NBSOIL
Nature-Based Solutions for Soil Management

Soil Health Index - online tool – initial version

Deliverable 2.1

30.11.2023

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[1] **R**=Document, report; **DEM**=Demonstrator, pilot, prototype; **DEC**=website, patent fillings, videos, etc.; **OTHER**=other

[2] **PU**=Public, **CO**=Confidential, only for members of the consortium (including the Commission Services), **CI**=Classified

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1 Introduction

NBSoil aims to establish an advisor- and farmer-oriented data integration framework ("*NBSoil health index tool*") that takes into targets and requirements of monitoring, verification and reporting that are expected to be defined in the upcoming period with the implementation of the European Directive on Soil Monitoring and Resilience (European Commission, 2023).

The NBSoil health index tool will provide an online instrument oriented to next-generation soil advisors and farmers, integrating quantitative measurement data from different sources (mainly laboratory, but also quantitative *on-farm* digital tools, satellite information, etc.) and informing them on achievements and progress in soil health function (mitigation of soil threats) at the field scale.

The tool will be implemented online via the NBSoil webside and a guidebook for its usage will be provided, both being integrated within the NBSoil academy course formats for facilitating usage and dissemination.

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2 Outline of the Soil Health Index Tool (initial verions)

2.1 Scientific background

In order to comprehensively evaluate a management system in practice there are two basic requirements:

(1) Various soil target functions or ecosystem services (e.g., food production, climate protection, groundwater protection, etc.) must be taken into account (e.g., Greiner et al., 2017).
(2) The natural location influences, which represent the unchangeable framework of change potential in response to management, must be taken into consideration and weighted to define achievable management targets e.g., Bøe et al., 2023).

An existing assessment method that takes these two elements into account is the "Soil Management Assessment Framework" (SMAF; http://soilquality.org/home.html) from the USDA-NRCS (Andrews et al., 2004; Wienhold et al., 2009). SMAF aims at a site-specific assessment of management impacts on soil functions based on measurable indicators that are combined to form a soil quality index. The approach is comprehensively documented (Stott, 2019), validated (e.g., soil cultivation: Nunes et al. 2020; e.g., SOC accrual: Nunes et al. 2021) and is constantly being further developed (e.g., Norris et al., 2020).

Besides these strengths of SMFA, its suitability as a basis for the NBSoil health index tool is also due to NBSoil's orientation towards soil advisors as soil experts, The SMAF-framework takes into consideration the integration of expert knowledge and data interpretation and therefore provides a particularly useful basis for the tool developed in NBSoil.

2.2 Soil functions

The key outcome of the soil health index tool is a quantitative estimation of soil functions. Soil functions capture ecosystem services of soils that are relevant for human societies. Following previous work (e.g., Zwetsloot et al., 2021) five key soil functions will be considered, being:

- **Productivity function:** Nature based solutions for sustainable soil use have to ensure provision of biomass production for food, feed, fibre and energy.
- **Water resource function:** Nature based solutions for sustainable soil use should contribute to ensure the quality of water resources and enhance soils' capability for infiltration, storage and purification of water, thereby significantly contributing to climate change adaptation.
- **Nutrient use function:** Nature based solutions for sustainable soil use are intended to close nutrient cycles, thereby reducing losses that negatively affect other ecosystems and improving the efficiency of nutrient use in human land use systems.
- **Climate function:** Nature based solutions for sustainable soil use strengthen soils as greenhouse gas sinks via sequestration of CO_2 as stable organic matter and reduction of N_2O losses via improved nitrogen use efficiency.

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- **Biodiversity function:** Nature based solutions for sustainable soil use ensure and improve the function of soils as terrestrial habitat with the highest diversity of organisms that in turn are key components of all other soil functions.

2.3 Soil indicators

Indicators are measurable single soil properties that serve as descriptors for given soil functions and are a key component of soil health assessment and monitoring schemes. The assignment of indicators for the single soil functions used for the NBS tool follows an expert selection aiming to capture a minimum dataset that optimally meets two criteria,

1. Indicators should be **measurable with standard protocols** at reasonable costs in order to potentially allow large scale implementation into monitoring schemes.
2. Indicators should be **sensitive to management change** in order to capture improvement vs. degradation of soil properties.

A preliminary set of indicators has been implemented in the NBSoil health index tool for an initial version. In the course of the project, these indicators will be further extended and updated based on

1. Broad discussion and assessment by soil experts involved in the project
2. Review of the scientific literature and
3. Indicator selections made in the course of the implementation of the European Directive on Soil Monitoring and Resilience.

Table 1 gives an example of relations of the indicators implemented in the initial version of the tool to soil functions.

Indicator	Function	Comment
	Biological indicators	
Soil organic carbon concentration	All	Easy to measure in lab, widely available, essential for most soil functions.
Total nitrogen	Production function, nutrient function, water function	Easy to measure in lab, essential for production, assessment of nitrogen cycles and groundwater risks.
Microbial biomass carbon	Nutrient function, biodiversity function	Sum indicator for soil microbes, robust, relevant for estimating

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		nutrient cycles and overall microbial functionality of soil ecosystems.
	Physical indicators	
Bulk density	Production function, water function	Relevant to estimate soil compaction risk that negatively affects production and water cycles. Undisturbed sampling required.
Aggregate stability	Water function	Key indicator for erosion/runoff mitigation and thus infiltration of rainfall into the soil. Comparatively easy measurement protocol.
Available water	Water function, production function	Key indicator for climate change adaptation. Requires undisturbed sample and relatively laborious measurement.
	Chemical indicators	
pH	Production function, nutrient function	Basic soil indicator driving several soil functions related to nutrient availability and turnover and thereby production. Easy to measure.
Electric conductivity	Production function, nutrient function	Basic soil indicator providing the sum of dissolved ions in soil solution; estimate for available nutrients and risk for salinization. Easy to measure.

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2.4 Scoring functions

A key component of the indicator model is the development of location-specific target functions for the individual indicators. These functions represent the site-specific connection of the indicator (e.g., soil organic carbon concentration) with the target function (e.g., high climate function through C sequestration) and are scaled as a dimensionless quantity to a numerical value from 0 to 1 (or 0 -10).

Corresponding to the SMAF framework, the indicator-objective function relationships can be represented by three main curve shapes (Figure 1): (a) local optimum (e.g., optimal function), (b) more-is-better (e.g., logistic growth function), and (c) less-is -better (e.g., inverse logistic function).

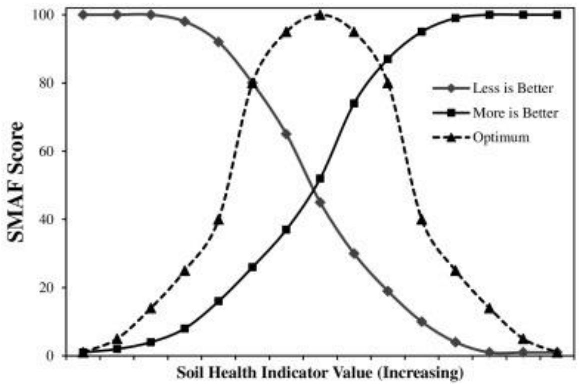

Figure 1: Scoring curves for the evaluation of measurement indicators in the SMAF (Source: Veum et al., 2017)

A concrete example from Wienhold et al. (2009) illustrates the procedure (Figure 2): The connection between nitrous oxide formation and water-filled pore space (WFPS) shows a strong increase in nitrous oxide emissions at a WFPS > 0.65. With regard to the climate protection function, this results in a scaled function that follows a negative growth function up to zero from this WFPS.

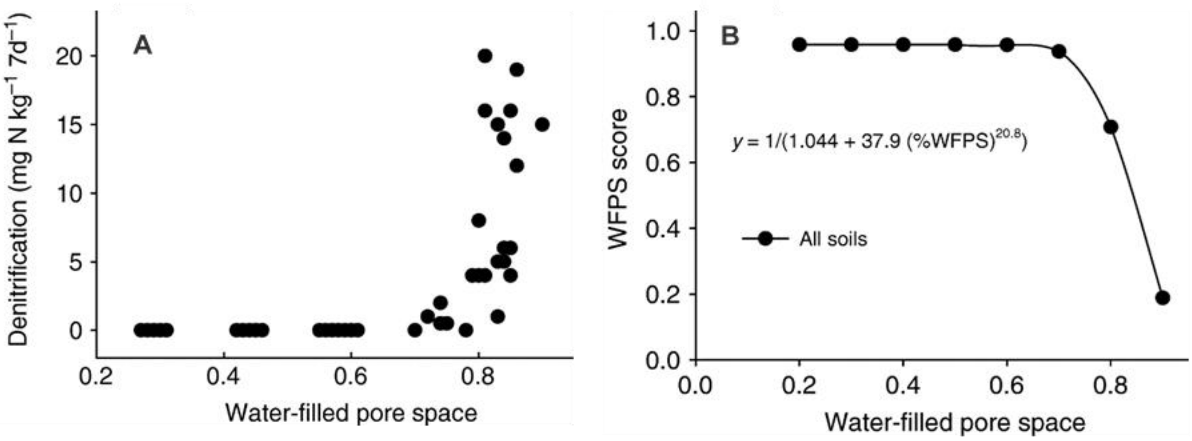

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Figure 2. Example of scoring of data (0-1) for climate function of soils based on the indicator water-filled pore space related to the formation of dinitrous oxide as a greenhouse gas emitted from soils (modified from Wienhold et al. 2009)

The general shape of the curve, as shown in the example in Figure 2 for the connection WFPS → climate function, is adapted to the specific location to take natural site factors into account (e.g., location of the optimum or maximum, course of increase or decrease of the curve). Figure 3 shows a classic example of site-specific (texture) scoring for the climate target indicator soil organic matter accrual.

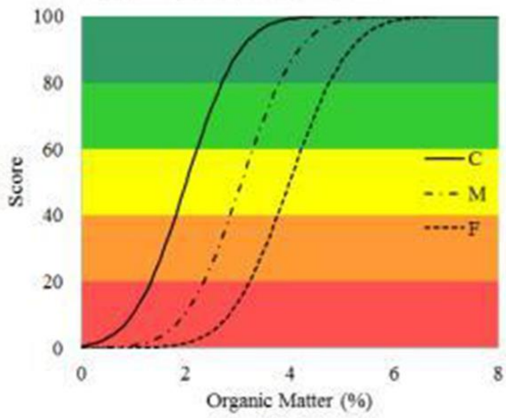

Figure 3. Example of site-specific adaptation of the course of the scoring function (score here: 0-100) for soil organic matter as a frequently used indicator for climate protection (C sequestration) for different soil texture classes (C…coarse, M…medium F…fine textured; Source: Fine et al., 2017).

The scoring functions and their sit-specific adjustment for the individual indicators for the NBSoil health index tool will be developed from various data sources available in literature, measured at the NBS demo sites and derived from expert knowledge. It should be taken into account any indicator model for soil quality assessment is continually improved and developed with the amount of available data (see for example the SMAF for soil organic matter: Nunes et al. 2021).

The overall assessment of a field for the achievement of a soil health is ultimately carried out by additively combining the individual indicators according to the formula (Andrews et al. 2004):

$$SF = \left(\frac{\sum_{i=1}^{n} I_i}{n}\right) \times X \qquad \textit{(Equation 1)}$$

where SF is the soil function index value for the objective function, which results from the sum of the n individual indicators and is transferred to a corresponding scale (e.g. 0-10) with a factor X (e.g. 10).

This provides a summary indication that can be used for the comparative evaluation of management systems and/or individual management elements with regard to their achievement of objectives for certain soil functions relevant to the environment and production.

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2.5 Initial version of implementation for online use and visualization

An initial version of the Index tool has been developed for eight soil indicators that are individually scored and visualized in a spider diagram (Figure 4). Thereby an individual field (This sample) is compared to the score of all available data in a database (Mean) to allow to advisors/farmers to better evaluate the outcome for their case of interest. The distribution of the scored data which are used in the database is plotted at the bottom.

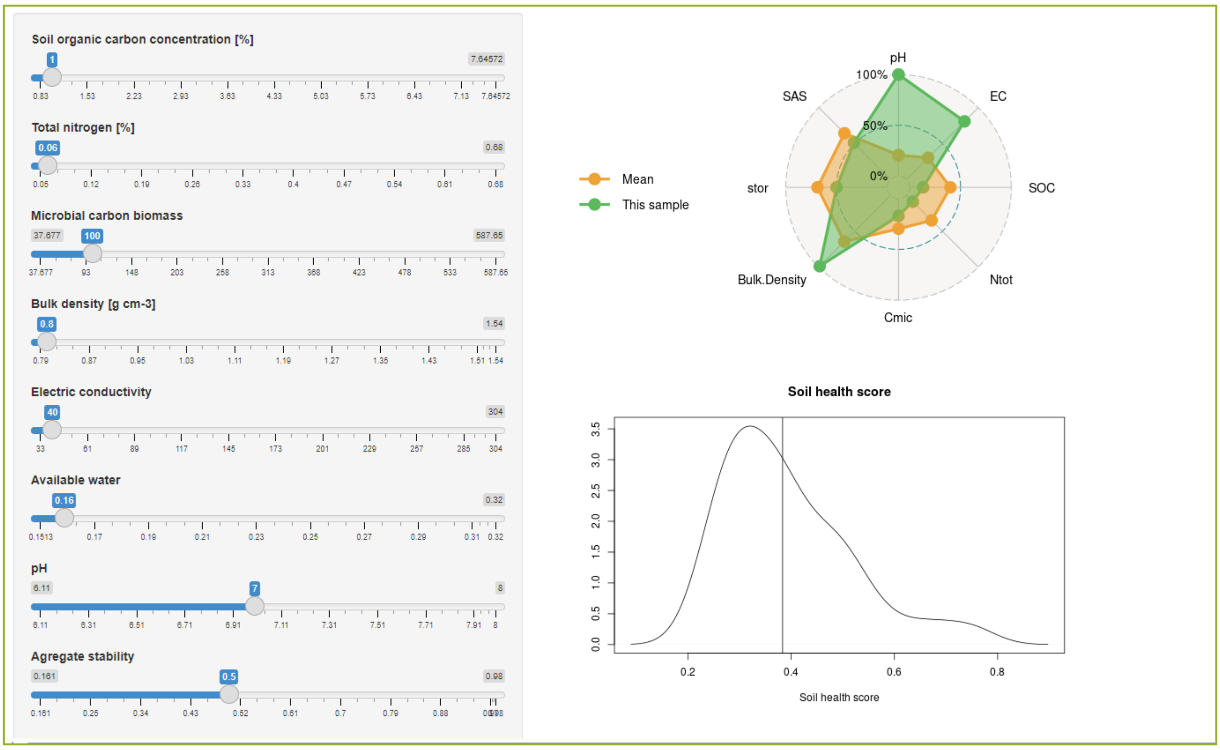

Figure 4. Initial version of the online soil health index tool.

In subsequent steps, the online implementation of the first version of the tool will be developed as described above, i.e.;

- Implementation of soil functions
- Selection of core indicators
- Construction of background database
- User guidebook and testing
- Development of course material for dissemination of the tool.

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