Report on definition of typical combinations of farming systems and agricultural practices in Europe and China and their effects on soil quality

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Report on definition of typical combinations of farming systems and agricultural practices in Europe and China and their effects on soil quality

Deliverable 7.1 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 10

LIST OF TABLES 13

Executive summary 14

1 Introduction 16

1.1 Integration of WP7 in iSQAPER 16

Figure 1. Approach to evaluate the environmental footprint in WP7 16

1.2 Objectives 16

2 Upscaling approaches in geospatial environmental studies 17

2.1 The scale of social and environmental policies 17

2.2 The concept of upscaling 17

2.3 Upscaling approaches: Models 18

2.4 Upscaling approaches: Clustering 20

2.5 Upscaling approaches: Co-design 20

2.6 Challenges for upscaling the soil environmental footprint 21

3 Approach to evaluate the soil environmental footprint in WP7 22

3.1 Framework 22

Figure 2. Approach to evaluate the environmental footprint in WP7 23

Food production 23

Water availability and variability 23

Greenhouse gas emissions from agricultural land 24

3.2 Indicators for upscaling 24

3.3 Definition of thresholds 25

4 Data 26

4.1 Data sources 26

4.1.1 Soils 26

JRC Soils: European Soil Data Center (ESDAC) 26

Table 2.SGDBE Attributes 26

SoilGrids: World Soil Data 27

GSDE: Gridded Global Soil Dataset for use in Earth System Models 27

4.1.2 Agricultural systems and management 27

MAPSPAM: Spatial Production Allocation Model 27
Table 3. crops included in the MapSpam dataset 27
EarthStat 28
Global Map of Irrigation Areas (GMIA) 28
Farm structure survey 28
Survey on agricultural production methods 29
4.1.3 Climate and hydrology 29
ECMWF: European Centre for Medium Range Weather Forecasts Climate 29
Table 4. Datasets available in ECMWF climate 29
Climate Research Unit Climate 30
University of New Hampshire: Global Runoff Data Centre 30
CORDEX database 30
4.1.4 Social data 30
GRUMP: Global Rural-Urban Mapping Project 30
World Bank 31
IIASA SSP Scenario database 31
4.2 Data catalogue 31
Table 6. Variables used in WP7 32
5 Selecting farming systems, agricultural management practices and soil quality indicators for upscaling 33
5.1 Selecting farming systems for upscaling 33
5.1.1 Farming systems in iSQPAPER D2.2 33
Table 7. Classification of Farming Systems adopted in Deliverable 2.2 34
5.1.2 Farming systems in other projects 34
SmartSOIL 34
Table 8. Farming systems considered in the SmartSOIL project. 35
Catch-C 35
5.2 Proposal of farming systems for upscaling in iSQAPER 37
5.3 Selecting agricultural management practices for upscaling 37
5.3.1 Agricultural practices in iSQAPER D3.2 37
Table 10. Agricultural practices in D3.2 38
5.3.2 Agricultural practices in other projects 38
WOCAT 38
SmartSOIL 39

Table 12. Management practices analysed in SmartSOIL project 39

CATCH-C 39

5.4 Proposal of management practices for upscaling in iSQAPER 40

5.5 Soil quality indicators linked to soil ecosystem services 40

5.5.1 Soil quality indicators in iSQAPER D3.1 and D3.2 40

5.5.2 Soil quality indicators in CATCH-V 41

5.6 Proposal of soil quality indicators to represent soil ecosystem services for upscaling 42

6 Definition of farming systems, agricultural management practices, and soil quality indicators 42

6.1 Farming systems 43

6.2 Agricultural management practices 46

6.2.1 Soil management 46

Figure 11. Tillage practice in Europe: Conventional tillage (% of arable land) 48

Figure 12. Tillage practice in Europe: Reduced tillage (% of arable land) 48

6.2.2 Crop management 49

Figure 13. Winter crop in Europe ((% of arable land)) 49

Figure 14. Crop rotation practice in Europe (% of arable land) 50

Figure 15. Bare soil in Europe (% of arable land) 50

6.2.3 Nutrient management 51

6.2.4 Water management 58

6.2.5 Organic agriculture 60

6.3 Spatial analysis of soil quality indicators 62

7 Effect of agricultural management practices on soil quality 67

7.1 Bottom-up analysis: based on experimental data from WP3 and WP4 67

7.1.1 Approach 67

7.1.2 Functional relations 68

Table 14. Effect of agricultural management practices on crop yield (based on D3.2) 68

7.2 Top-Down analysis: based on probabilistic estimates from spatial data ... 69

7.2.1 Regression analysis 69

Yield 69

Soil organic carbon 71
Water holding capacity 72
7.2.2 Conditional probability analysis 73
Yield 73
Soil organic carbon 76
Water holding capacity 77
8 Gaps in knowledge and further work 77
8.1 Gaps in knowledge and data 77
8.2 Further work 78
Step 1 79
Step 2 79
9 References 79
EU DG Eurostat 82
IPCC AR4 83
JRC soil data 83
LUCAS soil survey 84
MITERRA model, Alterra 85
WOCAT documentation 87

LIST OF FIGURES

Figure 1. Approach to evaluate the environmental footprint in WP7....................16

Figure 2. Approach to evaluate the environmental footprint in WP7....................23

Figure 3. Harvested cereal area fraction in Europe and China (%) 43

Figure 4. Harvested rice area fraction in Europe and China (%)..........................43

Figure 5. Harvested maize area fraction in Europe and China (%).......................44

Figure 6. Harvested soybean area fraction in Europe and China (%) 44

Figure 7. Harvested vegetables area fraction in Europe and China (%)................45

Figure 8. Harvested pasture area fraction in Europe and China (%) 45

Figure 9. Harvested permanent crops area fraction in Europe and China (%) 46

Figure 10. Organic matter management in Europe: Residue management (% of arable land)...47

Figure 11. Tillage practice in Europe: Conventional tillage (% of arable land)......48

Figure 12. Tillage practice in Europe: Reduced tillage (% of arable land) 48

Figure 13. Winter crop in Europe ((% of arable land))......................................49

Figure 14. Crop rotation practice in Europe (% of arable land) 50

Figure 15. Bare soil in Europe (% of arable land)...50

Figure 16. Cereal K application rate (kg/ha)..51

Figure 17. Cereal N application rate (kg/ha)..51

Figure 18. Cereal P application rate (kg/ha) 52

Figure 19. Rice K application rate (kg/ha)...52

Figure 20. Rice N application rate (kg/ha)...53

Figure 21. Rice P application rate (kg/ha) 53

Figure 22. Maize K application rate (kg/ha) 54

Figure 23. Maize N application rate (kg/ha) 54

Figure 24. Maize P application rate (kg/ha) 55

Figure 25. Soybean K application rate (kg/ha) 55

Figure 26. Soybean N application rate (kg/ha) 56

Figure 27. Soybean P application rate (kg/ha) 56

Figure 28. Potato K application rate (kg/ha) 57

Figure 29. Potato N application rate (kg/ha) 57

Figure 30. Potato P application rate (kg/ha) 58

Figure 31. Total irrigated area in 1000 ha 58

Figure 32. Percentage of irrigated area of equipped area for irrigation (%) 59

Figure 33. Area equipped for irrigation (ha) 59

Figure 34. Percentage of area equipped for irrigation 60

Figure 35. Area of organic farming as percentage of the utilized agricultural area (UAA), from SmartSOIL...61

Figure 36. Cereal yield in Europe and China (t/ha) 62

Figure 37. Rice yield in Europe and China (t/ha) 62

Figure 38. Maize yield in Europe and China (t/ha) 63

Figure 39. Soybean yield in Europe and China (t/ha)..63

Figure 40. Vegetables yield in Europe and China (t/ha) 64

Figure 41. Pasture yield in Europe and China (t/ha) 64

Figure 42. Permanent crops yield in Europe and China (t/ha) 65

Figure 43. Soil organic carbon in Europe and China (% in weight) 65

Figure 44. Water holding capacity in Europe and China (mm/m).........................66

Figure 45. results of the linear regression analyses performed on crop yield as a function of irrigated area for the seven farming systems in Europe: Cereal (1st row left), Rice (1st row right), Maize (2nd row, left), Soybean (2nd row, right), Vegetables 3rd row, left), Pasture (3rd row, right) and Permanent crops (4th row) 70

Figure 46. results of the linear regression analyses performed on crop yield as a function of irrigated area for the seven farming systems in China: Cereal (1st row left), Rice (1st row right), Maize (2nd row, left), Soybean (2nd row, right), Vegetables 3rd row, left), Pasture (3rd row, right) and Permanent crops (4th row) 71

Figure 47. results of the linear regression analyses performed on soil organic carbon as a function of irrigated area for Europe (left) and China (right)..................72

Figure 48. results of the linear regression analyses performed on water holding capacity as a function of irrigated area for Europe (left) and China (right) 73

Figure 49. Results of the conditional probability analyses performed on crop yield as a function of irrigated area for the seven farming systems in Europe: Cereal (1st row left), Rice (1st row right), Maize (2nd row, left), Soybean (2nd row, right), Vegetables 3rd row, left), Pasture (3rd row, right) and Permanent crops (4th row) 74

Figure 50. Results of the linear regression analyses performed on crop yield as a function of irrigated area for the seven farming systems in China: Cereal (1st row left), Rice (1st row right), Maize (2nd row, left), Soybean (2nd row, right), Vegetables 3rd row, left), Pasture (3rd row, right) and Permanent crops (4th row) 75

Figure 51. results of the linear regression analyses performed on soil organic carbon as a function of irrigated area for Europe (left) and China (right)..................76

Figure 52. Results of the linear regression analyses performed on water holding capacity as a function of irrigated area for Europe (left) and China (right) 77

LIST OF TABLES

Table 1. Indicators summary. These indicators will also include the list of indicators proposed by WP4 and WP5 for the local case studies, to ensure the harmonization of the methodologies included in the SQAPP 24

Table 2.SGDBE Attributes 26

Table 3. crops included in the MapSpam dataset...27

Table 4. Datasets available in ECMWF climate 29

Table 5. Sources of information on agricultural systems and soil management practices 32

Table 6. Variables used in WP7...32

Table 7. Classification of Farming Systems adopted in Deliverable 2.2.................34

Table 8. Farming systems considered in the SmartSOIL project..........................35

Table 9. Classes adopted in the Catch-C project for farm specialization and farm land use. Adapted from Catch-C (2013). 36

Table 10. Agricultural practices in D3.2 38

Table 11. Categories of management practices in WOCAT according to three classification criteria 38

Table 12. Management practices analysed in SmartSOIL project.........................39

Table 13. Soil quality indicators adopted in Catch-C project 42

Table 14. Effect of agricultural management practices on crop yield (based on D3.2)..68

Table 15. Effect of agricultural management practices on soil organic carbon (based on D3.2) 68

Table 16. Effect of agricultural management practices on water holding capacity (based on D3.2) 69

Executive summary

Numerous technical improvements and agricultural management practices have facilitated the improvement of soil ecosystem services with an improved environmental footprint. It is to be expected that these changes in agricultural practices will continue into the future. Based on historical records of crop and soil management practices in Europe and China and models of the main ecosystem services, WP7 will estimate the future environmental footprint under different climate and policy scenarios. In doing this, due attention will also be given to global environmental and climate policies.

A main effort in D7.1 is to identify and characterize a relatively limited number of typical farming systems in Europe and China with relevant crop and soil management practices building on work from previous WPs of the iSQAPER project. In this document we present the proposed methodology for upscaling in the iSQAPER project. Upscaling intends to assess soil environmental footprint and therefore it is focused on three main ecosystem services linked to soil quality: food provisioning, water provisioning and regulation, and climate regulation. The analysis is based on three categories: farming systems, agricultural management practices and soil quality factors.

The work in WP7 builds on elements and resources for the characterization of the soil threats, pedoclimatic zones, typical farming systems, and typical agricultural practices, that have been analysed and reported in WP 2, 3, 5, and 6. Many aspects and data have been mainly collected from different iSQAPER partners, official databases (such as Eurostat) and also from global datasets (JRC, MapSpam, EarthStat, ISRIC, FAO). We build from these publicly available datasets on soil, agriculture, physical context and socioeconomic context. These data have been compiled, processes and projected on a common geospatial framework that allows for cross-data analyses.

The categorization of farming systems, agricultural management practices and soil quality indicators is based on work carried out in iSQAPER and previous projects concerned with soil health. This work has been carefully reviewed and analysed in order to extract the most relevant features for upscaling. In each agricultural region there may be a very large number of indicators for upscaling. In our methodology, we provide a balance between the maximum number of indicators that can be distinguished and the minimal number of systems that should be considered in order to obtain a representative view of the effect of soil management practices on the environmental footprint. As a result, a proposal is made to consider seven categories of farming systems (cereals, rice, maize, soybean, vegetables, pasture and permanent crops), five categories of agricultural management practices (soil management, crop management, nutrient management, water management and organic agriculture) and three categories of soil quality indicators that can be linked to ecosystem services (crop yield, organic carbon and water holding capacity). All these categories are based on analyses carried out in WP3, 5 and 6 of the iSQAPER project. Based on these studies the categories have been properly defined and characterized.

The farming systems selected in this deliverable provide a broad overview of the different types of systems that are common in Europe and China. These farming systems are characterized in this Deliverable 7.1, including: geographical zones, spatial extent, productivity level and intensity of land and resource (fertilizer and manure) use, management practices, and irrigation. We have compiled data from all categories of farming systems, management practices and soil quality indicators and present a spatial representation of the available information for Europe and China. It includes, spatial location, intensity of resource use and crop yield for farming systems, degree of implementation for agricultural practices and available information on soil quality status. These generalised results for Europe and China will be compared with inventories conducted in the case study regions. This will be done in Task 7.3.

We present an analysis of the combinations of farming systems and agricultural management practices in Europe and China, together with an estimation of the influence of AMPs on soil quality, based on geostatistical inference derived from the spatial datasets and on iSQAPER project results derived from the long term experiments and from the case study sites. This approach will be validated in bottom-up expert assessment through a questionnaire that will be circulated among project partners.

1 Introduction

1.1 Integration of WP7 in iSQAPER

WP7 upscales the effect of agricultural management practices on representative farming systems to evaluate the soil environmental footprint in Europe and China. Current and future scenarios will be evaluated. The work relies on the extensive and comprehensive work developed in WPs 2 to 8 (Figure 2). WP7 also develops a socio-economic analysis to represent the social, economic and demographic changes that induce changes in farming systems and management practices. WP2 provides detailed pedoclimatic analysis, that is the basis of the spatial analysis in WP7. The background information on farming systems, agricultural management practices and soil quality indicators developed in WPs 3 and 5 supports the assessment with rich data and analysis of the process at the site level. The effect of agricultural systems in soil quality is based in the data provided in WPs 5 and 6. The scenarios for policy are based on interactions and ongoing discussions with WPs 4 and 8. WP7 captures the real farmers and policy knowledge by co-developing a dynamic model with stakeholders; the interaction will take place by informal consultations and in a formal workshop.

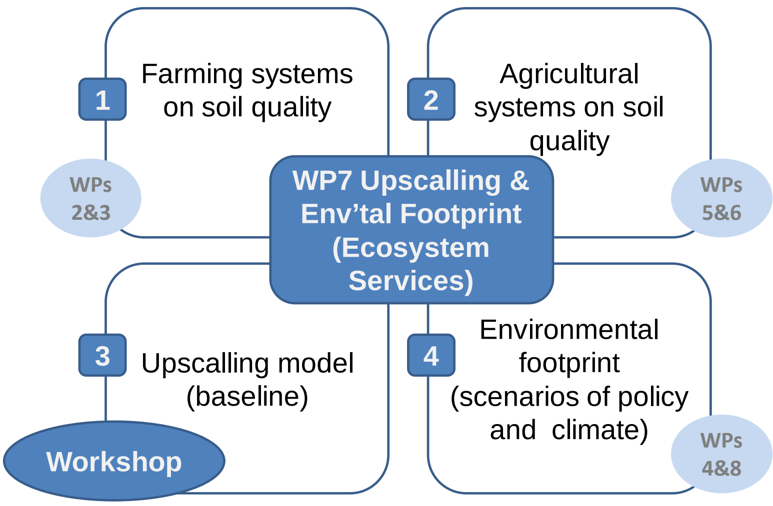

Figure 1. Approach to evaluate the environmental footprint in WP7

1.2 Objectives

This Deliverable 7.1 is framed into Work Package (WP) 7 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 7.1 defines typical combinations of farming systems and agricultural practices and their effects on soil quality. Soil quality is relevant in WP7 because it determines the soil environmental footprint, which is one of the main objectives of the work. In this WP, soil environmental footprint is understood as the beneficial or damaging impacts of the soil management on the environment. It may be evaluated by the amount of natural resources that are required (e.g., water) or produced (e.g., crop productivity) by agricultural practices or through the amount of harmful gases that are sequestered or produced (e.g., CO_2 or NOx).

This iSQAPER deliverable presents the conceptual basis for upscaling project results and evaluation of soil environmental footprint under several future scenarios. Following this introduction, Section 2 summarises previous knowledge on upscaling approaches in geospatial environmental studies, Section 3 presents the approach developed for iSQAPER in this WP; Section 4 describes the data catalogue and sources; Sections 5 and 6 include the spatial analysis of the farming systems and agricultural practices. Section 7 presents the analysis of combinations of farming systems and agricultural management practices in Europe and China, together with an estimation of the influence of AMPs on soil quality, based on iSQAPER project results, and Section 8 outlines further steps to analyze all these variables with the aim of evaluating the effect of management practices on the soil environmental footprint.

2 Upscaling approaches in geospatial environmental studies

2.1 The scale of social and environmental policies

The knowledge that humans are impacting the environment at planetary scales has led to reflect on the scientific frameworks that would upscale the interactions and feedback mechanisms empirically observed at local scales (Verburg et al. 2016). The need to anticipate correctly the interactions at the higher level is driven by the scales of social-environmental policies (Vergurg et al., 2016).

2.2 The concept of upscaling

Societies and ecosystems interact over many spatial and temporal scales (Cumming et al., 2006) and upscaling refers to the process of reconstituting activities or phenomena at a higher or larger geographical scale (Cumming et al., 2006).

The concept of scale has been extensively reviewed (e.g. Wiens 1989; Levin 1992; Gibson et al. 2000; Turner et al. 2001) and used in subtly different ways in biophysical and social sciences (Gibson et al. 2000). Social and geographical scales are often, but not always, aligned (Cumming et al. 2006). In bio-physical sciences, scale usually refers to the spatial and temporal dimensions of a pattern or process and it is also called “geographic scale”. Geographical scale has two main attributes: resolution of the observations and extent (Turner et al. 2001; Rietkirk et al. 2002). In the social sciences, scale includes the representative nature of social structures from individuals to organizations as well as the social institutions that govern the spatial and temporal extent of resource access rights and management responsibilities (e.g. Barbier 1997; Chidumayo 2002; Ziker 2003; Bodin and Norberg 2005).

Upscaling is often a form of extrapolation to a larger extent or coverage. Most social and environmental variables vary with extent but are not generally proportional to it. These scale-specific variables include the soil health and soil management data considered in iSQAPER. The upscale approach may be addressed by simple statistical transformation, but often the problem is better solved when we have an understanding of underlying social and ecological processes.

Depending on the research question or the environmental policy application, the appropriate resolution of the data varies temporally, spatially, and in the layers of information (e.g., in soil data, the profile). Regardless of the scale used to address a research or public policy question, the temptation is always there to extrapolate from fine-resolution data or to interpolate from coarse resolution studies. In both cases, the relevance of data and analyses conducted on one spatial level to other levels cannot be taken for granted. Spatial heterogeneity on the micro-scale may not be detected using coarse spatial resolution, and conversely, general patterns on the macro-scale may not be detected using fine spatial resolution (Turner et al., 1989; Levin, 1992; Wiens, 1989; Qi and Wu, 1996).

Several general questions need to be considered in geospatial environmental studies, including the following: (i) what are the best criteria for selecting the spatial (and temporal) unit of intervention and analysis? (ii) how do the key measures of risk and management dynamics vary with scale? (iii) how do we integrate processes occurring at diverse spatial and temporal scales? All of these questions can only be addressed through solid biophysical, agronomic and socio-economic understanding of the system in time and space.

The upscaling approaches depend on the research question and the spatial extent. The research questions in WP 7 are: (a) what is the effect of soil management practices on soil ecosystem services? and (b) what is the environmental footprint of different climate and management scenarios? The spatial extent of the analysis is the national or continental level in Europe and China.

2.3 Upscaling approaches: Models

Models that represent the scientific knowledge are auxiliary tools that may be used in upscaling, especially when it is necessary to represent socio-ecological processes, which is the case of iSQAPER (soil properties and management practices). Soil properties are represented based on the work detailed in WP2 and WP4. In contrast, management practices are socio-economic responses that include behavioural assumptions that are difficult to capture.

Validation of a model is good modelling practice, but is seen as an extremely complex challenge for integrated and complex system models (Parker et al. 2002). Procedures for evaluation and validation are rarely rigorously applied to the global-scale integrated assessment models used to inform major global assessments due to the lack of consistent time series of empirical data.

Overall, the design of conceptual models and the structure of modelling frameworks should be used as a tool to structure our current understanding of the system, rather than as a way to develop theory on socio-ecological systems.

The overwhelming number of possible feedbacks in complex systems can cause our models to become overly complex (Voinov and Shugart, 2013). Feedbacks make models extremely sensitive to error propagation in which small deviations in initial parameters can lead to large system-wide changes, especially in the case where the feedback is reinforcing itself.

In general terms, if we are to address policy-relevant issues in our approaches, we will need to provide a higher spatial and temporal resolution in our models accounting for the scales at which policy making operates.

Current large scale assessment models are not often taken very seriously by people in the region because they generate information that is simply not useful at the local level.

A few ways have been proposed to better incorporate these multi-scale issues in large-scale models. Most of these, reviewed by Ewert et al. (2011) for agricultural systems, are based on the linking of models operating at different scales in a top-down manner in which local dynamics are simulated in response to higher-scale model dynamics (e.g. Raworth 2012). Bottom- up interactions and feedbacks can conceptually be implemented in such coupled model systems but are only infrequently operationalized due to the complex and iterative interactions between models that would become necessary. Alternative approaches of capturing cross-scale dynamics by a more explicit representation of the scalar dynamics in a single approach have been given much less attention (Ewert et al.; 2011; van Wijk 2014). Some have warned that cross-scale dynamics are probably highly a-symmetric: where the importance of effects going up-scale (from land user up to global trade flows and climate change) are likely to be relatively weak, the feedbacks from the global processes down to local land users are very strong (e.g. price changes, regulations, subsidies, etc.) (Giller et al, 2008). However, while we agree on the a-symmetry of these cross-scale dynamics these are strongly depending on the process characteristics and societal context.

An alternative approach is the upscaling of local dynamics through the identification of aggregate response patterns that are based on the scaling of local responses. Instead of representing the behaviour of individuals, in this approach the agency (aggregate behaviour) of communities is captured while still retaining the differential characteristics of these communities based on their composition and socio-cultural context (Dobbie et al. 2015). Upscaling may also be achieved through nesting detailed models at individual level within a more aggregate model to derive aggregate responses.

Upscaling methods that include modelling can be divided into four major classes (Bierkens et al. 2000):

- averaging observations or model outputs,
- finding representative parameters or input variables,
- averaging model equations, and
- model simplification.

The different classes are based upon five criteria (Bierkens et al., 2000):

- whether a model is involved,
- whether the model is linear in its input variables and parameters,
- whether the model can be employed at many locations or time steps,
- whether the form of the model is the same at the two scales involved, and
- whether the larger scale model can be analytically derived from the smaller scale model.

Geostatistical methods estimate variability as a realization from a stochastic function, where the weights depend upon both the sample configuration and a model of spatial-temporal structure estimated from the data (e.g. block kriging).

Approaches for finding non-exhaustive representative information include deterministic functions and stochastic methods (Bierkens et al.; 2000). Deterministic functions provide full coverage with a method of interpolation.

Stochastic methods, with statistics estimated from known information, describe unknown variations with conditional realizations from a stochastic function, ultimately yielding a single probability distribution.

Methods for averaging model equations (i.e., temporal/volume and ensemble averaging) and model simplification (i.e., lumped conceptual and meta modelling) are discussed by Bierkens et al. (2000).

2.4 Upscaling approaches: Clustering

Clustering methods are useful to detect the agricultural farming systems with different degree of impacts of the agricultural management practices on soil quality. Clustering methods use spatial statistics as exploratory tools that allow the detection and identification of clusters without a pre-determined hypothesis about cluster location (Besag and Newell 1991; Lawson 2001). In WP7 we use a probabilistic approach to detect the significant effect of agricultural management practices on soil quality indicators. This approach may provide three measures of clustering: (a) the nearest neighbor distance (i.e. the distance from the tested measurement); (b) the maximum clustering distance (the distance where clustering is maximized); and (c) the significant clustering distance (i.e. the distance at which clustering is statistically significant) (Getis and Franklin, 1987).

The fine scale resolution data, when available, can provide detailed information on the processes responsible for the effect of soil management practices, allowing testing and validation of spatial data and to improve the continental scale estimates. However, data for the spatial analysis and management decisions often take place on a much coarser resolution, and more general mechanisms may not be inferred from such fine resolution data (e.g. greening policies).

2.5 Upscaling approaches: Co-design

While models are mostly used as tools for researchers aimed at exploring system functioning, co-design and co-production of research has become important in global change research (Cornell et al. 2013).

Co-production approaches are used in decision support systems in which the algorithms are updated with stakeholder input during the process (Eikelboom and Janssen, 2013; Vonket al. 2005). Co-design is the central aim of Task 7.3.

2.6 Challenges for upscaling the soil environmental footprint

Here we try to provide answers to three questions: What are the appropriate levels of abstraction and representation given the questions we seek to address? What tools are available to use in iSQAPER?

The typical upscaling–downscaling exercise involves the following four steps (Bloschl 2005): (i) analyzing the local data and scrutinizing the literature to decide on the model type, (ii) estimating the parameters from the data, (iii) verifying the upscaling–downscaling model against an independent data set, and (iv) performing the actual upscaling–downscaling step.

Bloschl (2005) discusses upscaling–downscaling for six important cases: (i) upscaling point rainfall to catchments, (ii) temporal disaggregation of rainfall, (iii) statistical downscaling of the output of global circulation models, (iv) flood frequency as a function of catchment scale, (v) upscaling and downscaling soil moisture, and (vi) subsurface media characterization and generation. Overviews of both upscaling and downscaling methods are provided in the following subsections.

Costantini and L'Abate (2016) reviewed the upscaling approaches that are available that represent aspects of soil health and soil management. Approaches differ in scope, purpose and structure. Most approaches are designed in response to either a science question or a management question, and address a specific spatial and temporal scale.

Here we intent to use the upscaling results to support management and policy decisions, and the questions posed by different stakeholders.

We will use scenarios to explore the possible outcomes of uncertain (societal) developments. Scenario simulations are important in raising policy issues and creating societal awareness of possible future challenges. Scenarios are used to capture some of the assumed range in uncertainty of major drivers of societal change such as population, economic development and policy.

For policy design, upscaling and scenario analysis can play a role in designing possible solutions, e.g. the optimal distribution and location of soil management choices. In this sense, the approach is goal-oriented and may use optimization techniques to design solutions accounting for present and future boundary conditions set by the socio-ecological system (Seppelt et al., 2013). Although such approaches can account for the constraints associated with the implementation of the prescribed ‘optimal’ management, they do not provide insights in the pathway to achieving these outcomes.

By making simulations the approach can support target-setting by analysing the trade-offs resulting from alternative ‘optimal’ management strategies.

Alternatively, upscaling can be used to investigate the effectiveness and unintended consequences of proposed policy measures through ex-ante assessment (Helming et al., 2011).

Appropriate methods must reconcile different spatial and temporal scales. Appropriate approaches require insights into the questions posed by a range of stakeholders, and address the concerns of policy makers and society as a whole.

How do current upscaling approaches handle these issues and address the questions of soil environmental footprint? The selected set of soil quality indicators can be integrated in various ways to combine the relevant dimensions of environmental footprint. In this Deliverable, we direct our attention to typical combinations of farming systems and agricultural practices. In particular, a cluster analysis of the five farming systems indicators is employed to investigate the structure of the data space. Here, crop dimensions remain transparent, as they are not merged into one value which is a usual procedure in conventional studies. In contrast, the cluster analysis keeps the individual dimensions discernible. The cluster method, however, does not automatically generate an environmental footprint indicator ranking. This needs an additional qualitative interpretation of the different clusters. The qualitative interpretation is feasible because it has to be performed only for a limited number of resulting representative indicator combinations.

3 Approach to evaluate the soil environmental footprint in WP7

3.1 Framework

The focus of the dynamic analyses carried out in WP7 is soil management environmental footprint. We analyse how agricultural management practices improve or deteriorate critical soil properties that are relevant to determine the beneficial or damaging impact of soils on the environment. 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 factors that are considered essential.

The benefits that are derived from ecosystems are collectively referred as ecosystem services. We have selected three main ecosystem services directly linked to soil quality: food, water and climate regulation. These basic ecosystem services are relevant in Europe and China and may be directly linked to social welfare. These ecosystem services may be affected by soil threats, like water quality problems, erosion, decrease of soil organic carbon, and others. We have identified four major soil threats that can be linked to soil ecosystem services, as presented in Figure 1. The linkages are defined based in the science reported in WP3 and WP 5 and discussed below.

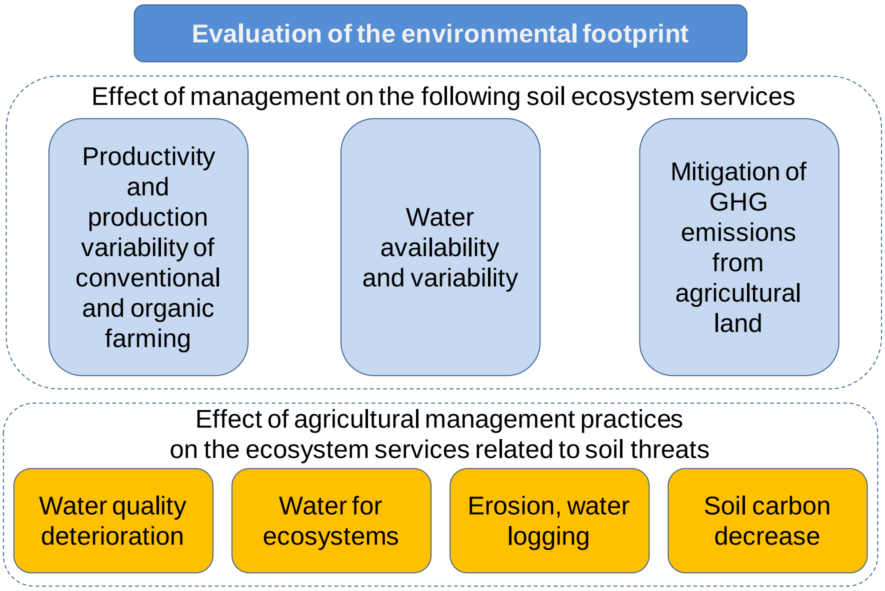

Figure 2. Approach to evaluate the environmental footprint in WP7

Here is brief description of the ecosystem services that will be considered:

Food production

The productivity and production variability of main groups of crops will be evaluated based on simplified functions that respond to management practices, as analysed in Deliverable 3.2 from long term experiment site data. These groups will include: the main extensive field crops (wheat, maize and soybean), rice, horticulture, and permanent crops and pasture. These crops are also very relevant to livestock production, especially maize and soybeans. Soybeans are relevant to greenhouse gas mitigation since it is a leguminous crop, capable of fixing nitrogen and therefore does not require nitrogen fertilisation at the same level as cereals. Both organic and conventional agriculture will be taken into account. Food production may be affected by soil and water pollution originated by poor management practices.

Water availability and variability

Water is a key factor to be managed to enhance agricultural benefits. In rainfed farming systems, the objective of management may be to maximize soil infiltration and soil water holding capacity or to drain excess water to ensure good crop growth. In irrigation, the aim is to provide water from external sources to supplement rainfall at timely intervals for the crop. Irrigated agriculture has experienced a tremendous expansion during the second half of the twentieth century and water availability may be a limiting factor for such practice in the future. The water availability for agriculture will be estimated with the WAPAA model (Garrote et al. 2015) to represent the potential for irrigation and the water available for ecosystems. Water also plays a significant role as regulating service, dampening natural fluctuations. An evaluation of the risk of extreme events (floods and drought) will be included. Here the actual water consumption of existing irrigated agriculture will be evaluated. This indicator has direct linkage to the availability of water for ecosystem services, soil erosion and water logging.

Greenhouse gas emissions from agricultural land

The GHG emissions from agricultural land will be calculated on the basis of the SmartSOIL project methodology (SmartSOIL, D3.2; Olesen et al. 2014). The GHG emission mitigation management measures can be related with changes in soil organic carbon stocks and flows and to the nitrogen ferlitiser inputs, ultimately providing useful information on effectiveness of these measures under varying conditions and assumptions regarding their effect on nutrient availability and yield.

3.2 Indicators for upscaling

The objective is to identify and characterize a relatively limited number of representative farming systems, agricultural practices and pedoclimatic units that will inform on the environmental footprint at the Europe and China wide scale. These units of analysis and thresholds are defined: (a) building on work from previous WP of the iSQAPER project; (b) structuring the analysis as proposed in Section 2 of this document; (c) taking into account additional global sources of data; and (d) exploring the possible validation and contribution of the case studies, that will be included in Task 7.2.

The indicators in the databases of WP 3, 5 and 6 regarding the typical farming systems and soil management practices are summarised in the following table (Table 1). These indicators will be made spatially explicit if enough information is available.

Table 1. Indicators summary. These indicators will also include the list of indicators proposed by WP4 and WP5 for the local case studies, to ensure the harmonization of the methodologies included in the SQAPP

Indicators	Description / Comment
Main farming systems	We aggregate into five main farming systems: Field crops, Rice, Permanent crops, Pasture and grasslands, Horticulture.
Total utilized agricultural area at the continental scale (UAA)	Area is expressed in 1000 ha and is based on the sum of all crop areas, including grazing.
Area of main farming system	The area of main farming system is expressed in 1000 ha of the total utilized agricultural area.
Crop yield in the main farming system	The average crop yield, in kg of dry matter per ha, is provided for the main farming systems. The unit of analysis will be 0.5 x 0.5 degree resolution
Main soil management practices of the main farming system	Main combinations of soil management practices relevant for soil ecosystem services for the main farming system.
Use of soil management practices based on areas relative to arable land	Agricultural management practices relevant for soil health. The implementation level is expressed as the percentage of land under a certain management practice, compared to the total area of arable land.
Irrigated area	The total irrigated area (in 1000 ha) may be derived from the SAPM 2010 survey from Eurostat.
Main limiting factor to attain potential production	The combinations of main limiting factors which affect potential production in the main farming

	system provided by partners for regions of case study countries (bottom-up assessment).
Nitrogen fertilizer use	The average nitrogen fertiliser use (kg N /ha), consisting of both animal manure and mineral fertilizer.
Organic farming percentage of the agricultural area	The area of organic farming is expressed as percentage of the utilized agricultural area, and it excludes the farms in conversion to organic farming.
Climate classification	We aggregate into five main climate zones: Boreal, Atlantic, Alpine, Continental and Mediterranean.
Pedoclimatic zones	Pedoclimatic zones as defined by WP2
Other aspects related to implementation at the farmer and policy levels	To be decided in Task 7.3 and implemented in Task 7.4

3.3 Definition of thresholds

The upscaling approach is framed in qualitative terms. The objective is to identify management practices that have positive or negative effects on soil quality indicators linked to soil ecosystem services and thus assess the projected impact of alternative policies in future scenarios.

The upscaling approach will deal with qualitative variables formulated in a domain of five categories. The proposed methodology for identifying categories is inspired on the Likert scale. Likert scaling is a bipolar scaling method, measuring either positive or negative response to a statement. Experts will be asked to fill a questionnaire about the impact of management practices on soil quality. Based on their responses and on the analyses carried out in WP3, the effect of the management practice for every farming system will be classified in the following categories:

Positive (++): This category means that the management practice will certainly improve the soil quality indicator, with effects larger than 10%

Beneficial (+): This category means that the management practice has potential to improve the soil quality indicator, but the effects may depend on additional factors. The improvement will be between 5% and 10%

Neutral (=): This category represents a neutral impact of the management practice on the soil quality indicator under analysis. It corresponds to a positive or negative effect of less than 5%.

Unfavourable (-):This category means that the management practice may degrade the soil quality indicator, but the effects may depend on additional factors. The degradation will be between 5% and 10%

Negative (--): This category means that the management practice will certainly degrade the soil quality indicator, with effects larger than 10%

4 Data

4.1 Data sources of geo-spatial data

This section presents the sources of information consulted to build the data catalogue. Sources of information have been classified in four categories: soil data, agriculture data, physical context data and socioeconomic context data. For each source of information, we present a description of the content and present some information related to the type of data available.

4.1.1 Soils

JRC Soils: European Soil Data Center (ESDAC)

The Soil Geographical Database of Europe (SGDBE). The raster library provides 1kmx1km coverages of many soil attributes, listed in Table 2. Available formats are ESRI grid or Google Earth kmz. Below si an example.

Table 2.SGDBE Attributes (definition included in https://esdac.jrc.ec.europa.eu/ESDB_Archive/ESDBv2/fr_intro.htm)

AGLIM1	AGMLIM2	BORDER_SOIL1	BORDER_TYPE	CFL	CL	COUNTRY
DT	FAO85_FULL	FAO85_LEV1	FAO85_LEV2	FAO85_LEV3	FAO90_FULL	FAO90_LEV1
FAO90_LEV2	MAT1	MAT11	MAT12	MAT2	MAT21	IL
MAT22	NON_SOIL	PAR_MAT_DOM	PAR_MAT_DOM1	PAR_MAT_DOM2	PAR_MAT_DOM3	PAR_MAT_SEC
PAR_MAT_SEC1	PAR_MAT_SEC2	PAR_MAT_SEC3	PC	PCAREA	ROO	SLOPE_DOM
SLOPE_SEC	SMU	SOIL	SOIL1	SOIL1M	SOIL2	SOIL3
SOIL90	SOIL901	SOIL902	STU	TD1	TD2	TEXT_DEP_CHG
TEXT_SRF_DOM	TEXT_SRF_SEC	TEXT_SUB_DOM	TEXT_SUB_SEC	TEXT1	TEXT2	USE_DOM
USE_SEC	USE1	USE2	WM1	WM2	WR	WRB_ADJ1
WRB_ADJ2	WRB_FULL	WRB_LEV1	WRB_SPE1	WRB_SPE2	ZMAX	ZMIN

For example, the WM1 attribute is a code for normal presence and purpose of an existing water management system on more than 50% of the STU. The following values are present:

- 0 No information
- 1 Not applicable (no agriculture)
- 2 No water management system
- 3 A water management system exists to alleviate waterlogging (drainage)
- 4 A water management system exists to alleviate drought stress (irrigation)
- 5 A water management system exists to alleviate salinity (drainage)

- 6 A water management system exists to alleviate both waterlogging and drought stress
- 7 A water management system exists to alleviate both waterlogging and salinity

SoilGrids: World Soil Data

SoilGrids is designed as a globally consistent, data-driven system that predicts soil properties and classes using global covariates and globally fitted models. It provides maps a 250x250 m^2 resolution with probability of each soil class (according the World Reference Base – WRB - an USDA Soil Taxonomy; TAXNWRB and TAXOUSDA databases), most probable soil class and several soil properties: Physical (Bulk density, Clay content, Coarse fragments, Silt content, Sand content) and Chemical (Cation exchange capacity, Soil organic carbon content, Soil pH in H2O, Soil pH in KCl)

GSDE: Gridded Global Soil Dataset for use in Earth System Models

GSDE provides soil information including soil particle-size distribution, organic carbon, and nutrients, etc. and quality control information in terms of confidence level. GSDE is based on the Soil Map of the World and various regional and national soil databases, including soil attribute data and soil maps. It includes general information for soil profiles for 11 types of soil and 34 soil properties for 8 depths. Two versions are available with resolution 30 seconds (~1km) and 5 minutes (~10km).

4.1.2 Agricultural systems and management

MAPSPAM: Spatial Production Allocation Model

The MapSpam Cropland dataset (You et al., 2017) provides raster information about 42 important crops. Each of the crops can be measured in terms of four variables: area harvested, physical area, production, and yield. Each crop and variable can be decomposed into two production systems: irrigated and rainfed. The maps are globally available in 5 minute (~10km)grid resolution. The crops included in the MapSpam dataset are listed on Table 3.

Table 3. Crops included in the MapSpam dataset

Banana	Barley	Bean	Cassava	Cereals Other
Chickpea	Cocoa	Coconut	Coffee Arabica	Coffee Robusta
Cotton	Cowpea	Fibers Other	Fruit Temperate	Fruit Tropical
Groundnut	Lentil	Maize	Millet Pearl	Millet Small
Oil Crops Other	Oil Palm	Pigeonpea	Plantain	Potato
Pulses Other	Rapeseed	Rest of Crops	Rice	Roots & Tubers Other
Sesame Seed	Sorghum	Soybean	Sugar Beet	Sugar Cane
Sunflower	Sweet Potato	Tea	Tobacco	Vegetable
Wheat	Yam			

EarthStat

EarthStat offers geographic data sets related to agriculture and the environment. EarthStat is a collaboration between the Global Landscapes Initiative at The University of Minnesota's Institute on the Environment and the Ramankutty Lab at The University of British Columbia, Vancouver. They provide data on Cropland and Pasture area, Harvested Area and Yield for 175 crops, Greenhouse Gas Emissions from Croplands, Climate Variation Effects on Crop Yields for 4 major crops (Maize, Soybean, Rice and Wheat), Yield Trends and Changes for 4 major crops, Water Depletion and WaterGap3 Basins, Yield Gaps and Climate Bins for Major Crops, Nutrient Application for Major Crops, Total Nutrient Consumption for 140 Crops, Total Nutrient Balance for 140 Crops, Potential Natural Vegetation and Carbon Stocks in Potential Natural Vegetation.

Data are available in different formats and coverages. For instance, data for the 175 crops are available in Netcdf, Geoitiff or GoogleEarth forms at 5 minute (~10km) grid resolution (Monfreda et al. 2008).

Global Map of Irrigation Areas (GMIA)

The GMIA is a global irrigation mapping facility developed by the Land and Water Division of FAO and the Rheinische Friedrich-Wilhelms-Universität in Bonn. They provide a world coverage raster at a resolution of 5 min (~10 km) of several variables:

- Area equipped for irrigation expressed as percentage of total area
- Area equipped for irrigation expressed in hectares per cell
- Area actually irrigated expressed as percentage of area equipped for irrigation
- Area irrigated with groundwater expressed as percentage of total area equipped for irrigation
- Area irrigated with surface water expressed as percentage of total area equipped for irrigation
- Area irrigated with water from non-conventional sources expressed as percentage of total area equipped for irrigation

This dataset is distributed by Aquastat (a FAO database).

Farm structure survey

The basic farm structure survey (FSS) is conducted consistently throughout the EU with a common methodology at a regular base and provides therefore comparable and representative statistics across countries and time, at regional levels (down to NUTS 3 level). Every 3 or 4 years the FSS is carried out as a sample survey, and once in ten years as a census. The 2010 census covers the EU-27 Member States, Croatia, Iceland, Norway, Switzerland, Montenegro and Serbia.

Survey on agricultural production methods

The Survey on agricultural production methods (SAPM) was a one-off survey in 2010 to collect farm level data on agri-environmental measures to support monitoring of the relevant European Union policies (e.g. the Common Agricultural Policy, Rural Development Policy, etc.) and to establish agri-environmental indicators. European Union Member States could choose whether to carry out the SAPM as a sample survey or as a census survey. Data were collected on tillage methods, soil conservation, landscape features, animal grazing, animal housing, manure application, manure storage and treatment facilities and irrigation.

4.1.3 Climate and hydrology

ECMWF: European Centre for Medium Range Weather Forecasts Climate

ECMWF provides are several data products related to climate, including reanalysis of observations and average derived variables. The available datasets are summarized in Table 4.

Table 4. Datasets available in ECMWF climate

Dataset	Description	Licence
cams_gfas	Global Fire Emissions and Smoke (GFAS) in the Copernicus Atmosphere Monitoring Service (CAMS)	Copernicus
cams_nrealtime	CAMS Near Real-time	Copernicus
cera20c	Coupled ECMWF Reanalysis (CERA) (Jan 1901 - Dec 2010)	general
era15	ECMWF Global Reanalysis Data - ERA-15 (Jan 1979 - Dec 1993)	general
era20c	Reanalysis of the 20th-century using surface observations only (Jan 1900 - Dec 2010):	general
era20cm	ERA-20CM: Ensemble of climate model integrations (Final version)	general
era20cmv0	ERA-20CM: Ensemble of climate model integrations (Experimental version)	general
era20c_ofa	ERA-20C feedback (January 1900 - December 2010), containing in situ, surface observations	general
era40	ECMWF Global Reanalysis Data - ERA-40 (Sep 1957 - Aug 2002)	general
era5	ERA5	Copernicus
era5_test	ERA5 Test version	era5_test
geff_reanalysis	GEFF Reanalysis Dataset	general
icoads	ICOADS v2.5.1 with interpolated 20CR feedback	research
interim	ECMWF Global Reanalysis Data - ERA Interim (Jan 1979 - present)	general
interim_land	ERA Interim/LAND	general
ispd	ISPD v2.2	research
macc	MACC	Copernicus
macc_nrealtime	MACC Near Real-time	Copernicus
s2s	Subseasonal to Seasonal	s2s
tigge	TIGGE (THORPEX Interactive Grand Global Ensemble)	tigge
uerra	Uncertainties in Ensembles of Regional ReAnalysis	uerra
yopp	YOPP (Year Of Polar Prediction)	general

These data can be downloaded in netcdf format, but their time resolution is very fine (usually sub-daily) and require massive processing. The most widely used is ERA40 reanalysis data, at 6 h and 128 km resolution.

Climate Research Unit Climate

The Climate Research Unit of the University of East Anglia distribute different climate datasets, both climatological averages and time series. The most relevant is the CRU CL 2.0 dataset, world raster at 10 min (~20 km) resolution of climatological averages for pre (Precipitation), wet (Wet days), tmp (Mean temperature), dtr (Mean diurnal temperature range), rhm (Relative humidity), ssh (Sunshine), frs (Ground frost), wnd (10 m wind speed)

University of New Hampshire: Global Runoff Data Centre

The GRDC of the University of New Hampshire distribute the Global Composite Runoff Fields. It is a world coverage raster of 0.5 degrees(~60 km) resolution with mean annual runoff and mean monthly runoff.

CORDEX database

The Coordinated Regional Downscaling Experiment (CORDEX) distributes data of Regional Climate Model (RCM) and Impact Assessment Model (IAM) simulations performed within the CORDEX framework. Data include meteorological variables (precipitation, temperature, wind speed, pressure, …) derived from RCMs and other variables (runoff, evapotranspiration, crop yield, crop water requirements,…) relevant for impact sectors derived from IAMs. These data can be adopted as the basis for future physical context data in iSQAPER upscaling model.

4.1.4 Social data

GRUMP: Global Rural-Urban Mapping Project

The Global Rural-Urban Mapping Project, Version 1 (GRUMPv1) data collection consists of eight global data sets: population count grids, population density grids, urban settlement points, urban-extents grids, land/geographic unit area grids, national boundaries, national identifier grids, and coastlines. All grids are provided at a resolution of 30 arc-seconds (~1km), with population estimates normalized to the years 2000, 1995, and 1990. All eight data sets are available for download as global products, and the first five data sets are also available as continental, regional, and national subsets. The data are distributed by the Socio-Economic Data and Applications Center (SEDAC) of Columbia University. An additional source of information is the population database of the University of Southampton (http://www.worldpop.org.uk/).

World Bank

The World Bank provides yearly country data in tabular form for many socio-economic variables. A relevant dataset is World Development Indicators, classified in several topics: Agriculture & Rural Development, Aid Effectiveness, Climate Change, Economy & Growth, Education, Energy & Mining, Environment, External Debt, Financial Sector, Gender, Health, Infrastructure, Labor & Social Protection, Poverty, Private Sector, Public Sector, Science & Technology, Social Development, Trade, Urban Development

IIASA SSP Scenario database

The Shared Socioeconomic Pathways (SSP) database of the International Institute for Applied Systems Analysis (IIASA) includes quantitative projections of key variables of the SSPs scenarios. The database includes projections for population and economic development. Specifically, for the following elements quantifications are available: (a) population by age, sex, and education; (b) urbanization; and (c) economic development (GDP). For each SSP a single population and urbanization scenario, developed by the International Institute for Applied Systems Analysis (IIASA) and the National Center for Atmospheric Research (NCAR), is provided. These can be adopted as a basis for the specification of socioeconomic context in iSQAPER scenarios.

4.2 Data catalogue of farming systems and agricultural management practices

The analysis will be done at the Europe and China wide scale. However, the resolution of the data is not uniform, and some of the data are only available at local scale level and are taken from the case studies.

Most of the activity data (e.g. crop areas) are based on Eurostat data from 2008. Part of the management data may be derived from the Survey on Agricultural Production Methods (SAPM); see also Council regulation (EC) No 1166/2008, which was held together with the Farm Systems Survey (FSS) in 2010.The WOCAT technologies documentation will also be considered as an essential data source, since it gives useful information on the impacts of the AMPs on socio-economic, socio-cultural and ecological dimension.

The database includes the data provided by D2, D3, D5, and D6 complemented by regional and global data summarised in Tables 2 and 3. Some data sources provide gridded datasets that will be projected into a standard format in geographical coordinates (latitude/longitude) with spatial resolution of 5 minutes. In other cases, indicators are available by administrative units (country, region, province). If possible these data will be spatially distributed within the unit using proxy variables. A complete analysis of other data sources is included in Section 4.1 of this deliverable.

We have compiled information from heterogeneous sources with different resolutions and we have structured them in a data catalogue with a unified structure and spatial resolution. This data catalogue is the basis for the dynamic model used to project model results into future scenarios. The data catalogue finally selected is included in

Table 5 (see Sections 5 and 6 for complete information and discussion). Variables are clustered in tables according to the Farming Systems, the Management Practices and the Soil Quality Indicators.

Table 5. Sources of information on agricultural systems and soil management practices

Source of information
iSQAPER WP 2, 3, 5 and 6
EU - SmartSOIL and CATH-C projects
WOCAT documentation
EU - Farm Systems Survey - FSS (Farm Systems Survey EU)
EU - CCAT survey results, as policies/subsidies are drivers for farmers to uptake the measures
EU - From LUCAS soil survey - Information about tillage and residues (what is seen on the field), however data are not yet available at point level, as there is discussion with the MS on the location availability at point level. DG Eurostat is the owner of this survey, and they should be asked for permission to use data.
EU – model - Alterra provided the data on the questions at EU level, based on MITERRA and other data sources (Eurostat, FAOSTAT, JRC) to estimate changes in SOM
EU modelled – Calculation of data on farms and farm and soil management at EU27 NUTS-2 level. Alterra identified missing data and how to face filling.
EU - Measures to climate change mitigation in agriculture Information on measures and activities across EU27 on basis of Smith et al. studies and IPCC AR4.
EU - Farm Accountancy Data Network (FADN)

Table 6. Variables used in WP7

Crop	Variable	Extension	Units	Resolution
Farming systems considered in this WP7				
Cereal Rice Maize Soybean Vegetable Pasture Permanent crops	Harvested area fraction	World	Percentage	Five arc-minute
Management practices considered in this WP7				
Organic matter addition	Residue Management	EU-25	percentage of arable land	NUTS2
No tillage	Conventional tillage Reduced tillage	EU-25	percentage of arable land	NUTS2
Crop rotation	Normal winter crop cover Cover crops	EU-25	percentage of arable land	NUTS2
Irrigation	Total irrigated area Percentage of irrigated area of equipped area for irrigation	World	Ha percentage	Five arc-minute

	Area equipped for irrigation Percentage of area equipped for irrigation			
Organic agriculture	Area of organic farming	EU-25	percentage of utilized agricultural area	NUTS2
Nutrient application	N, K and P in cereal N, K and P in rice N, K and P in maize N, K and P in soybean N, K and P in potato	World	kg/ha	Five arc-minute
Soil quality indicators linked to soil ecosystem services considered in this WP7				
Yield	Cereal Rice Maize Soybean Vegetable Pasture Permanent crops	World	t/ha	Five arc-minute
Soil organic carbon		Organic carbon content	t/ha percentage in weight	Five arc-minute
Water holding capacity	All agric areas	World	mm/m	Five arc-minute

5 Selecting farming systems, agricultural management practices and soil quality indicators for upscaling

5.1 Selecting farming systems for upscaling

The objective of this section is to identify a set of farming systems to be considered in the upscaling model. We elaborate the results obtained in WP2 including information from other sources: previous projects and public databases. We first present the main conclusions of Deliverable 2.2 and then briefly review other farming system classifications developed in previous projects.

5.1.1 Farming systems in iSQPAPER D2.2

One of the aims of WP2 is to develop a classification of crop and livestock farming systems in various pedo-climatic zones across Europe and China. Deliverable 2.2 adopted a definition of farming system based on the review of diverse approaches and proposed an operational classification for the Soil Quality Application (SQAPP). Their results are summarized in Table 7.

Table 7. Classification of Farming Systems adopted in Deliverable 2.2

1. ARABLE LAND		2. PERMANENT CROPS	3. PASTURES	4. LIVESTOCK specialization
1.1. Non irrigated	1.2. Arable irrigated			
1.1.1. Cereals: Wheat, Barley, Sorghum, Millets, Oats	1.1.1. Cereals: Wheat, Barley, Sorghum, Millets, Oats	2.1. Vineyards	3.1. Extensive	4.1. Cattle
1.1.2. Rice	1.1.2. Rice	2.2. Fruit trees and berry plantation	3.2. Intensive	4.2. Sheep
1.1.3. Maize	1.1.3. Maize	2.3. Olive groves		4.3. Goats
1.1.4. Pulses: Soybean, Peas, Been, Lentil, Other (Groundnut, Pigeonpea, Cowpea)	1.1.4. Pulses: Soybean, Peas, Been, Lentil, Other (Groundnut, Pigeonpea, Cowpea)	2.4. Banana		4.4. Pigs
1.1.5. Oil crops: Sunflower, Oilseed rape, Oilcrops, Other	1.1.5. Oil crops: Sunflower, Oilseed rape, Oilcrops, Other	2.5. Oil Palm		4.5. Chickens
1.1.6. Fodder crops: Alfalfa, Red clover, Other	1.1.6. Fodder crops: Alfalfa, Red clover, Other	2.6. Tea		4.6. Ducks
1.1.7. Roots and tubers: Potato, Sugarbeet, Sweet potato, Yam	1.1.7. Roots and tubers: Potato, Sugarbeet, Sweet potato, Yam	2.7. Sugarcane		
1.1.8. Fiber crops: Cotton, Fiber, Other	1.1.8. Fiber crops: Cotton, Fiber, Other			
1.1.9. Tobacco	1.1.9. Tobacco			
1.1.10. Cassava (manioka)	1.1.10. Cassava (manioka)			
1.1.11. Vegetable	1.1.11. Vegetable			
1.1.12. Fallow	1.1.12. Fallow			

The classification of FSs is divided in four main categories: Arable Land, Permanent Crops, Pastures and Livestock. A total of 39 FSs were identified.

5.1.2 Farming systems in other projects

SmartSOIL

The project SmartSOIL was carried out in the period 2011-2015. Its aim was to improve soil carbon management in European arable and mixed farming systems. They developed the SmartSOIL toolbox as an interactive platform with tools showing the impacts of field management practices on soil organic matter and soil organic carbon (SOC) content. As part of the project, they produced a deliverable on typical farming systems and trends in crop and soil management in Europe (SmartSOIL, 2015).

The farming systems of SmartSOIL were derived from the SEAMLESS project, where a classification was developed distinguishing 21 farm types (Andersen, 2010). For SmartSoil, these 21 farm types were aggregated into six main categories: Field crops, Permanent crops, Mixed farms, Pastures and grasslands, Industrial crops, and horticulture. The results are shown in Table 8.

Table 8. Farming systems considered in the SmartSOIL project.

Field crops	Permanent crops	Mixed farms
Soft wheat (SWHE) Durum wheat (DWHE) Rye and meslin (RYEM) Barley (BARL) Oats (OATS) Grain maize (MAIZ) Other cereals (OCER) Paddy rice (PARI) Rapeseed (RAPE) Sunflower (SUNF) Soybean (SOYA) Other oil (OOIL) Pulses (PULS) Other crops (OCRO) Fallow land (FALL)	Olive for oil (OLIV) Apples and pears (APPL) Other fruit (OFRU) Citrus (CITR) Table grapes (TAGR) Table olives (TABO) Wine (TWIN) Nurseries (NURS)	Fodder maize (MAIF) Fodder on arable land (OFAR) Fodder root crops (ROOF) Soft wheat (SWHE) Rye and meslin (RYEM) Barley (BARL) Oats (OATS) Grain maize (MAIZ) Other cereals (OCER)
Pasture and grasslands	Industrial crops	Horticulture
Fodder on arable land (OFAR) Grassland (GRAS)	Potato (POTA) Sugar beet (SUGB) Fibre crops (TEXT) Tobacco (TOBA) Other industrial crops (OIND) Flowers (FLOW)	Tomatoes (TOMA) Other vegetables (OVEG)

Catch-C

The Catch-C project aims at identifying and improving the farm compatibility of sustainable soil management practices for farm productivity, climate-change mitigation, and soil quality. The project developed an “agri-environment farm type” typology, by combining soil and climate data with farm specialization data. They identified agri-environmental zones based on climate, soil texture and slope, which were later combined with farming activities (as defined by the Farm Accountancy Data Network) and land uses to describe farm typologies. This typology was presented on Deliverable 2.242 (Catch-C, 2014) and is summarized in Table 9, which shows the classes adopted for specialization and land use. A farming system is a combination of two suitable classes, one from each column.

Table 9. Classes adopted in the Catch-C project for farm specialization and farm land use. Adapted from Catch-C (2013).

Specialization		Land Use
Arable systems (specialized field crops and mixed cropping) >1/3 of standard gross margin from general cropping (arable farming) Or > 1/3 but < 2/3 of standard gross margin from horticulture Or > 1/3 but < 2/3 of standard gross margin from permanent crops Combined with < 1/3 of standard gross margin from meadows and grazing livestock and < 1/3 from granivores		1 Land independent Utilized Agricultural Area (UAA) = 0 or Livestock Units (LU)/ha> 5
Permanent crops > 2/3 of standard gross margin from permanent crops		2 Horticultural Not 1 and > 50% of UAA in horticultural crops
Horticulture > 2/3 of standard gross margin from horticultural crops		3 Permanent crops (notgrassland) Not 1 and 2 and > 50% of UAA in permanent crops
Dairy cattle > 2/3 of standard gross margin from dairycattle		4 Temporary grass Not 1,2 or 3 and > 50% of UAA in grassland and > 50% ofgrassland in temporary grass
Beef and mixed cattle > 2/3 of standard gross margin from cattle and< 2/3 from dairy cattle		5 Permanent grass Not 1,2,3 and > 50% of UAA in grassland and < 50% of grassland in temporary grass
Sheep, goats and mixed grazing livestock > 2/3 of standard gross margin from grazing livestock and < 2/3 from cattle		6 Fallow land Not 1,2,3,4 or 5 and > 50% of UAA in fallow
Pigs >2/3 of standard gross margin from pigs		7 Cereal Not 1,2,3,4,5 or 6 and > 50% of UAA in cereals
Poultry and mixed pigs/poultry > 2/3 of standard gross margin from pigs and poultry and < 2/3 from pigs		8 Specialized crops Not 1,2,3,4,5,6,7 and > 25% in specialized crops
Mixed livestock > 1/3 and < 2/3 of standard gross margin frompigs and poultry and/or >1/3 and < 2/3 from cattle		9 Mixed crops (others) Not 1,2,3,4,5,6,7 or 8
Mixed farms All other farms		

5.2 Proposal of farming systems for upscaling in iSQAPER

One of the requirements of the iSQAPER upscaling model is simplicity. Farming system classifications have been developed for different purposes. In the upscaling model we need to balance model complexity and representatively. For this reason, farming systems have been grouped into seven categories, which represent a large fraction of the food produced globally. The categories are the following:

Cereals: this farming system includes extensive cereals like wheat, barley, oats or rye. They are grown in temperate regions, usually rain fed, although they might require supplemental irrigation in some locations. Winter varieties may allow for growing another crop in the remaining season. Farming practices usually rely on machinery for harvesting and the use of herbicides and fertilizer is frequent.

Rice: this farming system is represented by 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: this farming system includes arable land devoted to maize cultivation.

Soybean: this farming system includes arable land devoted to maize cultivation

Vegetables: this farming system includes 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: this farming system includes grass-based livestock systems for meat and dairy production.

Permanent crops: this farming system includes 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.

5.3 Selecting agricultural management practices for upscaling

This section is devoted to the identification of management practices to be considered in the upscaling model. It is based on several sources dealing with the characterization and study of agricultural practices, like public databases and research projects. We first present the analysis of the effect of agricultural management practices carried out in Deliverable 3.2 and then briefly review other AMP classifications developed in previous projects.

5.3.1 Agricultural practices in iSQAPER D3.2

Deliverable 3.2 chose five management practices to evaluate their long-term effect on soil quality indicators. This decision was based on practices commonly selected on previous EU projects, practices described in the iSQAPER long term experiment (LTE) documentation and the agreement reached in the iSQAPER WP3 group. The adopted management practices are listed on Table 1.

Table 10. Agricultural practices in D3.2

Reference (baseline)	Management practice
No organic input	Organic matter addition
Conventional tillage	No tillage
Monoculture	Crop rotation
Noirrigation	Irrigation
Conventional farming	Organic agriculture

5.3.2 Agricultural practices in other projects

WOCAT

The WOCAT initiative maintains the Global Database on Sustainable Land Management (SLM) that documents and assesses SLM practices with the objective of sharing and spreading valuable knowledge in land management, supporting evidence-based decision-making, and scaling up identified good practices. It includes a catalogue of 942 SLM technologies that control land degradation and enhance productivity or other ecosystem services. Not all measures are direcly linked to soil quality. They are classified according to different criteria. For instance, Table 11 shows categories according to three different classification criteria.

Table 11. Categories of management practices in WOCAT according to three classification criteria

Main purpose	SLM measures	SLM group
improve production	agronomic measures	natural and semi-natural forest management
reduce, prevent, restore land degradation	vegetative measures	forest plantation management
conserve ecosystem	structural measures	agroforestry
protect a watershed/ downstream areas – in combination with other Technologies	management measures	windbreak/ shelterbelt
preserve/ improve biodiversity	other measures	area closure (stop use, support restoration)
reduce risk of disasters		rotational systems (crop rotation, fallows, shifting cultivation)
adapt to climate change/ extremes and its impacts		pastoralism and grazing land management
mitigate climate change and its impacts		integrated crop-livestock management
create beneficial economic impact		improved ground/ vegetation cover
create beneficial social impact		minimal soil disturbance
		integrated soil fertility management
		cross-slope measure

		integrated pest and disease management (incl. organic agriculture)
		improved plant varieties/ animal breeds
		water harvesting
		irrigation management (incl. water supply, drainage)
		water diversion and drainage
		surface water management (spring, river, lakes, sea)
		ground water management
		wetland protection/ management
		waste management/ waste water management
		energy efficiency technologies
		beekeeping, aquaculture, poultry, rabbit farming, silkworm farming, etc.
		home gardens
		ecosystem-based disaster risk reduction
		post-harvest measures

SmartSOIL

The focus of the SmartSOIL project was management of soil organic carbon (SOC). They identified key management practices affecting SOC flows and stocks and their applicability in various farming systems and agro-ecological zones in Europe. The project had also a dynamic orientation, because scenarios of future crop and soil management systems in Europe were developed to evaluate the potential for improved productivity and enhanced soil SOC sequestration. The management practices included in their analysis are listed on Table 12.

Table 12. Management practices analysed in SmartSOIL project

Permanent crops	Field crops	Horticulture	Pasture and grasslands
Reduced tillage (RT)	Reduced tillage (RT)	Reduced tillage (RT)	Spontaneous
Spontaneous catch crops (CC1)	Conventional tillage (CT)	Conventional tillage (CT)	Managed by farmer
Cultivated catch crops (CC2)	Direct planting (DP)	Direct planting (DP)	
Residue Management (RM)	Rotation and adding legumes (RA)	Rotation and adding legumes (RA)	
RT + CC + RM	Residue Management (RM)	Residue Management (RM)	
Other combination	RT + DP + RA + RM	RT + DP + RA + RM	
	RT + DP + RA	RT + DP + RA	
	RT + RA	RT + RA	
	Other combination	Other combination	

CATCH-C

The Catch-C project compiled a standard list of management practices where they were classified in five categories: Rotation, Grassland management, Tillage, Crop protection and Water management, as discussed below.

Rotation: divided in two subcategories: Crop rotation (Monoculture, Roration with cereals, Rotation with legume crops, Rotation with tuber or root crops, Rotation with fallow land and Rotation with grassland) and Intercropping/green manure/catch crop (Intercropping, Rotation with cover/catch crops, Rotation with green manures)

Grassland management: Permanent grazing, Rotational grazing, Zero grazing

Tillage: Conventional tillage, No/zero tillage, Shallow non inversion tillage/reduced tillage, Shallow non inversion tillage/minimum tillage, Deep non inversion tillage, Deep ploughing, Direct drilling, Contour ploughing, Terrace farming, Controlled traffic farming

Crop protection: divided in two subcategories: Crop protection-weeds (Mechanical weeding, Herbicide application) and Crop protection-pests (Push-pull strategies, Patches or stripes or natural vegetation, Pheromones application, Insecticide application, Fungicide application, Nematode application, Soil fumigation and Soil solarization)

Water management: divided in two subcategories: Water management-irrigation (Surface irrigation, Drip irrigation, Sprinkler irrigation) and Water management-drainage (Subsurface drainage)

5.4 Proposal of management practices for upscaling in iSQAPER

The management practices adopted for upscaling are the same categories adopted in Deliverable 3.2 to evaluate their effect on different soil quality indicators. This will allow us to take advantage of 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: 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.

Irrigation: Application of water to the field through surface, sprinkler or drip irrigation.

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.

5.5 Soil quality indicators linked to soil ecosystem services

5.5.1 Soil quality indicators in iSQAPER D3.1 and D3.2

iSQAPER has paid a lot of attention to the characterization of soil quality through indicators. Deliverable 3.1 presented a critical review of existing soil quality concepts and indicators, focusing on three categories: Chemical (Total organic C, Total N, Available P, CEC (incl. avail. K), Labile C)., Biological (Microbial Biomass, N mineralization, Molecular analyses, Earthworms, Disease incidence, Yield, Tea bag test) and Physical (Bulk density, Particle-size distribution, Soil depth, Aggregate stability, Water holding capacity, Penetration resistance; Spade diagnosis). Deliverable 3.2 focussed on six indicators to study the effect of management practices in LTEs:

Yield: provides a good indication of soil quality and is of most concern to farmers. It is also an important ecosystem service.

Soil organic matter / soil organic carbon: plays a central role in the maintenance of soil fertility and other soil functions. Its environmental and economic relevance is based on the capacity of soil organic matter (SOM) to limit physical damage and to improve nutrient availability.

pH:is a measure of soil acidity, which controls nutrient availability to crops. If soil pH is too high, nutrients such as phosphorus, copper, manganese, iron and boron become unavailable to crops. If pH is too low, potassium, phosphorus, calcium, magnesium and molybdenum become unavailable.

Aggregate stability / soil structure: is a key factor in the functioning of soil, its ability to support plant and animal life, and regulate environmental quality with particular emphasis on soil carbon sequestration and water holding capacity.

Water holding capacity: is an important determinant of crop production. Soil texture, mineralogy and content of organic matter are key components that determine soil water holding capacity.

Earthworms: Earthworms can increase soil porosity and improve soil structure; they can increase mineralization of SOM in the short-term by altering physical protection within aggregates and enhance microbial activity and nutrient cycling.

5.5.2 Soil quality indicators in CATCH-C

In the Catch-C project an analysis was performed to estimate the effect of management practices on a set of soil quality indicators linked to different factors. The selected soil indicators were grouped in five categories: Productivity, Climate Change, Soil Quality Chemical, Soil Quality Physical and Soil Quality Biological. The indicators are listed in Table 13.

Table 13. Soil quality indicators adopted in Catch-C project For full meaning see: http://www.catch-c.eu/)

Productivity	Climate Change	Soil Quality Chemical	Soil Quality Physical	Soil Quality Biological
Yield	SOC concentrations	pH	Bulk density	Earthworm number
N uptake	SOC stocks	N_t content	Penetration resistance	Earthworm biomass
NUE	CO_2 emissions	N_t stock	Permeability	Microbial Biomass C
N surplus	N_2O emissions	C/N	Aggregate stability	PPNEM
	CH_4 emissions	N min	Runoff yield	FUNGNEM
		K avail	Sediment yield	BACNEM
		P avail		BACPLFA
				FUNGPLFA

5.6 Proposal of soil quality indicators to represent soil ecosystem services for upscaling

Previous studies have used a diversity of soil quality indicators. The selection of indicators for upscaling is based on simplicity 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.

Water holding capacity: WHC is selected because it is directly linked to soil functions of temperature (i.e., soils with higher water content regulate temperature better and are not exposed at risk of high temperature stress to crops and fauna) and flood regulation. This quantity may be estimated from proxy data included in soil databases.

6 Definition of farming systems, agricultural management practices, and soil quality indicators

The sections below present a geographical analysis of the farming systems, agricultural management practices and soil quality indicators based on the data sources detailed in Section 4. The analysis is 0.5 degree grid or Nuts 2, as described for each dataset in Section 4.

6.1 Farming systems

Figures 3 to 9 represent the spatial extent of the farming systems selected for upscaling.

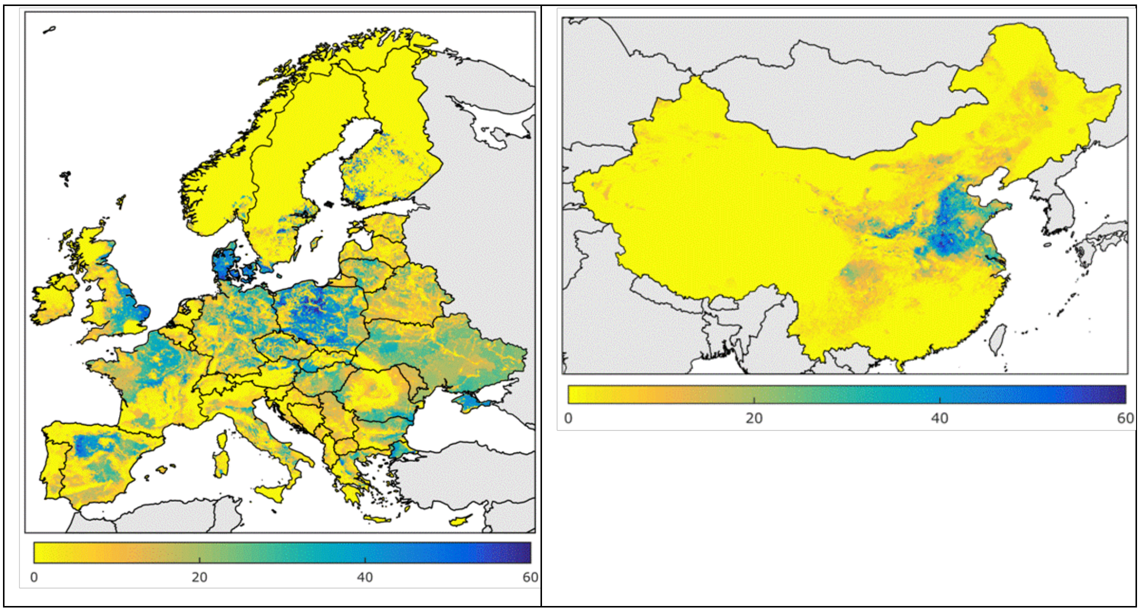

Figure 3. Harvested cereal area fraction in Europe and China (%)

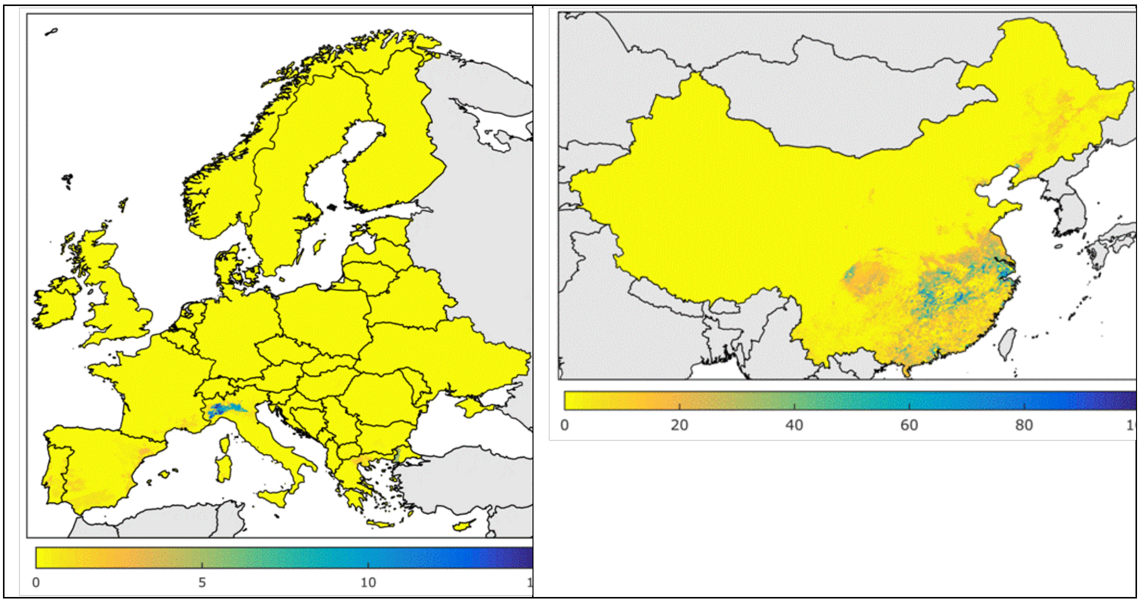

Figure 4. Harvested rice area fraction in Europe and China (%)

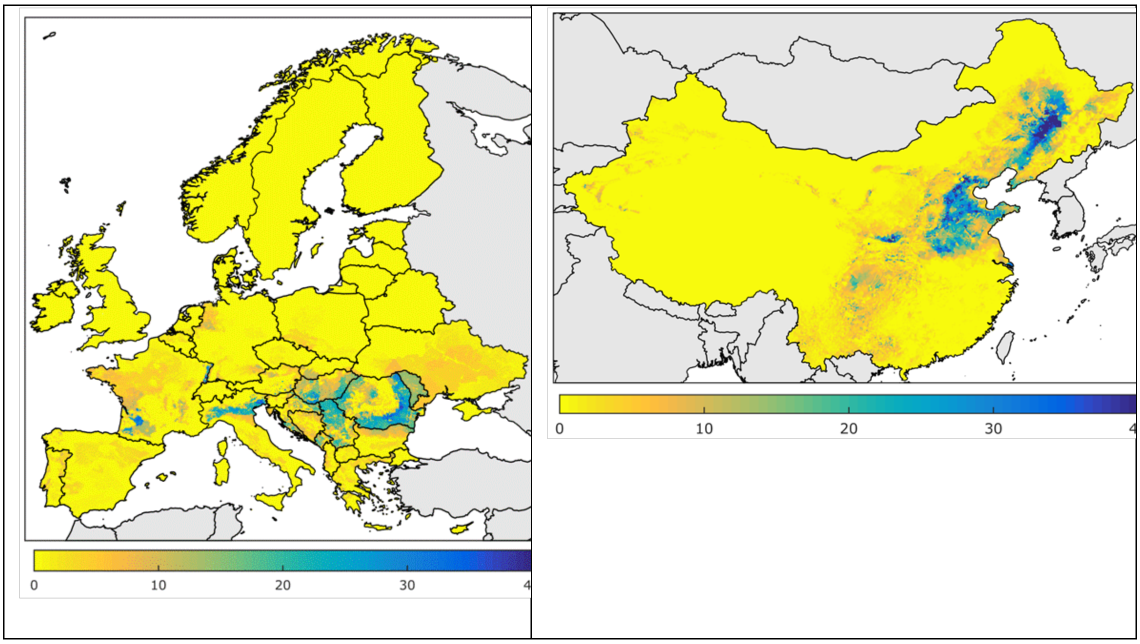

Figure 5. Harvested maize area fraction in Europe and China (%)

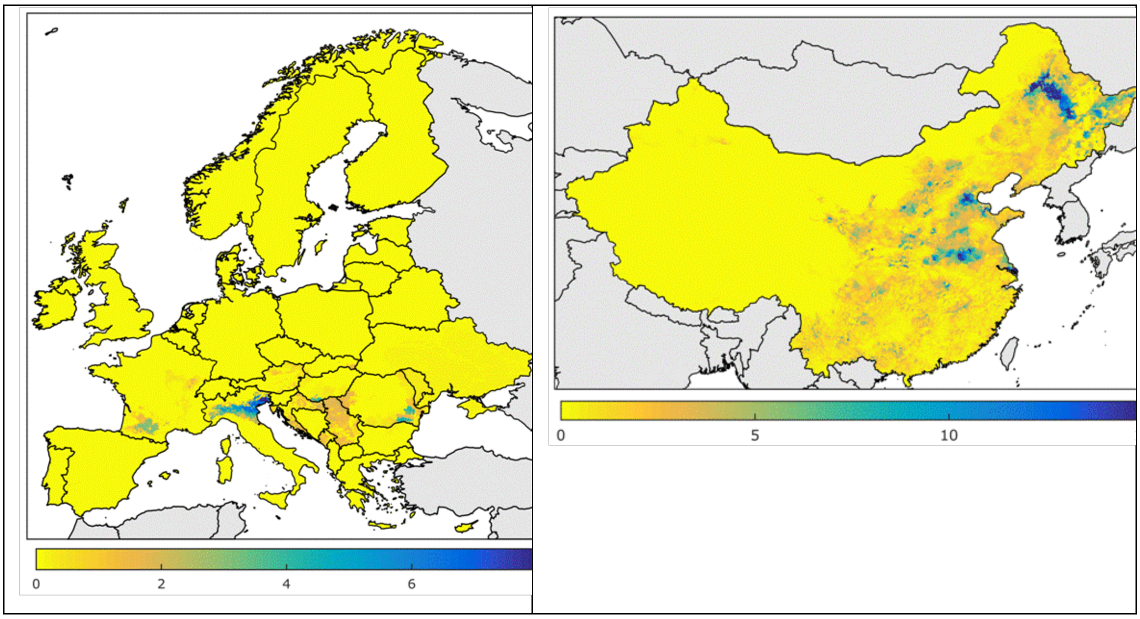

Figure 6. Harvested soybean area fraction in Europe and China (%)

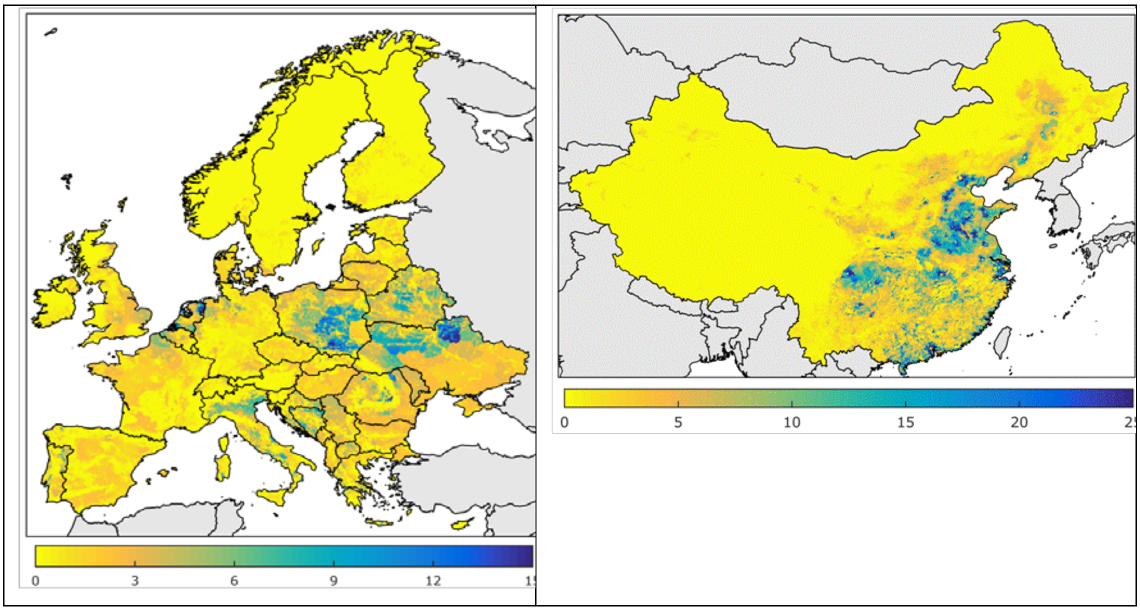

Figure 7. Harvested vegetables area fraction in Europe and China (%)

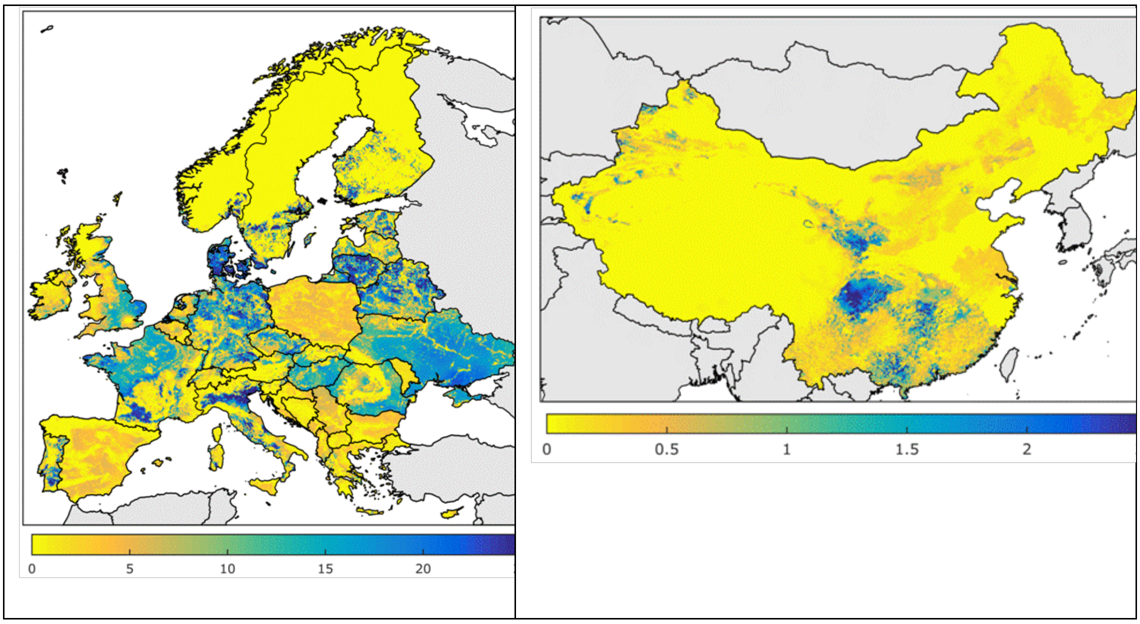

Figure 8. Harvested pasture area fraction in Europe and China (%)

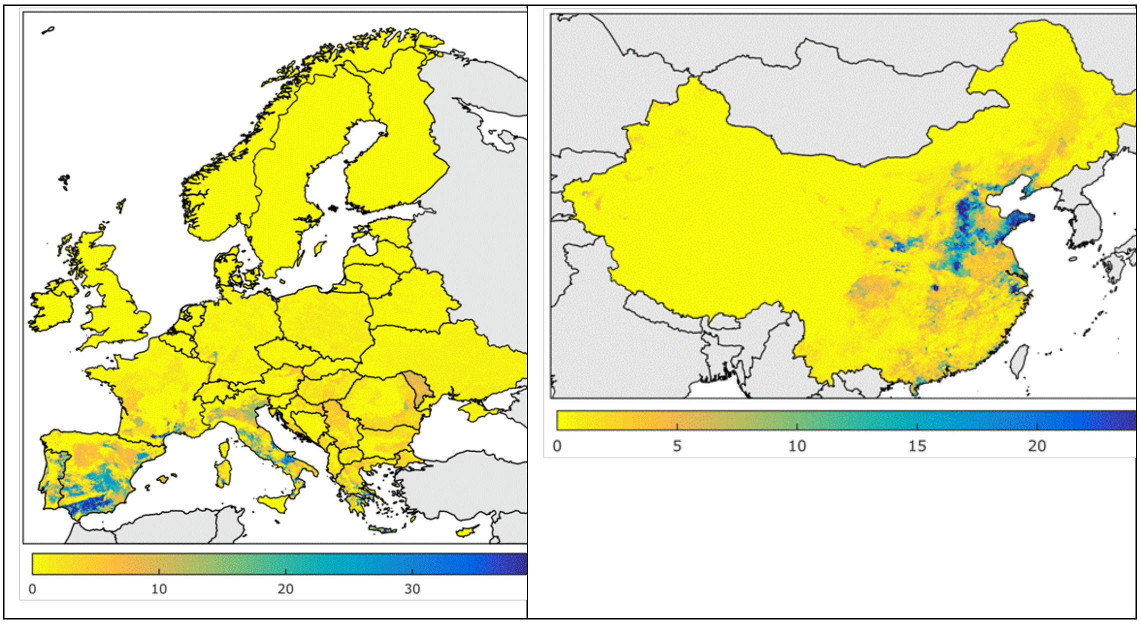

Figure 9. Harvested permanent crops area fraction in Europe and China (%) (grape wine, fruit trees, olive trees)

6.2 Agricultural management practices

In this section we provide the spatial analysis of the information regarding management practices in Europe and China, as described below.

6.2.1 Soil management

In Figure 10 it can be seen that most of the regions in Europe are barely implementing residue management with percentages lower than 20% out of total arable land. There is no region with percentages higher than 60%.

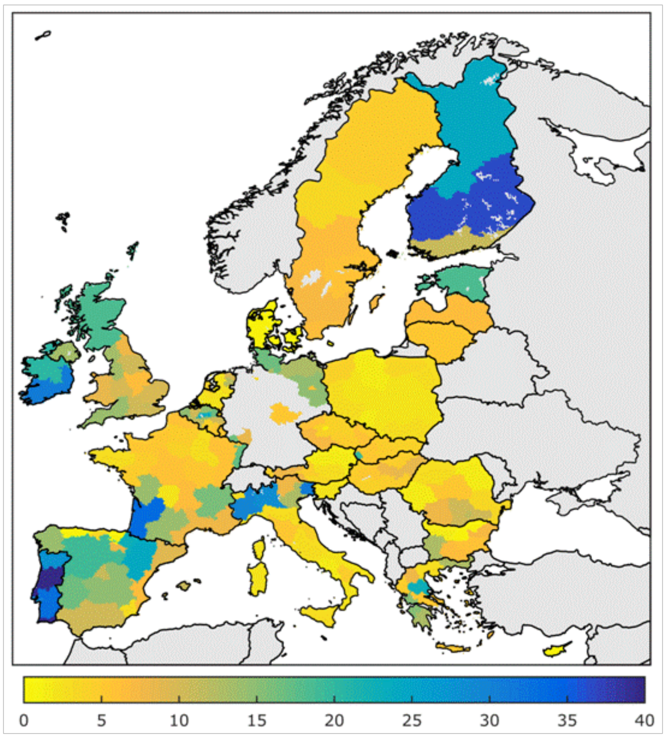

Figure 10. Organic matter management in Europe: Residue management (% of arable land, including pasture and permanent crops)

Tillage practices in Europe were derived from the Survey on Agricultural Production Methods, which was held in 2010. The implementation level is expressed as the percentage of land under a certain management practice, compared to the total area of arable land. Most of soil management practices data for Germany regions are missing. We derived the use for the following measures at NUTS2 level.

As mentioned before, conventional tillage is found to be the most common practice for all the regions. Many of the regions represented in Figure 11 shows that they are implementing more than 60% of conventional tillage out of total arable land.

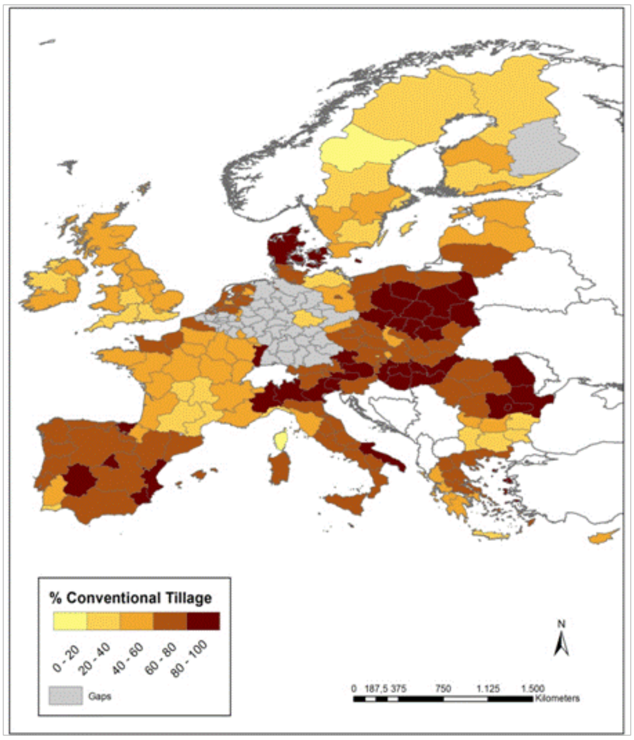

Figure 11. Tillage practice in Europe: Conventional tillage (% of arable land)

Unlike conventional tillage, the soil management practice of reduced tillage is not extensively undertaken. Only Cyprus, Halle region in Germany and Severoiztochen region in Bulgaria are implementing approximately 60-80% of reduced tillage and no region is implementing more than 80% of reduced tillage out of total arable land (Figure 12).

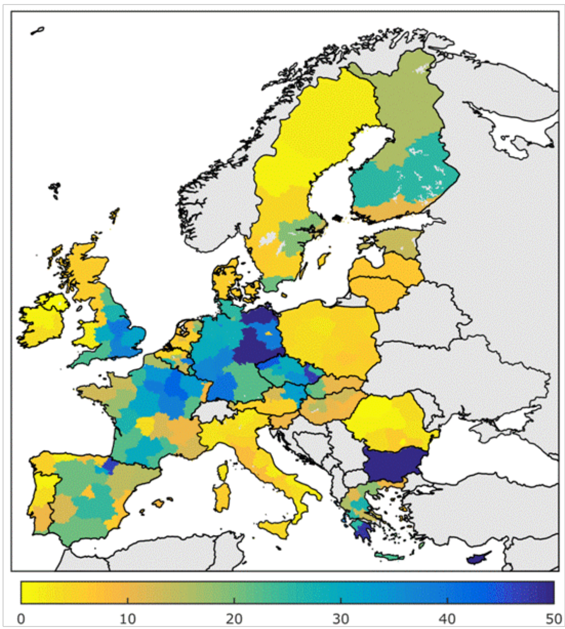

Figure 12. Tillage practice in Europe: Reduced tillage (% of arable land)

6.2.2 Crop management

Normal winter crop cover is more extensively undertaken between ranges of 40-60% out of total arable land. A few regions from United Kingdom, France, Germany, Czech Republic, Poland, Greece, Italy and Spain are implementing between ranges of 60-80% out of total arable land. Only Cyprus is implementing more than 80% of normal winter crop cover (Figure 13). Sweden, Denmark, Wales region in United Kingdom and Vorarlberg region in Austria show the highest percentage of crop rotation (more than 80% out of total arable land) comparing to the rest of regions in Figure 14. Figure 15 represents bare soil in Europe.

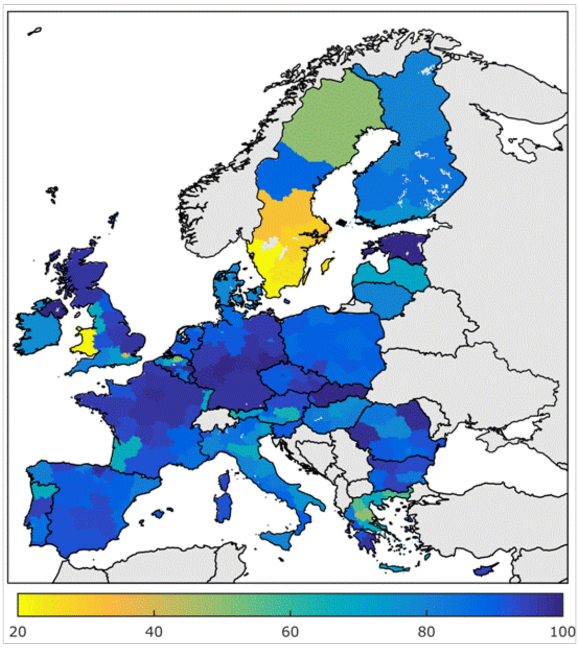

Figure 13. Winter crop in Europe ((% of arable land))

x

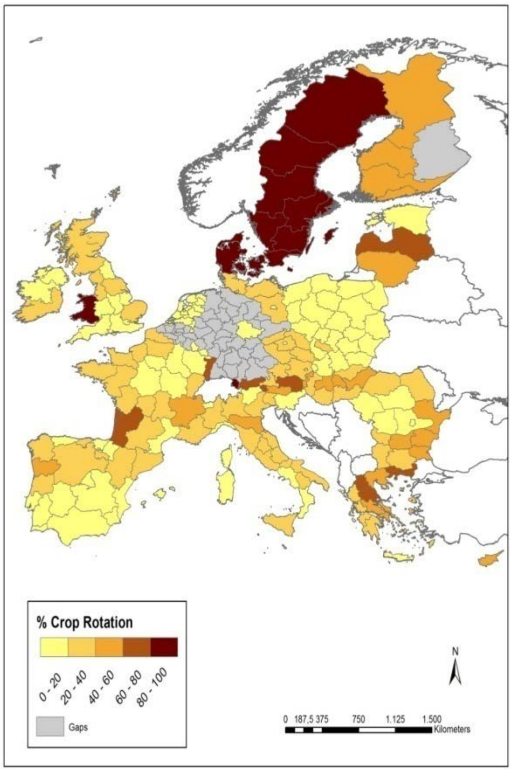

Figure 14. Crop rotation practice in Europe (% of arable land)

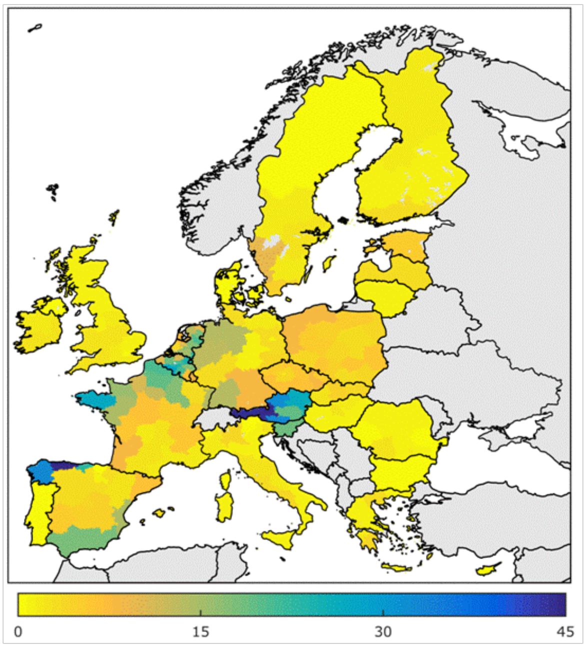

Figure 15. Bare soil in Europe (% of arable land)

6.2.3 Nutrient management

Nutrient management provides information about the level of inputs used in the agricultural systems. This information is useful as proxi for other soil pollution variables not available in spatial datasets, such as the use of other agrochemicals (e.g., pesticides) and plastics in the soil. The data presented in nutrient management needs to be re-analysed for anomalies in some regions. This will be done in Task 7.2.

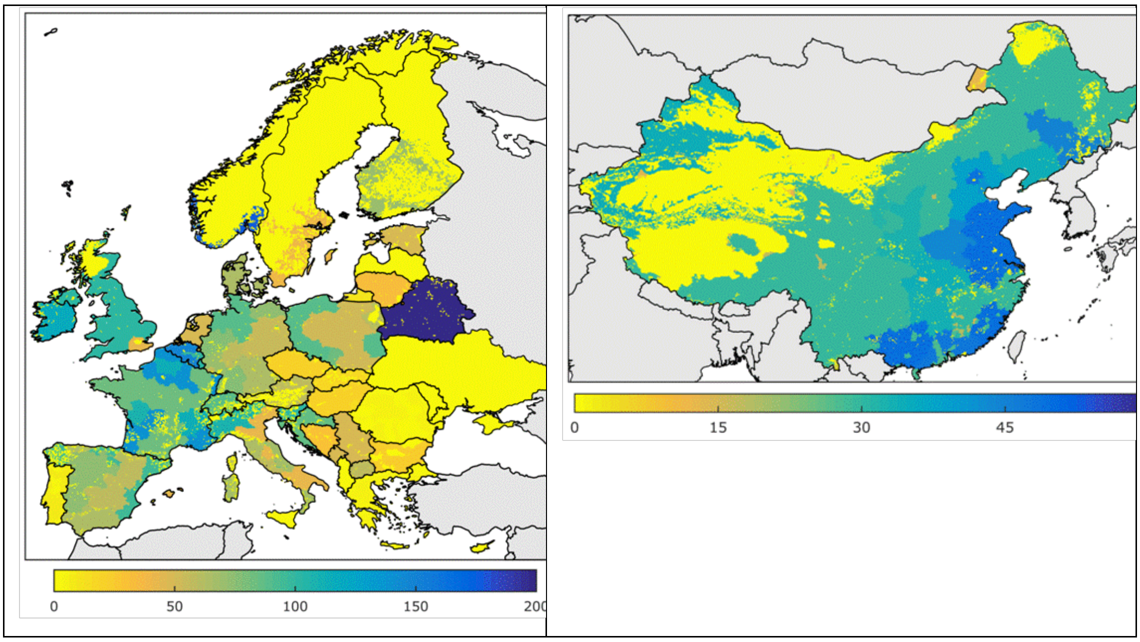

Figure 16. Cereal K application rate (kg/ha)

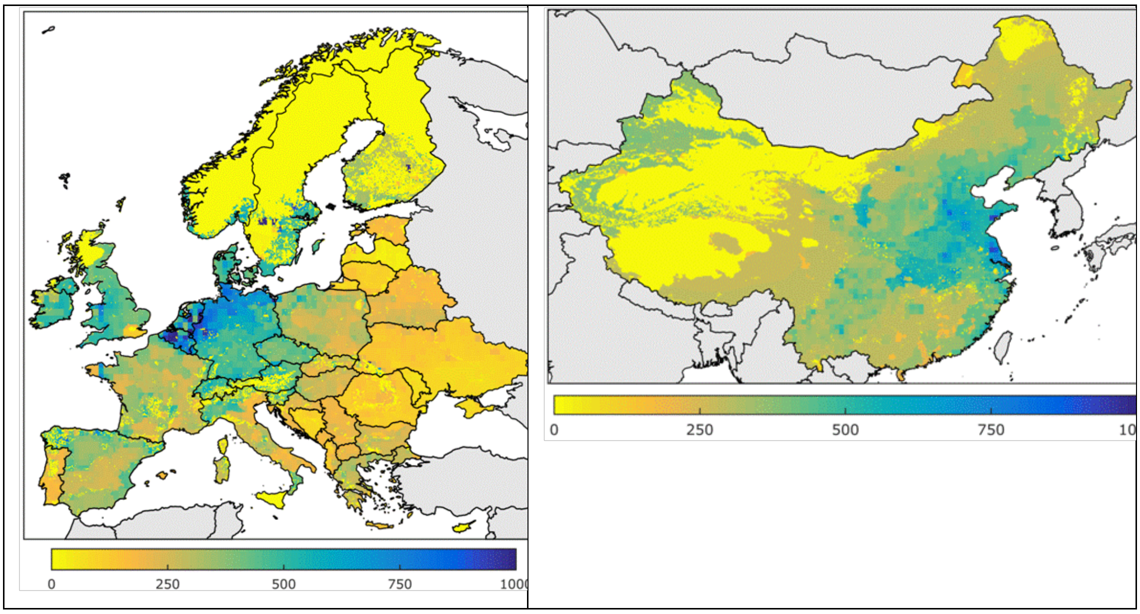

Figure 17. Cereal N application rate (kg/ha)

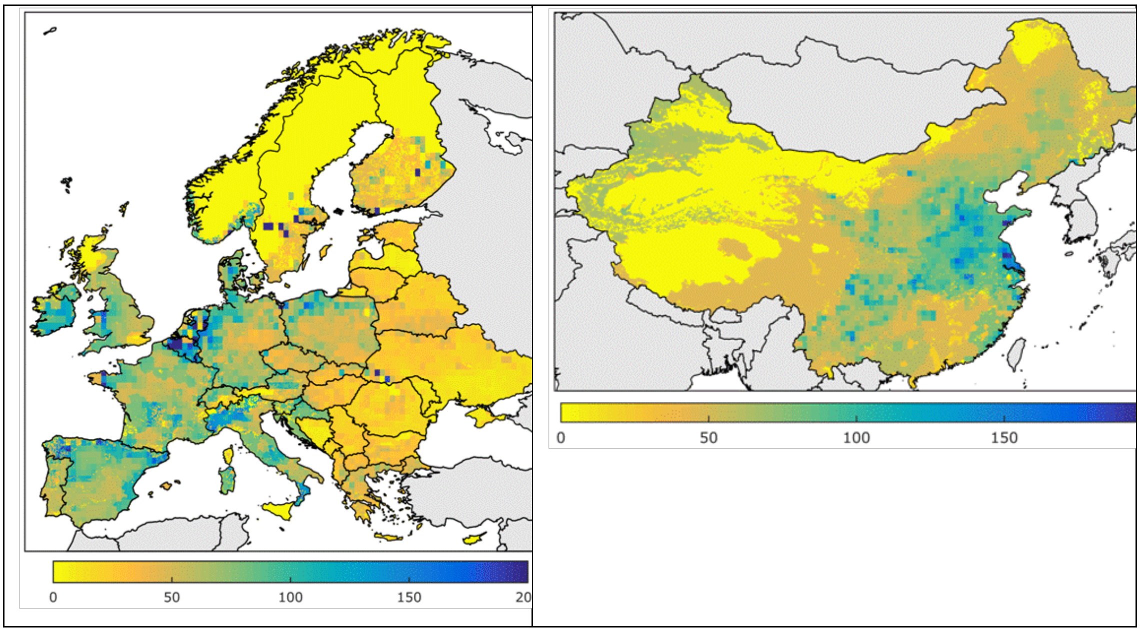

Figure 18. Cereal P application rate (kg/ha)

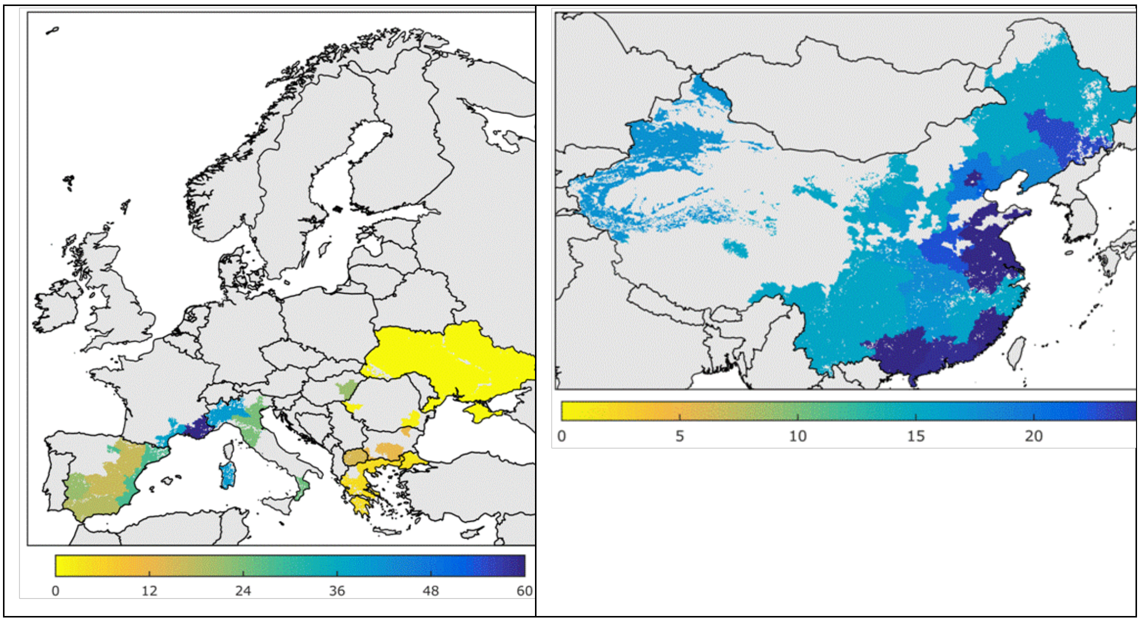

Figure 19. Rice K application rate (kg/ha)

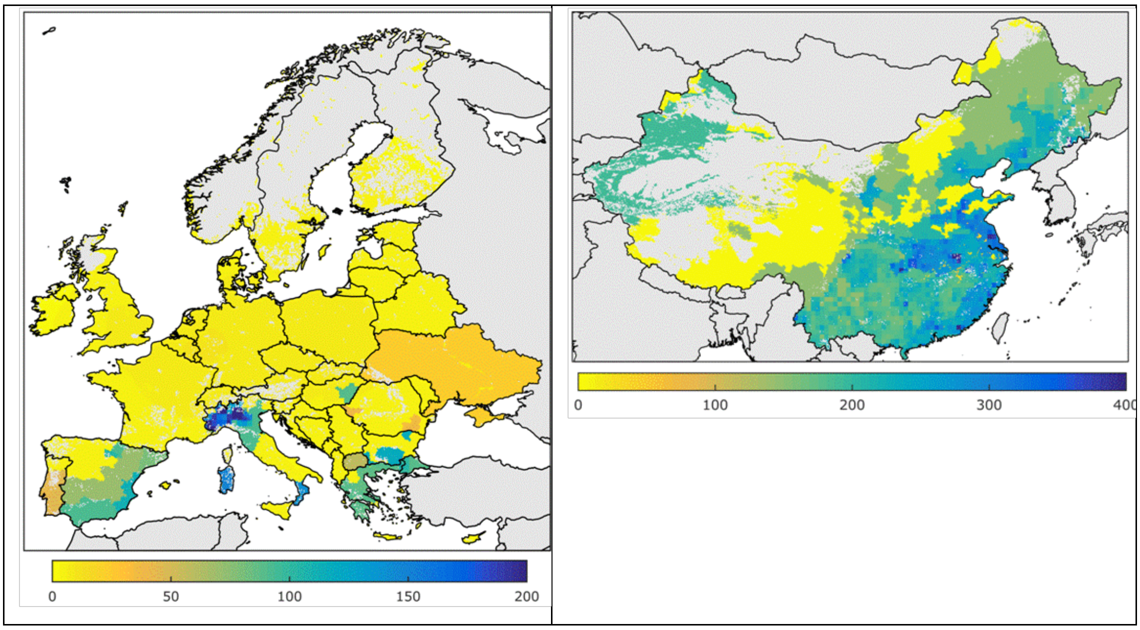

Figure 20. Rice N application rate (kg/ha)

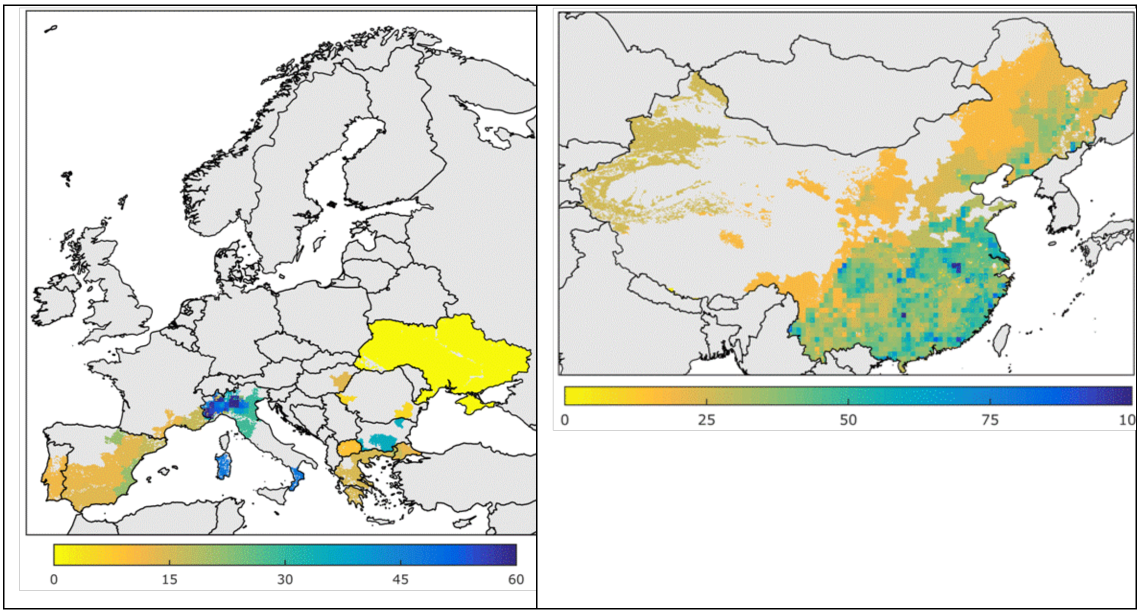

Figure 21. Rice P application rate (kg/ha)

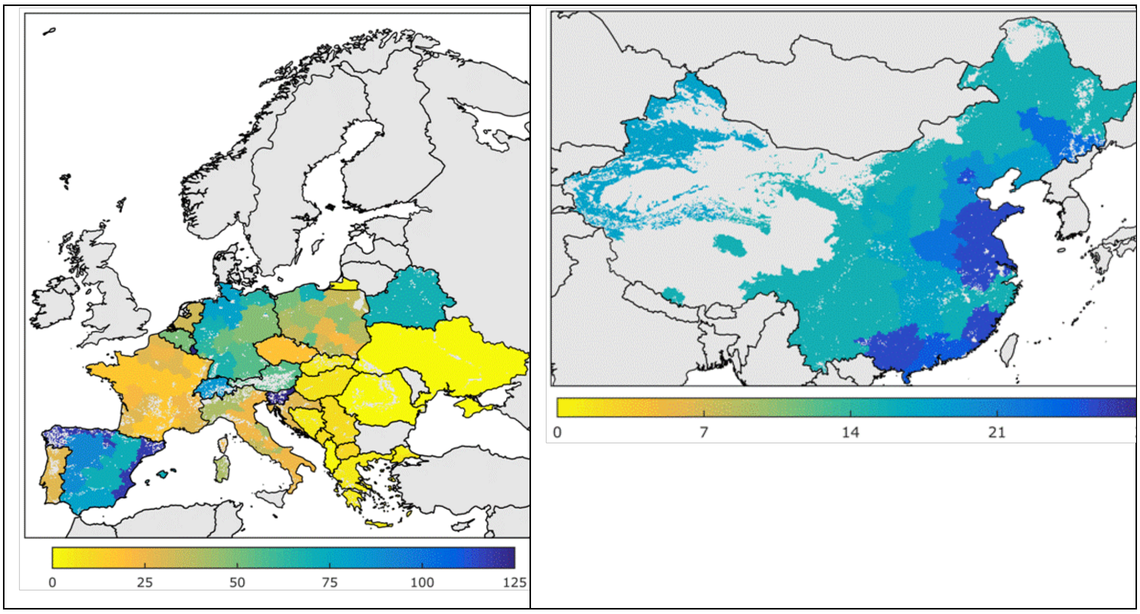

Figure 22. Maize K application rate (kg/ha)

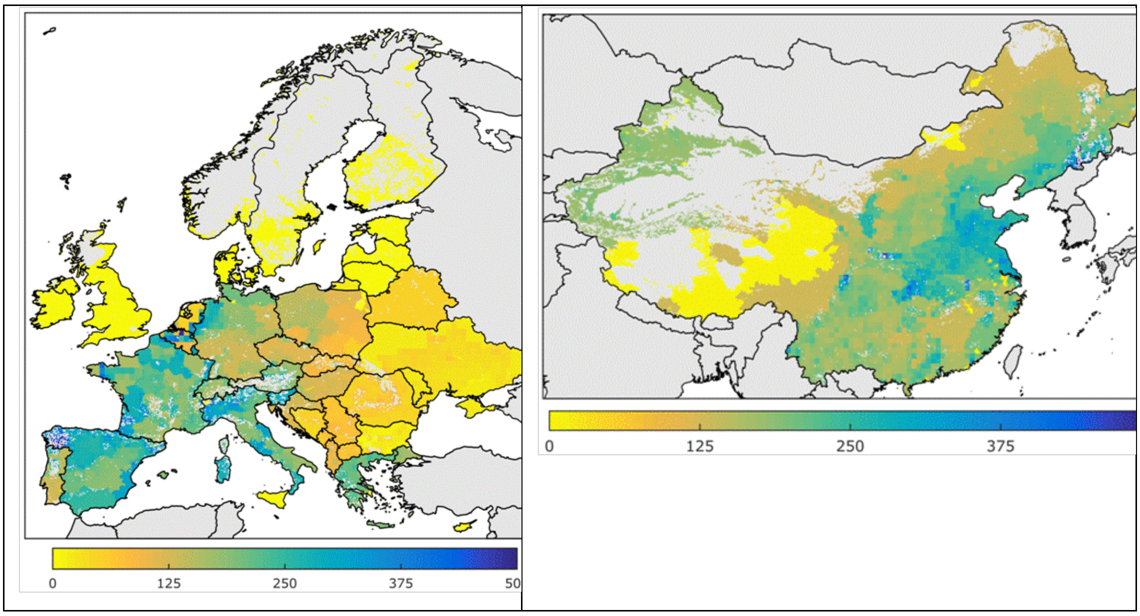

Figure 23. Maize N application rate (kg/ha)

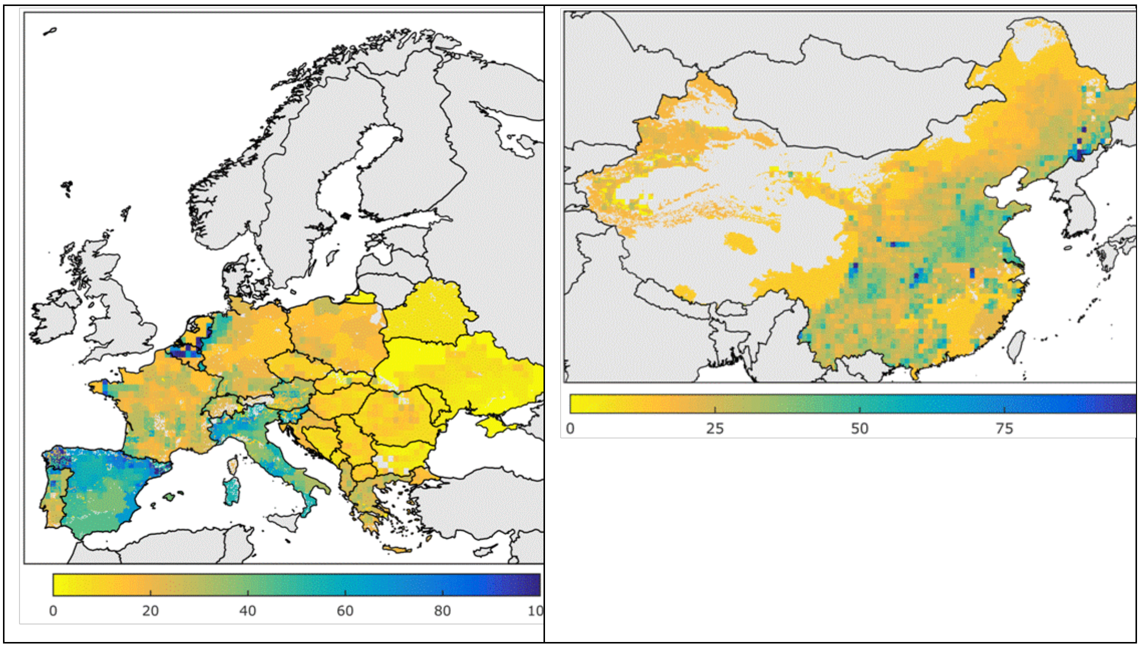

Figure 24. Maize P application rate (kg/ha)

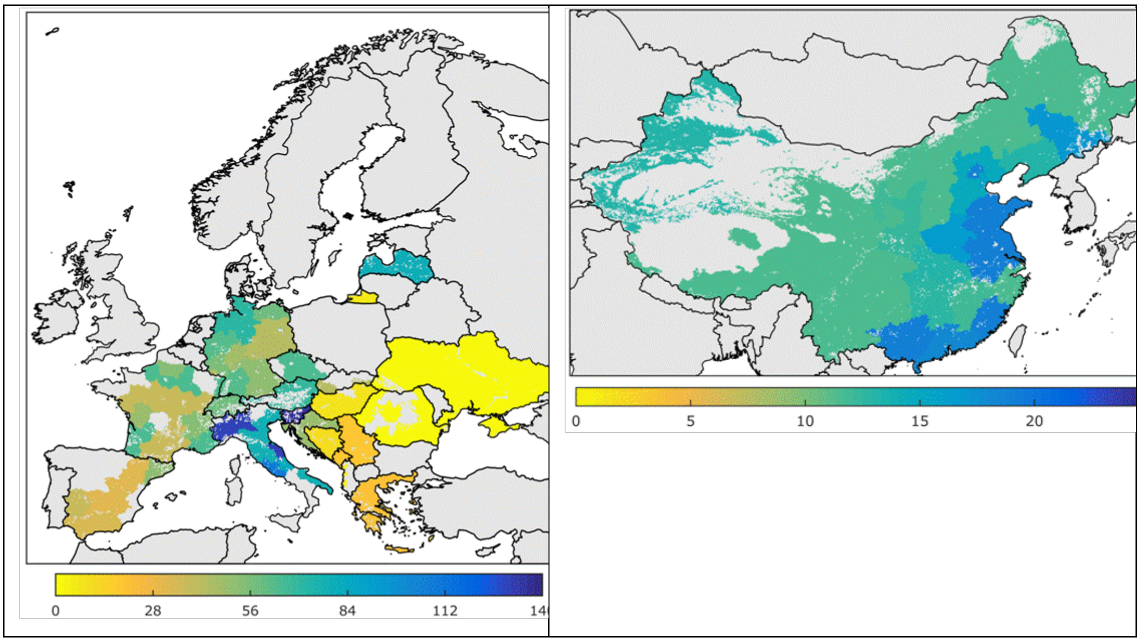

Figure 25. Soybean K application rate (kg/ha)

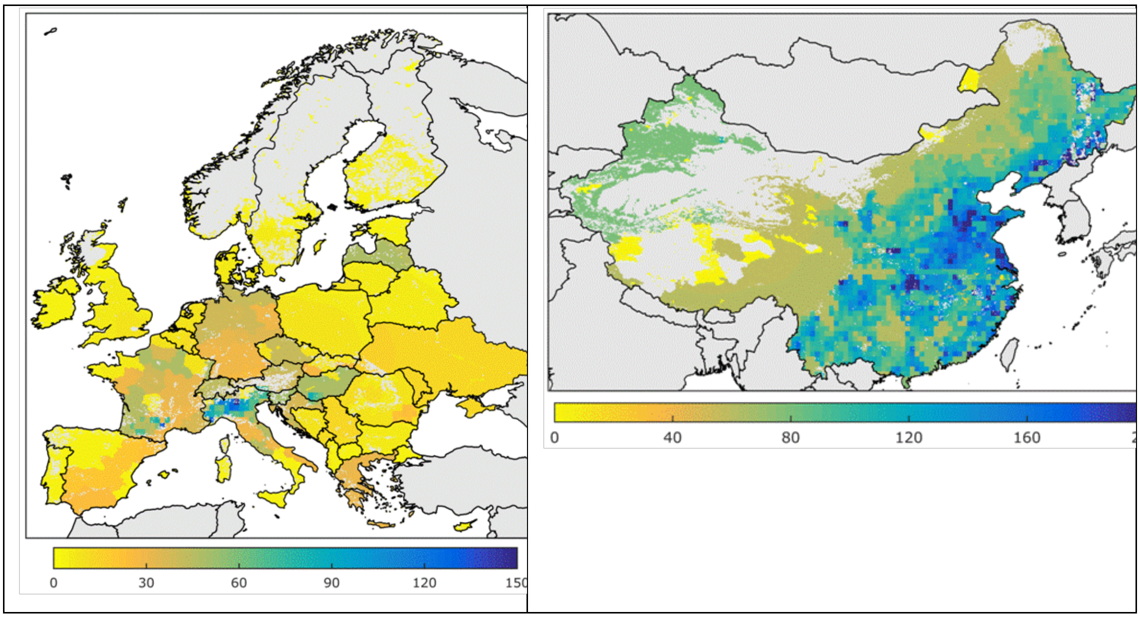

Figure 26. Soybean N application rate (kg/ha)

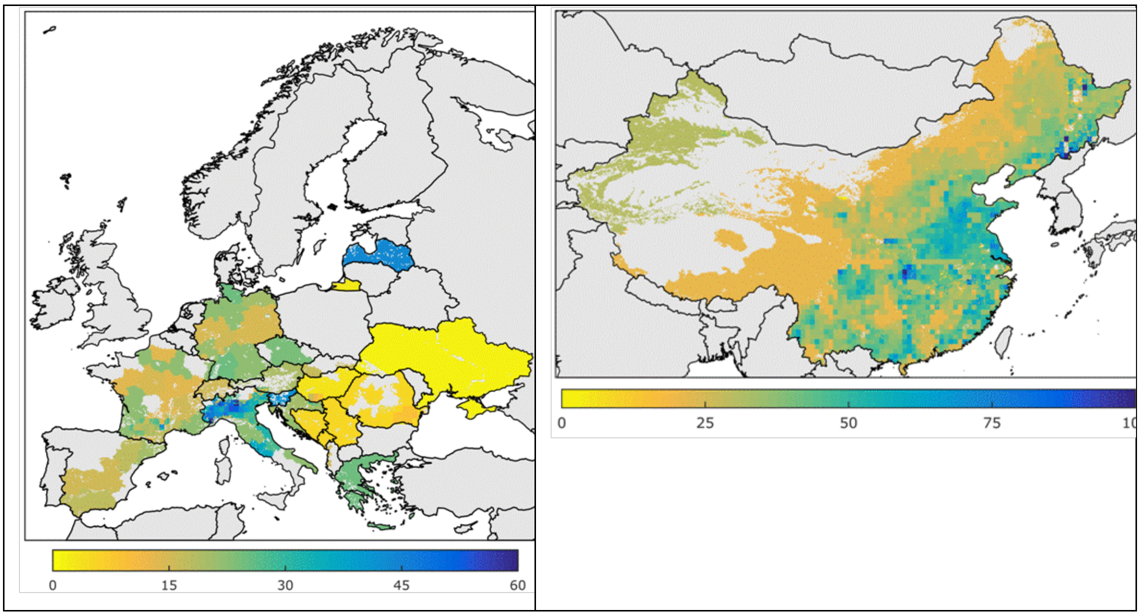

Figure 27. Soybean P application rate (kg/ha)

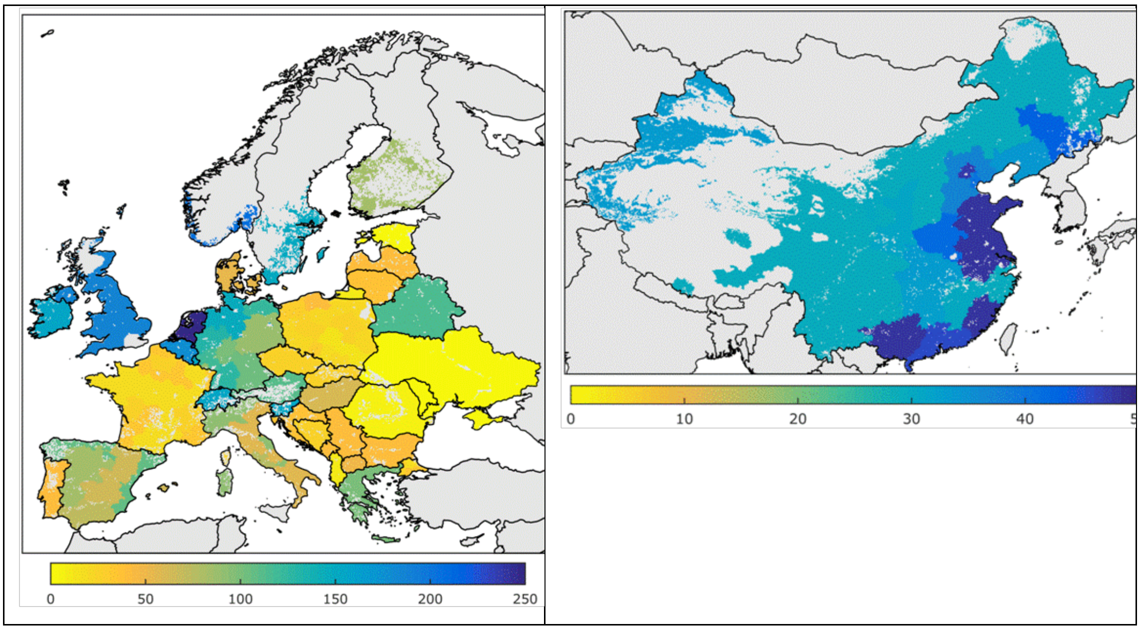

Figure 28. Potato K application rate (kg/ha)

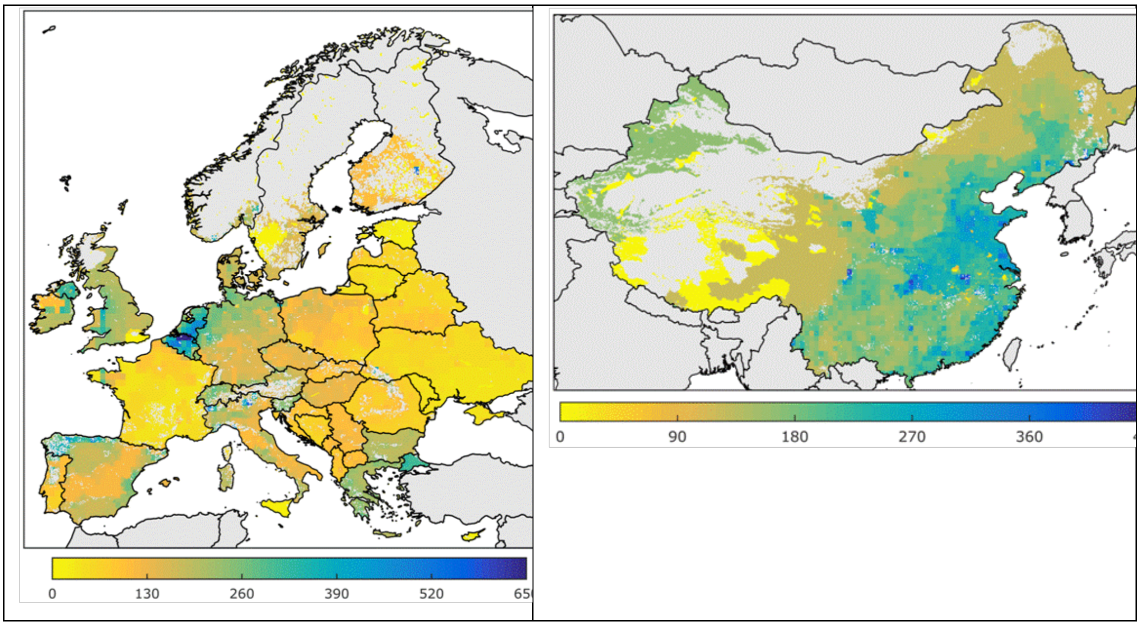

Figure 29. Potato N application rate (kg/ha)

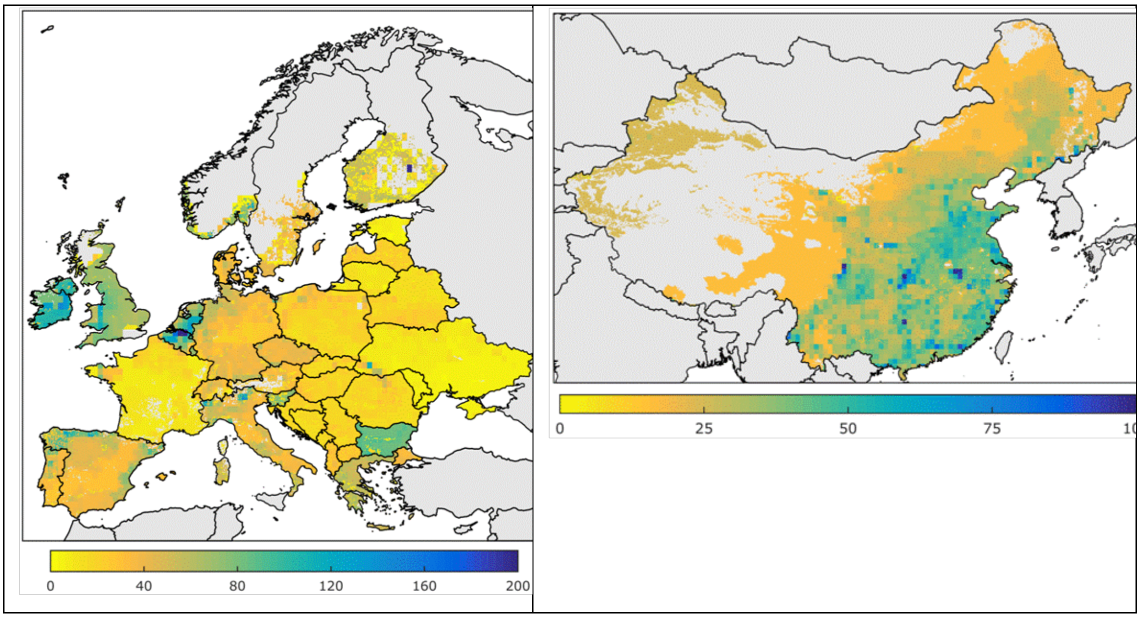

Figure 30. Potato P application rate (kg/ha)

6.2.4 Water management

The total irrigated area (in 1000 ha) was derived from the SAPM 2010 survey from Eurostat (ef_poirrig). The area that was irrigated at least once per year was used. It is also possible to use the potential area that can be irrigated or subdivide the area to the main crop (groups). Also the total volume of water used for irrigation is available. Figure 31 shows how Mediterranean regions are the most irrigated areas as well as Denmark. Data for Ireland is missing.

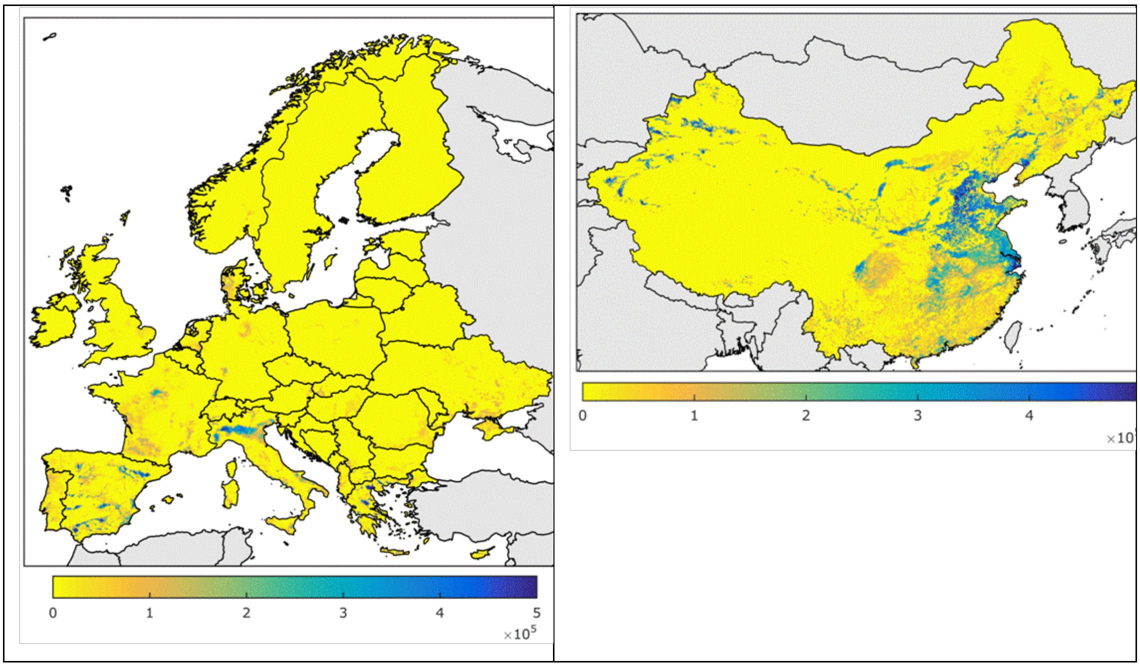

Figure 31. Total irrigated area in 1000 ha

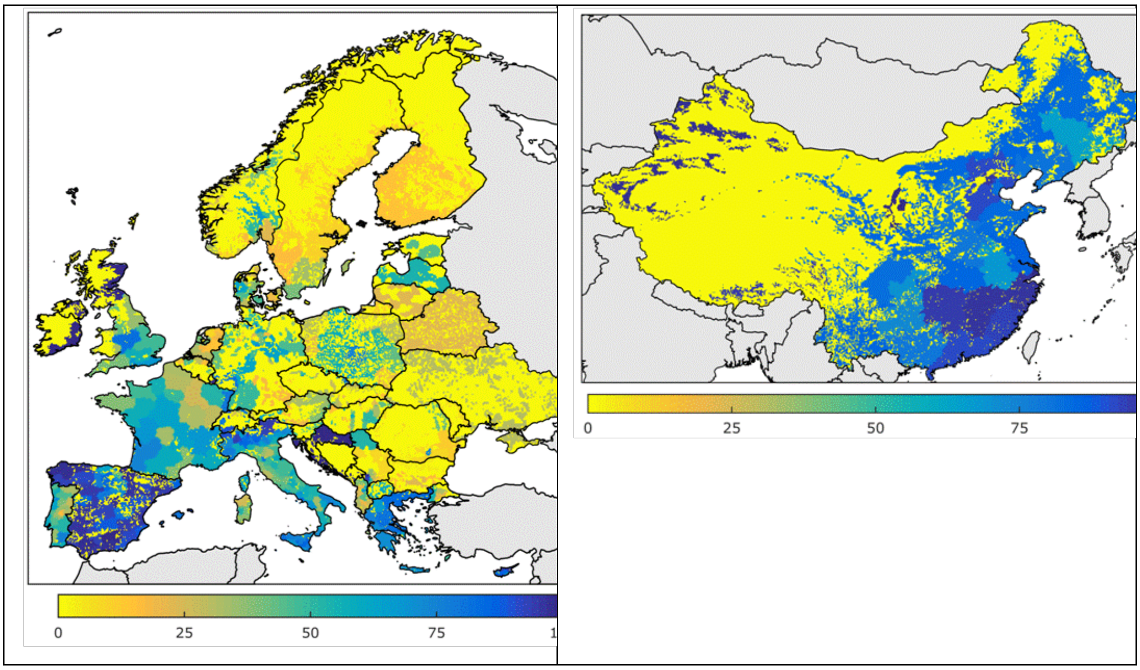

Figure 32. Percentage of irrigated area of equipped area for irrigation (%)

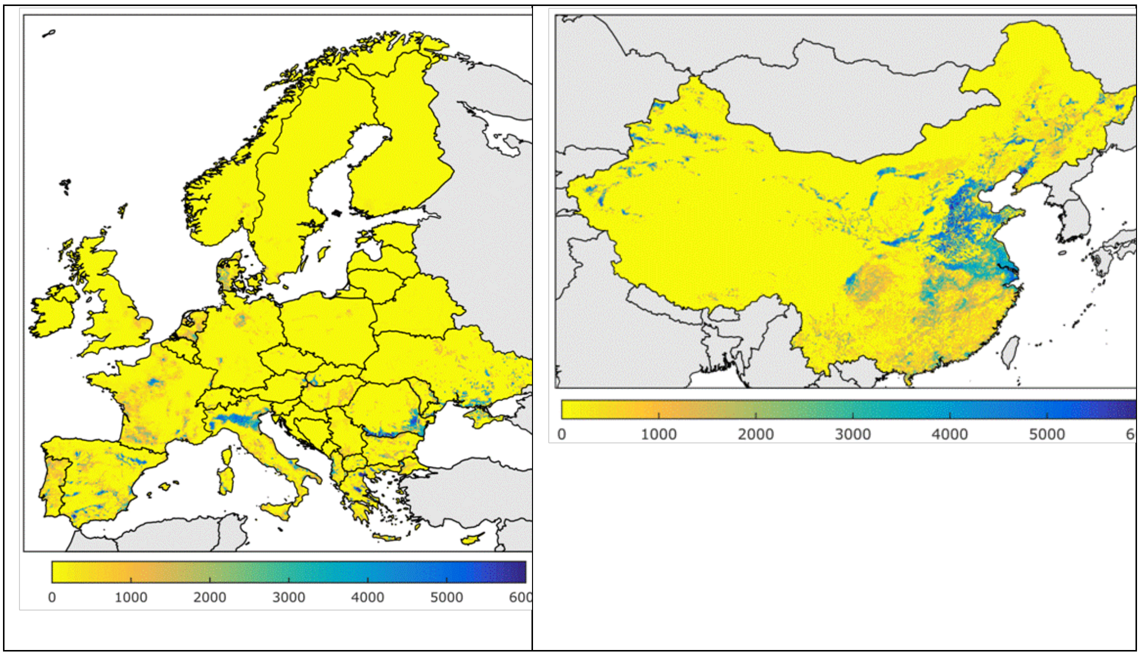

Figure 33. Area equipped for irrigation (ha)

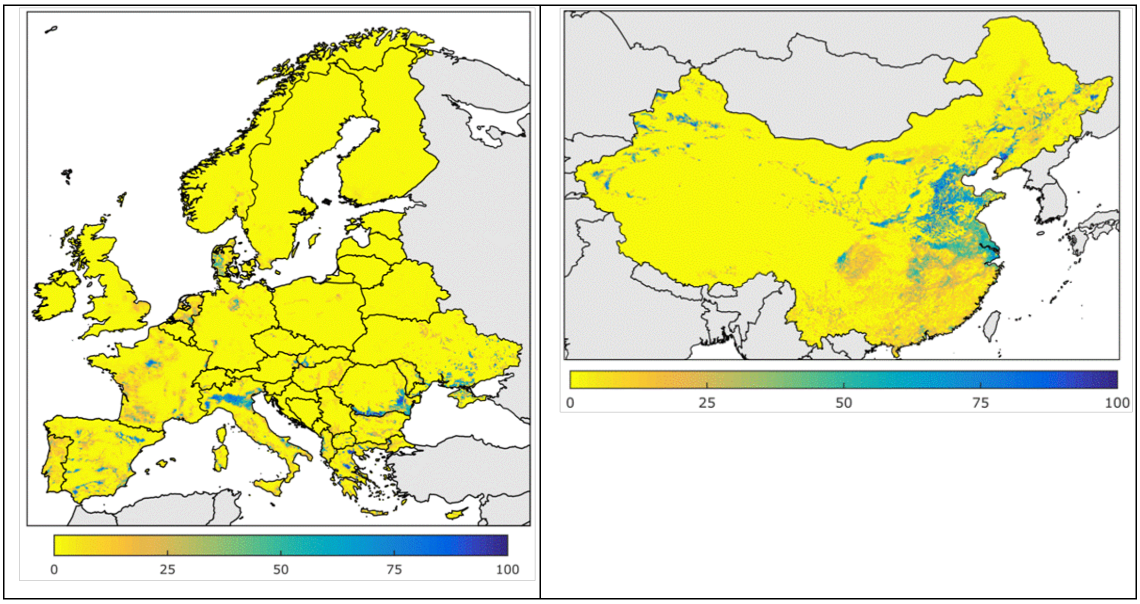

Figure 34. Percentage of area equipped for irrigation

6.2.5 Organic agriculture

The area of organic farming is expressed as percentage of the utilized agricultural area (UAA). These data are based on the 2010 FSS statistics at regional level from Eurostat (ef_mporganic) and exclude the farms in conversion to organic farming. The Eurostat data also offer the possibility to detail the area of organic farming by main crops. Most of regions show very low percentages of organic farming around 0-5% out of UAA. Only Salzburg region in Austria and Severozapad region in Czech Republic show the highest percentages between ranges 20-30% out of UAA (Figure 35).

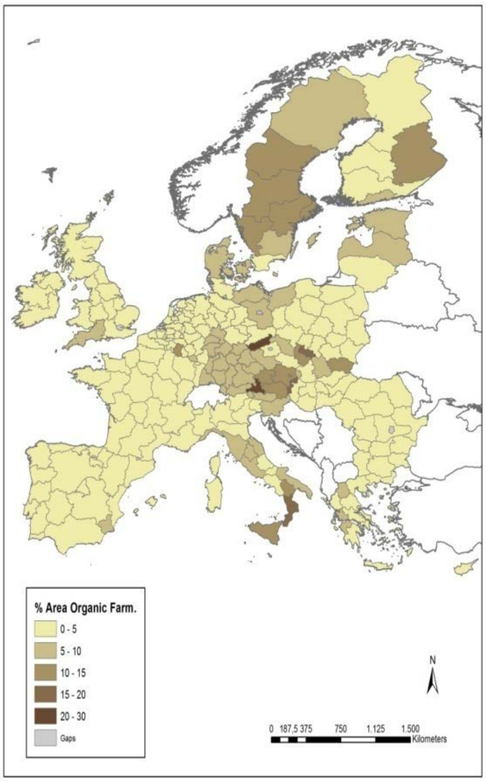

Figure 35. Area of organic farming as percentage of the utilized agricultural area (UAA), from SmartSOIL

6.3 Spatial analysis of soil quality indicators

The soil quality indicators presented below are those linked to the ecosystem services evaluated in WP7 of iSQAPER, as presented in Section 3.1. of this Deliverable.

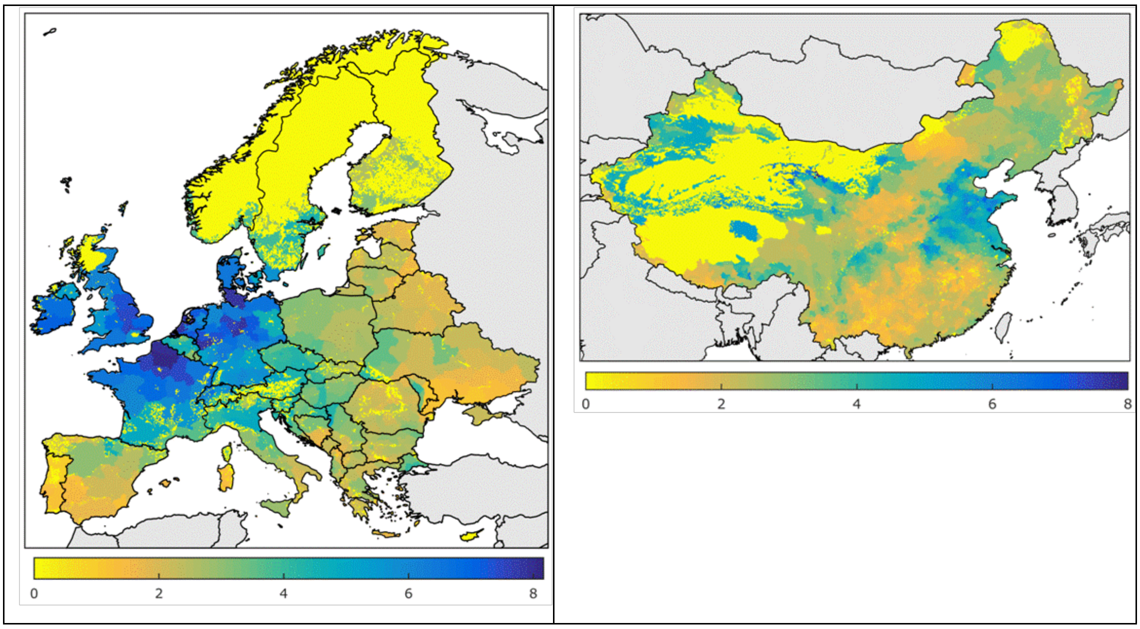

Figure 36. Cereal yield in Europe and China (t/ha)

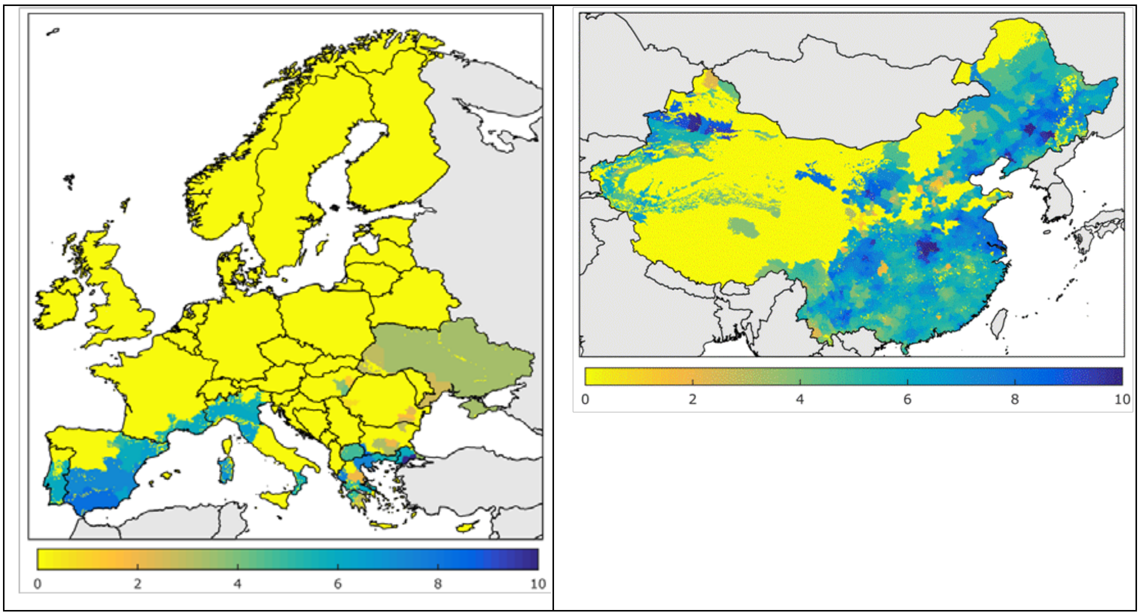

Figure 37. Rice yield in Europe and China (t/ha)

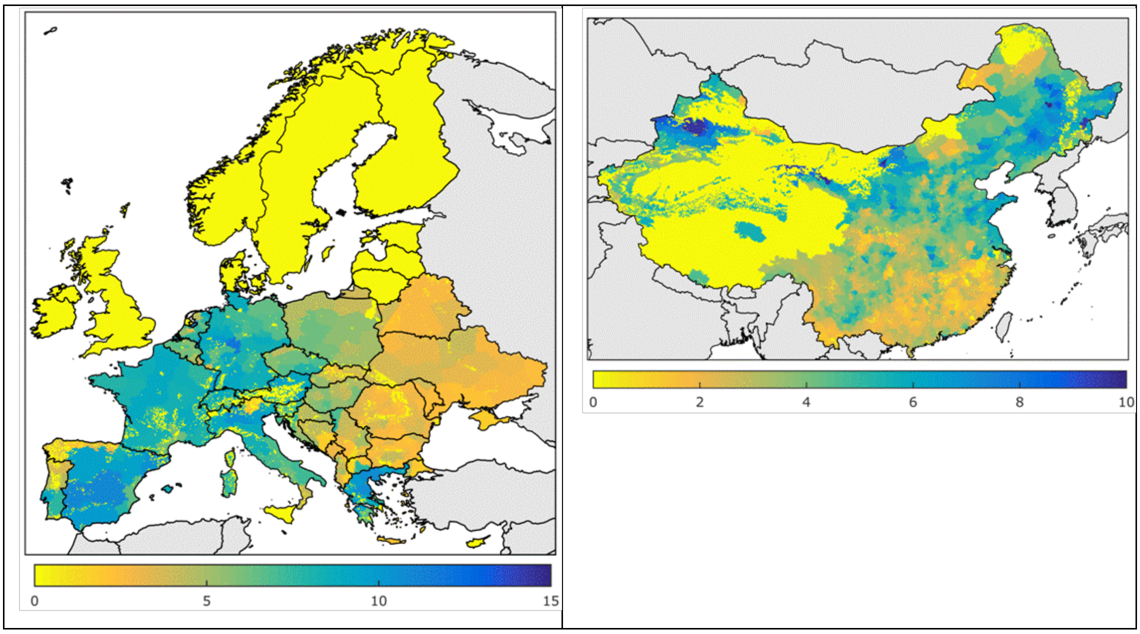

Figure 38. Maize yield in Europe and China (t/ha)

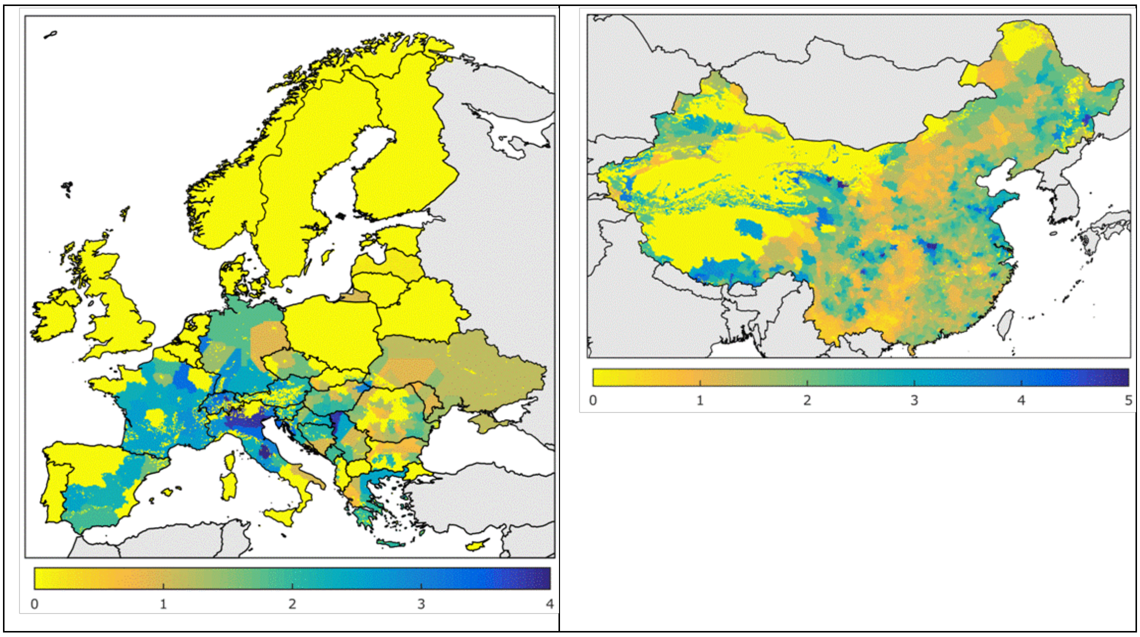

Figure 39. Soybean yield in Europe and China (t/ha)

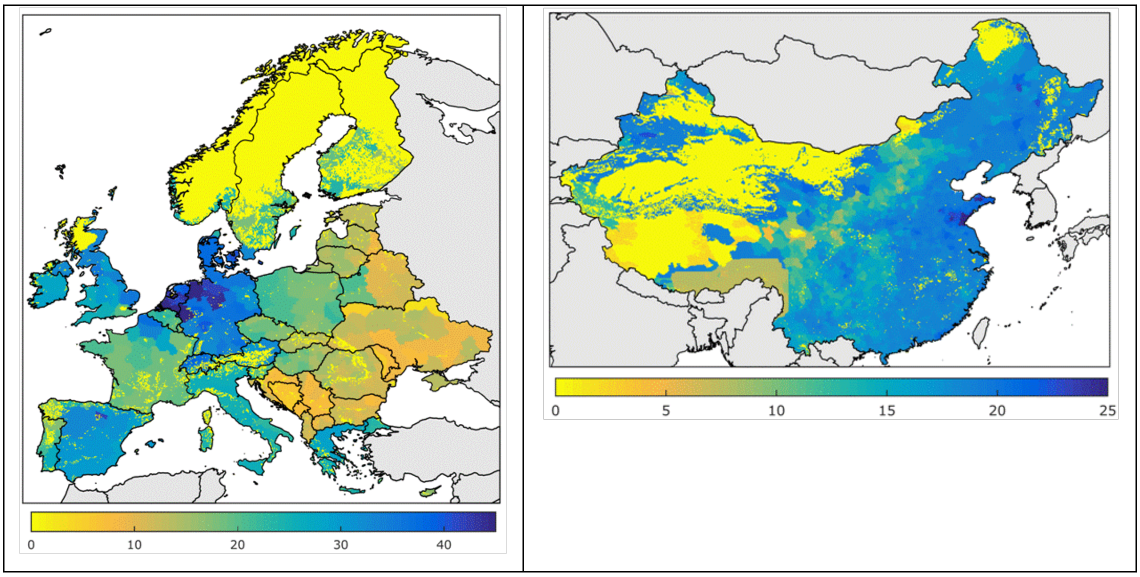

Figure 40. Vegetables yield in Europe and China (t/ha)

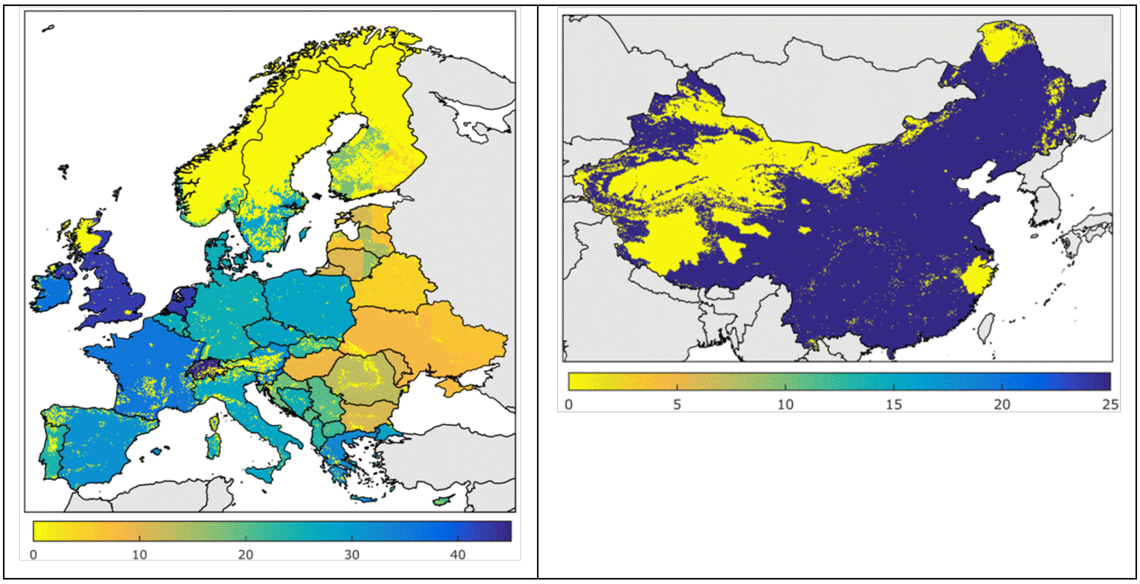

Figure 41. Pasture yield in Europe and China (t/ha)

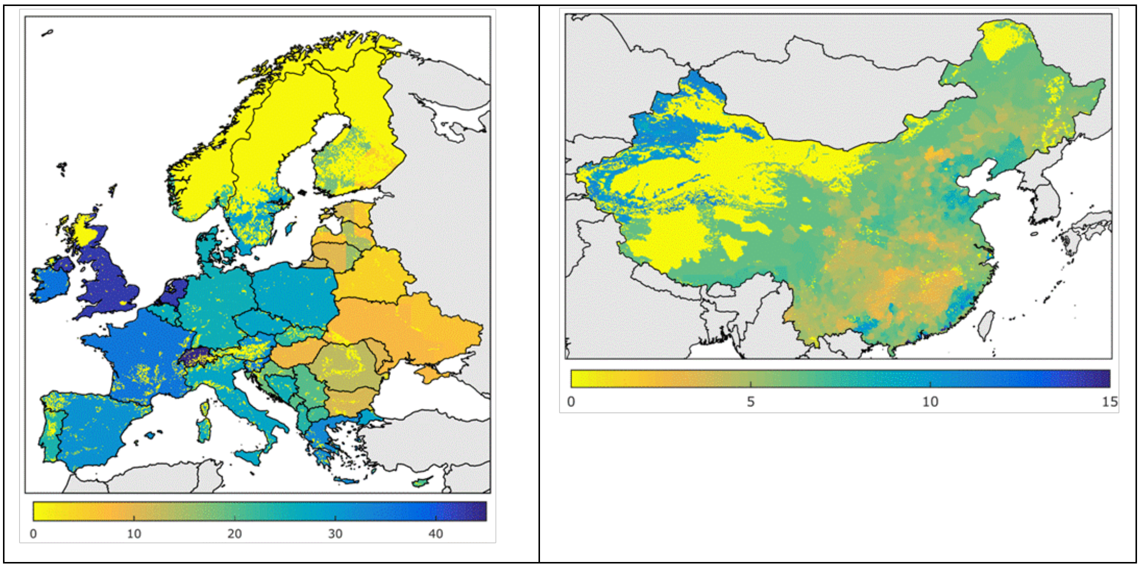

Figure 42. Permanent crops yield in Europe and China (t/ha)

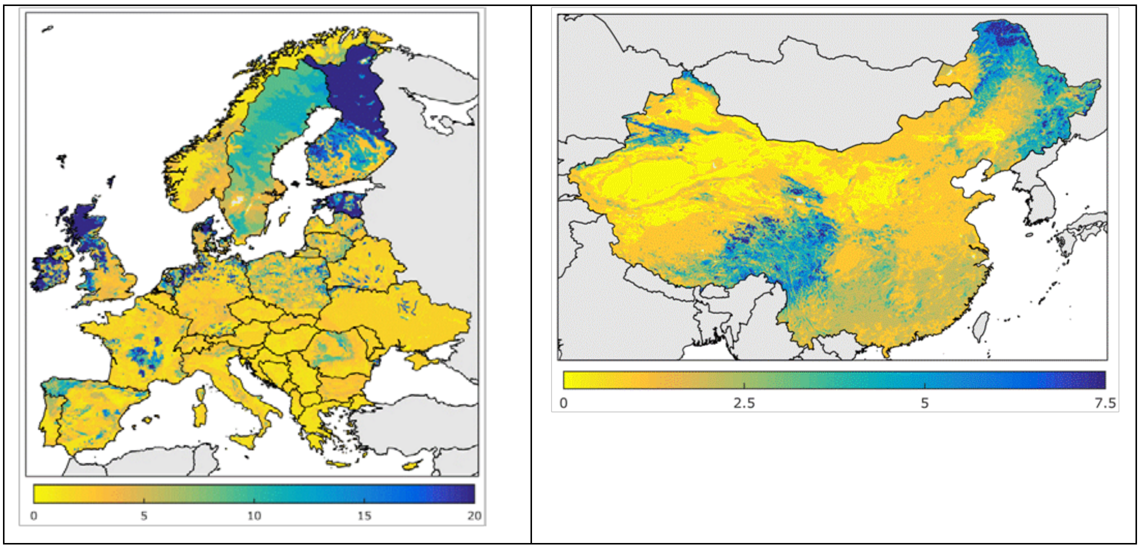

Figure 43. Soil organic carbon in Europe and China (% in weight)

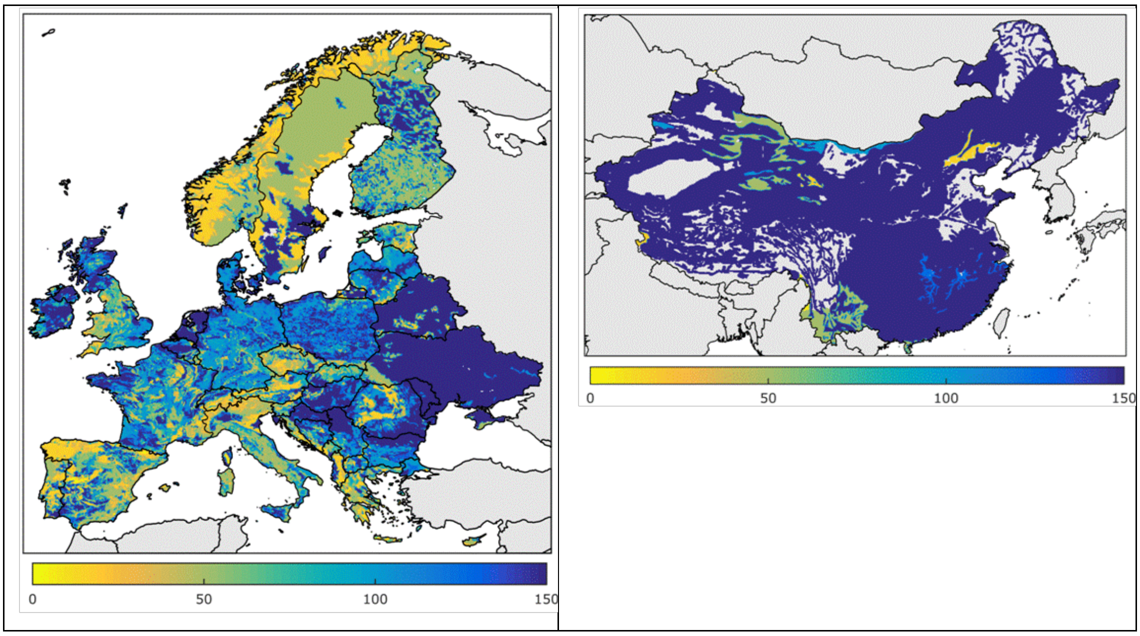

Figure 44. Water holding capacity in Europe and China (mm/m)

7 Effect of agricultural management practices on soil quality

The approach presented here is guided to the final aim of WP7 that is to evaluate the effect of different scenarios of agricultural management practices on soil environmental footprint and ecosystem services (as summarised in Figure 2).

7.1 Bottom-up analysis: based on experimental data from WP3 and WP4

7.1.1 Approach

The upscaling model is based on functional relations that establish the effect of categories of management practices on soil quality indicators for each type of farming system. In this section we present the functional relations adopted for the iSQAPER upscaling model. They are based on analysis of information provided by the case studies and from the LTE sites. The starting point are the conclusions of Deliverable 3.2 on the long term effect of agricultural management practices on soil quality indicators.

The dynamic upscaling model is based on functional relations that establish the effect of categories of management practices on soil quality indicators for each type of farming system. In this section we present the methodology adopted to specify the functional relations required for the iSQAPER upscaling model. The specification of the functional relations will be addressed in Deliverable 7.2.

The proposed methodology is based on the combination of two complementary approaches: a top-down approach, where functional relations are derived from global data, and a bottom-up approach, where functional relations are derived from expert assessment based on experiences compiled on iSQAPER long term experiment (LTE) sites and on case study (CS) sites.

The objective of the work is to specify a set of functional relations linking agricultural management practices to soil quality indicators. The relations are formulated in a qualitative way and describe the long-term tendency that can be expected to be observed in a soil quality indicator after the application of a certain category of management practice during a long period of time. For instance, functional relation F_{ij} is defined as: $\Delta SQI_i=f(APM_j)$, where ΔSQI_i is the expected change in soil quality indicator i and AMP_j is agricultural management practice j.

AMPs maybe characterized by the intensity of their application. Initially, APMs will be described by Boolean variables, which means that functional relations will only distinguish between the application or no application of the corresponding AMP. If there is enough information, AMP intensity may be further characterized in a qualitative domain.

The change in SQIs will be described in a qualitative domain of five values, identified as [**--** , **-** , **=** , **+** , **++**]. The interpretation of these qualitative categories is the following:

- **Positive (++)**: This category means that the management practice will certainly improve the soil quality indicator, with effects larger than 10%
- **Beneficial (+)**: This category means that the management practice has potential to improve the soil quality indicator, but the effects may depend on additional factors. The improvement will be between 5% and 10%

- **Neutral (=)**: This category represents a neutral impact of the management practice on the soil quality indicator under analysis. It corresponds to a positive or negative effect of less than 5%.
- **Unfavourable (-)**:This category means that the management practice may degrade the soil quality indicator, but the effects may depend on additional factors. The degradation will be between 5% and 10%
- **Negative (--)**: This category means that the management practice will certainly degrade the soil quality indicator, with effects larger than 10%

7.1.2 Functional relations

Bottom up analyses are based on information provided by the case studies and from the LTE sites. The starting point are the conclusions of Deliverable 3.2 on the long term effect of agricultural management practices on soil quality indicators (Tables 14 to 16).

Table 14. Effect of agricultural management practices on crop yield (based on D3.2)

	Organic matter	No tillage	Crop rotation	Irrigation	Organic farming
Cereals	=	+	++	=/++	+
Rice	=	n.a.	n.a.	n.a./++	+
Maize	=	=	+	=/++	=
Soybean	=	=	+	=/++	=
Vegetables	+	=	=	=/++	+
Pasture	+	+	n.a.	=/++	+
Permanent crops	+	+	n.a.	=/++	+
Del 3.2	1.2	0.95	1.2.	n.d.	0.75

Table 15. Effect of agricultural management practices on soil organic carbon (based on D3.2)

	Organic matter	No tillage	Crop rotation	Irrigation	Organic farming
Cereals	=	++	n.a.	n.a.	n.a.
Rice	=	n.a.	n.a.	n.a.	n.a.
Maize	=	+	n.a.	n.a.	n.a.
Soybean	=	+	n.a.	n.a.	n.a.
Vegetables	+	+	n.a.	n.a.	n.a.
Pasture	++	++	n.a.	n.a.	n.a.
Permanent crops	=	=	n.a.	n.a.	n.a.
Del 3.2	1.25	1.10	n.a.	n.a.	n.a.

Table 16. Effect of agricultural management practices on water holding capacity (based on D3.2)

	Organic matter	No tillage	Crop rotation	Irrigation	Organic farming
Cereals	=	+	++	=/++	+
Rice	=	n.a.	n.a.	n.a./++	+
Maize	=	=	+	=/++	=
Soybean	=	=	+	=/++	=
Vegetables	+	=	=	=/++	+
Pasture	+	+	n.a.	=/++	+
Permanent crops	+	+	n.a.	=/++	+
Del 3.2	+	+	n.a.	=/++	+

7.2 Top-Down analysis: based on probabilistic estimates from spatial data

In the top down analysis information on functional relations is derived from global data available in the data catalogue. We have explored two types of data-based inference: linear regression and conditional probability. In this section we present preliminary results of these two approaches, which will be further developed, validated and combined with bottom up approaches in Deliverable 7.2.

The preliminary analyses have been performed on the global datasets of soil quality indicators and other variables. We have explored the effect of potential causal variables on soil quality indicators. We selected the variables with better quantitative, spatially explicit information in the data catalogue.

7.2.1 Regression analysis

In this section we present regression analyses on available data for available soil quality indices. We selected crop yield as SQI and irrigation as AMP.

Yield

Figure 45 shows the results of the linear regression analyses performed on crop yield as a function of irrigated area (in the grid cell) for the seven farming systems in Europe. We present the scatter plot of the global data (grid cells with values of both variables >0), the linear fit (represented by the red line), the linear regression equation and the correlation coefficient. Figure 46 shows the results of the linear regression analyses performed on crop yield as a function of irrigated area (in the grid cell) for the seven farming systems in China. Results shown in Figures 45 and 46 are not very encouraging. The scatter plot does not show a clear relation between both variables for any farming system and correlation coefficients are very low, suggesting that the degree of actual dependence between both variables is very low.

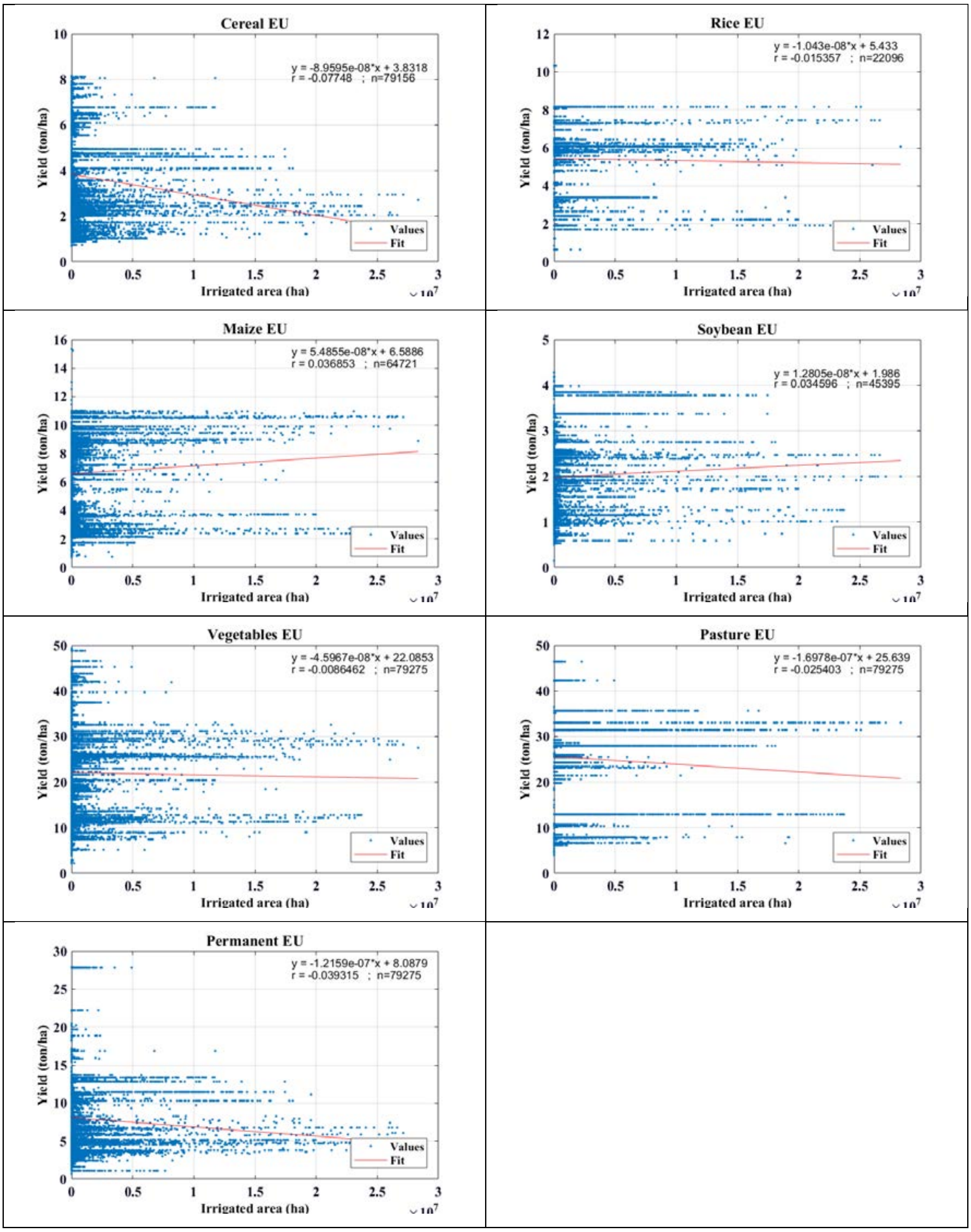

Figure 45. results of the linear regression analyses performed on crop yield as a function of irrigated area for the seven farming systems in Europe: Cereal (1st row left), Rice (1st row right), Maize (2nd row, left), Soybean (2nd row, right), Vegetables 3rd row, left), Pasture (3rd row, right) and Permanent crops (4th row)

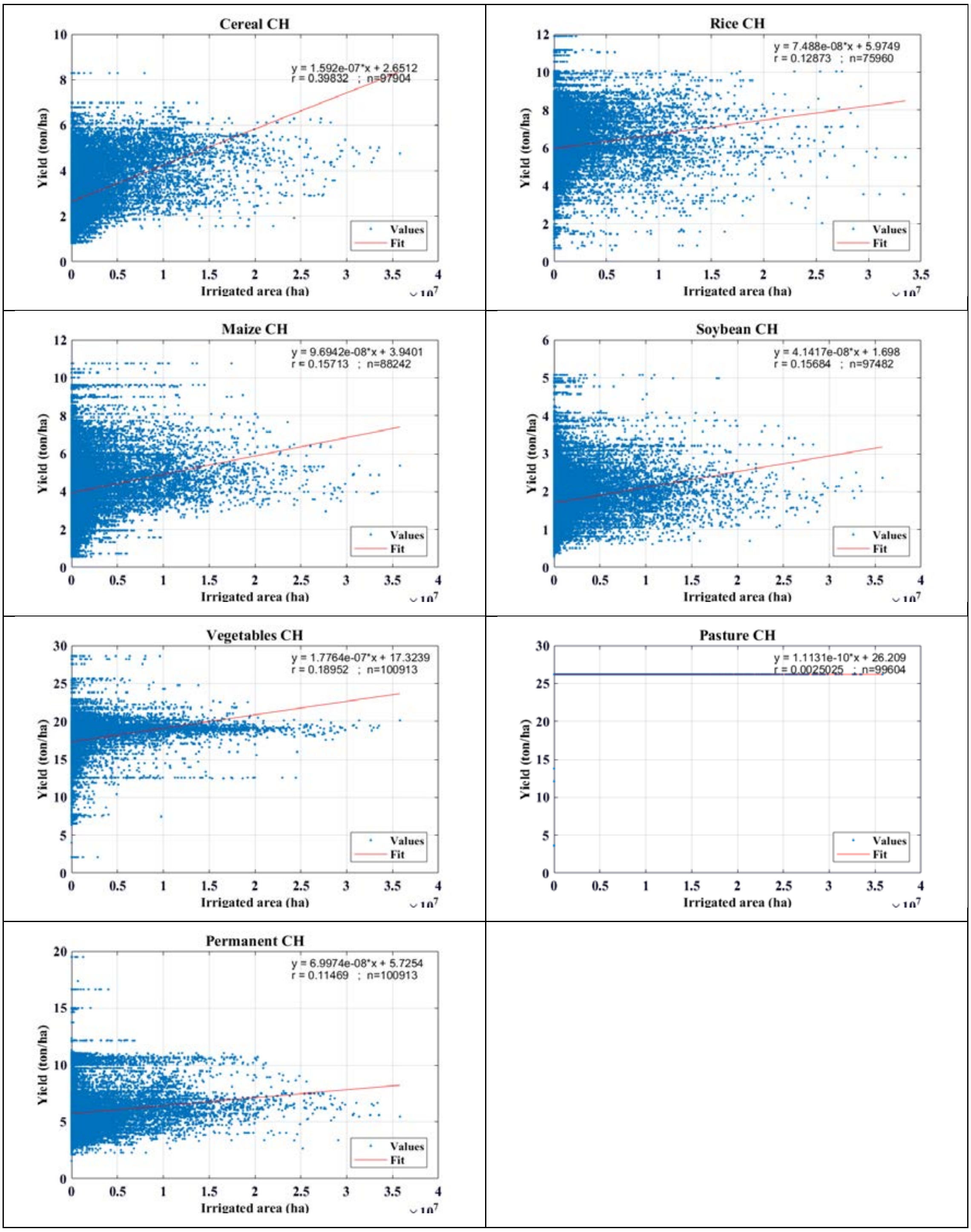

Figure 46. results of the linear regression analyses performed on crop yield as a function of irrigated area for the seven farming systems in China: Cereal (1st row left), Rice (1st row right), Maize (2nd row, left), Soybean (2nd row, right), Vegetables 3rd row, left), Pasture (3rd row, right) and Permanent crops (4th row)

Soil organic carbon

Figure 47 shows the results of the linear regression analyses performed on Soil Organic Carbon(SOC) as a function of irrigated area (in the grid cell) in Europe and China. They correspond to the total farming area, because no data were available for individual farming systems. As in the previous figures, we present the scatter plot of the global data (grid cells with values of both variables >0), the linear fit (represented by the red line), the linear regression equation and the correlation coefficient. In this case, although the correlation coefficient is still very low, there seems to be a relation between SOC and irrigated area. It appears that as irrigated area is greater, SOC is drastically reduced. This relation is not linear, and this explains that the correlation coefficient is so low. A possible non-linear functional relation will be explored in Deliverable 7.2.

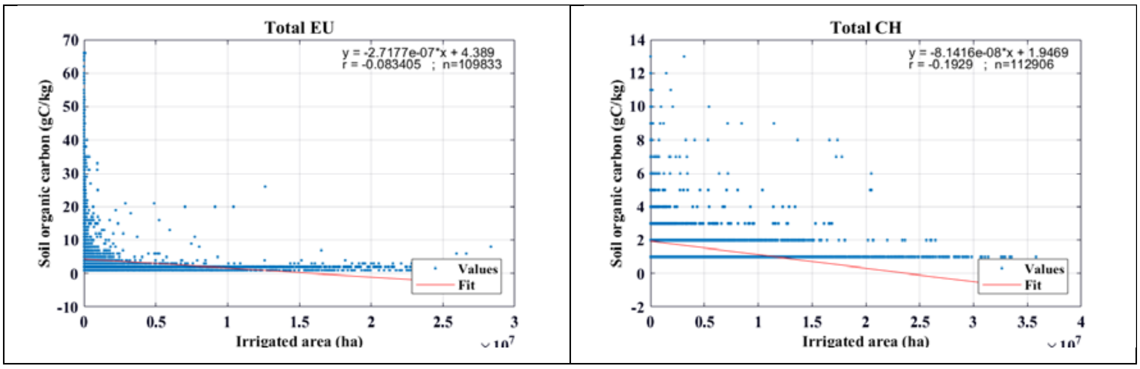

Figure 47. results of the linear regression analyses performed on soil organic carbon as a function of irrigated area for Europe (left) and China (right)

Water holding capacity

Figure 48 shows the results of the linear regression analyses performed on Water Holding Capacity (WHC) as a function of irrigated area (in the grid cell) in Europe and China. No data were available as a function of farming systems. We present the scatter plot of the global data (grid cells with values of both variables >0), the linear fit (represented by the red line), the linear regression equation and the correlation coefficient. In this case, there seems to be a relation between WHC and irrigated area. WHC appears to grow as irrigated area grows. This relation is not linear, as shown by the low values of the correlation coefficient, and will be explored in Deliverable 7.2.

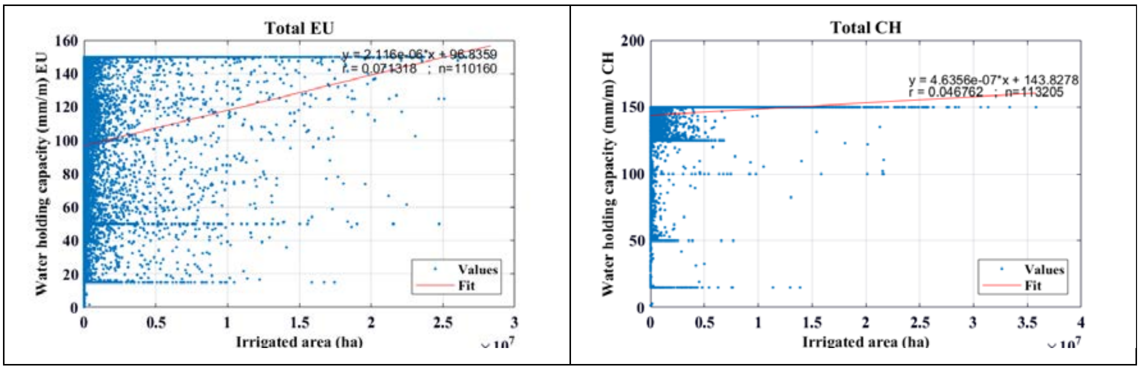

Figure 48. results of the linear regression analyses performed on water holding capacity as a function of irrigated area for Europe (left) and China (right)

7.2.2 Conditional probability analysis

Conditional probability analysis is an alternative approach to linear regression analysis. To explore the relation between two variables, we analyse the joint probability distribution function (PDF). We compare the marginal PDF of the SQI with the PDFs of the SQI conditioned to different values of the AMP variable. If the two variables are not related, the different PDFs are similar. If the variables are related, the PDF of the SQI will change as the conditioning values change.

Yield

Figure 49 shows the results of the conditional probability analyses performed on crop yield as a function of irrigated area (in the grid cell) for the seven farming systems in Europe. We present the global PDF of crop yield (in blue) and the PDFs of crop yield conditioned to no irrigated area (in black) and to irrigated area greater than zero (in red).

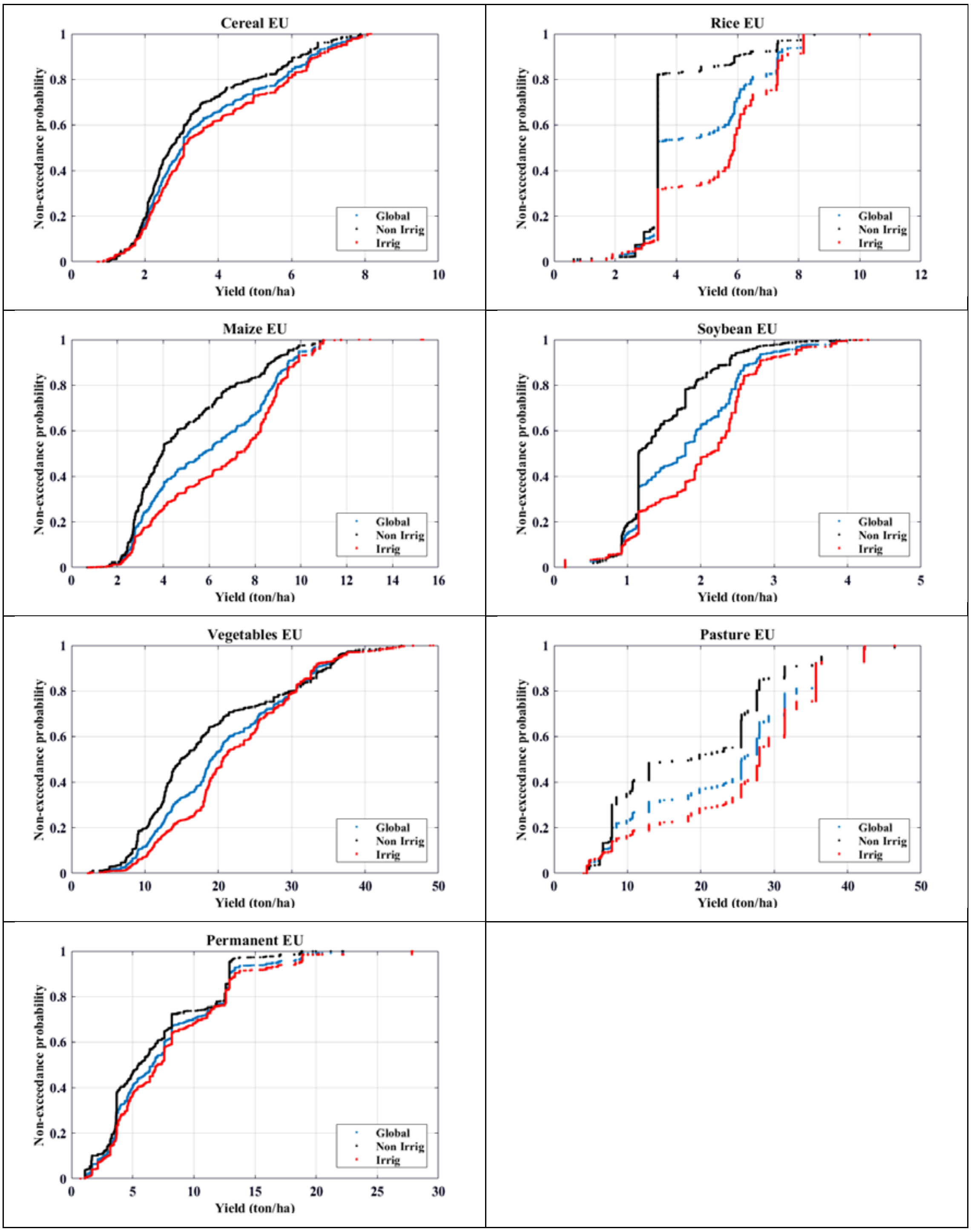

Figure 49. Results of the conditional probability analyses performed on crop yield as a function of irrigated area for the seven farming systems in Europe: Cereal (1st row left), Rice (1st row right), Maize (2nd row, left), Soybean (2nd row, right), Vegetables 3rd row, left), Pasture (3rd row, right) and Permanent crops (4th row)

Figure 50 shows the results of the conditional probability analyses performed on crop yield as a function of irrigated area (in the grid cell) for the seven farming systems in China.

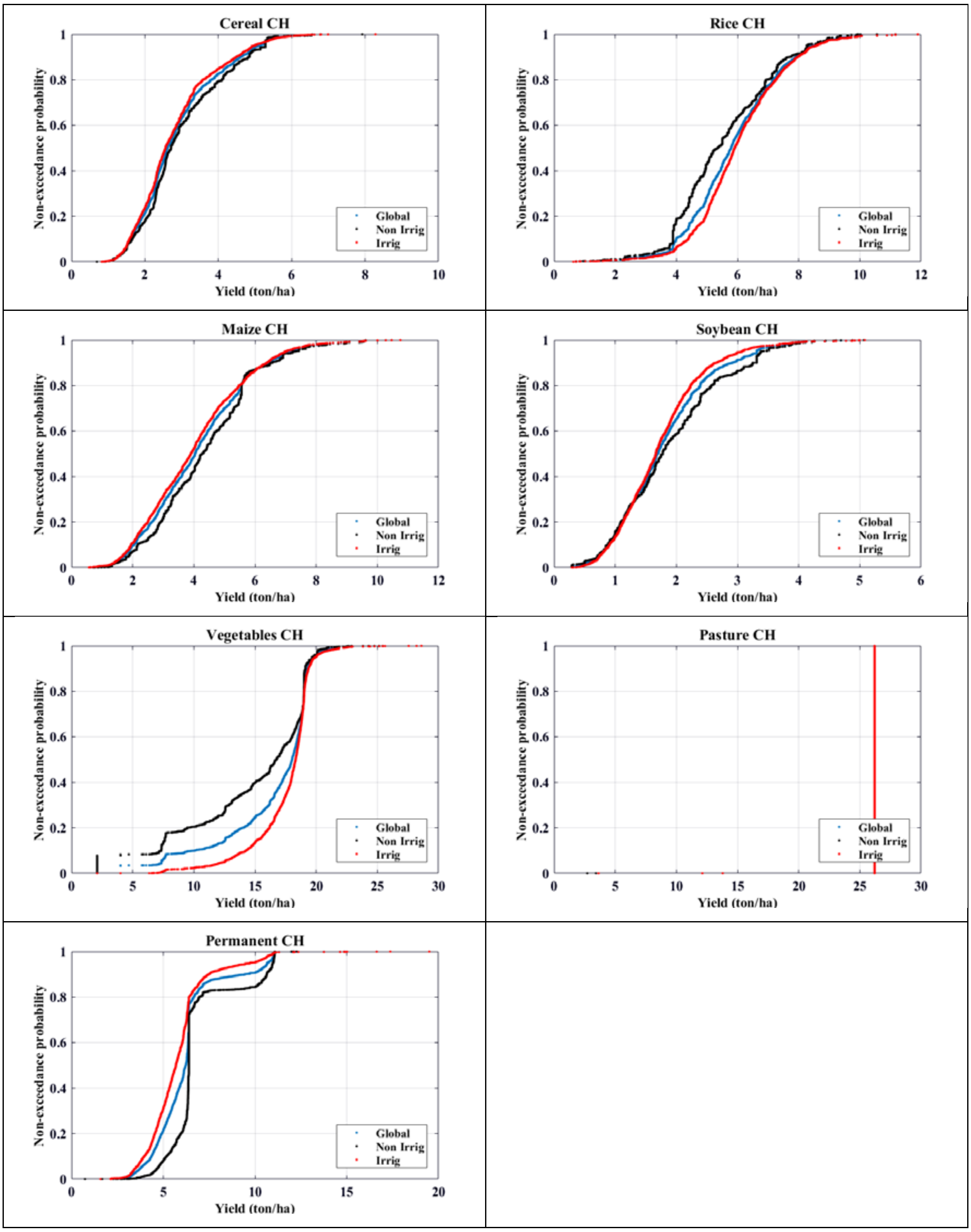

Figure 50. Results of the linear regression analyses performed on crop yield as a function of irrigated area for the seven farming systems in China: Cereal (1st row left), Rice (1st row right), Maize (2nd row, left), Soybean (2nd row, right), Vegetables 3rd row, left), Pasture (3rd row, right) and Permanent crops (4th row)

The effect of irrigation is more apparent in this analysis than in the regression analysis. By comparing the PDFs with and without irrigation we can estimate the expected effect of irrigation on crop yield. We work under the assumption that all other factors influencing crop yield (climate, soil type, other management practices, and other scenarios to be co-defined with stakeholders) have a similar effect in irrigated and non-irrigated areas. Although this assumption is certainly questionable, the results suggest that irrigation has a global positive effect on crop yields for most farming systems in Europe. The relationship is more clear for Maize and Soybean, and less apparent in Cereal and Permanent Crops. In the cases of Rice and Pastures the effect is also significant, but the discontinuities in the PDFs suggest that data may not be enough to draw a sound conclusion. The effect of irrigation in China is weaker than in Europe. Results suggest a positive effect on Rice and vegetables and a neutral or negative effect in the other farming systems, although the PDFs are very close in most cases.

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Soil organic carbon

Figure 51 shows the results of the conditional probability analyses performed on Soil Organic Carbon (SOC) as a function of irrigated area (in the grid cell) in Europe and China. They correspond to the total farming area, because no data were available for individual farming systems. As in the previous figures, we present the global PDF of crop yield (in blue) and the PDFs of crop yield conditioned to no irrigated area (in black) and to irrigated area greater than zero (in red).Results for both regions suggest that irrigation reduces soil organic carbon, or, at least, that it is generally applied to soils with less organic carbon content. However, the data available produce an irregular PDf, particularly in China, and this may introduce some uncertainty on the conclusions.

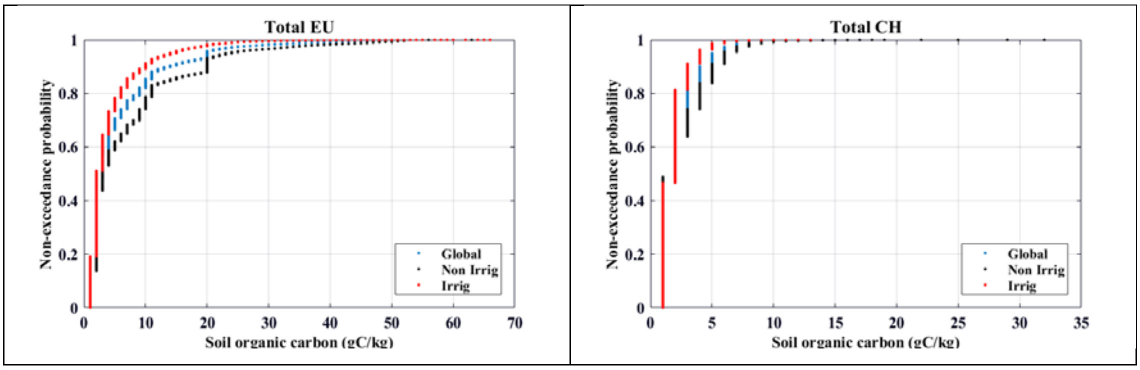

Figure 51. results of the linear regression analyses performed on soil organic carbon as a function of irrigated area for Europe (left) and China (right)

Water holding capacity

Figure 52 shows the results of the conditional probability analyses performed on Water Holding Capacity (WHC) as a function of irrigated area (in the grid cell) in Europe and China. Results show a positive effect of irrigation on WHC, particularly in Europe. This effect may be due to the fact that there is less probability to invest in irrigation of a soil has low WHC. This relation will be further explored in Deliverable 7.2.

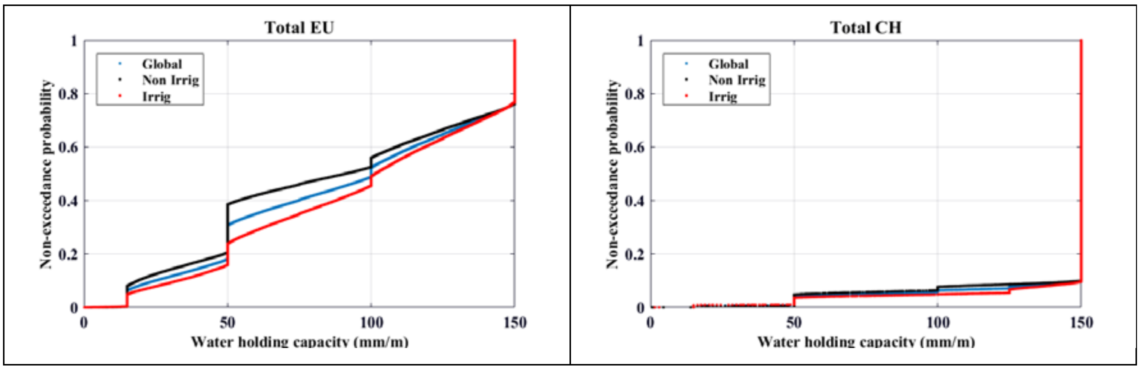

Figure 52. Results of the linear regression analyses performed on water holding capacity as a function of irrigated area for Europe (left) and China (right)

8 Gaps in knowledge and further work

8.1 Gaps in knowledge and data

Work in Task 7.1 has made use of available knowledge and data to define the framework for upscaling. However, available knowledge and data is far from complete, and the upscaling process necessarily involves filling these gaps with ad-hoc decisions.

The data compiled from upscaling have been collected by different disciplines, and different schools within each discipline concerned, and often for different purposes. They have been collected with different questions in mind, different disciplinary epistemologies, different methods and techniques. This challenge is particularly relevant in the upscaling context, where we need to merge natural science (systemic) models with social-science.

Regardless of the scale considered in a spatial analysis of the effect of soil management practices on soil environmental footprint, it is important to remember that, as is the case with most statistical analyses, these can only describe a pattern and changes in a pattern; only if the local data validate the continental results, these are useful, since only local observed measurement provide some underlying processes can be inferred.

In the mapping examples described in this Deliverable 7.1, the spatial statistical analysis was used to describe possible pattern of effect on soil quality indicators, but we cannot infer on the process of effect. Combined results from global and local analyses are essential to indicate that the process improving soil environmental footprint.

General questions that need to be considered in geospatial studies include the following:

- what are the best criteria for selecting the spatial (and temporal) unit of analysis?
- how do the key measures of effect dynamics vary with scale?
- how do we integrate processes occurring at diverse spatial and temporal scales?
- are we uncovering new relevant information or covering up the lack of data with massive environmental correlates?
- how do we decide which environmental or climate changes to follow?
- how do we move beyond considering isolated indicators to considering overall soil health and the factors contributing to it?

All of these questions can only be addressed through solid biological, agronomic and socioeconomic understanding of the system in time and space. As far as whether to go upscale (extrapolate) or downscale (interpolate), we quote Levins (1968), who stated, “the detailed analysis of a model for purposes other than that which it was constructed may be as meaningless as studying a map under a microscope.”

The continental soil health perspective demands an understanding of both the soil system, the human-derived forces and impacts, and the possibilities ofthreshold-dependent changes and tipping points (Moore et al., 2001).

Static indicators of soil health are perhaps insufficient to understand the impacts ofchanging conditions (Jackson et al., 2009). Modelling the dynamical relationships between social and soil processes is needed as part of the evidence base for making appropriate management decisions. The approach presented here will help to address the management questions that can only be addressed by upscaling.

Complex socio-ecological systems are unpredictable and parameteriszing social dynamics, such as individual behaviour and governance, is probably impossible (Silver 2012). Therefore, the ability of a model to provide consistent output for evaluating scenarios is very useful.

8.2 Further work

The scope of this deliverable is to set up the framework for upscaling in iSQAPER by defining typical combinations of farming systems and agricultural practices in Europe and China and identifying their effects on soil quality. This work will be refined in Deliverable 7.2, where the potential of agricultural management practices will be assessed by involving the case studies and other project partners and stakeholders.

Further analysis to be carried out in task 7.2 includes the following steps:

Step 1

WP7, led by the UPM, will engage the case study managers in iSQAPER to fill a questionnaire relevant to the adequacy of the approach to evaluate the environmental footprint in the case studies, and the data that could be provided to validate the approach (Task 7.2).

Step 2

UPM will propose a revision of the methods based on the results of the questionnaire and evaluate what we need to know in addition to the data provided that will be helpful to assess the effect of soil management practices on the environmental footprint.

9 References

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