NBSOIL
Nature-Based Solutions for Soil Management

Smartphone use for Soil Citizen Science – initial version

Deliverable 4.7

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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

On-farm soil health assessment is an important approach that complements other sources of information available to farmers, such as (i) results from soil samples tested in a laboratory (typically aiming on soil nutrient supply for optimizing fertilization, and (ii) remote sensing data from satellites that provide information on the crop vigour which is, among others, responding to the status of soil-related growth factors (e.g., water, nutrients).

Digital smartphone tools are intended

(i) to standardize and guide visual assessments of the state of soil, and
(ii) to provide image-analytics-based (semi)quantitative data on soil (e.g., soil colour) and/or soil status-related observations (e.g., indicator plants).

With the improvement of smartphone imaging quality (hardware side) and advances in image analytics (software side), there is currently a dynamic development intending to provide novel digital tools for soil assessment (e.g., Aitkenhead et al., 2016; Fan et al., 2017; Gupta et al., 2023).

Within NBSoil we aim to explore the use of mobile apps for soil health monitoring to provide tools to next-generation soil health advisors on relevant measures that are considered responsive to nature-based solutions, in particular soil organic carbon and soil structure.

For the initial version of smartphone digital tools, we screened for currently available tools and their capabilities in order to

(i) provide an overview and identify current capabilities and potential knowledge gaps (section 2), and
(ii) make an initial selection of tool(s) to be prioritized for testing on NBSoil demo-sites and inclusion into MOOC and further advanced training courses (section 3).

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2 Overview on smartphone digital soil health assessment tools

Subsequently we provide an overview of available smartphone apps for soil health assessment. Depending on the source, the apps are currently available in different languages – thus besides their applicability for the target soil health diagnostics in NBSoil, for broader stakeholder usability the selected tools require language-specific manuals.

2.1 VESS – Visual Evaluation of Soil Structure

Purpose: Assessment of the quality of soil structure.

Link: https://play.google.com/store/apps/details?id=ch.hepia.vess&hl=en&gl=US

Description: The App guides through the assessment of soil structure based on the appearance and feel of soil aggregates. It is based on a spade test with subsequent visual evaluation of the aggregates. The scoring scale ranges from 1 (very good structure) to 5 (poor structure). VESS assessment is recommended layerwise, mainly in case of visible layering upon taking a spade sample. The VESS method is widely tested and evaluated in numerous scientific publications (Ball et al. 2007; Guimarães et al. 2011).

2.2 BodenDOK

Purpose: Assessment of the quality of soil structure.

Link: https://play.google.com/store/apps/details?id=ch.fhnw&hl=de_AT&gl=US

Description: The BodenDok App guides the user step by step through the observation and evaluation of the local site conditions as well as the procedure and assessment of the spade test. Soil assessment is based on a data sheet where different parameters regarding site, vegetation, management, problems and soil surface can be evaluated. Additionally, the app provides photos to compare the results as well as the possibility to insert own pictures. Furthermore, there is a website (www.spatenprobe.ch) with additional information (Johannes et al. 2023).

2.3 Soil Color

Purpose: Analysis of soil color.

Link: https://play.google.com/store/apps/details?id=org.soilcolor.soilcolorapp&hl=en&gl=US

Description: This App offers a digital tool to analyse the color of soil samples. The App uses different color scales for the evaluation of soil color: RGB (red, green, blue), CMYK (cyan, magenta, yellow and key values) as well as HSV (hue, saturation and value). Based on this color models, the app analyses the color of the picture of the soil sample.

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2.4 Moulder: Soil aggregates

Purpose: Assessment of aggregate stability with the slake test.

Link: https://play.google.com/store/apps/details?id=slaker.sydneyuni.au.com.slaker&hl=en&gl=US

Description: This app provides a tool to measure the stability of soil aggregates in water. A specified number of soil aggregates is placed in a petri dish with water. Aggregate stability is assessed by the change in area of the soil aggregates over time. The results of this visual assessment are then fit into a model and transformed to values that can be used as a soil aggregate stability indicator (Fajardo et al. 2016).

2.5 microBIOMETER Reader

Purpose: Analysis of microbial biomass.

Link: https://play.google.com/store/apps/details?id=com.pes.microbiometer&hl=en_US

Description: The microBIOMETER Reader is an app that reads and analyses the results of the microBIOMETER soil test kit. This test kit is used to anlayse microbial biomass and the fungal to bacterial ratio. With the test kit, microbes are extracted from soil aggregates and particles. While the soil settles at the bottom, the soil microbes remain suspended. The microBIOMETER Reader is now used to analyse the sample. This includes a visual assessment of the color intensity of the soil solution which is compared to standard colors on the testcard. This test can be used for soil, compost and compost extracts (Gordon 2021; Sain 2022).

2.6 SOCit – Soil Organic Carbon information

Purpose: Quantification of SOC content.

Link: https://apps.apple.com/gb/app/socit/id631266307

Description: This app guides the user through the process of estimating the SOC content in the topsoil. By tracking the position of the user, the system can get information on site information like elevation, climate and geology from digital maps. Site conditions being considered, a photograph of the soil sample helps to predict the SOC content in the soil. This application is only available for Scotland (A new soil carbon app for Scottish farmers | The James Hutton Institute 2023).

2.7 SOC +

Purpose: Calculation of SOC content.

Link: https://play.google.com/store/apps/details?id=com.paquete.cos3&hl=en_US

Description: This app helps to calculate the SOC content within the different horizons of a soil profile. Therefore, some data has to be entered into the app: bulk density in mg mL^{-1}, horizon thickness in cm, stone content in % and organic carbon content in %. Based on this data, the app is able to quickly calculate the SOC content of the respecting soil horizon (Bautista et al. 2016).

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2.8 TeaBagIndex

Purpose: Microbial activity, decomposition.

Link: https://play.google.com/store/apps/details?id=com.spotteron.teabagindex&hl=de_AT&gl=US

Description: The TeaBagIndex app collects data on soil observations and in particular on the dynamics of decomposition in the soil. Citizen Scientists can choose between 3 activities: 1) Recording basic soil observations like soil color, soil life and land-use, 2) assessing and recording soil texture and soil structure using the finger test and the spade test and 3) recording the teabag index. The teabag index is a measure of decomposition rates of buried tea bags within 3 months according to a standardised procedure. Two different varieties of tea bags (green tea and rooibos tea) with varying recalcitrance of the material are used. The methods can easily be carried out by citizen scientists such as children and students. The collected data is transmitted to the database of the "Global Tea Bag Index Network".

2.9 Soilmentor

Purpose: Soil health monitoring.

Link: https://play.google.com/store/apps/details?id=com.vidacycle.soilmentor&hl=en_ZA

Description: This app provides a tool for GPS tracked soil health monitoring. Results of simple soil health tests like earthworm count, soil insect score, rooting depth, nodulation of legumes, rhizosheats, % bare earth, brix barometer, carbon stocks (0-30 cm), slake test and infiltration rate can be recorded and saved in the app. As an output, the app creates trends for each indicator that was measured. Additionally, the app provides species lists for recording biodiversity.

2.10 SOILapp

Purpose: Soil quality assessment using the spade test.

Link: https://play.google.com/store/apps/details?id=eu.capsella.soilhealth.spade_test&hl=en_ZA

Description: SOILapp provides a tool for assessing soil quality using the spade test. The app guides through the performance of the spade test and provides a form that includes defined features for different soil layers to record soil observations. In the end, the app gives a summary of the results, which can be commented and shared with other users. For a proper interpretation of the results, knowledge about the history of the site is very helpful.

2.11 OneSoil Scouting: Farming Tool

Purpose: Management tool for arable farms.

Link: https://play.google.com/store/apps/details?id=io.onesoil.scouting

Description: This app helps to operate and manage an arable farm. It provides the opportunity to keep track of the crop development and plant health by calculating the NDVI. Also a local weather forecast is available on the app. Furthermore the app provides a template to plan a diverse crop rotation and also recommends

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suitable crops. Finally, notes about specific fields can be saved, tagged with photos and shared with colleagues. This helps to keep an overview of the farm.

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3 Priorization and first application testing

Based on the assessment of currently available tools, a priority was given to soil structure assessment and related smartphone Apps. The underlying reasons were:

1) Soil structure is a key soil health indicator that covers various target soil functions (production, water filtering and storage, nutrient dynamics via rootability and oxygen availability, biodiversity via pore habitats, climate function via storage of SOC in aggregations and pores) and therefore essentially contributes to mitigate several soil threats (soil erosion, soil compaction, biodiversity loss, loss of organic matter).
2) Soil structure is related to several indicators considered relevant in monitoring soil threats within the upcoming European soil legislation such as aggregate stability and plant available water. Specifically, visual soil structure assessment is directly related to the SOC/Clay ratio that is suggested as a potential indicator capturing both, soil structure and the function of SOC in structure formation/stabilization (Baritz et al., 2021).
3) Visual evaluation of soil structure quality has been successfully implemented in different countries (e.g., UK, Switzerland, Germany, France, New Zealand) evaluated in numerous scientific studies (see recent meta-analysis of Olivares et al., 2023).
4) Visual evaluation of soil structure has been partially connected to other image-based evaluation tools for land-use systems such as indicator plants and related to information of general soil functioning (see: SoilDiag: https://wiki.tripleperformance.fr/wiki/Soildiag).

A first evaluation of VESS within a farmers/advisers' course has been made to infer on the usability, sensitivity and reproducibility when applied in a practical course setting and define subsequent needs for preparing course materials and potentially optimizing the App within NBSoil.

Figure 1 show the soil profile (Cambisol, silty loam). Soil samples have been taken with a spade (Figure 2) from different land management/land-uses systems in the surroundings and judged with a VESS note by 30 participants. The spade tests contained different land uses (forest, pasture, arable land) and different management within arable land (growing winter hard cover crop, winter triticale-pea mixture, bare soil after corn). The VESS scores are given in Table 1. Figure 3 shows the best (VESS 1) and worst (VESS 4) scored samples assessed by the participants.

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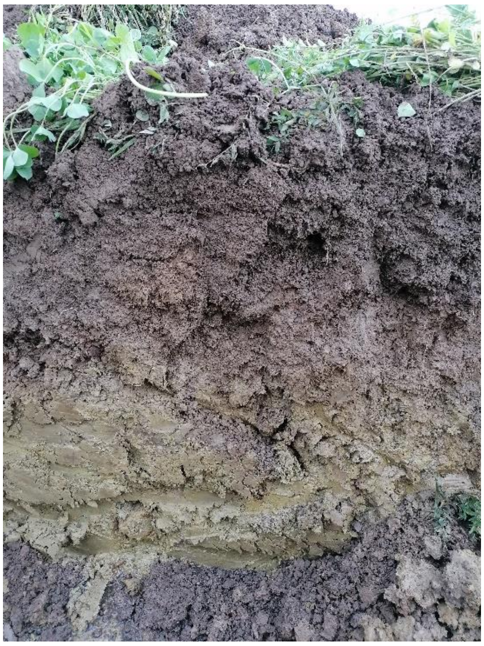

Figure 1. Representative soil profile at the site where VESS assessment has been done for different soil use and management systems.

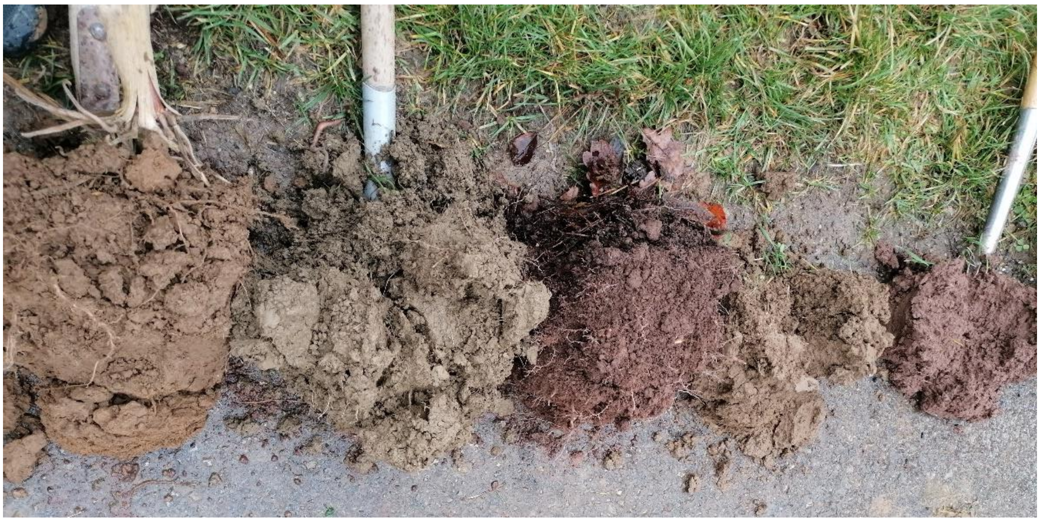

Figure 2. Spade tests used for VESS assessment of five land use and management systems.

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Table 1. VESS sores attributed to the different spade tests.

Land use	VESS Score
Forest soil	1
Pasture soil	2
Cover cropped arable soil	2
Triticale-pea mixture	3
Bare soil after corn harvest	4

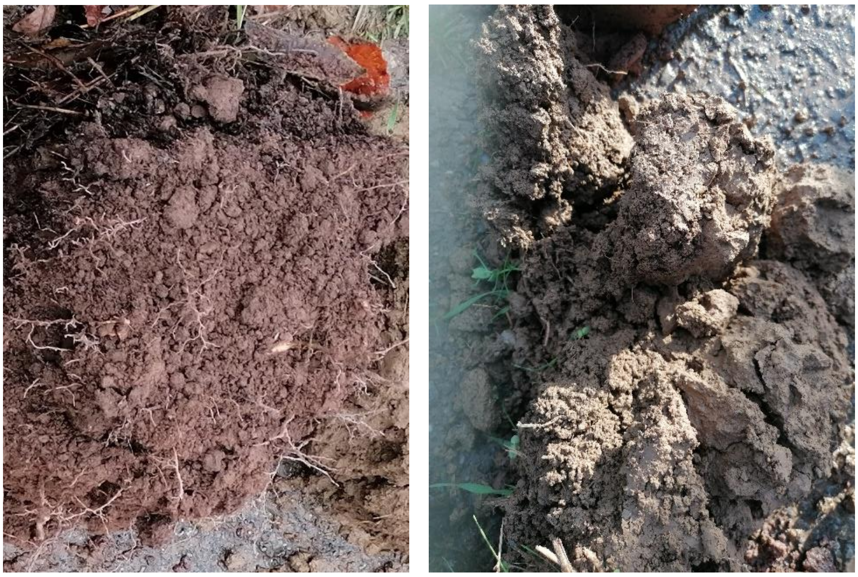

Figure 3. Spade sample with highest (left; forest soil: VESS SQ 1) and lowest (right; bare soil after corn harvest; VESS SQ4) score attributed by 30 participants in a soil health course.

The scoring by the participants showed high agreed in the attribution of VESS scores, besides the arable soils with triticale-pea (recently sown) and the bare arable soil after corn harvest which showed lowest differentiation and thus some overlap in the scoring. This first testing indicated that VESS scoring guided by a mobile app can effectively provide a standardized soil structure assessment by farmers/advisers. Subsequent tests in the samples with simple field methods for soil organic matter (NaOH and $KMnO_4$ extracts) and soil biological

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(respiration test) properties showed very good agreement with the VESS scoring and are considered to be added to the currently available VESS app version in the course of NBS.

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4 Next steps

Next steps will cover:

- Application of the VESS App at selected testing sites and evaluation of potential combinations with other in-field soil diagnostics.
- Preparation of teaching material (manuals, videos) for NBSoil courses to familiarize stakeholders / soil advisers with the usage of smartphone Apps.
- Coordination of integration of smartphone app data into the general GIS tool developed in WP 4.

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