Deliverable 8.2. Inventory of policy relevant data and sources extracted from WPs 3-7 and applicable to policy design: the importance of effective data combining

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Deliverable: 8.2
Milestone type: Report
Issue date: November 2020
Project partner: IEEP

DOCUMENT SUMMARY	
Project Information	
Project Title	Interactive Soil Quality Assessment in Europe and China for Agricultural Productivity and Environmental Resilience
Project Acronym	iSQAPER
Call identifier	The EU Framework Programme for Research and Innovation Horizon 2020: SFS-4-2014 Soil quality and function
Grant agreement no:	635750
Starting date	1-5-2015
End date	30-4-2020
Project duration	60 months
Web site address	www.isqaper-project.eu
Project coordination	Wageningen University
EU project representative & coordinator	Prof. Dr. C.J. Ritsema
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Deliverable Information	
Deliverable title	Inventory of policy relevant data and sources extracted from WPs 3-7 and applicable to policy design: the importance of effective data combining
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Delivery Number	D8.2
Work package	8
WP lead	Institute for European Environmental Policy
Nature	Public
Dissemination	Report
Editor	
Report due date	May 2020
Report publish date	November 2020
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Introduction

This report presents an inventory of policy-relevant data and sources arising from the iSQAPER project, as well as an overview of the importance of data combination in the context of soil quality assessment.

Data and sources are presented with regard to:

- Evidence for **agricultural management effects** provided by long-term field trials across Europe and China on soil physical, chemical and biological properties, including interactions, and related ecosystem services such as agricultural productivity and yield stability
- Innovative **soil quality indicators** and the use of existing soil quality indicators and assessment techniques
- Soil quality related information with **characterisations of crop and livestock farming systems** in various pedo-climatic zones across Europe and China
- Scenarios of how widespread application (**upscaling**) of improved agricultural management practices can contribute to a lower soil environmental footprint at a continental scale (Europe and China)
- Soil & agriculture related **policy**

The project developed an overview of a number of good practices with regard to agricultural management practices which are presented and linked to online. In addition, sources of information with relevance to the policy goals and policy measures presented in the EU's Farm to Fork Strategy, 2030 Biodiversity Strategy, and revised Common Agricultural Policy are presented.

Why is combining data important in assessing soil quality?

Soils are a complex system and provide multiple ecosystem services and functions, and they are faced with numerous combined threats. To provide an accurate picture of a soil's utility or quality, one data point is not sufficient, one parameter or indicator does not provide a true understanding[1]. Soil quality can only be assessed by a combination of indicators, capturing soil physical, chemical and biological properties.[2] The choice of indicators used depends on the targeted soil functions or ecosystem services.

[1] Bongiorno, G. (2020) Assessing soil quality in agro-ecosystems: For reversing soil degradation and enhancing soil Multifunctionality. https://bit.ly/37Qao68

[2] Bünemann, E. K. et al. (2018) Soil quality - A critical review. Soil Biology and Biochemistry, Volume 120, May 2018, pp 105-125. https://www.isqaper-is.eu/soil-quality/concepts-of-soil-quality-indicators/146-concepts-of-soil-quality

Opportunities for data combining – Examples from iSQAPER

The iSQAPER project looked at the assessment of soil quality and within this briefing we bring together some important examples for data combination that helps to support better soil assessment, and in so doing, policy making across all the spheres touched by soil threats, from agriculture and nature protection to climate mitigation and adaptation.

1. **Aid understanding of anticipated soil conditions – the development of pedoclimatic zones, combining soil parameters with climatic parameters to develop soils zones to provide a better basis for determining mapped coverage of soil conditions and likely crop suitability.**

Edaphic and climatic conditions co-determine site characteristics influencing both diversity and productivity of natural and agroecosystems, respectively. Consequently, pedoclimatic zonation, a spatial determination of different soil classes under a climatic zone provides more detailed site-specific information combining soil and climatic characteristics in order to finetune cropping patterns and practices.

Our analysis highlights the main features of farming by soil in Europe. Results suggest that farmers consciously take the pedoclimatic condition of farming, in all its complexity, into account when selecting their cropping patterns. In other words, farming by soil is a common practice in the different climatic regions of Europe.

The fact that both zonal and azonal soils are among the soil types that might be cropped differently from the main cropping pattern of given regions shows that apart from climatic factors, soil conditions also have a dominant role in selecting the most suitable crops. However, we have strong reasons to believe that soil suitability-based cropping is not practiced to its full potential over the continent at the moment. For example, our findings suggest that legumes are not always adapted to their potential production area for the local pedoclimatic conditions in several zones.

It is clear from our analysis, for example in zones where climatic conditions limit crop production more than in other zones, that the role of soil type due to its buffering ability in the mitigation of disadvantageous conditions, for example through moisture conservation, is very important. On the other hand, while land users need to optimise their cropping systems for the prevailing ecological conditions, economic motivations may alter agricultural practices or cropping patterns.

We can assume farmers select crops according to edaphic conditions whenever economic considerations do not override the ecological consideration of farming. The future direction in the greening of the Common Agricultural Policy should include incentives that promote the optimisation of soil resource use for the most profitable option that considers the local pedoclimatic conditions as well.[3]

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[3] Tóth, G., Kismányoky, T., Kassai, P., Hermann, T., Fernandez-Ugalde, O., Szabó, B. 2020. Farming by soil in Europe: status and outlook of cropping systems under different pedoclimatic conditions. PeerJ 8:e8984 http://doi.org/10.7717/peerj.8984

2. **Developing an integrated indicator set to link soil parameters to soil quality and the delivery of ecosystem services – what should I test to understand my soil's condition and quality?**

Soil quality is best assessed by a combination of visual assessments (VSA) in the field and samples taken for laboratory analysis, covering chemical, physical and biological indicators. For example, such an indicator set could comprise indicators for soil organic matter, acidity, soil structure, water holding capacity and biological activity. Both long-term experiments and farm surveys using this approach revealed that management practices such as reduced tillage, organic agriculture, organic matter inputs and crop rotation positively affect soil quality, but with trade-offs between different ecosystem services.

A promising novel indicator identified by the iSQAPER project is labile carbon measured as permanganate oxidizable carbon (POXC), since it reflects various soil processes and functions such as nutrient cycling, erosion control, disease suppressiveness and climate regulation.[1] It is relatively cheap, fast and easy to measure, and more responsive to management than total soil organic carbon.

One problem in soil monitoring and assessment is the sensitivity of indicators to changes in agricultural management. For many traditional indicators it may take many years for changes in agricultural management practices to become measurable in a robust way. A combination of novel indicators, such as POXC, and Visual Soil Assessment[4] can provide an approach that overcomes this limitation to some extent.

The interpretation of indicator values depends on site conditions such as soil texture and land use. Making existing soil data widely available can provide the basis for assessing soil quality at a given site.

3. **Combining soil quality and soil management indicators to provide a scaled-up, macro-level systems assessment of ecosystem services, developing approaches to assess the benefits from changes in agricultural management**

Extrapolation beyond experimental agronomic knowledge to a larger extent of coverage (i.e. upscaling) requires the combination of social and environmental variables. These scale-specific variables include the soil health and soil management data considered in iSQAPER. Upscaling is addressed in iSQAPER by developing a model that reflects an understanding of underlying social and ecological processes.

The upscaling approach considered a combination of geospatial environmental and social data, including the following:

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[4] Alaoui, A, Lúcia Barão, Carla S.S. Ferreira, Gudrun Schwilch, Gottlieb Basch, Fuensanta Garcia-Orenes, Alicia Morugan, Jorge Mataix-Solera, Costas Kosmas, Matjaž Glavan, Brigitta Szabó, Tamás Hermann, Olga Petrutza, Vizitiu Jerzy Lipiec, Magdalena Frąc, Endla Reintam, Minggang Xu, Jiaying Di, Hongzhu Fan, Wijnand Sukkel, Julie Lemesle, Violette Geissen, Luuk Fleskens. (2020). Visual Assessment of the Impact of Agricultural Management Practices on Soil Quality. Agronomy Journal. https://acsess.onlinelibrary.wiley.com/action/downloadSupplement?doi=10.1002%2Fagj2.20216&file=agj220216-sup-0001-SuppMat.pdf

I. a range of spatial and temporal units of analysis, from a grid of 50x50 km to the continental scale, and from current to potential implementation of optimal greening measures;
II. a suite of key measures of risk and management dynamics;
III. a combination of soil processes derived from experimental data in iSQAPER.

The combination of these data through a modelling approach leads to two main outcomes:

(a) the effect of soil management practices on soil ecosystem services; and (b) the environmental footprint of different management scenarios. The spatial extent of the analysis is the national or continental level in Europe and China.

4. Assessing the reliability of global soil data through an app for land management in agriculture at a specific location

One of the purposes of the iSQAPER project was to make soil data accessible to end users including land managers, in order to improve awareness of soil data and soil threats, and to use such data to make recommendations for improved soil management. Global soil data is used as a first approximation for local soil information, and app users are encouraged to enter their own data in the app to receive more accurate soil quality scores and improved recommendations. Nevertheless, it was deemed important to know what the accuracy of the global soil data is, and was assessed by comparing measured and predicted values of soil properties. Our findings on the accuracy of soil properties' estimates of the SQAPP beta version (2018)[5] were that the SQAPP is unlikely to provide reliable estimates, at a chosen location, for the following soil properties: bulk density, nutrient status (available P, total N and exchangeable K), macrofauna and microbial biomass C, directly affecting the ability of SQAPP to correctly identify the status, at a given location, of the corresponding soil threats (to classify). Concerning soil electrical conductivity, the range of soils studied does not allow to draw a meaningful conclusion.

In relation to soil texture, pH and soil organic carbon, SQAPP, at a given location, will provide a rough estimate. The ability of SQAPP to correctly identify the status of soil threats that are linked to these soil properties remains low.

Our findings on soil threats' estimates using SQAPP beta version (2018)[6] can be retrieved from our report: "Report on SQAPP Assessment as a tool to monitor soil quality improvement".

[5] Fernando Teixeira & Gottlieb Basch (2018). Report on SQAPP Assessment as a tool to monitor soil quality improvement. Part 1. Correlation results and discussion. Project: iSQAPER | Work Package 6 | Task 6.3

[6] Fernando Teixeira & Gottlieb Basch (2019). Report on SQAPP Assessment as a tool to monitor soil quality improvement. Part 2. Soil threats, Soil Quality Index and recommendations for SQAPP. Project: iSQAPER | Work Package 6 | Task 6.3

The classification of the soil threats within the correct class (Low, Moderate, High) through SQAPP estimates was successful for around 53% of cases. Out of the wrongly classified cases, in 21% of the cases SQAPP attributed the threat level "high" instead of "low" or vice versa.

Data quality of global data can be improved as larger datasets and more complex algorithms are used to predict soil properties and soil threat indicators across spatial areas. However, if management information, which is not easily available, is not considered in such approaches, global data is unlikely to go beyond a coarse estimate.

The testing of soil data should also be adapted in order to better consider the quality of highly skewed data such as soil salinity and heavy metal contamination: a good classification of low salinity in a vast majority of cases cannot conclude that the dataset accurately represents soil salinity in the locations where elevated levels are observed in practice.

5. Using multiple soil property and soil threat data to produce recommendations for improved agricultural management.

The SQAPP's ultimate purpose is to provide recommendations on improving soil management, enabling sharing of innovative agricultural management practices (AMPs) for improved agricultural productivity and environmental resilience. The main premise of the approach to rank AMPs is that one should focus on practices that can overcome multiple low indicator scores simultaneously. This requires a complete set of indicator scores which yields more accurate results and more targeted recommendations).

The appropriateness of recommendations was discussed with land managers on several occasions, including at final demonstration events at all study sites. The possible judgments on a recommendation are:

a) The AMP is not relevant. This occurs when underlying soil property and soil threat data contain errors (e.g. growing halophytes can be recommended in non-saline soils if underlying data suggests soil salinity is an issue).

b) The AMP is not appropriate. This occurs when AMPs are considered to be more widely applicable than is deemed appropriate in practice. It can also be that farm characteristics render a given AMP inappropriate, e.g. due to farm size and resource constraints.

c) The AMP is not effective. If an AMP has been tested in a given context and found not be effective, land managers may prefer alternative AMPs with more promising prospects to enhance soil quality.

d) The AMP is already implemented. As no information on current soil management is available, it is likely land managers have already adopted AMPs that are recommended for their context.

e) The AMP is not preferred. The land manager may recognize the potential of an AMP but still have reasons not to implement it, e.g. due to cost, labour constraints, or incompatibility with other management practices, or socio-cultural aversion. A whole category of AMPs (involving land use changes) was omitted from the list of AMPs for this reason: although converting arable land to grassland or forest may be a sustainable solution in many cases, it is not a realistic prospect for most land managers.

f) The AMP is considered interesting. The land manager sees the AMP as a potential part of the solution for soil issues faced.

Based on stakeholder feedback, the AMPs were refined and the scoring of AMPs adjusted in the final version of SQAPP. Further refinement will be possible in the future as app users rank and label the recommended AMPs in the app.

Key lessons for assessing soil quality to support effective decision and policy making to protect soils, land and associated ecosystem services

- Importance of spatially verifiable data in order to pinpoint and compare data points and combine with spatial data on soil type.
- Importance of reference points allowing information on soil condition and land management to be collected, compared to baseline data and conclusions to be tested
- Importance of spatial data on agricultural management practices employed
- Importance of testing and trials for novel soil quality indicators across a variety of landscapes and agricultural management practices

Inventory of policy relevant data and sources extracted from WPs 3-7 and applicable to policy design

The ISQAPER project has developed a wide range of policy relevant data and sources. These are presented below in relation to the most relevant policy goals and instruments being developed as of 2020, and the main scientific outputs of the project.

Publications & most relevant information for policy makers

A significant number of articles were published as a result of research under the ISQAPER project. The most relevant for policy design are highlighted below, sorted by topic. All scientific articles can be found here: https://www.isqaper-is.eu/key-messages/publications

Publication	Topic	Summary of main findings
Tóth G, Kismányoky T, Kassai P, Hermann T, Fernandez-Ugalde O, Szabó B. **Farming by soil in Europe: status and outlook of cropping systems under different pedoclimatic conditions**. PeerJ. 2020;8:e8984.	Characterisations of crop and livestock farming systems	Despite of the importance of soils in agronomy, to date no comprehensive assessment of cropping in Europe has been performed from the viewpoint of the soil variability and its relationship to cropping patterns. In order to fill this knowledge gap, we studied the cropping patterns in different soils of European climate zones with regards to the shares of their crop types in a comparative manner. The study highlights the main features of farming by soil in Europe. Farming by soil in this context means the

Publication	Topic	Summary of main findings
Published 2020 May 28. doi:10.7717/peerj.8984 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7261479/		consideration of soil characteristics when selecting crop types and cropping patterns. Results suggest that, in general, farmers consciously take pedoclimatic condition of farming into account when selecting their cropping patterns. *In other words, farming by soil is a common practice in the different climatic regions of Europe. However, we have strong reasons to believe that soil suitability-based cropping is not practiced to its full potential over the continent. For example, the findings of our European assessment suggest that production areas of legumes are not always optimized for the local pedoclimatic conditions in some zones*. These findings also underline that economic drivers are decisive, when farmers adopt their cropping (eg. oil crops on Albeluvsiols in Europe). Win-win situations of economic considerations and soil suitability based management are observed in all pedoclimatic zones of Europe. The country analysis shows that cropping is progressively practiced on more suitable areas, depending also the crop tolerance to variable pedoclimatic conditions In conclusion, we can assume that pedoclimatic conditions of cropping are respected in most of Europe and farmers crops according to edaphic conditions whenever economic considerations do not override the ecological concerns of farming.
Alaoui, A, Barão, L, Ferreira, CS, et al. **Visual assessment of the impact of agricultural management practices on soil quality**. Agronomy Journal. 2020; 112: 2608– 2623. https://doi.org/10.1002/agj2.20216	Agricultural management effects & indicators	The intensification of agricultural practices to increase food and feed outputs is a pressing challenge causing deterioration of soil quality and soil functions. Such a challenge demands provision of empirical evidence to provide context-sensitive guidance on agricultural management practices (AMPs) that may enhance soil quality. The objectives of this study are to identify the most promising AMPs (and their combinations) applied by farmers with the most positive effects on soil quality and to evaluate the sensitivity of the soil quality indicators to the applied AMPs. The effect of selected AMPs on soil quality was assessed using a visual soil assessment tool in a total of 138 pairs of plots spread across 14 study site areas in Europe and China covering representative pedo-climatic zones. The inventory and scoring of soil quality were conducted together with landowners. Results show that 104 pairs show a positive effect of AMPs on soil quality. Higher effects of the AMPs were observed in lower fertile soils (i.e., Podzols and Calcisols) as opposed to higher fertile soils (i.e., Luvisols and Fluvisols). *For the single use applications, the AMPs with positive effects were crop rotation; manuring, composting, and no-tillage; followed by organic agriculture and residue maintenance. Cluster analysis showed that the most promising combinations of AMPs with the most positive effects on soil quality are composed of crop rotation, mulching, and min-till.*
Bai Z.G., Caspari T., Ruiperez-Gonzalez M., Batjes N.H., Mäder, P., Bünemann E.K., de Goede, R, Brussaard, L., Xu M.G., Santos Ferreira C.S., Reintam E., Fan H.Z.,	Agricultural management effects	• Effects of four paired management practices on five soil quality indicators were analysed. • Yield was lower under no-tillage (NT) and organic agriculture, but with environmental benefits.

Publication	Topic	Summary of main findings
Mihelič R., Glavan M., Tóth Z., 2018. **Effects of agricultural management practices on soil quality: A review of long-term experiments for Europe and China**. Agriculture, Ecosystems and Environment, 265, 1-7 https://www.sciencedirect.com/science/article/pii/S016788091830224X		• Soil Organic Matter (SOM) increased under NT, organic matter addition, crop rotation and organic farming. • Number of earthworms was the most sensitive indicator for the paired practices. • Soil pH appears to be the least sensitive indicator.
Lúcia Barão, Abdallah Alaoui, Carla Ferreira, Gottlie Basch, Gudrun Schwilch, Violette Geissen, Wijnand Sukkel, Julie Lemesle, Fuensanta Garcia-Orenes, Alicia Morugán-Coronado, JorgeMataix-Solera, Costas Kosmas, Matjaž Glavan, Marina Pintar, Brigitta Tóth, Tamás Hermann, Olga Petruta Vizitiu, Jerzy Lipiec, Fei Wang. 2019. **Assessment of promising agricultural management practices**. Science of the total environment, 649: 610-619. https://doi.org/10.1016/j.scitotenv.2018.08.257	Agricultural management effects	Aims: 1) map the current distribution of previously selected 18 promising AMPs in several pedo-climatic regions and farming systems located in ten and four study site areas (SSA) along Europe and China, respectively; and 2) identify the soil threats occurring in those areas. In each SSA, farmers using promising AMP's were identified and questionnaires were used to assess farmer's perception on soil threats significance in the area. 138 plots/farms using 18 promising AMPs, were identified in Europe (112) and China (26).*Results show that promising AMPs used in Europe are Crop rotation (15%), Manuring & Composting (15%) and Min-till (14%), whereas in China are Manuring & Composting (18%), Residue maintenance (18%) and Integrated pest and disease management (12%).* In Europe, soil erosion is the main threat in agricultural Mediterranean areas while soil-borne pests and diseases is more frequent in the SSAs from France and The Netherlands. In China, soil erosion, SOM decline, compaction and poor soil structure are among the most significant. This work provides important information for policy makers and the development of strategies to support and promote agricultural management practices with benefits for soil quality.
Else K. Bünemann, Giulia Bongiorno, Zhanguo Bai, Rachel E. Creamer, Gerlinde De Deyn, Ron de Goede, Luuk Fleskens, Violette Geissen, Thom W. Kuyper, Paul Mäder, Mirjam Pulleman, Wijnand Sukkel, Jan Willem van Groenigen, Lijbert Brussaard. 2018. **Soil quality – A critical review**, Soil Biology and Biochemistry, Volume 120 https://www.sciencedirect.com/science/article/pii/S0038071718300294	Indicators	• We review soil quality and related concepts in terms of definitions and assessment. • The most common indicators are organic matter, pH, available P and water storage. • Biological/biochemical indicators are under-represented but show great potential. • Soil quality assessment should specify targeted soil threats, functions and ecosystem services. Increasingly interactive assessment tools must be developed with target users.

Publication	Topic	Summary of main findings
Giulia Bongiorno, Else K. Bünemann, Chidinma U. Oguejiofor, Jennifer Meier, Gerrit Gort, Rob Comans, Paul Mäder, Lijbert Brussaard, Ronde Goede. 2019. **Sensitivity of labile carbon fractions to tillage and organic matter management and their potential as comprehensive soil quality indicators across pedoclimatic conditions in Europe**. Ecological Indicators 99, 38-50 https://www.sciencedirect.com/science/article/pii/S1470160X18309415	Indicators	Soil quality is defined as the capacity of the soil to perform multiple functions, and can be assessed by measuring soil chemical, physical and biological parameters. Among soil parameters, labile organic carbon is considered to have a primary role in many soil functions related to productivity and environmental resilience. Our study aimed at assessing the suitability of different labile carbon fractions, namely dissolved organic carbon (DOC), hydrophilic DOC (Hy-DOC), permanganate oxidizable carbon (POXC, also referred to as Active Carbon), hot water extractable carbon (HWEC) and particulate organic matter carbon (POMC) as soil quality indicators in agricultural systems. To do so, we tested their sensitivity to two agricultural management factors (tillage and organic matter input) in 10 European long-term field experiments (LTEs), and we assessed the correlation of the different labile carbon fractions with physical, chemical and biological soil quality indicators linked to soil functions. We found that reduced tillage and high organic matter input increase concentrations of labile carbon fractions in soil compared to conventional tillage and low organic matter addition, respectively. POXC and POMC were the most sensitive fractions to both tillage and fertilization across the 10 European LTEs. In addition, POXC was the labile carbon fraction most positively correlated with soil chemical (total organic carbon, total nitrogen, and cation exchange capacity), physical (water stable aggregates, water holding capacity, bulk density) and biological soil quality indicators (microbial biomass carbon and nitrogen, and soil respiration). *We conclude that POXC represents a labile carbon fraction sensitive to soil management and that is the most informative about total soil organic matter, nutrients, soil structure, and microbial pools and activity, parameters commonly used as indicators of various soil functions, such as C sequestration, nutrient cycling, soil structure formation and soil as a habitat for biodiversity. Moreover, POXC measurement is relatively cheap, fast and easy. Therefore, we suggest measuring POXC as the labile carbon fraction in soil quality assessment schemes in addition to other valuable soil quality indicators.*
Giulia BONGIORNO. **Novel soil quality indicators for the evaluation of agricultural management practices: a biological perspective**[J].Frontiers of Agricultural Science and Engineering,2020,7(3):257-274. https://www.engineering.org.cn/en/10.15302/J-FASE-2020323	Indicators	Developments in soil biology and in methods to characterize soil organic carbon can potentially deliver novel soil quality indicators that can help identify management practices able to sustain soil productivity and environmental resilience. This work aimed at synthesizing results regarding the suitability of a range of soil biological and biochemical properties as novel soil quality indicators for agricultural management. The soil properties, selected through a published literature review, comprised different labile organic carbon fractions [hydrophilic dissolved organic carbon, dissolved organic carbon, permanganate oxidizable carbon (POXC), hot water extractable carbon and particulate organic matter carbon], soil disease suppressiveness measured using a - bioassay, nematode communities characterized by amplicon sequencing and qPCR, and microbial community level physiological profiling measured with MicroResp . Prior studies tested the sensitivity of each of the novel

Publication	Topic	Summary of main findings
		indicators to tillage and organic matter addition in ten European long-term field experiments (LTEs) and assessed their relationships with pre-existing soil quality indicators of soil functioning. Here, the results of these previous studies are brought together and interpreted relative to each other and to the broader body of literature on soil quality assessment. *Reduced tillage, increased carbon availability, disease suppressiveness, nematode richness and diversity, the stability and maturity of the food web, and microbial activity and functional diversity. Organic matter addition played a weaker role in enhancing soil quality, possibly due to the range of composition of the organic matter inputs used in the LTEs. POXC was the indicator that discriminated best between soil management practices, followed by nematode indices based on functional characteristics.* Structural equation modeling shows that POXC has a central role in nutrient retention/supply, carbon sequestration, biodiversity conservation, erosion control and disease regulation/suppression. The novel indicators proposed here have great potential to improve existing soil quality assessment schemes. Their feasibility of application is discussed and needs for future research are outlined.
Stankovics, P., Tóth, G., Tóth, Z., 2018. **Identifying gaps between the legislative tools of soil protection in the EU member states for a common European soil protection legislation**. Sustainability 10:8 Paper: 2886 https://www.mdpi.com/2071-1050/10/8/2886	Policy	This study is aimed at specifying the possible obstacles, differences, and gaps in legislature and administration in the countries that formed the blocking minority against the Soil Framework Directive (the Directive) proposed by the EC in 2006. The individual legislation of the opposing countries on the matter, were summarized and compared with the goals set by the Directive, in three highlighted aspects: (1) soil-dependent threats, (2) contamination, and (3) sealing. We designed a simple schematic evaluation system to show the basic levels of differences and similarities. *We found that the legislative regulations concerning soil-dependent degradation and contamination issues in the above countries were generally well defined, complementary, and thorough. A common European legislation can be based on harmonised approaches between them, focusing on technical implementations. In the aspect of sealing we found recommendations, principles, and good practices rather than binding regulations in the scrutinised countries. Soil sealing is an issue where the proposed Directive's measures, could have exceeded those of the Member States.*

Upscaling

ISQAPER conducted detailed work to evaluate and model the upscaling of the agricultural management practices examined in the project under different policy scenarios. These are used to evaluate changes in the soil quality indicators driven by changes in agricultural management practices. Changes in soil environmental footprint are quantified in terms of the effect of management practices on soil productivity, nutrients and biodiversity. Details are found below and are of great relevance to policy makers looking to implement improved soil policy.

Publication	Summary of main findings
Iglesias, A. et al. (2018) Report on definition of typical combinations of farming systems and agricultural practices in Europe and China and their effects on soil quality. iSQAPER Project Deliverable 7.1, 87 pp https://www.isqaper-is.eu/documents/category/13-upscaling-from-local-to-regional	A main effort is to identify and characterize a relatively limited number of typical farming systems in Europe and China with relevant crop and soil management practices. 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, 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.
Garrote L., Santillán D., Iglesias A. (2018) Report on key management practices affecting soil quality and their applicability in various farming systems. iSQAPER Project Deliverable 7.2 140 https://www.isqaper-is.eu/documents/category/13-upscaling-from-local-to-regional	The main focus of this Deliverable 7.2 is to understand at the continental scale, how agricultural management practices that mitigate soil threats also affect other ecosystem services in different farming systems in Europe and China. Our results show that even with an additional 10% implementation, the effect of improved management is significant in most European and China regions and all the crops considered in this study
Garrote L., Santillán D., Iglesias A. (2019) **Report on the evaluation of scenarios of changed soil environmental footprint for a range of policy scenarios**. iSQAPER Project Deliverable 7.4 https://www.isqaper-is.eu/documents/category/13-upscaling-from-local-to-regional?download=94:scenarios-of-changed-soil-environmental-footprint-for-a-range-of-policy-scenarios	Future soil management policy scenarios are evaluated through the application of the upscaling model to policy scenarios to obtain the spatial representation of soil quality indicators in order to evaluate soil environmental footprint. Policy scenarios evaluated: **Expected**: The Expected scenario maintains the observed tendency in the implementation of beneficial agricultural management practices. **Regional Targets**: This scenario assumes the same rate of implementation of agricultural management practices, but considers that policy efforts are focused on areas where soil threats are more active and soil quality indicators are poorer. The emphasis, therefore, is place on targeting the regions that where the practices would be more beneficial. **Towards 2050**: This scenario assumes an intensification on the rate of implementation of agricultural management practices as a result of public policies. Our results show that the “Expected scenario” is not enough to make significant contributions towards improving the soil environmental footprint and the Towards 2050 scenario delivers

Publication	Summary of main findings
	important benefits. The Regional Targets scenario delivers important benefits in key challenging areas, where the effects improve greatly the soil environmental footprint. The implication is that focusing on "hot spots" of soil quality degradation could be a good way of prioritising action on soil quality.

Good Practice

In each of the study sites the iSQAPER team, together with local farmers or land users, identified the main agricultural management practices used locally. The practices vary according to the climatic zone, soil type and crop produced. Some of them were conventional and designed to maximise yield while other innovative* practices were being used with the explicit purpose of also benefitting or improving soil quality. In the European study sites the most common innovative practices were: manuring & composting, crop rotation and minimum tillage. The most common in China were: manuring & composting, residue maintenance/mulching and integrated pest and disease management (incl. organic agriculture). For more details see: Impact of promising land management practices

In two separate field campaigns we compared the effects of the innovative to the conventional practices by assessing soil quality of 132 pairs of neighbouring fields. For more details of the visual assessment methods see: Visual soil and plant quality assessment

Of the original 132, one or two practices per country were identified as having the best proven effectiveness on improving soil quality in that location. Many of these practices are described in leaflets which explain the

- principles of the practice,
- the soil threat it is designed to address,
- the scientific evidence for its effectiveness.

These can be found online: https://www.isqaper-is.eu/key-messages/good-practice-leaflets

EU Policy Goals and Measures in 2020

Below are tables with links to data and sources gathered by the ISQAPER project in relation to specific Agricultural Management Practices that relate to policy goals and measures that are currently under discussion at EU level that relate to soil quality. Some ISQAPER policy briefs are also included where relevant.

Common Agricultural Policy (CAP)

Table 1: Proposed GAEC standards for supporting soil management

New GAEC standards	Potential soil threat addressed	Policy relevant data and sources
Potential direct effects for soil management		
GAEC 6: Tillage management to reduce the risk of soil degradation, including slope consideration in order to ensure minimum land management reflecting site-specific conditions to limit erosion	Soil erosion, loss of soil organic matter/soil carbon, compaction	• Tillage - https://www.isqaper-is.eu/soil-management/tillage ○ No tillage - https://www.isqaper-is.eu/soil-management/tillage/355-no-tillage ○ Minimum tillage - https://www.isqaper-is.eu/soil-management/tillage ○ Contour ploughing - https://www.isqaper-is.eu/soil-management/tillage/357-contour-ploughing ○ Strip tillage - https://www.isqaper-is.eu/soil-management/tillage/358-strip-tillage ○ Subsoiling - https://www.isqaper-is.eu/soil-management/tillage/359-subsoiling ○ Roughing the soil surface - https://www.isqaper-is.eu/soil-management/tillage/360-roughening-the-soil-surface ○ Raised beds - https://www.isqaper-is.eu/soil-management/tillage/361-raised-beds
GAEC 7: No bare soil in most sensitive period(s) to protect during winter	Soil erosion, loss of soil organic matter/soil carbon, soil biodiversity	• Cover crops - https://www.isqaper-is.eu/vegetation-management/vegetation-cover/374-cover-crops • Vegetation cover - https://www.isqaper-is.eu/vegetation-management/vegetation-cover
GAEC 8: Crop rotation to preserve soil potential (new)	Loss of soil organic matter/soil carbon, soil biodiversity, compaction	• Crop rotation/diversification - https://www.isqaper-is.eu/vegetation-management/crop-rotation-diversification/386-crop-rotation-diversification • Crop choice - https://www.isqaper-is.eu/vegetation-management/crop-choice
Potential for direct and indirect effects for soil management		
GAEC 1: Maintenance of permanent grassland as a general safeguard against conversion to preserve carbon stock*	Soil erosion, loss of organic matter/soil carbon, loss of soil biodiversity	• Herb-rich grassland - https://www.isqaper-is.eu/vegetation-management/crop-rotation-diversification/387-herb-rich-grassland • Rangeland rehabilitation

New GAEC standards	Potential soil threat addressed	Policy relevant data and sources
		• https://www.isqaper-is.eu/vegetation-management/vegetation-cover/376-rangeland-rehabilitation
GAEC 2: Preservation of carbon-rich soils such as peatlands and wetlands (new)	Loss of organic matter/soil carbon, loss of soil biodiversity, soil erosion	N/A
GAEC 3: Ban of burning arable stubble to maintain soil organic matter, except for plant health reasons	Loss of soil organic matter/soil carbon	• Physical disease control - https://www.isqaper-is.eu/pest-managment/disease-management/443-physical-disease-control
GAEC 4: Establishment of buffer strips along water course	Contamination (diffuse), soil erosion, loss of organic matter, compaction	• Riparian buffer zones and filter strips - https://www.isqaper-is.eu/vegetation-management/vegetation-bands/379-riparian-buffer-zones-and-filter-strips • Semi-natural landscape elements - https://www.isqaper-is.eu/vegetation-management/vegetation-bands/381-semi-natural-landscape-elements • Briefing: Protecting Europe's soils, protecting Europe's water bodies? - https://www.isqaper-is.eu/key-messages/briefing-papers/338-protecting-europe-s-soils-protecting-europe-s-water-bodies
GAEC 5: Use of Farm Sustainability Tool for Nutrients (new)	Contamination (diffuse)	• Integrated nutrient management - https://www.isqaper-is.eu/pollutant-management/balanced-applications/441-integrated-nutrient-management • Carbon and nutrient management - https://www.isqaper-is.eu/carbon-and-nutrient-management
GAEC 9: Maintenance of non-productive features and area to improve on-farm biodiversity	Loss of soil organic matter/soil carbon, soil biodiversity, compaction	• Semi-natural landscape elements - https://www.isqaper-is.eu/vegetation-management/vegetation-bands/381-semi-natural-landscape-elements •
GAEC 10: Ban on converting or ploughing permanent grassland in Natura 2000 sites to protect habitats and species (new)	Loss of organic matter/soil carbon, loss of soil biodiversity, soil erosion	• Herb-rich grassland - https://www.isqaper-is.eu/vegetation-management/crop-rotation-diversification/387-herb-rich-grassland • Multi-layered vegetation https://www.isqaper-is.eu/vegetation-management/multi-layered-vegetation

Source: Own compilation based on the Commission's Proposals for a new Regulation on CAP Strategic Plans, Annex III; Frelih-Larsen et al. (2016); and expert judgement Notes: *GAEC supersedes existing greening obligation.

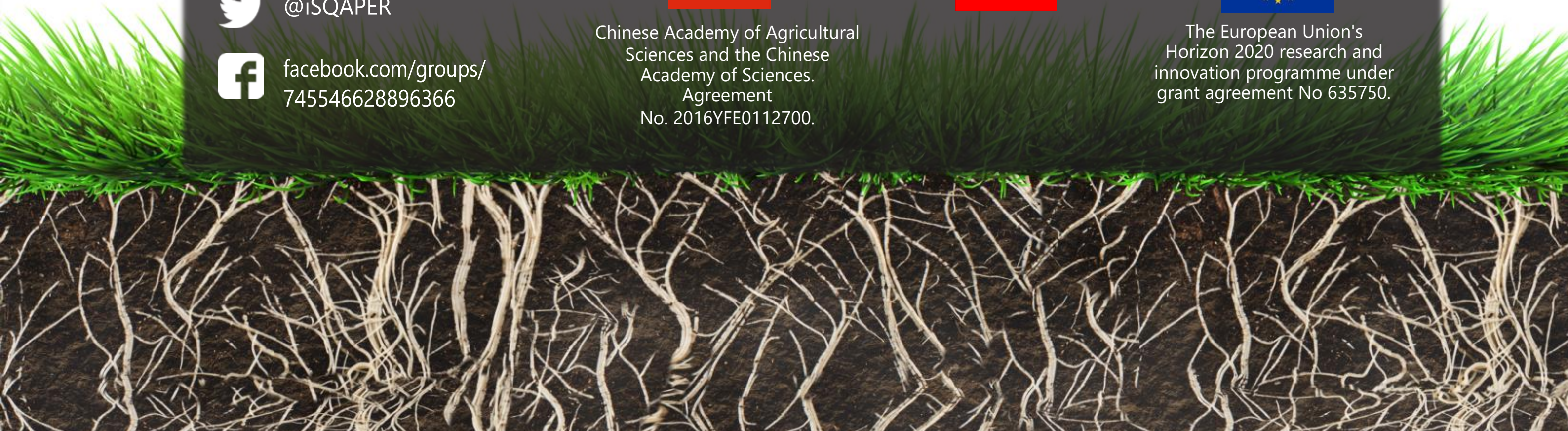
Table 2: Voluntary land management interventions with the potential to support soil management

Sustainable practices proposed under Eco-scheme: Schemes for the climate and the environment - (Art. 28)	Policy relevant data and sources
Agro-ecology (including organic farming)	• Briefing: Assessing soil quality in agro-ecosystems - https://www.isqaper-is.eu/key-messages/briefing-papers/277-assessing-soil-quality-in-agro-ecosystems-multifunctionality
Carbon farming	• Briefing : Climate and soil policy brief: better integrating soil into EU climate policy - https://www.isqaper-is.eu/key-messages/briefing-papers/473-climate-and-soil-policy-brief-better-integrating-soil-into-eu-climate-policy • Carbon and nutrient management - https://www.isqaper-is.eu/carbon-and-nutrient-management
Agro-forestry	• Agroforestry - https://www.isqaper-is.eu/vegetation-management/multi-layered-vegetation/388-agroforestry • Multi-layered vegetation • https://www.isqaper-is.eu/vegetation-management/multi-layered-vegetation • Shelterbelts https://www.isqaper-is.eu/vegetation-management/vegetation-bands/380-shelter-belts

Table 3: Biodiversity & Farm to Fork Strategies' Policy Goals

Policy Goal	Policy relevant data and sources
Bring back at least 10% of agricultural area under high-diversity landscape features. These include, inter alia, buffer strips, rotational or non-rotational fallow land, hedges, non-productive trees, terrace walls, and ponds. These help enhance carbon sequestration, prevent soil erosion and depletion, filter air and water, and support climate adaptation.	• Terrain management- https://www.isqaper-is.eu/terrain-management - highlights bunds and terraces, conservation agriculture - Terrain management - https://www.isqaper-is.eu/vegetation-management - highlight vegetation cover, vegetation bands e.g. https://www.isqaper-is.eu/vegetation-management/vegetation-bands/381-semi-natural-landscape-elements
Pesticides Reduce by 50% the use and risk of chemical pesticides by 2030. Reduce by 50% the use of more hazardous pesticides by 2030.	• Pest management - https://www.isqaper-is.eu/pest-managment (Includes sections on weed, pest, and disease management) • Environmental exposure to pesticides (EPP) - https://www.isqaper-is.eu/soil-quality/visual-soil-assessment/226-environmental-exposture-to-pesticides
At least 25% of the EU's agricultural land must be organically farmed by 2030.	See Table 1 and 2 for detailed examination of relevant measures
It is essential to step up efforts to protect soil fertility, reduce soil erosion and increase soil organic matter. To address these issues in a comprehensive way and help to fulfil EU and international commitments on land-degradation neutrality, the **Commission will update the EU Soil Thematic Strategy in 2021.**	See Table 1 and 2 for detailed examination of relevant measures
Goal of zero pollution from nitrogen and phosphorus flows from fertilisers through	• Briefing: Protecting Europe's soils, protecting Europe's water bodies? - https://www.isqaper-is.eu/key-messages/briefing-papers/338-

Policy Goal	Policy relevant data and sources
reducing nutrient losses by at least 50%, while ensuring that there is no deterioration in soil fertility.	protecting-europe-s-soils-protecting-europe-s-water-bodies • Green Manuring - https://www.isqaper-is.eu/carbon-and-nutrient-management/green-manuring • Liquid manure or slurry- https://www.isqaper-is.eu/carbon-and-nutrient-management/organic-amendments/417-liquid-manure-or-slurry - including methods of application that reduce leaching • Inorganic fertilizers - https://www.isqaper-is.eu/carbon-and-nutrient-management/inorganic-amendments/422-inorganic-fertilizers- including methods of application that reduce leaching • Integrated nutrient management • https://www.isqaper-is.eu/pollutant-management/balanced-applications/441-integrated-nutrient-management
Significant progress in the remediation of contaminated soil sites.	• Pollutant management - https://www.isqaper-is.eu/pollutant-management - Phytoremediation - https://www.isqaper-is.eu/pollutant-management/remediation/439-phytoremediation - Phytoremediation (including phytostabilization, phytodegradation, phytoextraction and phytovolatilization) is the practice of using living green plants to immobilize or adsorb contaminants from polluted soil. It is a cost-effective and environmentally friendly approach to tackling contamination issues. • Balanced applications - https://www.isqaper-is.eu/pollutant-management/balanced-applications • Briefing: Plastic pollution in soil - https://www.isqaper-is.eu/key-messages/briefing-papers/125-plastic-pollution-in-soil
Significant progress is needed on **identifying contaminated soil sites, restoring degraded soils, defining the conditions for their good ecological status, introducing restoration objectives, and improving the monitoring of soil quality**. (Also relevant to revised EU soil thematic strategy and Zero Pollution Action Plan for Air, Water and Soil)	• Soil quality: assessment, indicators & management - https://www.isqaper-is.eu/soil-quality - In this section of iSQAPERiS we integrate soil science and agricultural management practices. We review concepts of soil quality and measured or visually assessed soil properties (such as organic matter content or earthworm density) that can be used as indicators of quality.



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This project has received funding from:

Chinese Academy of Agricultural Sciences and the Chinese Academy of Sciences. Agreement No. 2016YFE0112700.

The European Union's Horizon 2020 research and innovation programme under grant agreement No 635750.