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Manual

Soil quality and agricultural management practices inventory at case study sites

Version – 2016 (1)

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General considerations

The main aim of this inventory is to link applied agricultural management practices (AMP) to the soil quality status at the case study sites, and to identify innovative practices that have improved soil quality (SQ). **This inventory should be completed together with the stakeholder in situ.** Scoring should be done with the consent of the stakeholder as well.

This inventory will be done across a representative number of fields across the main pedo-climatic zones apparent in the Case Study Site. It will be completed together with farmers and in a simple way to identify the AMPs which have improved soil quality. We propose to compare the soil quality of a farm where changes have occurred at least 5 years ago (**farm_AMP**) with another farm without changes in AMP (**farm_control)** within the same pedo-climatic zone and under comparable soil conditions, topography, etc., serving as control.
Thus we kindly request that you identify at least 3 different AMPs (or combinations) and 3 related controls. The selection of these AMPs should be done taking into account the following criteria:

- Include at least two different soil types in your selection;
- Please consider at least two different first level FS (arable, permanent, and grazing) for the selection of AMPs (see Annex 1).

Regarding mixed farming systems, please consider the existence of two different farming systems on the same farm in case it includes both arable cropping and pastures.

We aim for a large variety of AMPs, on a variety of soil types and farming systems – overall representing the case study area.

For this purpose, this questionnaire is based principally on Visual Soil Assessment (VSA) and should be completed by a study site researcher together with the farmer.

To carry out the evaluation of soil quality of a farm in situ, a representative plot has to be selected. This plot located in the farm_AMP should represent the most important characteristics of the farm under consideration with regard to the slope, soil and crop type. For the evaluation of soil quality, a plot (located in the farm_AMP) has to be compared to a control (located in the farm_control). They should be preferably not too far away from each other. For reasons of convenience, the term **plot** is referred to the farm_AMP and **control** refers to the farm_control throughout this inventory.

If different AMPs exist in one farm, you can select two or more AMP plots in the same farm. Even the control can be located in the same farm as the plot.

It is also possible to compare 2 plots with 1 control if they are in same pedo-climatic zone and have comparable soil type, topography, etc.

The evaluation of soil quality of both plot and the corresponding control is done using one single excel sheet.

In addition to this introduction, 3 other parts constitute this inventory (Excel document):

1) Specifications of Farming Systems under consideration (see Annex 2);

2) Identification of Agricultural Management Practices (AMP) (see Annex 1);

3) Soil Quality indicators (SQ-1).

Fill in the first part: FS and continue with AMP.

1. Specifications of Farming Systems under consideration

The list of the farming systems (FS) is given in Annex 2. In-situ soil quality evaluation of both plot and control should be made during same time period (spring or in summer when soil conditions are not too wet and not too dry) within a time interval of 1 – 3 days to have comparable weather and soil conditions.

2) Identification of Agricultural Management Practices (AMP)

In this part, general information on the plot and control are required such as location, area in km^2, name of AMP, etc. The data collected in this part will be further documented in detail with the help of the WOCAT technology questionnaire and entered into the WOCAT on-line database.

3) Soil quality indicators (SQ-1)

This part assesses the impact of the AMP on soil quality compared to the control.

Below each property described in this manual (PDF document), you find a reference with a link for more details on definition, importance, and assessment.

At the left side of this part (Excel document), please select the corresponding assessment for both plot and control. This will automatically set the scoring in the middle of this sheet.

The scores of each parameter consist of 3 evaluations: 0 for bad condition, 1 for moderate condition, and 2 for good condition.

Additional laboratory and a statistical analysis from the LTE data will help to calibrate the scoring of this inventory for comparison between AMP and control. This will be done after collecting all data of the study sites.

4) Material needed

- 1 spade – to dig out a 20cm cube of topsoil.
- 1 plastic basin (approx. 35x35x20cm) – to carry the soil for the drop shatter test.
- 1 hard square board (approx. 26x26x1.8cm) – on to which a soil cube is dropped for the shatter test.
- 1 heavy-duty plastic sheet (approx. 75x50cm) – on which to spread the soil, after the shatter test has been carried out.
- 1 VSA field guide (this manual printed in colour) – to make the photographic comparisons.
- Digital camera (use same for all sites). The photos should be taken under same light conditions in situ (the soil to be photographed should be covered by a white large parasol in order to diffuse sunlight) and second series of photos have to be taken in the lab (under same light conditions).
- Wire grid of about 1 cm^2 mesh and a wide-mouth bottle (for slaking test, see **page 16**)
- Infiltrometer or penetrometer and supporting material (see **page 19**)

5) Remarks

The assessment of all proposed indicators should be made in situ except the labile organic carbon (**page 23**) which can be either assessed in the lab or in the field.

The classification ranges of some indicators might still need to be re-evaluated after collecting all the study site data. For this purpose it is necessary to indicate the measured absolute values (e.g. pH).

If you choose to carry out infiltration instead of penetration resistance (**page 21**), please start with infiltration at the beginning of your field investigations and then evaluate the remaining indicators. After 20 Minutes, record the volume infiltrated in soil.

In general, the study site researchers should avoid walking on the plot under investigation to prevent any topsoil disturbance (i.e., topsoil compaction).

The content of this manual is based on the work of Graham Shepherd (2000), Ball et al. (2017); and Mueller et al. (2009, 2013). The link to each method is provide in the references of the corresponding method with the permission of Väderstad AB.

For questions, please contact Abdallah Alaoui (abdallah.alaoui@giub.unibe.ch).

References

Ball, B. C., Rachel, M. L., Guimarães, R. M. L., Cloy, J. M., Hargreaves, P. R., Shepherd, T. G., & McKenzie, B. M. (2017). Visual soil evaluation: A summary of some applications and potential developments for agriculture. Soil and Tillage Research, 173, 114–124. http://doi.org/10.1016/j.still.2016.07.006

Mueller, L., Shepherd, G., Schindler, U., Ball, B. C., Munkholm, L. J., Hennings, V., … Hu, C. (2013). Evaluation of soil structure in the framework of an overall soil quality rating. Soil and Tillage Research, 127, 74–84. http://doi.org/10.1016/j.still.2012.03.002

Shepherd, T. G. (2000) Visual Soil Assessment Volume 1: Field guide for cropping and pastoral grazing on flat to rolling country. Palmerston North, New Zealand: horizons.mw & Landcare Research.

Visual Soil Assessment used in this inventory

The key information for scoring the first and second indicator can be directly provided by the land user since the evaluation of these indicators is related to different times of the year.

1. Susceptibility to Wind and Water Erosion

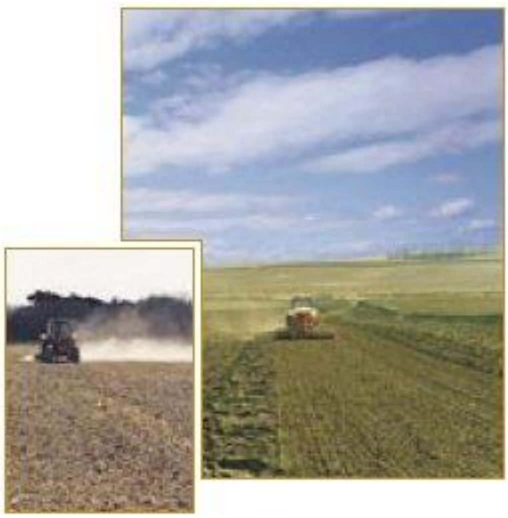
Importance:

The susceptibility of a soil to wind erosion depends on factors including soil moisture and wind velocity, surface roughness, organic matter content and particle size. Soils that have low volumes of organic matter and have lost their structure through compaction and over-cultivation are pulverised to dust on further cultivation, making them vulnerable to wind erosion if un-protected. Wind erosion reduces the productive potential of soils through nutrient losses, lower available water-holding capacity and reduced rooting volume and depth.
The water erodibility of soil on sloping ground is governed by factors including the amount and intensity of rainfall, the degree of slope, and the soil infiltration rate and permeability. The latter two are governed by soil structure and texture.

Assessment:

- Assess, based on knowledge of the area or visual observations during the season, whether the amount of wind erosion during and after cultivation has become a concern.
- Take into account the size of the dust plume or clouds raised during or after cultivation, and whether the material stays within the field, within the farm, or is blown into the surrounding area.
- Determine the severity of water erosion by augering or digging holes to compare the difference in topsoil depths between the crest and the bottom of the slope, and by observing the amount of sheet and rill erosion, as well as sedimentation into surrounding drains and streams.

Scoring:



Good condition: Score 2

Wind erosion is not a concern: only small dust plumes emanate from the cultivator on windy days. Most wind-eroded material is contained within the field. Water erosion is not a concern as there is only a little rill and sheet erosion. Topsoil depths in valley areas are <15cm deeper than on crests. Deal with water erosion and wind erosion separately if both have occurred. Reduce the score by one point.

Moderate condition: Score 1

Wind erosion is of moderate concern where significant dust plumes can emanate from the cultivator on windy days. A considerable amount of material is blown off the field, but is contained within the farm area. Water erosion is of a moderate concern with a significant amount of rilling and sheet erosion. Topsoil depths in valley areas are 15-30cm greater than on crests and sediment input into drains/streams may be significant.

Poor condition: Score 0

Wind erosion is a major concern. Large dust clouds can occur when cultivating on windy days. A substantial amount of topsoil can be lost from the field and deposited elsewhere in the district. Water erosion is a major concern, with severe rilling and sheet erosion occurring. Topsoils in valley areas are more than 30cm deeper than on the crests and sediment put into drains/streams may be high.

g

Figure 1. *Visual Scoring of Susceptibility to Wind and Water Erosion*

References:

http://adlib.everysite.co.uk/adlib/defra/content.aspx?id=000HK277ZX.0HDECKKQLJIF9JD

2. Surface ponding (under cropping)

Importance:

The length of time that water remains ponded on the surface indicates the rate of infiltration into the soil, and the time that the soil remains saturated. Prolonged water logging depletes oxygen and causes carbon dioxide to build up.
Anaerobic conditions develop and induce a series of chemical and biochemical reduction reactions that produce by-products that are toxic to plant roots. Organic substances can also anaerobically degrade in these soils and the soil goes 'sour'. Water logging delays cultivation because the low load-bearing capacities of the soil increase its susceptibility to damage through deformation and excessive wheel slip.

Assessment:

Assess the degree of surface ponding. Base the assessment on the time the water took to disappear following a wet period, or after heavy rainfall in the winter.

Scoring:

Good condition: Score 2

No evidence of surface ponding after 1 day following heavy rainfall on soils that were already at or near saturation.

Moderate condition: Score 1

Moderate surface ponding can occur up to 3 days after heavy rainfall on soils that were already at or close to saturation.

Poor condition: Score 0

Significant surface ponding can occur for longer than 3 days after heavy rainfall on soils that were already at or close to saturation.

Figure 2. *Visual Scoring of Surface Ponding*

References:

http://adlib.everysite.co.uk/adlib/defra/content.aspx?id=000HK277ZX.0HDECKKQLJIF9JD

ftp://ftp.fao.org/docrep/fao/010/i0007e/i0007e01.pdf

3. Presence of a cultivation pan

Importance:

Well-developed cultivation pans can impede the movement of water, air and oxygen through the profile, increasing the susceptibility to water logging and erosion by rilling and sheet wash. Well-developed cultivation pans are difficult for roots to penetrate and can cause them to grow horizontally, restricting vertical root growth and development. This reduces the ability of the root system to take up water and nutrients.

Assessment:

- Dig a hole of about 50 cm depth and examine the lower part of the topsoil by comparing it with the upper topsoil.
- Compare against the three photographs in Figure 3.

Scoring:

Good condition: Score 2

No tillage pan, with a friable, clearly apparent structure and soil pores throughout the topsoil.

Moderate condition: Score 1

Firm, moderately developed tillage pan in the lower topsoil, showing clear zones of compaction, but including areas with weakly developed structure, cracks, fissures and a few micro-pores.

Poor condition: Score 0

Very firm to hard, well developed tillage pan in the lower topsoil, showing severe compaction with no structure, no macro-pores and few or no cracks.

Figure 3. *Visual Scoring of the Presence of a Cultivation pan*

References:

ftp://ftp.fao.org/docrep/fao/010/i0007e/i0007e01.pdf

4. Soil Colour

Importance:

Soil colour can provide an indirect measure of other more useful properties of the soil that are not assessed so easily and accurately. A change in colour can give a general indication of a change in organic matter under a particular land use or management. Soil organic matter plays an important role in regulating most biological, chemical and physical processes in soil, which collectively determine soil health. It promotes infiltration and retention of water, helps to develop and stabilize soil structure, reduces the potential for wind and water erosion, and indicates whether the soil is functioning as a carbon "sink" or as a source of greenhouse gases.

Assessment:

- Compare the colour of a handful of soil from the structure test with soil taken from the nearest uncultivated area.
- Using the three photographs in Figure 4, compare the relative change in soil colour that has occurred. As topsoil colour can vary markedly between soil types, the photographs illustrate the trend rather than the absolute colour of the soil.

Scoring:

Good condition: Score 2	**Moderate condition: Score 1**	**Poor condition: Score 0**
Dark coloured topsoil that is not too dissimilar to that from the uncultivated area.	The colour of the topsoil is somewhat paler than the uncultivated area, but not markedly so.	Soil colour has become significantly paler compared with the uncultivated area.

Figure 4. *Visual Scoring of Soil Colour*

References:

http://adlib.everysite.co.uk/adlib/defra/content.aspx?id=000HK277ZX.0HDECKKQLJIF9JD

5. Soil porosity

Importance:

Soil porosity, and particularly macroporosity (or large pores), influences the movement of air and water in the soil. Soils with good structure have a high porosity between and within aggregates, but soils with poor structure have restricted drainage and aeration.

Poor aeration leads to the build-up of carbon dioxide, methane and sulphide gases, and reduces the ability of plants to take up water and nutrients, particularly nitrogen (N), phosphorus (P), potassium (K) and sulphur (S). Plants can only utilize S and N in the oxygenated sulphate (SO_4^{2-}), nitrate (NO_3^-) and ammonium (NH_4^+) forms. Therefore, plants require aerated soils for the efficient uptake and utilization of S and N. The number, activity and biodiversity of micro-organisms and earthworms are also greatest in well aerated soils and they are able to decompose and cycle organic matter and nutrients more efficiently.

Assessment:

- Remove a spade slice of soil (about 100 mm wide, 150 mm long and 200 mm deep) from the side of the hole and break it in half.
- Examine the exposed fresh face of the sample for soil porosity by comparing against the three photographs in Figure 5. Look for the spaces, gaps, holes, cracks and fissures between and within soil aggregates and clods.
- Examine also the porosity of a number of the large clods. This provides important additional information as to the porosity of the individual clods (the intra-aggregate porosity).

Scoring:

Good condition: Score 2	**Moderate condition: Score 1**	**Poor condition: Score 0**
Soils have many macropores between and within aggregates associated with good soil structure.	Soil macropores between and within aggregates have declined significantly but are present upon close examination of clods, showing a moderate amount of compaction.	No soil macro-pores are visually apparent within compact, massive structureless clods. The clod surface is smooth with few cracks or holes, and can have sharp angles.

Figure 5. *Visual Scoring of Soil Porosity*

References:

http://adlib.everysite.co.uk/adlib/defra/content.aspx?id=000HK277ZX.0HDECKKQLJIF9JD

ftp://ftp.fao.org/docrep/fao/010/i0007e/i0007e01.pdf

6. Soil structure and consistency

Importance:

Good soil structure is vital for growing crops. It regulates soil aeration and gaseous exchange rates, the movement and storage of water, soil temperature, root penetration and development, nutrient cycling and resistance to structural degradation and erosion. It also promotes seed germination and emergence, crop yields and grain quality.

Good structure also increases the window of opportunity to cultivate at the right time and minimises tillage costs in terms of tractor hours, horsepower requirements and the number of passes required to prepare the seedbed.

Assessment:

- Remove first the 0 – 5cm topsoil that contains dense and compacted root system without disturbing soil.
- Remove a 20cm cube of topsoil with a spade.
- Drop the soil sample a maximum of three times from a height of one metre (waist height) onto the firm base in the plastic box. If large clods break away after the first or second drop, drop them individually again once or twice. If a clod shatters into small units after the first or second drop, it does not need dropping again. Do not drop any piece of soil more than three times.
- Part each clod by hand along any exposed fracture planes or fissures.
- Transfer the soil onto the large plastic bag.
- Move the coarsest parts to one end and the finest to the other end. This provides a measure of the aggregate-size distribution. Compare the resulting distribution of aggregates with the three photographs in Figure 6.

Scoring:

Good condition: Score 2 Good distribution of finer aggregates with no significant clodding.	**Moderate condition: Score 1** Soil contains significant proportions of both coarse firm clods and friable, fine aggregates.	**Poor condition: Score 0** Soil dominated by extremely coarse, very firm clods with very few finer aggregates.

Figure 6. *Visual Scoring of Soil Structure Consistency*

References:

http://adlib.everysite.co.uk/adlib/defra/content.aspx?id=000HK277ZX.0HDECKKQLJIF9JD

ftp://ftp.fao.org/docrep/fao/010/i0007e/i0007e01.pdf

7. Soil slaking test (soil stability)

Importance:

Slaking is the breakdown of large, air-dry soil aggregates (>2-5 mm) into smaller sized microaggregates (<0.25 mm) when they are suddenly immersed in water. Slaking indicates the stability of soil aggregates and resistance to erosion, and suggests how well soil can maintain its structure to provide water and air for plants and soil biota when it is rapidly wetted. High soil stability suggests that organic matter is present in the soil to help bind soil particles and microaggregates into larger, stable aggregates. Slaking results in detached soil particles, reduced infiltration and plant available water, and increased runoff and erosion and causes surface sealing.

Assessment:

Select 3 air-dry aggregates, 4–6 cm diameter. Place soil fragments in the mesh of 1 cm diameter. Observe the soil fragment for 5–10 minutes. Refer to the stability class table below to determine the scores.

Scoring:

Good condition: Score 2	**Moderate condition: Score 1**	**Poor condition: Score 0**
No change, water is clean	Aggregate breaks down but some ones remain intact on the top	Aggregate breaks down completely into sand grains

Figure 7. *Soils with high SOM do not readily slake (fall apart) when wetted (left side). The soil on the right would be more likely to crust after a heavy rain.*

References:

Youtube:
http://soilquality.org/indicators/slaking.html
https://www.youtube.com/watch?v=GOos10UyRwY
https://www.youtube.com/watch?v=MOZi33vVsOA

8. Biodiversity (earthworm density)

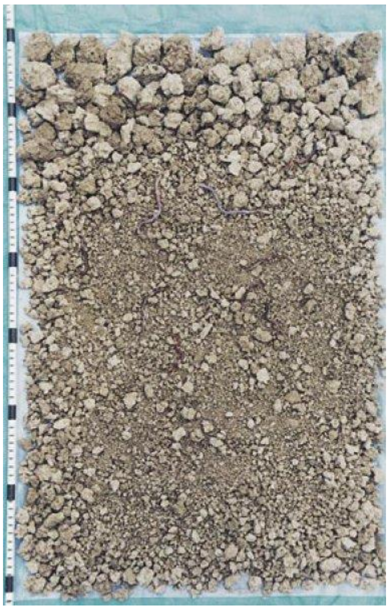
Importance:

Earthworms provide a good indicator of the biological health and condition of the soil because their population density and species are affected by soil properties and management practices. Through their burrowing, feeding, digestion and casting, earthworms have a major effect on the chemical, physical and biological properties of the soil. They shred and decompose plant residues, converting them to organic matter, and so releasing mineral nutrients. Compared with uningested soil, earthworm casts can contain 5 times as much plant available N, 3–7 times as much P, 11 times as much K, and 3 times as much Mg. They can also contain more Ca and plant-available Mo, and have a higher pH, organic matter and water content. Moreover, earthworms act as biological aerators and physical conditioners of the soil, improving: soil porosity, aeration, soil structure and the stability of soil aggregates, water retention, water infiltration, and drainage.

Assessment:

Count the earthworms by hand, sorting through the soil sample used to assess soil structure and compare with the class limits in Fig. 8. Earthworms vary in size and number depending on the species and the season. Therefore, for year-to-year comparisons, earthworm counts must be made at the same time of year when soil moisture and temperature levels are good. Earthworm numbers are reported as the number per 200-mm cube of soil. The class limits for earthworm numbers given in Figure 8 are based on the probability that only two thirds of the worms that are present will be found during a 5 minute search.

Scoring: (Earthworm counts per 20cm^3 of soil):



Good condition: Score 2

Number > 8

Moderate condition: Score 1

4 – 8

Poor condition: Score 0

< 4

Figure 8. *Visual Scoring of Earthworm Counts*

References:

http://adlib.everysite.co.uk/adlib/defra/content.aspx?id=000HK277ZX.0HDECKKQLJIF9JD

9. pH

Importance:

Soil pH is a measure of its acidity or alkalinity and is an important property because of its influence on the supply of nutrients (cations and anions) to plants, the chemical behaviour of toxic elements and the activity of microorganisms. There are two standard laboratory tests; using water (pH H_2O) and using 0.01M calcium chloride (pH $CaCl_2$), both of which use a 1:5 soil to solution ratio. Because these two methods give different values, **we suggest using pH H_2O**.

Assessment:

Assessing pH has to be carried out with a pH kit.

***Scoring*:**

Good condition: Score 2	Moderate condition: Score 1	Poor condition: Score 0
5.5 – 7.5	< 5.5 or > 7.5	< 4.5 or > 8

Figure 9. *pH values for scoring*

References:

http://www.blm.gov/wo/st/en/prog/more/soil2/soil2/indicators.html

(Adapted)

10. Infiltration rate / Penetration resistance

Please choose **one** of the following two methods.

A) Infiltration rate

Importance:

Infiltration rate or infiltration capacity is a good indicator of physical soil quality since it reflects the hydrodynamic aspect of soil structure. Infiltration capacity is defined as the maximum rate at which water soaks into or is absorbed by the soil through the soil surface. There are several devices and approaches to assess infiltration capacity in soils. Here, we propose the method developed at the University of Bern (Switzerland), which was calibrated to assess soil damage due compaction.

Assessment:

- Introduce the metal tube carefully into the soil to a depth of 20 cm using a rubber hammer. Do not disturb soil with horizontal movements while introducing the tube.
- Take out the metal tube by turning it slightly.
- Introduce the penetrometer carefully into the soil to a depth of 20 cm (without using the rubber hammer).
- Fill the Plexiglas tube with water (370 mL). Start to record time immediately. After 20 minutes record the volume of water infiltrated into the soil by measuring the height of the infiltrated water (1 cm = 7.1429 ml).
- Conduct at least **3 measurements** (within a radius of 0.50 m) to characterize one plot (one control).

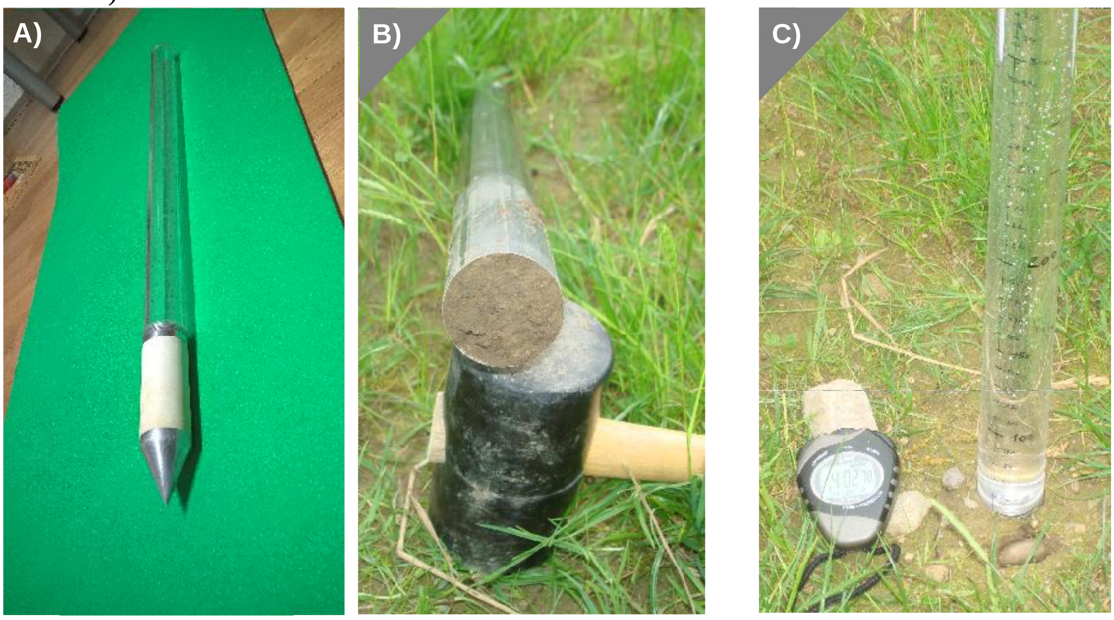


Figure 10a. *Exerimental setup to assess the infiltration rate with the proposed infiltrometer (address for order and support: abdallah.alaoui@cde.unibe.ch)*

Scoring:

Good condition: Score 2	Moderate condition: Score 1	Poor condition: Score 0
Water volume > 50 mL	30 mL<Water volume>50 mL	Water volume < 30 mL

B) Penetration resistance

Importance:

Penetration resistance (PR) is correlated with root growth, earthworm activity, and tillage effects. When PR exceeds 2 MPa, root growth is often reduced by half, while values > 3 MPa often prevent root growth. Tillage may increase the critical stress value of a hard-pan to > 3.5 MPa depending on the nature of the pore system and the type of soil structure.

Assessment:

In each plot, PR should be measured at least **10 times** within a radius of 0.50m down to a depth of 0.40 m. Measurements should be made with a cone with a cross-sectional area of 1 cm^2. The cone should be pushed slowly and regularly into the soil. The depth and the force resolutions are 0.01m and 1 N respectively (see manual below for more explanation). The vertical measurements have to be averaged for each depth layer and the measurements of the plot_AMP and these of the control have to be statistically compared.

Figure 10b. P*roposed penetrometer to assess soil penetration resistance. Use same devise for all sites:* Eijkelkamp, Giesbeek, The Netherlands

Scoring:

Good condition: Score 2	Moderate condition: Score 1	Poor condition: Score 0
< 2 MPa	2– 3 MPa	> 3 MPa

References:

https://en.eijkelkamp.com/products/field-measurement-equipment/penetrologger-set-a.html

11. Labile organic carbon

The labile organic carbon can be measured in the field by a prior solution preparation ($CaCl_2$ and $KMnO_4$).

Importance:

The labile fraction of soil carbon is the component of organic matter that feeds the soil food web and is closely associated with nutrient cycling and other important biological functions in the soil. Weil et al. (2003) have developed a field kit method for the determination of $KMnO_4$ oxidisable Carbon. In this test a dilute solution of $KMnO_4$ is used to oxidize OC. Generally, in the course of the experimental procedure the greater the loss in colour of the $KMnO_4$, the lower the absorbance reading will be, hence the greater the amount of oxidisable Carbon in the soil.

Assessment:

The method requires a field kit consisting of:

- A stock solution of 0.02 molar (20 mM) solution of $KMnO_4$ in 0.1 $MCaCl_2$ (at pH 7.2) and a 5-min settling period to enhance settling and clarify the supernatant.
- A palm-sized spectrometer for example a Hach (or generic) 550nm[(1)] for gauging the change in colour (the optical density) of the $KMnO_4$.
- Screw top tubes for shaking the soil suspension.
- Measurement pipettes.
- A scoop for measuring soil (five cc capacity).

The procedure is as follows:

- Calibrate the colorimeter using varying concentrations from 0 to 30 mM $KMnO_4$ (x-axis) of the stock solution (vs. colorimeter read-out in y-axis) and find the **first correlation function** y=f(x)
- Sun- or air-dry 20 g of the soil under investigation for 15-3 minutes.
- Shake vigorously for exactly two minutes.
- Stand upright for 5-10 minutes, protected from direct sunlight.
- Zero the colorimeter with a sample of distilled water.
- Pipette-off 0.5 ml of liquid from the top 1 cm of the “soil sample” mix.
- Add it to 45 ml of distilled water, top up to 50 ml.
- Mix well, then put 15 ml of this solution into the measuring cuvette (of the colorimeter).
- Place the cuvette in the colorimeter, put on the cover and press “read”.
- The spectrometer will measure the colour of the $KMnO_4$ solution.

Read the colorimeter digital display and use to:

- Calculate active carbon using the calibration line (**first correlation function**).

Record the amount of active carbon present (mg/g) using **the second correlation function** ($y = -0.84x + 1.2514$) (see Des McGarry[(2)]).

Figure 11. *Permanganate oxidisable carbon contents (mg/g) considered to be low, moderate and high for soils of various textures.**

Soil organic carbon status	**Sand**	**Sandy loam**	**Loam**	**Clay loam/Clay**
good	> 1	> 1.4	> 1.8	> 2.0
moderate	0.5 – 1.0	0.7 – 1.4	0.9 – 1.8	1.2 – 2.0
poor	< 0.5	< 0.7	< 0.9	< 1.2

Values (mg/g) of labile carbon considered to be "good", "moderate" and "poor" for soils of different textures. The table is taken from Moody and the values are based on several hundred laboratory-based organic matter determinations.

References:

Ray R. Weil, Kandikar R. Islam, Melissa A. Stine, Joel B. Gruver and Susan E. Samson-Liebig. 2003. Estimating active carbon for soil quality assessment: A simplified method for laboratory and field use:
(https://www.enst.umd.edu/sites/default/files/_docs/Weil_et_al_2003_corrected.pdf)

(1)http://www.hach.com/pocket-colorimeter-ii-wavelength-specific-model-550-nm/product?id=7640445216

(2)A Methodology of a Visual Soil - Field Assessment Tool - FAO.org
ftp://ftp.fao.org/agl/agll/lada/vsfast_methodology.pdf

Annex 1

Innovative soil-improving AMP

N.	List / Identification	Description	Expected impacts / Ecological benefits
1	No-till	A system where crops are planted into the soil without primary tillage	Reduces decomposition of OM rates leading to its increase in soil, enhances cycling of nutrients, enhances soil structure and increases water infiltration. Improves soil biological life including disease and weed suppression.
2	Min-till	Tillage operation with • reduced tillage depth • strip tillage • mulch tillage or a combination thereof	Reduces decomposition of OM rates leading to its increase in soil, enhances cycling of nutrients, enhances soil structure and increases water infiltration. Improves soil biological life including disease and weed suppression.
3	Permanent soil cover / Removing less vegetation cover	Avoiding a bare or sparsely covered soil exposed to weather conditions (rain, wind, radiation, etc) by ensuring a permanent cover (at least 30% of the soil surface) throughout the year, e.g. through cutting less grass, leaving a volunteer crop or crop residues, etc. (*see also cover crops and residue maintenance / mulching*)	• Improves infiltration and retention of soil moisture resulting in less severe, less prolonged crop water stress and increases availability of plant nutrients. • Provides source of food and habitat for diverse soil life: created channels for air and water, biological tillage and substrate for biological activity through the recycling of organic matter and plant nutrients. • Increases humus formation. • Reduces the impact of rain drops on soil surface resulting in reduced crusting and surface sealing. • Reduces runoff and erosion. • Reduces wind erosion. • Increases soil regeneration. • Mitigates temperature variations on and in the soil. • Improves the conditions for the development of roots and seedling growth.
4	Cover crops	a. Cover cropping: planting close-growing crops (usually annual legumes), b. Relay cropping**:** specific form of mixed cropping / intercropping in which a second crop is planted into an established stand of a main crop. The second crop develops fully after the main crop is harvested. c. Better crop cover: selecting crops with higher ground cover, increasing plant density, etc.	a. Protects soil, between perennials or in the period between seasons for annual crops. N-fixation in case of leguminous crops. b. Continuously covered soil. Reduces the insect/mite pest populations because of the diversity of the crops grown. Reduces the plant diseases. Reduces hillside erosion and protected topsoil, especially the contour strip cropping. Attracts more beneficial insects, especially when flowering crops are included in the cropping system.

			c. Protects soil against the impacts of raindrops or wind and keeps soil shaded; and increases moisture content.
5	Leguminous crop	A leguminous crop is a plant in the family Fabaceae (or Leguminosae) that is grown agriculturally, primarily for their grain seed called pulse, for livestock forage and silage, and as soil-enhancing green manure. Well-known legumes include alfalfa, clover, peas, beans, lentils, lupins, mesquite, carob, soybeans, peanuts, and tamarind.	Provides soil with nitrogen and additional nitrogen from chemical fertilizers is not necessary. *(See also cover crop and green manure)*
6	Green manure / Integrated soil fertility management	Green manure is a crop grown to be incorporated into the ground, while the more general term 'integrated soil fertility management' refers to a mix of organic and inorganic materials, used with close attention to context-specific timing and placing of the inputs in order to maximize the agronomic efficiency.	Increases organic matter content, thereby improving fertility and reducing erodibility. In case of leguminous green manure, tilling it back into the soil allows exploiting the high levels of captured atmospheric nitrogen found in the roots.
7	Manuring[a] / composting[b]	a) Manure is organic matter, mostly derived from animal feces (except in the case of green manure, which can be used as organic fertilizer in agriculture). b) Compost is organic matter that has been decomposed and recycled as a fertilizer and soil amendment. Compost is a key ingredient in organic farming.	a) Contributes to the fertility of the soil by adding organic matter and nutrients, such as nitrogen, that are trapped by bacteria in the soil. b) Improves soil fertility through nutrient content and availability, soil structure and microbiological activity; impacts plant growth and health directly and indirectly.
8	Residue maintenance / Mulching	Maintaining crops residues or spreading of organic (or other) materials on the soil surface.	• Reduces sheet and rill erosion. • Reduces wind erosion. • Maintains or improves soil organic matter content. • Conserves soil moisture. • Provides food and escapes cover for wildlife.

9	Crop rotation[a] / Control or change of species composition[b]	a. Practice of alternating the annual crops grown on a specific field in a planned pattern or sequence in successive crop years so that crops of the same species or family are not grown repeatedly on the same field b. Diversify species in rotation systems or grasslands	a. Reduces risk of pest and weed infestations. Improves distribution of channels or biopores created by diverse roots (various forms, sizes and depths). Improved distribution of water and nutrients through the soil profile. Allows exploration for nutrients and water of diverse strata of the soil profile by roots of many different plant species resulting in a greater use of the available nutrients and water. Increases nitrogen fixation through certain plant-soil biota symbionts and improved balance of N/P/K from both organic and mineral sources. Increases humus formation. b. Introduces desired / new species, reduces invasive species, controls burning, residue burning.
10	Cross-slope measure	Structural measure along the contour to break slope lengths, such as terraces, bunds, grass strip, trashlines, contour tillage	Reduces surface runoff and erosion (increase infiltration capacity).
11	Measures against compaction	a) Breaking compacted soil: e.g. deep ripping, subsoiling (hard pans); Digging the soil up to twice as deep as normally. b) Growing deep rooted plants in the rotation such as: annual alfalfa, beet, sunflower, okra, flax, turnip. c) Controlled traffic farming: is a system which confines all machinery loads to the least possible area of permanent traffic lanes d) Soil compaction models (considering tire size, inflation pressure, weather and soil conditions) to predict allowable wheel load and soil compaction maps to show how soil compaction varies at different locations and depths across the field	a-b)Looses soil to improve drainage, infiltration, aeration and rooting characteristics, and brings nutrients up from deep below c-d) Minimizes soil damage and preserves soil function in terms of water infiltration, drainage and greenhouse gas mitigation, and (d) provides useful information for decision making process for site-specific applications such as variable deep tillage to benefit from increased timeliness (and reduced management costs)
12	Integrated pest and disease management incl. organic agriculture	Appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to reduce or	Emphasizes the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms.

		minimize risks to human health and the environment.	
13	Water diversion and drainage	A graded channel with a supportive ridge or bank on the lower side. It is constructed across a slope to intercept surface runoff and convey it safely to an outlet or waterway	Reduces hazard towards adverse events (floods, storms,…), reduces soil waterlogging
14	Irrigation management	Controlled water supply and drainage: mixed rainfed – irrigated; full irrigation; drip irrigation	Improves water harvesting; increased soil moisture; reduces evaporation; improves excess water drainage; recharge of groundwater
15	Major change in timing of activities	Adaptation of the timing of land preparation, planting, cutting of vegetation according weather and climatic conditions, vegetation growth, etc.	Reduced soil compaction, soil loss, improved biomass, increased biomass, increased soil OM
16	Layout change according to natural and human environment/needs	eg exclusion of natural waterways and hazardous areas, separation of grazing types; increase of landscape diversity.	Reduces surface runoff and erosion, increases biomass, nutrients and soil OM, controls pests and diseases
17	Area closure / rotational grazing	Complete or temporal stop of use to support restoration	Improves vegetative cover, reduces intensity of use, and soil compaction and erosion.
18	Change of land use practices / intensity level	eg change from grazing to cutting (for stall feeding), from continuous cropping to managed fallow, from random (open access) to controlled access (grazing land), from herding to fencing, adjusting stocking rates.	Increases biomass, nutrient cycling, soil OM, improves soil cover, beneficial species (predators, earthworms, pollinators), biological pest / disease control, and increases / maintains habitat diversity. Reduces soil loss, soil crusting/sealing, soil compaction, and invasive alien species.

Task 3. Selecting innovative agricultural management practices (AMP) improving soil quality (WP5 – UNIBE)

Annex 2

Proposed categories of the farming systems for Europe:

(Proposal to ISQAPER WP2/D2.2/T2.4 – Tamás Kismányoky, University of Pannonia**)**

1. **ARABLE:** Farming systems according to the crop rotations highlighting the most important crops in the crop rotation.

1.1. Non irrigated arable land
   1.1.1. Cereals
   1.1.2. Maize
   1.1.3. Legumes
   1.1.4. Oil crops
   1.1.5. Fodder crops
   1.1.6. Root crops
   1.1.7. Follow

1.2. Permanently irrigated land
   1.2.1. Cereals
   1.2.2. Maize
   1.2.3. Legumes
   1.2.4. Oil crops
   1.2.5. Fodder crops
   1.2.6. Root crops
   1.2.7. Follow

2. PERMANENT CROPS

2.1. Vineyards
2.2. Fruit trees and berry plantation
2.3. Oil groves

3. PASTURES

3.1. Extensive*
3.2. Intensive*

* See definition of "extensive/intensive" below

***Extensive grazing land:** grazing on natural or semi-natural grasslands, grasslands with trees/ shrubs or open woodlands for livestock and wildlife.

***Intensive grazing/ fodder production:** improved or planted pastures for grazing/ production of fodder (for cutting and carrying: hay, leguminous species, silage etc.) not including fodder crops such as maize, cereals. These are classified as annual crops.