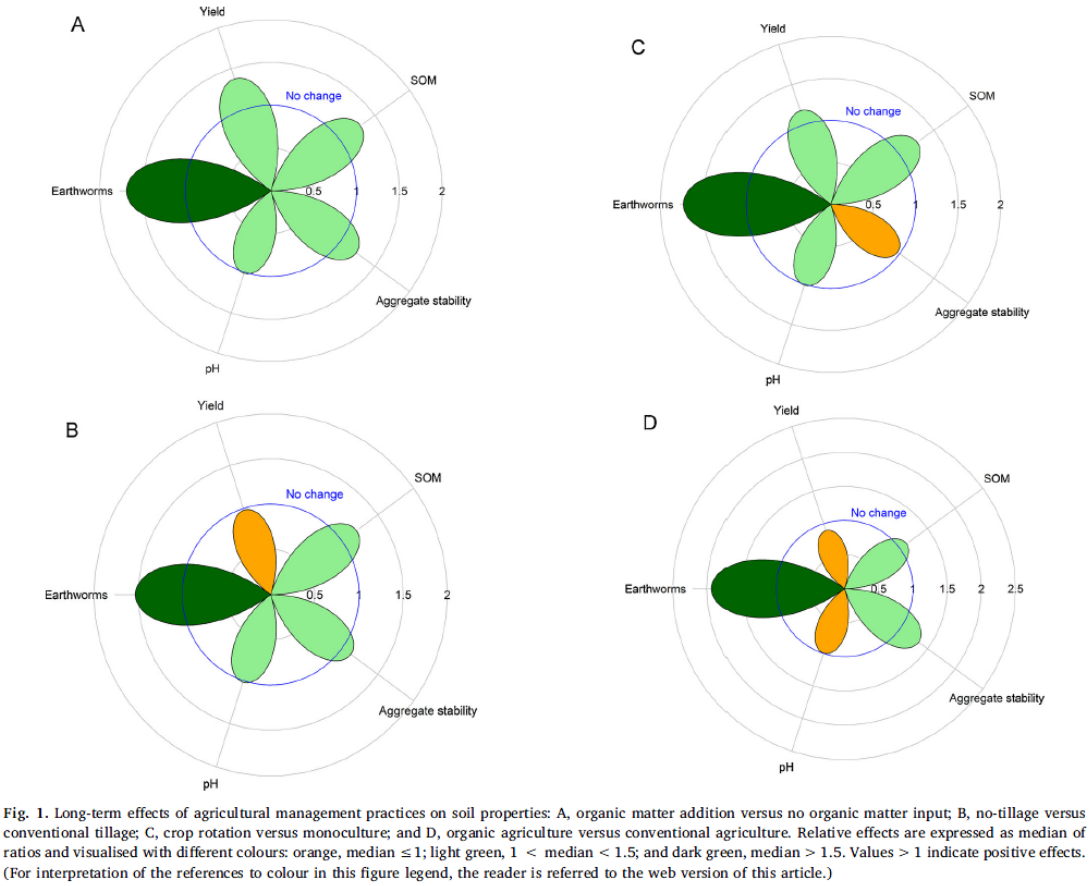


Figure 5. Bai et al. (2018) showing long term effect of agricultural management practices on soil properties

3.3 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.

The results of the LTE sites for the soil quality indices selected for upscaling are summarized in Figure 6. It shows the "flower graphs" for Yield, Water Holding Capacity and Soil Organic Matter. Each graph includes the effect of the five agricultural measures under analysis. In the case of Yield, three measures produce positive effects (organic matter addition, crop rotation and irrigation) and two measures produce negative impact (no tillage and organic farming). For the two other indices, all measures produce positive effects. The most relevant effect is no tillage, which produces a response ratio of 1.46. These values are taken as reference conditions, accounting for the variability of effects.

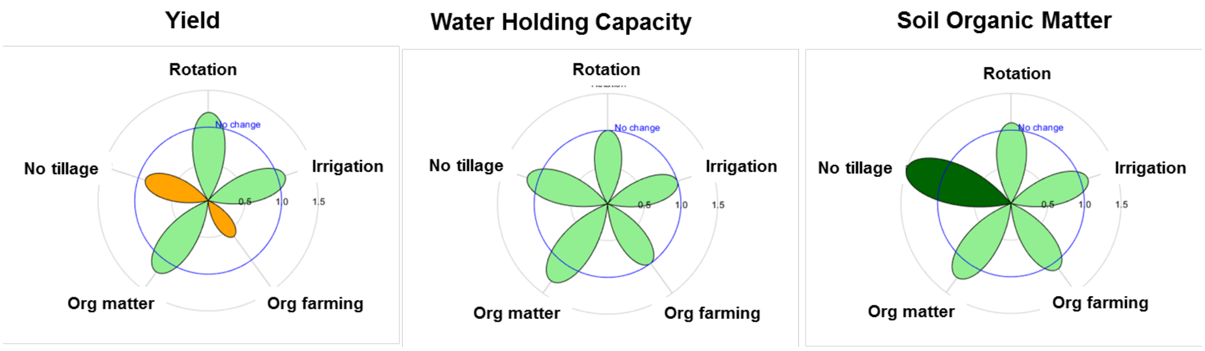


Figure 6. Effect of agricultural management practices on yield, water holding capacity and soil organic matter (Bai et al., 2018)

Table 2, 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. Most of the results show large uncertainty, represented by high values of the standard deviation.

Table 2. 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

3.4 Integrating knowledge from scientists' stakeholders

Functional relations are formulated in qualitative terms. The objective is to account for the positive or negative effects of management practices on soil quality indicators linked to soil ecosystem services and thus assess the projected impact of alternative policies in future scenarios. The proposed qualitative domain was defined in Deliverable 7.1 and was inspired on the Likert scale. Likert scaling is a bipolar scaling method, measuring either positive or negative response to a statement. 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 in the following categories:

Positive (++): This category means that the management practice applied to the local farming system will certainly improve the soil quality indicator with respect to the reference value obtained in the LTE, with effects larger than 10%. We adopt 12.5%.

Beneficial (+): This category means that the management practice applied to the local farming system has potential to improve the soil quality indicator with respect to the reference value obtained in the LTE, but the effects may depend on additional factors. The improvement will be between 5% and 10%. We adopt 7.5%.

Neutral (=): This category represents a neutral impact of the management practice applied to the local farming system on the soil quality indicator under analysis with respect to the reference value obtained in the LTE. It corresponds to a positive or negative effect of less than 5%. We adopt that the practice has no effect.

Unfavourable (-): This category means that the management practice applied to the local farming system may degrade the soil quality indicator with respect to the reference value obtained in the LTE, but the effects may depend on additional factors. The degradation will be between 5% and 10%. We adopt -7.5%.

Negative (--): This category means that the management practice applied to the local farming system will certainly degrade the soil quality indicator with respect to the reference value obtained in the LTE, with effects larger than 10%. We adopt -12.5%.

The resulting values of the application of management practices to farming systems are presented in the following tables.

Table 3. Effect of agricultural management practices on crop yield

	Organic matter	No tillage	Crop rotation	Organic farming
Cereals	=	+	++	+
Rice	=	n.a.	n.a.	+
Maize	=	=	+	=
Soybean	=	=	+	=
Vegetables	+	=	=	+
Pasture	+	+	n.a.	+
Permanent crops	+	+	n.a.	+
Mean (Del 3.2)	1.67	0.99	1.31	0.96
Median (Del 3.2)	1.37	0.98	1.17	0.89
St. Dev (Del 3.2)	1.19	0.12	0.40	0.30

Table 4. Effect of agricultural management practices on soil organic matter

	Organic matter	No tillage	Crop rotation	Organic farming
Cereals	=	++	++	+
Rice	=	n.a.	n.a.	+
Maize	=	+	++	=
Soybean	=	+	+	=
Vegetables	+	+	=	+
Pasture	++	++	n.a.	+
Permanent crops	=	=	n.a.	+
Mean (Del 3.2)	1.39	1.46	1.41	1.31
Median (Del 3.2)	1.29	1.20	1.25	1.12
St. Dev (Del 3.2)	0.33	0.69	0.61	0.56

Table 5. Effect of agricultural management practices on earthworms

	Organic matter	No tillage	Crop rotation	Organic farming
Cereals	=	+	++	+
Rice	=	n.a.	n.a.	+
Maize	=	=	+	=
Soybean	=	=	+	=
Vegetables	+	=	=	+
Pasture	+	+	n.a.	+
Permanent crops	+	+	n.a.	+
Mean (Del 3.2)	2.45	1.53	1.73	1.75
Median (Del 3.2)	1.69	1.53	1.73	1.93
St. Dev. (Del 3.2)	1.67	0.62	1.55	0.37

3.5 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 data catalogue is a compilation of variables under a unified structure and spatial resolution: a gridded data structure of 0.05 spatial degrees' resolution. Sources of information are heterogeneous, including a diversity of variables with different resolutions. The data catalogue finally selected is summarized in Figure 7 (see Deliverable 7.1 for complete information and discussion). Variables are clustered in tables according to the Local Conditions, the Farming Systems, the Management Practices and the Soil Quality Indicators.

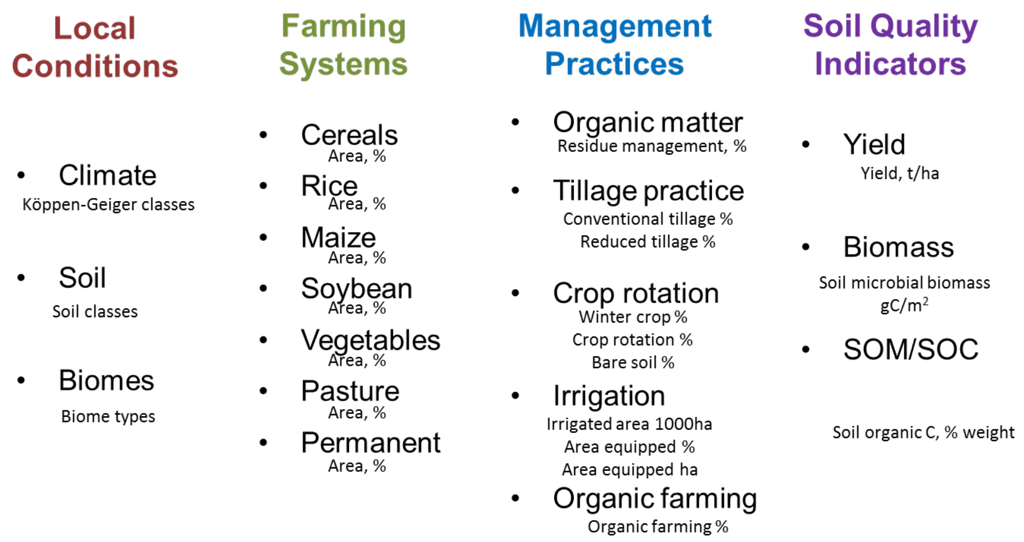


Figure 7. Variables included in the data catalogue relevant for the upscaling model

3.6 Drivers of change

The science developed in the iSQAPER project provides the basic building blocks for upscaling, but the intensity of the actions is determined by external factors that should be evaluated separately. These drivers of change will determine the extent of adoption of beneficial management practices and the corresponding improvement of soil quality indicators. Drivers of change may be natural, such as climate change, or man-made, such as socioeconomic development or policy priorities.

The upscaling model will identify a reduced set of scenarios where these drivers of change will be identified and characterized. The identification will include a diversity of factors, ranging from climatic factors or population dynamics to policy formulation. As a result of the analysis, a policy portfolio will be defined, consisting on a spatial representation of the degree of adoption of the different management practices considered. This activity is the object of task 7.4 and will be reported on Deliverable 7.4.

3.7 Spatio-temporal analysis

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.

The basic approach of the spatial analysis is illustrated on Figure 8. The domain is divided in grid cells with the same resolution as the data catalogue: 5 minutes. The model accounts for the current local values of the soil quality indicators and the current degree of implementation of management practices, if available. The external forcing is described through a scenario of policy drivers, that determine an additional implementation of certain management practices. Model inference estimates the changes in soil quality indicators as a result of the policy drivers.

A differential response is expected as a result of local conditions: farming system, current values of soil quality indicators and current degree of implementation influence the extent to which the soil react changes in management practices. These local effects are analysed in detail in the following section.

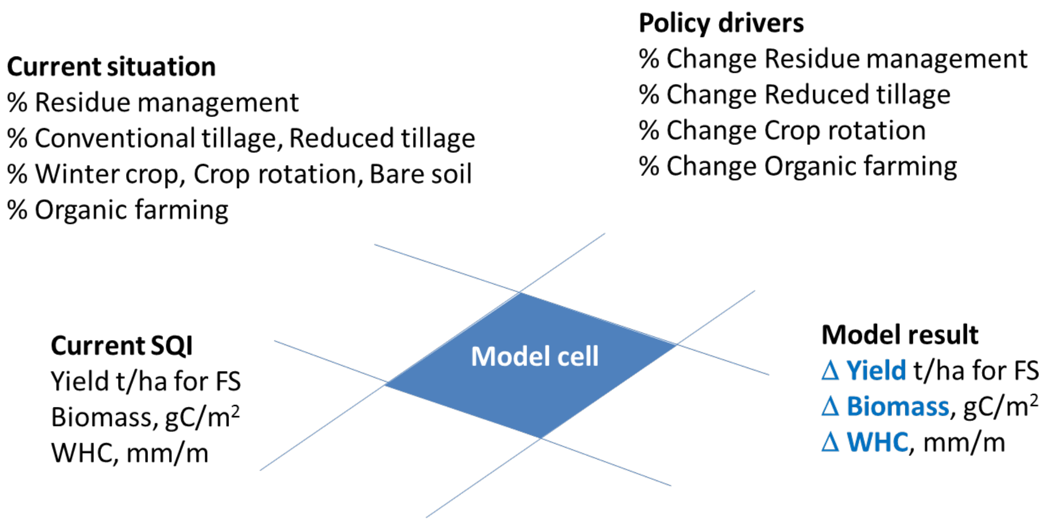


Figure 8. Basic spatial structure of the upscaling model

3.8 Quantification of soil ecosystem services in each point

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. Figures 9 and 10 show the climate zones for Europe and China and the yield distribution for the "Rice" farming system in the Arid (B) climatic zone in China.

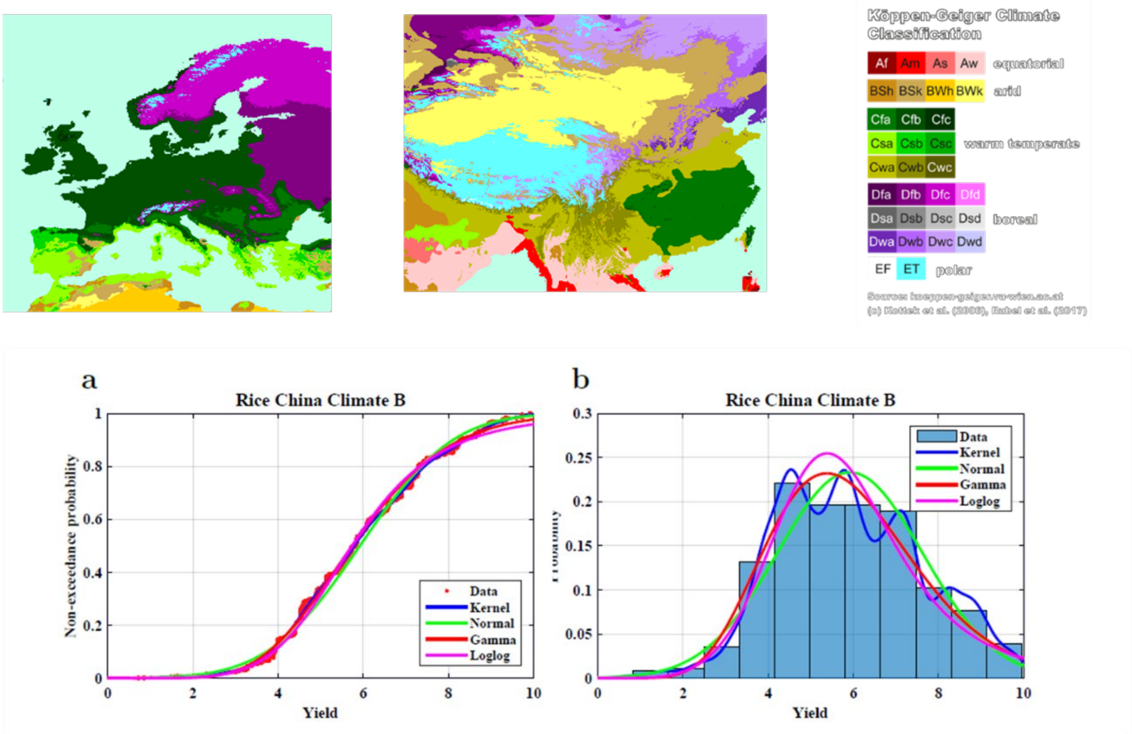


Figure 9. Köppen-Geiger climate classes in Europe and China (above) and sample yield distribution for the "Rice" farming system under Arid (B) climatic zone in China

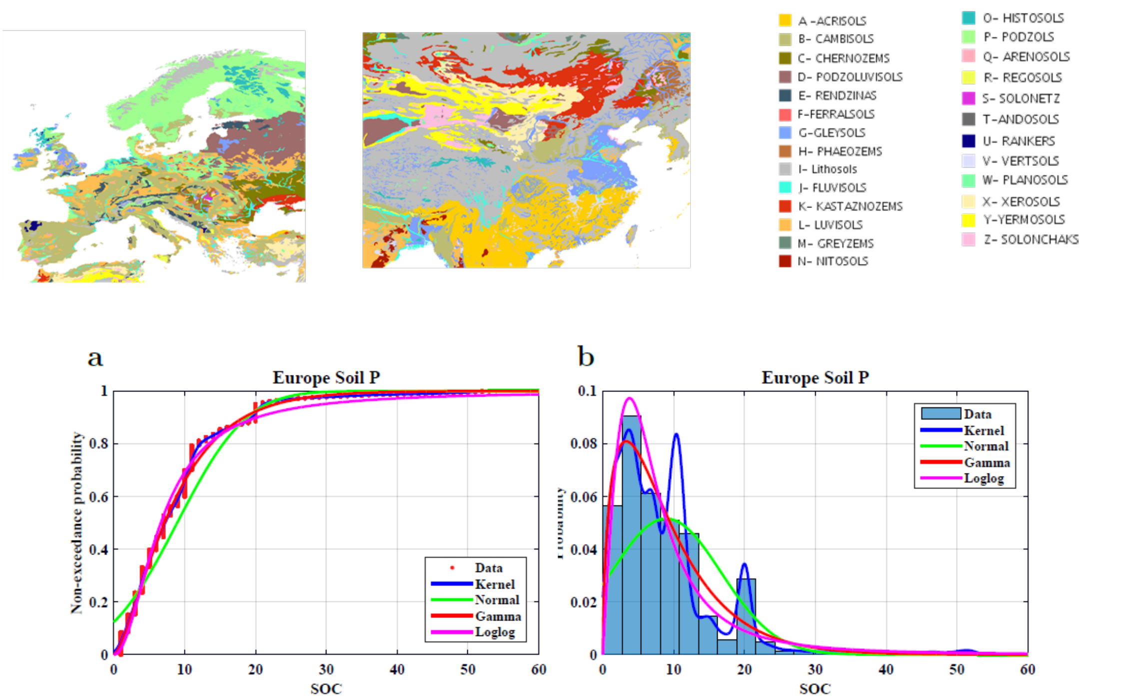


Figure 10. Soil classes in Europe and China (above) and sample Soil Organ Carbon distribution Podzols (B) soil type in Europe (below)

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. Figure 14 shows the soil types for Europe and China and the SOC distribution for the Podzols (P) soil type in Europe.

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 following categories may be defined according to the values of the standardized soil quality index:

Very small: The standardized soil quality index is less than -1.5

Small: The standardized soil quality index is larger than -1.5, but less than -0.5

Average: The standardized soil quality index is larger than -0.5, but less than 0.5

Large: The standardized soil quality index is larger than 0.5, but less than 1.5

Very large: The standardized soil quality index is larger than 1.5

Figure X illustrates this classification for the local group of rice yield in arid (B) climate in China.

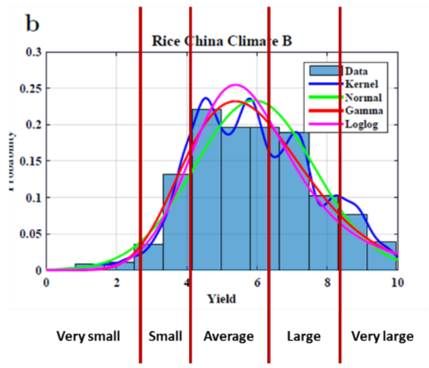


Figure 11. Distribution of categories for the local group of rice yield in arid (B) climate in China

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 5 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 following function definition.

If the standard soil quality indicator is smaller than -1, the response ratio is considered to be equal to the Median value plus the Standard Deviation of the distribution.

If the standard soil quality indicator is greater than 1, the response ratio is considered to be equal to the Median value minus the Standard Deviation of the distribution.

If the standard soil quality indicator is greater than -1 and smaller than 1, the response ratio is computed with the following equation:

$$RR = Median - SSQI.SD$$

where RR is the response ratio, SSQI is the standardized soil quality indicator and SD is the standard deviation of the distribution.

The response function is illustrated in Figure 15.

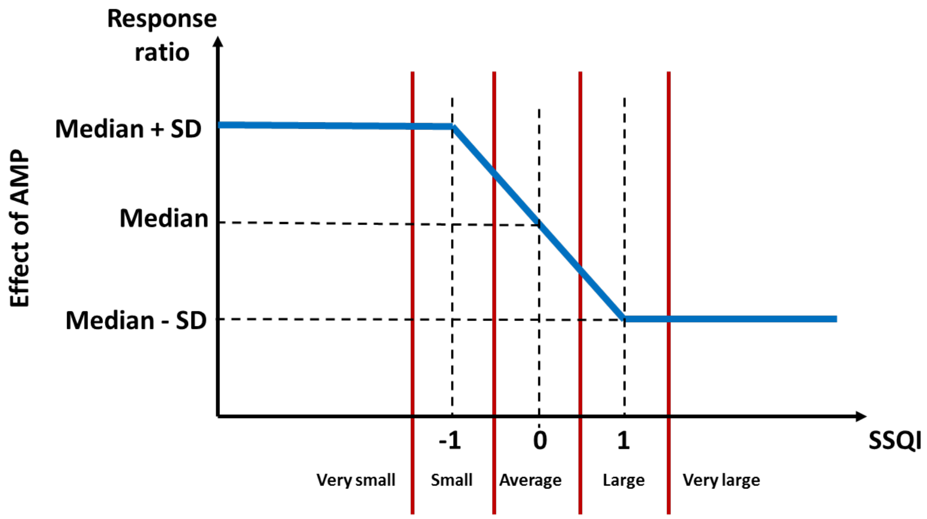


Figure 12. Function for the local influence model

4 Agro-climatic regions for policy analysis

4.1 Definition of policy implementation and agro-climatic regions

The basic idea is to perform a sensitivity analysis of soil quality indicators to agricultural management practices for the different farming systems. We assume a nominal increase of 10% in the application of the management practice under analysis and estimate the impact in terms of expected change of standardized soil quality indicators. The implementation of the management practice is carried out by selecting a random number of cells such that the practice is implemented in 10% of the cultivated area for the farming system under study The selection of cells is conditioned by the current degree of implementation of the practice in the different regions, if these data are available. We assume that the implementation level will be higher in areas where the current level of implementation is low, since policy will be more focused on increasing the implementation level in the regions where the practice is not fully adopted. This aspect is illustrated in Figure 13.

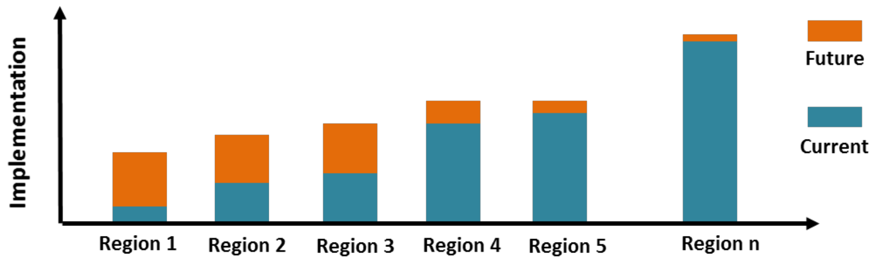


Figure 13. Distribution of cells selected for implementation: more density of cells in regions where the current level of implementation is less

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.

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 Figures 14 and 15.

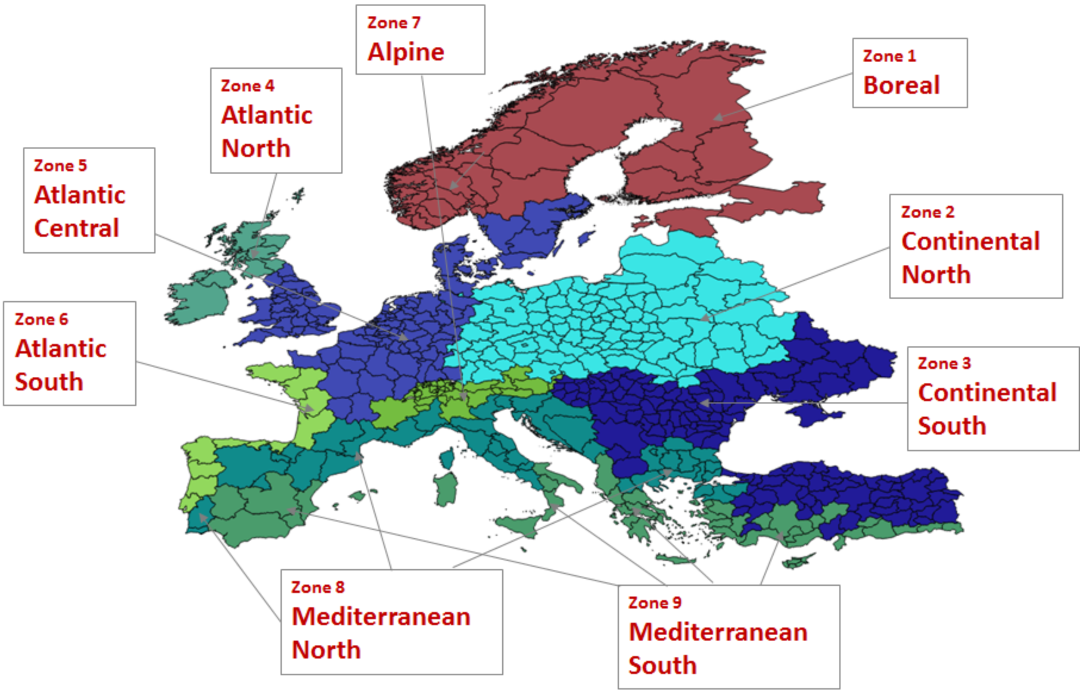


Figure 14. Agro-climatic regions adopted for upscaling in Europe

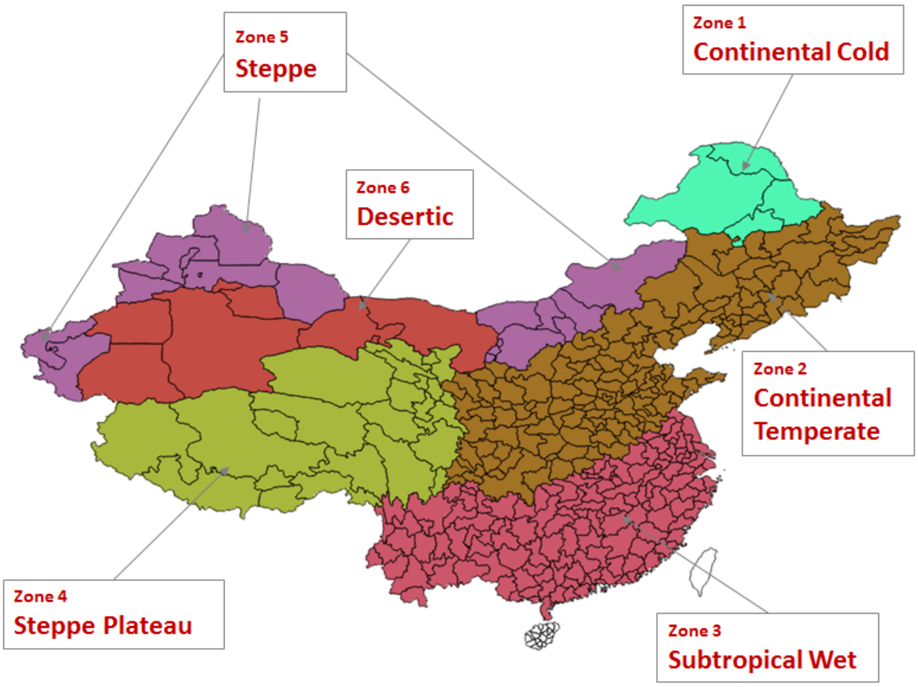


Figure 15. Agro-climatic regions adopted for upscaling in China

The codes used to identify farming systems and agro-climatic regions are shown in Table 6.

Table 6. Codes used in the visualization of results

Cropping pattern	Code	Region EU	Code	Region CH	Code
Cereals	Ce	Boreal	Bor	Continental-Cold	CnC
Rice	Ri	Continental-North	CoN	Continental-Temperate	CnT
Maize	Ma	Continental-South	CoS	Subtropical-Wet	StW
Soybean	Sb	Atlantic-North	AtN	Steppe-Plateau	StP
Vegetables	Vg	Atlantic-Central	AtC	Steppe	Stp
Pasture	Pa	Atlantic-South	AtS	Desertic	Des
Permanent crops	Pc	Alpine	Alp		
		Mediterranean-North	MdN		
		Mediterranean-South	MdS		

4.2 Proposed aggregated indicators for D7.4

The projected changes of the soil quality indicators are used to evaluate the impact of each policy scenario on the soil environmental footprint. This activity is one of the objectives of Task 7.4, and will be reported on Deliverable 7.4. Here we suggest a possible approach, which should be validated in the workshop to be conducted on Task 7.3 and fully implemented in Task 7.4.

The favourable or unfavourable effect of agricultural management practices on soil environmental footprint will be evaluated by analysing the expected evolution of main soil quality indicators. A positive change of several soil quality indicators implies a strong favourable impact on soil environmental footprint. Conversely, a negative change of soil quality indicators implies a negative impact on soil environmental footprint. A scale will be co-defined with the aid of the participants in the workshop to establish the relationship between the evolution of soil quality indicators and the impact on soil environmental footprint. A tentative preliminary scale for classification is shown in Figure 16. This scale was discussed on the stakeholder workshop (Deliverable 7.3).

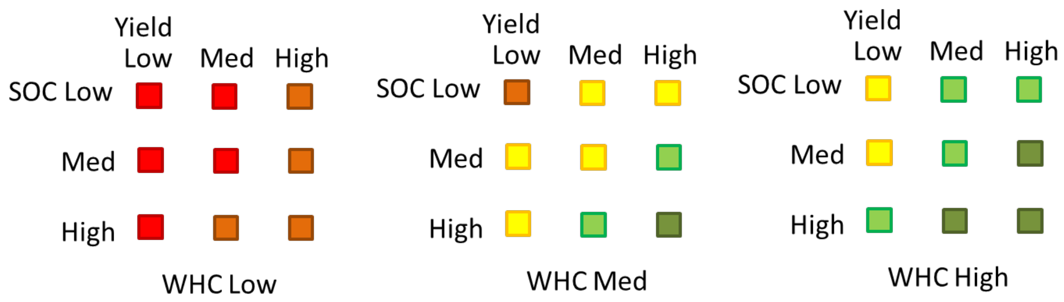


Figure 16. Tentative classification of soil environmental footprint based on expected changes of soil quality indicators

4.3 Validation of the approach

The upscaling model will be validated and co-designed in a workshop to be conducted as part of task 7.3. In the workshop, project partners, invited scientists and stakeholders will discuss the strengths and weaknesses of the proposed approach and will contribute to improve the model. This model validation task will be reported on Deliverable 7.3.

5 Effect of agricultural management practices in different agro-climatic regions in Europe and China

We first provide a global overview of the results. For each management practice, global results are summarized in a radar chart for each soil quality indicators showing the mean values of the response ratio for the seven farming systems. Each zones is displayed as a solid line in different colour. We present in separate groups the results obtained for Europe and China.

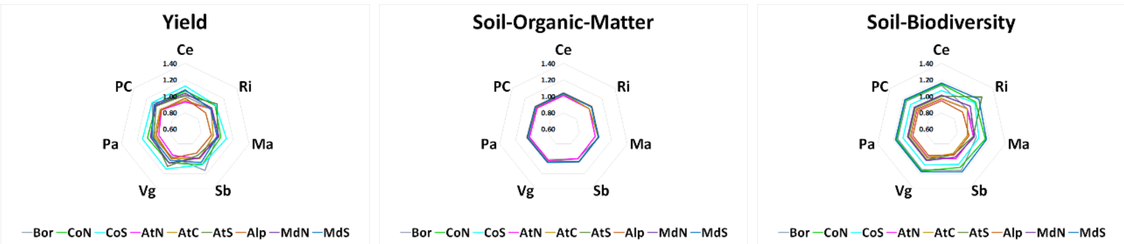
These charts allow easy analysis of variability among different farming systems and soil quality indicators. The size of the chart is proportional to the positive response ratio. The variability across farming systems can be examined by analysing the shape of the chart. A regular char indicates similar behaviour for all farming systems while an irregular chart suggests differences is behaviour. The variability across regions can be analysed through the dispersion of the different lines. The charts also allow to visualize differences in behaviours between Europe and China.

5.1 Effect of key management practices on soil ecosystem services

5.1.1 Effect of organic matter addition

The following charts show the global results of the simulation of a 10% increment in agricultural practices related to the management of organic matter.

Europe



China

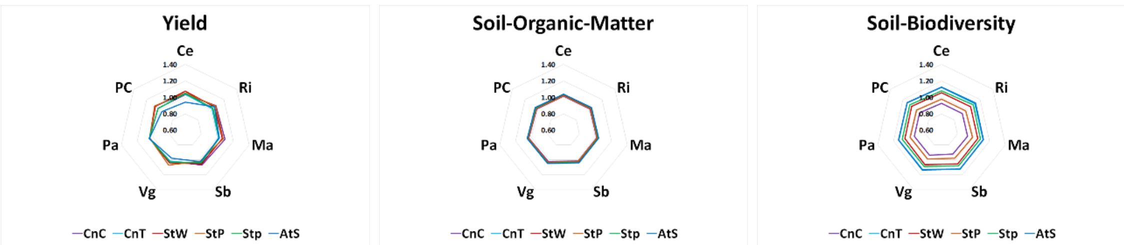
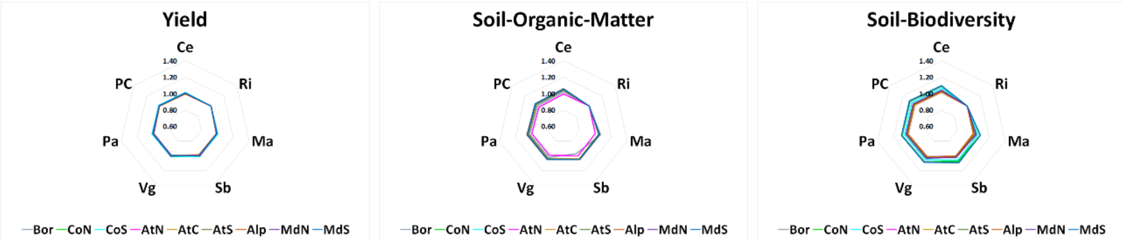


Figure 17. Effect of 10% increase in the implementation of agricultural practices related to the management of organic matter in Europe and China

5.1.2 Effect of improving tillage practices

The following charts show the global results of the simulation of a 10% increment in agricultural practices related to application of reduced tillage.

Europe



China

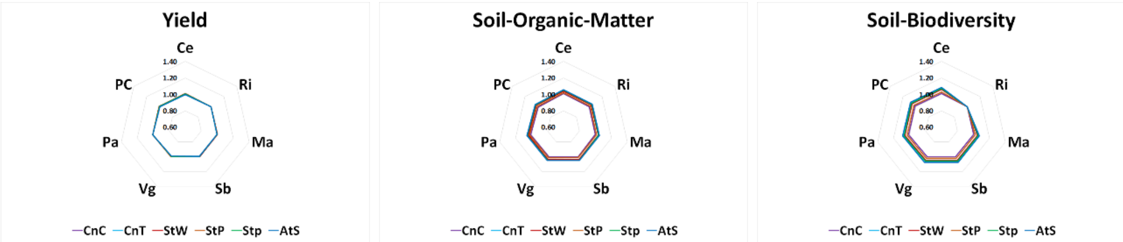
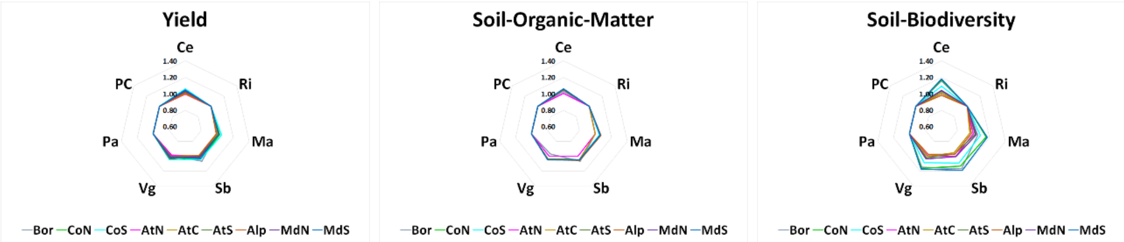


Figure 18. Effect of 10% increase in the implementation of agricultural practices related to reduced tillage matter in Europe and China

5.1.3 Effect of crop rotation

The following charts show the global results of the simulation of a 10% increment in agricultural practices related to the rotation of crops.

Europe



China

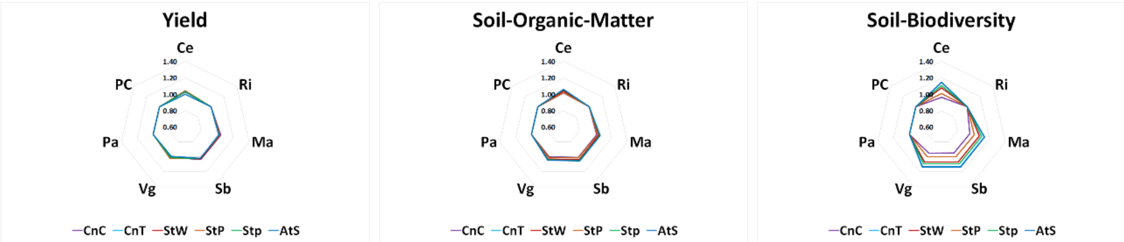
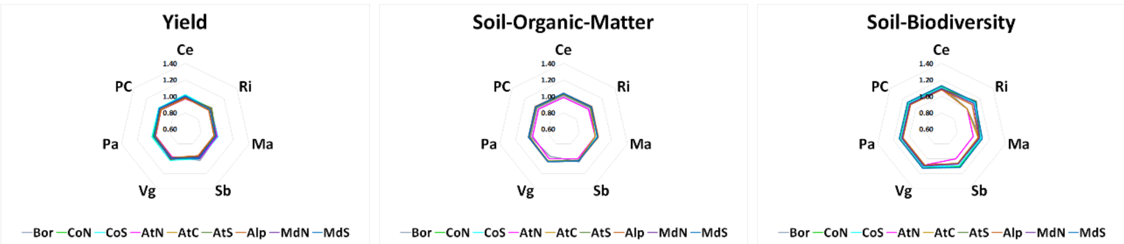


Figure 19. Effect of 10% increase in the implementation of agricultural practices related to crop rotation in Europe and China

5.1.4 Effect of organic farming

The following charts show the global results of the simulation of a 10% increment in agricultural practices related to organic farming.

Europe



China

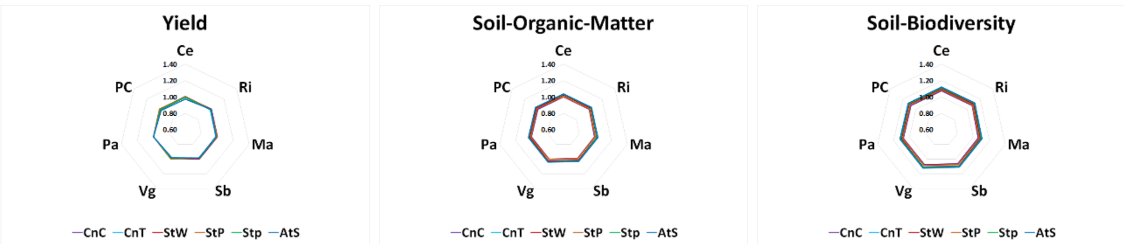


Figure 20. Effect of 10% increase in the implementation of agricultural practices related to organic farming in Europe and China

5.2 Effect of agricultural management practices in selected crops

In this section we present detailed results for mean values of the three soil quality indicators for the four management practices in the seven farming system of each region of Europe and China. The results are presented in a bar chart where the average response ratios of the three soil quality indicators are compared for the regions of Europe (left) and China (right).

5.2.1 Effect of improving organic matter

The following charts show the average results of the simulation of a 10% increment in agricultural practices related to the management of organic matter (Figures 21 and 22).

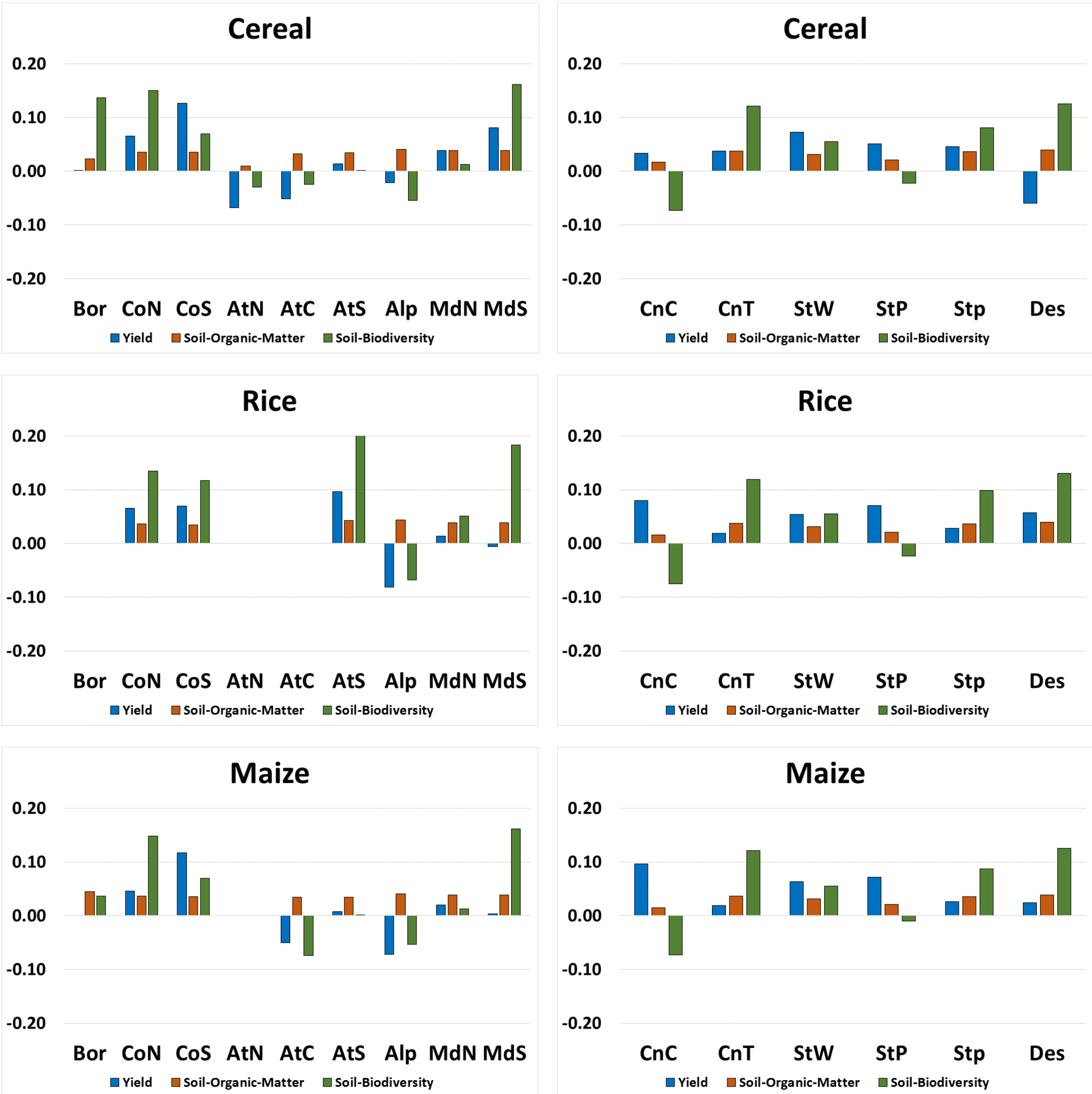


Figure 21. Effect of a 10% increase in the implementation of agricultural practices related to the management of organic matter

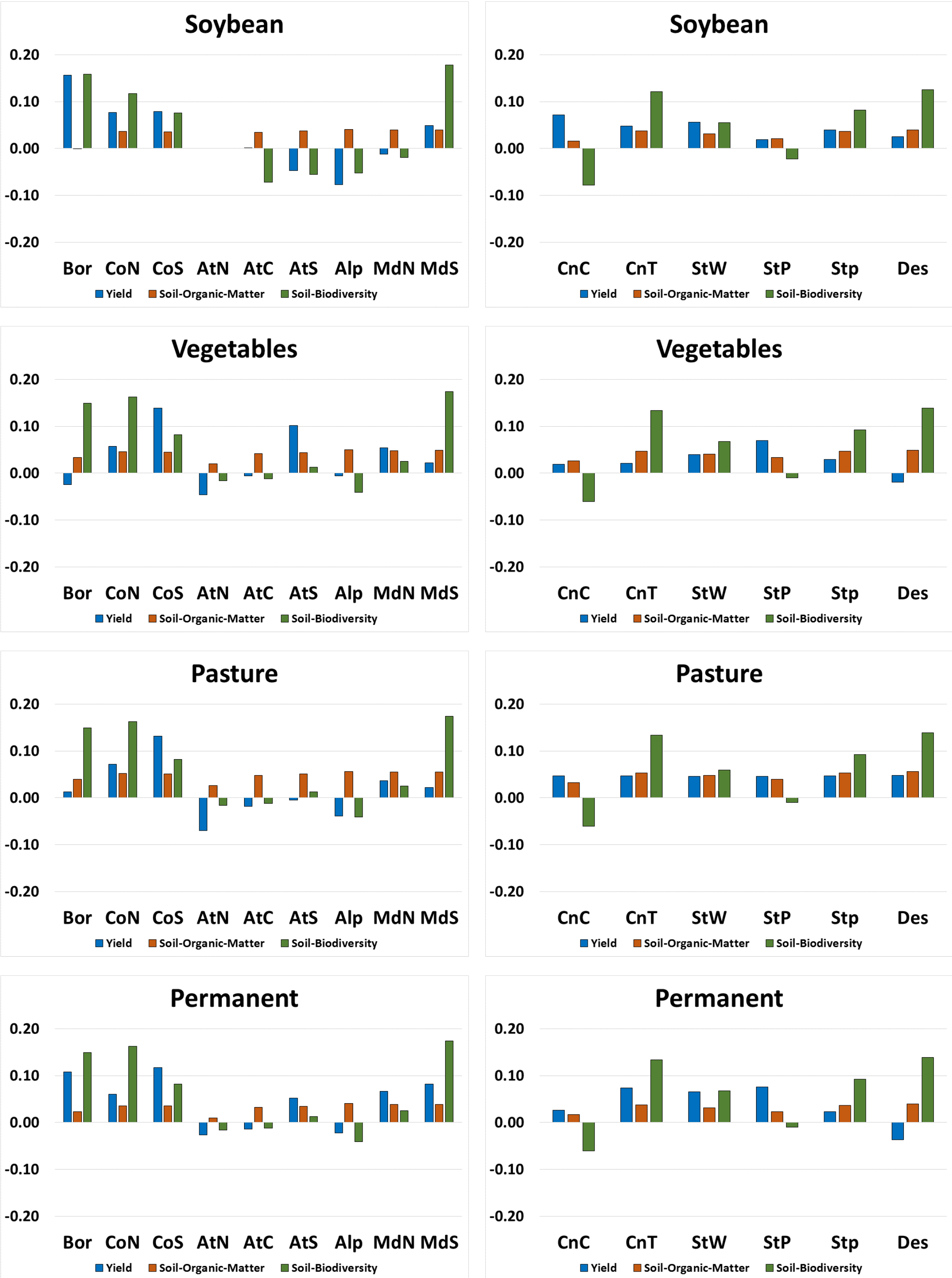


Figure 22. Effect of a 10% increase in the implementation of agricultural practices related to the management of organic matter

5.2.2 *Effect of reduced tillage*

The following charts show the average results of the simulation of a 10% increment in agricultural practices related to application of reduced tillage (Figures 23 and 24).

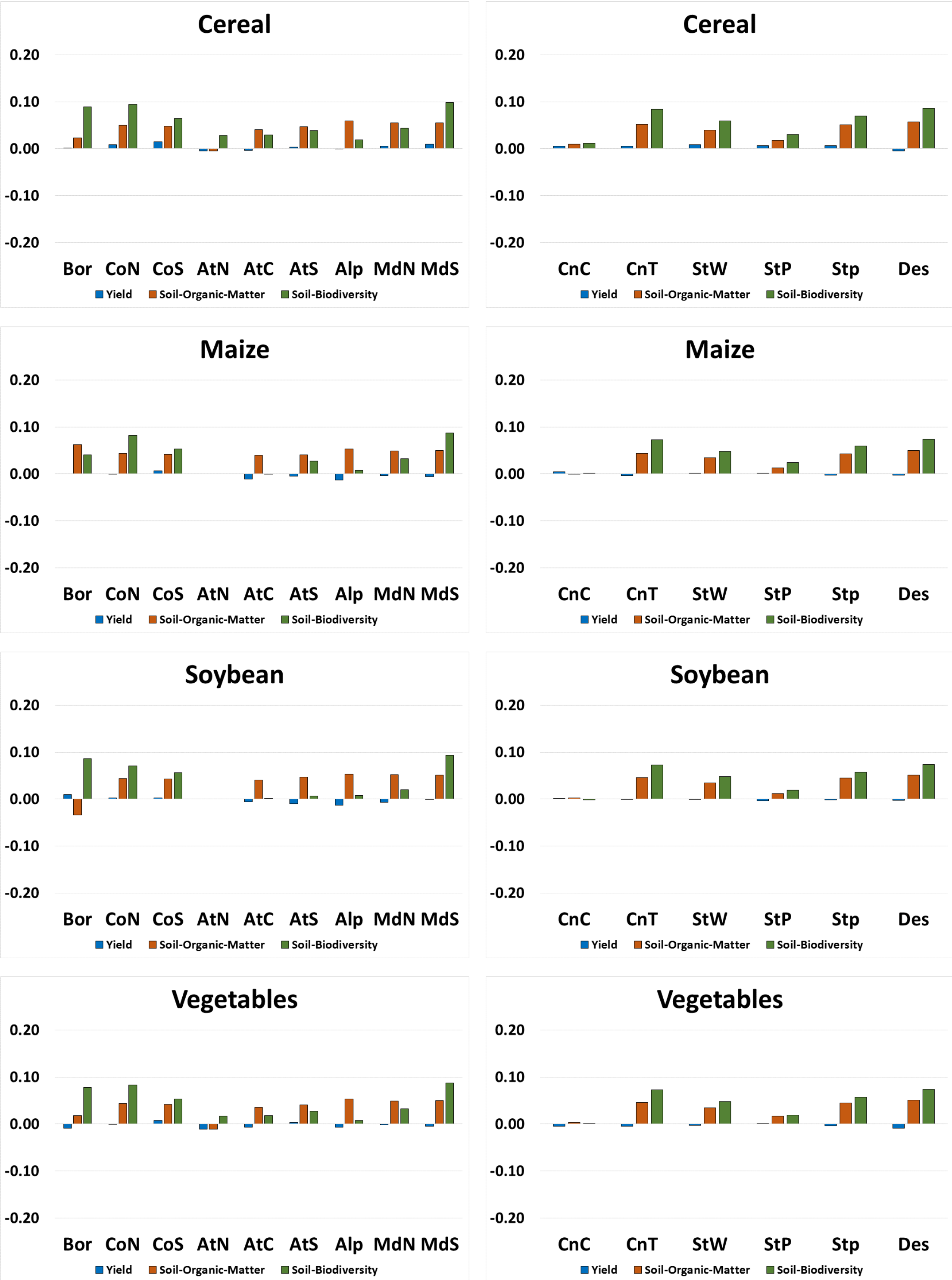


Figure 23. Effect of a 10% increase in the implementation of agricultural practices related to the management of organic matter

Figure 24. Effect of a 10% increase in the implementation of agricultural practices related to the management of organic matter

5.2.3 Effect of increasing crop rotation

The following charts show the average results of the simulation of a 10% increment in agricultural practices related to the rotation of crops (Figure 25).

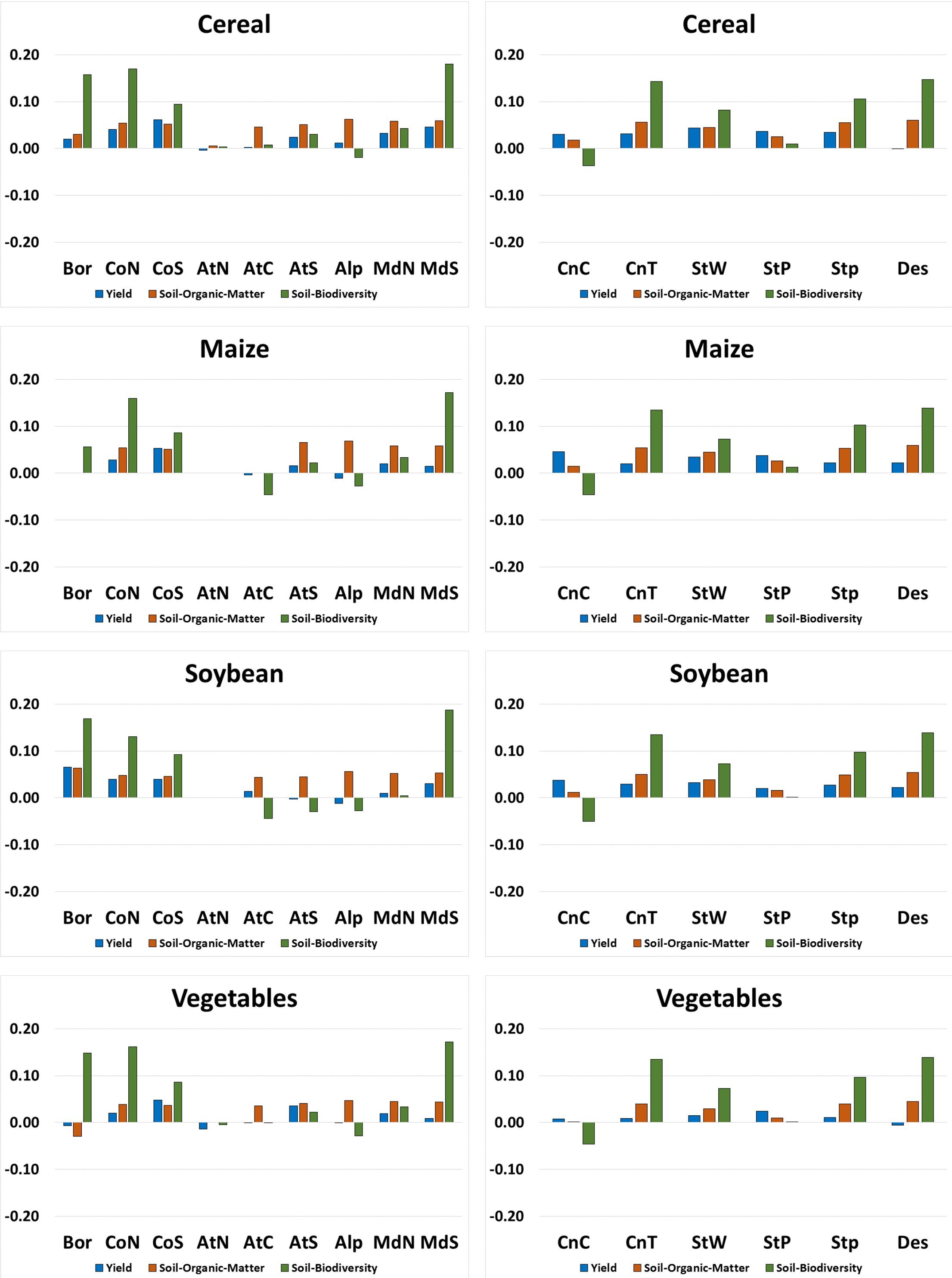


Figure 25. Effect of a 10% increase in the implementation of agricultural practices related to the management of organic matter

5.2.4 *Effect of improving organic farming*

The following charts show the average results of the simulation of a 10% increment in agricultural practices related to organic farming (Figures 26 and 27).

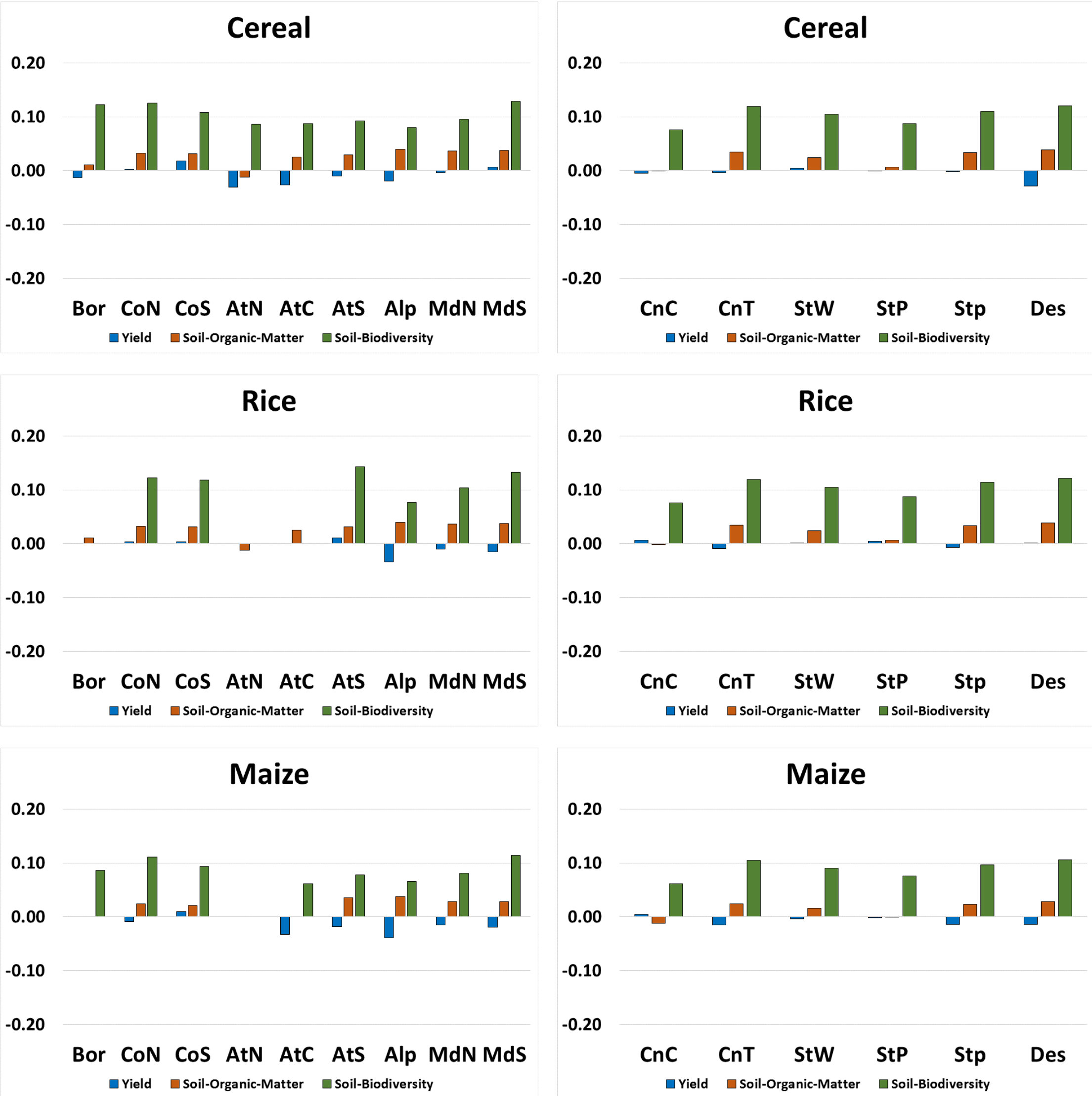


Figure 26. Effect of a 10% increase in the implementation of agricultural practices related to the management of organic matter

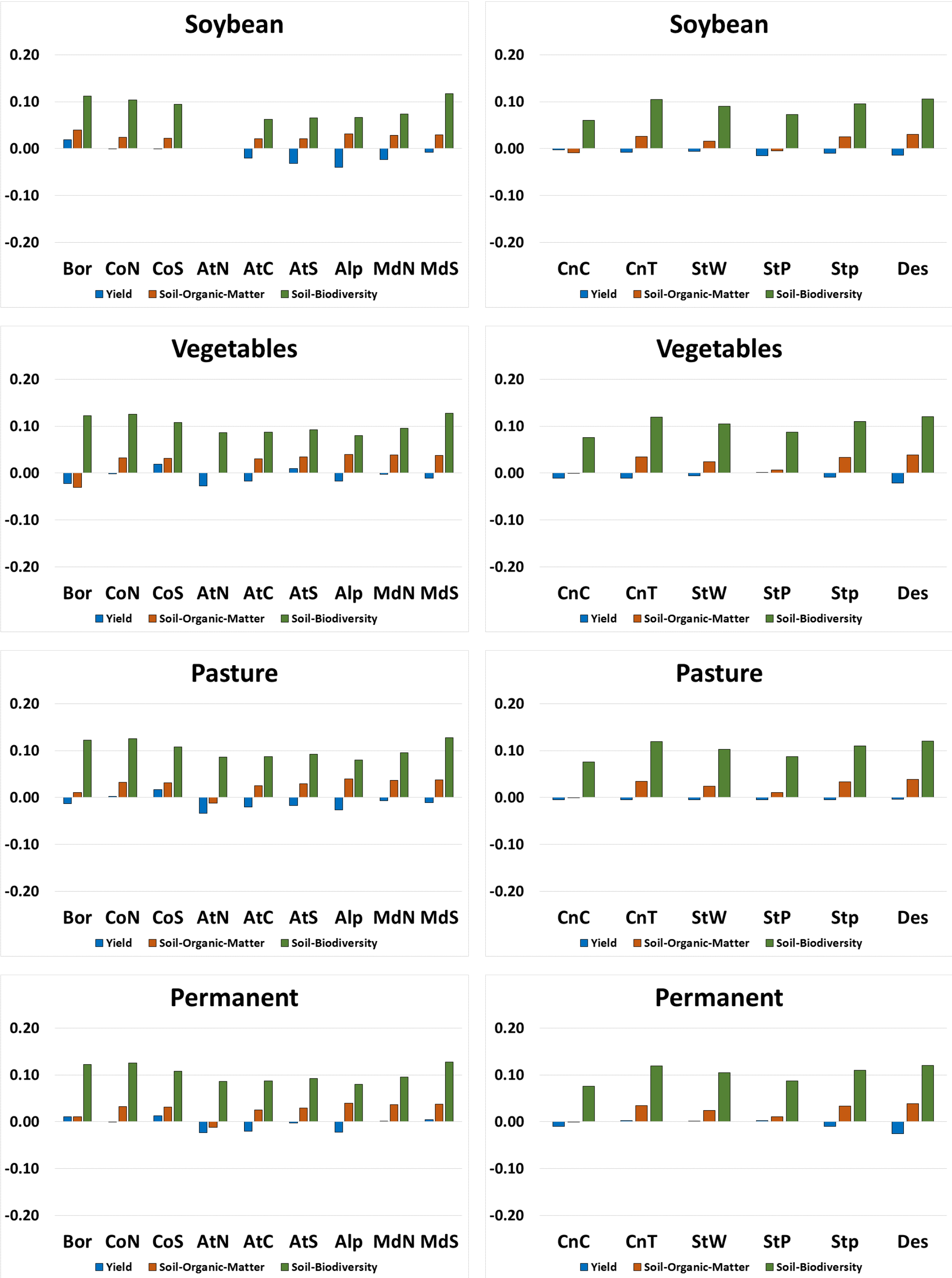


Figure 27. Effect of a 10% increase in the implementation of agricultural practices related to the management of organic matter

5.3 Variability of the projected effects of changes in agricultural management practices on soil ecosystem services

In this section we present the variability of the results obtained for the three soil quality indicators for the four management practices in the seven farming system of each region of Europe and China. The results are presented in a box chart that includes a line which represents the range of values (from the minimum to the maximum value) and a box centered around the mean which represents the bulk of the distribution (from the mean minus one standard deviation to the mean plus one standard deviation). We present in separate groups the results obtained for Europe and China. The results obtained for the three soil quality indicators are presented in the same line to facilitate comparison.

5.3.1 Variability of the effect of organic matter addition

The following charts show the variability of the results of the simulation of a 10% increment in agricultural practices related to the management of organic matter (Figures 28 and 31).

Europe

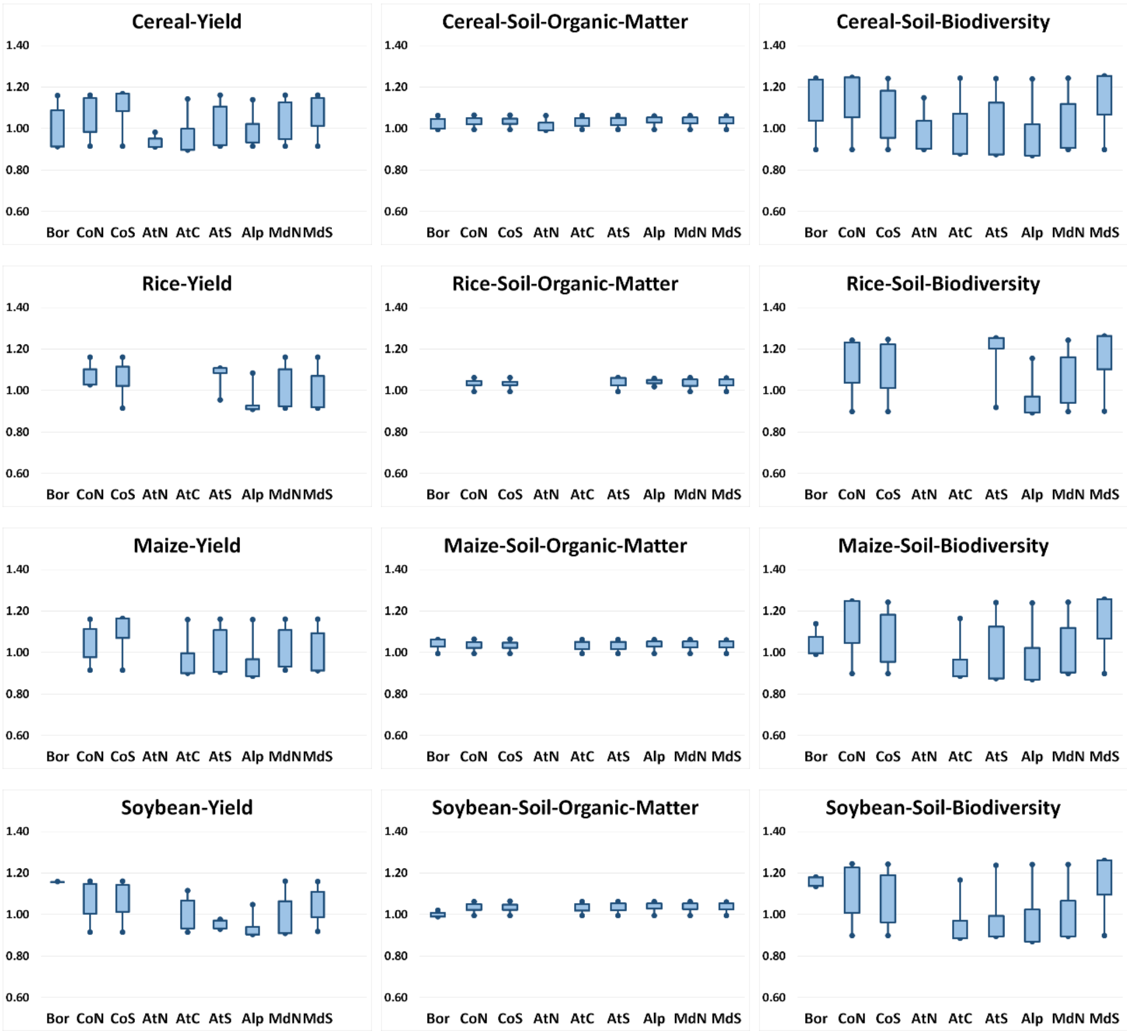


Figure 28. Variability of the results of the simulation of a 10% increment in agricultural practices related to the management of organic matter in Europe

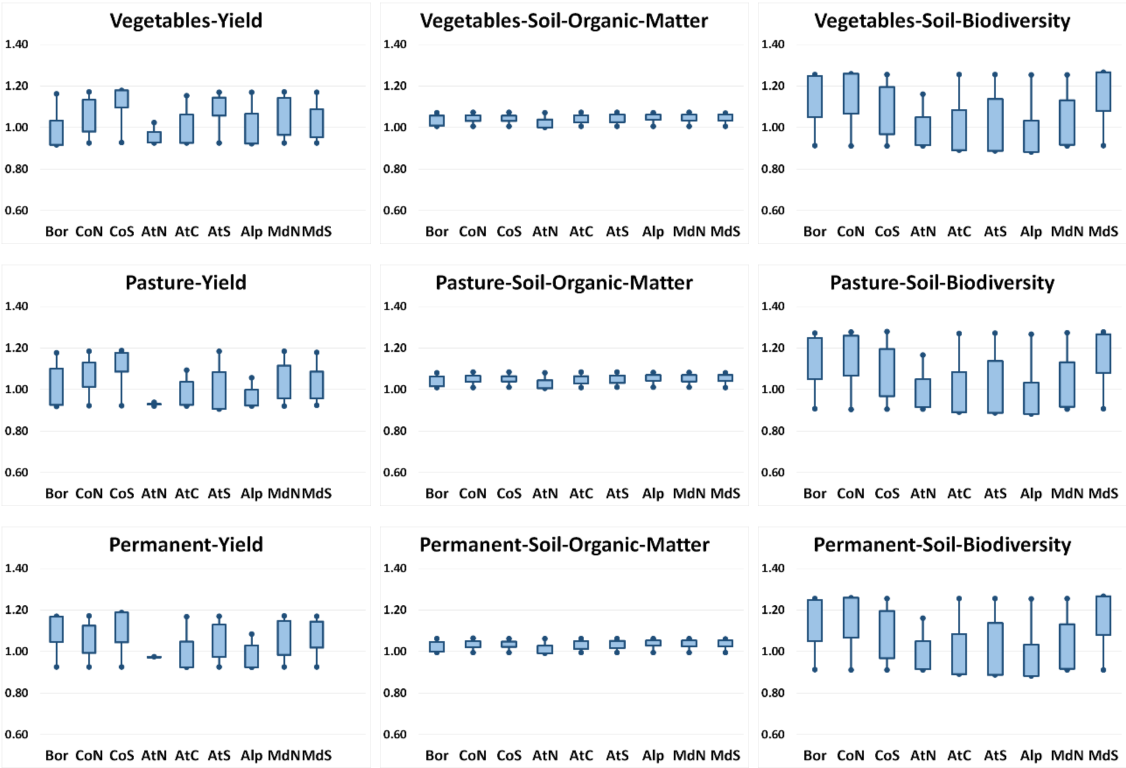


Figure 29. Variability of the results of the simulation of a 10% increment in agricultural practices related to the management of organic matter in Europe (continued)

China

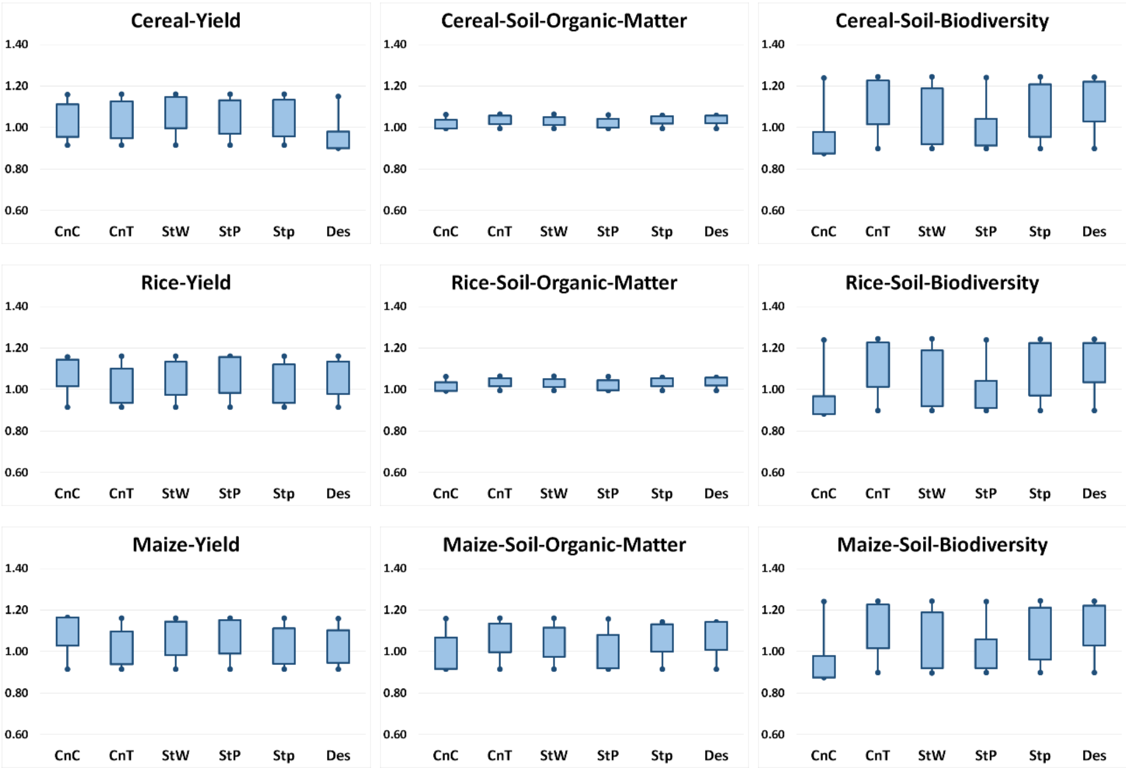


Figure 30. Variability of the results of the simulation of a 10% increment in agricultural practices related to the management of organic matter in China

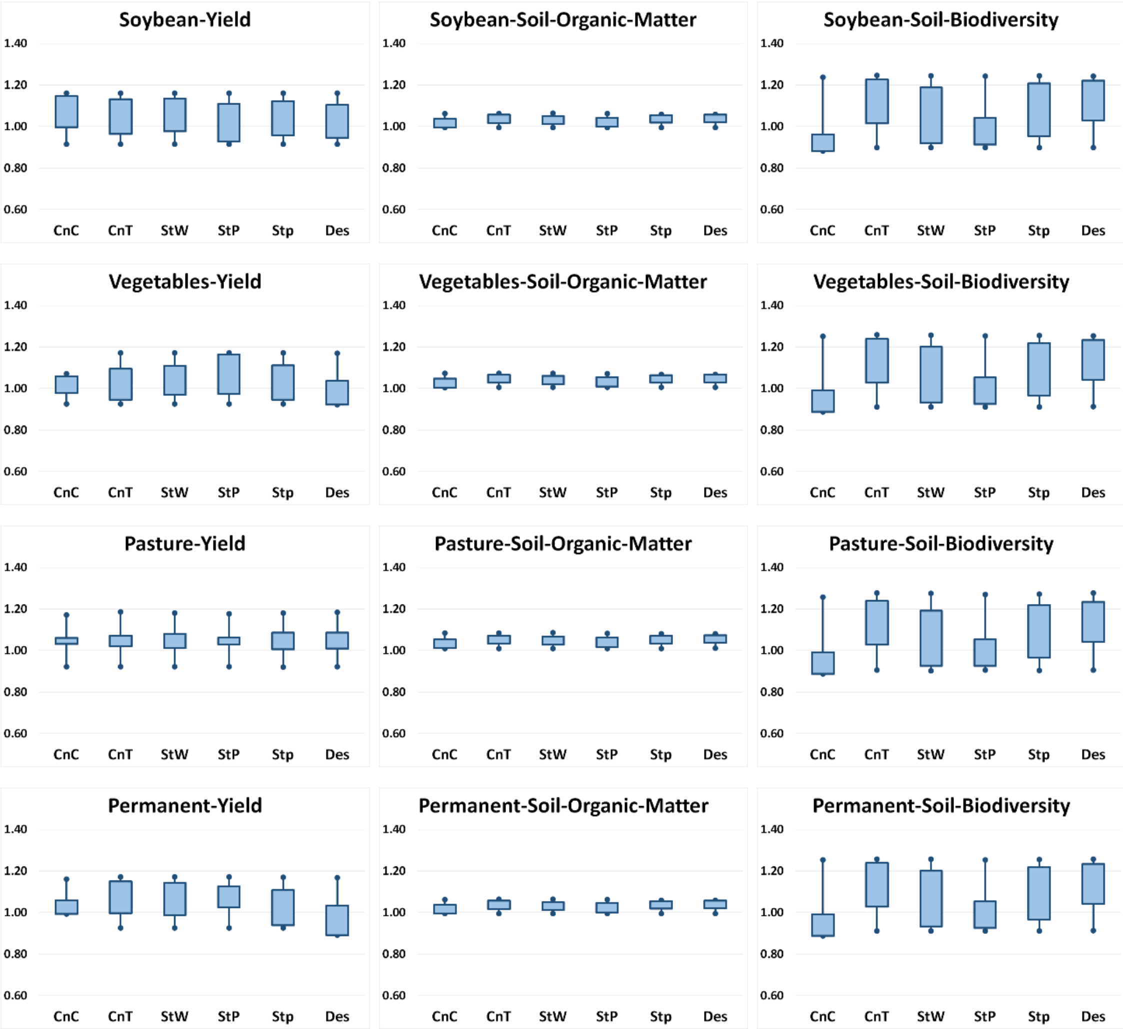


Figure 31. Variability of the results of the simulation of a 10% increment in agricultural practices related to the management of organic matter in China (Continued)

5.3.2 Variability of the effect of tillage practices

The following charts show the variability of the results of the simulation of a 10% increment in agricultural practices related to application of reduced tillage (Figures 32 to 33

Europe

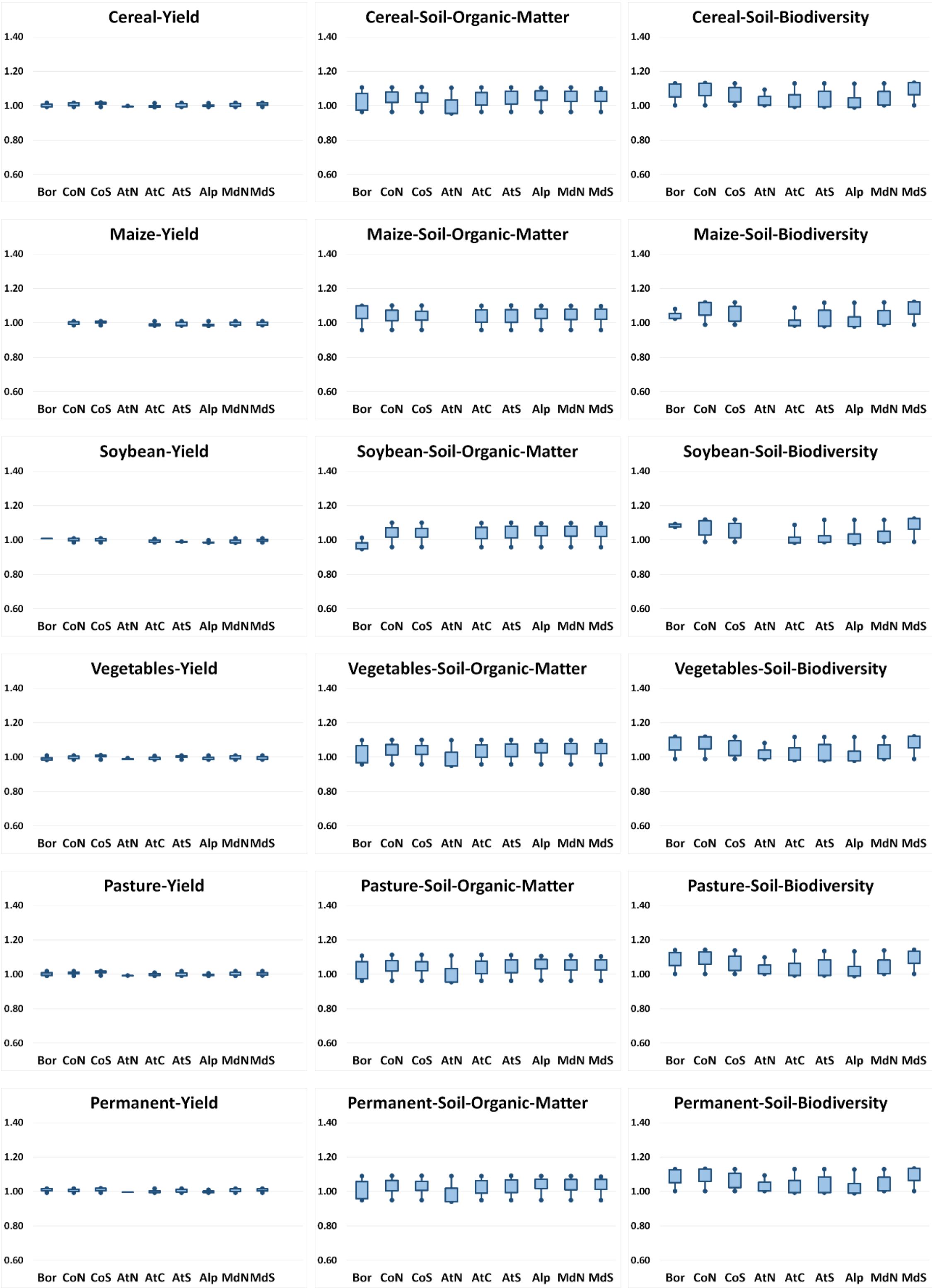


Figure 32. Variability of the results of the simulation of a 10% increment in agricultural practices related to the management of reduced tillage in Europe

China

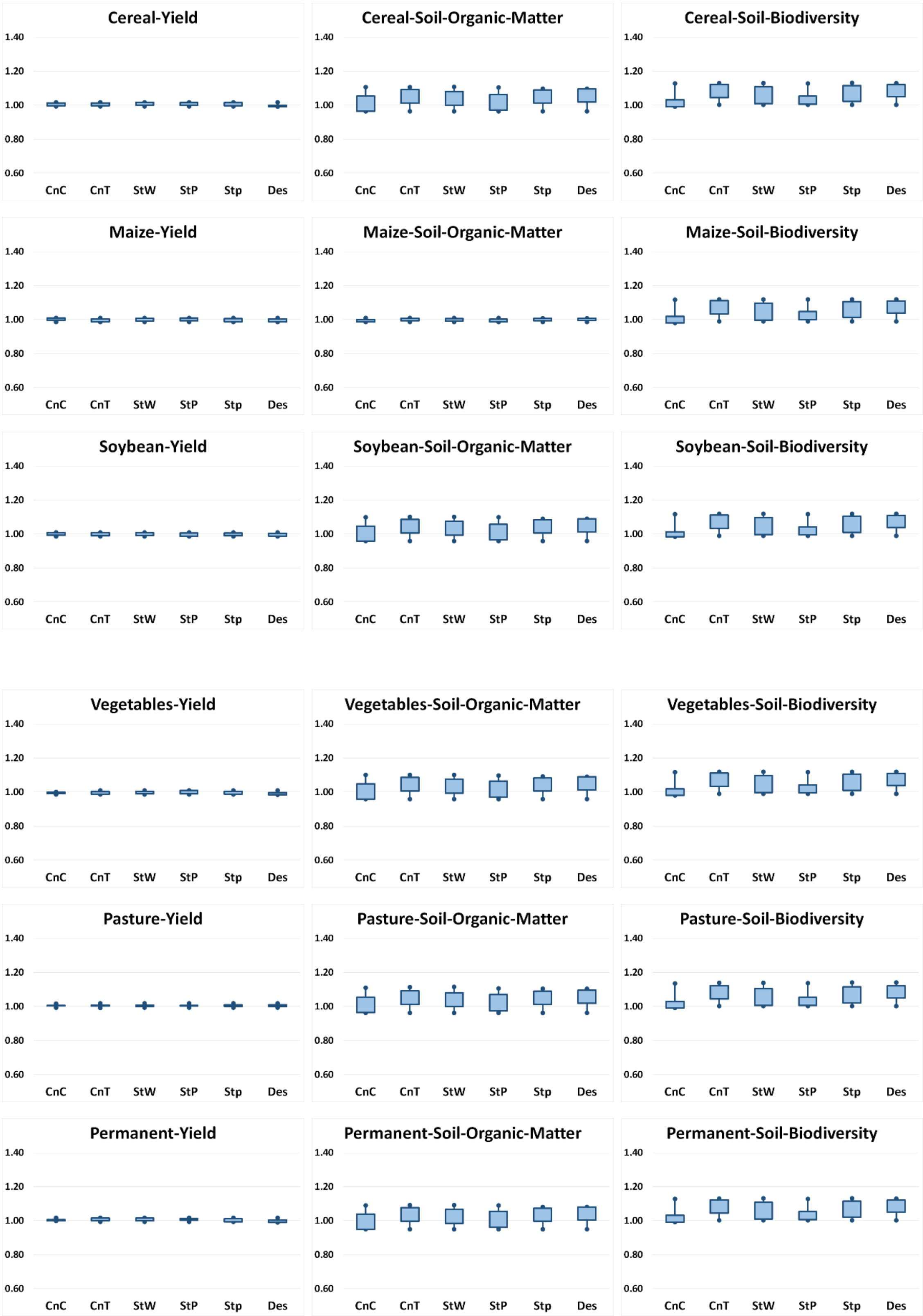


Figure 33. Variability of the results of the simulation of a 10% increment in agricultural practices related to the management of reduced tillage in China

5.3.3 Variability of the effect of crop rotation

The following charts show the variability of the results of the simulation of a 10% increment in agricultural practices related to the rotation of crops (Figures 34 to 39).

Europe

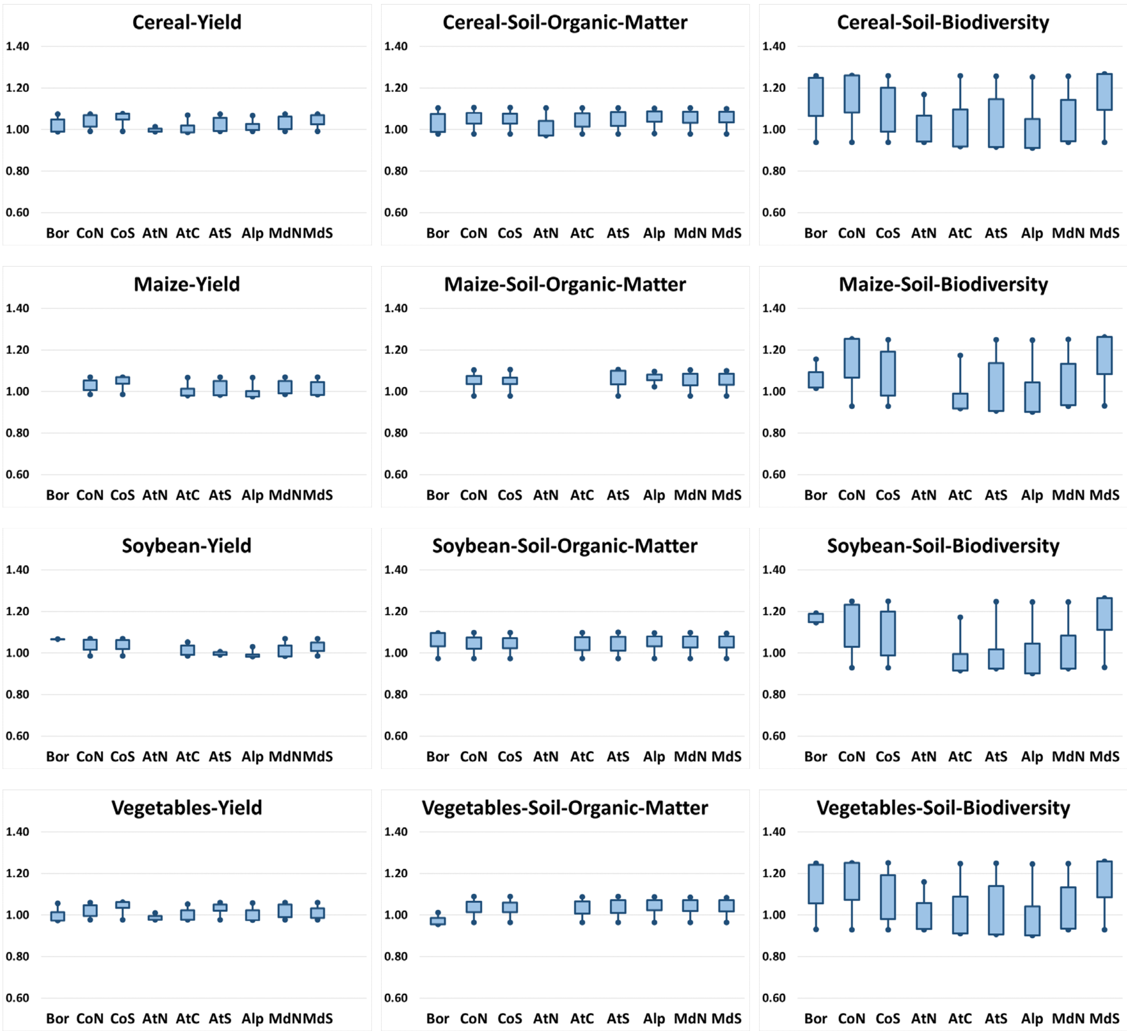


Figure 34. Variability of the results of the simulation of a 10% increment in agricultural practices related to the management to crop rotation in Europe

China

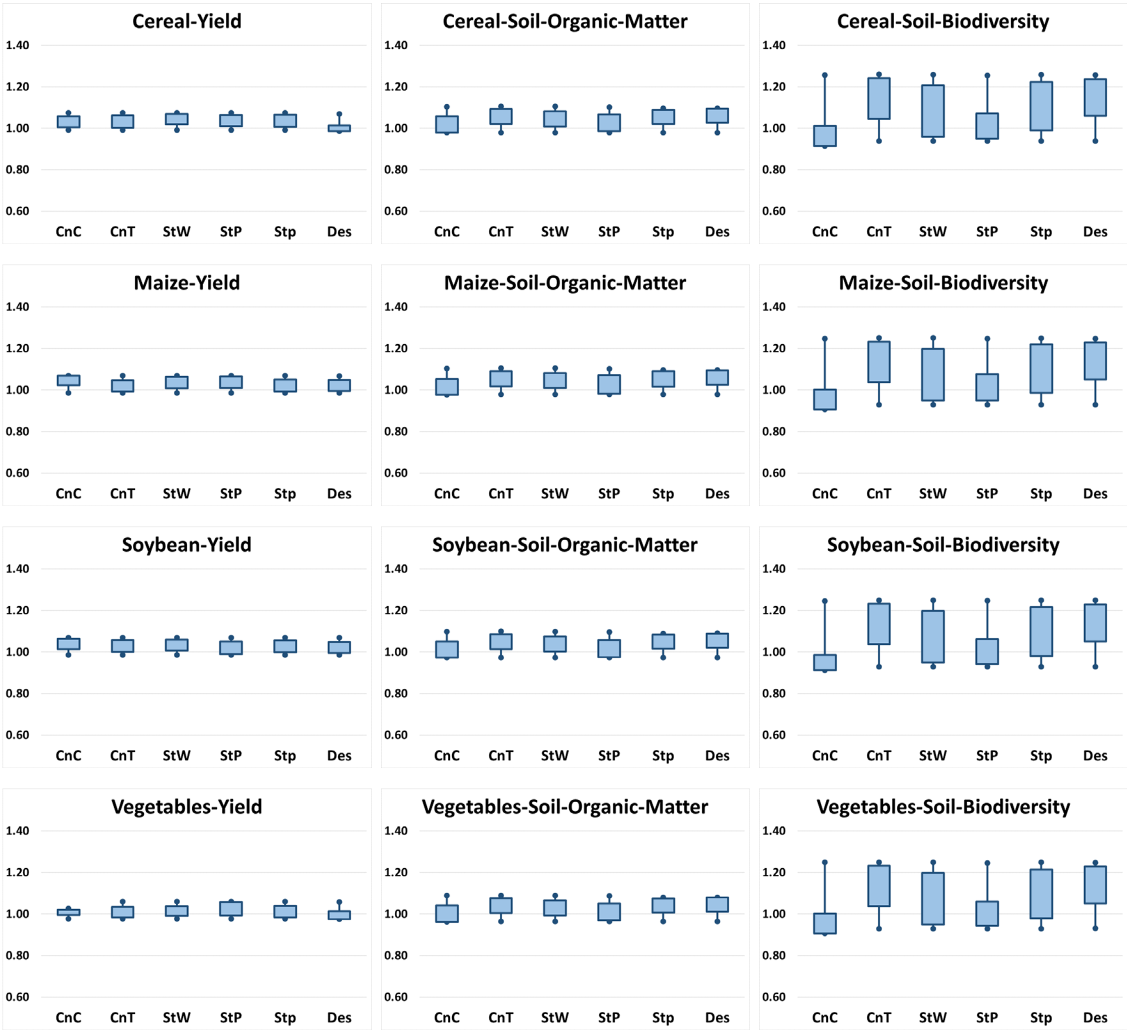


Figure 35. Variability of the results of the simulation of a 10% increment in agricultural practices related to the management of crop rotation in China

5.3.4 Variability of the effect of organic matter addition

The following charts show the variability of the results of the simulation of a 10% increment in agricultural practices related to the management of organic matter (figures 36 and 35).

Europe

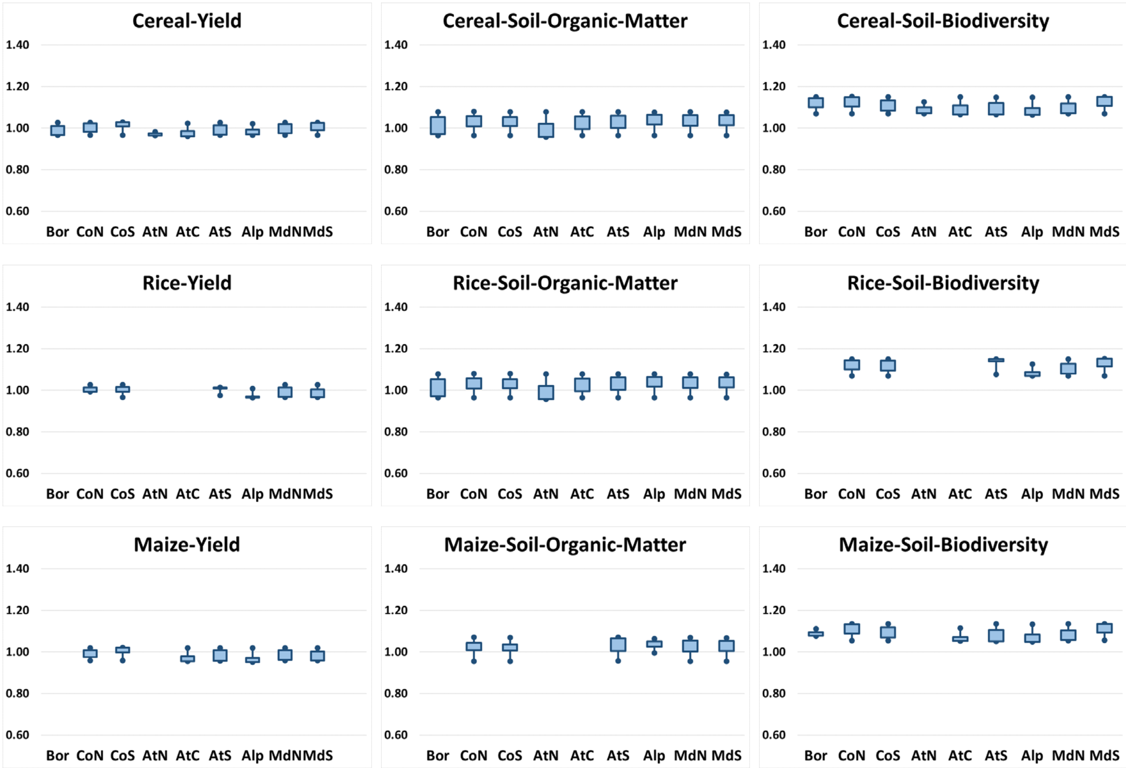


Figure 36. Variability of the results of the simulation of a 10% increment in agricultural practices related to the management of crop rotation in Europe

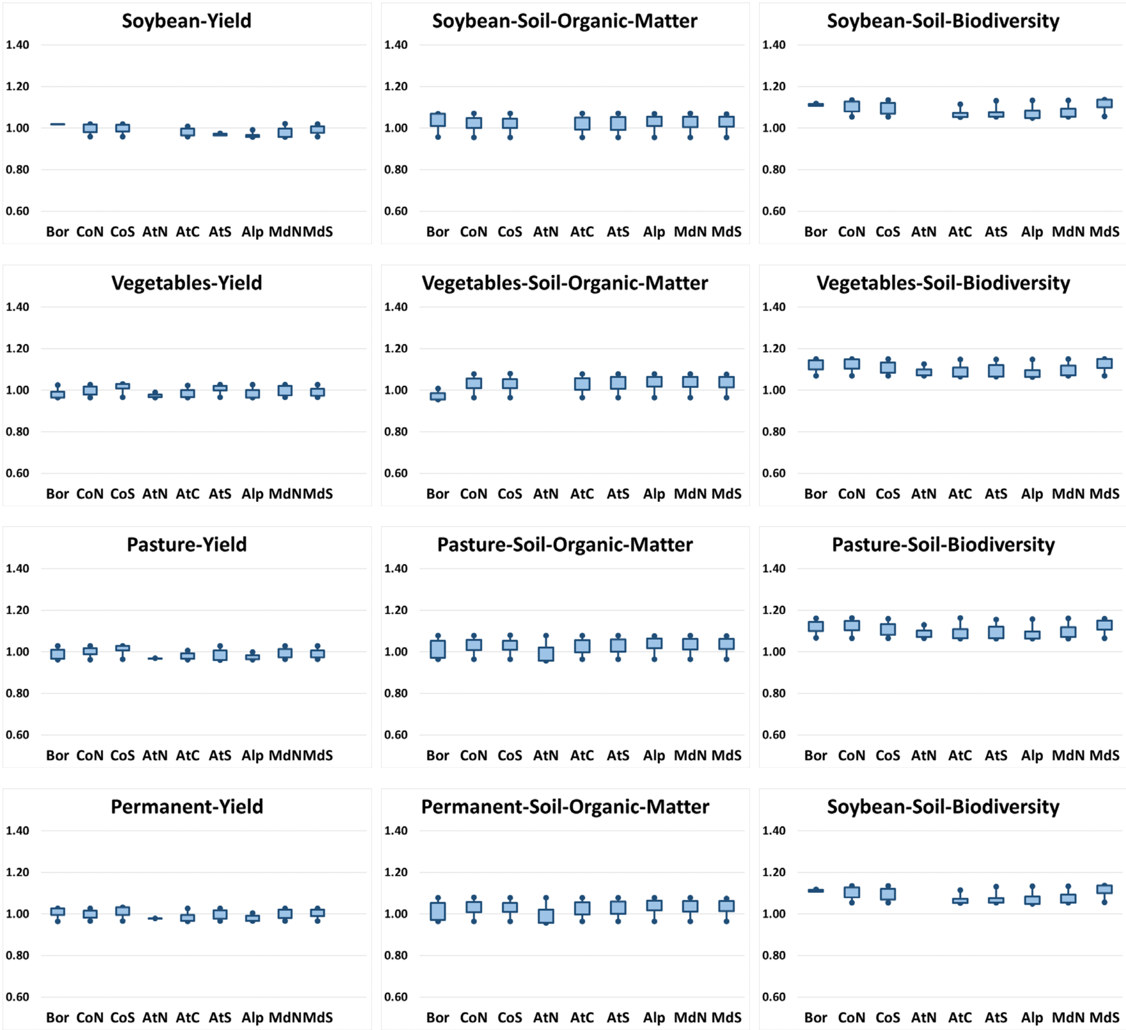


Figure 37. Variability of the results of the simulation of a 10% increment in agricultural practices related to the management of crop rotation in Europe (continued)

China

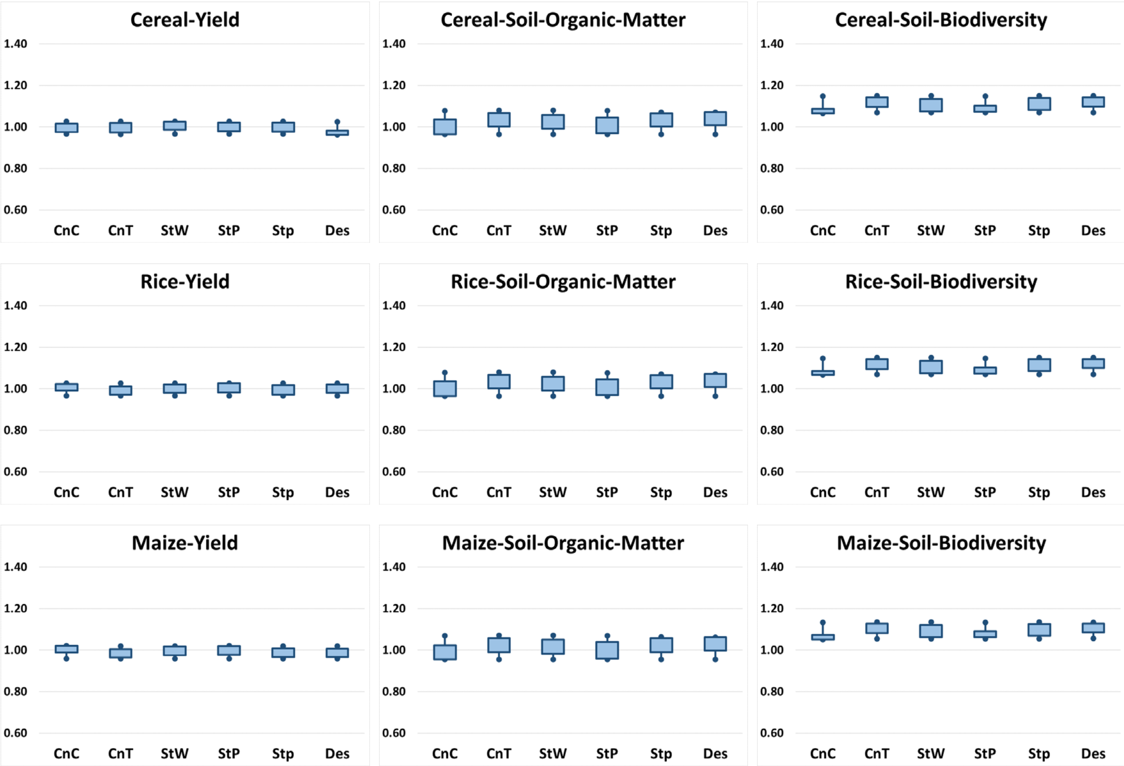


Figure 38. Variability of the results of the simulation of a 10% increment in agricultural practices related to the management of crop rotation in China

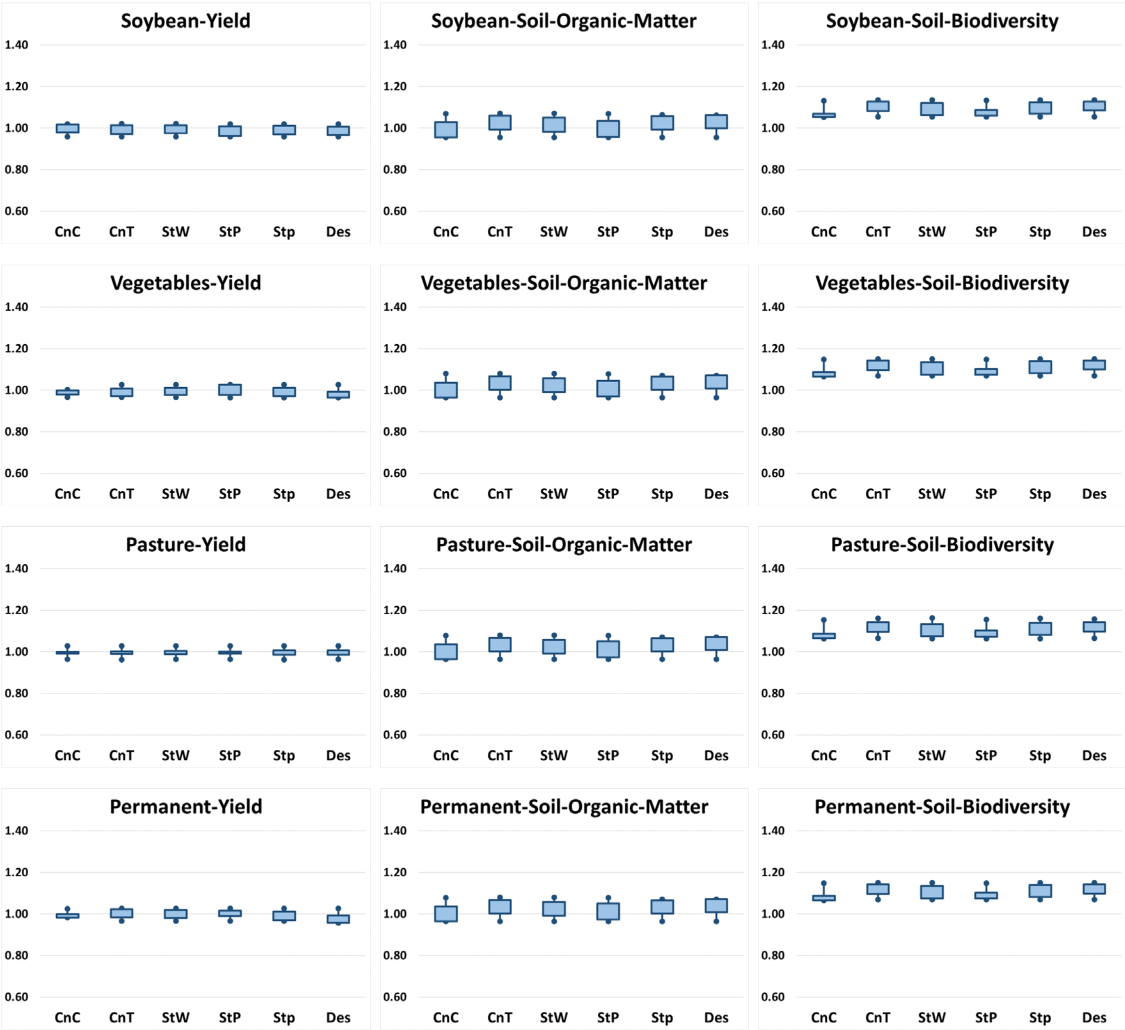


Figure 39. Variability of the results of the simulation of a 10% increment in agricultural practices related to the management of crop rotation in China (continued)

6 Detailed spatial results of the effect of key management practices in ecosystem services provided by each crop

Figures 40 to 185 present the detailed spatial results of the effect of key management practices in ecosystem services provided by each crop.

6.1 *Effect of projection of nutrient management*

6.1.1 *Cereals*

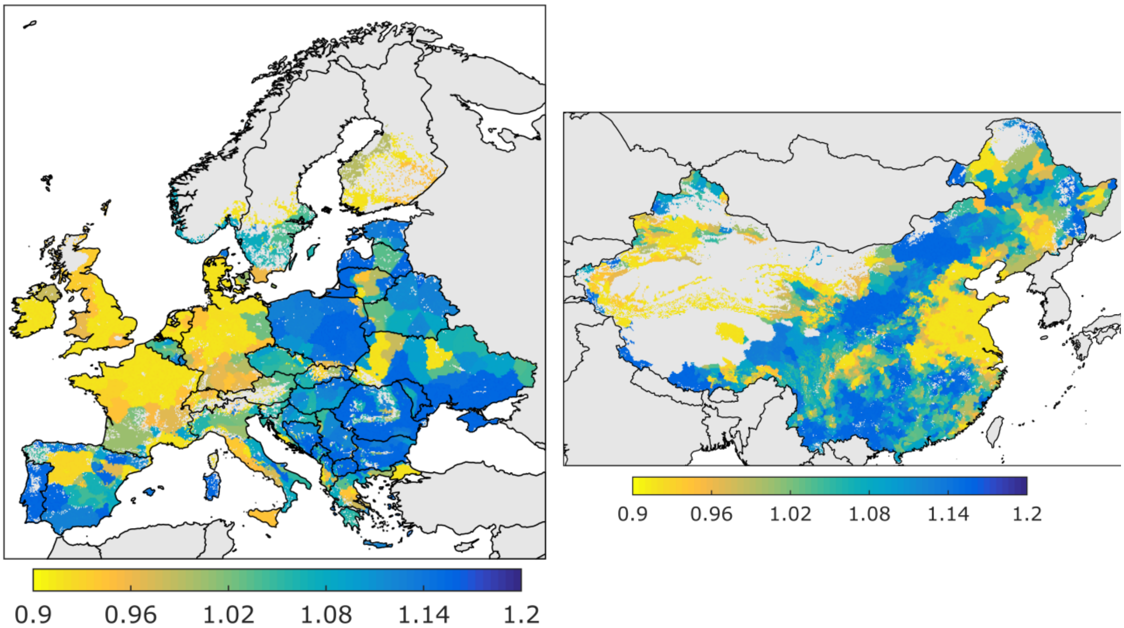


Figure 40. Projected effect of organic matter addition on mean increase in crop yield for cereal

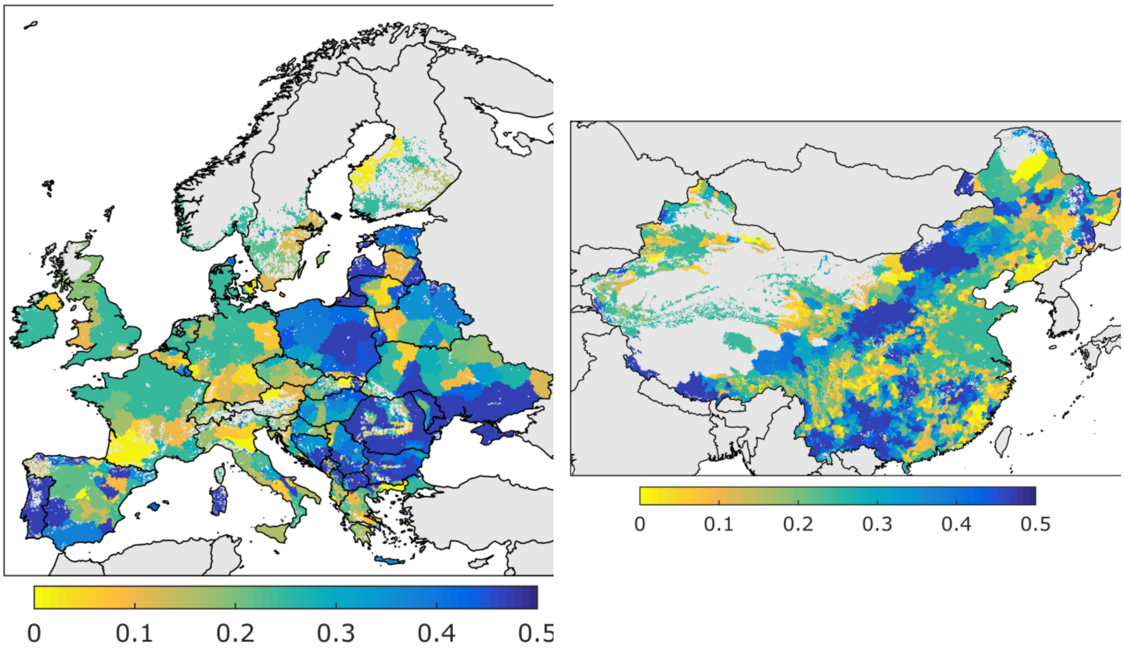


Figure 41. Standard deviation of the projected effect of organic matter addition on mean increase in crop yield for cereal

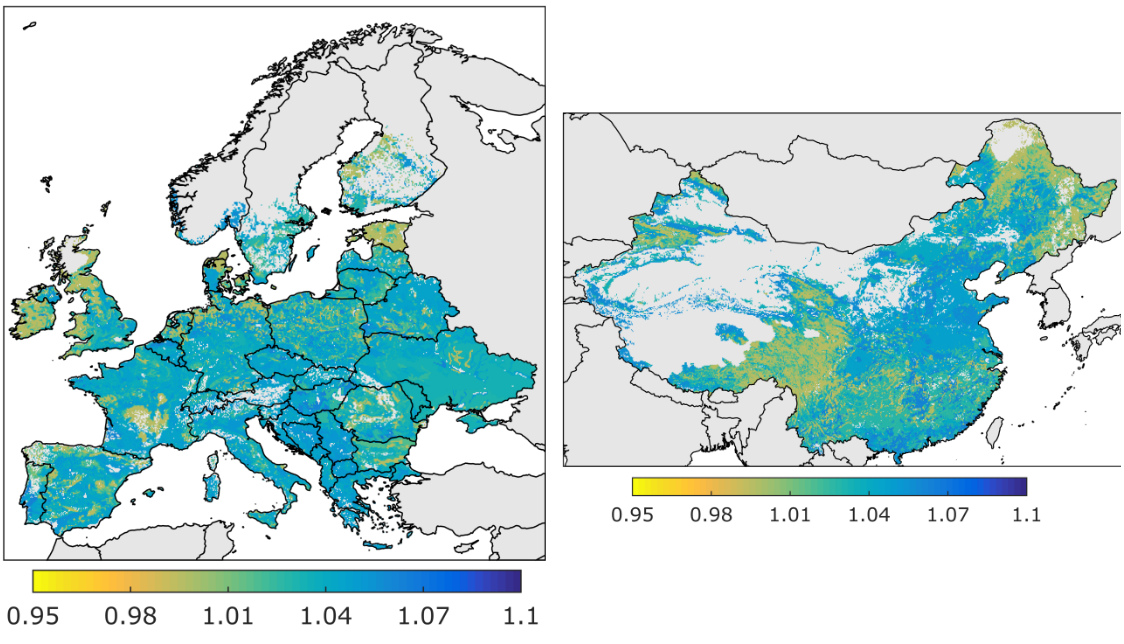


Figure 42. Projected effect of organic matter addition on mean increase in soil organic matter for cereal

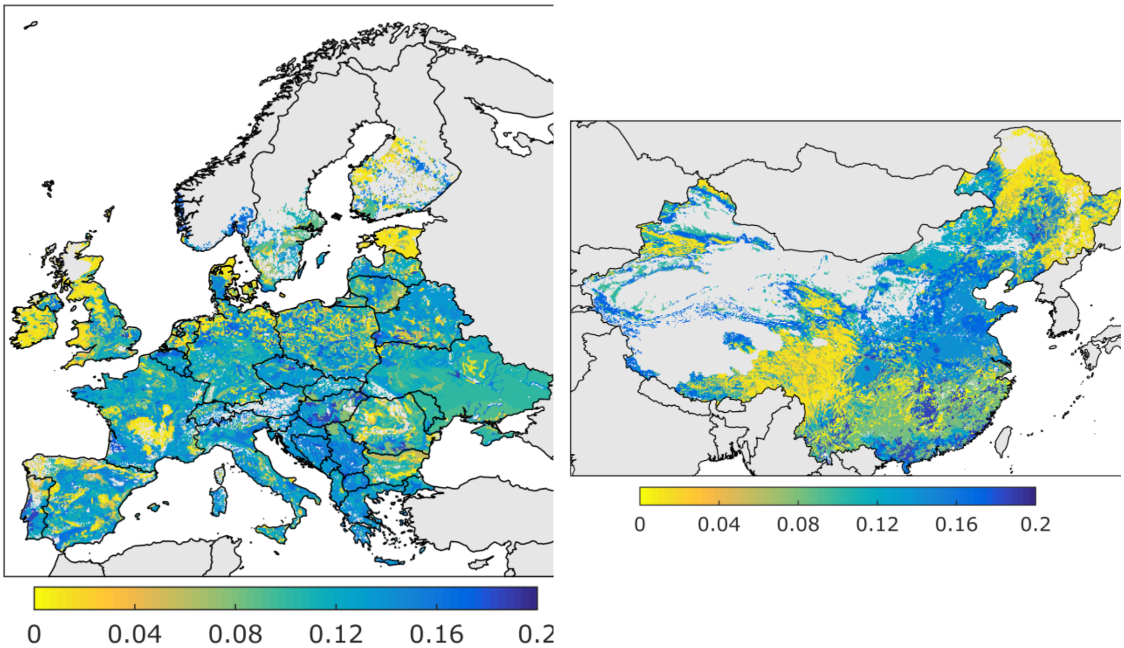


Figure 43. Standard deviation of the projected effect of organic matter addition on mean increase in soil organic matter for cereal

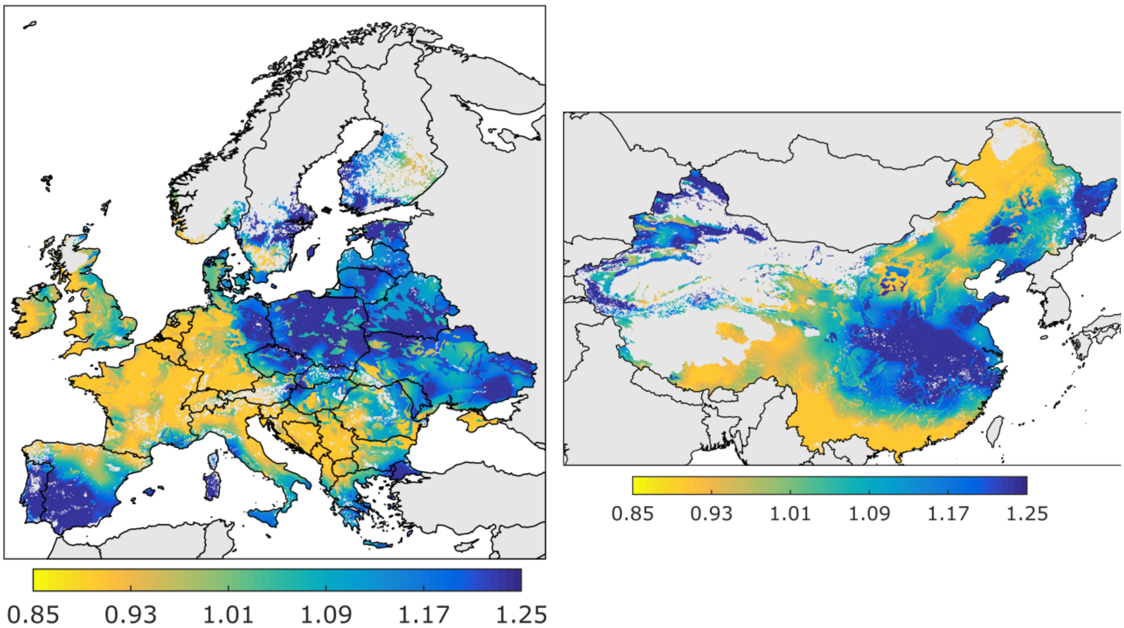


Figure 44. Projected effect of organic matter addition on mean increase in global soil biodiversity for cereal

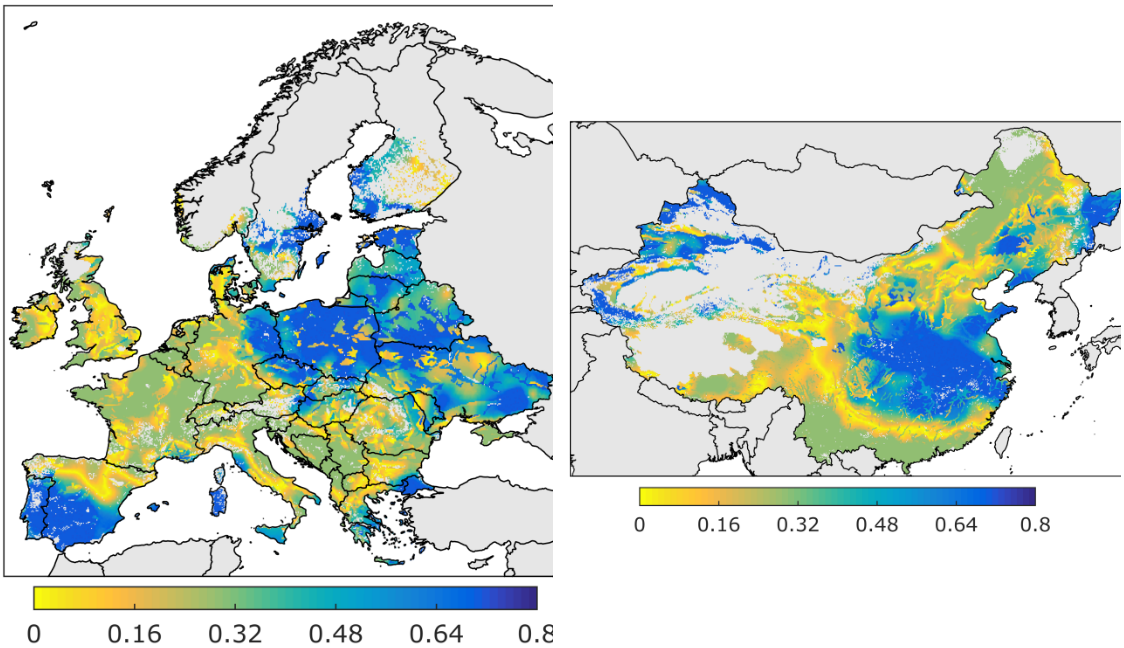


Figure 45. Standard deviation of the projected effect of organic matter addition on mean increase in global soil biodiversity for cereal

6.1.2 Rice

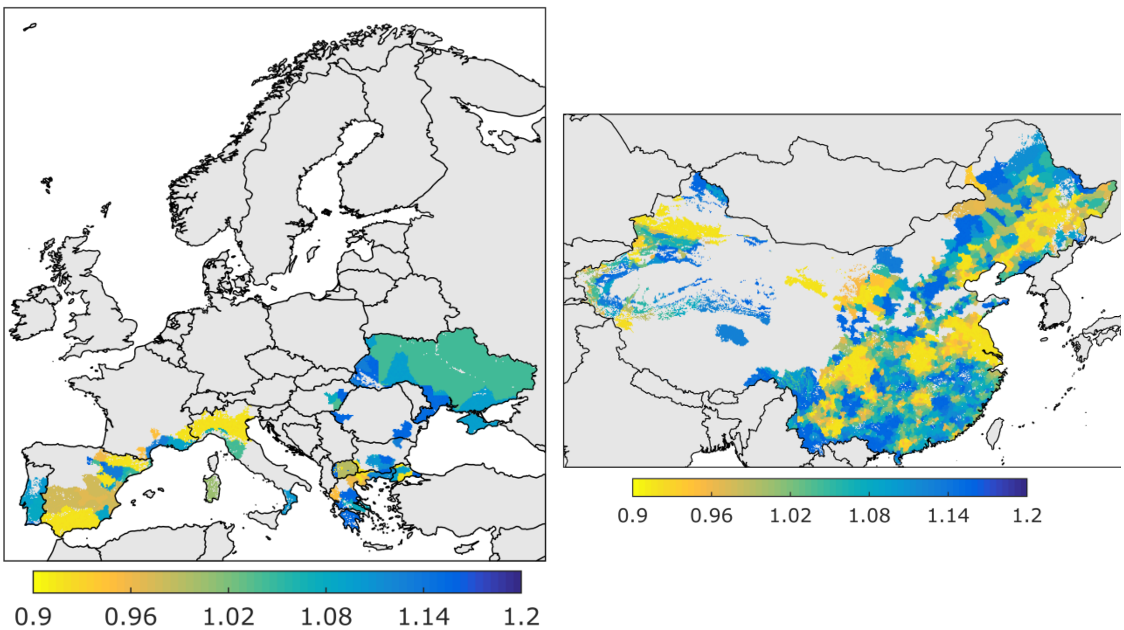


Figure 46. Projected effect of organic matter addition on mean increase in crop yield for rice

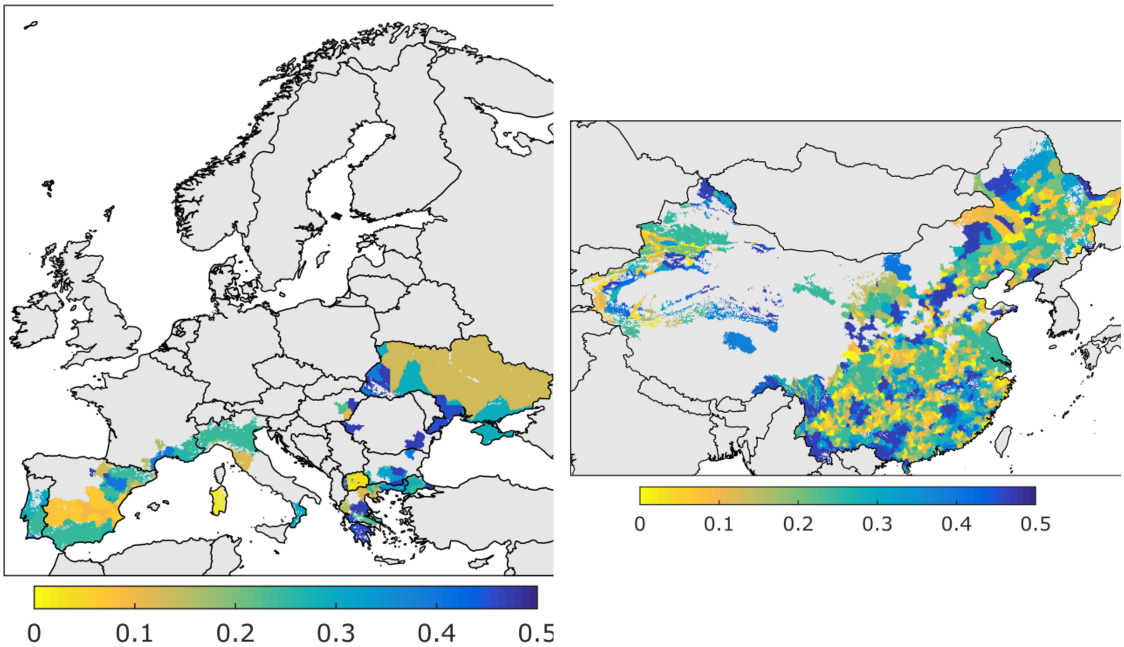


Figure 47. Standard deviation of the projected effect of organic matter addition on mean increase in crop yield for rice

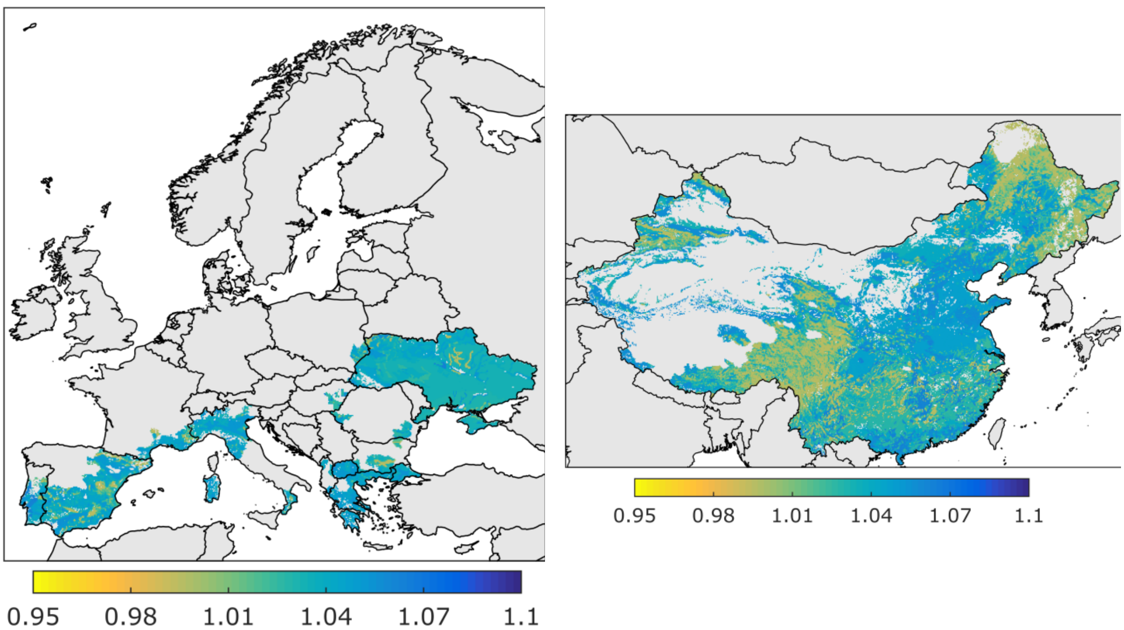


Figure 48. Projected effect of organic matter addition on mean increase in soil organic matter for rice

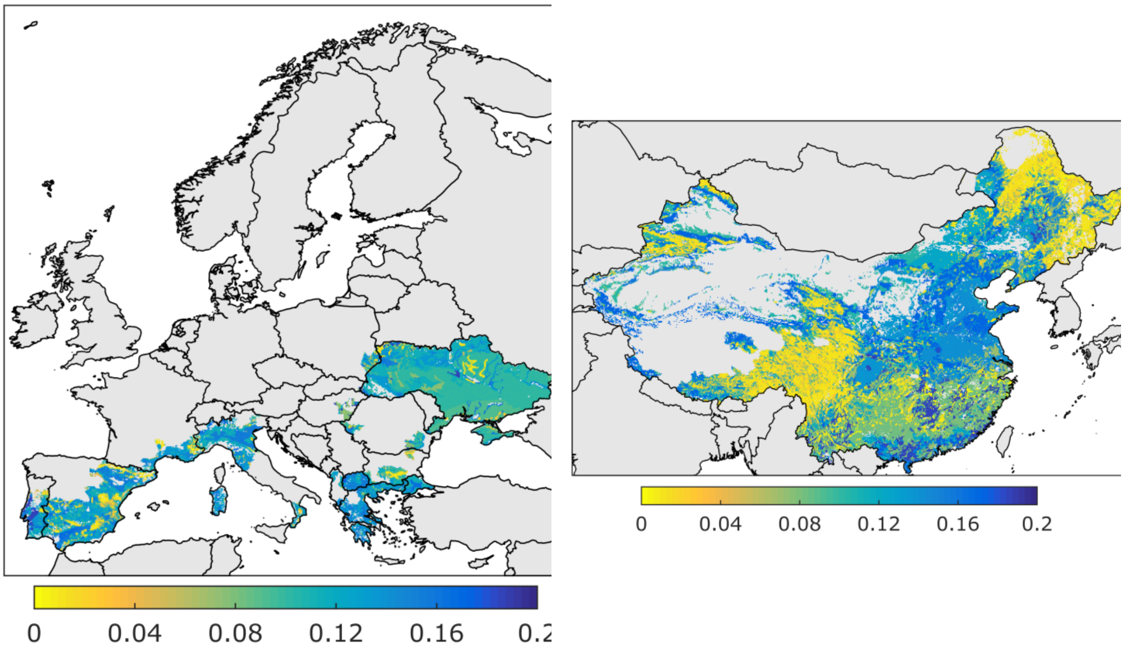


Figure 49. Standard deviation of the projected effect of organic matter addition on mean increase in soil organic matter for rice

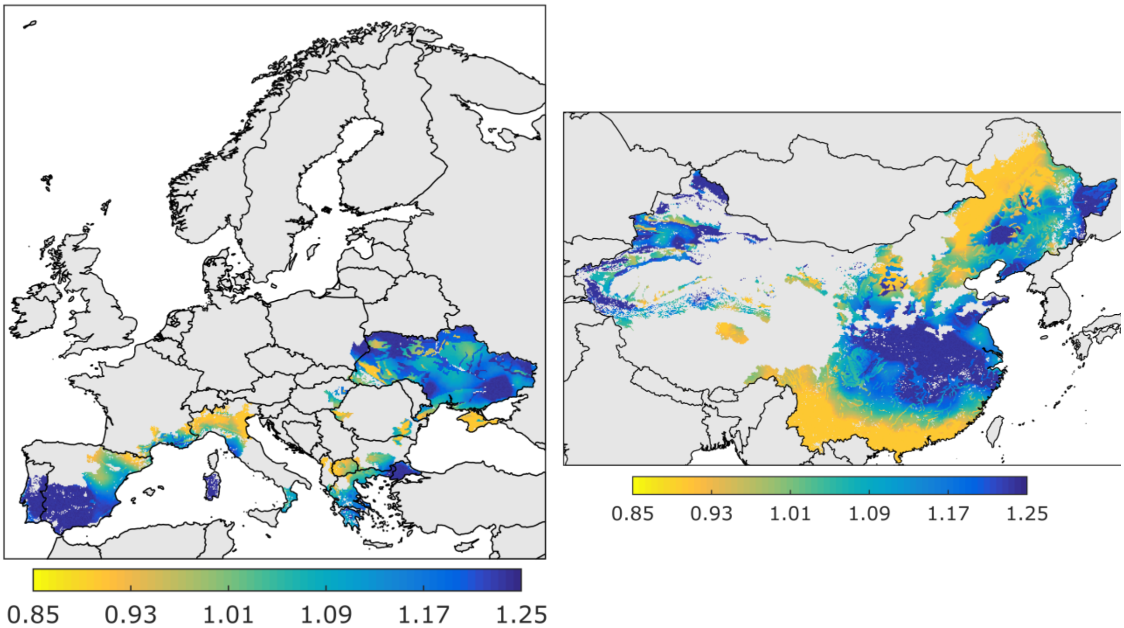


Figure 50. Projected effect of organic matter addition on mean increase in global soil biodiversity for rice

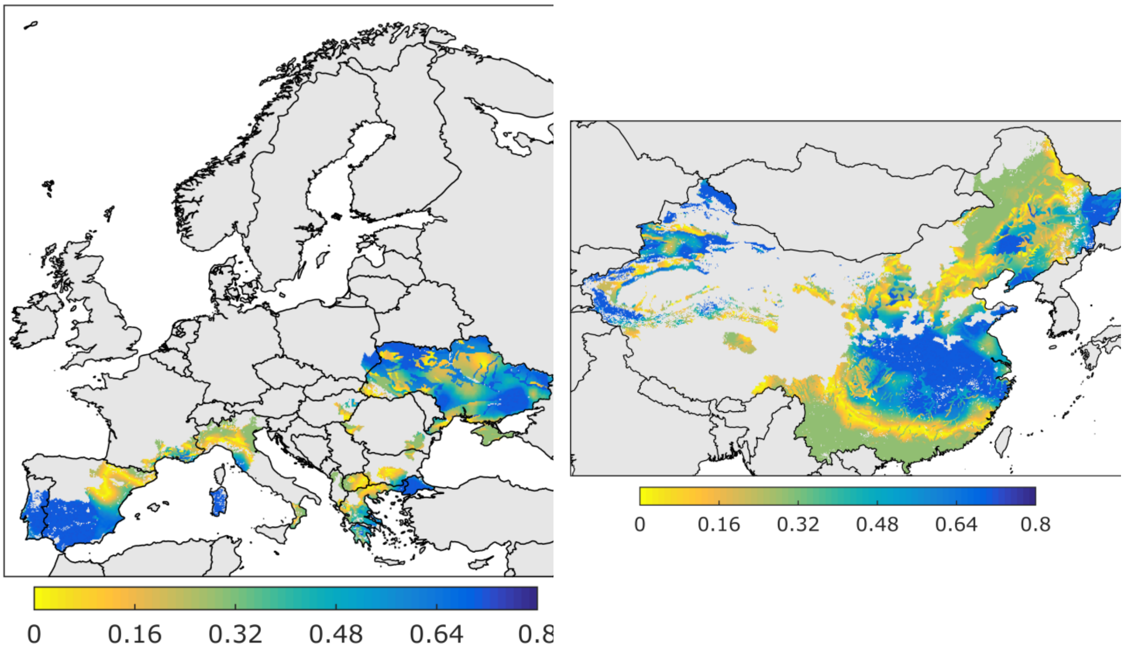


Figure 51. Standard deviation of the projected effect of organic matter addition on mean increase in global soil biodiversity for rice

6.1.3 Maize

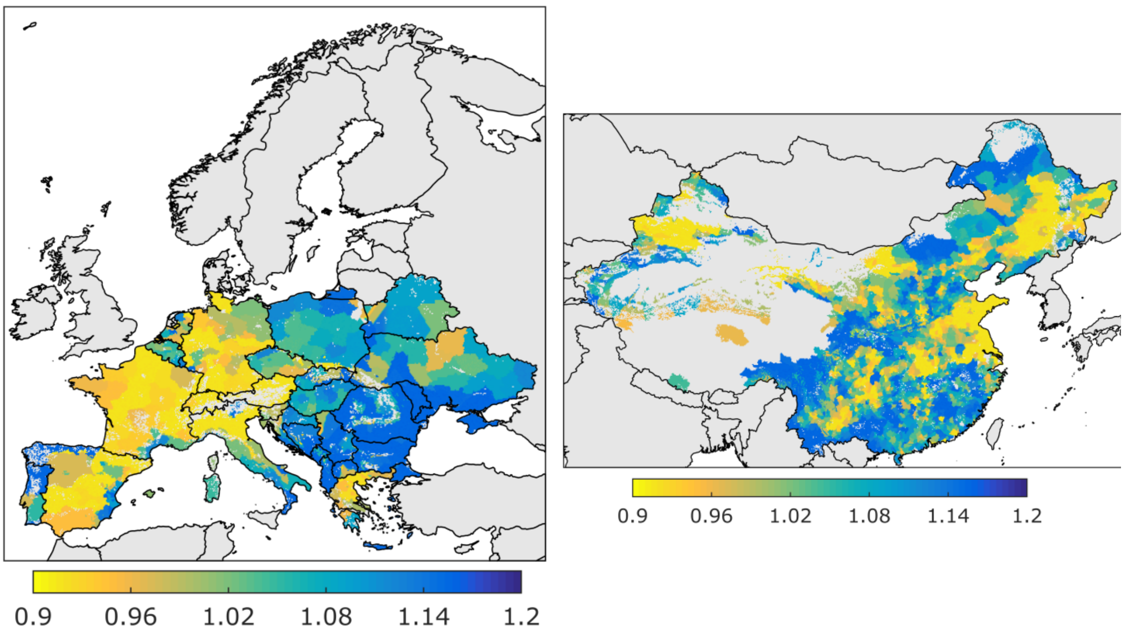


Figure 52. Projected effect of organic matter addition on mean increase in crop yield for maize

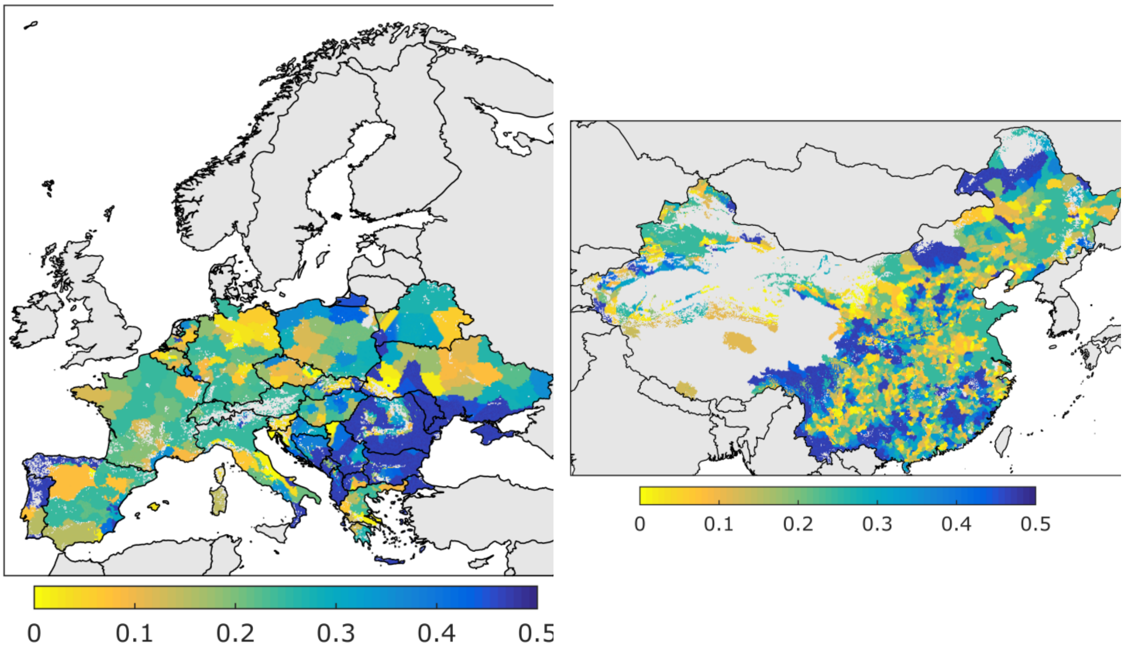


Figure 53. Standard deviation of the projected effect of organic matter addition on mean increase in crop yield for maize

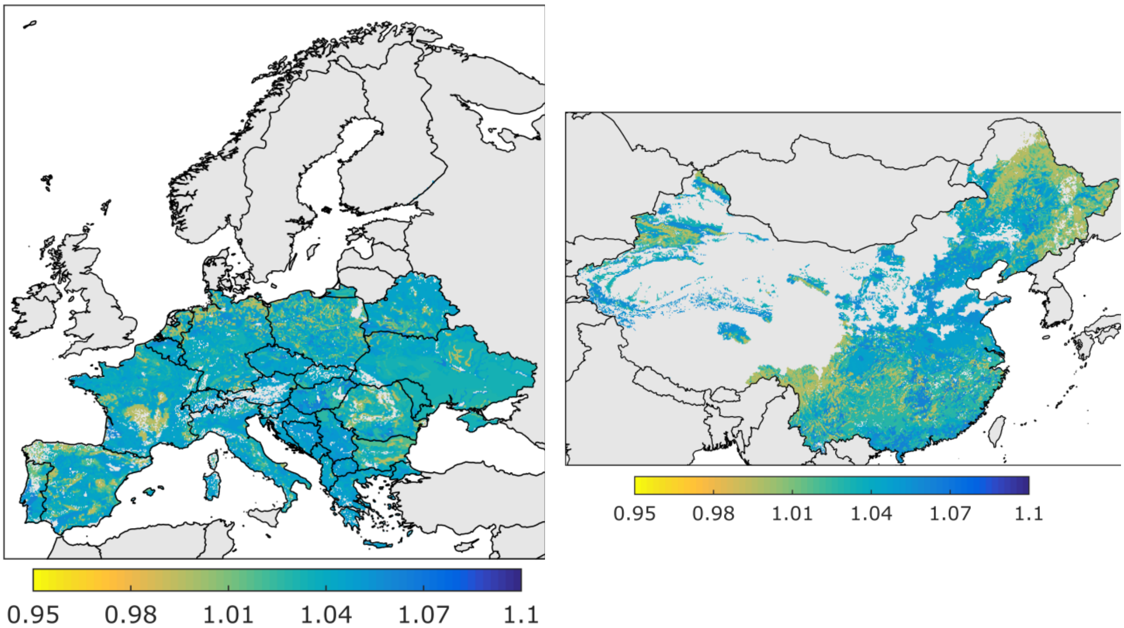


Figure 54. Projected effect of organic matter addition on mean increase in soil organic matter for maize

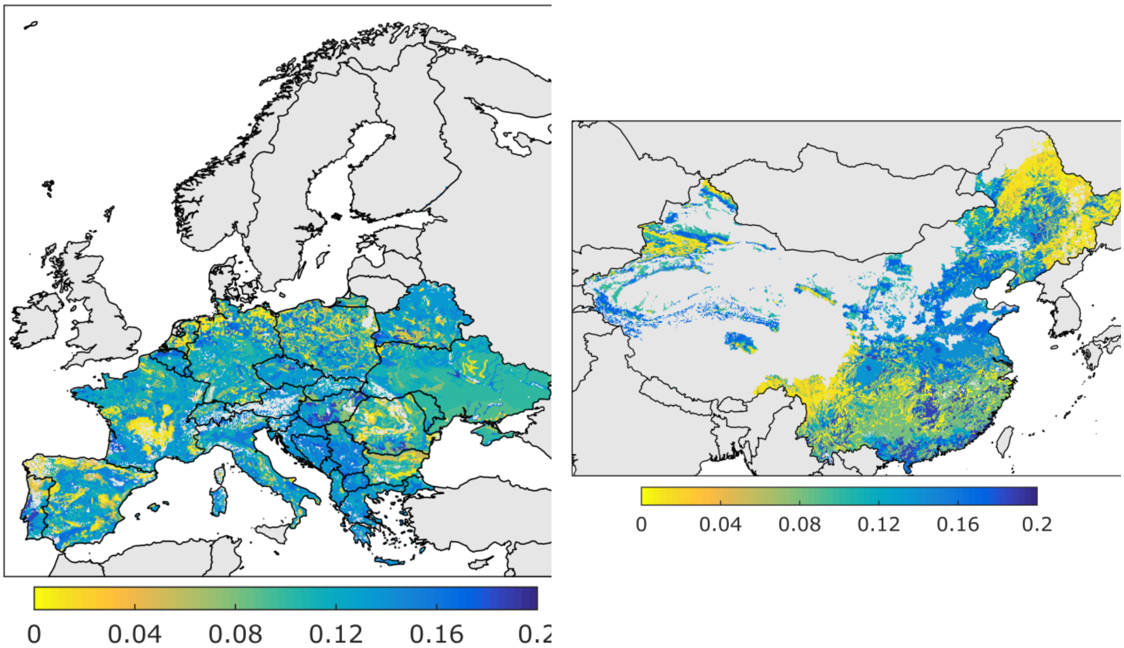


Figure 55. Standard deviation of the projected effect of organic matter addition on mean increase in soil organic matter for maize

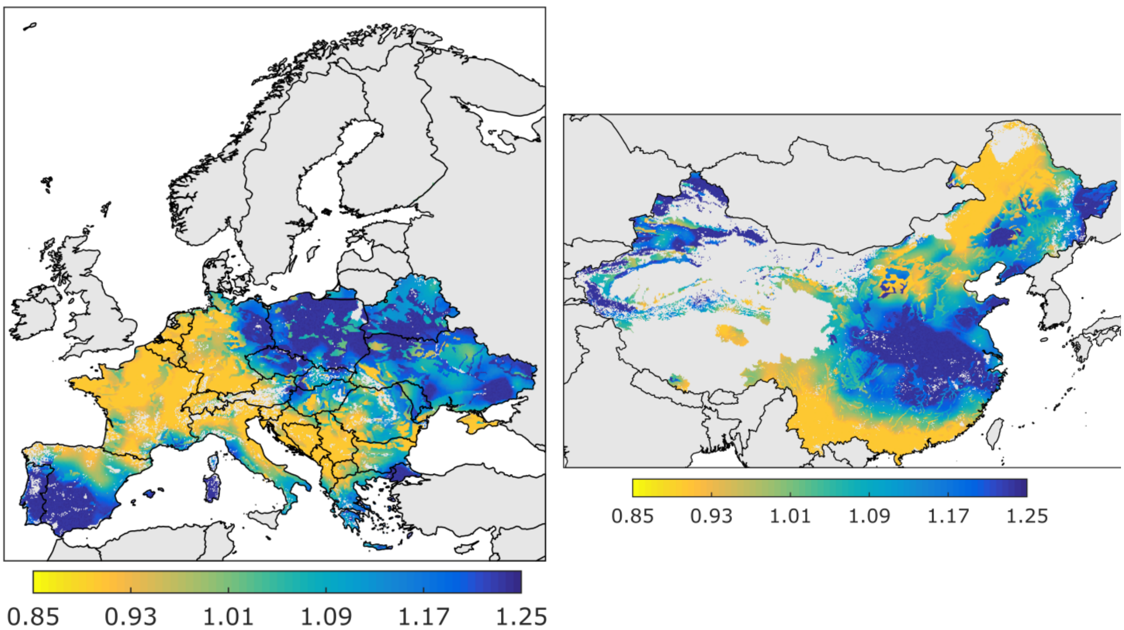


Figure 56. Projected effect of organic matter addition on mean increase in global soil biodiversity for maize

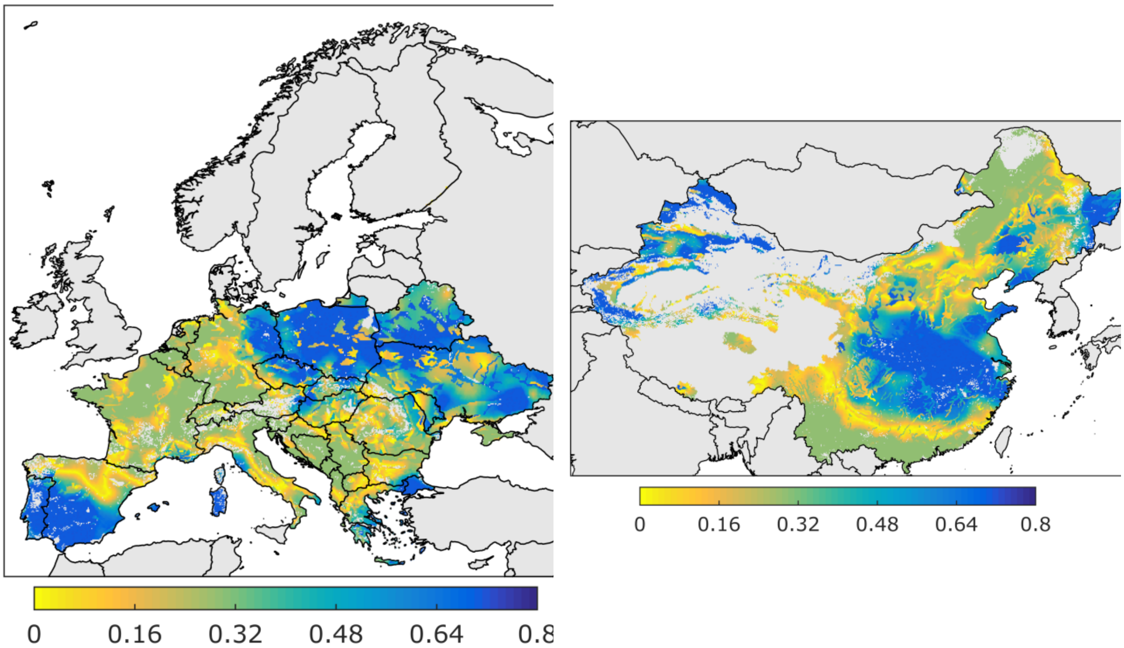


Figure 57. Standard deviation of the projected effect of organic matter addition on mean increase in global soil biodiversity for maize

6.1.4 Soybean

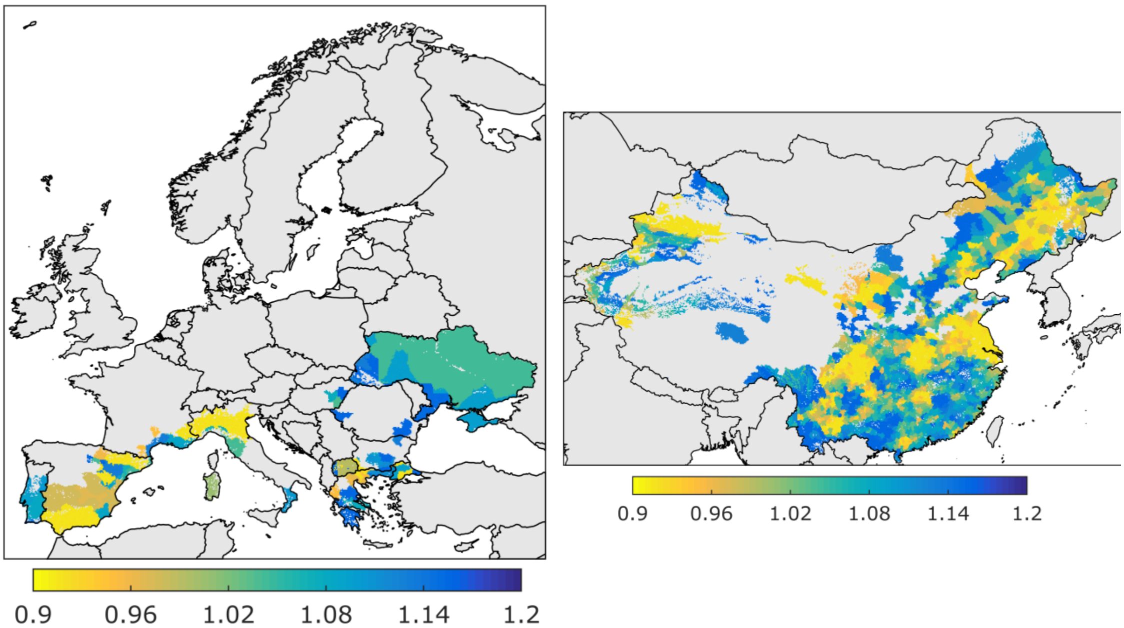


Figure 58. Projected effect of organic matter addition on mean increase in crop yield for soybean

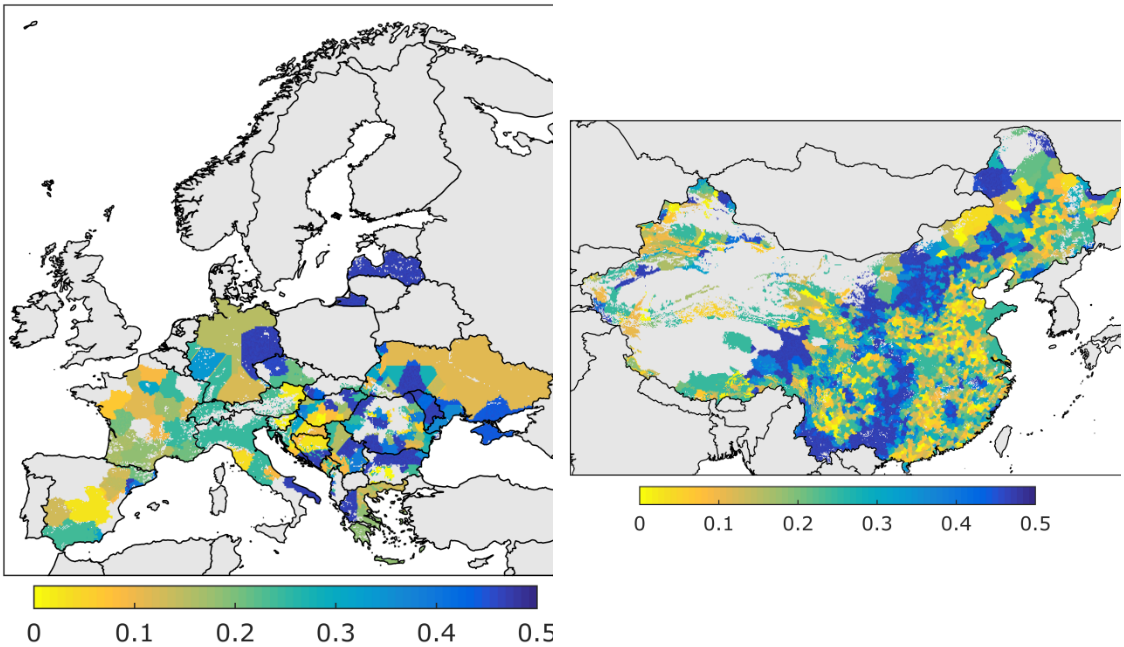


Figure 59. Standard deviation of the projected effect of organic matter addition on mean increase in crop yield for soybean

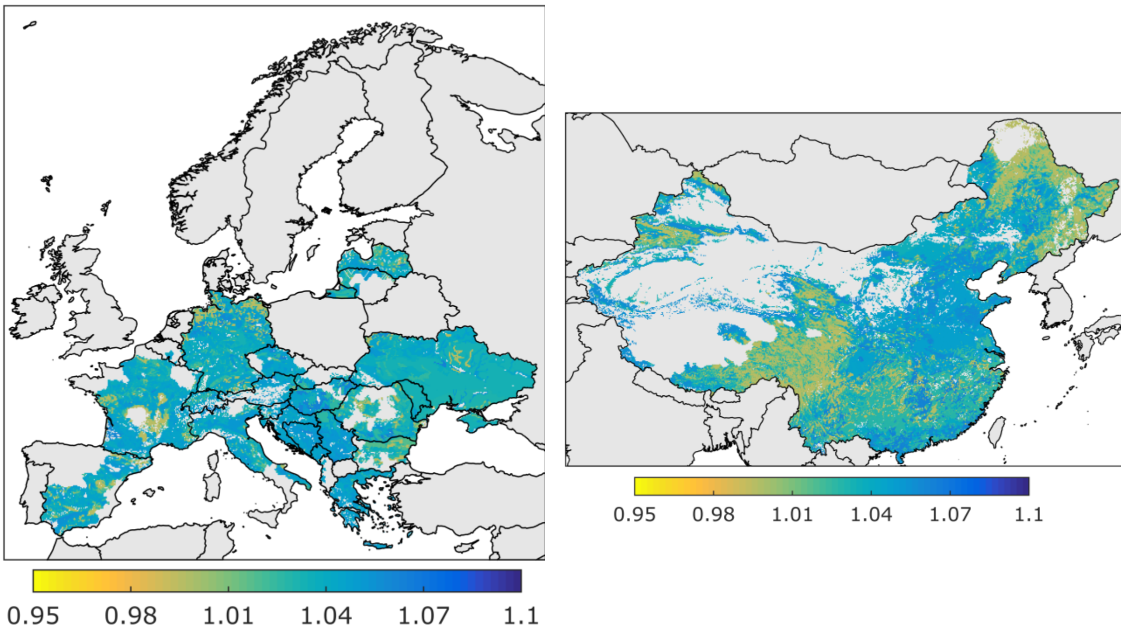


Figure 60. Projected effect of organic matter addition on mean increase in soil organic matter for soybean

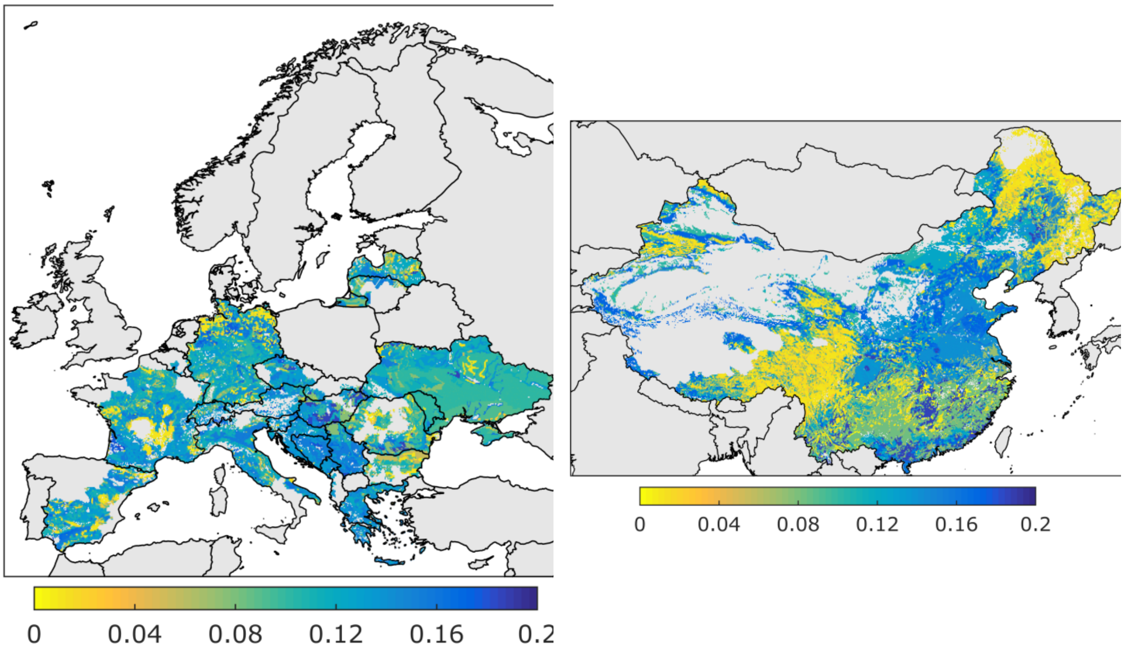


Figure 61. Standard deviation of the projected effect of organic matter addition on mean increase in soil organic matter for soybean

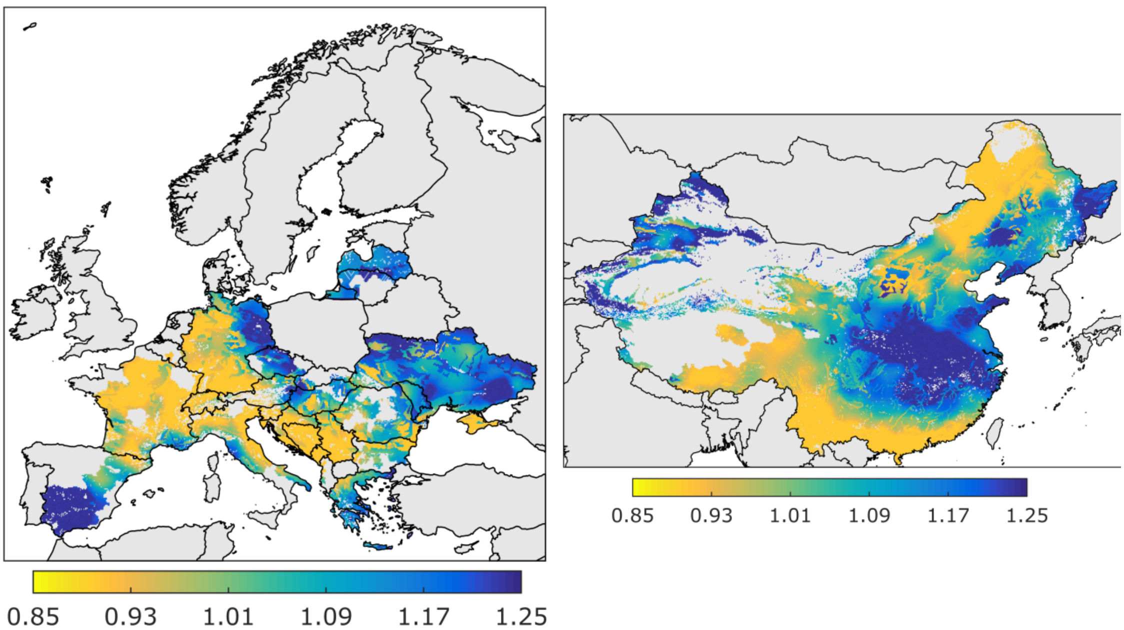


Figure 62. Projected effect of organic matter addition on mean increase in global soil biodiversity for soybean

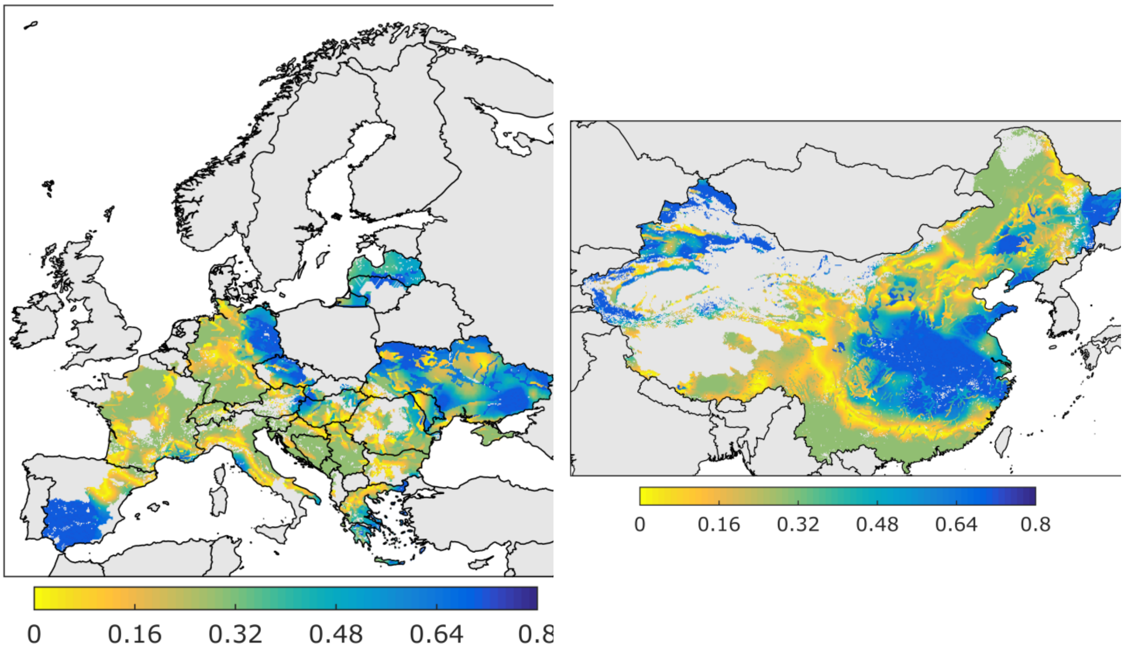


Figure 63. Standard deviation of the projected effect of organic matter addition on mean increase in global soil biodiversity for soybean

6.1.5 Vegetables

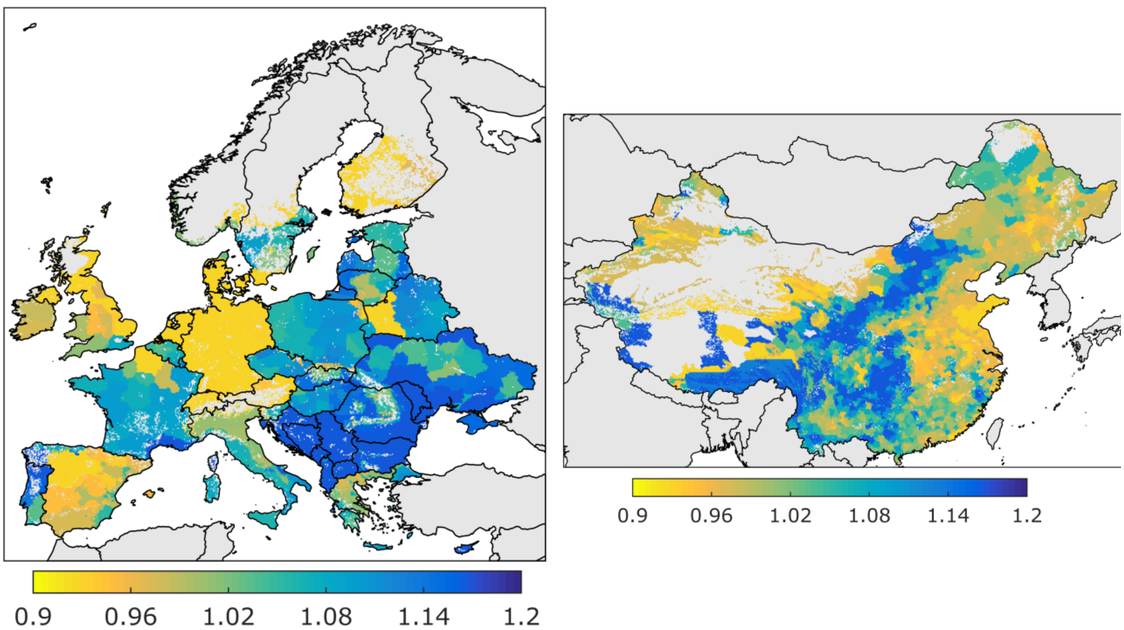


Figure 64. Projected effect of organic matter addition on mean increase in crop yield for vegetables

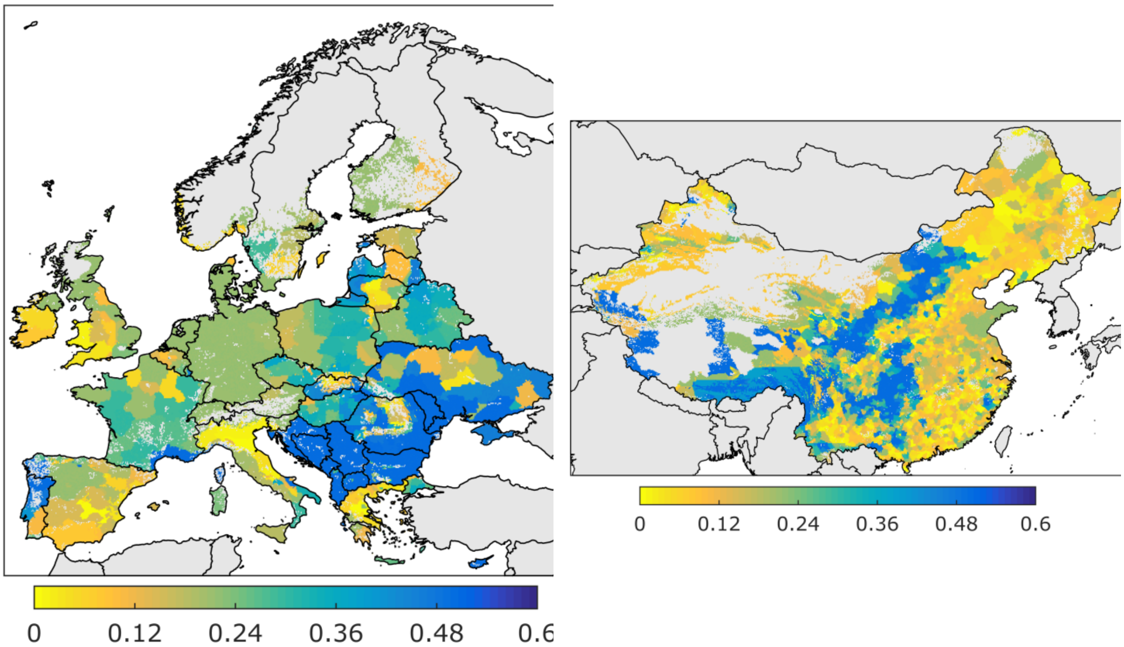


Figure 65. Standard deviation of the projected effect of organic matter addition on mean increase in crop yield for vegetables

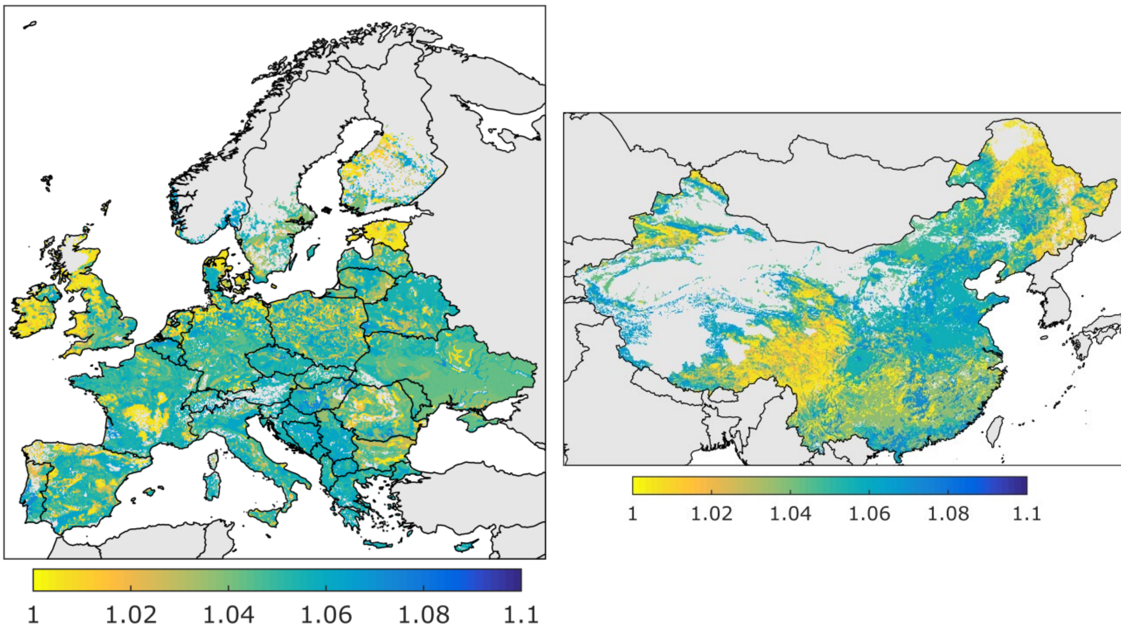


Figure 66. Projected effect of organic matter addition on mean increase in soil organic matter for vegetables

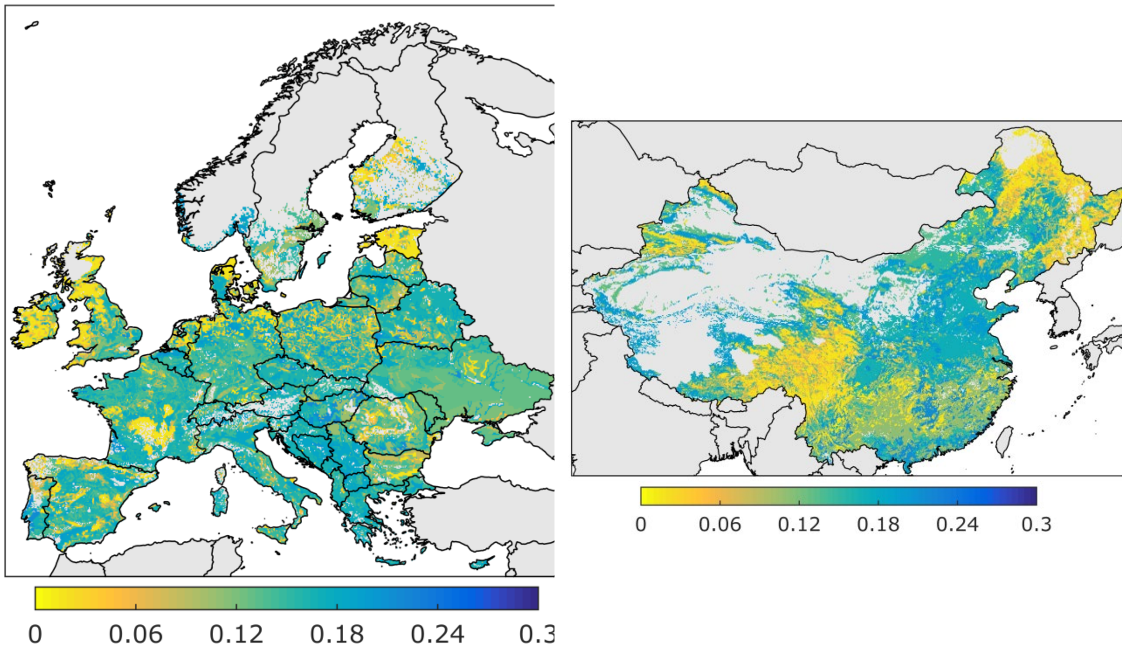


Figure 67. Standard deviation of the projected effect of organic matter addition on mean increase in soil organic matter for vegetables

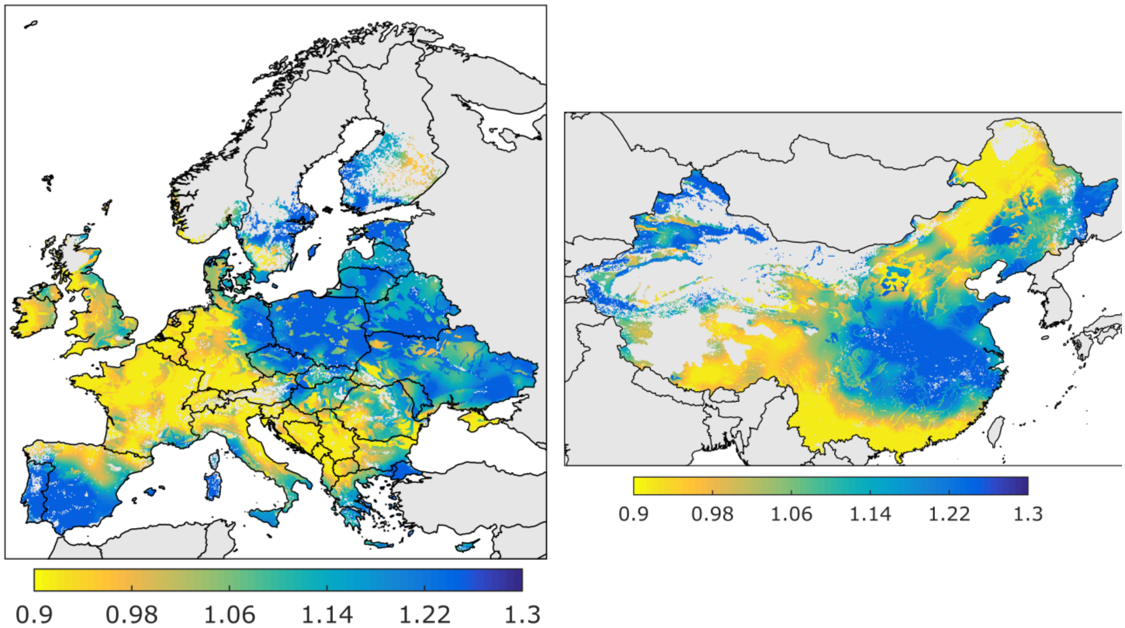


Figure 68. Projected effect of organic matter addition on mean increase in global soil biodiversity for vegetables

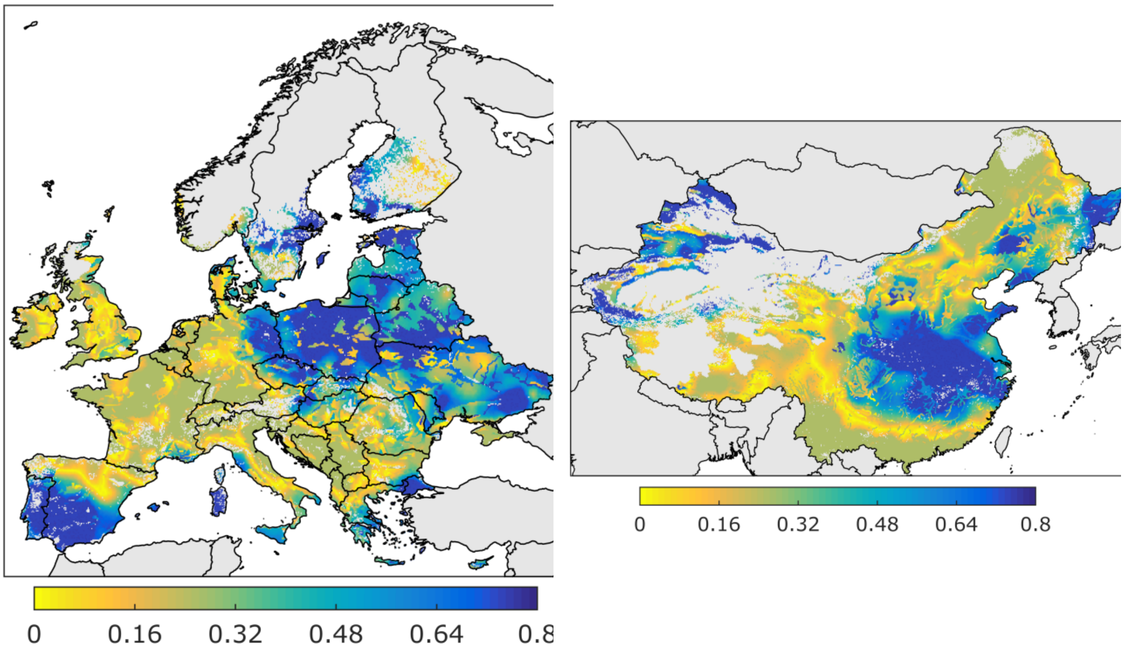


Figure 69. Standard deviation of the projected effect of organic matter addition on mean increase in global soil biodiversity for vegetables

6.1.6 Pasture

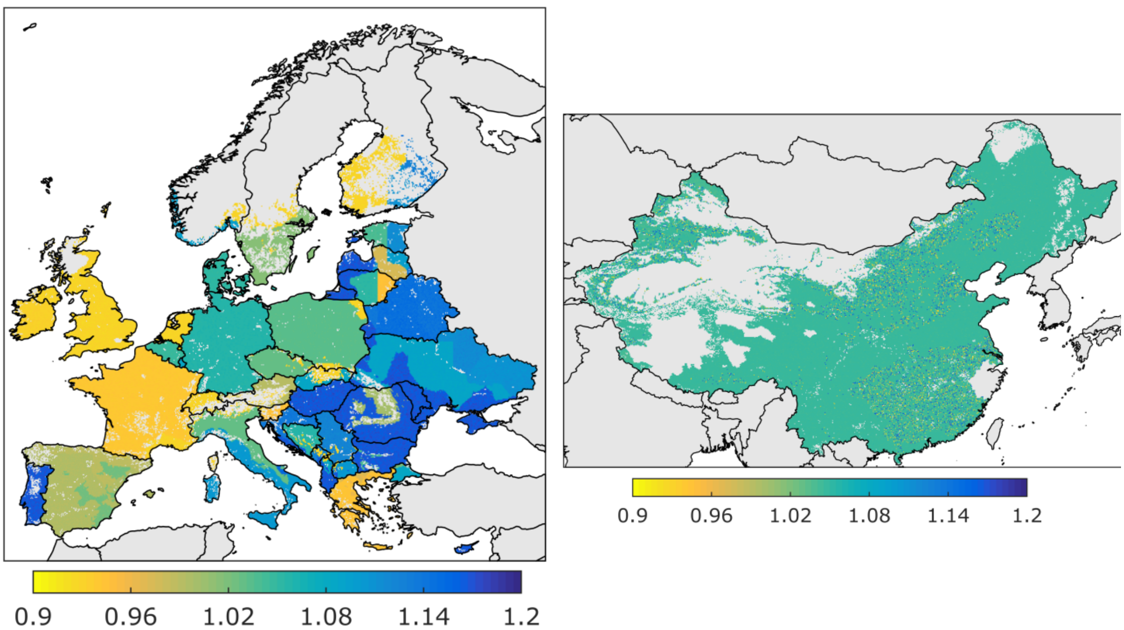


Figure 70. Projected effect of organic matter addition on mean increase in crop yield for pasture

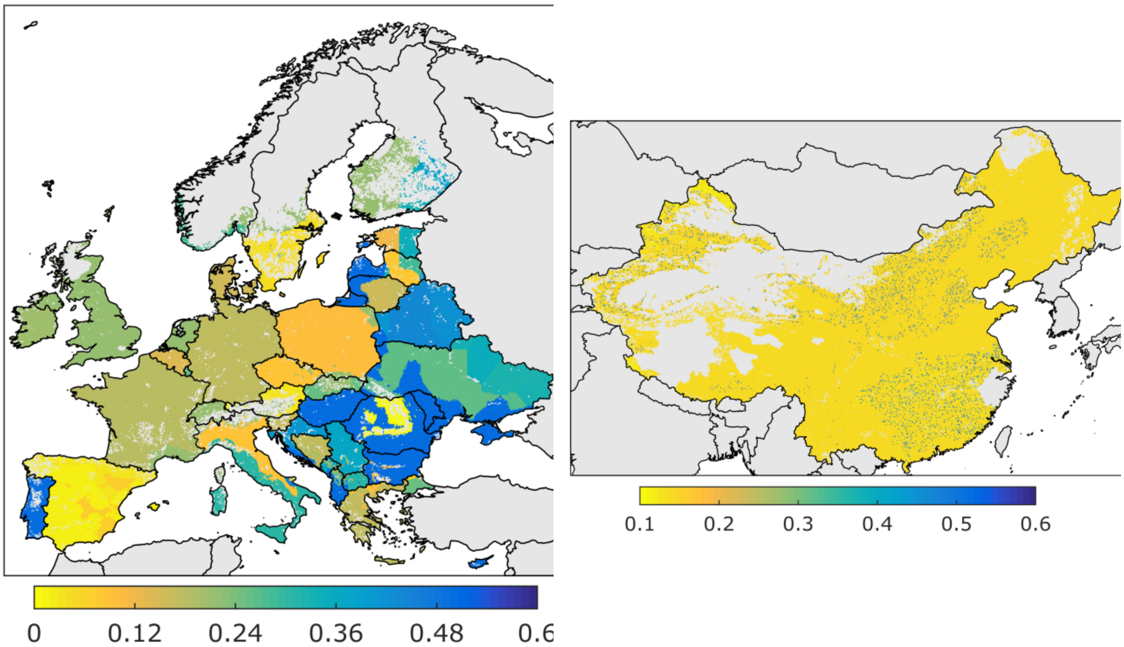


Figure 71. Standard deviation of the projected effect of organic matter addition on mean increase in crop yield for pasture

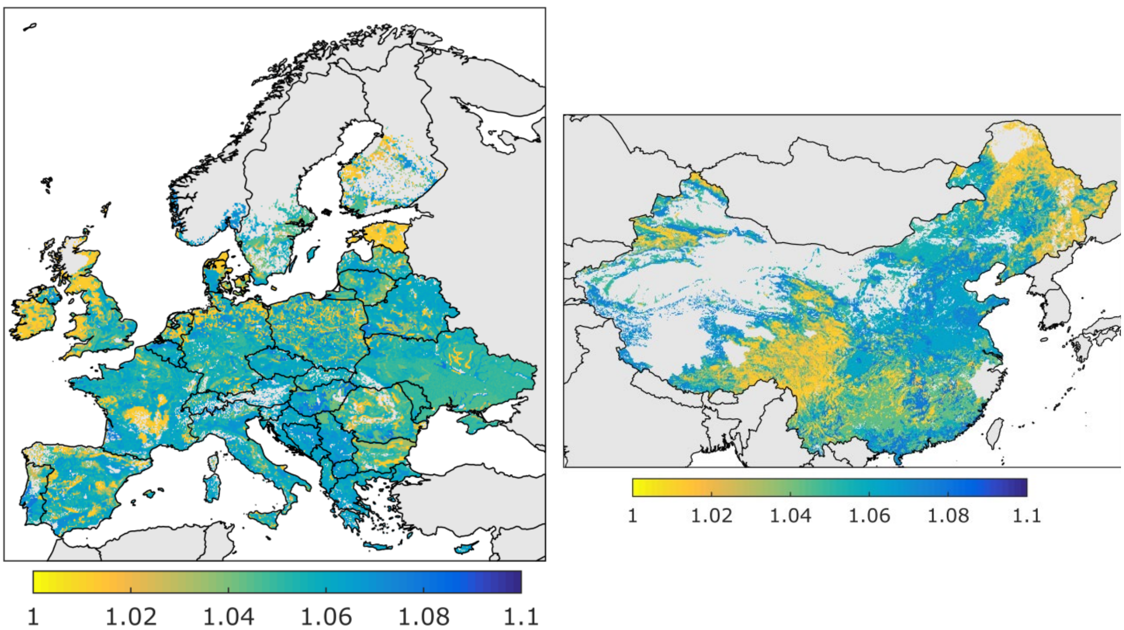


Figure 72. Projected effect of organic matter addition on mean increase in soil organic matter for pasture

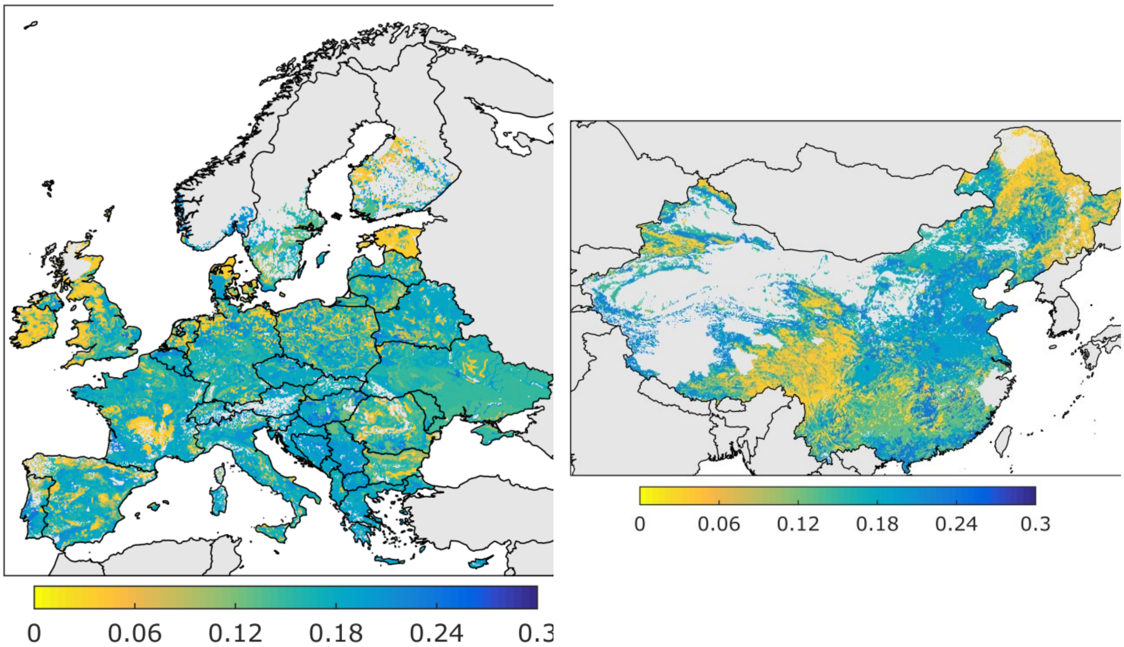


Figure 73. Standard deviation of the projected effect of organic matter addition on mean increase in soil organic matter for pasture

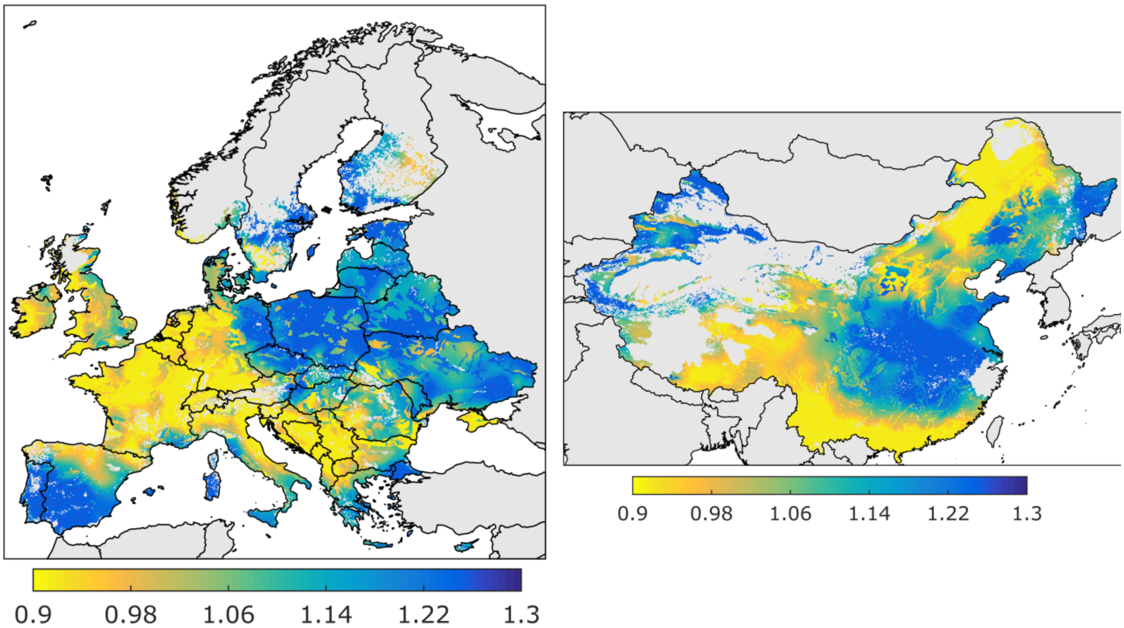


Figure 74. Projected effect of organic matter addition on mean increase in global soil biodiversity for pasture

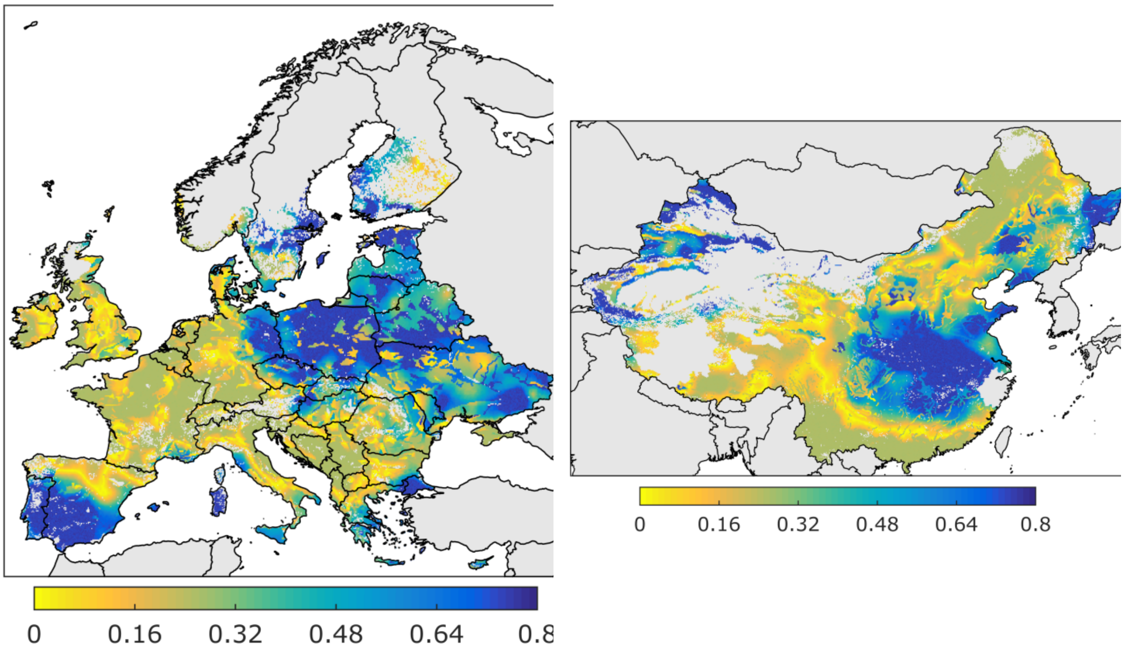


Figure 75. Standard deviation of the projected effect of organic matter addition on mean increase in global soil biodiversity for pasture

6.1.7 Permanent crops

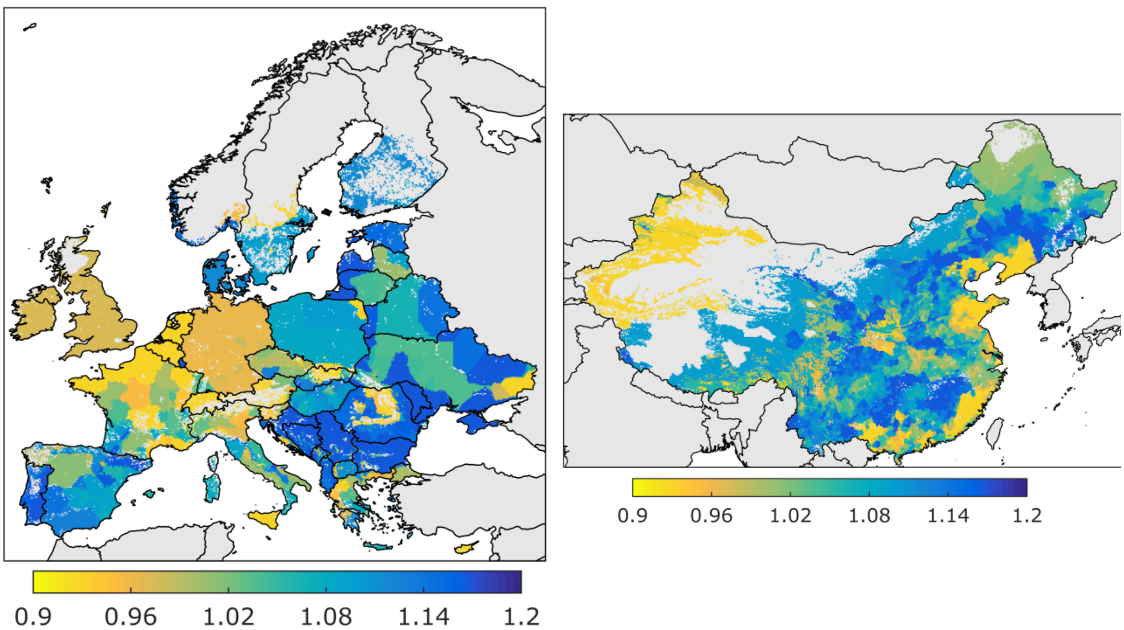


Figure 76. Projected effect of organic matter addition on mean increase in crop yield for permanent crops

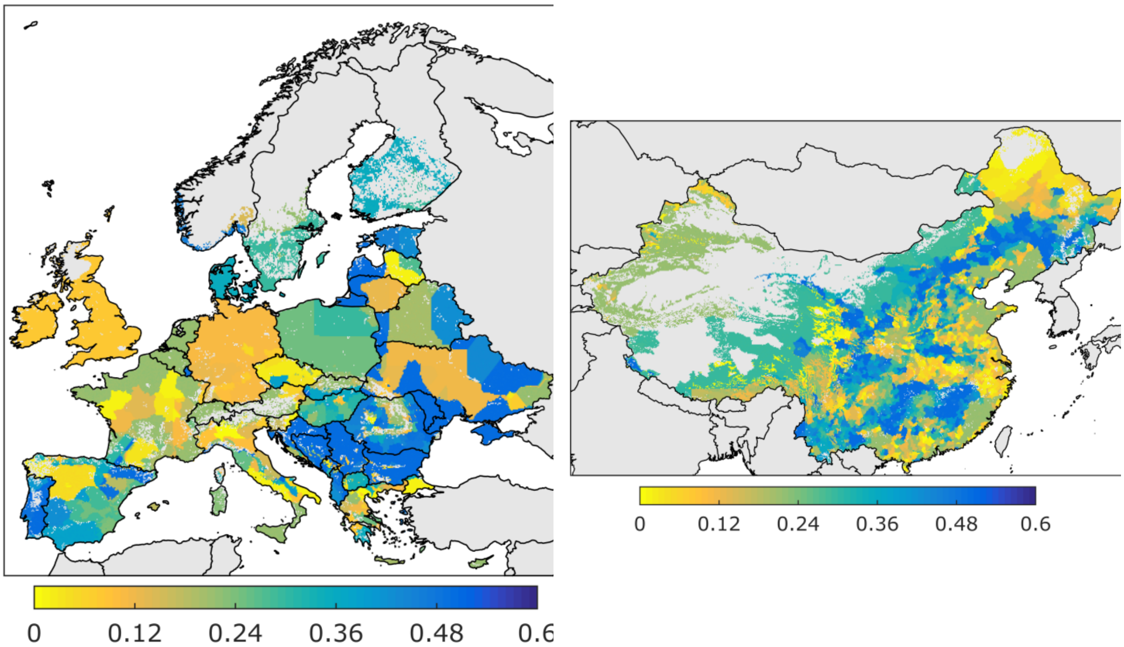


Figure 77. Standard deviation of the projected effect of organic matter addition on mean increase in crop yield for permanent crops

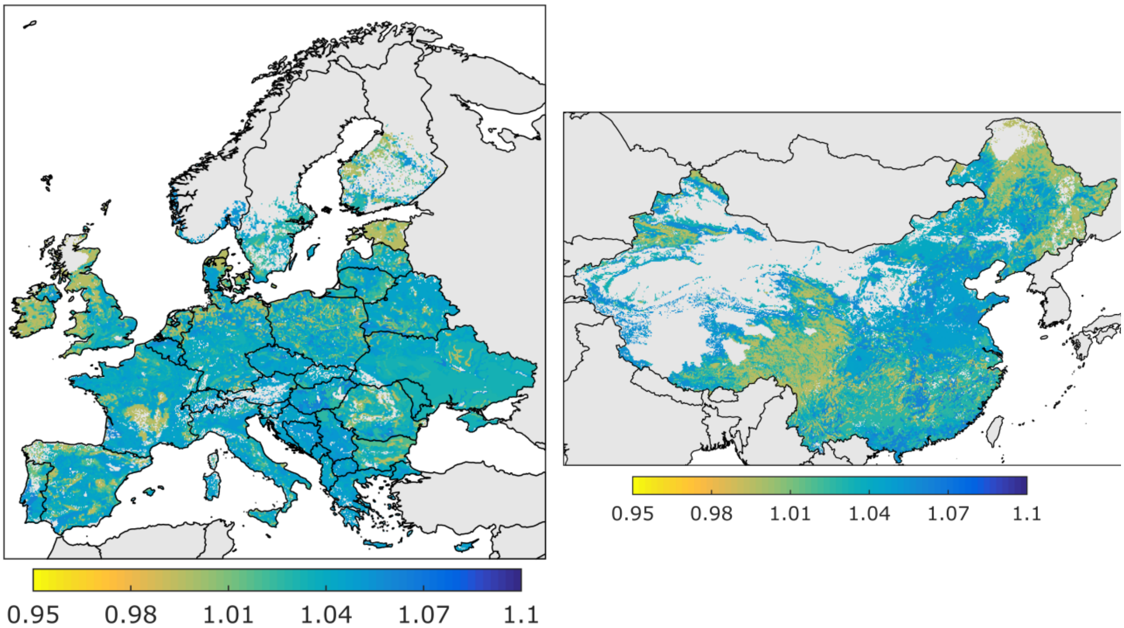


Figure 78. Projected effect of organic matter addition on mean increase in soil organic matter for permanent crops

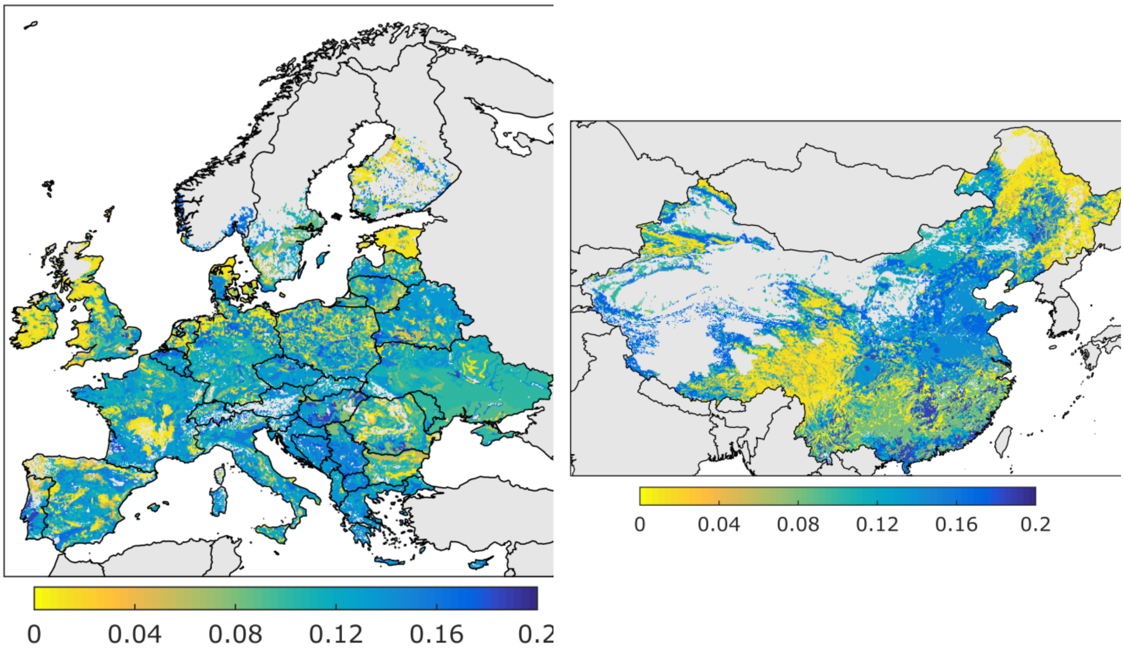


Figure 79. Standard deviation of the projected effect of organic matter addition on mean increase in soil organic matter for permanent crops

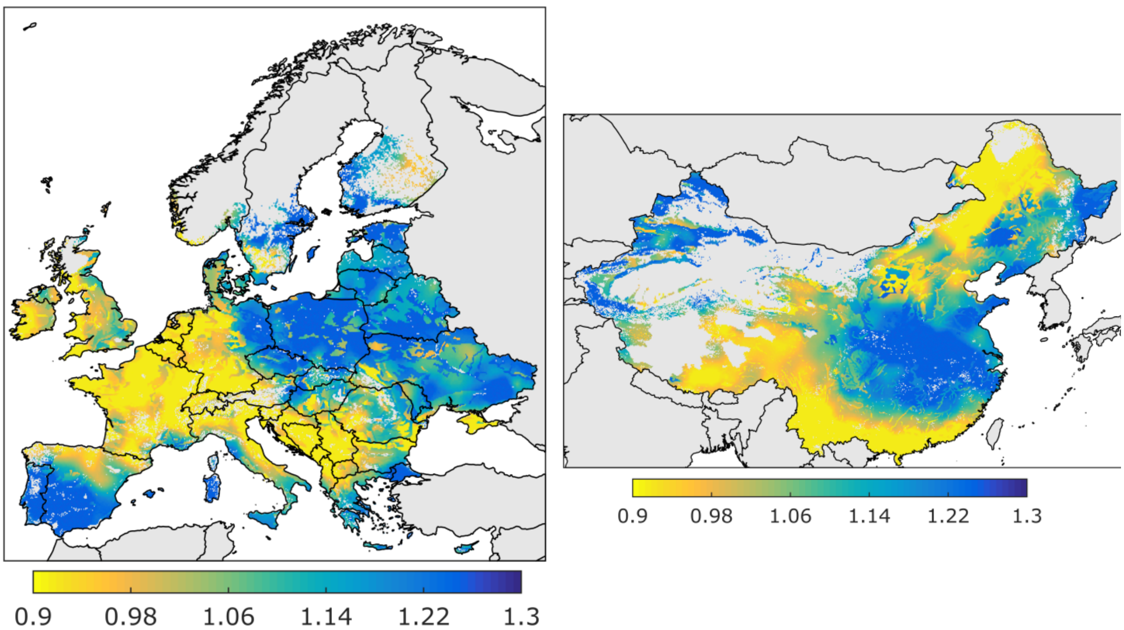


Figure 80. Projected effect of organic matter addition on mean increase in global soil biodiversity for permanent crops

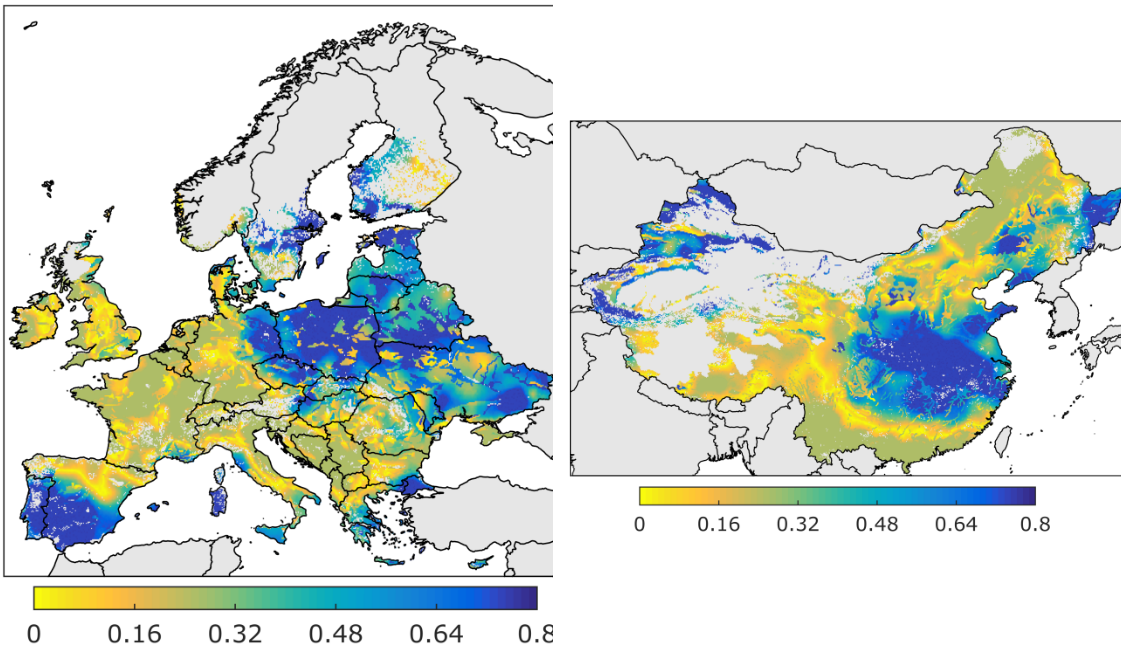


Figure 81. Standard deviation of the projected effect of organic matter addition on mean increase in global soil biodiversity for permanent crops

6.2 Projection of tillage practices

6.2.1 Cereal

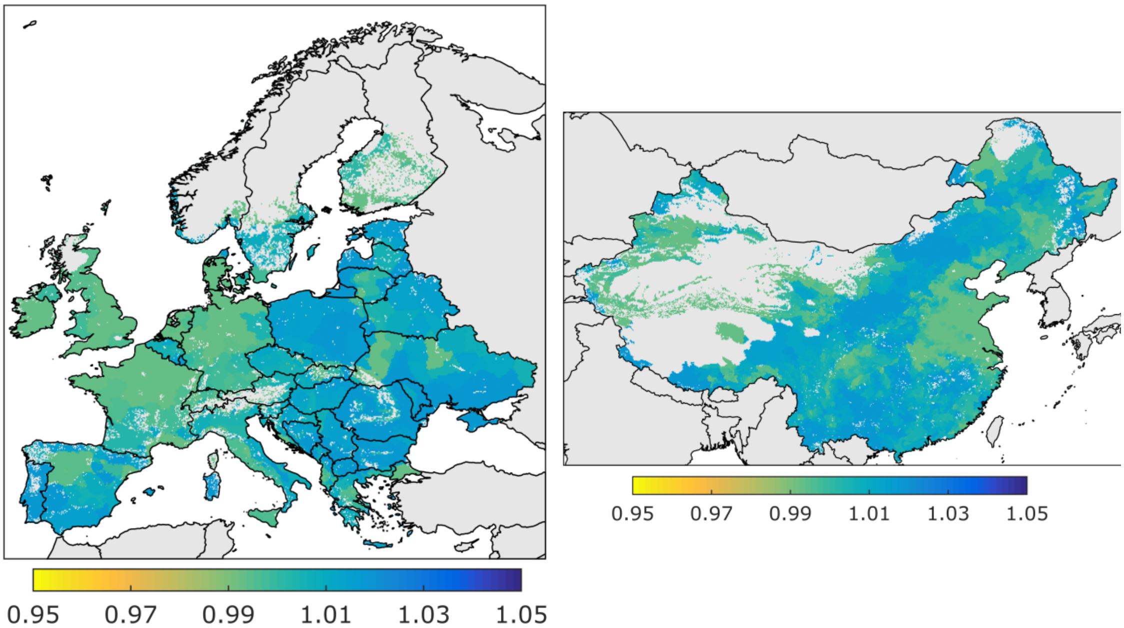


Figure 82. Projected effect of tillage practice on mean increase in crop yield for cereal

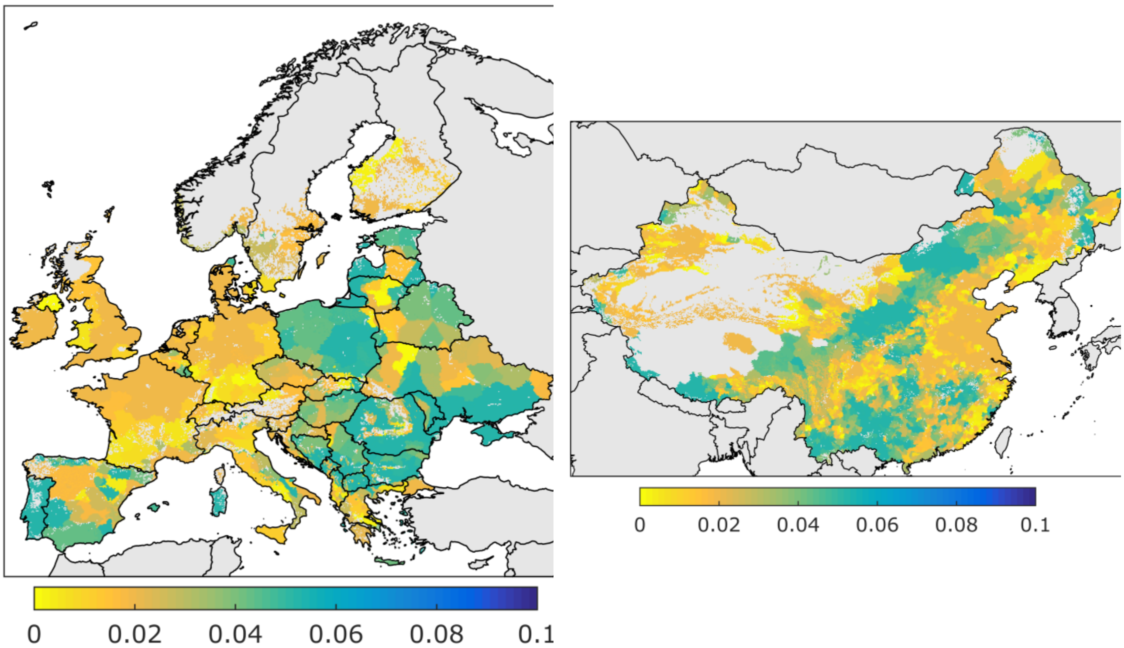


Figure 83. Standard deviation of the projected effect of tillage practice on mean increase in crop yield for cereal

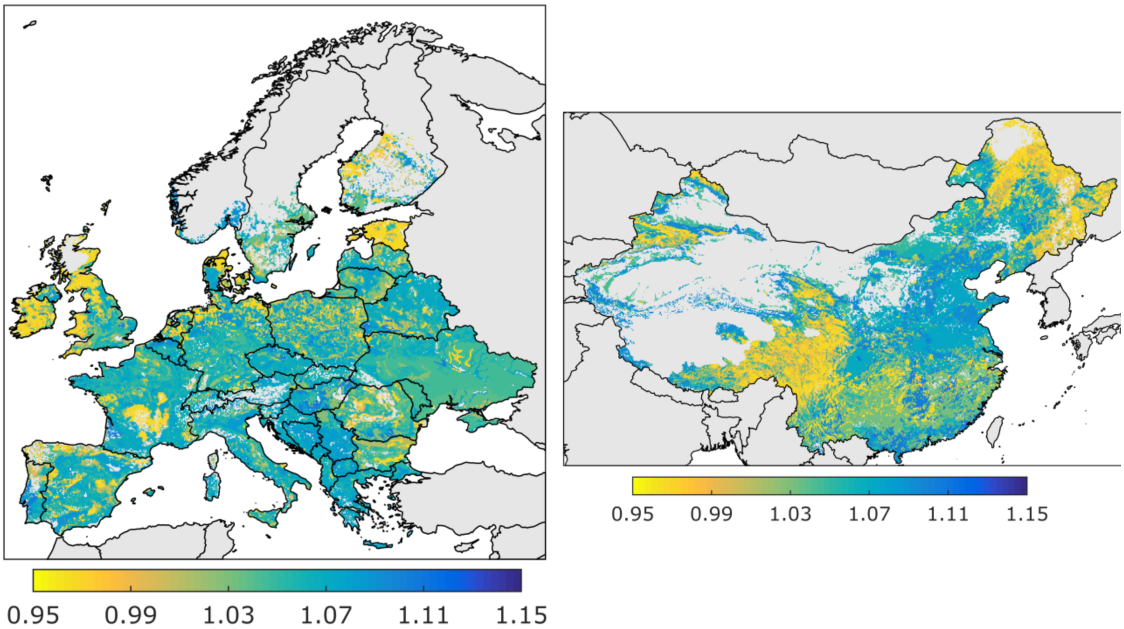


Figure 84. Projected effect of tillage practice on mean increase in soil organic matter for cereal

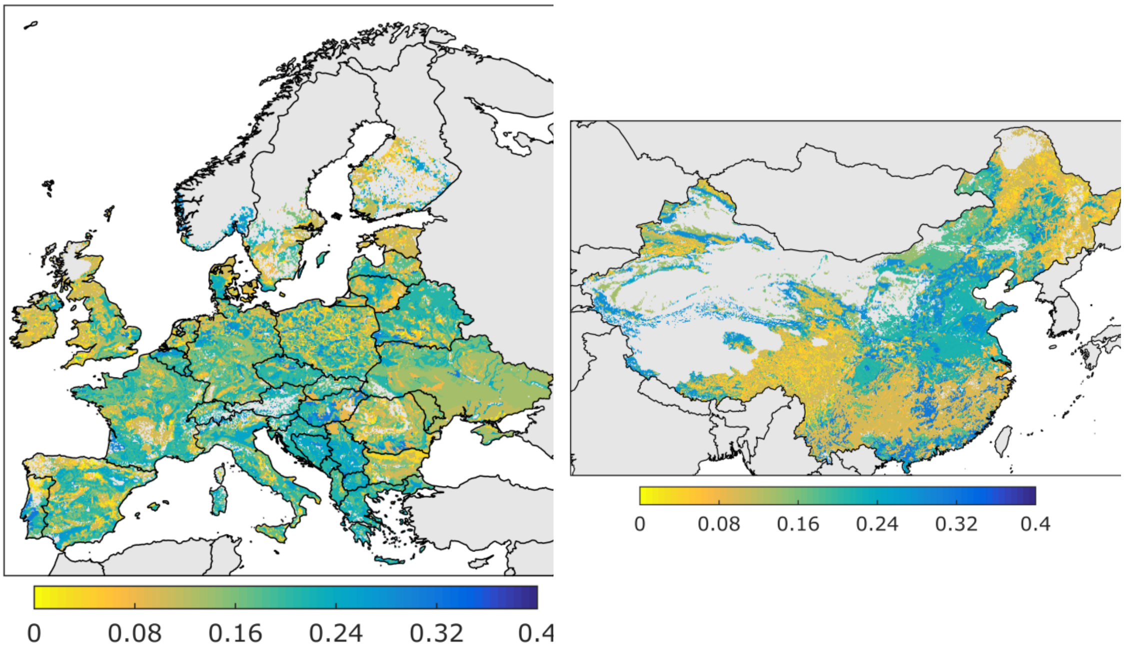


Figure 85. Standard deviation of the projected effect of tillage practice on mean increase in soil organic matter for cereal

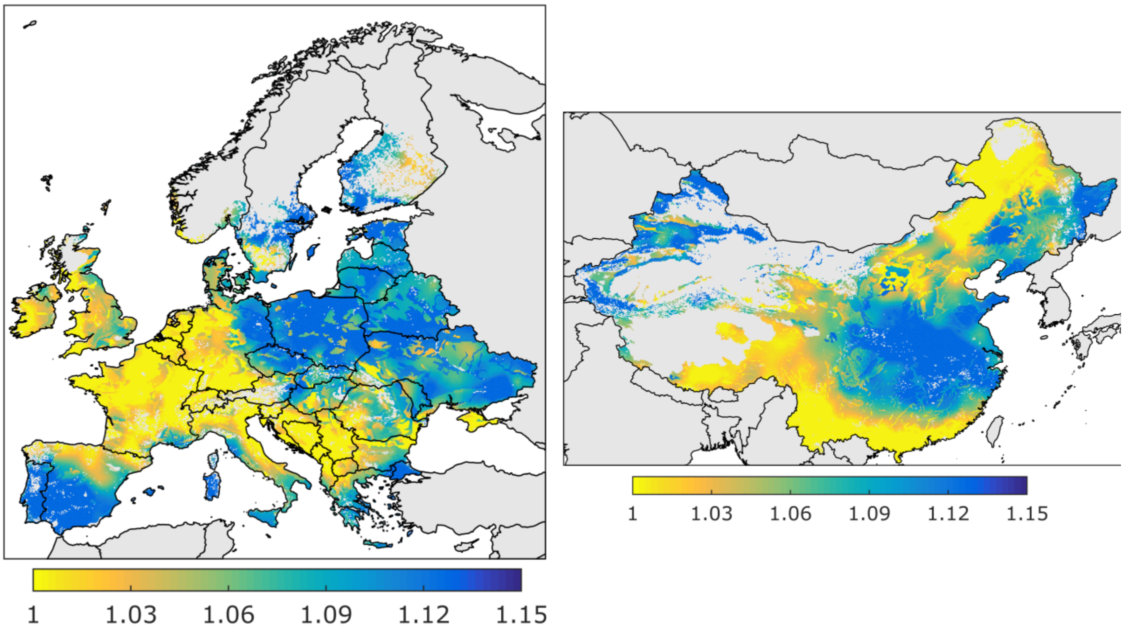


Figure 86. Projected effect of tillage practice on mean increase in global soil biodiversity for cereal

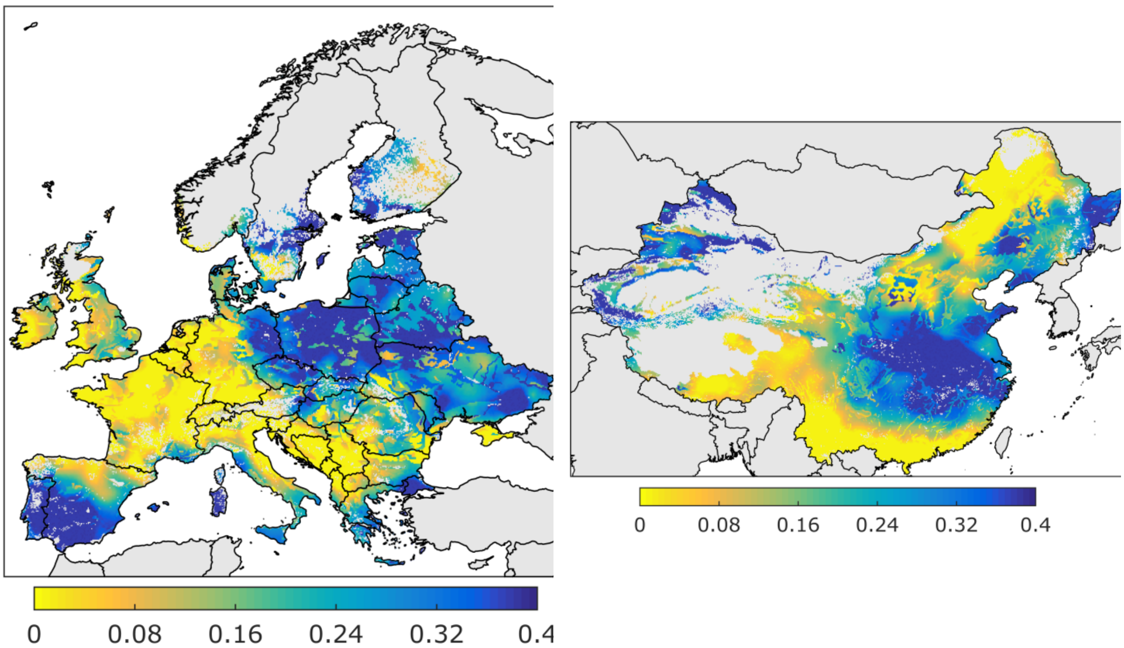


Figure 87. Standard deviation of the projected effect of tillage practice on mean increase in global soil biodiversity for cereal

6.2.2 Maize

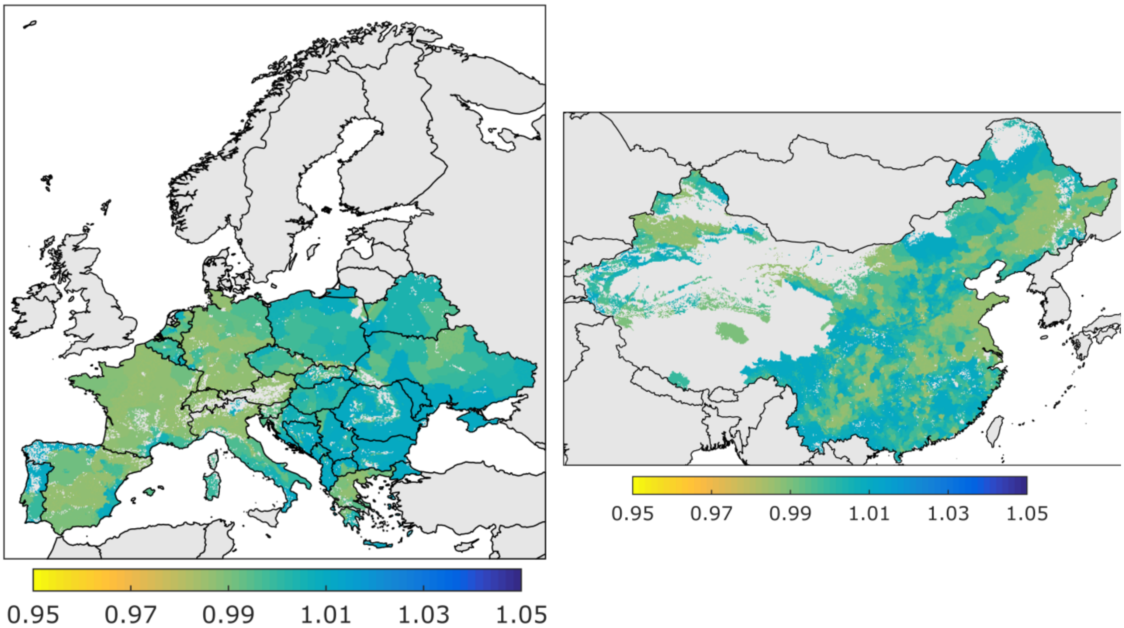


Figure 88. Projected effect of tillage practice on mean increase in crop yield for maize

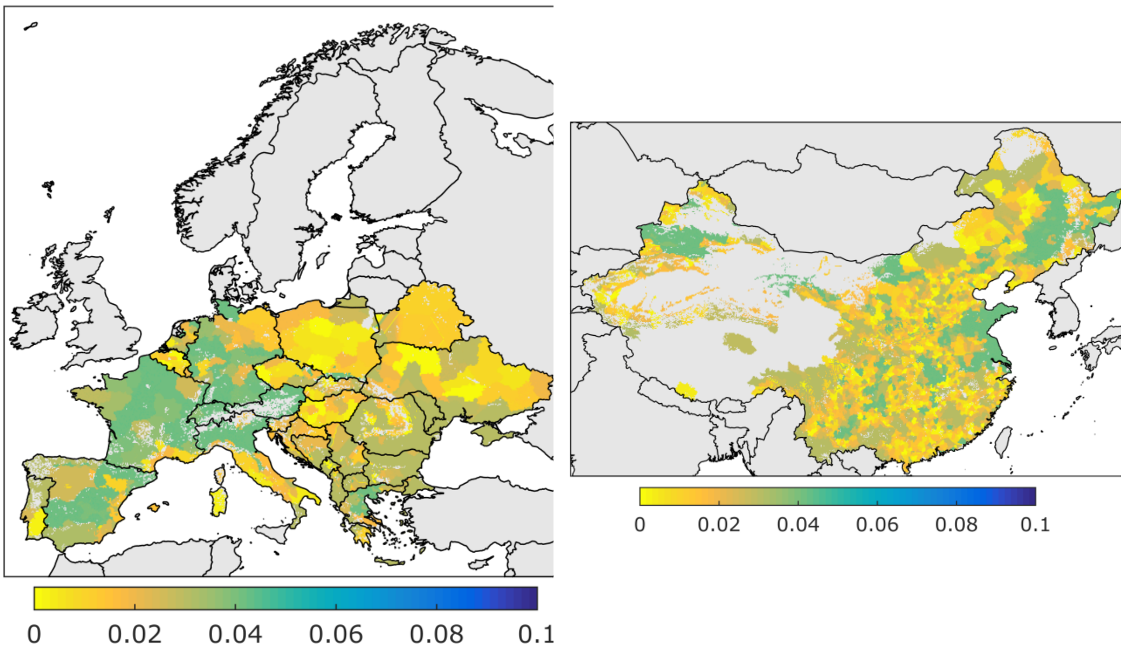


Figure 89. Standard deviation of the projected effect of tillage practice on mean increase in crop yield for maize

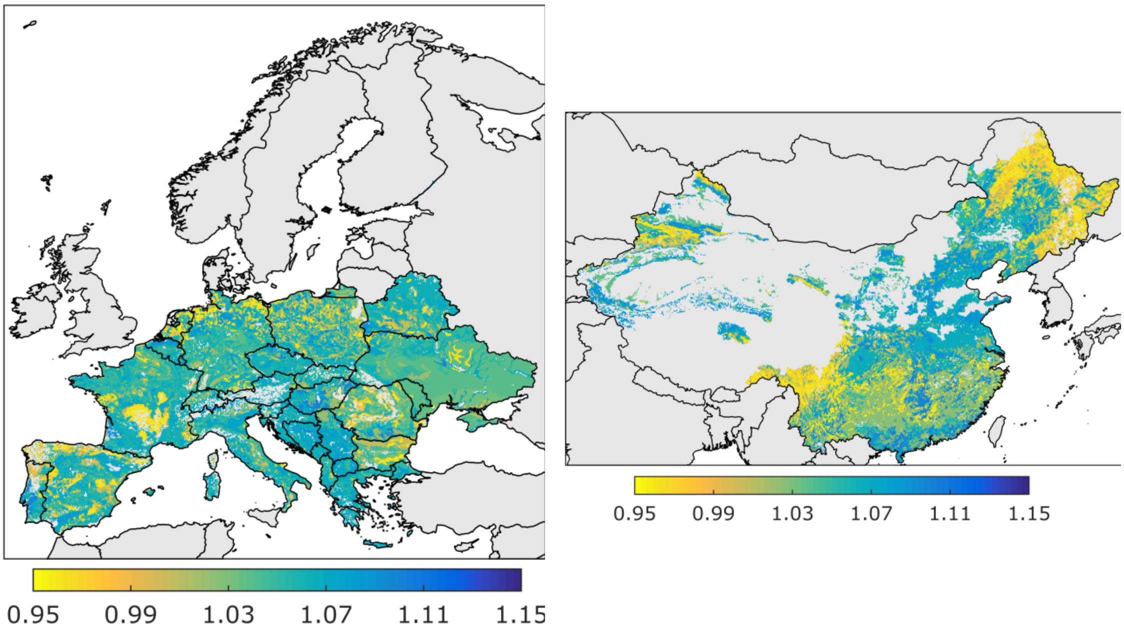


Figure 90. Projected effect of tillage practice on mean increase in soil organic matter for maize

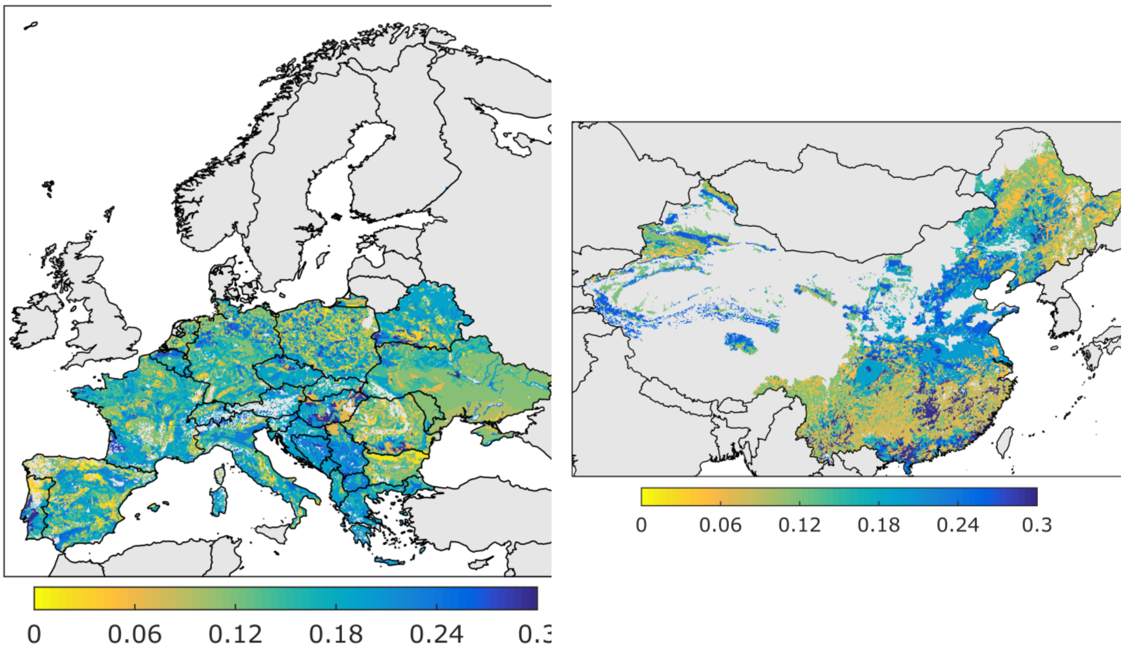


Figure 91. Standard deviation of the projected effect of tillage practice on mean increase in soil organic matter for maize

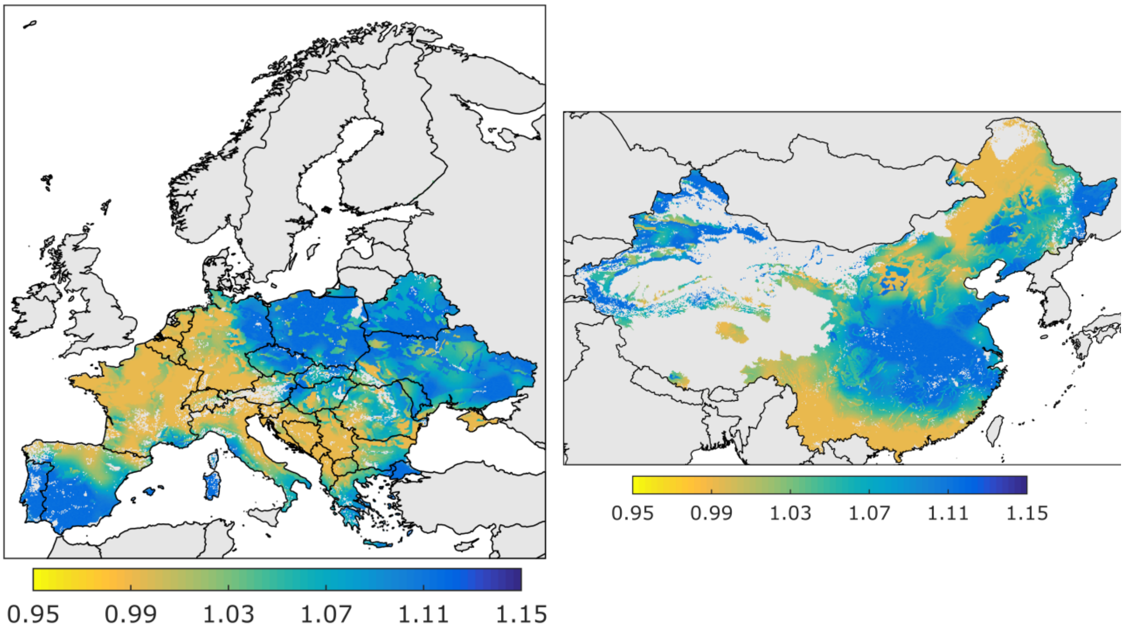


Figure 92. Projected effect of tillage practice on mean increase in global soil biodiversity for maize

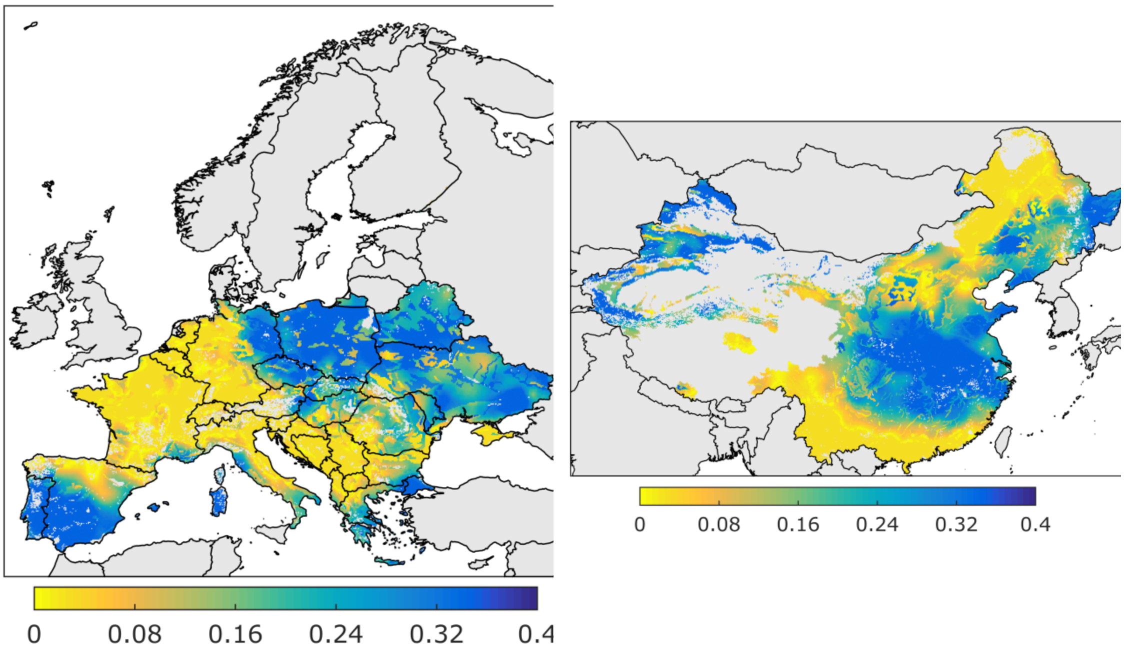


Figure 93. Standard deviation of the projected effect of tillage practice on mean increase in global soil biodiversity for maize

6.2.3 Soybean

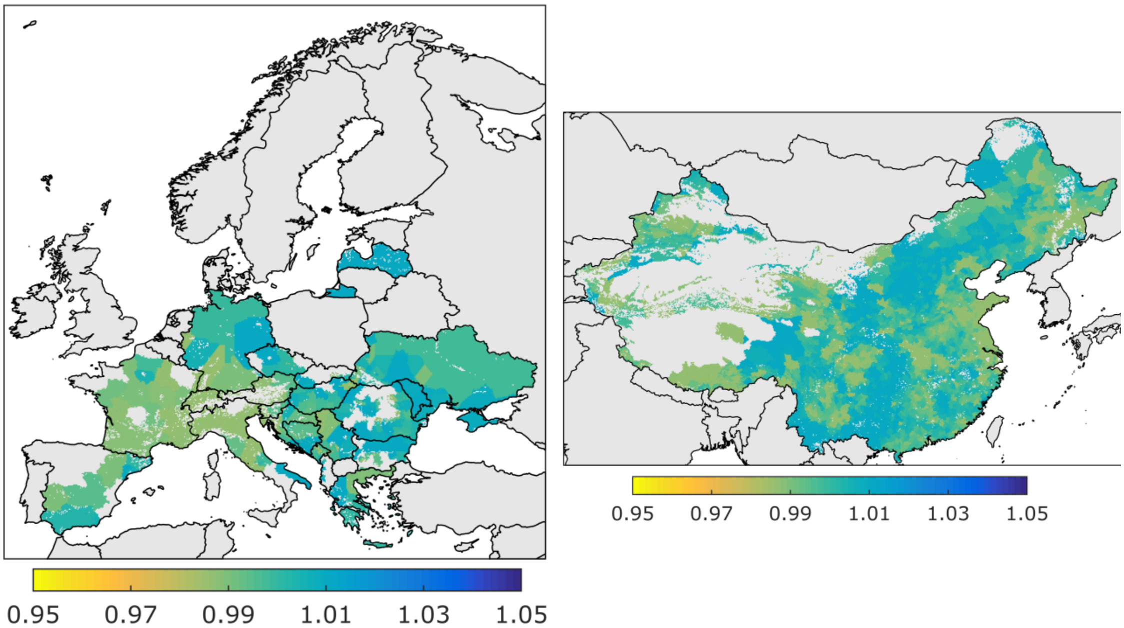


Figure 94. Projected effect of tillage practice on mean increase in crop yield for soybean

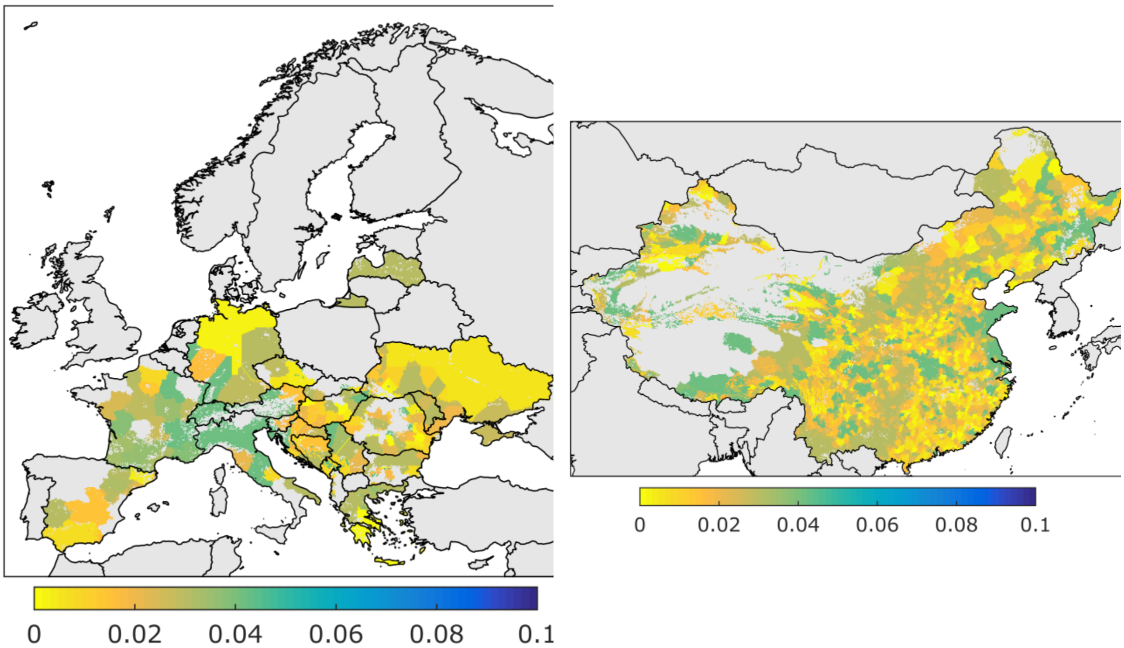


Figure 95. Standard deviation of the projected effect of tillage practice on mean increase in crop yield for soybean

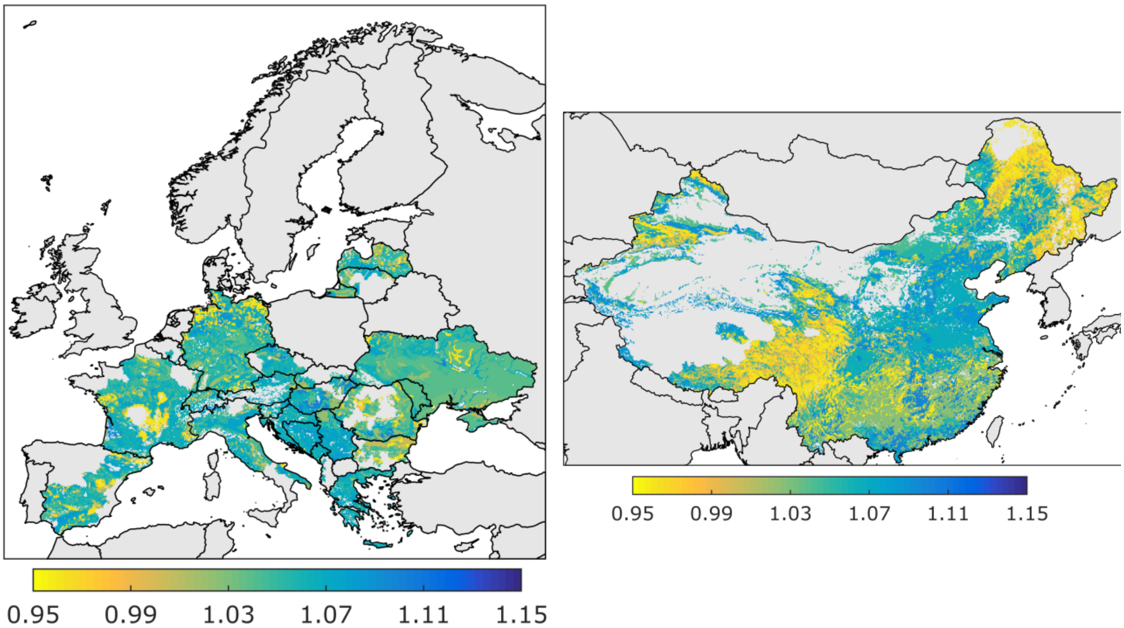


Figure 96. Projected effect of tillage practice on mean increase in soil organic matter for soybean

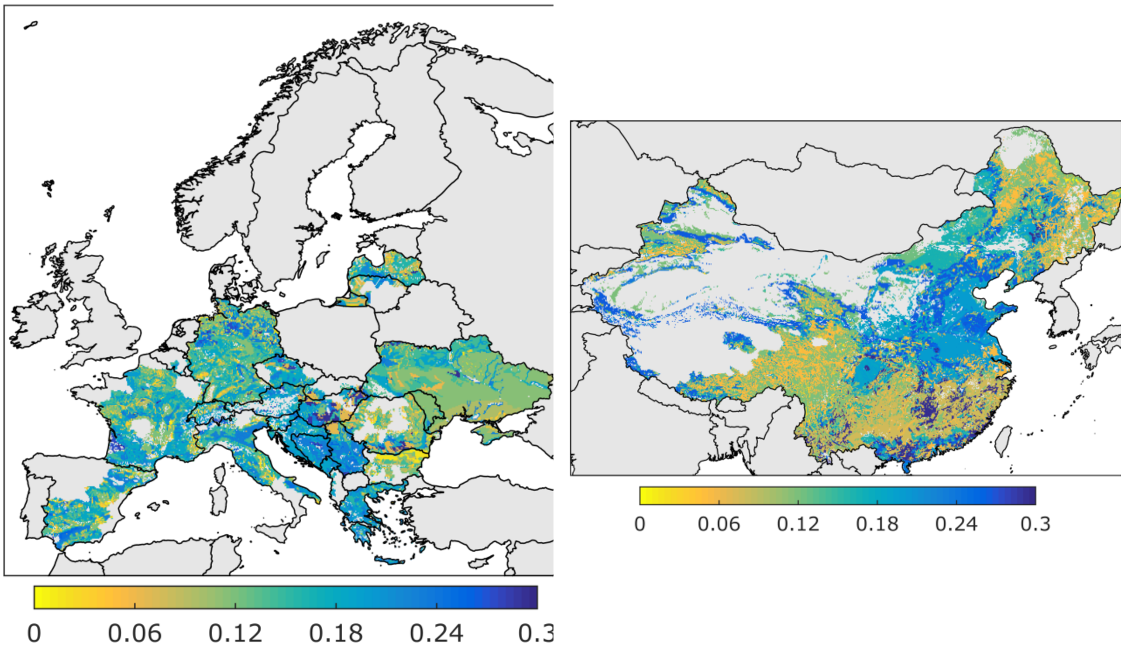


Figure 97. Standard deviation of the projected effect of tillage practice on mean increase in soil organic matter for soybean

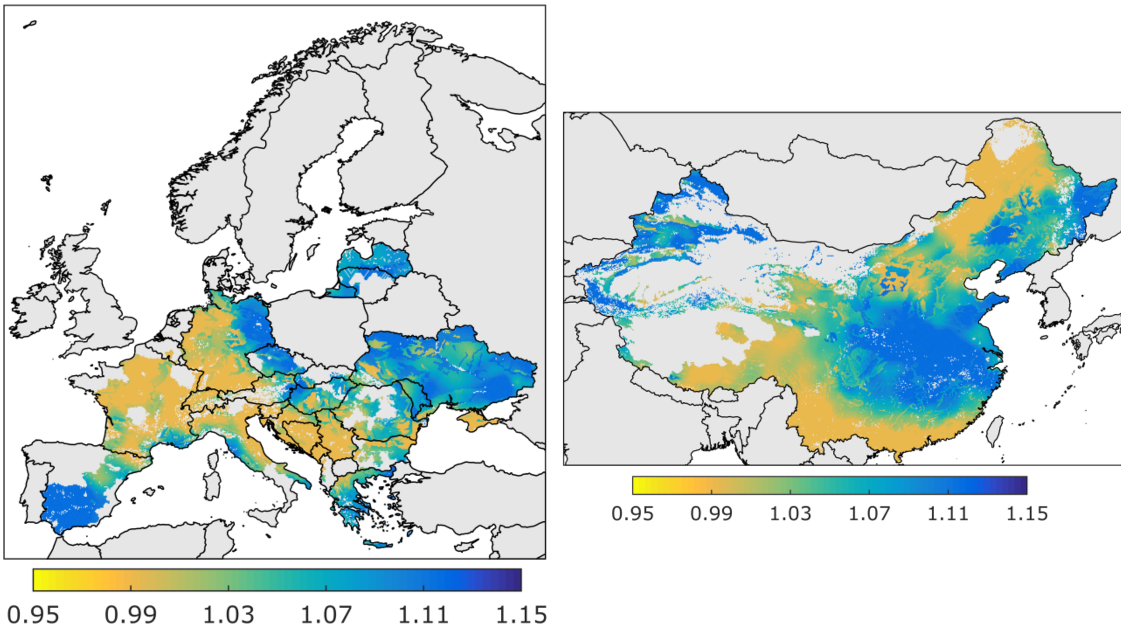


Figure 98. Projected effect of tillage practice on mean increase in global soil biodiversity for soybean

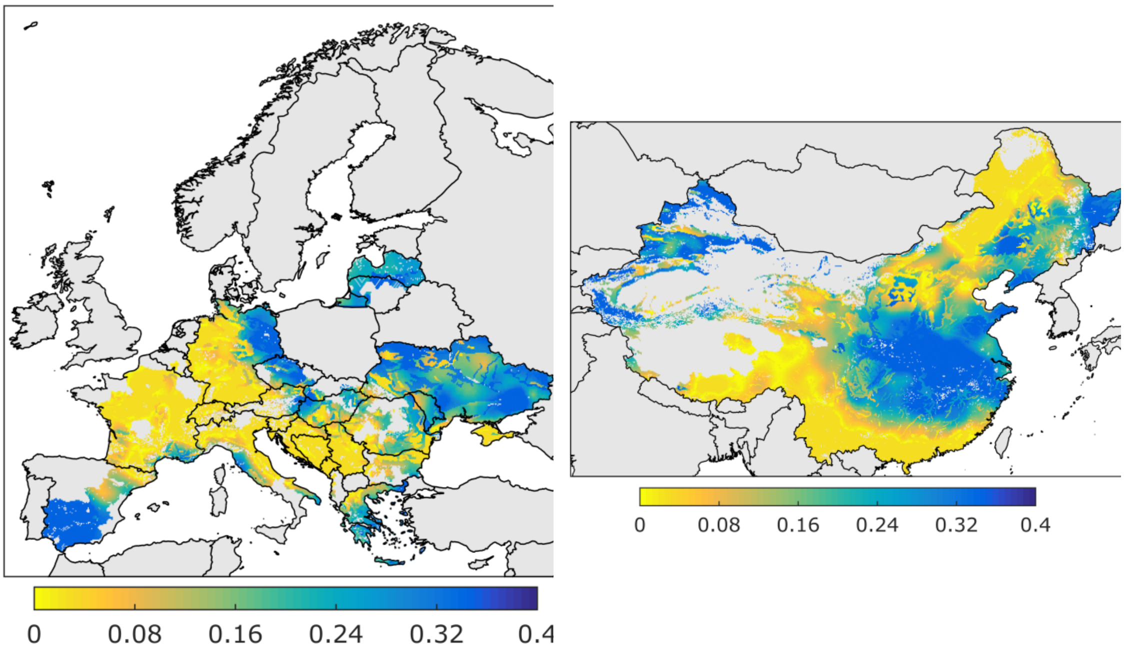


Figure 99. Standard deviation of the projected effect of tillage practice on mean increase in global soil biodiversity for soybean

6.2.4 Vegetables

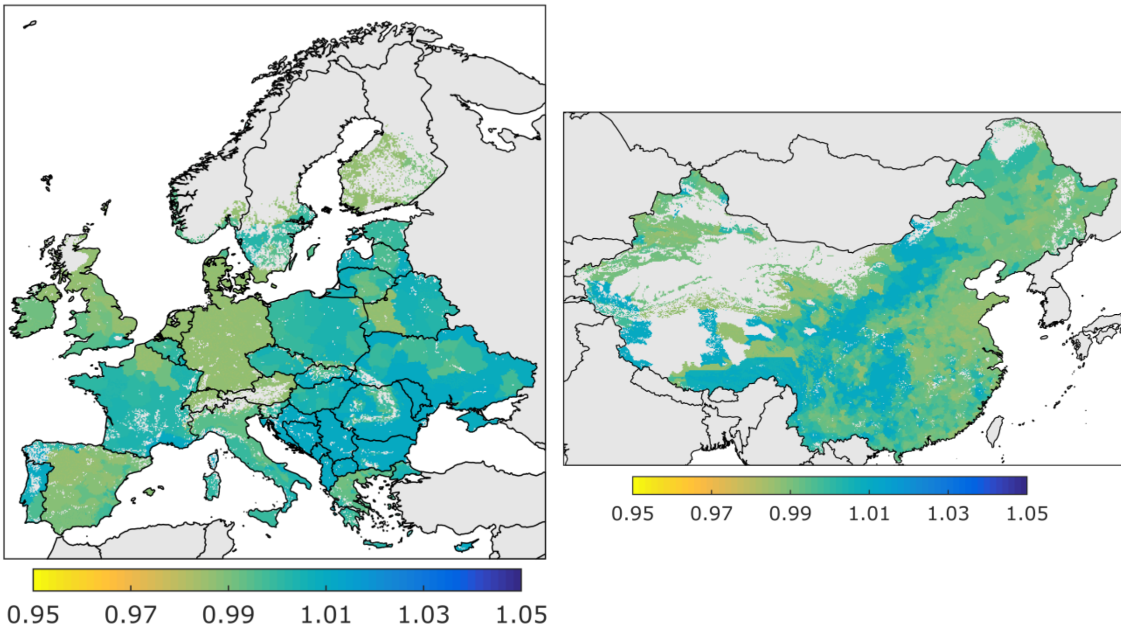


Figure 100. Projected effect of tillage practice on mean increase in crop yield for vegetables

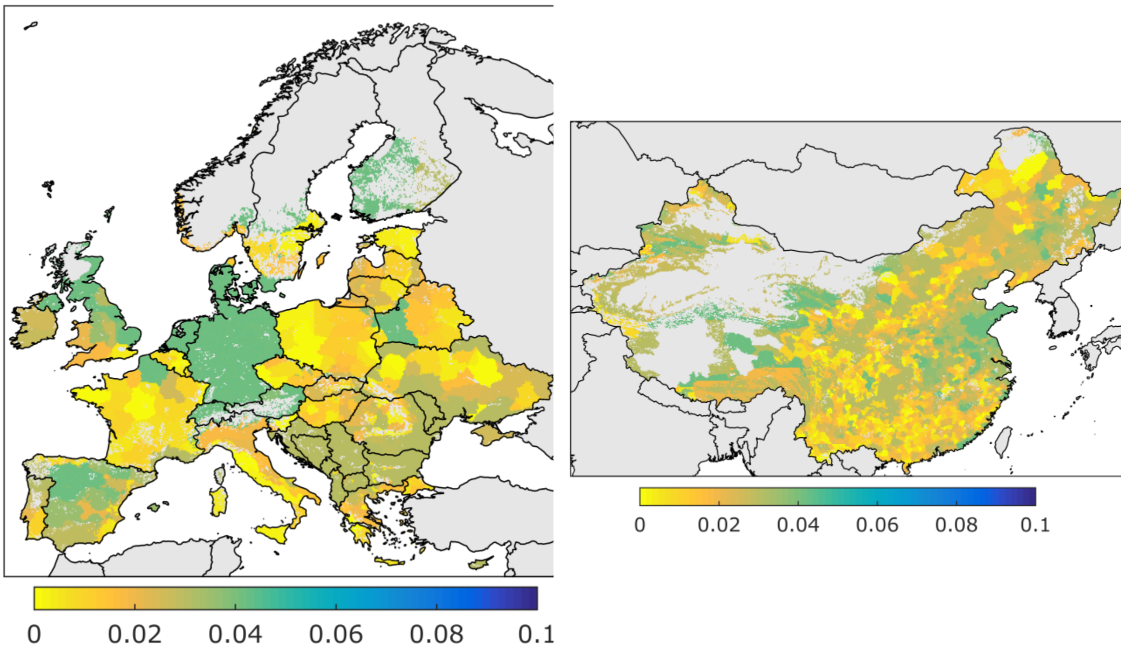


Figure 101. Standard deviation of the projected effect of tillage practice on mean increase in crop yield for vegetables

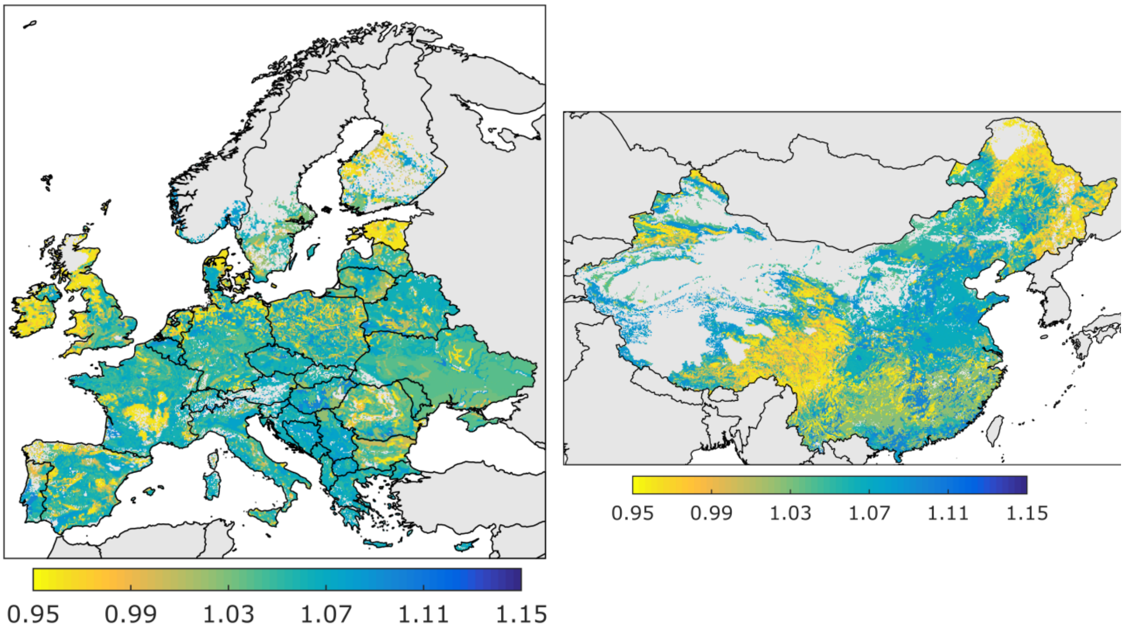


Figure 102. Projected effect of tillage practice on mean increase in soil organic matter for vegetables

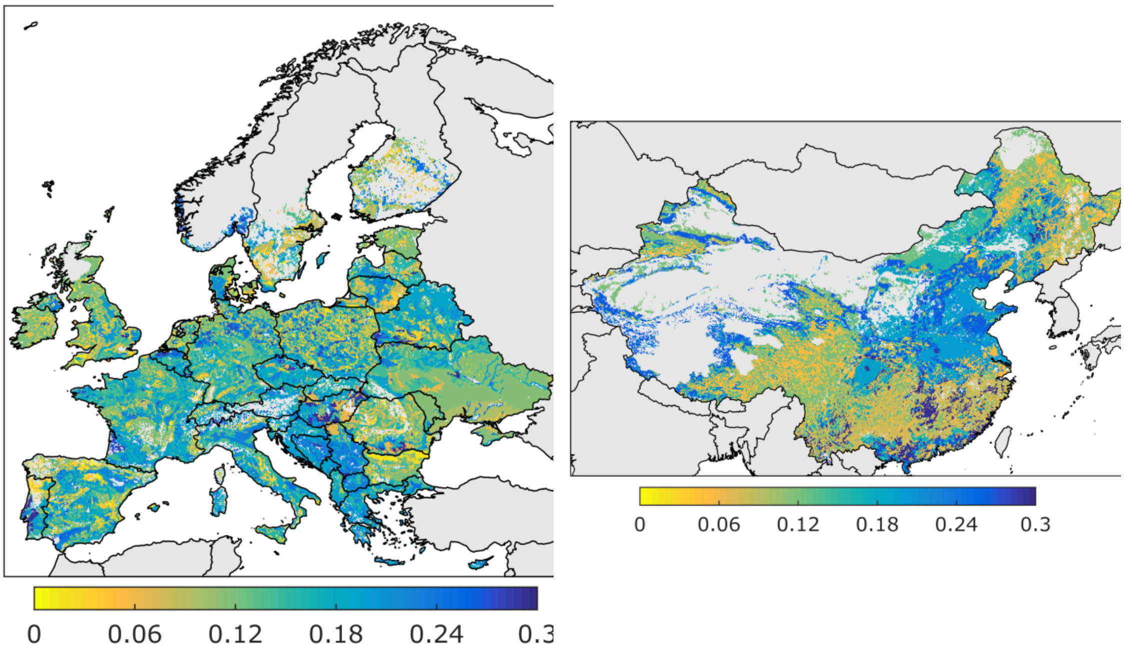


Figure 103. Standard deviation of the projected effect of tillage practice on mean increase in soil organic matter for vegetables

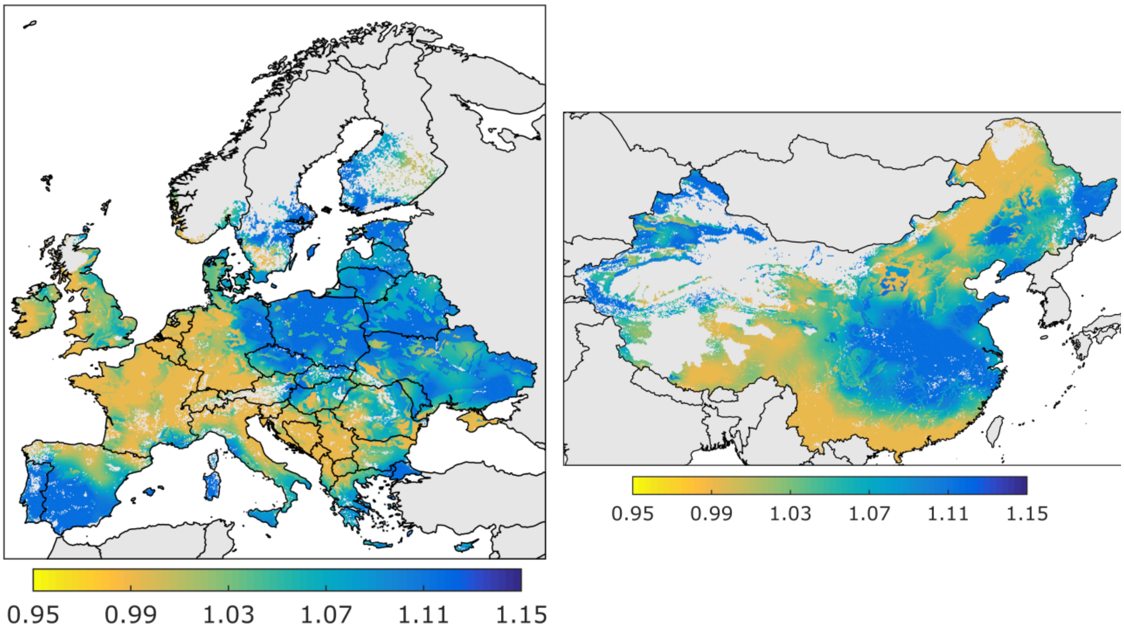


Figure 104. Projected effect of tillage practice on mean increase in global soil biodiversity for vegetables

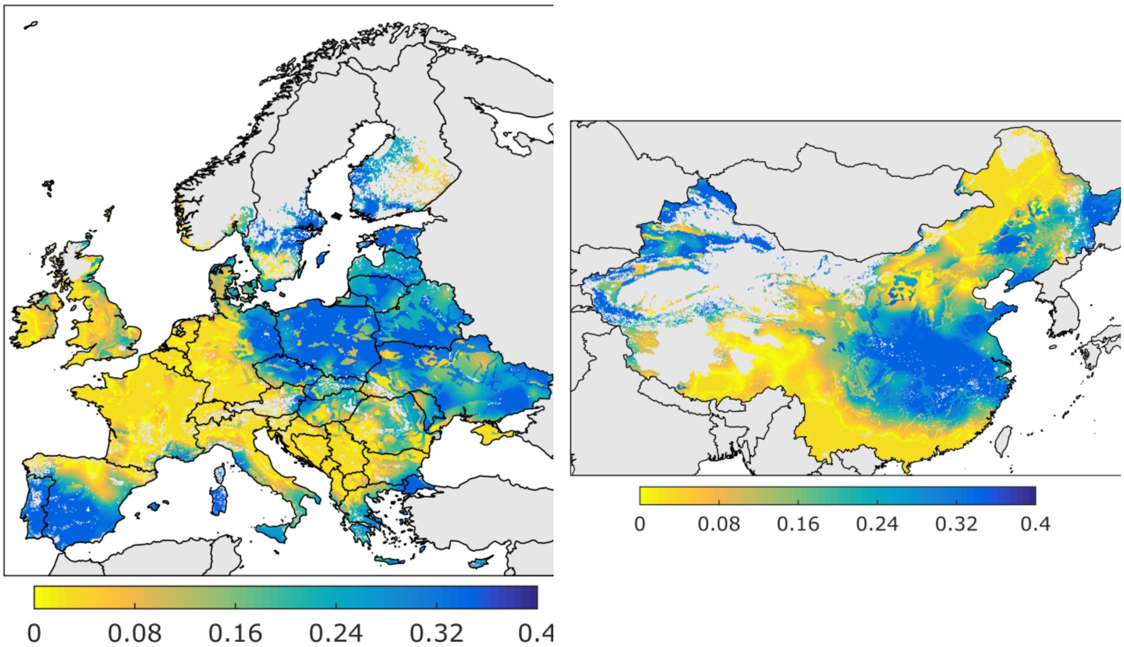


Figure 105. Standard deviation of the projected effect of tillage practice on mean increase in global soil biodiversity for vegetables

6.2.5 Pasture

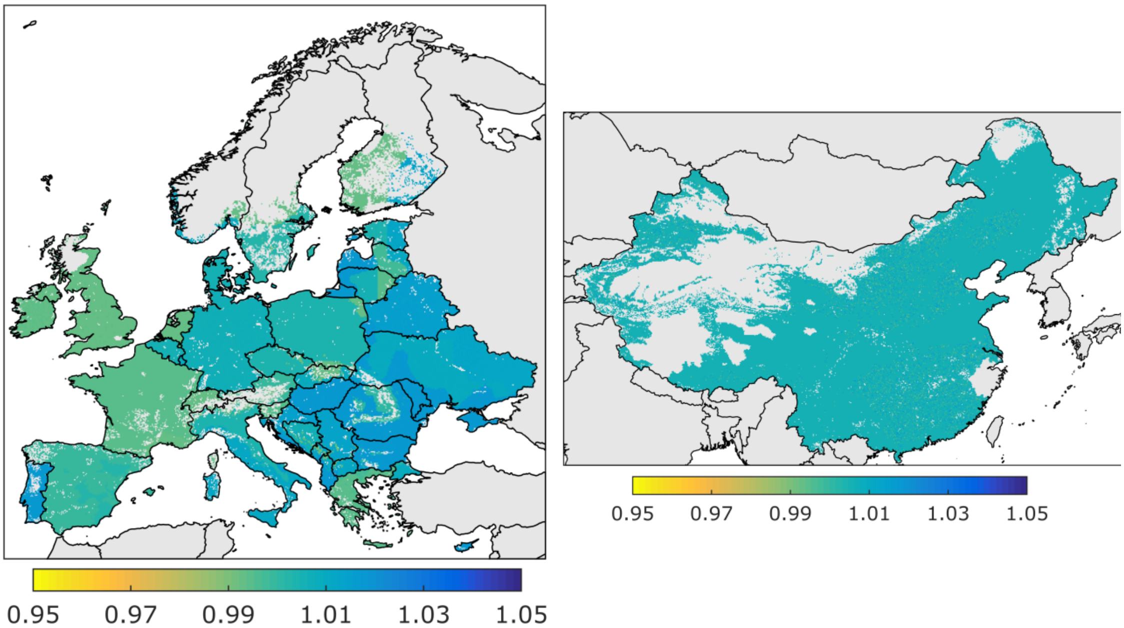


Figure 106. Projected effect of tillage practice on mean increase in crop yield for pasture

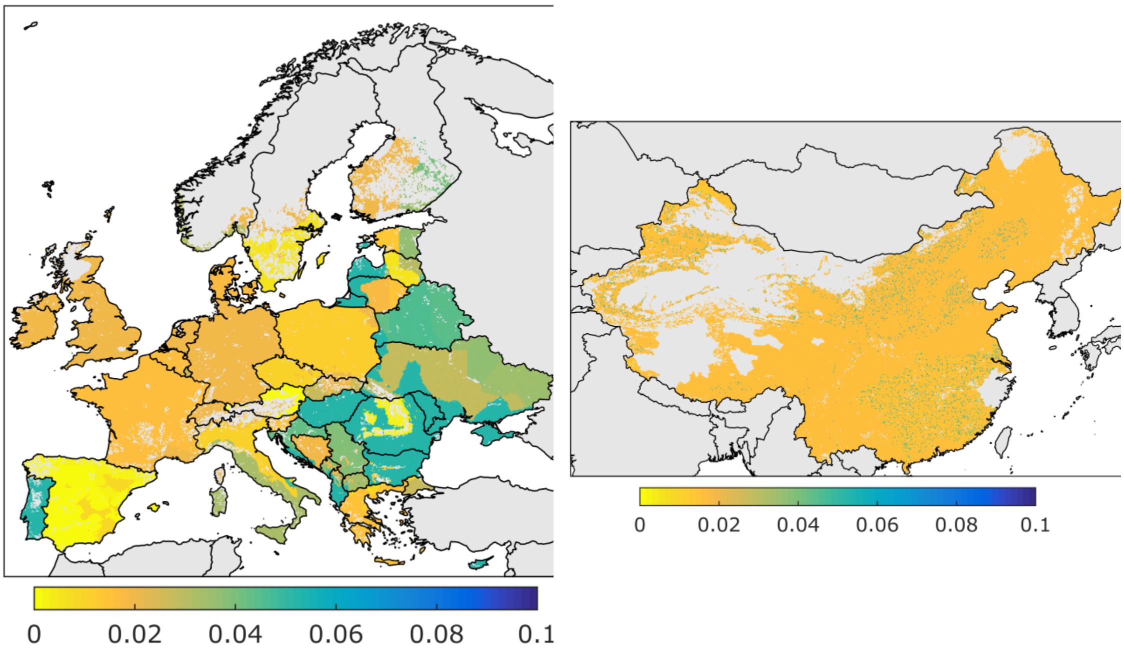


Figure 107. Standard deviation of the projected effect of tillage practice on mean increase in crop yield for pasture

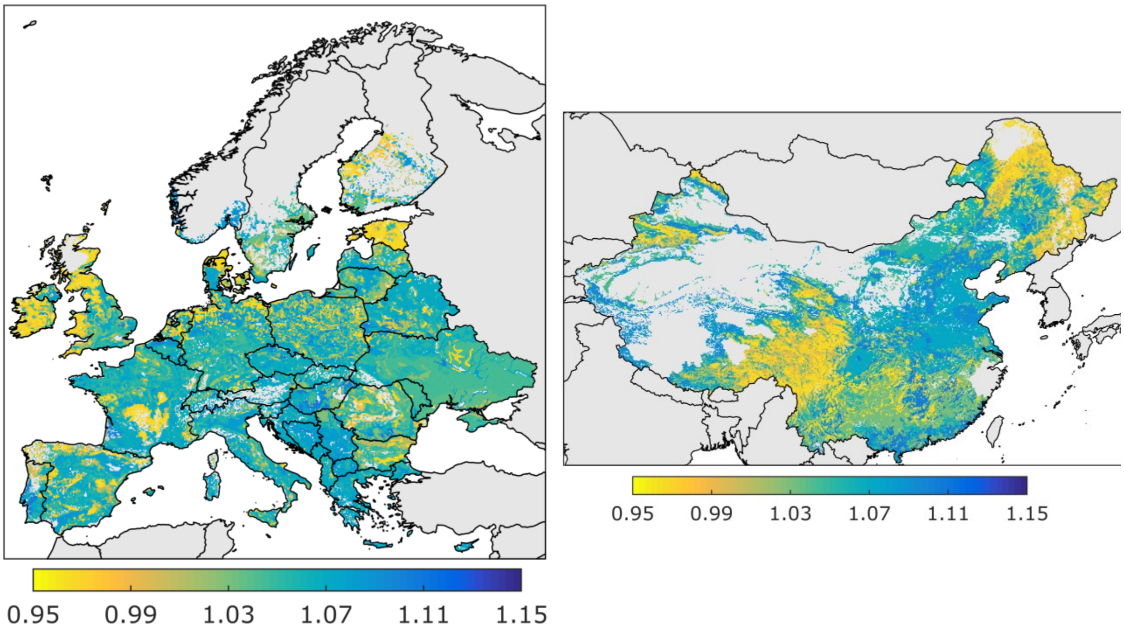


Figure 108. Projected effect of tillage practice on mean increase in soil organic matter for pasture

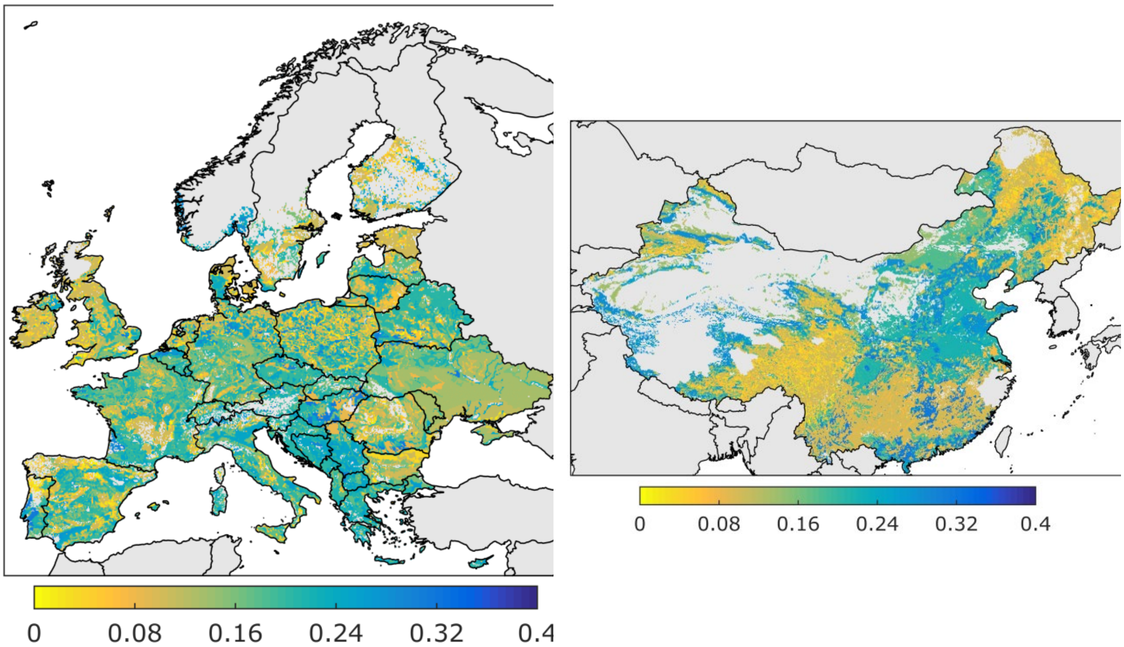


Figure 109. Standard deviation of the projected effect of tillage practice on mean increase in soil organic matter for pasture

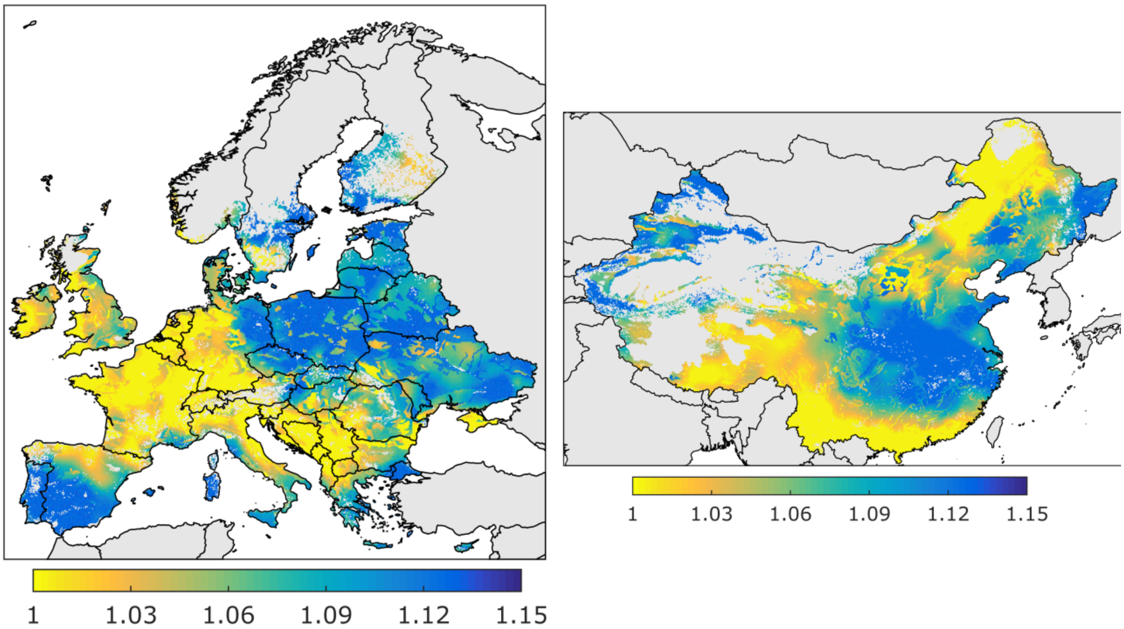


Figure 110. Projected effect of tillage practice on mean increase in global soil biodiversity for pasture

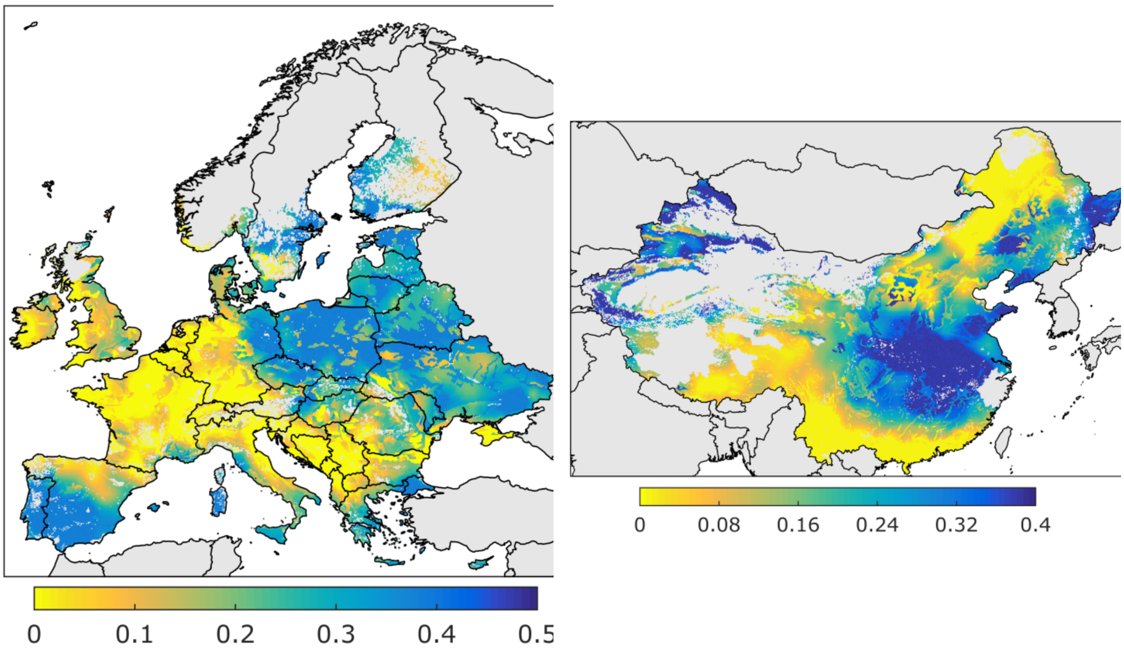


Figure 111. Standard deviation of the projected effect of tillage practice on mean increase in global soil biodiversity for pasture

6.2.6 Permanent crops

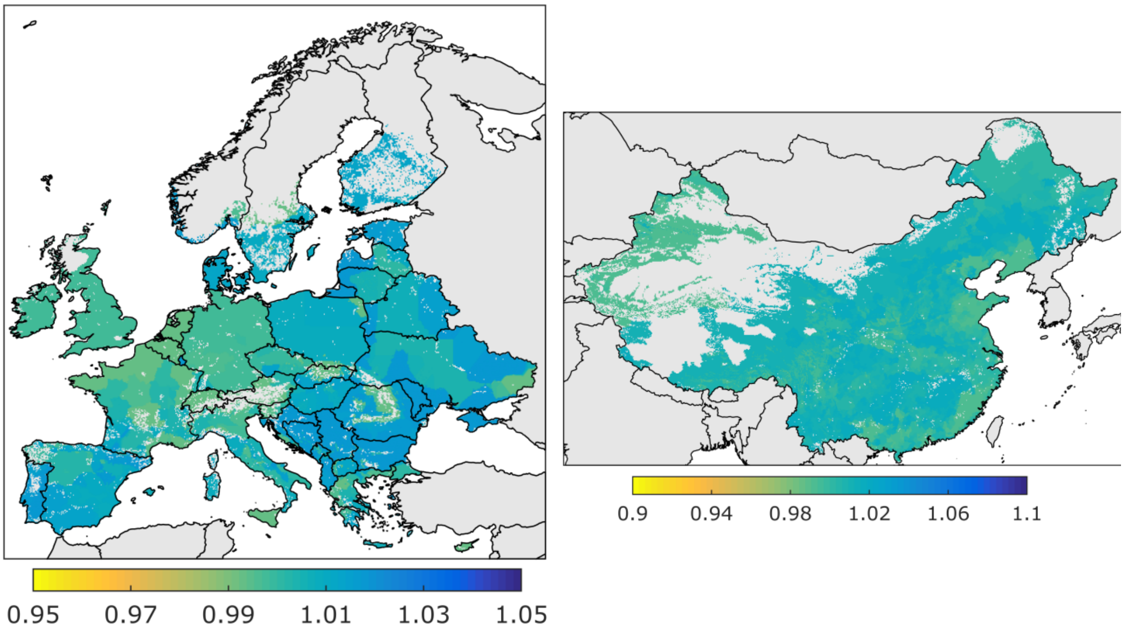


Figure 112. Projected effect of tillage practice on mean increase in crop yield for permanent crops

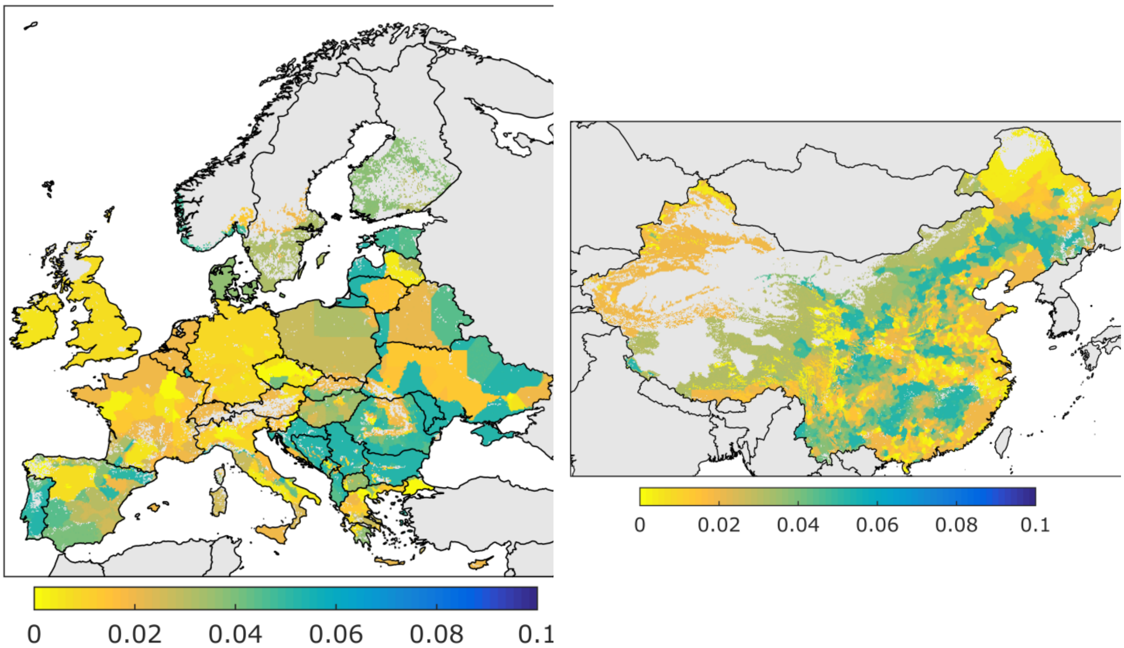


Figure 113. Standard deviation of the projected effect of tillage practice on mean increase in crop yield for permanent crops

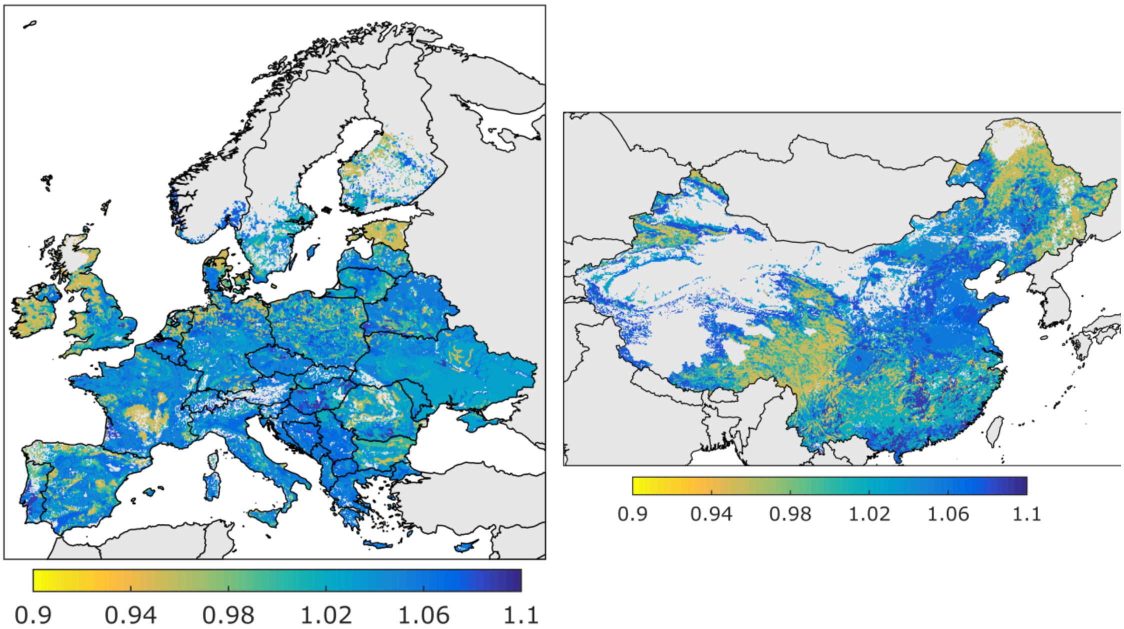


Figure 114. Projected effect of tillage practice on mean increase in soil organic matter for permanent crops

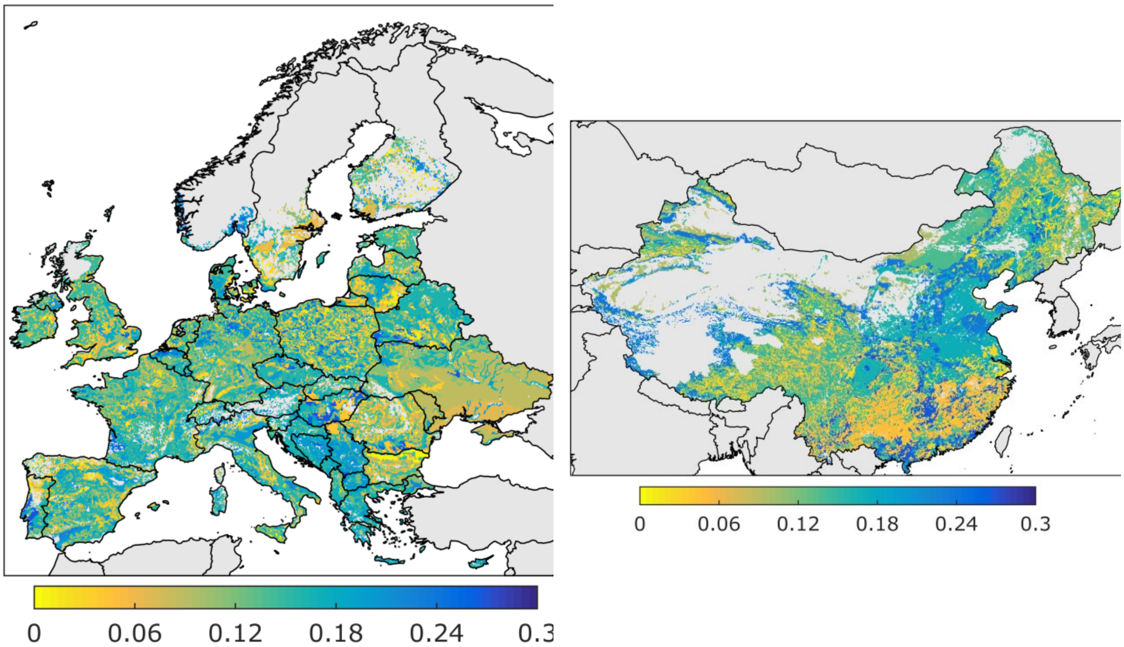


Figure 115. Standard deviation of the projected effect of tillage practice on mean increase in soil organic matter for permanent crops

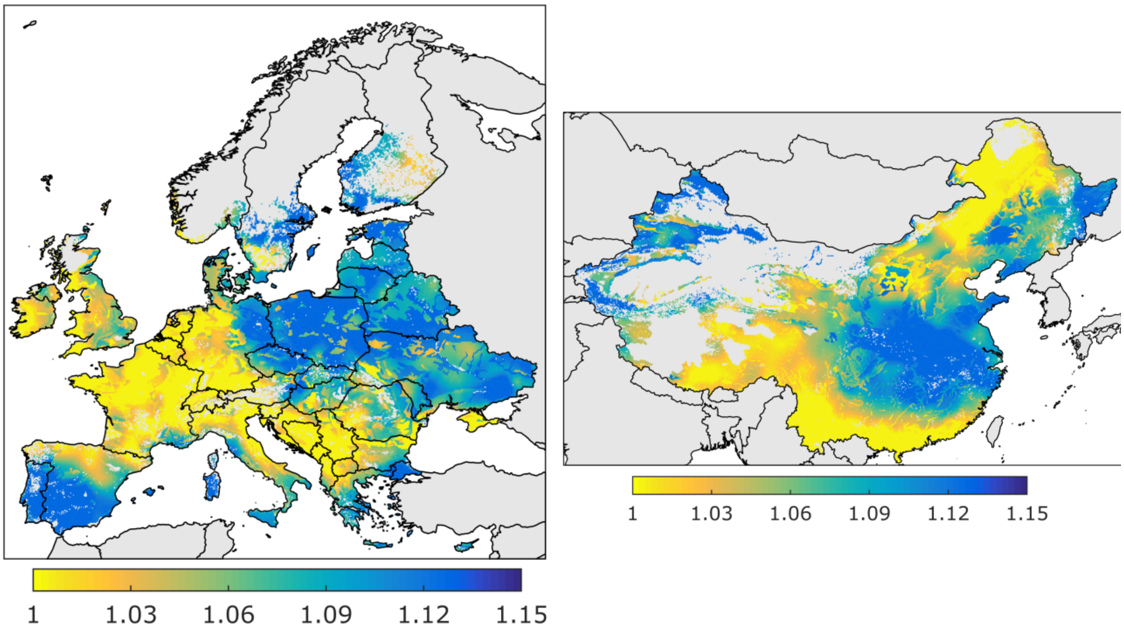


Figure 116. Projected effect of tillage practice on mean increase in global soil biodiversity for permanent crops

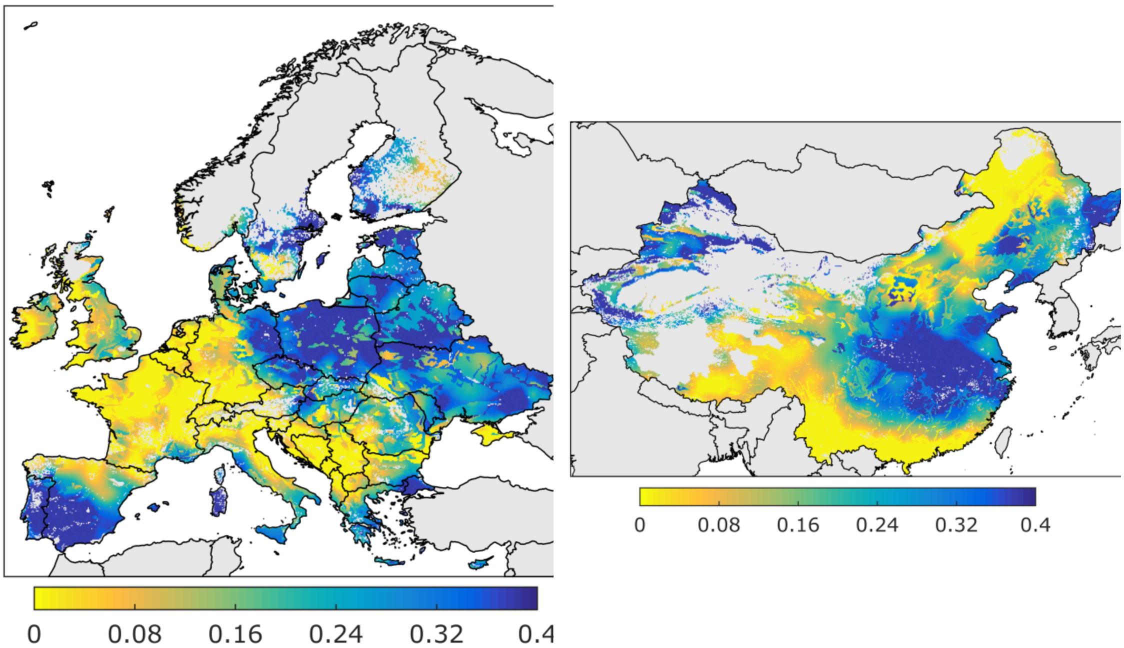


Figure 117. Standard deviation of the projected effect of tillage practice on mean increase in global soil biodiversity for permanent crops

6.3 Projection of crop rotation

6.3.1 Cereal

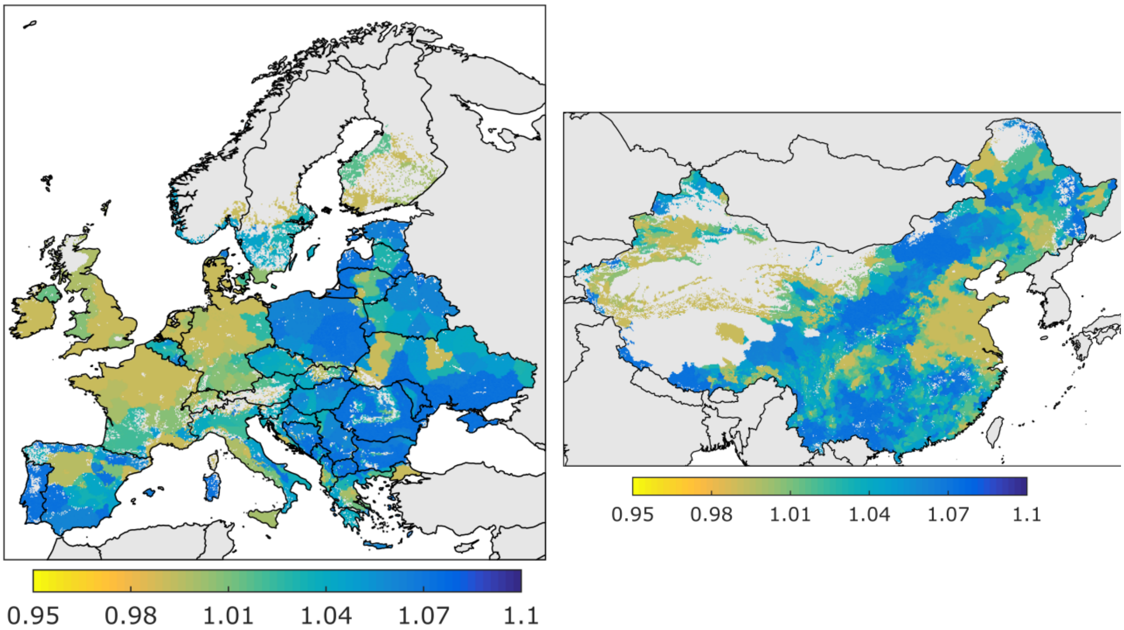


Figure 118. Projected effect of crop rotation on mean increase in crop yield for cereal

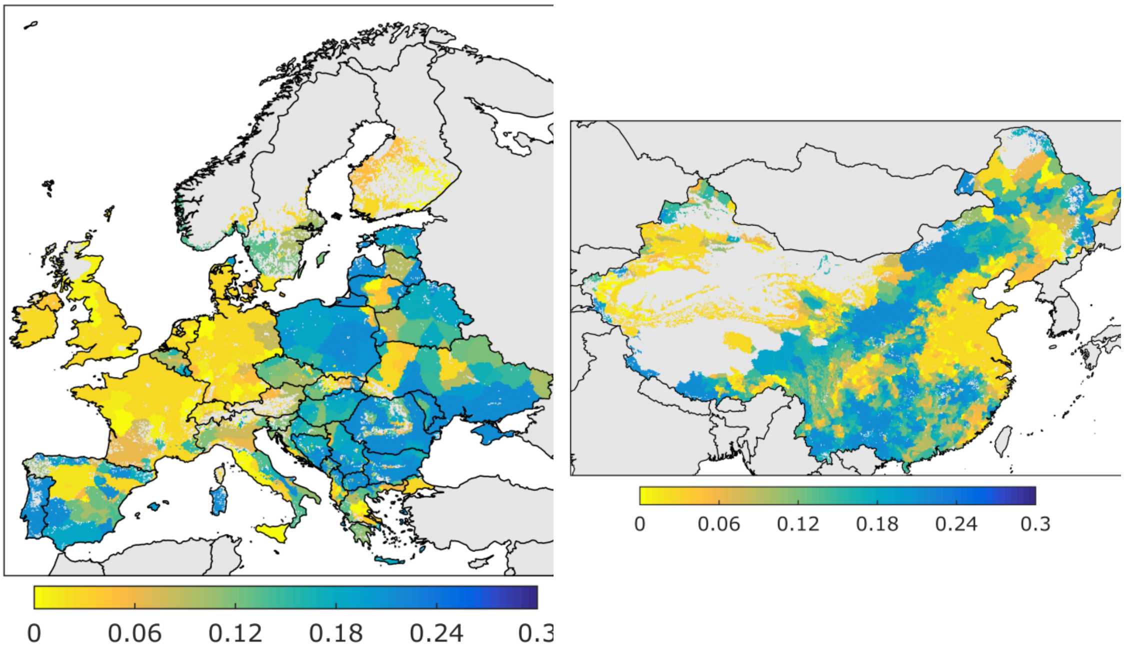


Figure 119. Standard deviation of the projected effect of crop rotation on mean increase in crop yield for cereal

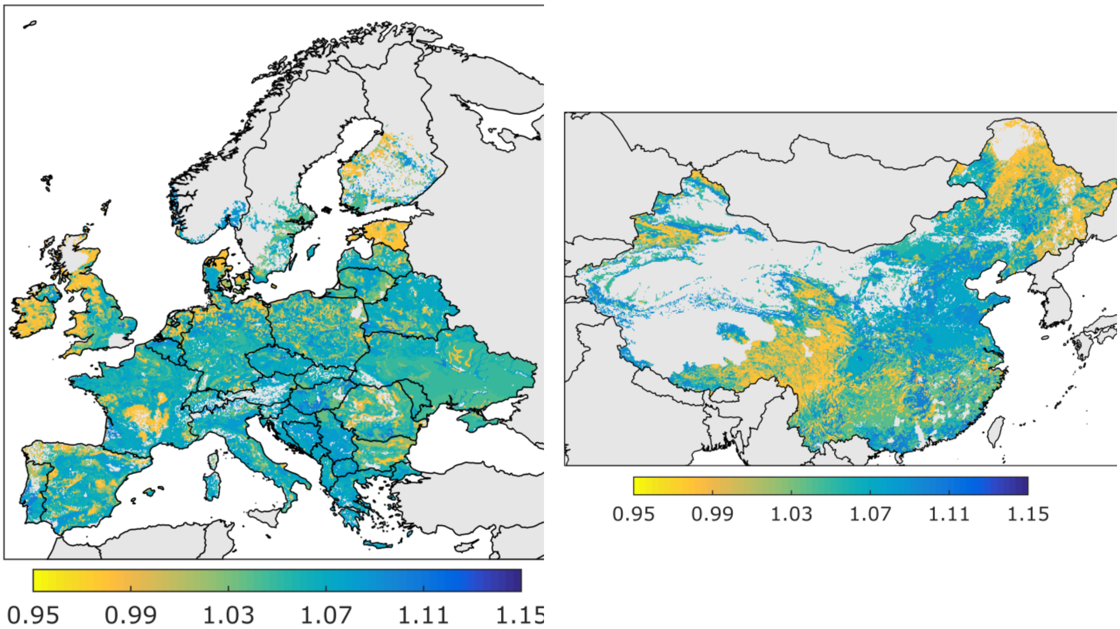


Figure 120. Projected effect of crop rotation on mean increase in soil organic matter for cereal

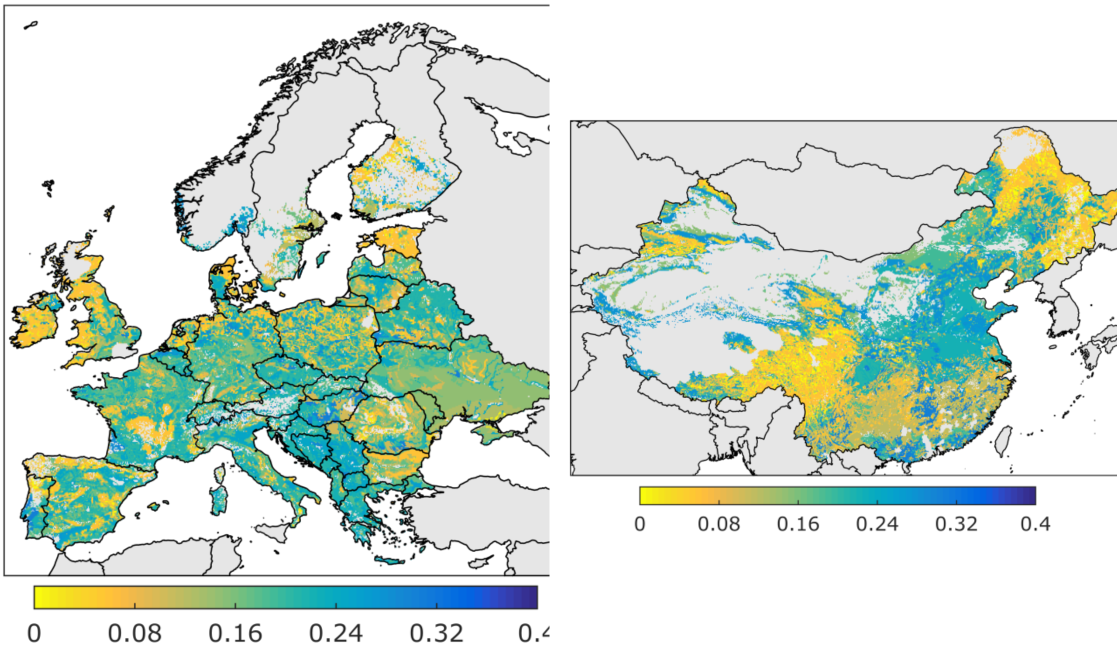


Figure 121. Standard deviation of the projected effect of crop rotation on mean increase in soil organic matter for cereal

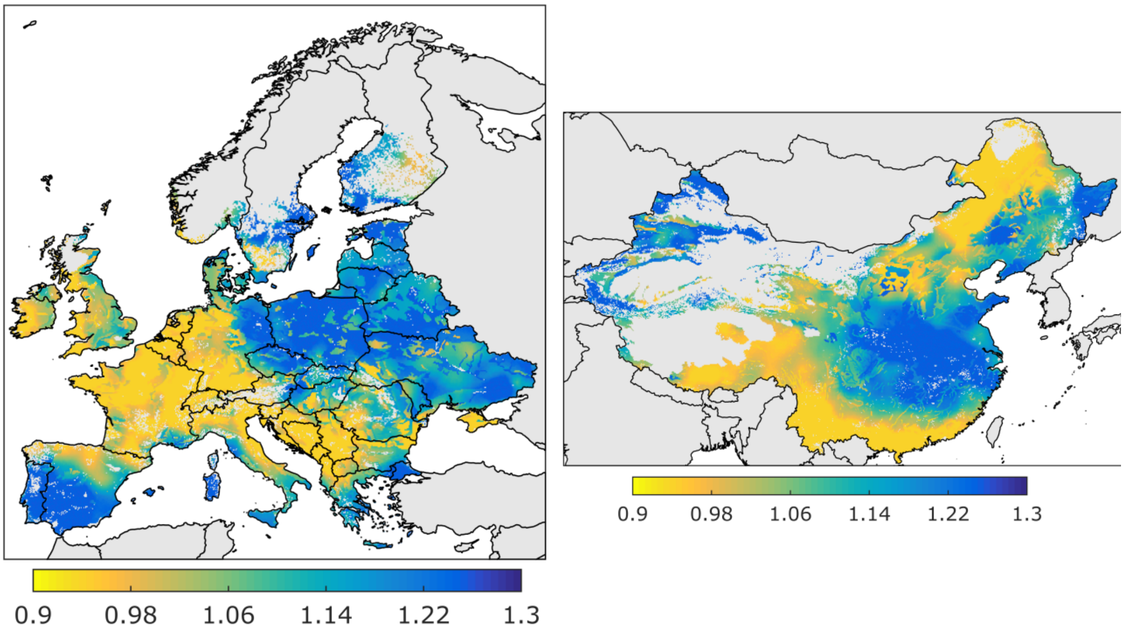


Figure 122. Projected effect of crop rotation on mean increase in global soil biodiversity for cereal

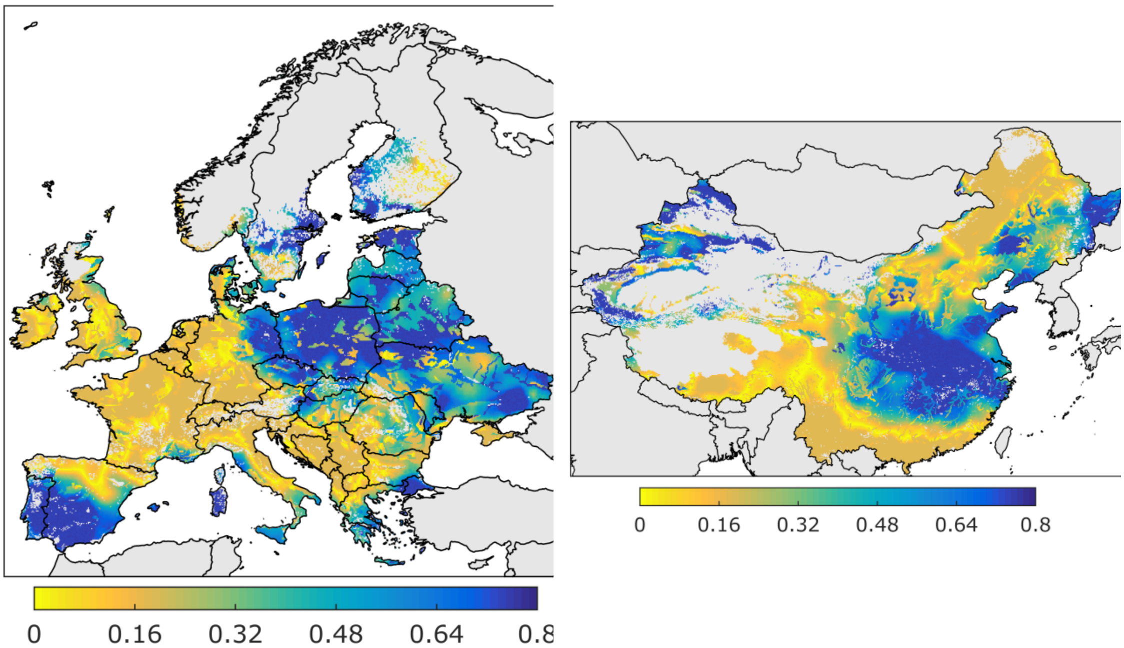


Figure 123. Standard deviation of the projected effect of crop rotation on mean increase in global soil biodiversity for cereal

6.3.2 Maize

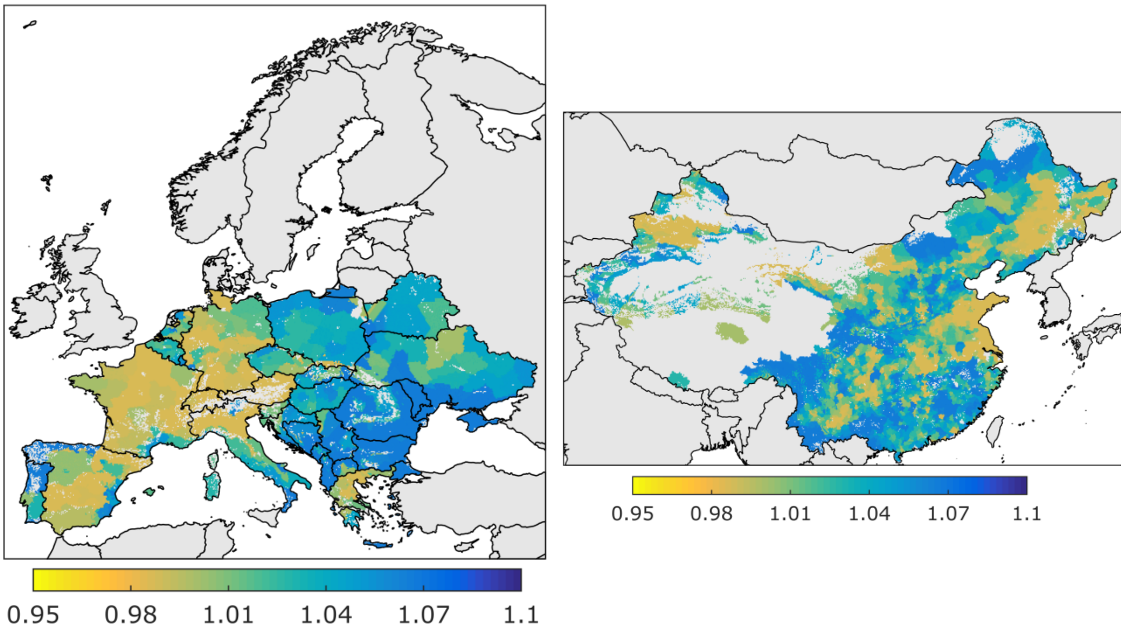


Figure 124. Projected effect of crop rotation on mean increase in crop yield for maize

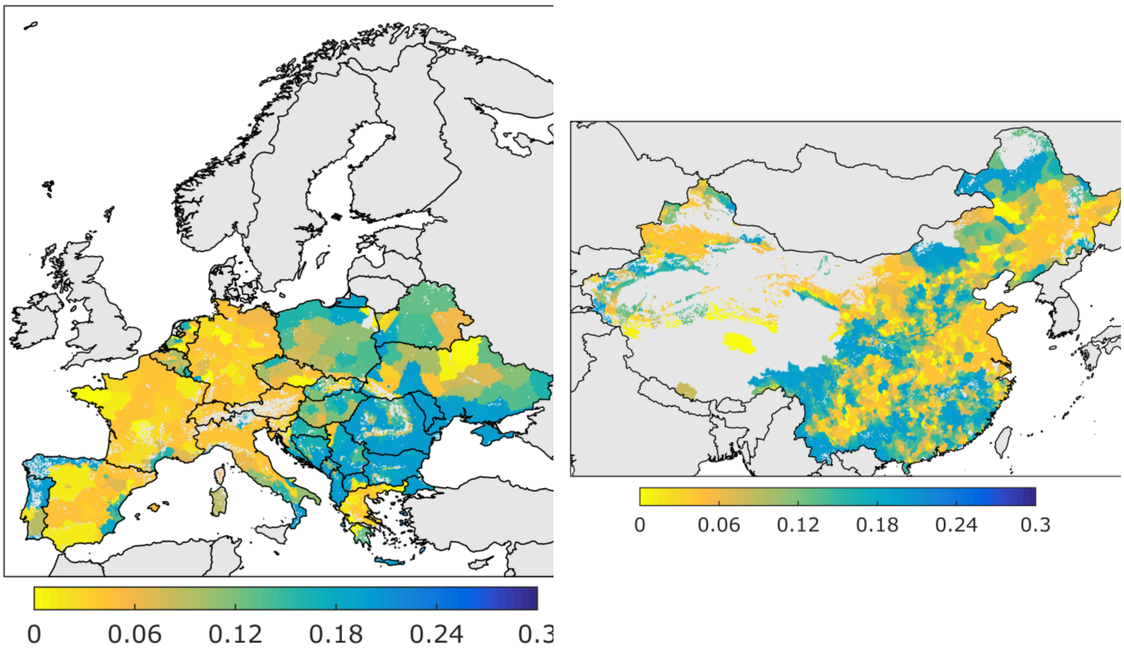


Figure 125. Standard deviation of the projected effect of crop rotation on mean increase in crop yield for maize

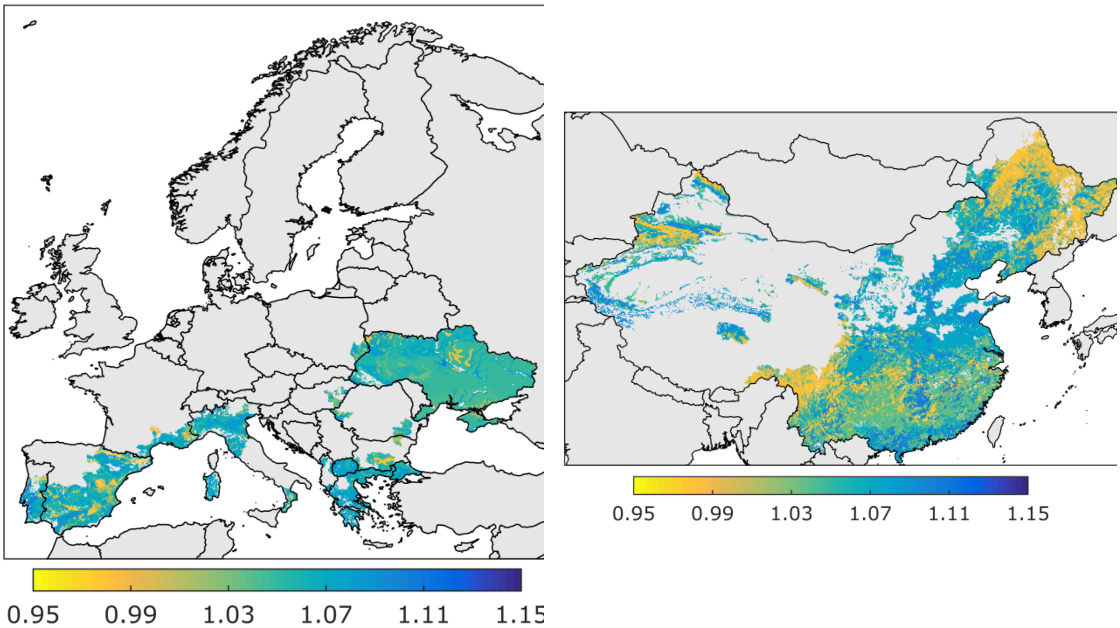


Figure 126. Projected effect of crop rotation on mean increase in soil organic matter for maize

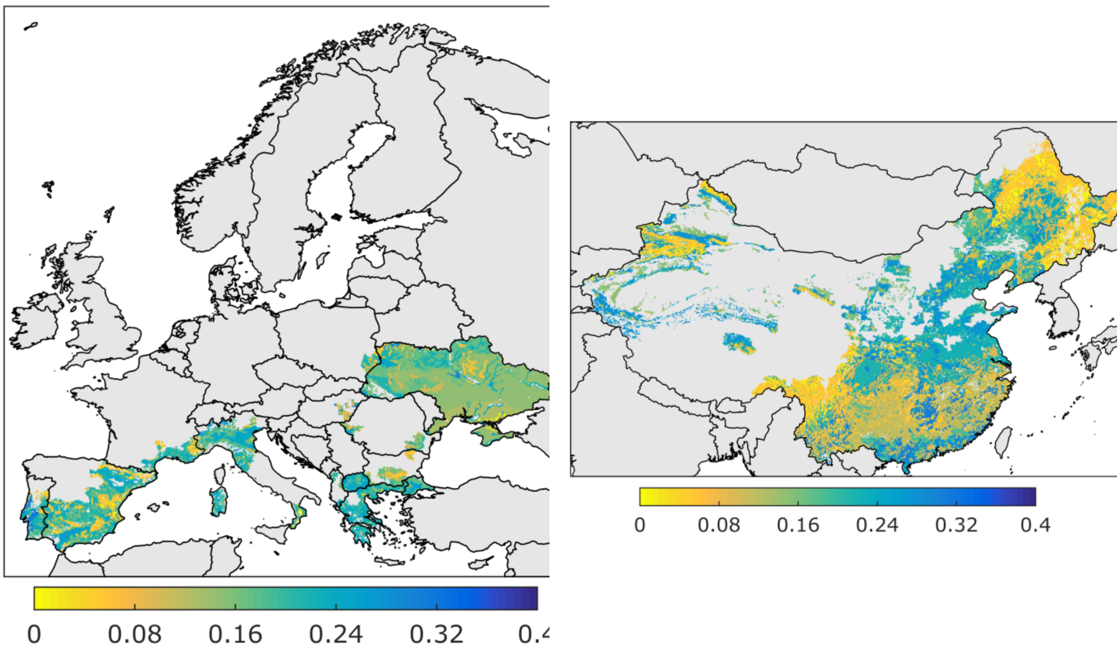


Figure 127. Standard deviation of the projected effect of crop rotation on mean increase in soil organic matter for maize

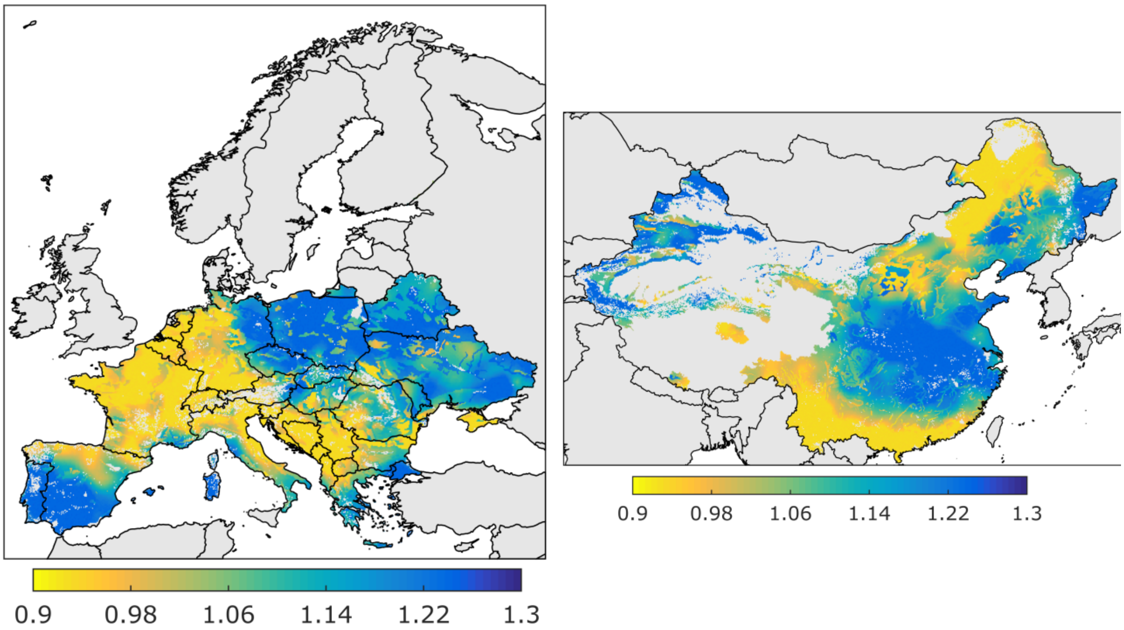


Figure 128. Projected effect of crop rotation on mean increase in global soil biodiversity for maize

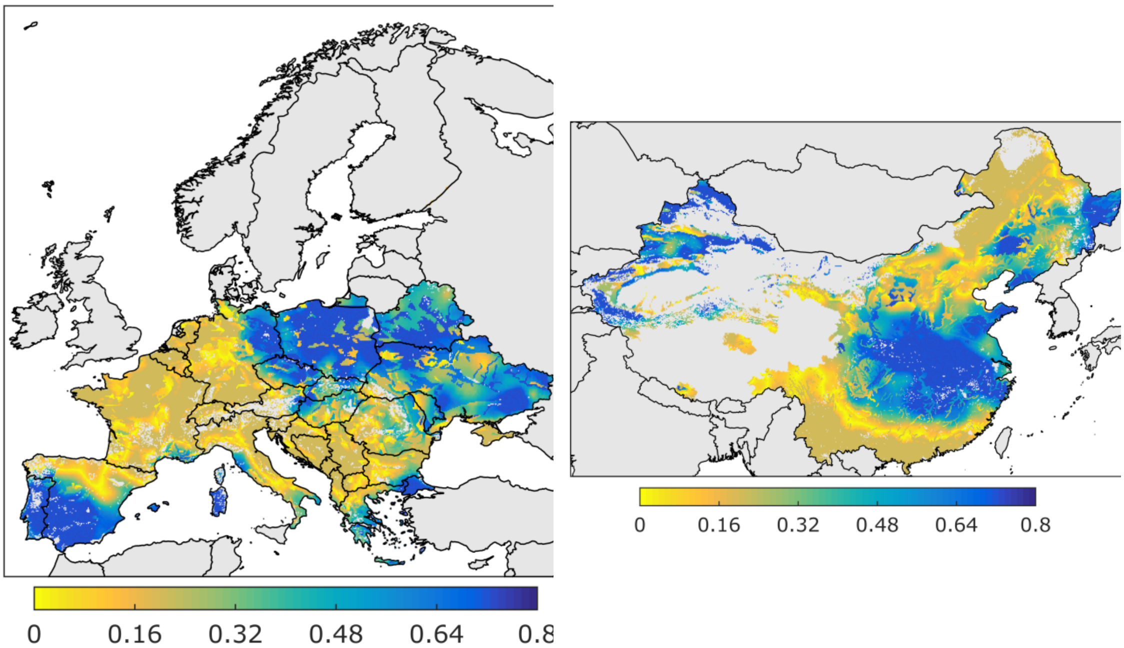


Figure 129. Standard deviation of the projected effect of crop rotation on mean increase in global soil biodiversity for maize

6.3.3 Soybean

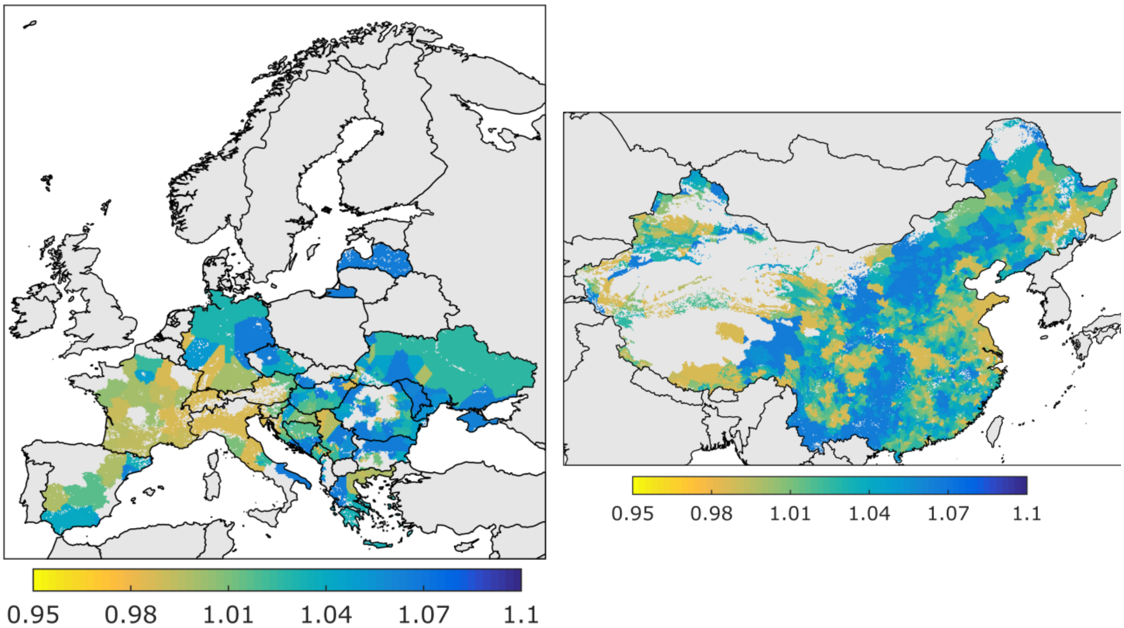


Figure 130. Projected effect of crop rotation on mean increase in crop yield for soybean

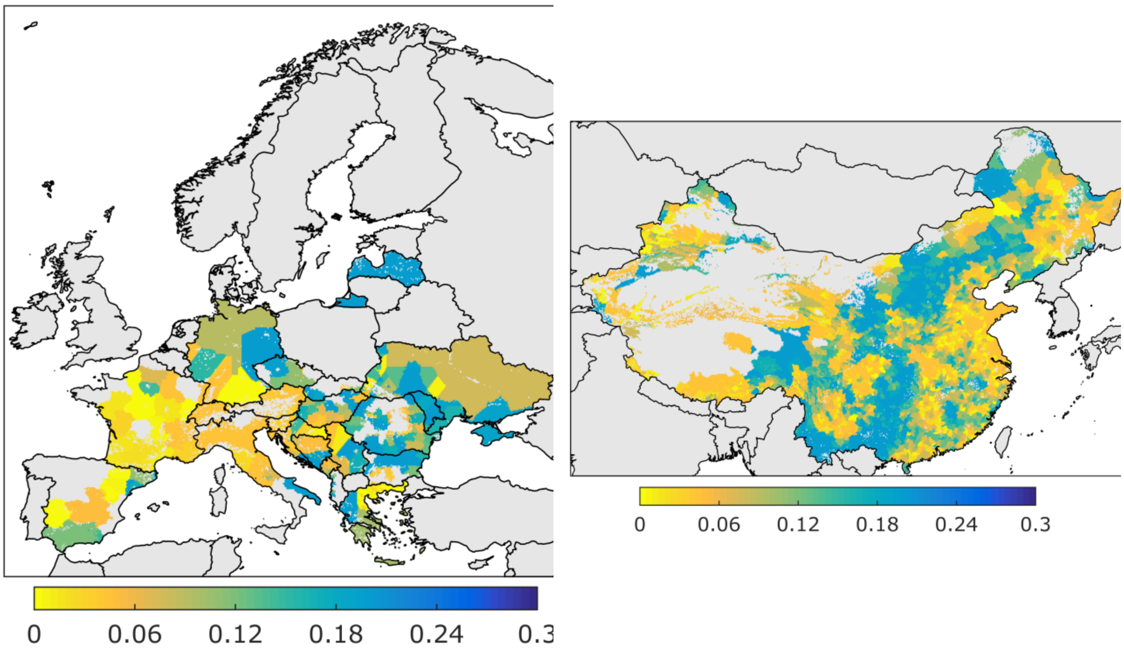


Figure 131. Standard deviation of the projected effect of crop rotation on mean increase in crop yield for soybean

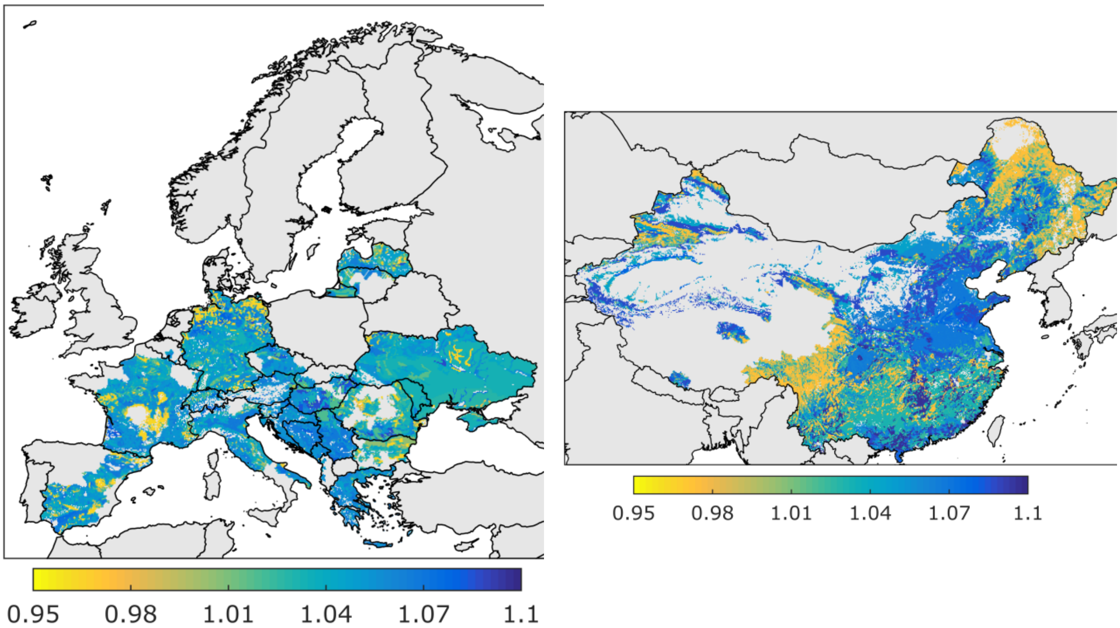


Figure 132. Projected effect of crop rotation on mean increase in soil organic matter for soybean

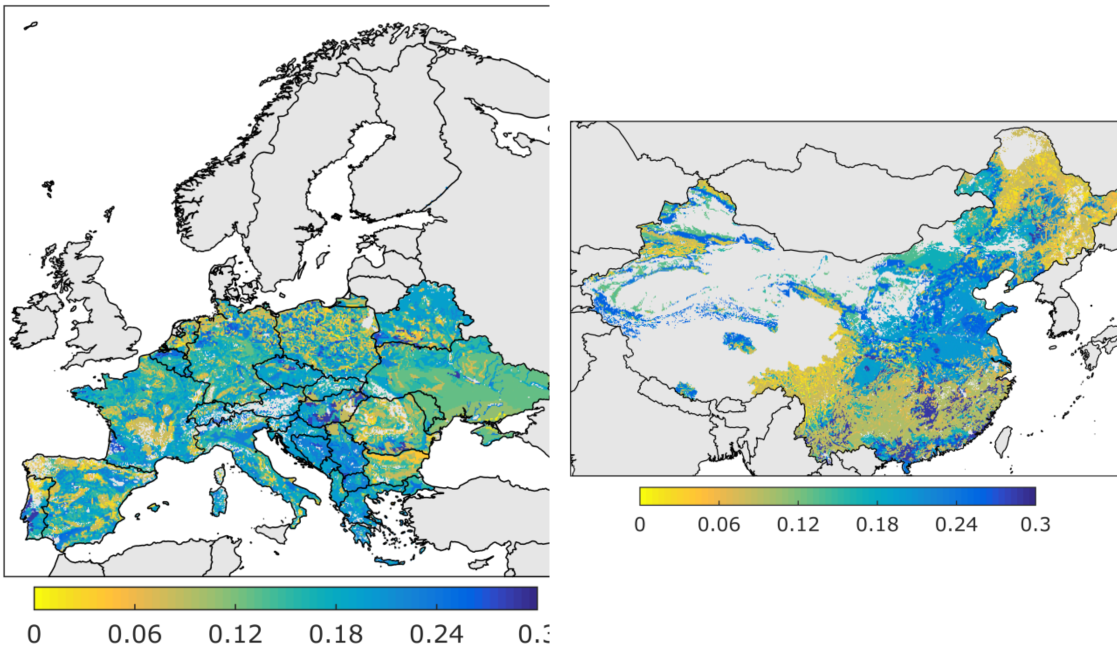


Figure 133. Standard deviation of the projected effect of crop rotation on mean increase in soil organic matter for soybean

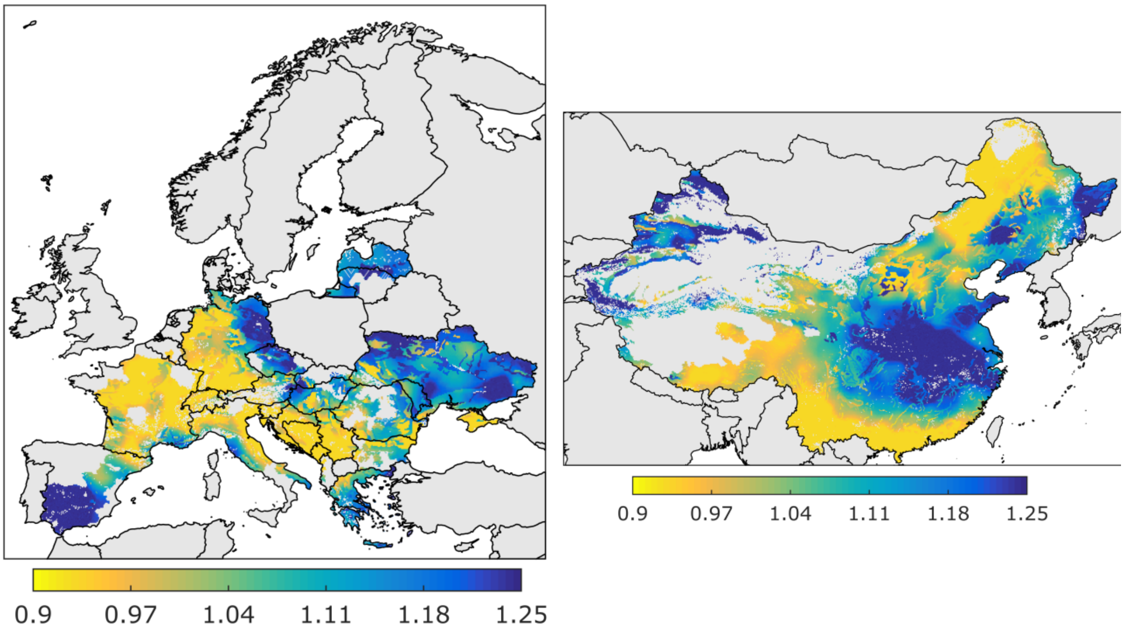


Figure 134. Projected effect of crop rotation on mean increase in global soil biodiversity for soybean

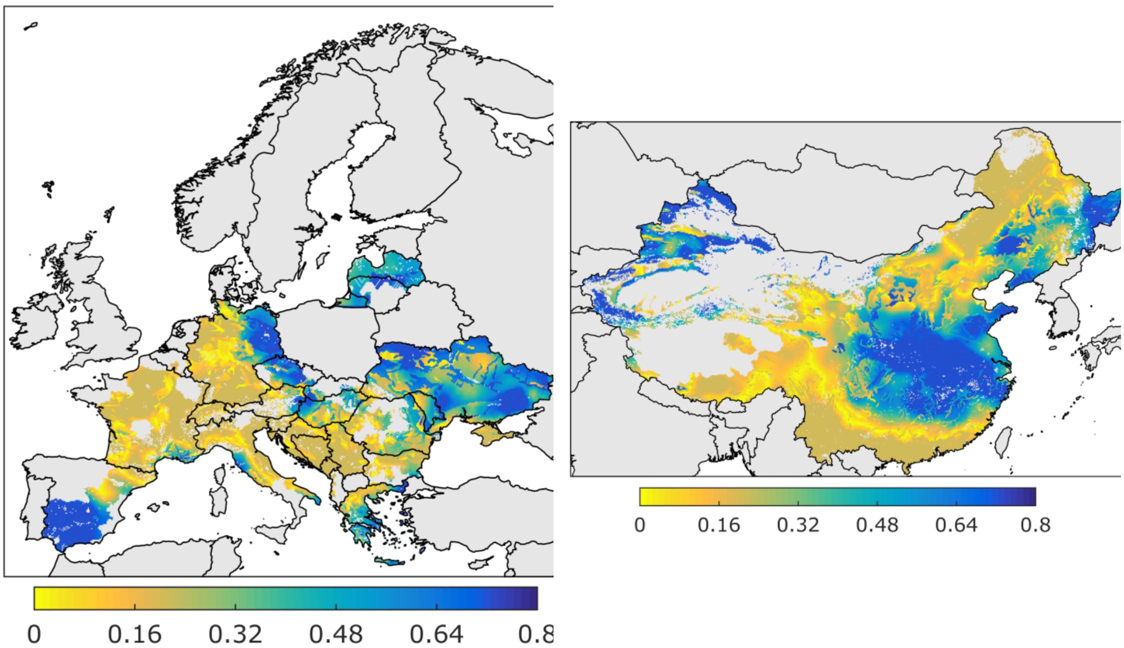


Figure 135. Standard deviation of the projected effect of crop rotation on mean increase in global soil biodiversity for soybean

6.3.4 Vegetables

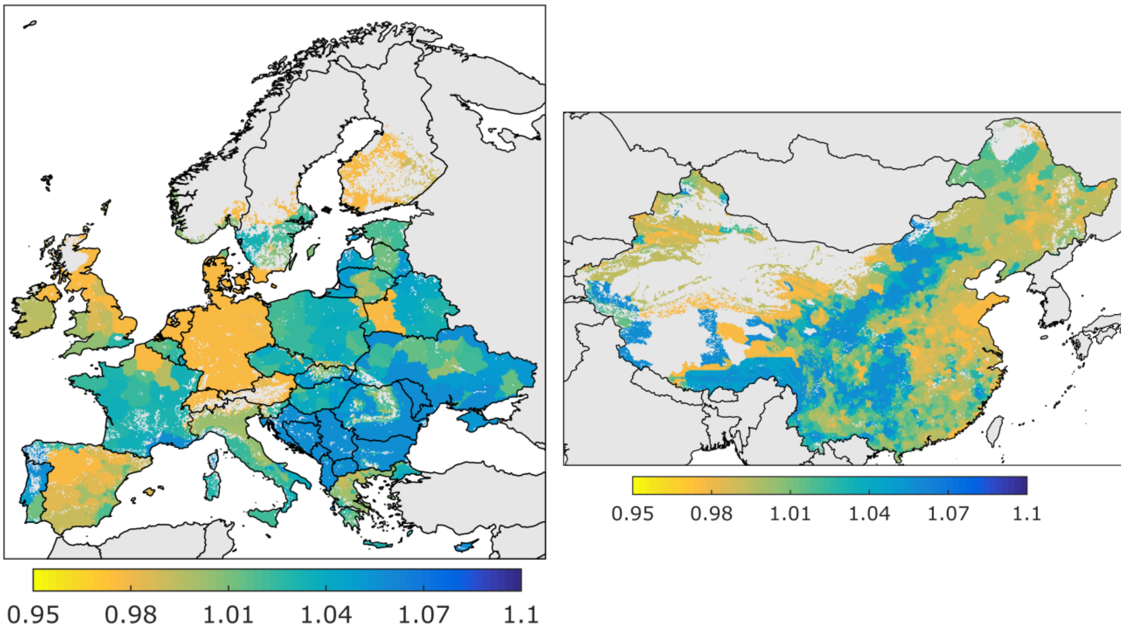


Figure 136. Projected effect of crop rotation on mean increase in crop yield for vegetables

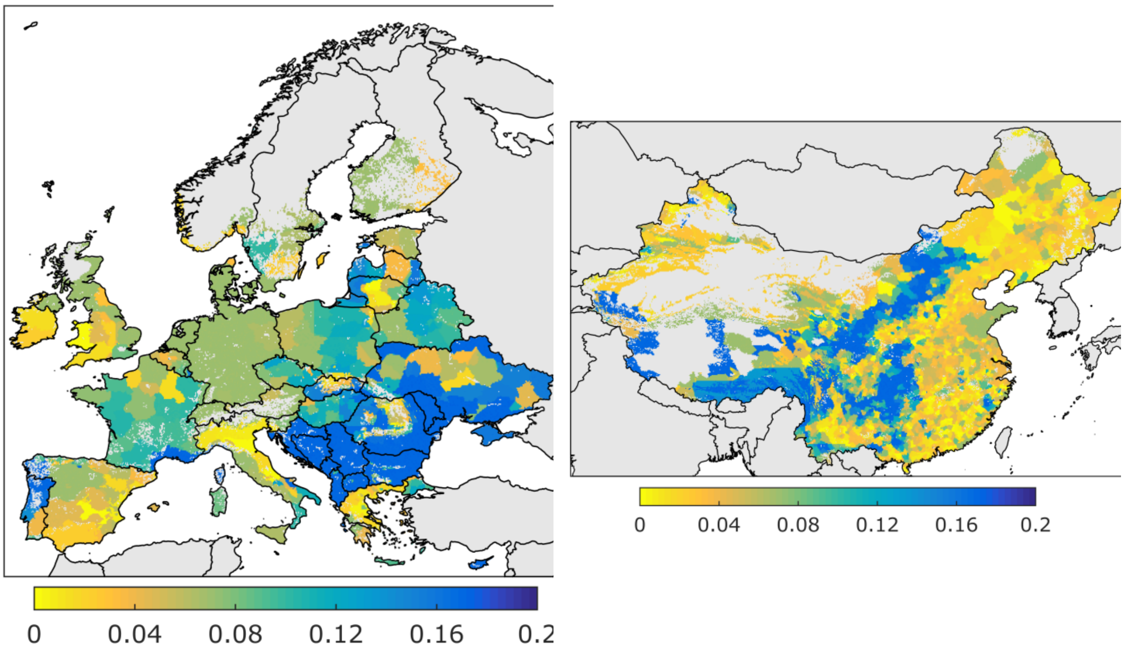


Figure 137. Standard deviation of the projected effect of crop rotation on mean increase in crop yield for vegetables

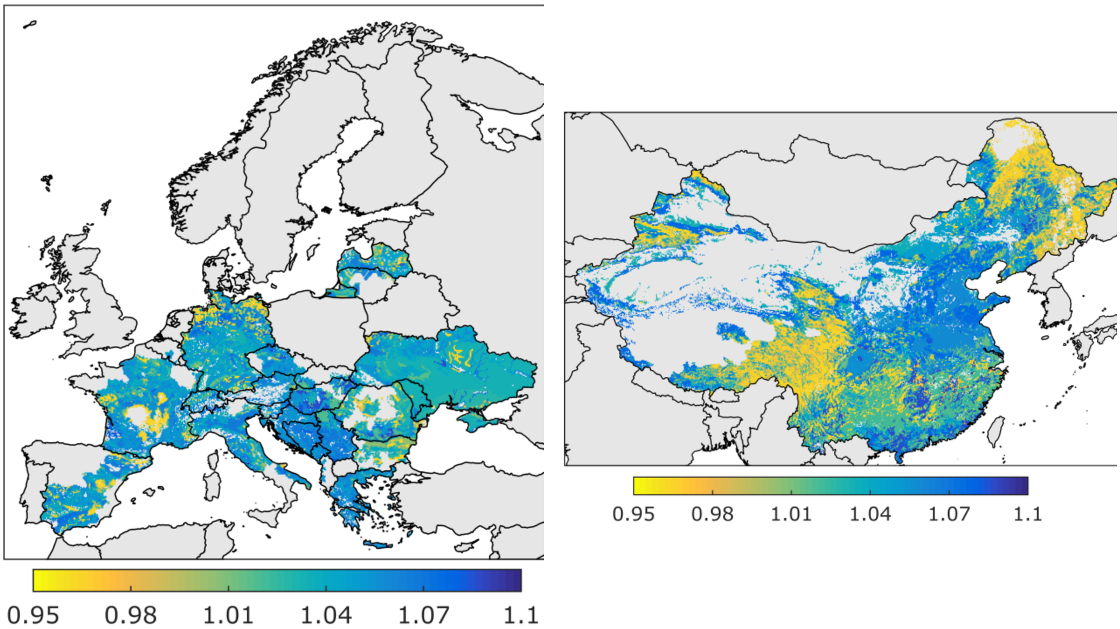


Figure 138. Projected effect of crop rotation on mean increase in soil organic matter for vegetables

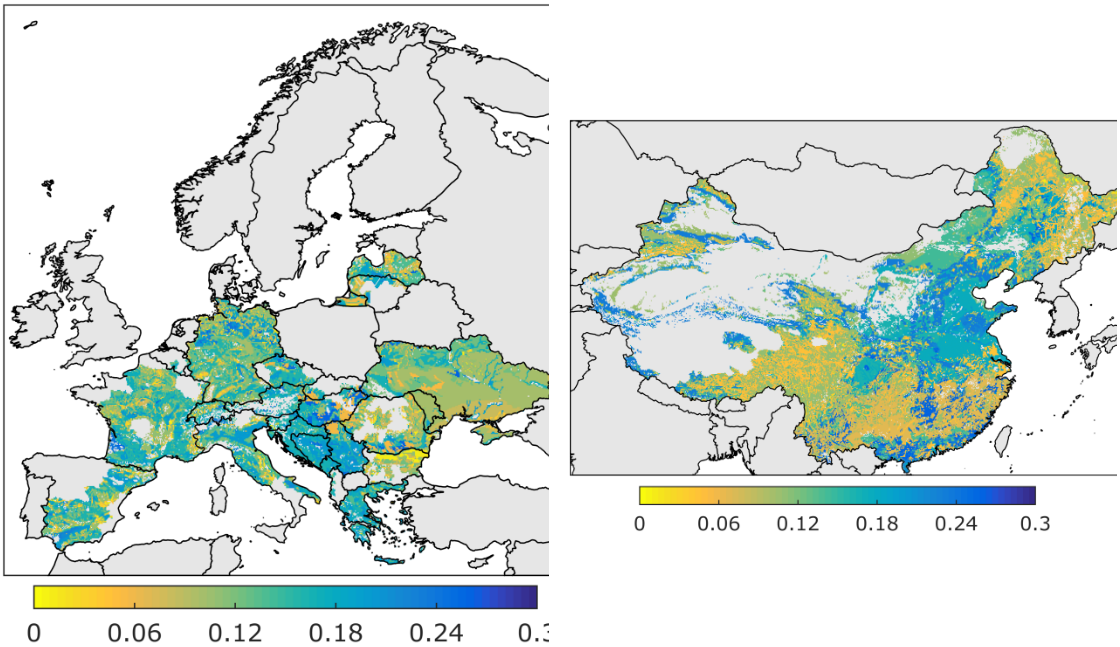


Figure 139. Standard deviation of the projected effect of crop rotation on mean increase in soil organic matter for vegetables

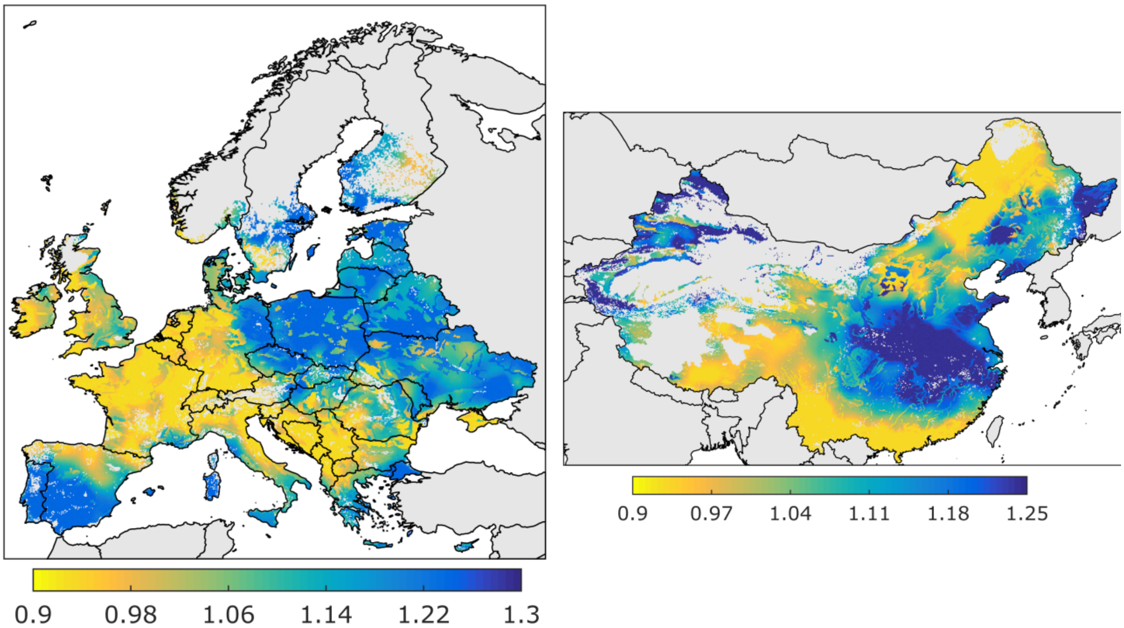


Figure 140. Projected effect of crop rotation on mean increase in global soil biodiversity for vegetables

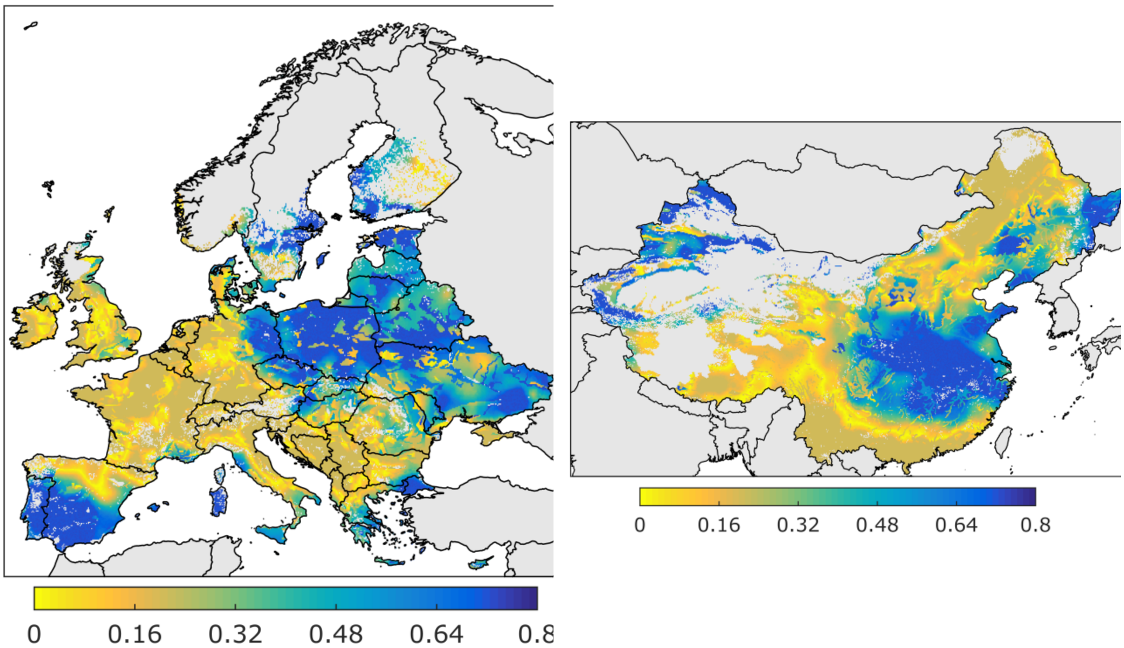


Figure 141. Standard deviation of the projected effect of crop rotation on mean increase in global soil biodiversity for vegetables

6.4 Projection of organic farming

6.4.1 Cereal

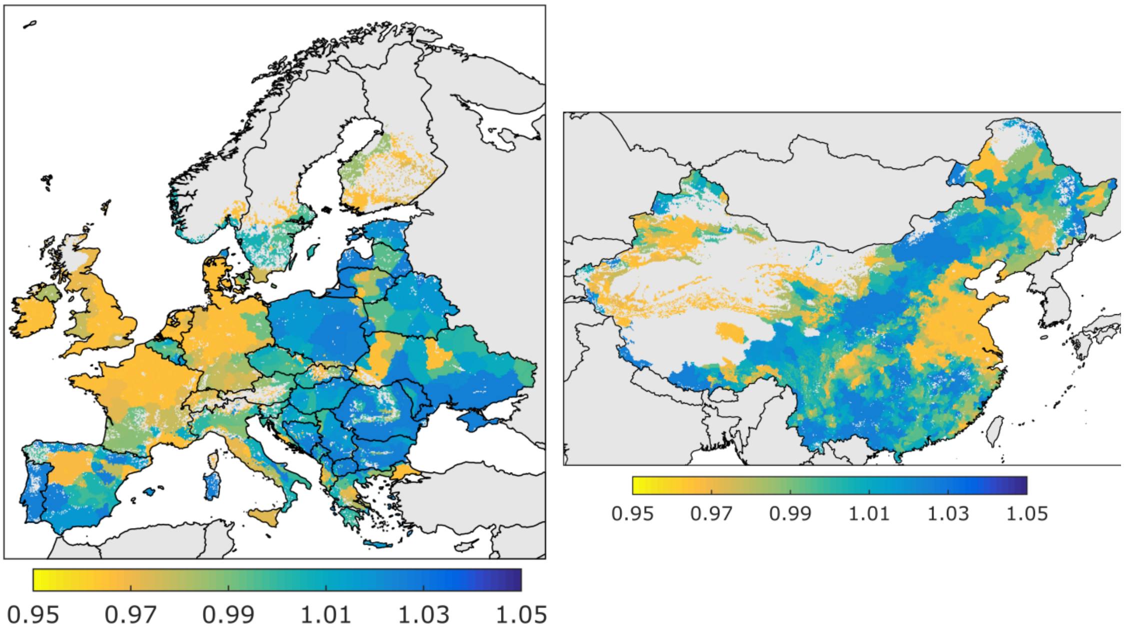


Figure 142. Projected effect of organic farming on mean increase in crop yield for cereal

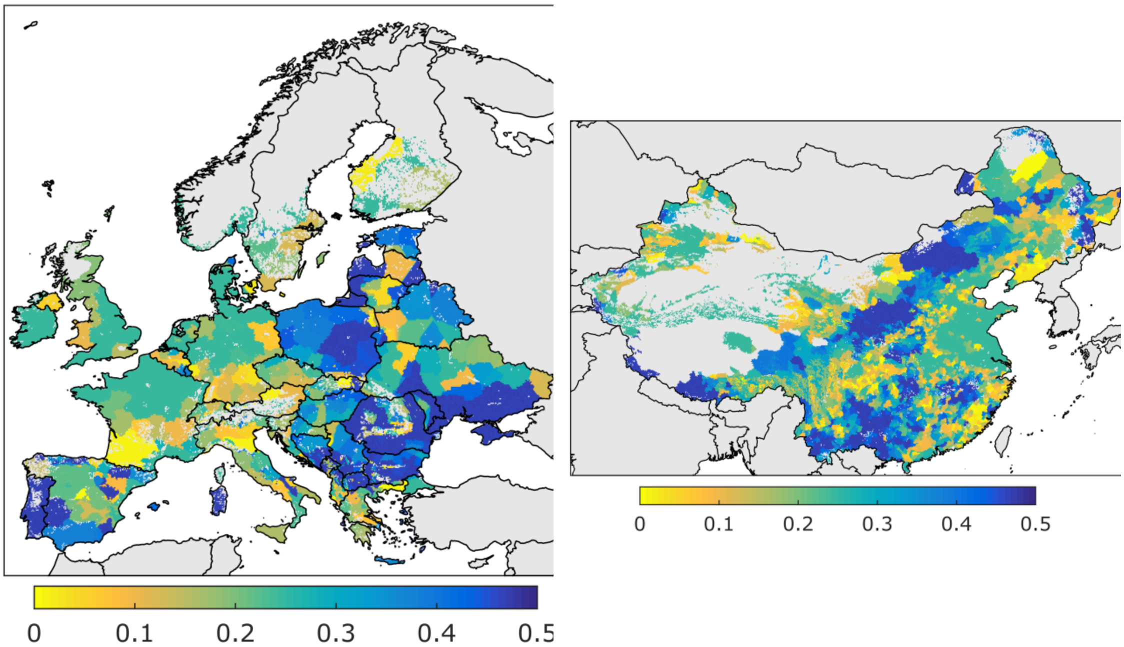


Figure 143. Standard deviation of the projected effect of organic farming on mean increase in crop yield for cereal

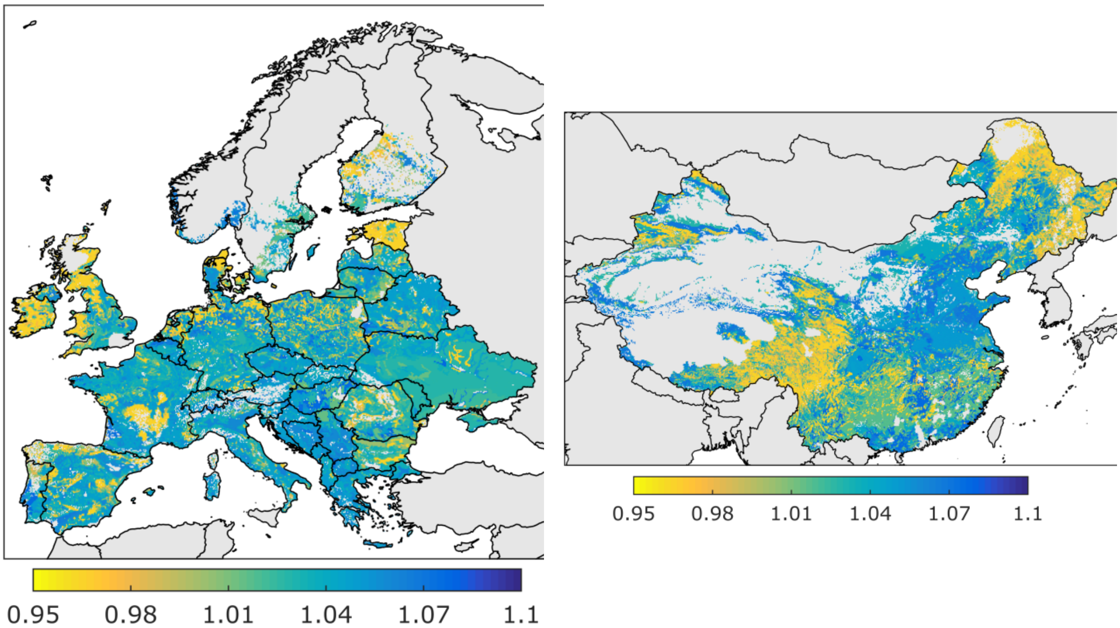


Figure 144. Projected effect of organic farming on mean increase in soil organic matter for cereal

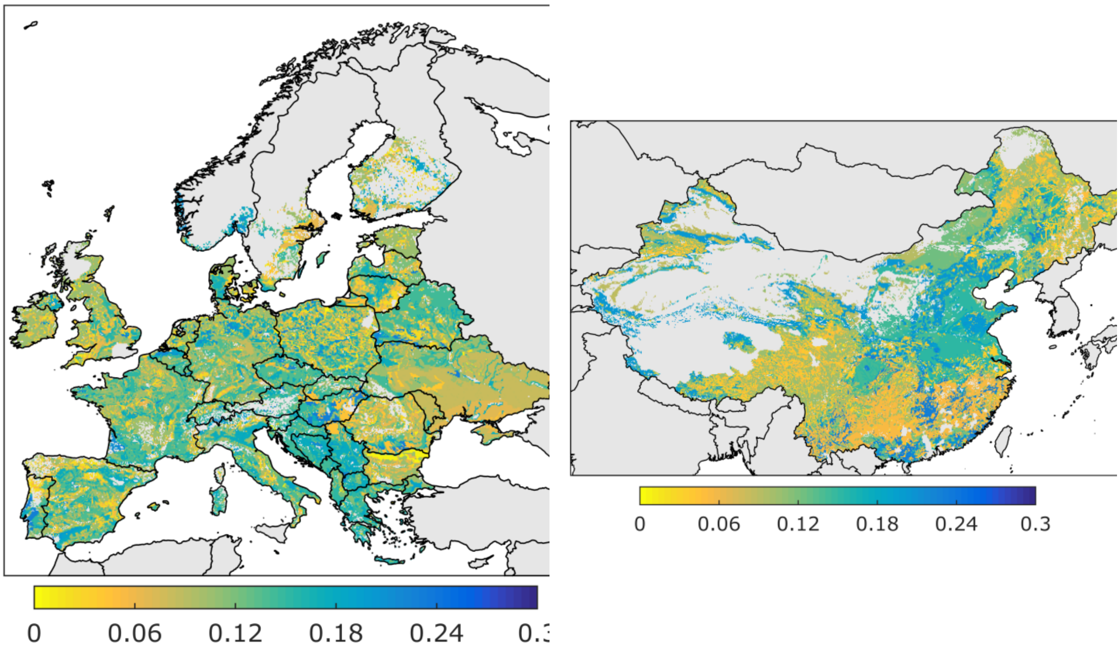


Figure 145. Standard deviation of the projected effect of organic farming on mean increase in soil organic matter for cereal

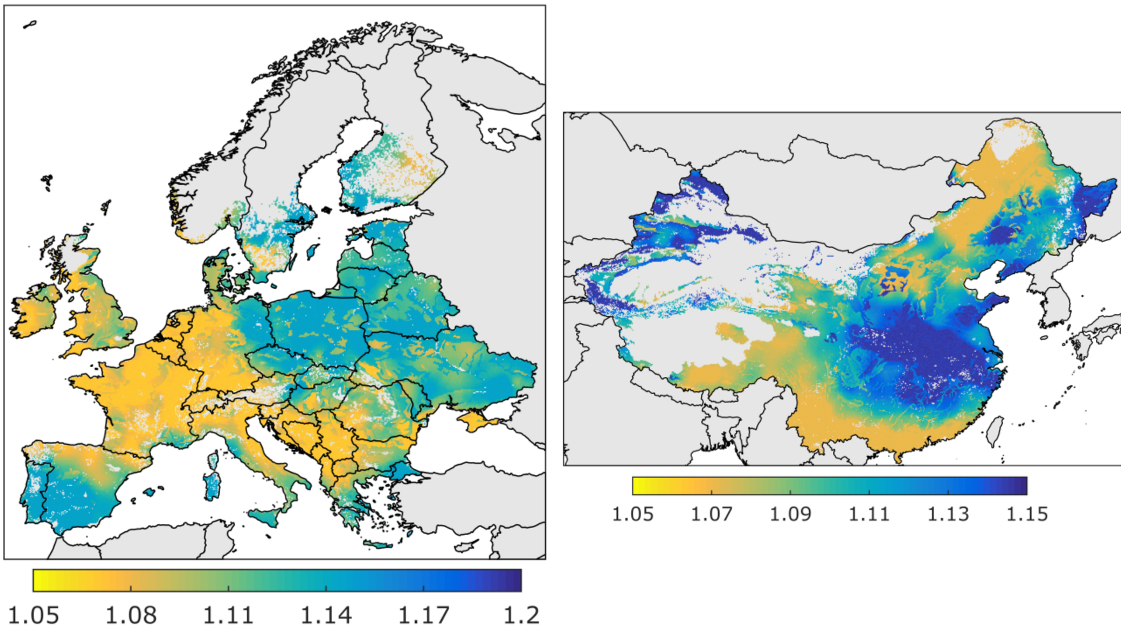


Figure 146. Projected effect of organic farming on mean increase in global soil biodiversity for cereal

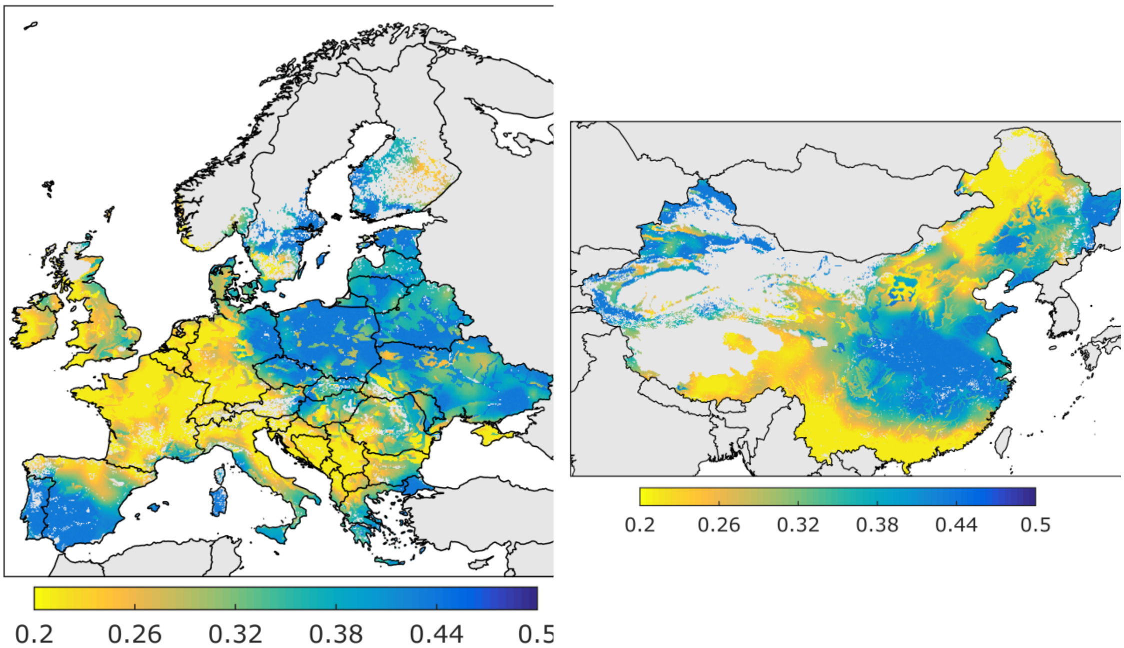


Figure 147. Standard deviation of the projected effect of organic farming on mean increase in global soil biodiversity for cereal

6.4.2 Rice

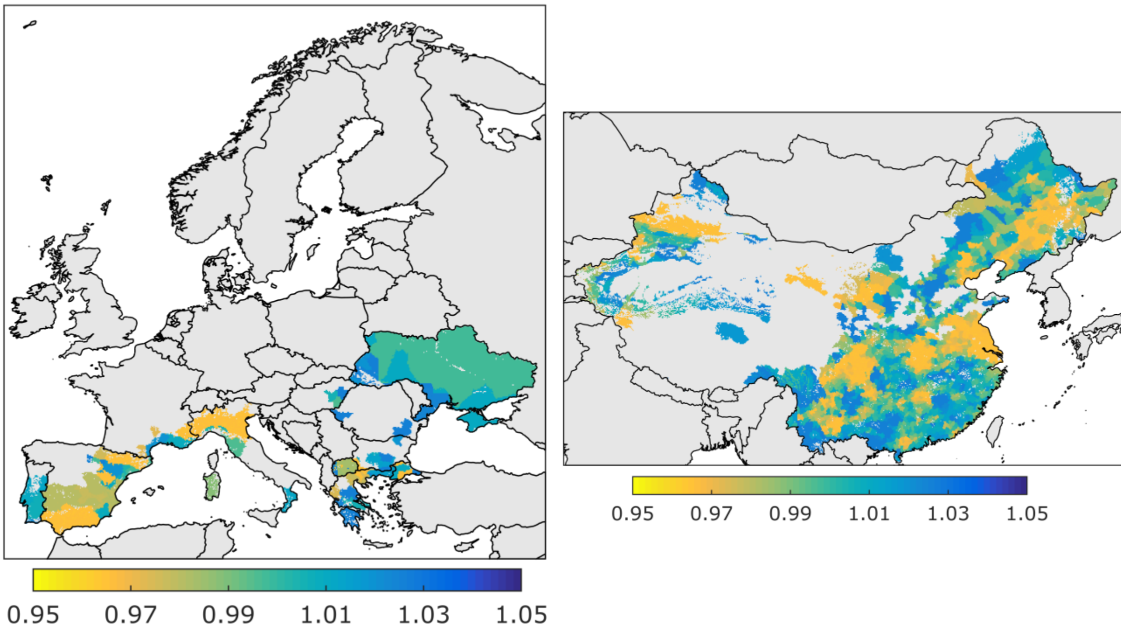


Figure 148. Projected effect of organic farming on mean increase in crop yield for rice

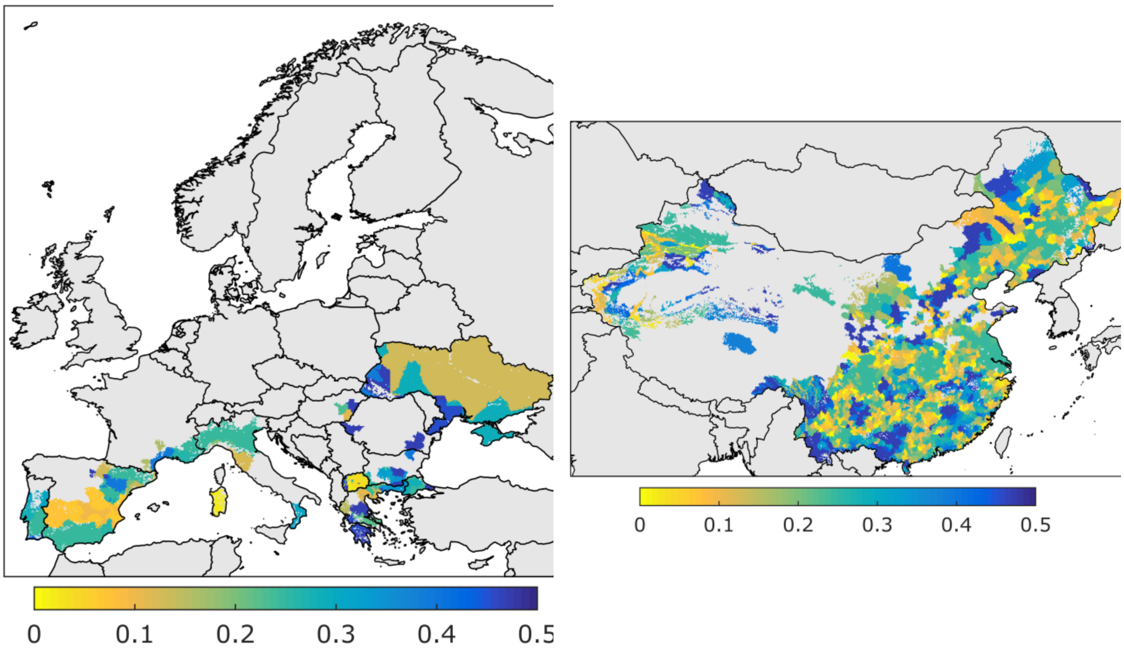


Figure 149. Standard deviation of the projected effect of organic farming on mean increase in crop yield for rice

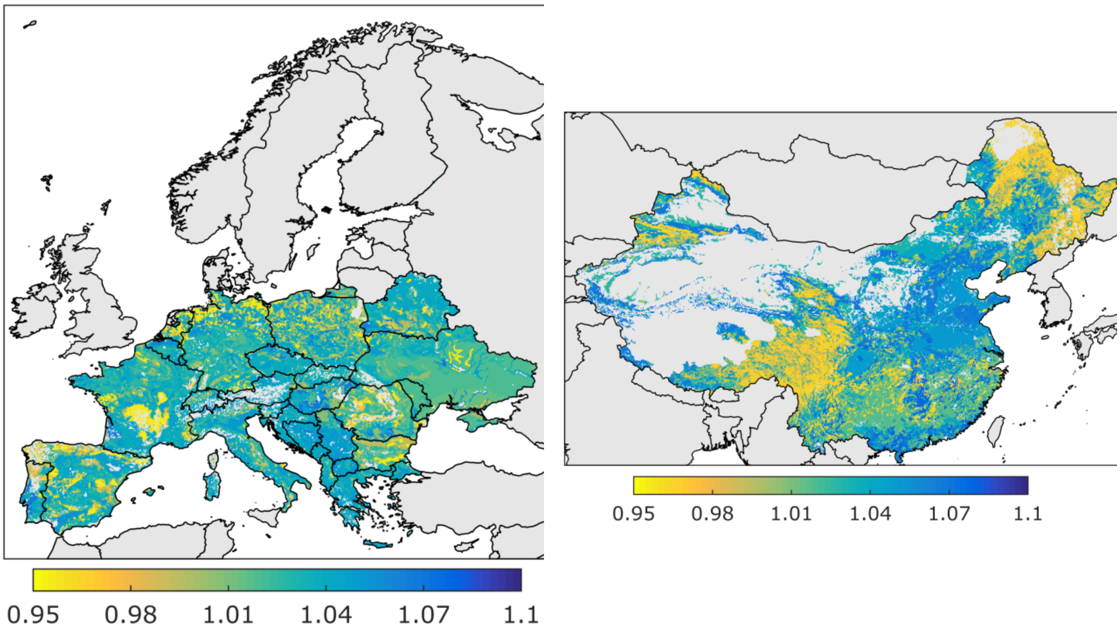


Figure 150. Projected effect of organic farming on mean increase in soil organic matter for rice

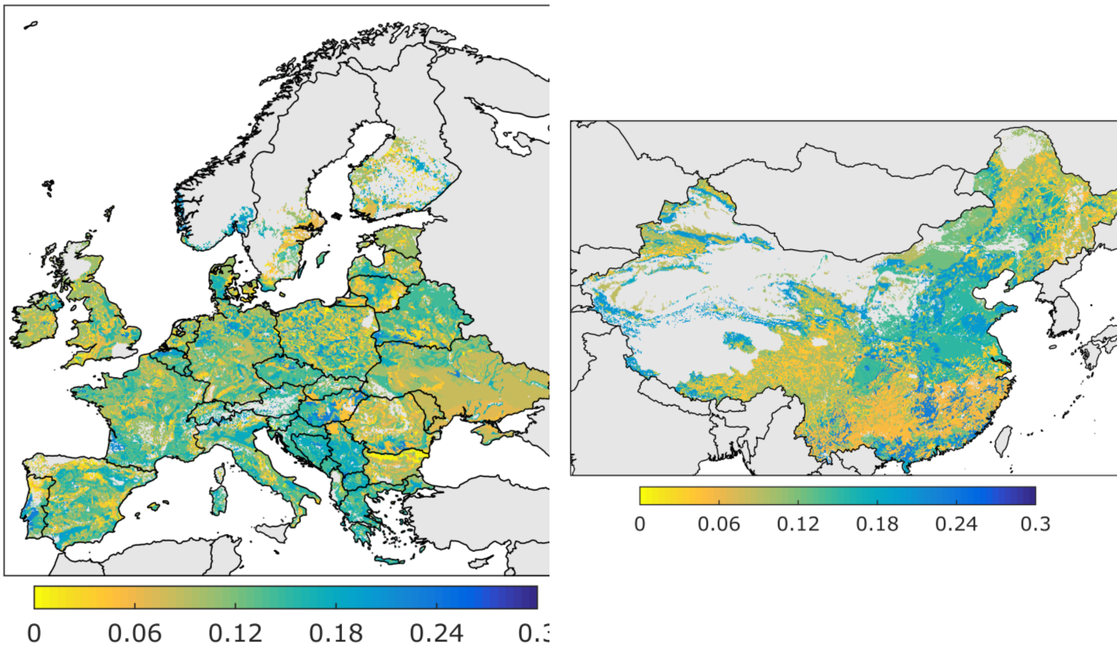


Figure 151. Standard deviation of the projected effect of organic farming on mean increase in soil organic matter for rice

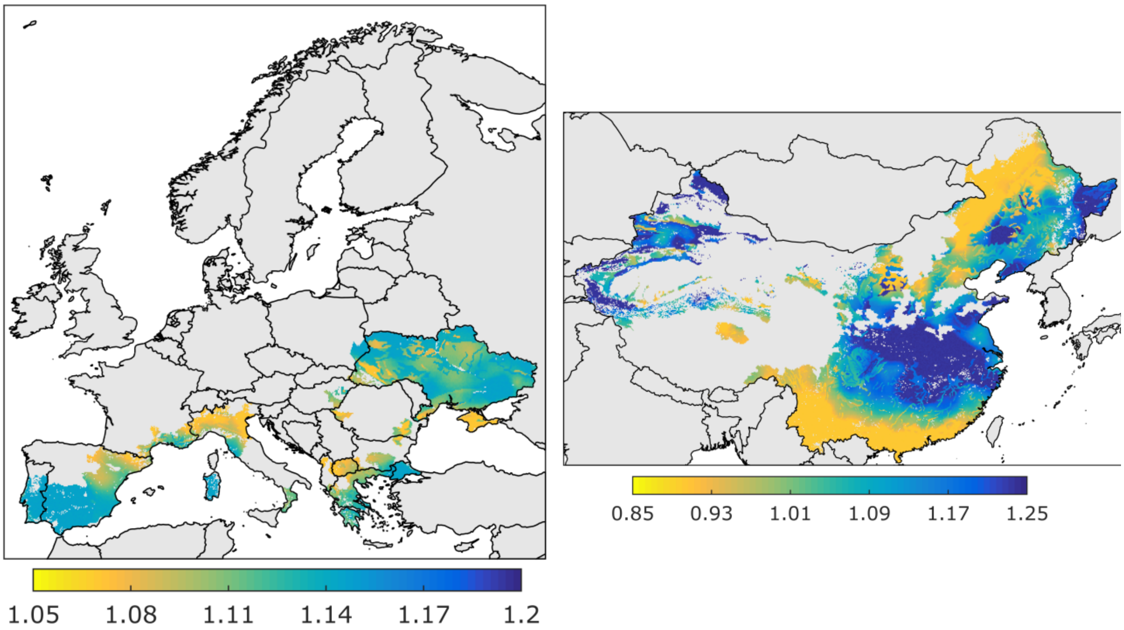


Figure 152. Projected effect of organic farming on mean increase in global soil biodiversity for rice

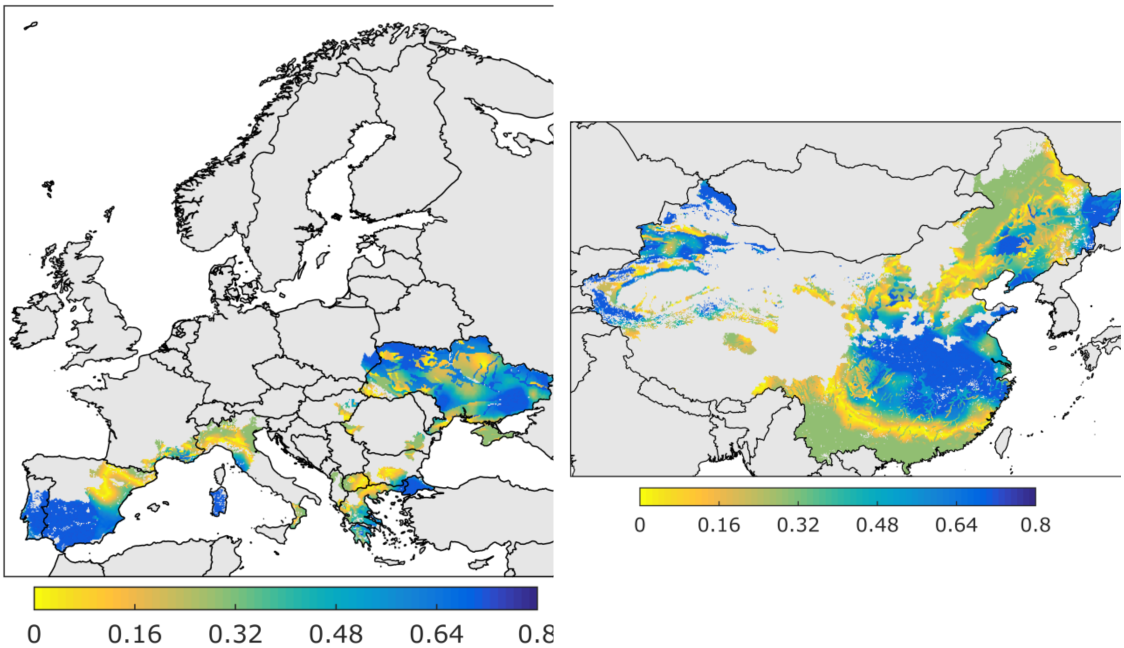


Figure 153. Standard deviation of the projected effect of organic farming on mean increase in global soil biodiversity for rice

6.4.3 Maize

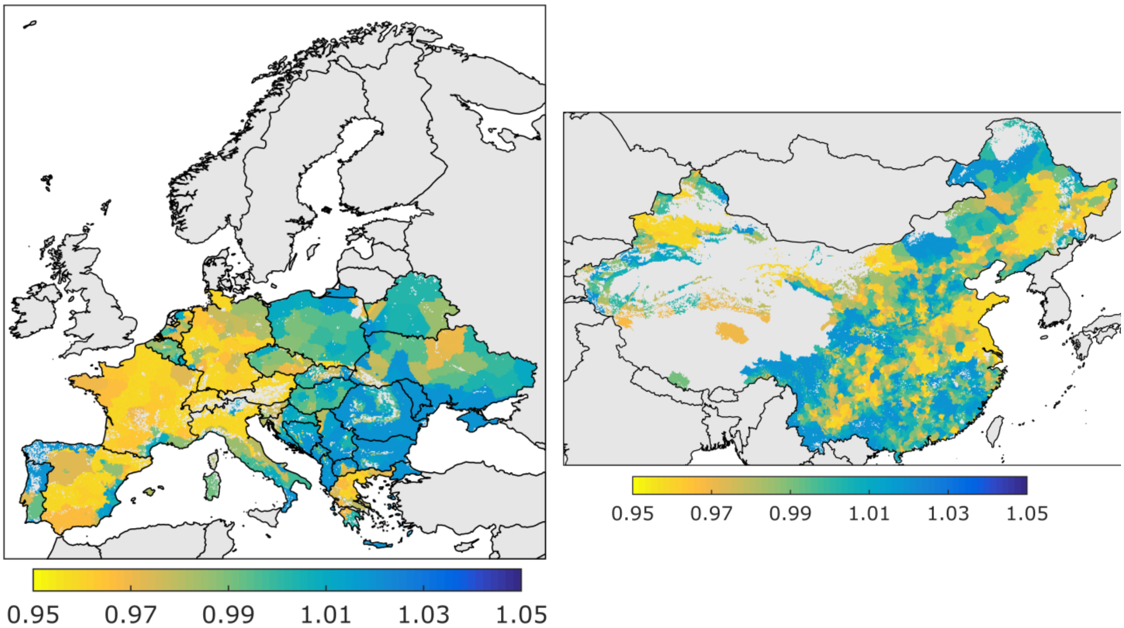


Figure 154. Projected effect of organic farming on mean increase in crop yield for maize

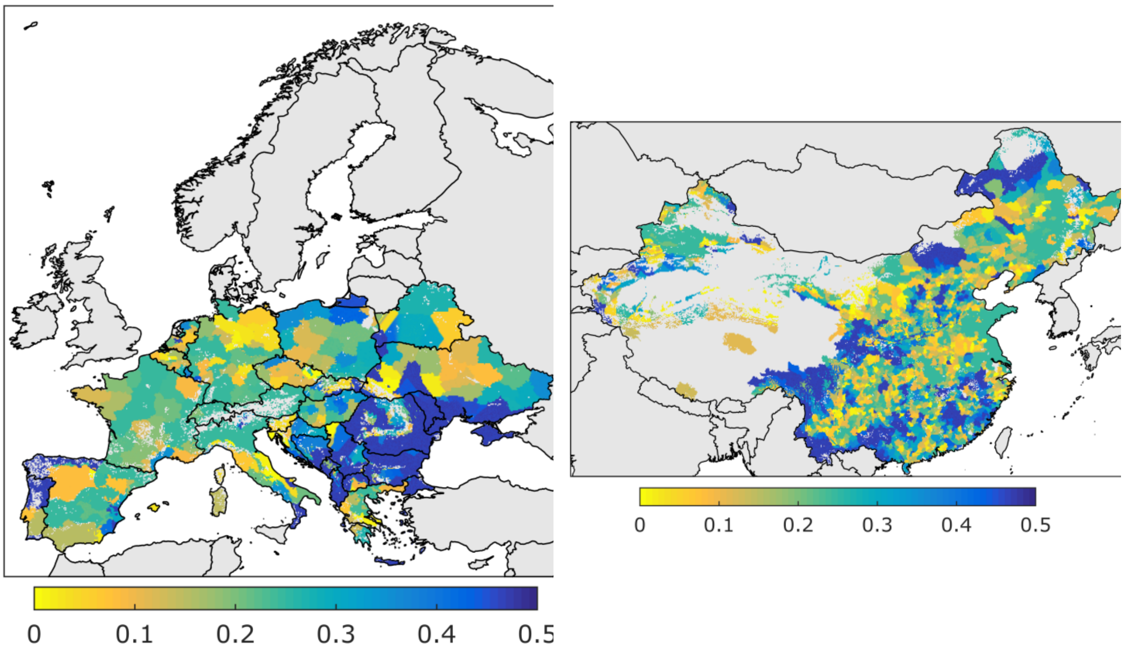


Figure 155. Standard deviation of the projected effect of organic farming on mean increase in crop yield for maize

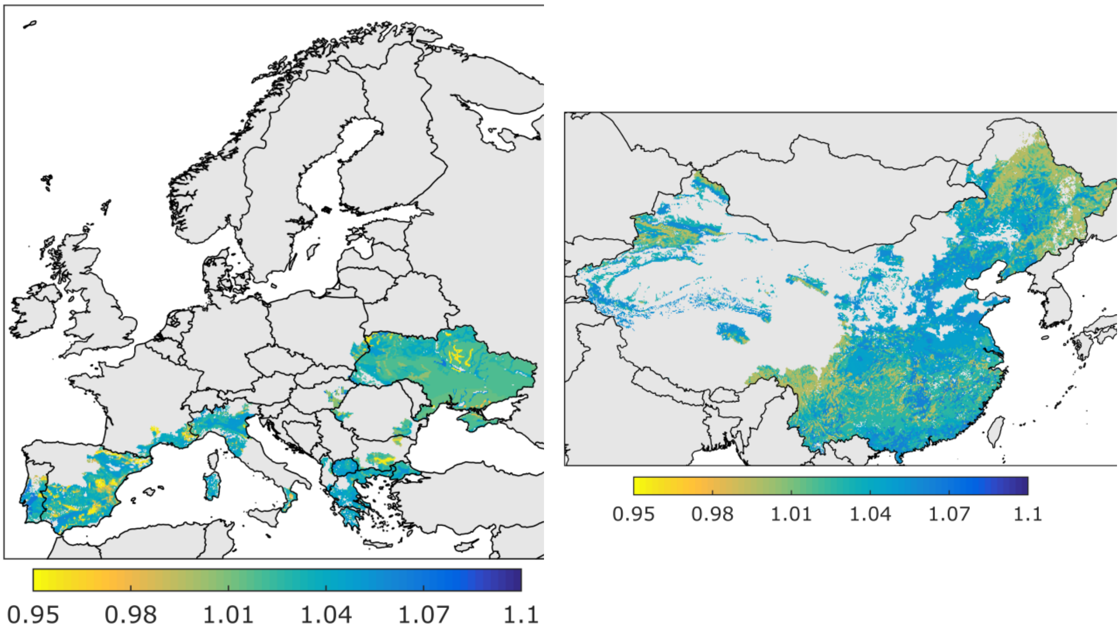


Figure 156. Projected effect of organic farming on mean increase in soil organic matter for maize

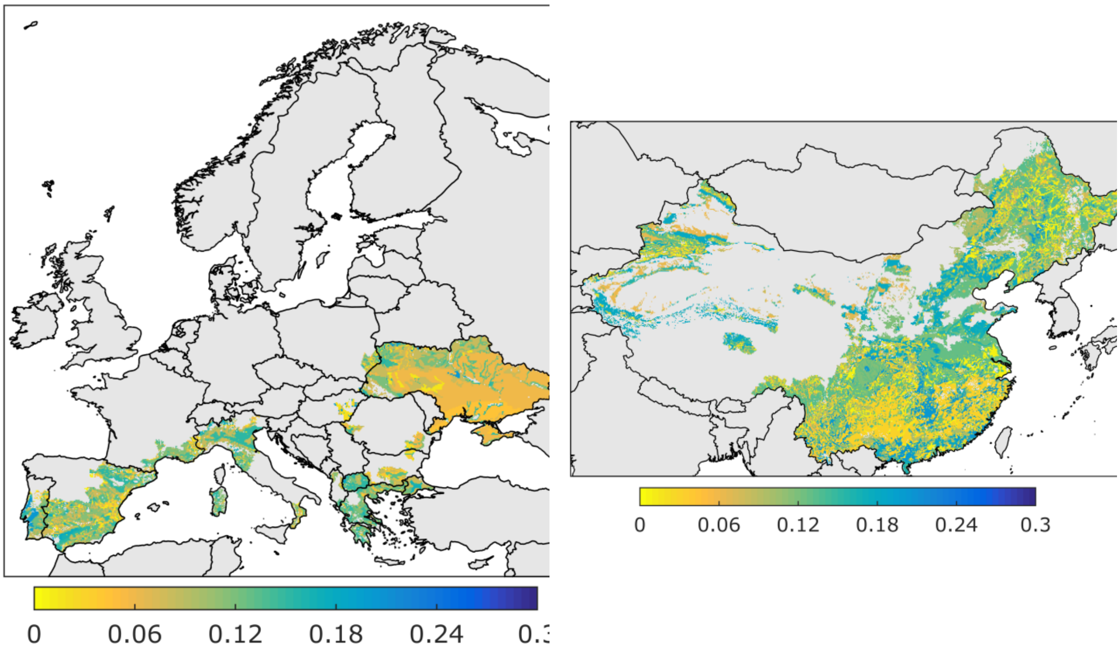


Figure 157. Standard deviation of the projected effect of organic farming on mean increase in soil organic matter for maize

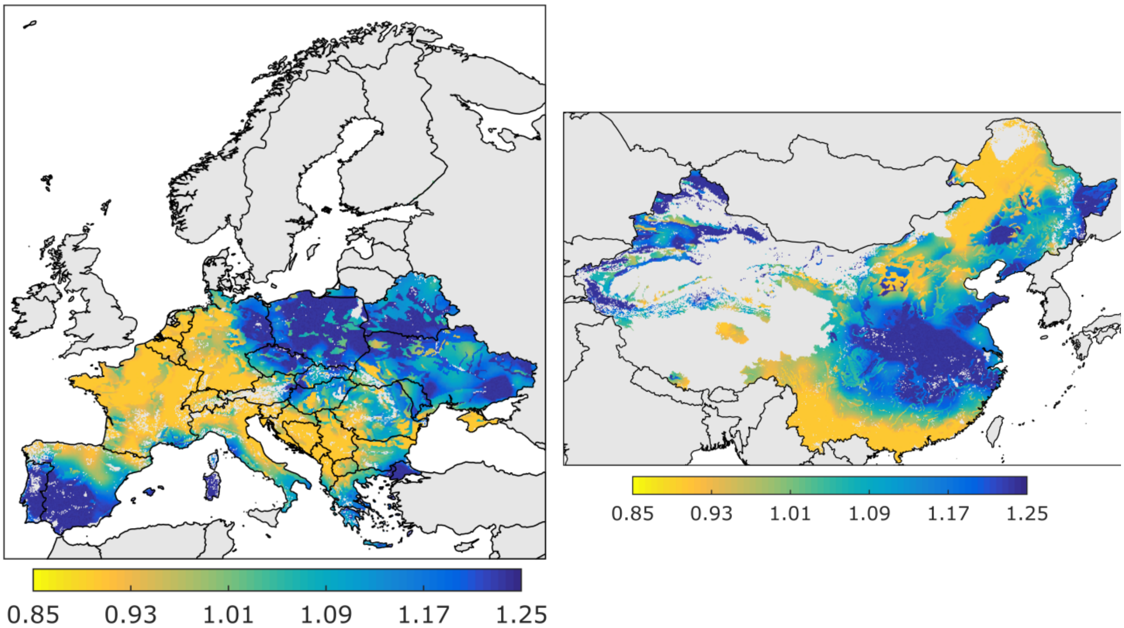


Figure 158. Projected effect of organic farming on mean increase in global soil biodiversity for maize

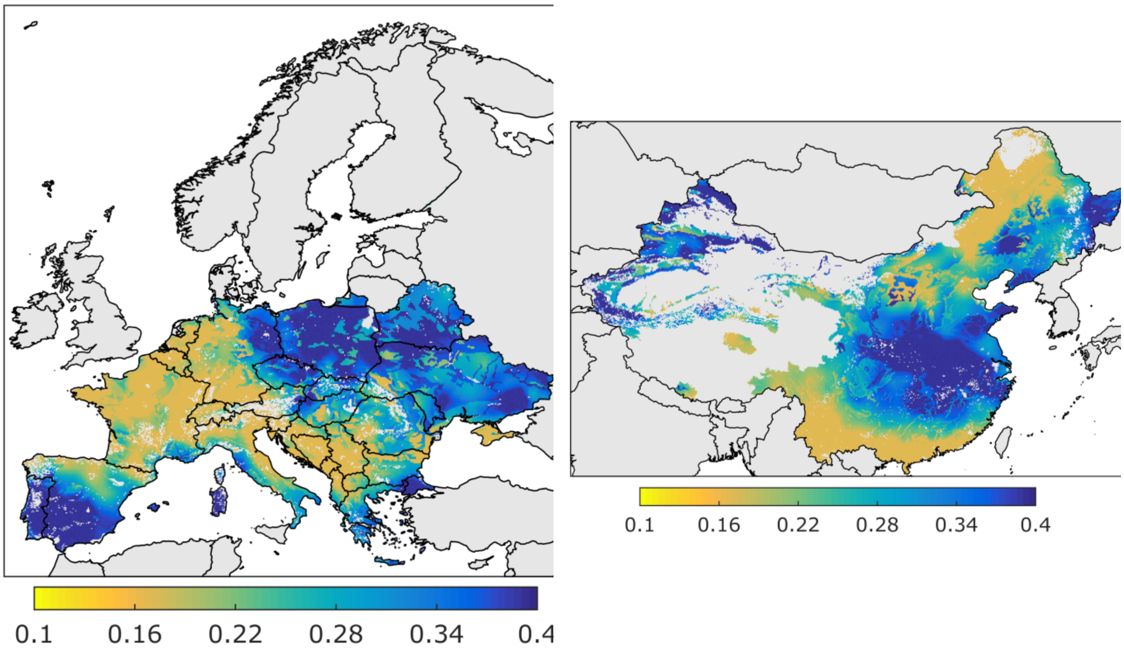


Figure 159. Standard deviation of the projected effect of organic farming on mean increase in global soil biodiversity for maize

6.4.4 Soybean

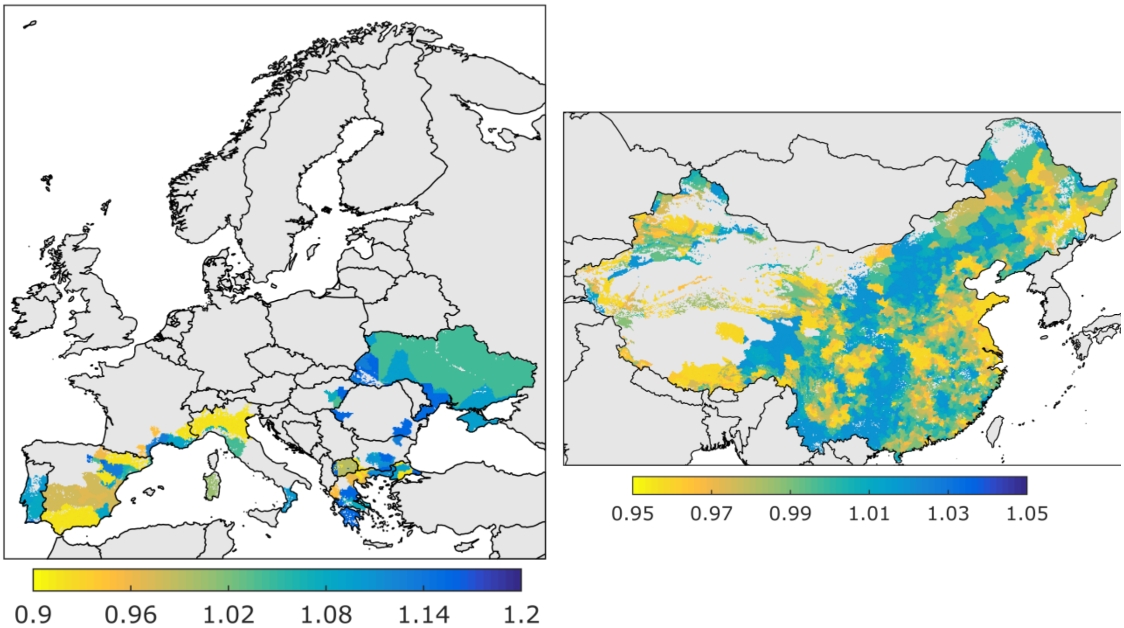


Figure 160. Projected effect of organic farming on mean increase in crop yield for soybean

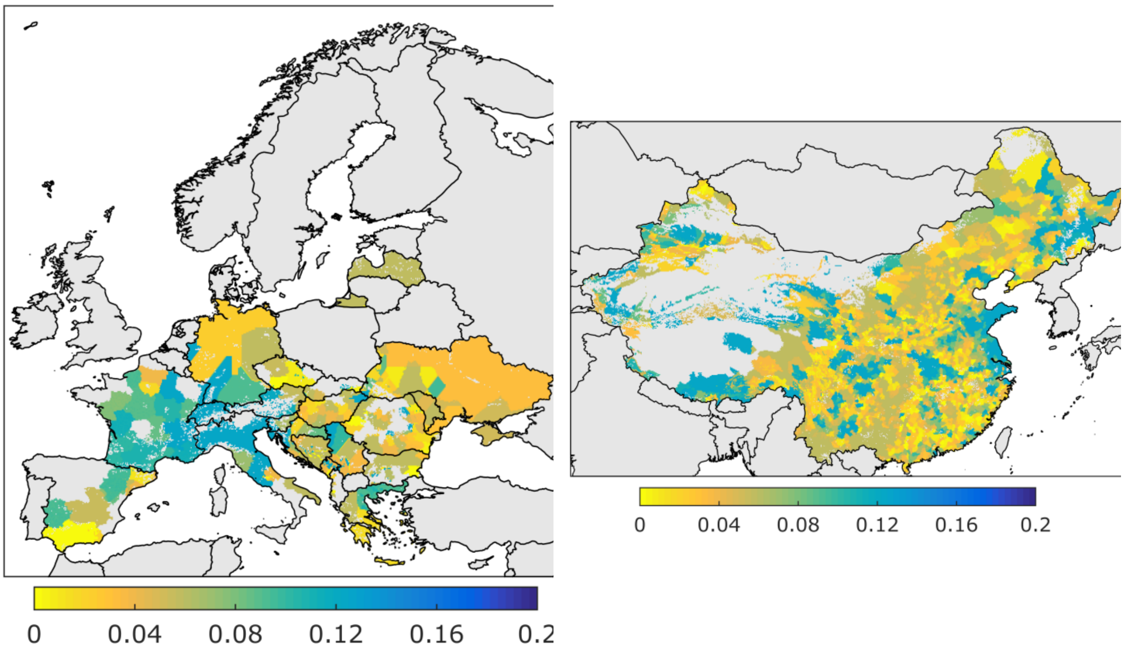


Figure 161. Standard deviation of the projected effect of organic farming on mean increase in crop yield for soybean

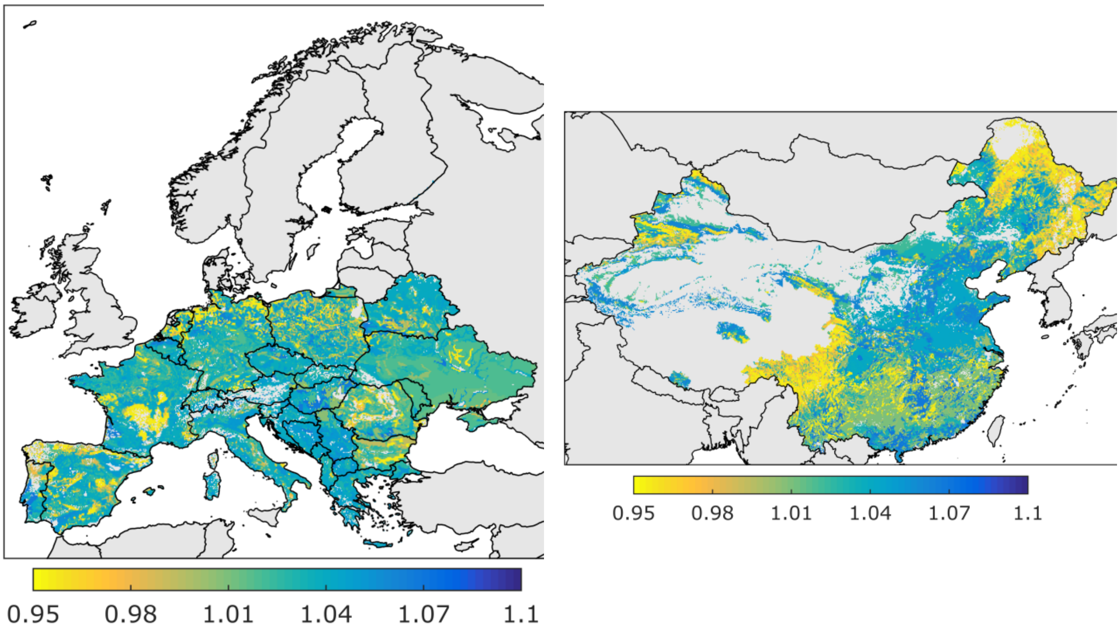


Figure 162. Projected effect of organic farming on mean increase in soil organic matter for soybean

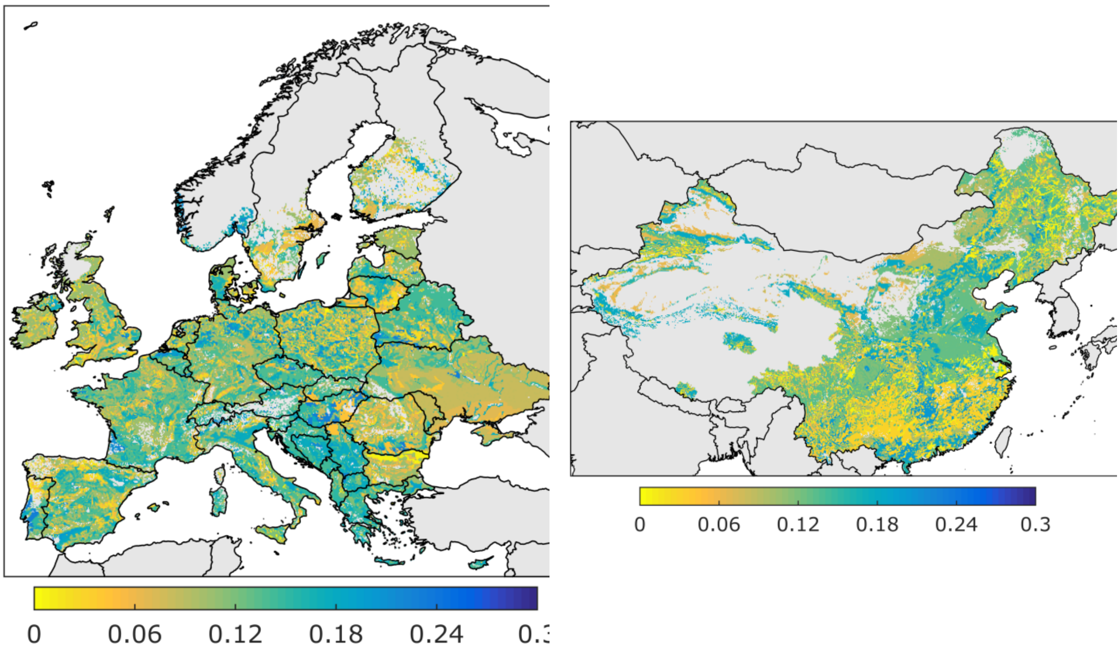


Figure 163. Standard deviation of the projected effect of organic farming on mean increase in soil organic matter for soybean

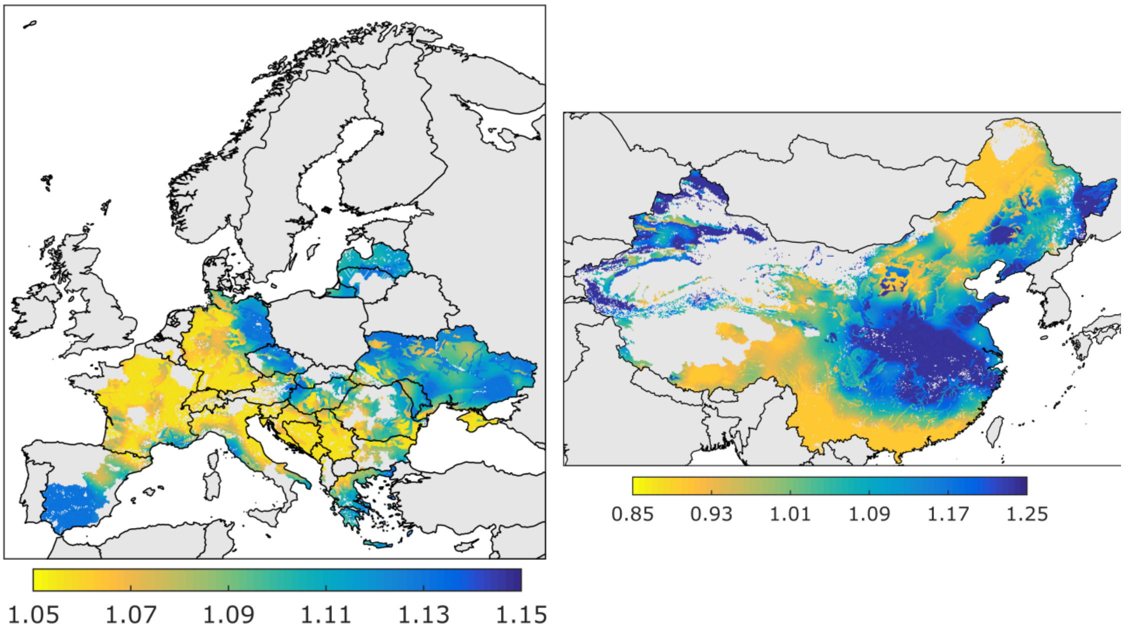


Figure 164. Projected effect of organic farming on mean increase in global soil biodiversity for soybean

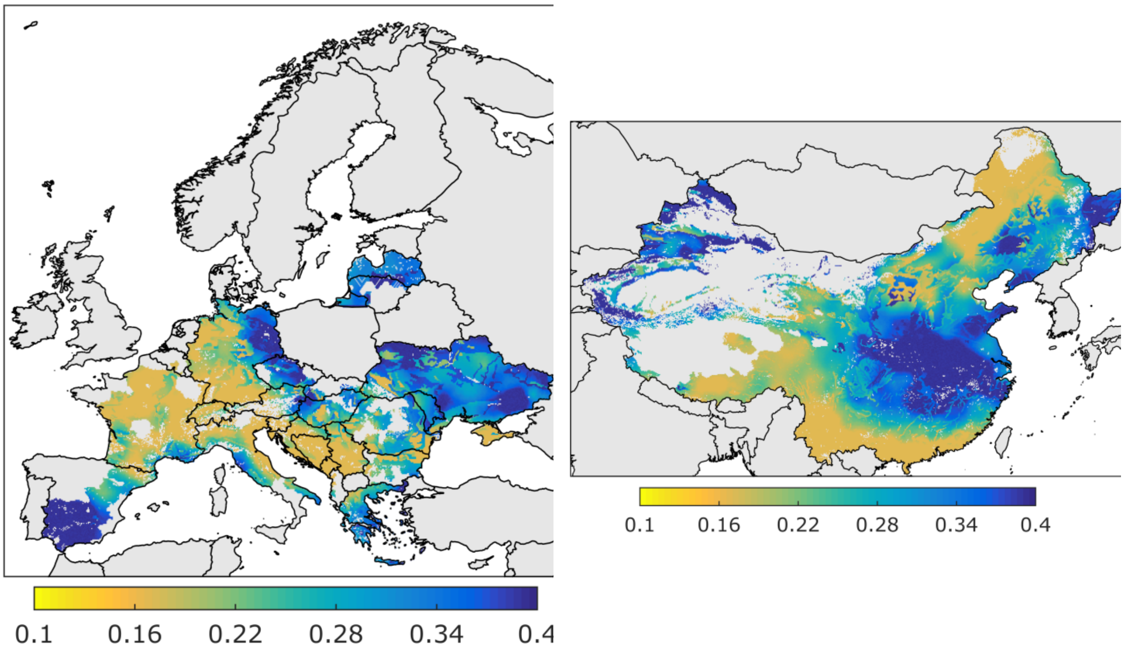


Figure 165. Standard deviation of the projected effect of organic farming on mean increase in global soil biodiversity for soybean

6.4.5 Vegetables

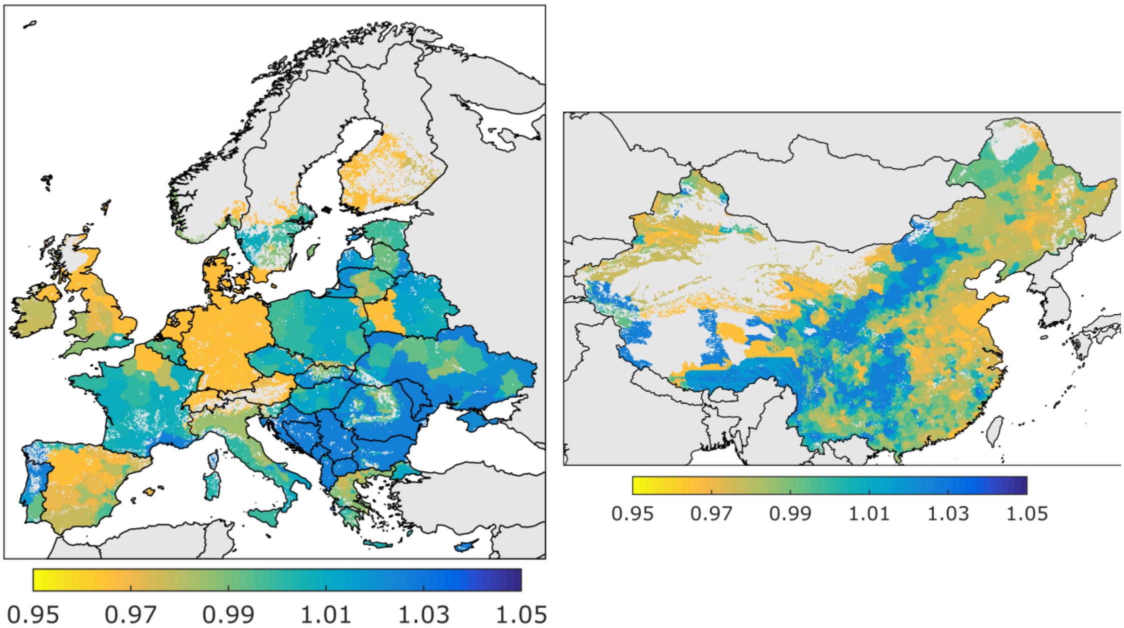


Figure 166. Projected effect of organic farming on mean increase in crop yield for vegetables

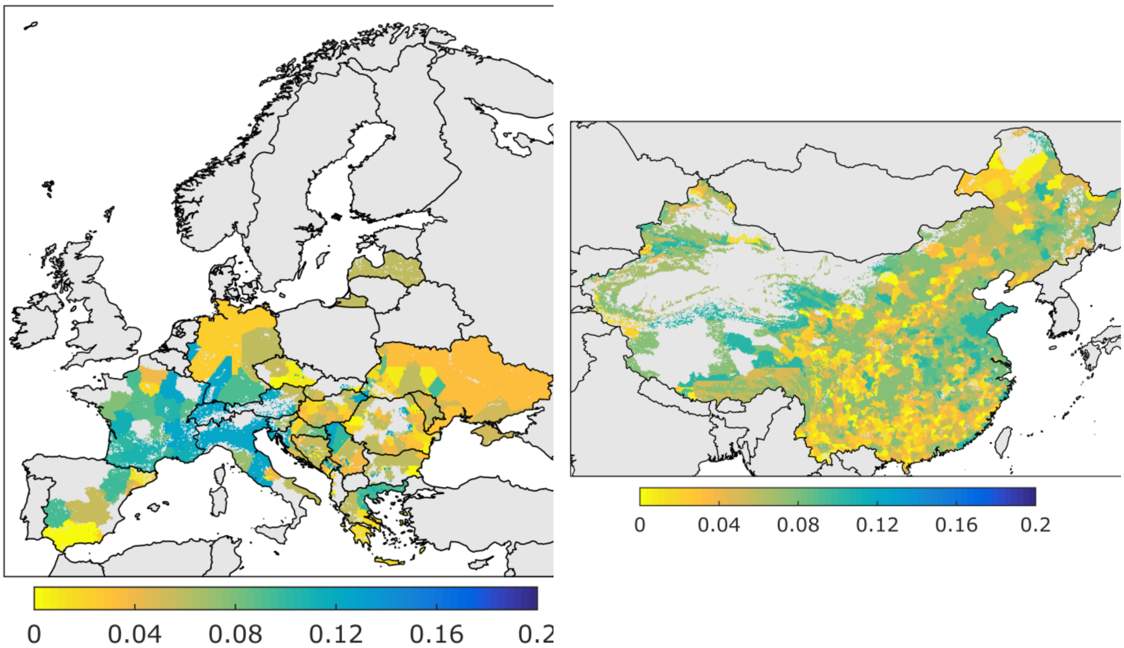


Figure 167. Standard deviation of the projected effect of organic farming on mean increase in crop yield for vegetables

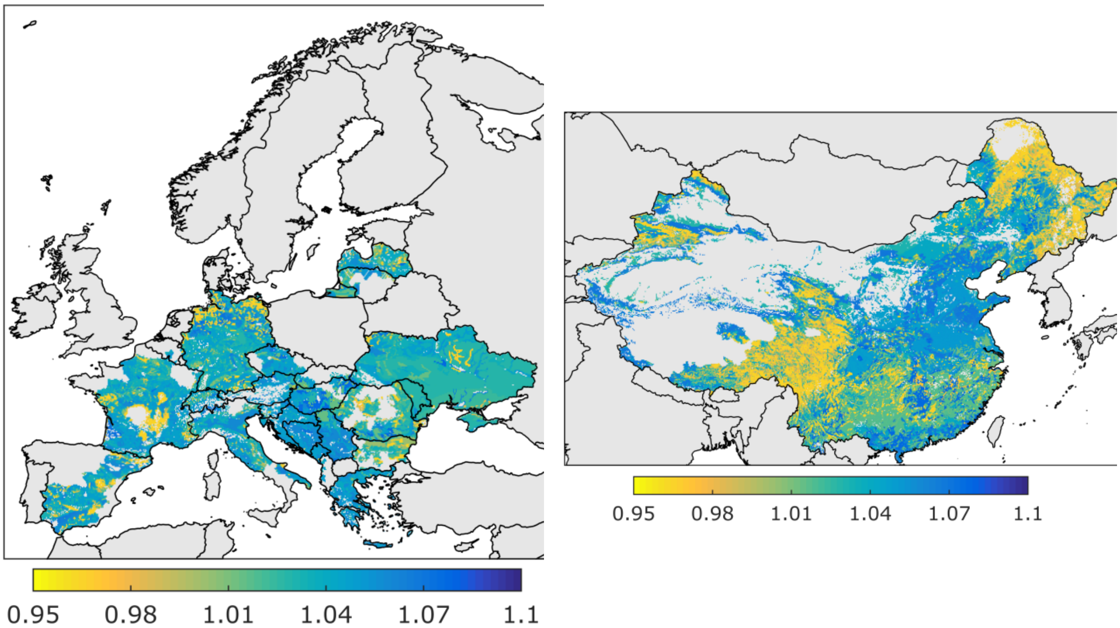


Figure 168. Projected effect of organic farming on mean increase in soil organic matter for vegetables

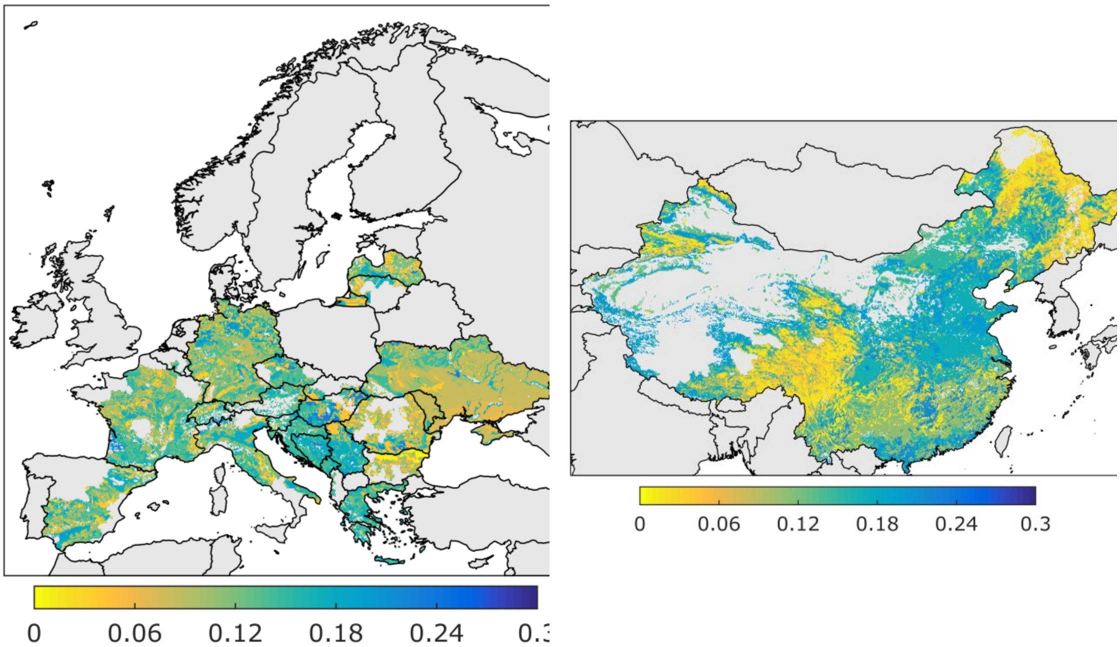


Figure 169. Standard deviation of the projected effect of organic farming on mean increase in soil organic matter for vegetables

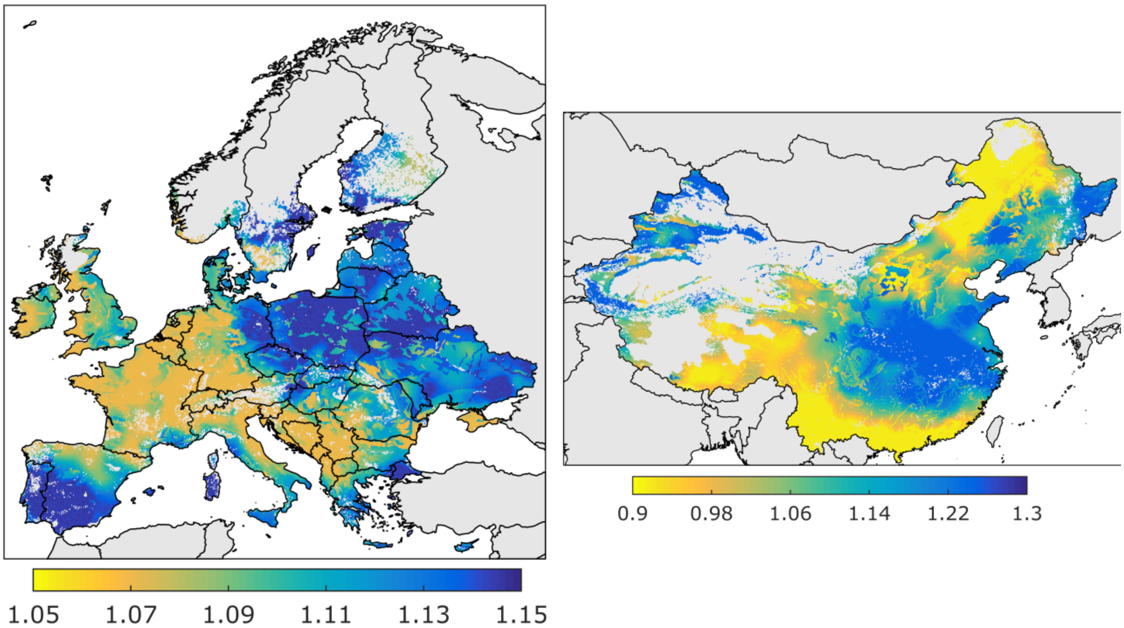


Figure 170. Projected effect of organic farming on mean increase in global soil biodiversity for vegetables

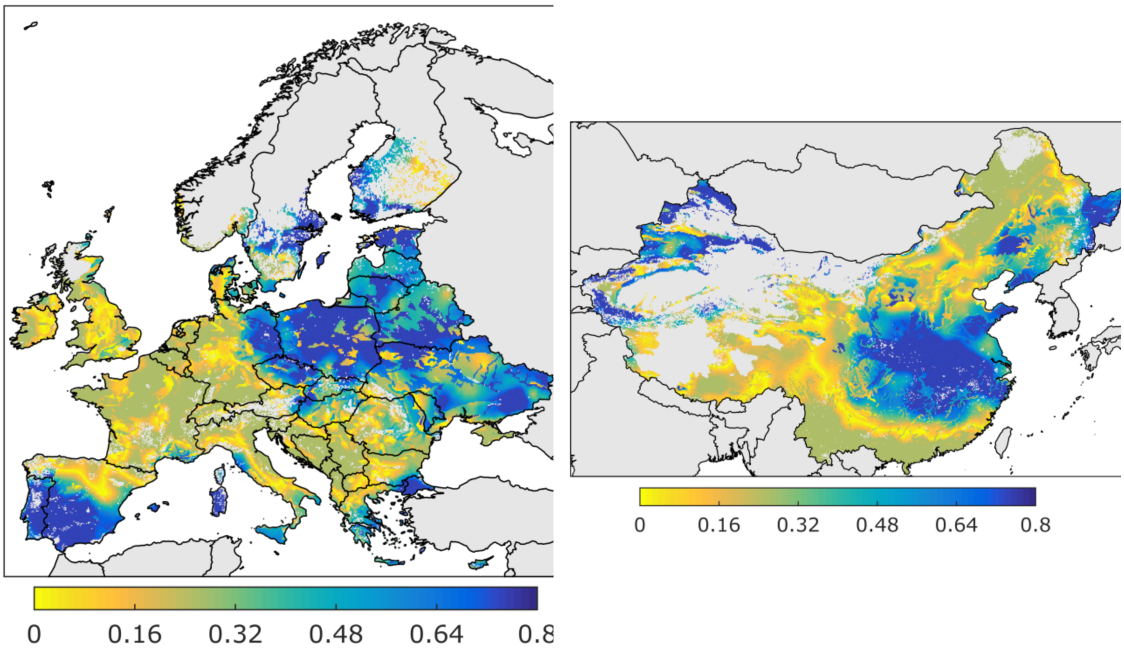


Figure 171. Standard deviation of the projected effect of organic farming on mean increase in global soil biodiversity for vegetables

6.4.6 Pasture

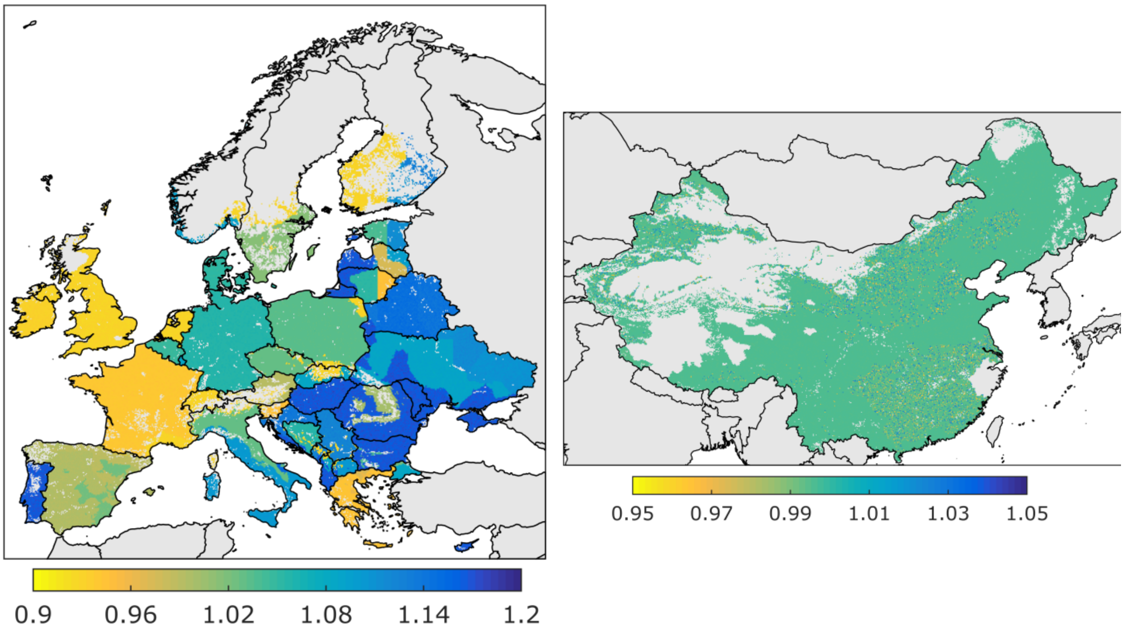


Figure 172. Projected effect of organic farming on mean increase in crop yield for pasture

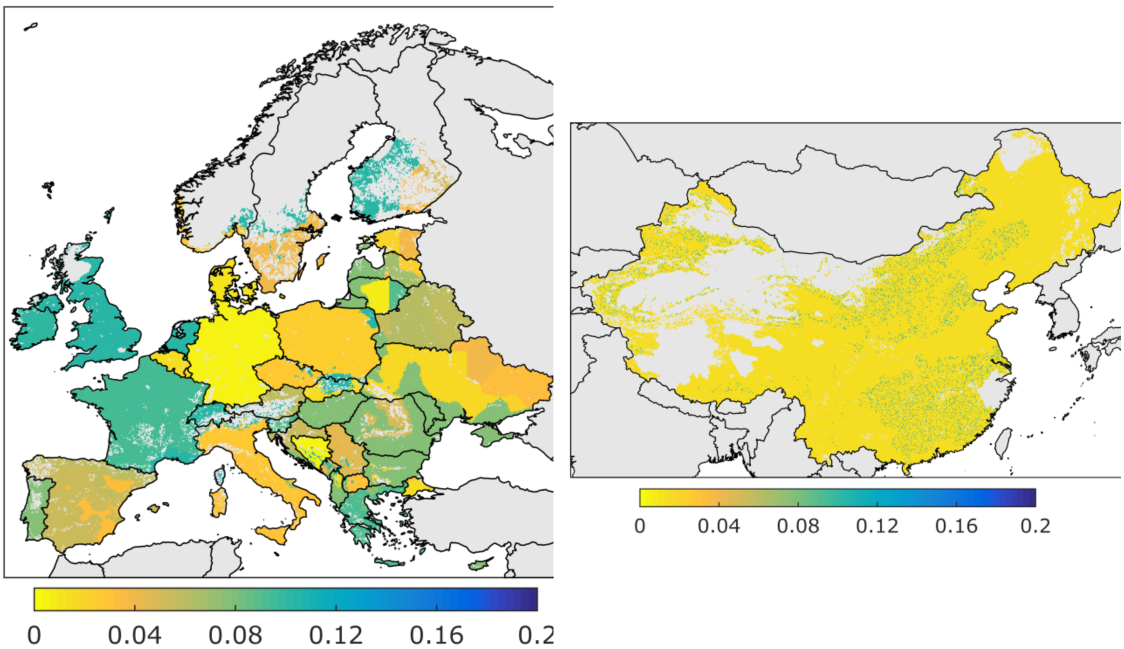


Figure 173. Standard deviation of the projected effect of organic farming on mean increase in crop yield for pasture

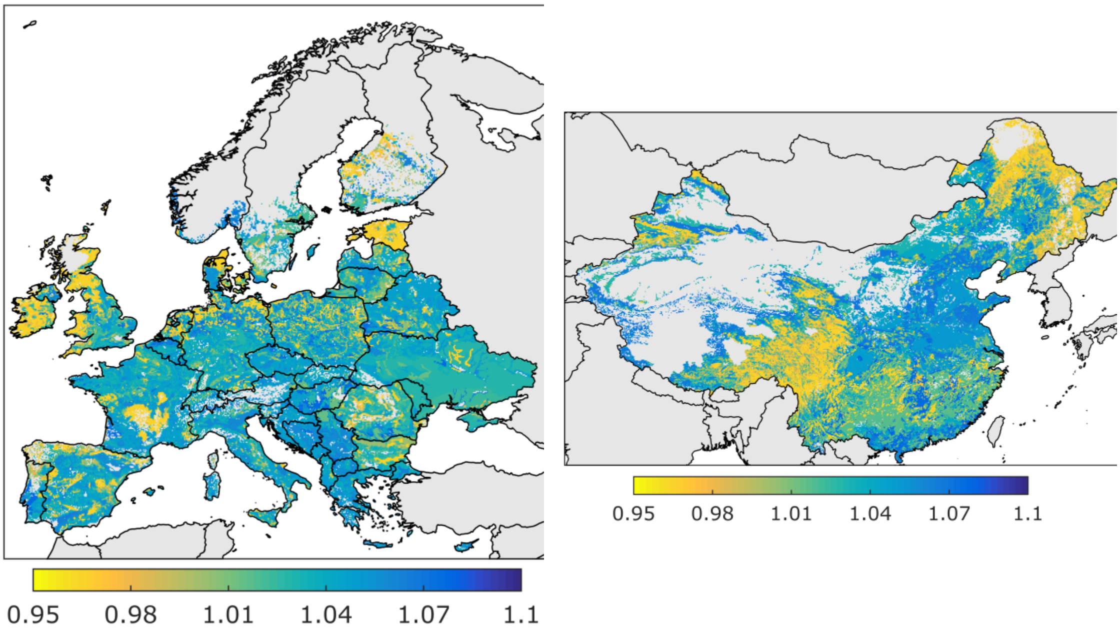


Figure 174. Projected effect of organic farming on mean increase in soil organic matter for pasture

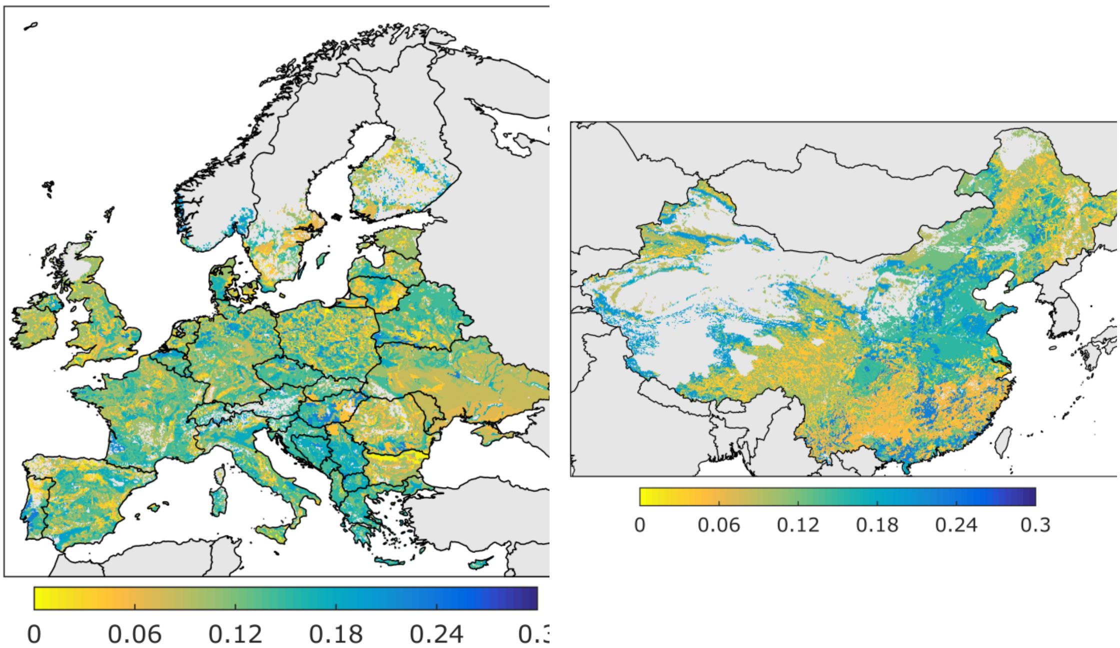


Figure 175. Standard deviation of the projected effect of organic farming on mean increase in soil organic matter for pasture

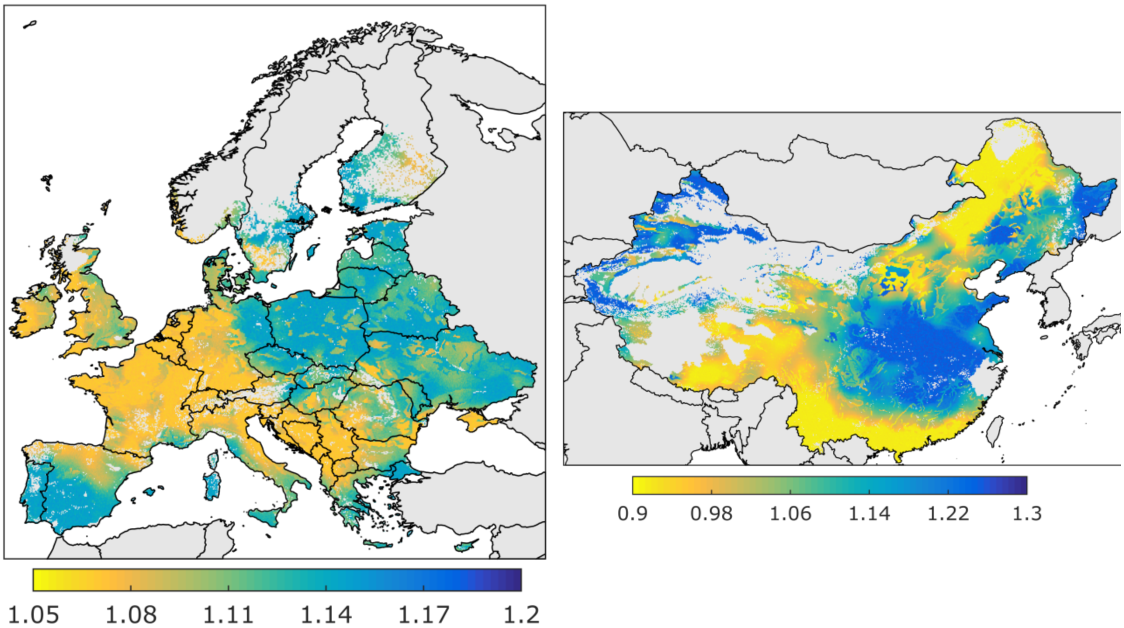


Figure 176. Projected effect of organic farming on mean increase in global soil biodiversity for pasture

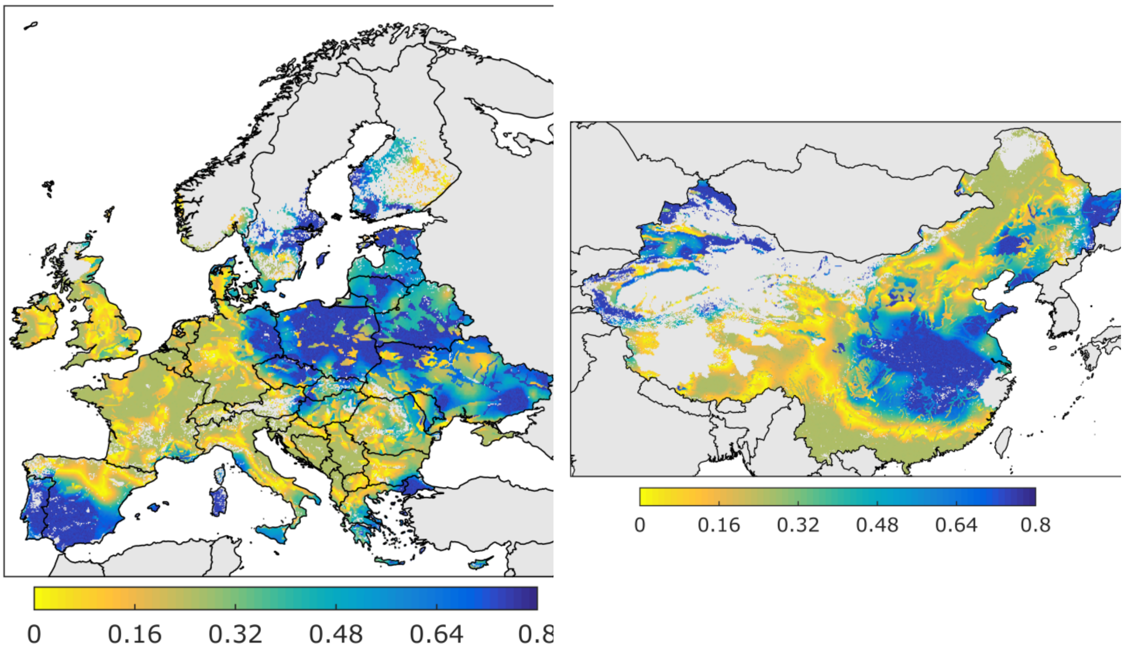


Figure 177. Standard deviation of the projected effect of organic farming on mean increase in global soil biodiversity for pasture

6.4.7 Permanent crops

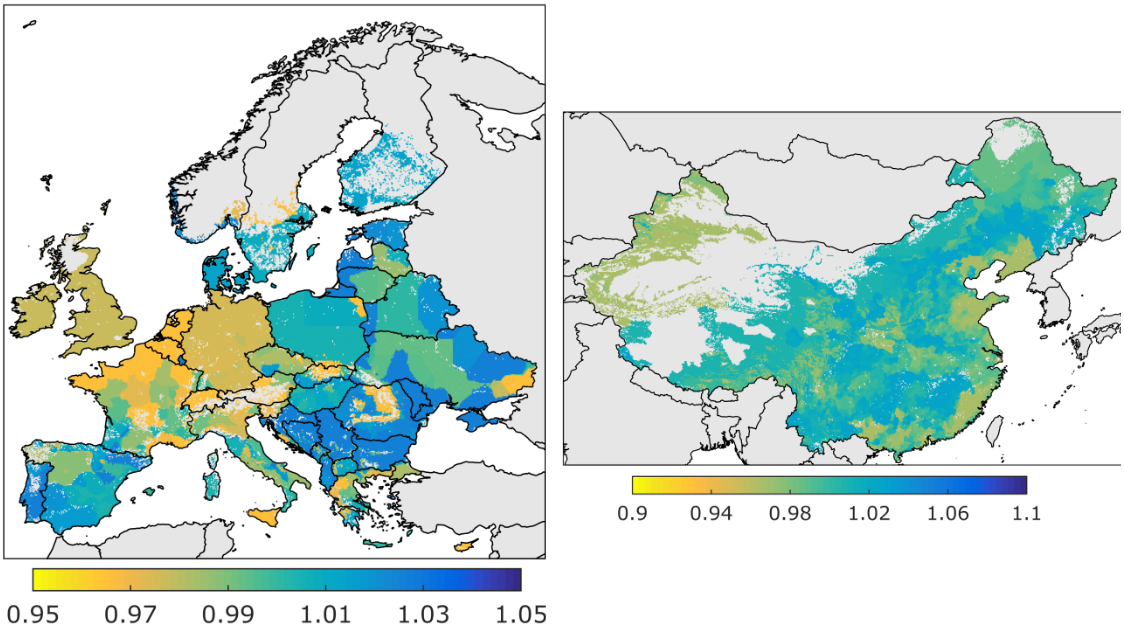


Figure 178. Projected effect of organic farming on mean increase in crop yield for permanent crops

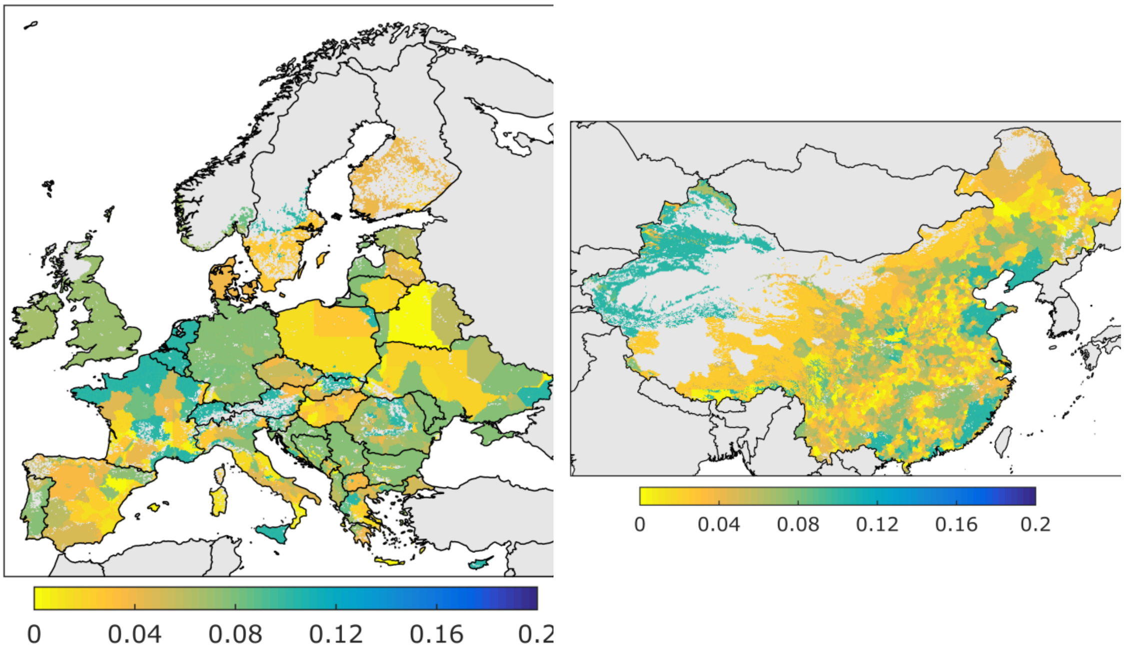


Figure 179. Standard deviation of the projected effect of organic farming on mean increase in crop yield for permanent crops

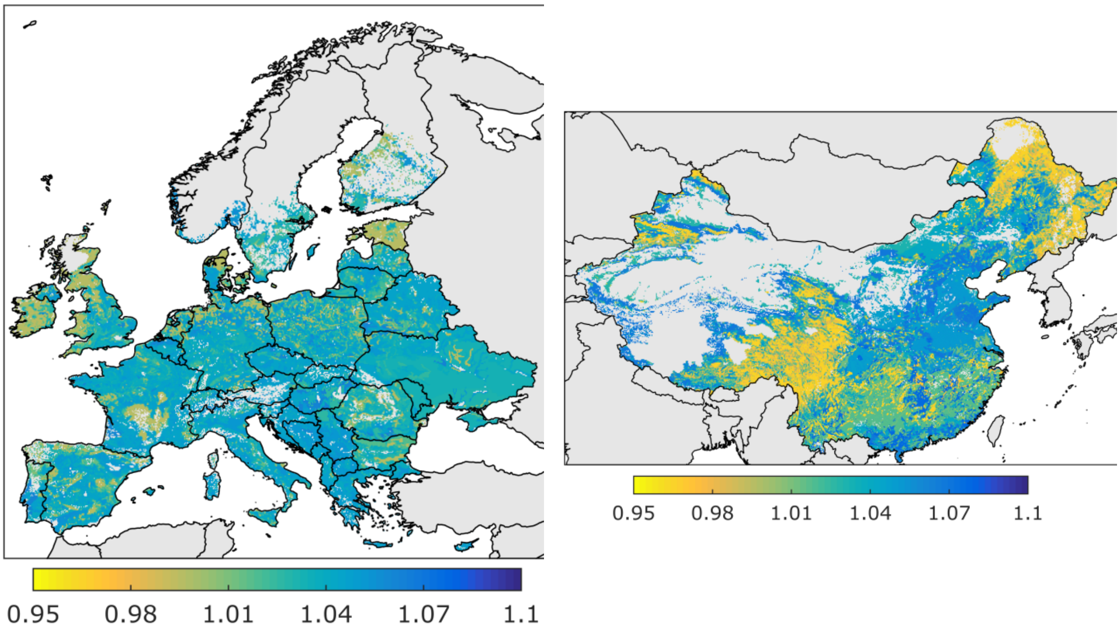


Figure 180. Projected effect of organic farming on mean increase in soil organic matter for permanent crops

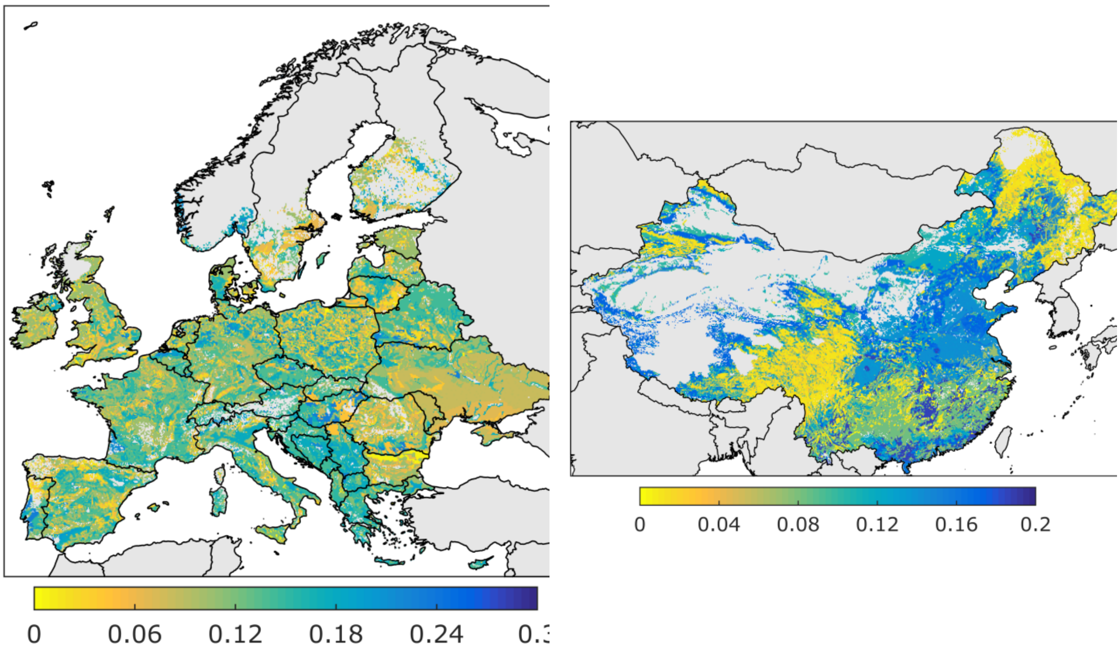


Figure 181. Standard deviation of the projected effect of organic farming on mean increase in soil organic matter for permanent crops

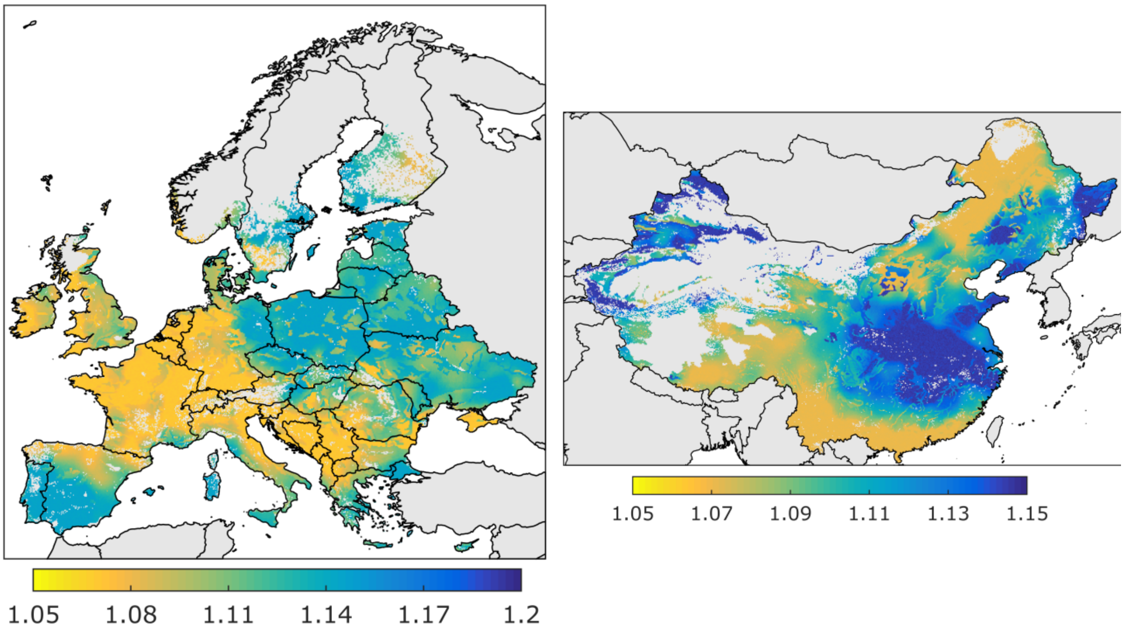


Figure 182. Projected effect of organic farming on mean increase in global soil biodiversity for permanent crops

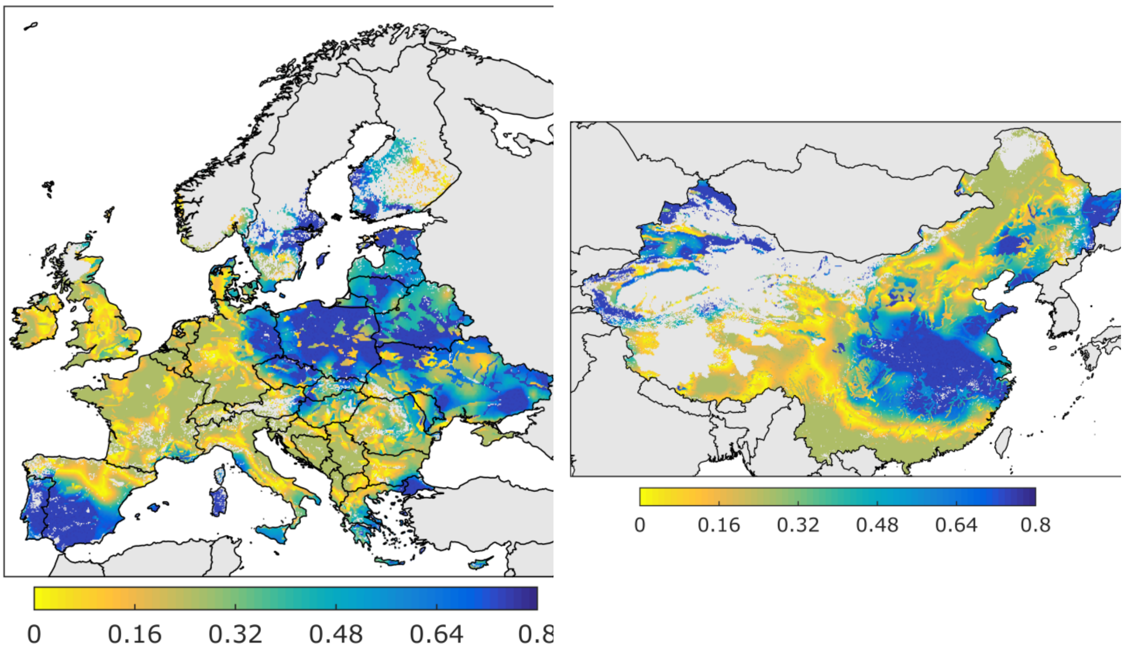


Figure 183. Standard deviation of the projected effect of organic farming on mean increase in global soil biodiversity for permanent crops

7 Gaps in knowledge and further work

7.1 Gaps in knowledge

Limitations of upscaling model (Detailed in Deliverable 7.1).

7.2 Further work

This framework will be used to define the ecosystem services and a SQI under policy scenarios (Deliverable 7.4).

Policy scenarios will be defined with WP8. Policy portfolios will include the selective implementation of certain combinations of management practices.

Results for individual farming systems will be grouped together to account for subgrid variability.

Results for different agricultural management practices will be combined to produce the effect of each policy scenario.

Results of different soil quality indicators will be combined to produce descriptions of improvement of soil environmental footprint,

Soil Environmental foot print scenarios will be analysed.

8 References

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