Deliverable 8.2. The Assessment of Soil and Soil Quality – The Importance of Effective Data Combining

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Why is combining data is 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.

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.

[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

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]

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.

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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

[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

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:

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

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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

[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

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".

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).

[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

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

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