# Manual – V2 – 2018

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**Assessment of soil and plant quality**
**for the season 2018**

# WP5

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iSQAPER
Interactive Soil Quality Assessment

# Content

# General consideration

This manual refers to the Excel sheet entitled “SQ1_SQ2_WP5_WP6.xlsx”. The study site teams are asked to check if the plot under consideration has been selected for additional investigations in WP6 (see list in “**Annex 1”** and “A) Introduction” in the excel sheet.

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 promising 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 field where changes have occurred at least 3 years ago (**field_AMP**) with another field *without changes in AMP* (**field_control)** within the same pedo-climatic zone and under comparable farming system, soil conditions, topography, etc., serving as control. In the field_AMP, a promising AMP (**Annex 2**) was implemented to address a given soil threat or to increase soil quality in general. The field_control should reflect what existed prior to implementation of AMP (in the field_AMP).

For season 2017, it was asked to 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:

- at least two different soil types are included in the selection;
- at least two different first level FS (arable, permanent, and grazing) are considered for the selection of AMPs (see **Annex 2**).

Regarding mixed farming systems, one should consider the existence of two different farming systems on the same field 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.

To evaluate soil quality of a field in situ, a representative plot has to be selected both in the AMP- and Control-fields. These plots should represent the most important characteristics of the field under consideration with regard to the slope, soil and crop type. They should be preferably not too far away from each other. For reasons of convenience, the term **plot_AMP** refers to the AMP-field and **control** refers to the Control-field throughout this inventory.

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

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

The evaluation of soil and plant quality of both plot_AMP and the corresponding control is done using one single excel sheet. The questionnaire developed for this purpose is based principally on Visual Soil Assessment (VSA).

Fill in the first part: Farming system and continue with AMP and proceed then with SQ_WP5.

## Specifications of Farming Systems under consideration

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.

## Identification of Agricultural Management Practices (AMP)

In this part, general information on the plot and control are required such as location, area in ha, name of AMP, etc.

## Soil quality indicators (SQ_WP5)

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.

To score soil quality in the SQ_WP5 sheet, choose the corresponding condition (poor, moderate or good condition).

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

Quantitative analyses based on laboratory and field measurements in selected study sites (**Annex 1**) will be supervised by WP6 and will help to calibrate the scoring of this inventory.

## Sampling and replications

In order to characterize properly the existing conditions under both situations, we propose to consider 3 representative plots that should be selected in the field with AMP and 3 in the field without AMP serving as control. The assessment of each indicator/property should be made three times for the field_AMP and 3 times in the field_control, resulting in 6 measurements for each indicator (**Fig. 1** below).
Soil data requires an accompanying geo-referenced description.

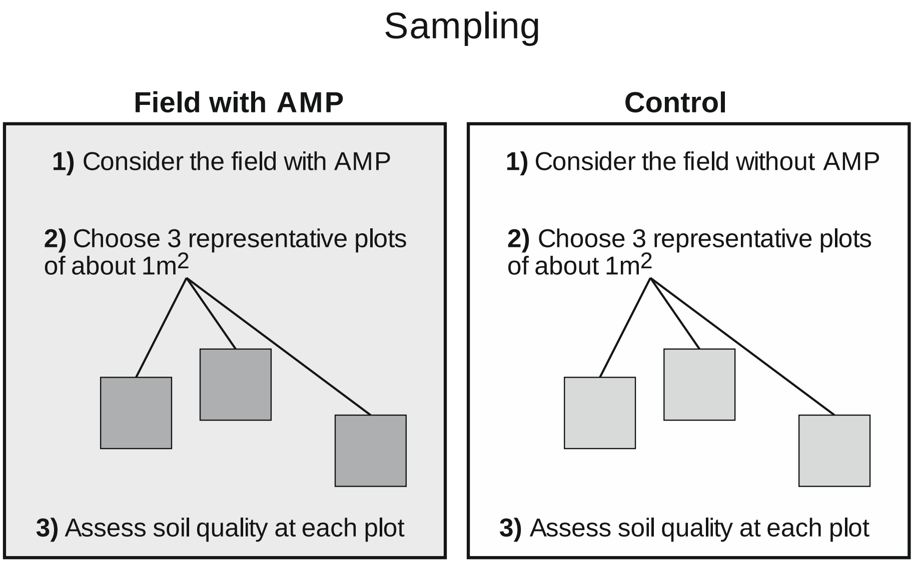



***Figure 1.*** *Sampling design for the assessment*

## Material needed for SQ_WP5

- 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 soil stability test, see **section 3**)
- Infiltrometer or penetrometer and supporting material (see **section 4**)
- A palm-sized spectrometer for example a Hach (or generic) 550nm for gauging the change in colour (the optical density) of the $KMnO_4$ (analysis of labile organic carbon, see **section 11**).

## Remarks

The assessment of all proposed indicators should be made in situ except the labile organic carbon (**section 11**) 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) in a separate field notebook.

If you choose to carry out infiltration instead of penetration resistance (**section 4A**), 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).

Texture determination is a prerequisite for the accurate determination of the scoring of labile organic carbon (**section 11**) and also for the quantitative analysis of the results obtained from the infiltration rate using additional software (**section 4A**). For this purpose, soils (volume of about 200–400 $cm^3$) of the investigated plots have to be sent to Violette Geissen (violette.geissen@wur.nl) for the texture analysis.

If you want to evaluate labile organic carbon of soil sampled at all plots at the end of your field work, you should store air dried soil samples (about 50 g of each plot) in a dry place.

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

# I. Baseline indicators

## 1. Surface ponding

***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 (**Fig. 2**).

***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*

# 2. Susceptibility to Wind and Water Erosion

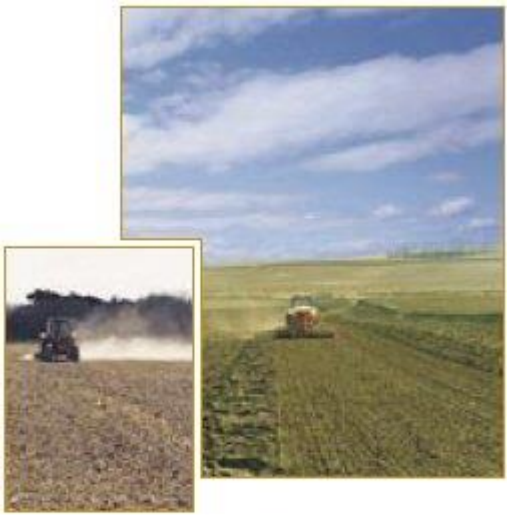
***Importance:***

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 (**Fig. 3**).
- 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.

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**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.

***Figure 3.*** *Visual Scoring of Susceptibility to Wind and Water Erosion*

# II. Soil indicators

## 1. 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 4**.

***Scoring:***

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

***Figure 4.*** *Visual Scoring of Soil Structure and Consistency*

# 2. 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**

Soils have many macropores between and within aggregates associated with good soil structure.

**Moderate condition: Score 1**

Soil macropores between and within aggregates have declined significantly but are present upon close examination of clods, showing a moderate amount of compaction.

**Poor condition: Score 0**

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*

# 3. 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 6.*** *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

# 4. Topsoil compaction

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 (**Fig. 7a**). 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 7a.*** *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 $cm^2$ using the penetrometer given in **Figure 7b**. 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 7b.*** *Proposed 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

# 5. Subsoil compaction

***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 8**.

***Scoring:***

| Good condition: Score 2 | Moderate condition: Score 1 | Poor condition: Score 0 |
| --- | --- | --- |
| No tillage pan, with a friable, clearly apparent structure and soil pores throughout the topsoil. | 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. | 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 8.*** *Visual Scoring of the Presence of a Cultivation pan*

***References:***

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

# 6. 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 9**, 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 9.*** *Visual Scoring of Soil Colour*

# 7. Number & colour of soil mottles

***Importance:***

Mottles are spots or blotches of different colour, generally grey or orange, interspersed with the dominant soil colour. The number, size and colour of soil mottles provide a good indication of how well the soil is aerated. Loss of structure reduces the number of macropores and coarse micropores that conduct air and water. With the loss of pores, oxygen in the soil is reduced and carbon dioxide builds up.

As oxygen depletion increases, orange, and ultimately grey mottles form. A high proportion of medium and coarse grey mottles indicate that the soil is waterlogged and starved of oxygen for a significant part of the year. Poor aeration and the build-up of carbon dioxide and methane reduce the uptake of water by plants and induce early wilting. Waterlogging can also reduce the uptake of nutrients, particularly nitrogen, phosphorous and potassium by wheat and maize.

Poor aeration retards the breakdown of stubble and other organic residues and can cause reactions that from chemicals that can be toxic to plant roots.

***Assessment:***

Assess the number, size and colour of mottles by comparing the side of the soil profile, or a number of soil clods from the soil structure test, with the three photographs in **Figure 10**.

***Scoring***

| **Good condition: Score 2** | **Moderate condition: Score 1** | **Poor condition: Score 0** |
|---|---|---|
| Mottles are generally absent. | Soil has common (10–25%) fine and medium orange and grey mottles. | Soil has abundant to profuse (>50%) medium and coarse orange and particularly grey mottles. |

***Figure 10.*** *Visual scoring of number and colour of soil mottles under arable cropping*

# 8. 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:***

In this method you pour a solution of mustard water on the soil allowing it to percolate down. The mustard solution irritates the skin of earthworms and they come to the surface to avoid it, where they can be collected, preserved and identified.

Preparation of the mustard solution: To make the solution, mix 2 litres of water with 20 grams ground yellow mustard seed in a container**.** This is the same powdered yellow mustard you will find in any grocery store (**Fig. 11**). You should mix up the mustard solution quite a bit to avoid its solidification on the bottom. A 2L jug of mustard solution is enough to sample a 25cm x 25 cm sample plot (see for instance Valckx et al., 2011).

Earthworm extraction:

- Choose a representative plot to sample.
- Sample the vegetation and remove the leaf litter in your sample area.
- Place the frame (25cm x 25 cm) on the ground.
- Slowly pour half of the jug of mustard water into the sample area.
- Over a period of 5 minutes, gather any worms that come to the surface being careful to wait until they are completely out of the ground
- After 5 minutes, pour the remaining mustard water into the sample area and again wait 5 minutes gathering any other worms that come to the surface.
- Have a collection tray to put them in until you're done, since they can come up in rapid succession.

See **Figure 11** for illustration.


***Figure 11.*** *Earthworms extraction (left side) and an example of yellow mustard seed (right side)*

This technique works well for all species of earthworms but only when the earthworms are active. If it has been very dry, very hot or very cold in the week(s) prior to sampling they may not respond as very well since they may be in aestivation (earthworm version of hibernation). In contrast, if air temperatures have been moderate and it has rained recently they are likely to be active and respond well to the liquid extraction. An exception – if the soil is very compacted and/or has a poor structure (heavy clay, fields, roads, etc.) the extractant doesn't move well through the soil and the earthworms will not respond because the liquid doesn't reach them.

***Scoring:***

Scoring of earthworm density should be made using **Table 1**.

***Table 1.*** *Visual scoring of Earthworms after Shepherd (2000)*

| Earthworm counts per a volume of soil of 8000 $cm^3$ | Scoring |
|---|---|
| Number > 8 | Good condition: Score 2 |
| 4 – 8 | Moderate condition: Score 1 |
| < 4 | Poor condition: Score 0 |

***References:***

Alaoui, A., Helbling, A. 2006. Evaluation of soil compaction using hydrodynamic water content variation: comparison between compacted and non-compacted soil. Geoderma 134, 97–108.

Shepherd, T.G. 2000: Visual Soil Assessment. Volume 1. Field guide for cropping and pastoral grazing on flat to rolling country. horizons.mw & Landcare Research, Palmerston North. 84p

Valckx, J., Govers, G., Hermy, M., Muys, B. Optimizing Earthworm Sampling in Ecosystems. A. Karaca (ed.), Biology of Earthworms, Soil Biology 24, DOI 10.1007/978-3-642-14636-7_2, Springer-Verlag Berlin Heidelberg

# 9. Degree of Clod Development

***Importance:***

The degree of clod development depends on many factors, including recent cultivations, water content at the time of tillage, the shear strength of clods and the quality of the soil structure. The loss of soil structure and the subsequent formation of clods reduce the quality of the soil tilth, impair seed germination and emergence and reduce crop yields and grain quality. Very cloddy soils indicate that the soil has become so degraded that it cannot maintain a fine aggregated seedbed throughout the growing season. The size, density and strength of soil clods increase with increasing loss of soil structure, so careful timing and considerable additional effort is needed to break them down to the required seedbed. This usually means that more intensive methods of cultivation and a greater number of passes are needed.

***Assessment:***

- Assess the degree of clod presence on the soil surface between rows by comparing it against the three photographs in **Figure 12**.
- Consider the amount of cultivation and time that was taken to prepare the seedbed. Some soil clods may slake during rainfall so, to be meaningful, several assessments should be made up to crop maturity.
- Note that if the seedbed is too fine, it may be at risk of slaking and therefore water erosion or ponding.

***Scoring:***

| **Good condition: Score 2** | **Moderate condition: Score 1** | **Poor condition: Score 0** |
|---|---|---|
| Good distribution of the friable, finer aggregates with no significant clods. A good seedbed is easily prepared. | Soil contains significant proportions of both coarse firm clods and friable fine aggregates. If cultivation is not carefully timed, clods slow significant tillage resistance. | Soil dominated by coarse, very firm clods with fewer finer aggregates. Clod resistance is high and the window for successful cultivation is very narrow. |

***Figure 12.*** *Visual Scoring of the Degree of Clod Development*

# 10. 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 H2O) 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 13.*** *pH values for scoring*

***References:***

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

# 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:***

1. Prepare stock solution of $CaCl_2$ (0.1 M)
2. Prepare $KMnO_4$ (0.02 M) in 0.1 M $CaCl_2$, adjust solution to pH 7.2 with 0.1M NaOH.
3. Transfer 2 ml of above solution into graduated polypropylene tube
4. Add distilled water to till 20 ml mark swirl to mix
5. Add 4.9±0.3 g (or 5 ml scoop of soil volume) of soil to the above solution [soils should be air dried in the sun for 15 mins and crumbled]
6. Wrist-Shake mixture for 2 mins and allow to stand/settle for 5 mins
7. Pipette 0.5 ml from upper 1 cm depth into another polypropylene tube and add 45 ml of distilled water
8. Make solution up to 50 ml mark with more distilled water
9. Transfer 15 ml of the above solution into a glass cuvette
10. Measure absorption (at 550 nm) with colorimeter(1)
11. Calibration: measure the absorbance of the following
    a. Distilled water filled in glass cuvette (blank) and set to zero
    b. 0.50 ml 0.005 M $KMnO_4$ to a graduated tube+ 45 ml distilled water and made to 50 ml mark and shake. Transfer 15 ml to a cuvette and measure absorbance
    c. Repeat the above procedure but with 0.01 M and 0.02 M $KMnO_4$.
    d. Make a calibration curve with absorbance (x-axis) and conc. (y-axis)
12. Determine the active labile carbon in soil using the equation of Weil et al., 2003: Labile carbon (mg/g) = [0.02 mol/l – (a+b x absorbance)] x (9000 mg C/mol) x (0.02l solution / 5 g soil).

***where a is the intercept and b is the slope of the calibration curve you have determined.***

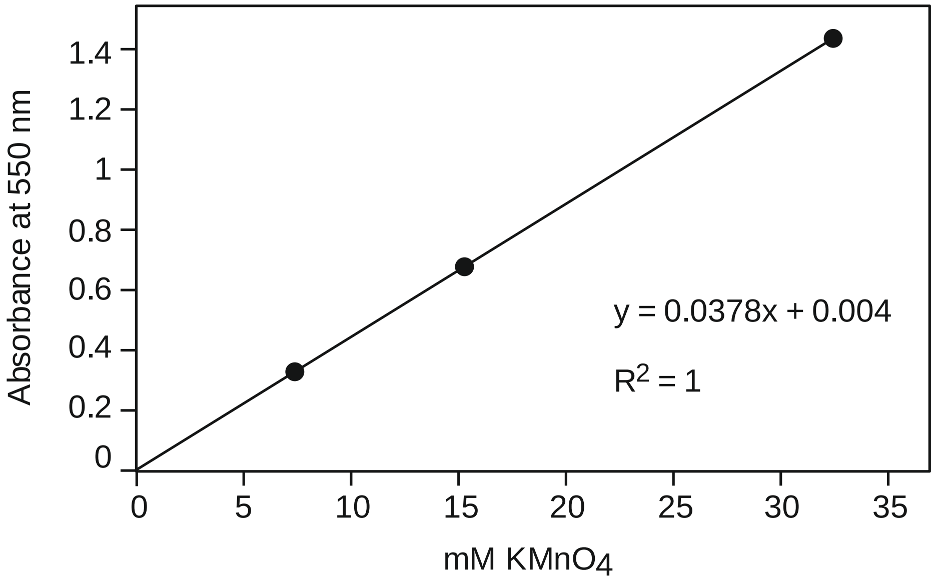


***Figure 14.*** *Example of calibration curve of four strengths of 20 mM $KMnO_4$ (x-axis) with colorimeter read-out (y-axis) (Des McGarry[2])*

***Scoring:***

***Table 2.*** *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

# III. Plant indicators

## 1. Crop Yield

***Importance:***

In agriculture, crop yield (also known as "agricultural output") refers to both the measure of the yield of a crop per unit area of land cultivation, and the seed generation of the plant itself (e.g. if three grains are harvested for each grain seeded, the resulting yield is 1:3). The figure, 1:3 is considered by agronomists as the minimum required to sustain human life. One of the three seeds must be set aside for the next planting season, the remaining two either consumed by the grower, or one for human consumption and the other for livestock feed. The higher the surplus, the more livestock can be established and maintained, thereby increasing the physical and economic well-being of the farmer and his family.

***Assessment:***

The unit by which the yield of a crop is measured is kilograms per hectare. This information should be provided by the farmer. Two questions should be addressed for this assessment.

i) Ask the farmer for the most important crop type(s) composing the crop rotation that should be considered in terms of incomes, or/and environmental impacts, they might be only one or two crops; and
ii) Comparison between the crop yield of each crop type between the situations before and after AMP implementation. This comparison may be qualitative since crop yield is affected by different conditions (e.g., weather).

We recommend completing the **Table 3**.

***Table 3.*** *Estimation of crop yield, information provided by the farmer*

| | **Crop yield (kg/ha)** | **Comparison with situation before AMP implementation** | | | |
|---|---|---|---|---|---|
| **Crop type** | Currently | Increase | stable | decrease | **Explanation** |
| Crop 1<br>Crop 2<br>Crop 3<br>Etc. | | | | | |

Crop yield can be estimated for all crops composing the crop rotation if possible, otherwise consider only the crop that is most impacted by the AMP implementation.

In the questionnaire "SQ1_SQ2_WP5_WP6_2018.xlsx" tick, you should report:
good conditions if the crop yield has increased; moderate if crop yield is stable, and poor if the crop yield has decreased.

# 2. Size & Development of the Root system

***Importance:***

Consolidation and compaction of the seedbed restricts plant growth and vigour by restricting root development, owing to increased mechanical resistance and impeded soil aeration. High mechanical resistance to roots limits plant uptake of water and nutrients, restricts the production of several plant hormones in roots, which are necessary for growth, and increases the susceptibility of the crop to lodging.

***Assessment:***

Determine the size and development of the root system, ideally when the soil is still moist by carefully removing the plant from the soil and gently shaking it to remove excess soil from the roots. Compare the root systems with the pictures in **Figure 15**.

***Scoring:***

| Good condition: Score 2 | Moderate condition: Score 1 | Poor condition: Score 0 |
|---|---|---|
| Unrestricted root development with the main large root bulb up to 25cm wide and 20-25cm deep. | The main root bulb is commonly 15cm wide and 15-18cm deep. Vertical root development is often restricted below 12cm with right-angle syndrome not uncommon. | Vertical and lateral root development is severely restricted, with root systems showing either right-angle syndrome, over thickening, or growth down coulter channels. |

***Figure 15:*** *Visual Scoring of Size and Development of Root System*

# 3. Root diseases

***Importance:***

Poor soil aeration, high levels of soil saturation and high mechanical resistance to root development due to soil structure degradation can increase root-rot and soil borne pathogens. They can also reduce the ability of root systems to overcome the harmful effects of pathogens resident in the topsoil. Plant diseases encouraged by degradation of soil structure include fusarium, pythium, phytophthoria, rhizoctonia, and vesicular-arbuscular mycorrhizal fungi (Department for Environment Food and Rural Affairs, defra).

***Assessment:***

To carry out an assessment of root diseases you will need?

i. A small spade and bucket to place the plants in
ii. A bucket of water for washing out the root systems
iii. Additional clean water for final examination
iv. A flat white tray containing water to be used for identifying and assessing root diseases
v. A magnifying glass

In order to assess/diagnose plant diseases, the following methods are used:

i. Carefully dig up 3 plants along the crop monitoring path, making sure that soil is left intact around the root system of the plant.
ii. For cereal root diseases, rate the severity of root disease identified. (insert disease cartoons) For other diseases, indicate whether or not they are present in the crop.
iii. At each collection point, visually assess the area of crop affected by the disease.
iv. Calculate an average area affected for the 10 sites observed.

Interpreting root disease assessment

Ratings of 1 or 2 for cereal root diseases' indicate that an economic yield loss is occurring. It will be necessary to review your agronomic management, in particular your selection of crop species and variety when planning future crop rotations.

***Scoring:***

Scoring should be made using **Figures 16 – 18** and related **Table 4 – 6.**

The final score to report in the excel questionnaire should be the one indicating the less good conditions. If one score (among the scores given in tables 4 to 6) indicates bad condition, please report bad condition in the excel questionnaire. You should score moderate conditions if the worse score among all score is moderate (in this case, bad conditions is not attributed in the tables 4 to 6). You should score good conditions in the excel sheet only in the case where all scores are good in the tables 4 to 6.

## *CEREAL CYST NEMATODE (CCN)*

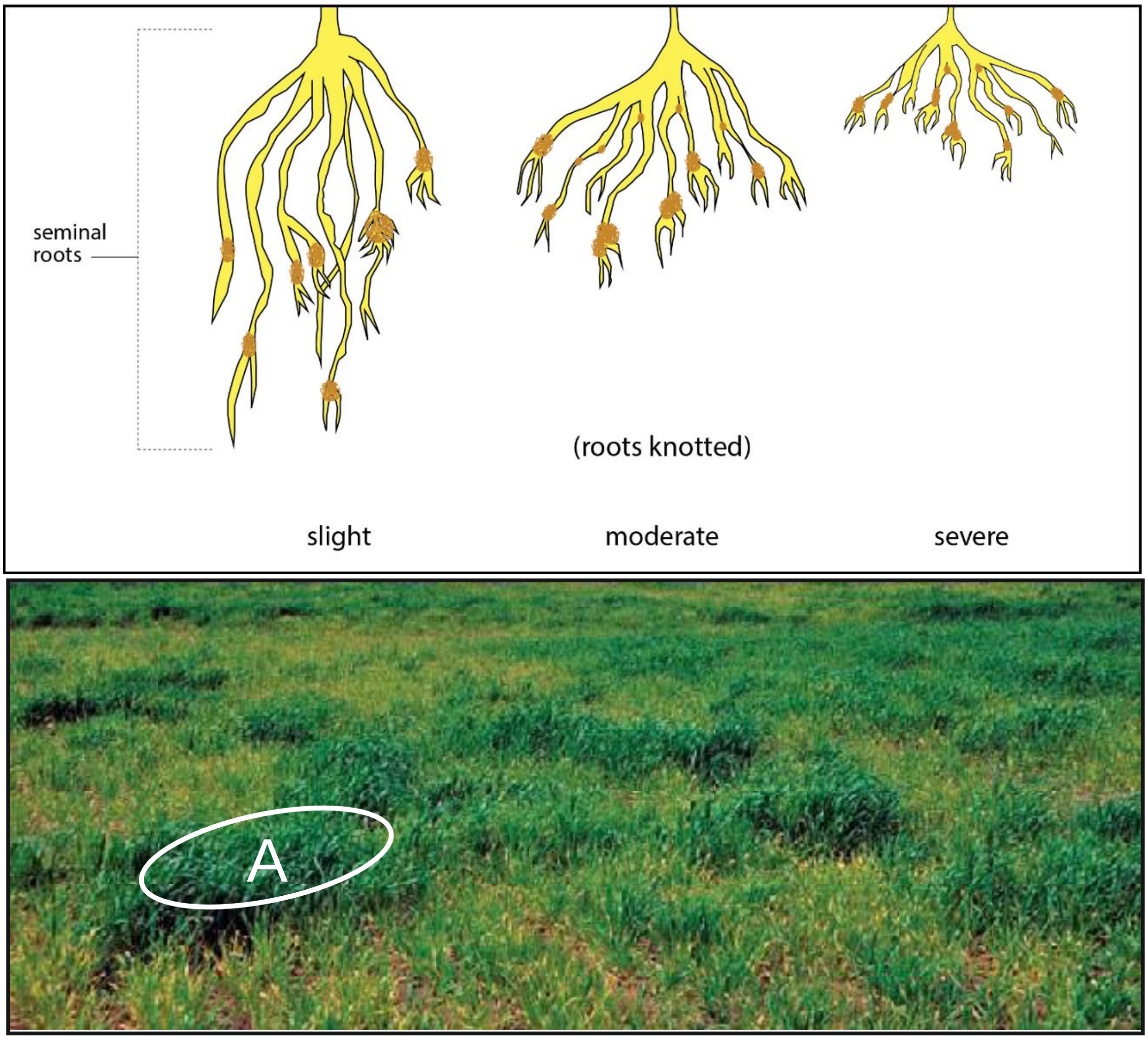


***Figure 16.*** *Root affected by cereal cyst nematode (top) (source: Department of Primary Industries and Regional Development). Scoring of the cyst nematode should refer to a healthy root located in same field (e.g. cercle A in the bottom).*

***Table 4.*** *Scoring of the* ***cyst nematode*** *assessment*

| **Cereal cyst nematode** | **Score** |
|---|---|
| Root length normal* on a severity scale of 0 - 5, rating is 0 | 0 |
| Roots are 40 % shorter than healthy roots, on a severity scale on 0 - 5 rating is between 1 - 1.5 | 1 |
| Roots are 60 % or more shorter than healthy roots, on a severity rating of 0 - 5 scoring 2 or more | 2 |

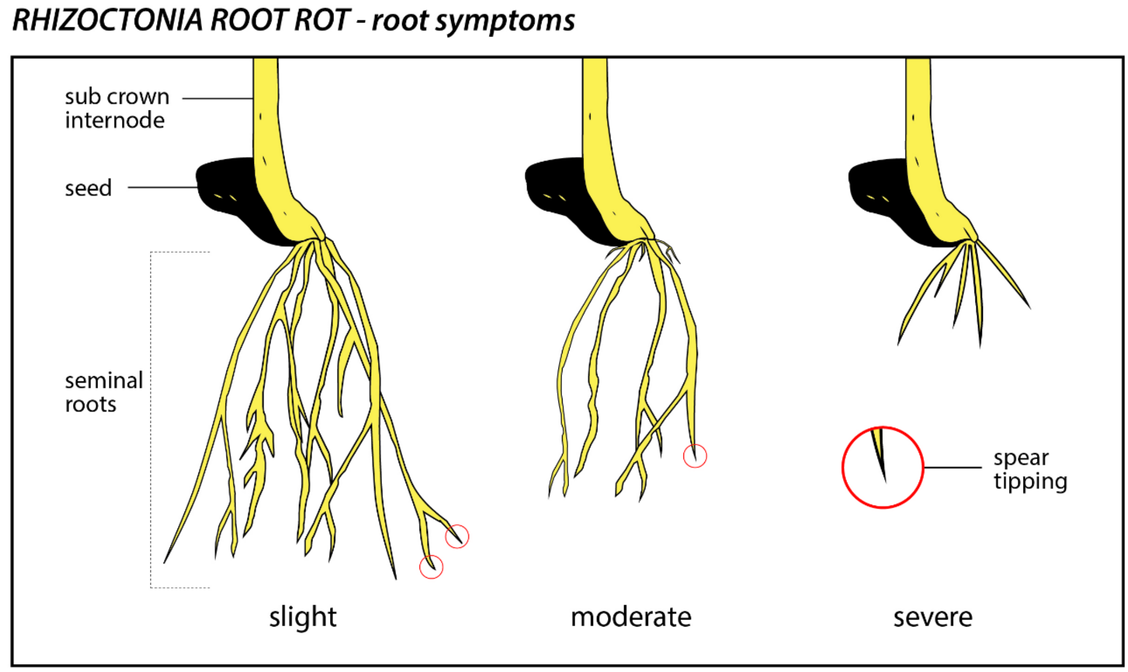


***Figure 17.*** *Roots affected by Rhizoctonia root rot*

***Table 5.*** *Scoring of the* **cyst nematode** *assessment*

| Rizoctonia | Score |
|---|---|
| No roots are shortened | 0 |
| Up to 25% of the roots are shortened | 1 |
| More than 25% of roots are shortened | 2 |

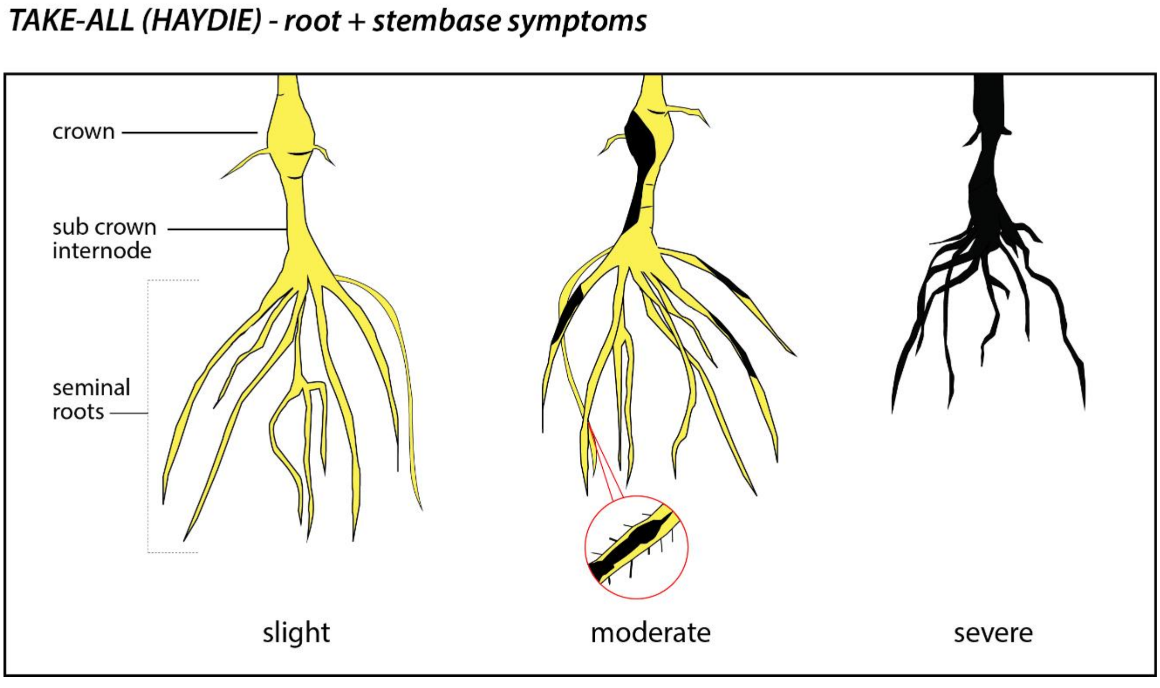


***Figure 18.*** *Roots affected by Take-all*

*Table 6. Scoring of the* **Take-all** *assessment*

| **Take-all** | **Score** |
|---|---|
| No lesion visible | 0 |
| 1 or 2 main seedling roots have lesions | 1 |
| 3 or more seedling roots have lesions | 2 |

***References:***


Department of Primary Industries and Regional Development. https://www.agric.wa.gov.au/mycrop/monitoring-root-disease

Department for Environment Food and Rural Affairs, defra. http://adlib.everysite.co.uk/adlib/defra/content.aspx?doc=202989&id=203609

# 4. Weed infestation

***Importance:***

The quality of the seedbed and the use and timing of herbicide sprays influence the level of weed infestation. Soil structural degradation reduces soil aeration and the rooting potential of the crop, allowing more vigorous weeds to establish and compete with the crop. A high weed population uses a lot of the soil moisture and nutrients otherwise available to the crop. In extreme cases, weeds can smother the crop.

***Assessment:***

Visual assessment is the most common method and useful for small areas. The example given in **Figure 19** show a cotton crop heavily infested with barnyard grass, melon and wild radish (Bayley and Brouwer, 2016). To assess the degree of weed infestation, we propose to delineate 1 m2 on soil surface and count the percentage of the degree of weed infestation using **Figure 20**.

***Figure 17.*** *An example of cotton crop heavily infested with barnyard grass, melon and wild radish*

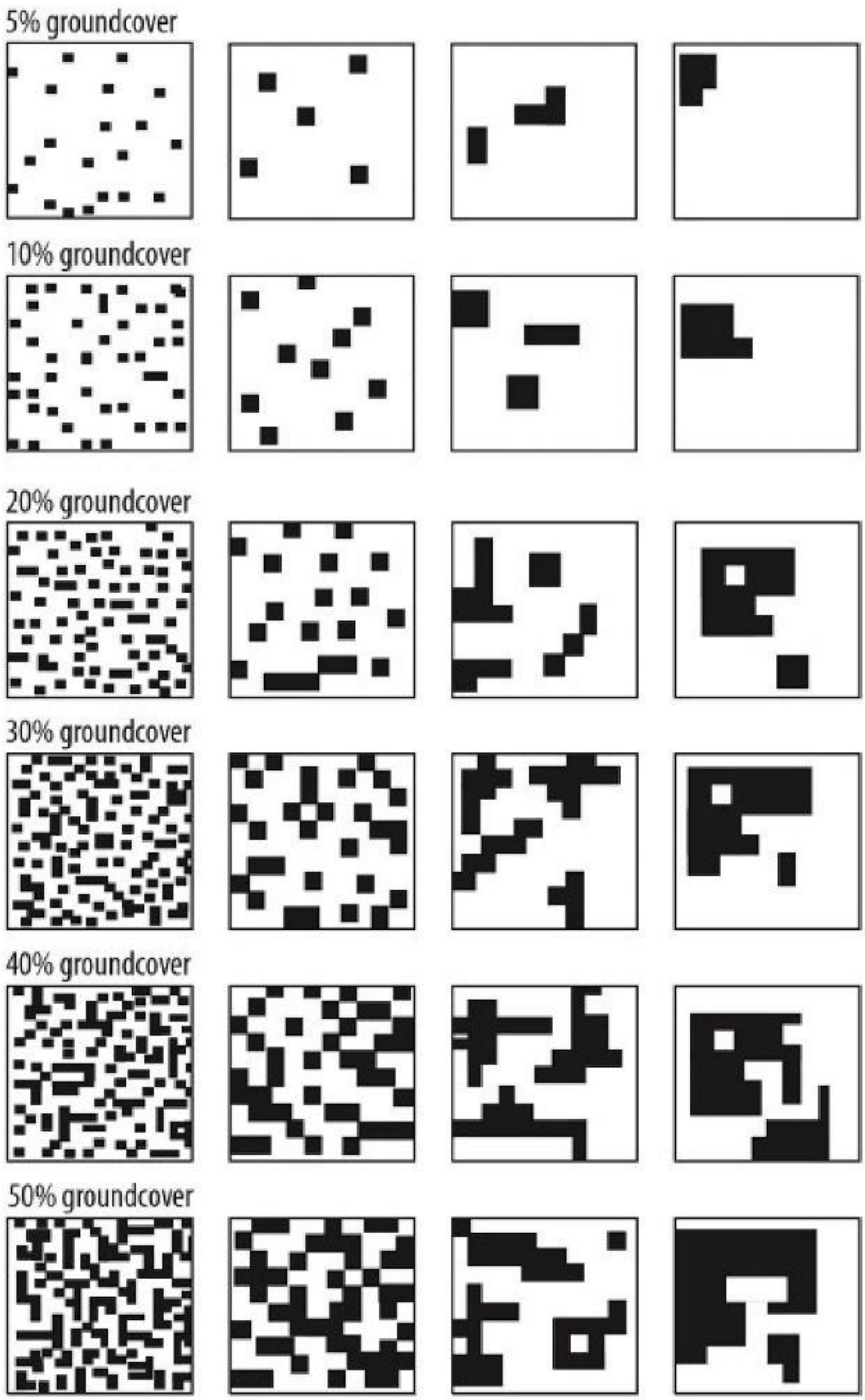


***Figure 20.*** *A guide to assess the degree of weed infestation.*

***References:***

Bayley, D., Brouwer, D. 2016. Managing Weeds: AgGuide – A Practical Handbook. Department of Primary Industries. 105 p.

# 5. Soil fauna

***Importance:***

The soil fauna includes those animals that pass one or more active stages in soil or litter; some may be temporary occupants of this habitat, most are permanent. Soil animals participate in the genesis of the habitat in which they live. They are found in all soil types and only the species composition, diversity, quantity and function of soil animals varies with changing soil types, the main groups represented, remain the same.

***Assessment:***

Method:

Soil sample should be sampled between 0 and 20 cm depth and about 1 kg of soil should be taken for the analysis.

A Tullgren funnel is an ordinary funnel into which a handful of soil or leaf litter (often soil sample is supported by a layer of mesh) is placed. The funnel is placed above a jam jar or other collecting vessel with slippery sides and with a piece of slightly moist tissue paper placed at the bottom of the jar. A light is then positioned so that it shines on the substrate within the funnel. Over a period of a few hours the insects, mites and other invertebrates present gradually work their way down, moving away from the source of light and heat, and fall into the jar where they can be examined.

Maximum extraction of soil micro fauna can be recorded after a duration of 16 to 22 hours of continuous heating at temperature ranges between 35.1oC to 35.2°C (Bano and Roy, 2016).

Classification:

Rough estimates of soil biodiversity indicate several thousand invertebrate species per site, as well as the relatively unknown levels of microbial and protozoan diversity. Soil ecosystems generally contain a large variety of animals, such as nematodes, microarthropods such as mites and Collembola, Symphyla, Chilopoda, Pauropoda, enchytraeids and earthworms. In addition, a large number of meso- and macrofauna species (mainly arthropods such as beetles, spiders, diplopods, chilopods and pseudoscorpion, as well as snails) live in the uppermost soil layers, the soil surface and the litter layer.

In general, soil invertebrates are classified according to their size in microfauna, mesofauna, macrofauna and megafauna (Wallwork, 1970; Menta, 2012).

i. Microfauna: organisms whose body size is between 20 µm and 200 µm. Just one group, protozoa, is found wholly within this category; among the others, small mites, nematodes, rotifers, tardigrades and copepod crustaceans all fall within the upper limit.

ii. Mesofauna: organisms whose body size is between 200 µm and 2 mm. Microarthropods such as mites and springtails, are the main representatives of this group, which also includes nematodes, rotifers, tardigrades, small araneidae, pseudoscorpions, opiliones, enchytraeids, insect larvae, small isopods and myriapods.

iii. Macrofauna: organisms whose size is between 2 mm and 20 mm. This category includes certain earthworms, gastropods, isopods, myriapods, some araneidae and the majority of insects.

iv. Megafauna: organisms whose size exceeds 20 mm. The members of this category include large size invertebrates (earthworms, snails, myriapods) and vertebrates (insectivores, small rodents, reptiles and amphibians).

We recommend recording number of organisms and their classification according to their size.

***Figure 21.*** *An illustration of a home-made apparatus of a Berlese funnel*

Assessment can be done using a home-made apparatus, or using Tullgren funnel purchased in a firm via internet.

***References:***

Berlese-Tullgren funnel apparatus. Installation, Operation and Maintenance Manual http://hydromech.gr/wp-content/uploads/2016/06/user-manual.pdf

Bano, R.m, Roy S. 2016. Extraction of Soil Microarthropods: A low cost Berlese-Tullgren funnels extractor. http://www.faunajournal.com/archives/2016/vol3issue2/PartA/3-1-13.pdf

Chesworth W. 2007 – NatureEncyclopedia of Soil Science - Seite 231 - Google Books-Ergebnisseite, P. 231–2 35.

Menta, C. 2012. Soil Fauna Diversity – Function, Soil Degradation, Biological Indices, Soil Restoration, In “Biodiversity Conservation and Utilization in a Diverse Word”, eds.: Gbolagade Akeem Lameed, ISBN 978-953-51-0719-4

Wallwork, J.A. 1970. Ecology of soil animals. McGraw-Hill, London.

# 6. Environmental Exposure to Pesticides (EEP)

***Importance:***

Any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest or weed is a pesticide. Pesticides can be classified according to their target, their mode or period of action, or their chemistry (Arias-Estévez et al., 2008). More than 500 different pesticide formulations are being used in our environment, mostly in agriculture (Azevedo, 1998), although the control of biological public health hazards also continues to be an important field of application. In the last 50 years, the use of pesticides has greatly increased the quantity and improved the quality of food for the growing world population. However, with increasing amounts used, concern about their adverse effects on nontarget organisms, including human beings, has also grown.

In fact, it has been estimated that less than 0.1% of the pesticide applied to crops actually reaches the target pest; the rest enters the environment gratuitously, contaminating soil, water and air, where it can poison or otherwise adversely affect nontarget organisms (Pimentel and Levitan, 1986). Furthermore, many pesticides can persist for long periods in an ecosystem—organochlorine insecticides, for instance, were still detectable in surface waters 20 years after their use had been banned (Larson et al., 1997).

Pesticides, the most cost-effective means of pest and weed control, allow the maintenance of current yields and so contribute to economic viability. Concern about the environmental impact of repeated pesticide use has prompted research into the environmental fate of these agents, which can emigrate from treated fields to air, other land and waterbodies. How long the pesticide remains in the soil depends on how strongly it is bound by soil components and how readily it is degraded. It also depends on the environmental conditions at the time of application, *e.g.*, soil water content. Pesticide use must ensure public safety and environmental protection with regards to both the chemical itself and their potentially harmful metabolites.

***Assessment:***

<u>You are asked to address the 2 following tasks:</u>

- List the pesticides, herbicides and insecticides used in the field-AMP and in the field-control during the year before the assessment (For the assessment of 2018, list the pesticides, herbicides and insecticides used during 2017) and provide rate of application. For pesticides, refer to the list given in "Pesticides_SCI_WP4.xlsx".
- Complete the excel sheet "Pesticides_SCI_WP4.xlsx" to obtain the Pesticide Soil Contamination Index (**PSCI**). Final scoring should be made using the Excel sheet "SQ1_SQ2_WP5_WP6_2018.xlsx". See the explanation below for this purpose.

The potential presence of pesticides in the environment as a result of each production activity was estimated following the approach of Wijnands (1997). Environmental exposure to pesticides (EEP) for soil, air and groundwater are calculated based on the amount of the active ingredients (AI), their vapour pressure at 20–25 °C (VP), 50% degradation time (half-life) and mobility ($K_{om}$) (Neeteson et al., 2001). The $EEP_{soil}$ per kg of commercial product consisting of various active ingredients is calculated as follows:

$$EEP_{soil}(kg.ha^{-1}.year^{-1}) = \sum_{i}^{n}\left(\%\ AI_i \times \frac{half\ life_i}{100}\right)$$

In this report, we develop an index to account for the Pesticide Soil Contamination Index (**PSCI**) which is a combination of two sub-indicators:

- Indicator on Pesticide Persistency and Movement in soil (**$PPM_{soil}$**) (Vogue, et al., 1994);
- Indicator on Soil Environmental Exposure to Pesticides (**$EEP_{soil}$**) (Wijnands, 1997).

The indicator $PPM_{soil}$ is obtained by combining two other indicators:

i. Pesticide Half-time life, and
ii. GUS or Groundwater Ubiquity Score which is an empirically derived value that related pesticide persistence (half-time) and sorption in soil (sorption coefficient, $K_{oc}$) (Vogue et al., 1994). The GUS may be used to rank pesticides for their potential to move toward groundwater according to:

$$GUS = log10(half - time) \times [4 - log10(K_{oc})]$$

Soil half-life (days), sorption coefficient ($K_{oc}$), GUS and classification of PPM for different pesticides are given in "Pesticides_SCI_WP4.xlsx" related to this report.

The **Figure 22** and **23** show the approach for the assessment of the Pesticide Soil Contamination Index (**PSCI**).

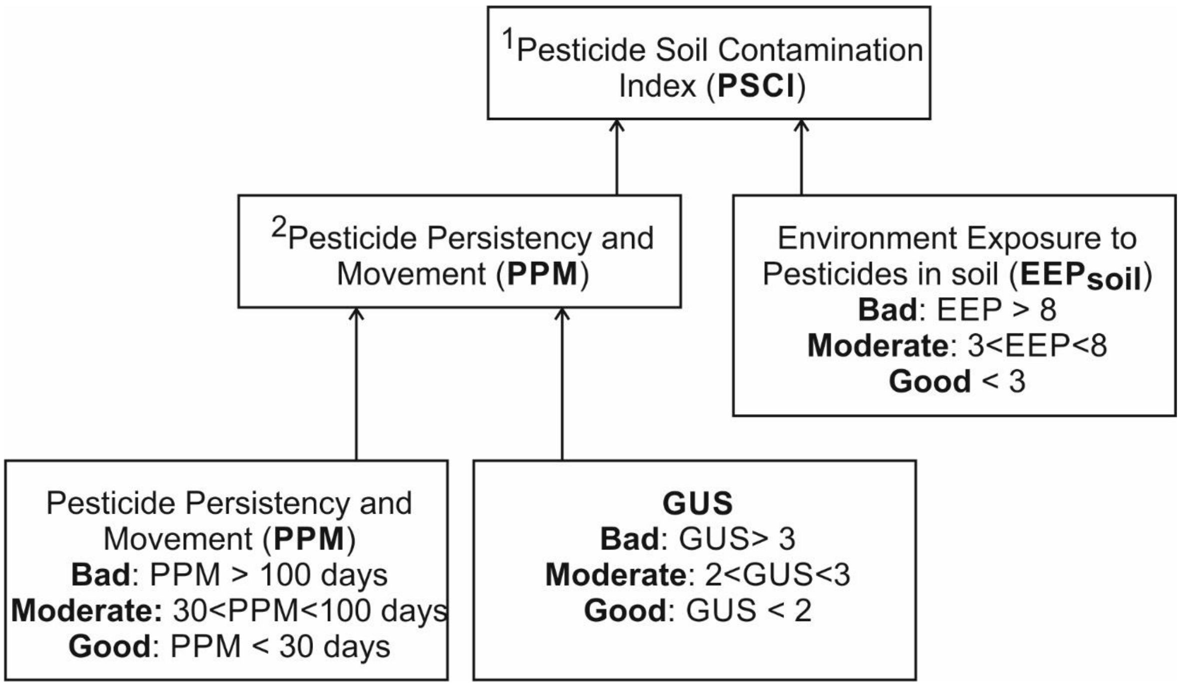


***Figure 22.*** *Approach for the assessment of the Pesticide Soil Contamination Index (**PSCI**); (1) and (2) result from combination of two different indicators.*

*Information provided by the farmer*

| | ***Pesticide*** | ***Application rate (kg/ha.year)*** | ***Application rate (%)*** | ***Soil Half - life(days)*** | ***Sorption Coefficient (soil Koc)*** | ***GUS*** | ***Pesticide persistence and movement (PPM)*** | ***Environmental Exposure to Pesticides (EEP)*** |
|---|---|---|---|---|---|---|---|---|
| 1) | 1,2-Dichloropropane (2) | 2 | 29% | 700 | 50 | 1.0 | Bad | Bad |
| 2) | 1,3-Dichloropropene | 2 | 29% | 32 | 32 | 1.0 | Moderate | Bad |
| 3) | 1-Naphthaleneacetamide | 3 | 43% | 10 | 100 | 1.0 | Good | Moderate |
| | **Do not change-->** | **7** | **100%** | | | | | |
| | | | | | | | Moderate | Bad |
| | | | | | | | 3 | |
| | | | | ***Pesticide contamination index:*** | | | **Bad** | |

***Figure 23.*** *Excel application (Pesticides_SCI_WP4.xlsx) developed for the assessment of Pesticide Soil Contamination Index (PSCI); the index can be calculated in the case of one pesticide (1), two pesticides (2), or three pesticides used together in same field (example in this figure).*

Each indicator will be ranked as “Bad”, “Moderate”, and “Good”. We adopt a conservative approach to classify the PSCI when mixing EEP and PPM meaning that the index is scored as “Good” only if both EEP and PPM have individually “Good” classification. When 2 or more pesticides are used together in same field, we adopt additional approach to account for the final classification of each indicator (assuming x = Bad, y = Moderate, and z = Good):

- In the case of 1 pesticides (row 1) in **Figure 23**), the score PSCI resulting from PPM and EEP is calculated as follows:
  - x + x → x (also for : y + y → y; z + z → z)
  - x + y → x, in the case of two different indicator, we take the worse.
- In the case of 2 pesticides (row 2) in **Figure 23**), similar principle as above will be adopted for each step.
- In the case of 3 pesticides used together in same field, we adopt the following principle:
  - Two similar indicators determine the final indicator: x + x + y → x; y + y + z → y, etc.
  - In the case of three different indicators (row 3) in **Figure 23**), the final score will be y (Moderate): example: x + y + z → y)

*References:*

Azevedo, A.S.O.N., 1998. Assessment and simulation of atrazine as influenced by drainage and irrigation. An interface between RZWQM and ArcView GIS. Doctor Thesis. Iowa State University, Ames, Iowa.

Larson, S.J., Capel, P.D., Majewski, M.S.1997. Pesticides in surface waters—distribution, trends, and governing factors R.J. Gilliom (Ed.), Series of Pesticides in Hydrologic System, vol. 3, Ann Arbor Press, Chelsea, Michigan.

Arias-Estévez, M., López-Periago, E., Martínez-Carballo, E., Simal-Gándara, J., Mejuto, J.C., García-Río, L. 2008. The mobility and degradation of pesticides in soils and the pollution of groundwater resources. Agriculture, Ecosystems & Environment, 123, (4), 247-260, https://doi.org/10.1016/j.agee.2007.07.011.

Pimentel, D., Levitan, L. 1986. Pesticides: amounts applied and amounts reaching pests. Bioscience, 36 (1986), pp. 86-91

Neeteson, J., Booij, R., Van Dijk, W., De Haan, J., Pronk, A., Brinks, H., Dekker, P., Langeveld, H. 2001. Projectplan 'Telen met toekomst'. (Publicatie No. 2, June 2001). Lelystad, The Netherland: PPO. B.V., Wageningen-UR.

Vogue, P.A., Kerle, E.A., Jenkins, J.J. 1994. OSU Extension Pesticides Properties Database. npic, National Pesticides Information Center. http://npic.orst.edu/ingred/ppdmove.htm

Wijnands, F.G. 1997. Integrated crop protection and environment exposure to pesticides: methods to reduce use and impact of pesticides in arable farming. European Journal of Agronomy 7, 251-260.

# **Annex 1** – Selected Study Sites for testing (WP5 & WP6)

**All 24 pairs of AMP-Control plots to assessed in 2018 under WP6, based on the "Guide for SQ assessment for WP6"**

Green cell background: AMP test-plots initially selected by Lúcia!

n.k. = not known

medium blue cell background: new selection by (Lúcia), Gottlieb and J.K. at 14.12.2017 and later

violet cell background: CSS2 France has totally new numbers, not used by Lucia; see below, explanations to CSS2 France!

| CSS | Plot No. Lucia (latest) | Farm identification (old version) | Plot. No. iSQAPER new | AMP No. | AMP: Agricultural management practice | Soil Type | Farming System | Name of the farmer | Latitude (J.K. 2) | Longitude (J.K. 2) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 Netherlands | **1.1** | 1. Vredepeel | **1-1 AMP** | 2 | min-till | antroposol/gleyic **podsol**; sand to sandy loam with an organic matter content of approx 4%. | irrigated land with arable and vegetable crops | Mark Kroonen | **51,539481°** | **5,848589°** |
| | **Control** | | **1-1 Control** | / | CONVENTIONAL TILL | | | | **51,539474°** | **5,848187°** |
| | **1.3** | 3. Vredepeel | **1-3 AMP** | 12 | organic agriculture | antroposol/gleyic podsol; sand to sandy loam with an organic matter content of approx 4%. | irrigated land with arable and vegetable crops | Mark Kroonen | **51,543047°** | **5,849341°** |
| | **Control** | | **1-3 Control** | / | CONVENTIONAL AGRICULTURE | | | | **51,539442°** | **5,846824°** |
| 2 France | **2.2 AMP1 b** | n.k. | **2-1 AMP b** | 1; 9 | No till | Cambisol | 1.1.2 | Gonzague Jouzel | **48,001360°** | **-1,449080°** |
| | **2.3 Control 1** | | **2-1 Control** | / | conventionnal till | Cambisol | 1.1.2 | Jérôme Lemesle | **48,070890°** | **-1,109390°** |
| | **2.7 Control 3 a** | n.k. | **2-3 Control a** | / | Temporary pasture | Cambisol | 3.2 | Jean Pierre Lemesle, Fayel site | **48,068390°** | **-1,105920°** |
| | **2.9 AMP3** | | **2-3 AMP** | 18 | Permanente Pasture | Cambisol | 3.2 | Gaec de la Branchette | **48,068970°** | **-1,108080°** |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 3 Portugal | **3.2** | 2. Frederíco | **3-2 AMP** | 8 | Mulching (sluge from domestic wastewater treatment plant) | Fluvisols | Arable land: Maize | Frederico Inácio | **Plot coordinates for CSS3 are still missingand doubtful!** | |
| | **Control** | | **3-2 Control** | / | Control | Fluvisols | Arable land: Maize | ESAC (Vagem Grande) | | |
| | **3.7** | 7. Horta - António | **3-7 AMP** | 13 | Water diversion and drainage | Cambissols | Permanent crops: vineyards | Horta (Horácio Cruz) | | |
| | **Control** | | **3-7 Control** | / | Control | Cambissols | Permanent crops: vineyards | Horta (António Ferreira) | | |
| 4 Spain | **4.5** | Site 9 | **4-5 AMP** | 2; 3 | Min tillage/ permanent soil cover | Regosol | Permanent | Fernando Antón (ELX) | **38,164218°** | **-0,712572°** |
| | **Control** | | **4-5 Control** | / | Intensive tillage /Soil not covered | Regosol | Permanent | n.b. | **38,190709°** | **-0,687498°** |
| | **4.12** | Site 23 | **4-12 AMP** | 9; 7 | Rotation crop / manuring | Cambisol | Arable permanently irrigated | Antonio Oliver (PILAR HORADADA) | **37,854892°** | **-0,831659°** |
| | **Control** | | **4-12 Control** | / | inorganic fertilization Monoculture | Cambisol | Arable permanently irrigated | n.b. | **37,853980°** | **-0,831980°** |
| 5 Greece | **5.9** | Crete-17 | **5-9 AMP** | 1 | No till | Regosol | Permanent crops | Kounalaki Ekaterine (Her) | **35,320803°** | **25,236560°** |
| | **Control** | | **5-9 Control** | / | Intensive till (control) | Regosol | Permanent crops | Diakaki-Kerouli Vasilia | **35,321462°** | **25,236689°** |
| | **5.12** | Crete-24 | **5-12 AMP** | 18 | Intensive grazing | Cambisol | Pastures | Bretsos Manolis | **35,295923°** | **24,907333°** |
| | **Control** | | **5-12 Control** | / | Intensive grazing (control) | Cambisol | Pastures | Bretsos Manolis | **35,296190°** | **24,907585°** |
| 6 Slovenia | **6.9** | Anton ČEMAŽAR, 17 | **6-9 AMP** | 9 | Crop rotation | Cambisol | Non irrigated arable land | Čemažar Anton | **46,093771°** | **14,495881°** |
| | **Control** | | **6-9 Control** | / | Crop rotation | Cambisol | Non irrigated arable land - control | Pavel Zatler | **46,093537°** | **14,495542°** |
| | **6.12** | Janez KOŽELJ, 23 | **6-12 AMP** | 18 | Change of land use practice | Cambisol | pastures | Janez Koželj | **46,124762°** | **14,495882°** |
| | **Control** | | **6-12 Control** | / | Change of land use practice | Cambisol | pastures - control | Janez Koželj | **46,124491°** | **14,497139°** |

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|---|---|---|---|---|---|---|---|---|---|---|
| 7 Hungary | **7.1** | Badacsonyi Kutató | **Still to be defined!** | | | | | | **Plot identificaton CSS7 is not safe!** | |
| | | | | | | | | | **Plot coordinates are still missing** | |
| | **7.5** | Baki Agrocentrum | | | | | | | | |
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| 8 Romania | **8.8** | Movila Miresii - farmer 8 | **8-8 AMP** | 14 | Irrigation management | Chernozems | Non irrigated arable land | Movila Miresii | | |
| | **Control** | | **8-8 Control** | / | Control | n.b. | n.b. | Movila Miresii | | |
| | **8.11** | Silistea - farmer 11 | **8-11 AMP** | 18 | Intensity level of grazing | Chernozems | Pastures extensive | Silistea | | |
| | **Control** | | **8-11 Control** | / | Control | n.b. | n.b. | Silistea | | |
| 9 Poland | **9.1** | 1-Jerzy Kłopotek | **9-1 AMP** | 7 | With substrate after mushrooms production - maize | Podzols | Non irrigated arable land | Jerzy Klopotek | **51,993824°** | **22,550696°** |
| | **Control** | | **9-1 Control** | / | Without substrate after mushrooms production - cereals | Podzols | Non irrigated arable land | Jerzy Klopotek | **51,996773°** | **22,547874°** |
| | **9.3** | 3-Sebastian Podstawka | **9-3 AMP** | 12 | Organic acriculture - hops | Cambisols | Permanent crops | Sebastian Podstawka | **51,313861°** | **22,450944°** |
| | **Control** | | **9-3 Control** | / | Conventional agriculture - hops | Cambisols | Permanent crops | Sebastian Podstawka | **51,302610°** | **22,422940°** |
| 10 Estonia | **10.13** | 13-Rannu Seeme | **Still to be defined!** | | | | | | **Plot identificaton CSS10 is not safe!** | |
| | | | | | | | | | **Plot coordinates are still missing** | |
| | **10.14** | 14-Soone | | | | | | | | |
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| 11 China - | **11.4** | Puyang Liu | **11-4 AMP** | 6, 7a | Green manure; Manuring & composting and Irrigation management | Acrisols | Permanent crops | Puyang Liu | **Plot identificaton CSS11 is not safe!** | |

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| Qiyang | **Control** | | **11-4 Control** | / | Extensive management | Acrisols | Permanent crops | Wuyuan Zhou | **Plot coordinates are still missing** | |
| 12 China - Suining | **12.1** | 1-Chaosheng Deng (2 replicates) | **12-1 AMP** | 8 | Return maize straw | Plaggic Anthrosols (Eutric) | Maize-Wheat rotation | Chaosheng Deng | **Plot identificaton CSS12 is not safe!** | |
| | **Control** | | **12-1 Control** | / | Only cominbed chemical N,P,K fertilizers | Plaggic Anthrosols (Eutric) | Maize-Wheat rotation | Chaosheng Deng | **Plot coordinates are still missing** | |
| 14 China - Gongzhuling | **14.1** | Zhenjun Li | **14-1 AMP** | 8 | Residue maintenance/Mulching | Phaeozems | Non irrigated arable land | Zhenjun Li | **Plot identificaton CSS14 is not safe!** | |
| | **Control** | | **14-1 Control** | / | Remove straw | Phaeozems | Non irrigated arable land | Libo Wang | **Plot coordinates are still missing** | |
| | **14.4** | Baijun Xu | **14-4 AMP** | 8; 14 (?) | Residue maintenance/Mulching and Irrigation management | Chernozem | Irrigated arable land | Baijun Xu | | |
| | **Control** | | **14-4 Control** | / | Conventional tillage and irrigation | Chernozem | Irrigated arable land | Fu wang | | |

## **Annex 2 –** Promising Agricultural Management Practices (AMP)

| N. | List / Identification | Description | Expected impacts / Ecological benefits |
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| 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<br>• reduced tillage depth<br>• strip tillage<br>• mulch tillage<br>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.<br><br>(*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.<br>• 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.<br>• Increases humus formation.<br>• Reduces the impact of rain drops on soil surface resulting in reduced crusting and surface sealing.<br>• Reduces runoff and erosion.<br>• Reduces wind erosion.<br>• Increases soil regeneration.<br>• Mitigates temperature variations on and in the soil.<br>• Improves the conditions for the development of roots and seedling growth. |
| 4 | Cover crops | a. Cover cropping: planting close-growing crops (usually annual legumes),<br>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.<br>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.<br>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.<br>Attracts more beneficial insects, especially when flowering crops are included in the cropping system.<br>c. Protects soil against the impacts of raindrops or wind and keeps soil |

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| | | | 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.<br><br>*(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).<br>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.<br><br>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.<br>• Reduces wind erosion.<br>• Maintains or improves soil organic matter content.<br>• Conserves soil moisture.<br>• Provides food and escapes cover for wildlife. |

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| 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<br>b. Diversify species in rotation systems or grasslands | a. Reduces risk of pest and weed infestations.<br>Improves distribution of channels or biopores created by diverse roots (various forms, sizes and depths).<br>Improved distribution of water and nutrients through the soil profile.<br>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.<br>Increases nitrogen fixation through certain plant-soil biota symbionts and improved balance of N/P/K from both organic and mineral sources.<br>Increases humus formation.<br>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.<br>b) Growing deep rooted plants in the rotation such as: annual alfalfa, beet, sunflower, okra, flax, turnip.<br>c) Controlled traffic farming: is a system which confines all machinery loads to the least possible area of permanent traffic lanes<br>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<br><br>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. |

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| | | 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.<br>Reduces soil loss, soil crusting/sealing, soil compaction, and invasive alien species. |
| 19 | Plastic | | |

## **Annex 3 –** 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.