Interreg CENTRAL EUROPE

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PoLaRecCE

PTF method to evaluate the status of soil organic matter

SUBJECT * MERGEFORMAT Best available practices and on-site techniques for environmental site assessment

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Table of contents

List of figures

Executive summary

The PoLaRecCE project's Deliverable 2.1.2 is connected to Activity 2.2, focusing on developing toolboxes for environmental site assessments. Its goal is to provide a guideline for applying the pedotransfer function (PTF) to assess soil carbon (C) storage, a key indicator of soil quality. The document also introduces Visual Soil Assessment (VSA) as a simple method for evaluating soil quality through visual indicators of physical, biological, and chemical properties. Soil organic carbon (SOC) is crucial for various benefits, including reducing carbon emissions, restoring soil function, improving resilience, and enhancing agricultural productivity. The document is written in clear language for end-users and includes explanatory boxes for easy understanding, with proper citations for further study.

1. Introduction

1.1. Objectives

The objective of Deliverable 2.1.2 is to provide a guideline for the application of the pedotransfer fuction (PTF), that provides certain indicators, which can serve as robust parameters for evaluating the content of soil C storage. Additionally, in order to provide complementary parameter for environmental site assessment, knowing that soil C storage is strictly related to soil quality, the application of Visual Soil Assessment (VSA) is also presented as a simple and easy method able to give immediate feedback on soil quality assessment through visual indicators of key physical, biological and chemical soil properties [1].

1.2. Scope

Most C in soils is present in an organic form (soil organic carbon, SOC), and the storage of organic C in soils can have multiple benefits, including: i) offsetting of anthropogenic C emissions, ii) the restoration of soil function, iii) the improvement of soil resilience (to erosion, pollution, disease and drought), iv) increasing agricultural productivity and sustainability, and v) improving the improvement of food security [2]. Consequently, the evaluation of SOC storage is a subject of interest for the recovery of agricultural soil function by non-food farming and adapted soil management at degraded sites.

1.3. Relations to other documents

A short description of how this document relates to other documents developed within the project.

In the PoLaRecCE project, this Deliverable 2.1.2 is linked to Activity 2.2, which includes all activities for the development of toolboxes for environmental site assessment (D 2.1.1, D 2.1.2 and D 2.1.3).

1.4. Intended Audience

This document is intended for farmers, advisors and policymakers involved in the recovery of degraded sites for non-food farming .

1.5. Usage guidelines

As a training material for end-users, this document has been written in an easy-to-understand language, supported by explanatory boxes summarizing the evaluating method (Boxes 1 and 2). However, proper citations and references are provided to allow those interested to further explore the topic.

2. Approach for evalating soil carbon storage

2.1. Identifying goals of soil indicators for radip and easy soil assessment

The objectives of the proposed approach to soil organic C evaluation are: 1) quantifying the content of C stock of soils in degraded sites; 2) evaluating the associated soil quality, which is expected to affect soil functionality and the other multiple benefits promoted by SOC storage; 3) providing a simple and rapid assessment methodology for advisors and policymakers involved in the recovery of degraded sites for non-food farming.

2.2. Identifying standardized soil indicators

2.2.1. Development of pedotransfer functions (PTFs) for bulk density prediction conventions for all documents

Bulk density measurement is needed to quantify the soil C stocks (i.e., soil organic C on an area basis; Mg C ha^{-1}). However, the bulk density values are often missing from databases. The pedotransfer functions (PTFs) approach has the potential to help public officials or private companies to fill gaps in their database, allowing them to calculate soil C stocks.

The development of PTFs for predicting bulk density is based on textural data and TOC (total organic C) content. A relationship between TOC and/or particle size content (in g kg^{-1}) and bulk density (in Mg m^{-3}) is defined, and the amount of C and particle size content can be used to determine the bulk density values. Subsequently, the organic C stock in soils without skeleton (rock fragments >2 mm) is calculated by the following equation:

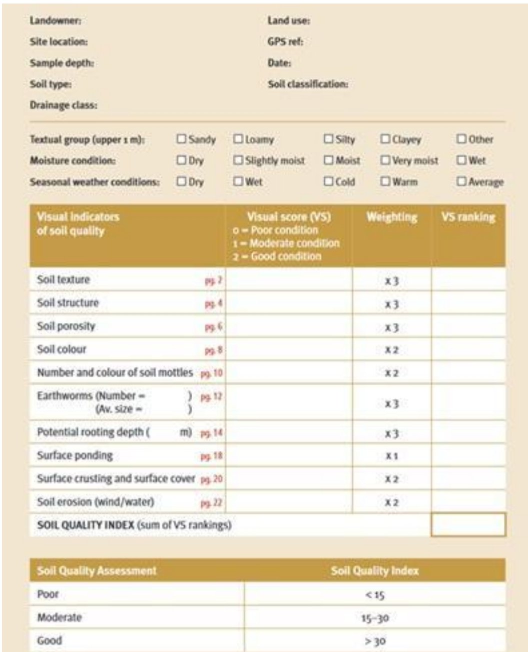
$$C\ stock\ \left[Mg\ ha^{-1}\right] = \ TOC\ \left[g\ kg^{-1}\right] \cdot bulk\ density\ \left[Mg\ m^{-3}\right] \cdot depth\ [m] \cdot\ 10\ m^{2} ha^{-1} \qquad (1)$$

2.2.2. Development of pedotransfer functions (PTFs) for bulk density prediction conventions for all documents

Visual Soil Assessment (VSA) is a simple and easy method able to give immediate feedback on soil quality assessment through visual indicators of key physical, biological and chemical soil properties [1].

VSA methodology is based on the visual assessment of key indicators of soil "status" and crop performance, which are presented on a scorecard (Figure 1). With the exception of soil texture, the soil indicators are dynamic indicators, i.e. they can change under different management regimes and land use pressures. Because they are sensitive to change, they are useful early warning indicators of changes in soil condition and as such provide an effective evaluation tool.

By following the FAO guide (https://www.fao.org/3/i0007e/i0007e.pdf) and observing the soil, you can fill in the form below. Each parameter is rated on a scale from 0 to 2 and a weight is assigned to each parameter observed. The sum of the values obtained makes it possible to obtain a soil quality index based on physical parameters, which is also directly correlated with the C content in the soil.



Landowner: | Land use:
Site location: | GPS ref:
Sample depth: | Date:
Soil type: | Soil classification:
Drainage class:

Textual group (upper 1 m):	☐ Sandy	☐ Loamy	☐ Silty	☐ Clayey	☐ Other
Moisture condition:	☐ Dry	☐ Slightly moist	☐ Moist	☐ Very moist	☐ Wet
Seasonal weather conditions:	☐ Dry	☐ Wet	☐ Cold	☐ Warm	☐ Average

Visual indicators of soil quality		Visual score (VS) 0 = Poor condition 1 = Moderate condition 2 = Good condition	Weighting	VS ranking
Soil texture	pg. 2		x 3	
Soil structure	pg. 4		x 3	
Soil porosity	pg. 6		x 3	
Soil colour	pg. 8		x 2	
Number and colour of soil mottles	pg. 10		x 2	
Earthworms (Number =) (Av. size =)	pg. 12		x 3	
Potential rooting depth (m)	pg. 14		x 3	
Surface ponding	pg. 18		x 1	
Surface crusting and surface cover	pg. 20		x 2	
Soil erosion (wind/water)	pg. 22		x 2	
SOIL QUALITY INDEX (sum of VS rankings)				

Soil Quality Assessment	Soil Quality Index
Poor	< 15
Moderate	15–30
Good	> 30

Figure 1. Scorecard provided by the FAO for the Visual Soil Assessment development.
https://www.fao.org/3/i0007e/i0007e00.pdf

3. A simple and rapid assessment methodology for advisors and policy makers involved in recovery of degraded sites for non-food farming

3.1. Soil survey and sampling

For the determination of C stock by PTF approach and VSA, a field survey and soil sampling are performed.

For each field, at least 2 sites should be assessed. For field larger than 1 ha, an adequate number of sites should be assessed (at least 2 sites over 1 ha).

For the quantification of C stock, soil must be dug down to a depth of at least 50 cm at each site (Figure 2). In addition, soil samples must be taken at fixed depths (0-5, 5-10, 10-15, 15-20, 20-30 and 30-50 cm) in order to measure the amount of carbon present. In at least 1/3 of sites, undisturbed soil cores are taken at fixed depths (0-5, 5-10, 10-15, 15-20, 20-30 and 30-50 cm) for the measurement of bulk density and particle size distribution.

The VSA is performed in each site by the visual assessment of key soil condition and crop performance indicators of soil quality, presented as a scorecard.

Figure 2. Soil pit dug down to 50 cm for C stock quantification by pedotransfer function (PTF) and Visual Soil Assessment (VSA)

3.2. Development of pedotransfer functions (PTFs) for bulk density prediction and quantification of soil C stocks

The measurement of bulk density is needed to quantify soil C stocks (i.e., soil organic C on an area basis referred to a specific depth; Mg C ha^{-1}). However, bulk density values are often missing from databases.

Bulk density (BD) can be estimated using common pedotransfer functions (PTFs) for BD, but their applicability is often critical as significant overestimation or underestimation of SOC stocks can occur (e.g., [3]). To obtain consistent results, the best practice is to determine a local PTF and derive BD values from soil organic C and particle size content [4].

For the determination of PTF and quantification of soil C stocks, air-dried soil samples are sieved to 2 mm and an aliquot was finely ground. For all samples, total organic C (TOC) are measured by Dumas combustion or other internationally recognised method. Particle size distribution are measured using the pipette method [5] or laser granulometry or other internationally recognised method.

The BD of each site is quantified by dividing the mass of oven-dried (105°C) soil samples collected from 0 to 50 cm by the volume of soil cores collected, correcting both oven-dried mass and volume for that of roots and coarse fragments [6].

Statistically significant correlations between BD and TOC and/or particle size content (sand, silt and clay) are checked. In order to predict bulk density, according to the correlation result, the PTF is calculated by statistical interpolation of the best significant model (higher r^2) relating organic C and/or particle size content and BD measured.

The accuracy of the PTF in predicting soil bulk density is then evaluated by calculating the root mean square error (RMSE, equation 2) and the mean error (ME, equation 3).

$$RMSE = \sqrt{\frac{\sum_{1}^{N}(BD_{mi} - BD_{pi})^2}{N}} \quad (2)$$

$$ME = \frac{\sum_{1}^{N}(BD_{mi} - BD_{pi})}{N} \quad (3)$$

where BD_{mi} and BD_{pi} were the measured and predicted BD (g cm^{-3}), respectively, for the *i*-th observation, and N is the total number of observations.

RMSE value <0.26 g cm^{-3} demonstrates a satisfying performance of the calculated PTF [4]. ME value allows to evaluate if negative or positive bias of the PTF occurs, indicating tendency of underestimation or overestimation. Clearly, good performance is indicated by value close to 0.

The soil C stock can thus determined used estimated BD value using equation (1).

In Box 1 a summary of how to proceed for prediction of bulk density is reported.

Box 1 - HOW TO PROCEED FOR CF MONITORING BY PTF FOR PREDICTION OF BULK DENSITY

When?

- The prediction of soil bulk density (BD) by pedotransfer function (PTF) should carried out when the BD density data is not available. BD can thus be estimated from other soil parameters, such as soil organic C and/or particle size distribution (clay, silt, sand).

Where?

- For each field, data on C organic content should be available

- For about 1/3 of fields, measured bulk density should be available
- Data on particle size distribution should be optional if the calculated PFT based on C organic content has a good accuracy

What?

- By statistical interpolation the best significant model (higher r^2) relating organic C content and BD measured is evaluated, in order to predict bulk density
- A relationship between organic C (in g kg^{-1}) and bulk density (in Mg m^{-3}) is defined by statistical interpolation, and the PTF predicting the bulk density values from the amount of C is determine
- The accuracy of PTF in predicting soil bulk density is then evaluated by calculating the root mean square error (RMSE, Eq. (2)) and mean error (ME, Eq. (3)) on available data. A satisfying performance of the calculated PTF has RMSE value less than 0.26 g cm^{-3} [4]. If the accuracy of model is not satisfying, particle size distribution should be used in the model verifying then the accuracy of the new PTF.
- The C stock in each field can be calculated by Eq. (1) using predicted BD

3.3. Soil quality assessment by VSA

As reported in section 2.2.2, the Visual Soil Assessment (VSA) method is based on the visual assessment of key soil condition and crop performance indicators of soil quality, presented as a scorecard [1]. Figure 3 shows an example of a scorecard used in the Interreg PoLaRecCE project. As soil quality is known to be strictly related to soil C storage, the VSA can be a simple, quick, cheap and indirect method to estimate the effect of C sequestration on soil quality that can be used by farmers themselves. For each indicator, a visual score (VS) from 0 (poor) to 2 (good) is given based on field observations and comparison of soil samples with the photo gallery in the VSA manual [1]. Each score is then multiplied by a weighting factor based on the relative importance of each indicator in assessing soil quality (Figure 3). The sum of the VS rankings gives the overall Soil Quality Index score for the sample being assessed. Compare this with the rating scale at the bottom of the scorecard to determine whether your soil is in good, moderate or poor condition. The VSA scorecards [1] are specific to land use (annual crops, orchards, etc.), so great care needs to be taken in selecting the most appropriate scorecard.

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Visual Soil Assessment – annual crops

SOILSCORE CARD – VISUAL INDICATORS FOR ASSESSING SOIL QUALITY IN ANNUAL CROPS (FAO, 2008)

Site identification			
Landowner		Land use	
Site location		GPS coordinates	
Sample depth		Date	
Soil type		Soil classification	
Drainage class		Authors	

Textural group (upper 1 m)	□ Sandy □ Loamy □ Silty □ Clayey □ Other
Moisture condition	□ Dry □ Slightly moist □ Moist □ Very moist □ Wet
Seasonal weather condition	□ Dry □ Wet □ Cold □ Warm □ Average

Visual indicators of soil quality	Visual score (VS) 0=poor condition 1=moderate condition 2=good condition	weighting	VS ranking
Soil texture		X 3	
Soil structure		X 3	
Soil porosity		X 3	
Soil colour		X 2	
Number and colour of soil mottles		X 2	
Earthworms (number ....) (average size ......)		X 3	
Potential rooting depth (........... m)		X 3	
Surface ponding		X 1	
Surface crusting and surface cover		X 2	
Soil erosion (wind/water)		X 2	
SOIL QUALITY INDEX (sum of VS ranking)			

Soil quality assessment	Soil Quality Index
Poor	< 15
Moderate	15-30
Good	> 30

Figure 3. Visual Soil Assessment -VSA- scorecard for annual crops (modified from [1]).

A summary of procedure of the VSA approach is given in Box 2. For more details, the reader is referred to the FAO Field Guide [1].

Box 2 - HOW TO PROCEED FOR SOIL QUALITY ASSESSMENT BY VSA[§]

When?

- The test should be carried out when the soils are moist and suitable for cultivation.

Where?

- Select sites that are representative of the field avoiding heavily disturbed by traffic or at the field border

- For each field, at least 2 sites should be assessed. For field >1 ha, an adequate number of sites should be assessed (at least 2 sites over 1 ha)
- Record the position of the sites for future monitoring
- Dig a pit of 50x50 cm^2 until a depth of 50 cm with a spade

What?

- Work through the scorecard (Figure 3), assigning a VS to each indicator by comparing it with the photographs (or table) and description reported in the FAO Field Guide (FAO, 2008)

§Summary of how to proceed for VSA is reported (the complete description is available at https://www.fao.org/3/i0007e/i0007e.pdf)

4. Glossary

A list of notions/terms specific to this document with short explanations

Notion	Description
PTF	Pedotransfer function
VSA	Visual Soil Assessment
BD	Bulk density
Organic C	Soil organic carbon

5. Bibliography

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