



## **D2.3. BASELINE ASSESSMENT OF MAIN SOIL PHYSICAL, CHEMICAL, AND BIOLOGICAL PROPERTIES**

**Lead Beneficiary: Università Cattolica del Sacro Cuore (UCSC)**

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## DOCUMENT INFORMATION

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| <b>Grant Agreement</b>         |                                                                                                                                                                                                                                                 |
| <b>Project title</b>           | Sustainable innovations for Regenerative Agriculture in the Mediterranean area                                                                                                                                                                  |
| <b>Project acronym</b>         | SIRAM                                                                                                                                                                                                                                           |
| <b>Project coordinator</b>     | Edoardo Puglisi, UCSC                                                                                                                                                                                                                           |
| <b>Project duration</b>        | 1 June 2022 – 31 May 2025 (36 months)                                                                                                                                                                                                           |
| <b>Related work packages</b>   | WP4 - Formulation and tailoring of regenerative agriculture solutions for different Mediterranean scenarios                                                                                                                                     |
| <b>Related task(s)</b>         | T2.2: Assessing initial soil properties and setup of regenerative agriculture solutions.<br>T4.1: Regenerative agroecosystem management.<br>T4.2: Monitoring of soil, plant and microbial indicators.<br>T6.3: Training programme and workshops |
| <b>Lead organisation</b>       | UCSC                                                                                                                                                                                                                                            |
| <b>Contributing partner(s)</b> | IRTA, ARC, UC, CRRA                                                                                                                                                                                                                             |
| <b>Due date</b>                | 30 November 2023                                                                                                                                                                                                                                |
| <b>Submission date</b>         | 30 November 2023                                                                                                                                                                                                                                |
| <b>Dissemination level</b>     | Public                                                                                                                                                                                                                                          |

## EXECUTIVE SUMMARY

The present deliverable (D2.3) reports the initial analytical assessment of soil, down to max 0.4 m, for all experimental sites. Key soil physical, chemical, and biological properties for each field experiment have been investigated in the first 18 months of the project. Assessing initial soil conditions are key for selecting the proper Regenerative Agriculture practices to be introduced into experimental treatments in comparison with the traditional land management schemes.

## **1. Description of methods used for baseline soil assessment.**

### **1. Texture (Sedimentation Analysis):**

This method involves separating soil particles based on their size through sedimentation. By suspending soil in water and allowing it to settle, particles settle at different rates, allowing the determination of the soil texture, typically categorized as sand, silt, and clay.

### **2. pH (Potentiometric Determination in H<sub>2</sub>O and/or KCl/CaCl<sub>2</sub>):**

pH measurement is conducted to determine the acidity or alkalinity of the soil. This method measures the concentration of hydrogen ions in the soil solution. Measurements can be made in water (H<sub>2</sub>O) or solutions like potassium chloride (KCl) or calcium chloride (CaCl<sub>2</sub>) to determine exchangeable acidity.

### **3. Organic Carbon Content (Wet Oxidation with Potassium Dichromate – Walkley and Black):**

This method involves wet oxidation of soil organic matter using potassium dichromate. The Walkley and Black method provides an estimate of the organic carbon content in the soil, offering insights into soil fertility and microbial activity.

### **4. Total Nitrogen (Kjeldahl):**

Kjeldahl method is used to determine the total nitrogen content in soil. It involves digesting the soil sample with concentrated sulfuric acid, converting nitrogen to ammonium sulfate, and then quantifying the nitrogen content.

### **5. Total Nitrogen (Dry Combustion with Elemental Analyser - Dumas):**

This method involves the dry combustion of soil samples using an elemental analyser (such as the Dumas method). The organic nitrogen in the sample is converted into nitrogen gas, which is then quantified. This provides a measure of the total nitrogen content in the soil, including both organic and inorganic forms.

### **6. Available Phosphorous (Olsen with Bicarbonate 0.5 M and pH 8.5):**

The Olsen method extracts available phosphorous by treating soil with bicarbonate at a specific pH (8.5). It provides an indication of phosphorous that is readily available to plants, influencing root development and flowering.

### **7. Exchangeable Potassium (Ba Chloride, pH 8.1):**

This method uses barium chloride at a specific pH (8.1) to extract exchangeable potassium from the soil. It measures the amount of potassium readily available for plant uptake.

### **8. Exchangeable Potassium (Ammonium Acetate, pH 7.0):**

This method uses ammonium acetate at a specific pH (7.0) to extract exchangeable potassium from the soil. The extracted potassium represents the fraction readily available for plant uptake.

### **9. Cation Exchange Capacity (Ba Chloride, pH 8.1):**

Cation exchange capacity (CEC) is determined using barium chloride at pH 8.1. CEC reflects the soil's ability to retain and exchange essential nutrients, such as calcium, magnesium, and potassium.

### **10. Bulk Density (Cylindrical Core Method):**

Bulk density is measured by taking cylindrical core samples of the soil. The mass of the soil core is divided by its volume to determine bulk density, providing information about soil compaction and porosity.

11. **Electrical Conductivity (Electrical Resistance of a 1:2 Soil:Water Suspension):**

This method measures the electrical conductivity of a soil-water suspension, providing information about the soil's salinity. High electrical conductivity may indicate elevated salt levels in the soil.

12. **Organic Carbon Granulodensimetric Fractions (AFNOR):**

This method assesses the distribution of organic carbon among different particle size fractions. It provides insights into how organic carbon is distributed across different soil particle sizes.

11. **Water Holding Capacity (Richard Plates):**

Water holding capacity is determined using Richard plates. This method measures the amount of water retained by the soil under specific conditions, assessing the soil's ability to retain water for plant use.

## 2. Overview of case studies in SIRAM (Sustainable Innovations for Regenerative Agriculture in the Mediterranean Area) project and tested pillars

Case studies (CSs) in SIRAM have been selected to represent a range of pedo-climatic, ecological, and social areas across the Mediterranean region. In each CS, at least 2 SIRAM pillars (i.e., beneficial microorganisms, crop varieties, agronomical practices, and waste biomasses) have been selected to be tested, as depicted in Figure 1, where the modular use of the logo colours gives an immediate glance of the plan.

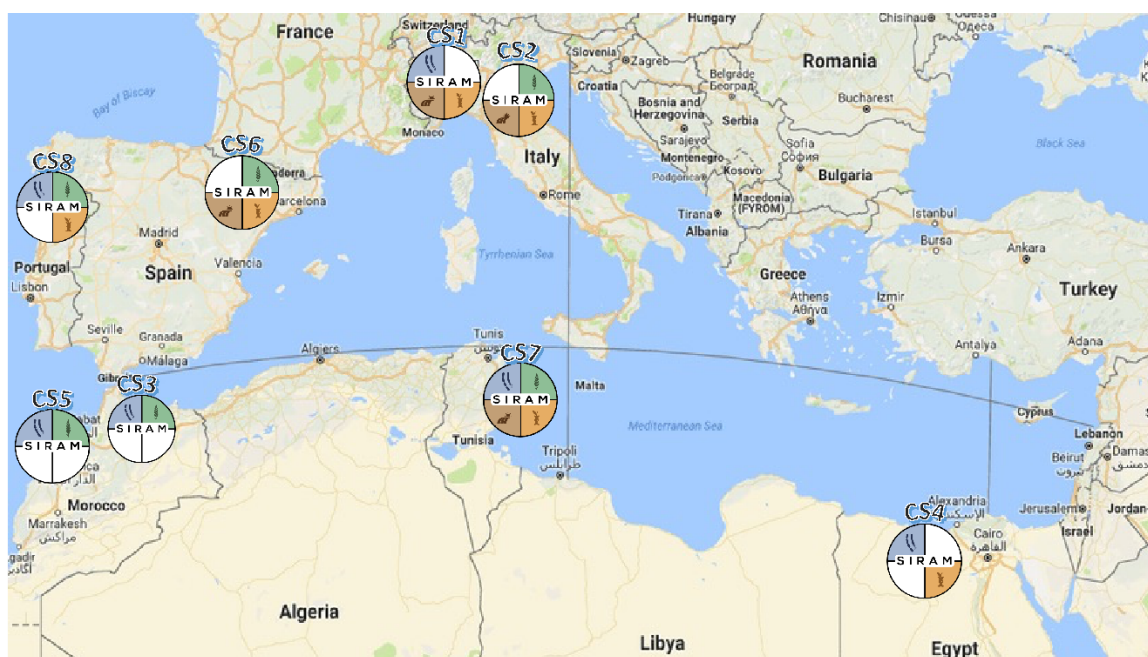


**Figure 1.** Geographical distribution of the 8 SIRAM Mediterranean case studies. Each CS location is marked by the SIRAM logo, with highlighted the pillars being implemented.

Selected method to analyse main physico-chemical soil properties at the beginning of the experiments and regenerative agriculture practices applied within each CS involved in the task are described in detail below.

*SIRAM Pillars legend: A=Agronomical practices, B=biomasses, M=Microorganisms, R=Resistant varieties.*

### 3. Summary of main soil physical, chemical, and biological properties in SIRAM (Sustainable Innovations for Regenerative Agriculture in the Mediterranean Area) project

#### 3.1 Case Study 1: Emilia-Romagna, Italy. Regenerative forage farming and slurry use (lead: UCSC), 3 SIRAM pillars (A, B, M)



Activities in CS1 started in October 2022 and are focused on the following aspects: (1) adoption of Regenerative agriculture practices (i.e., no-till plus cover crops) and beneficial microorganisms to enhance soil quality and functioning; (2) assessment of positive interactions between manure and beneficial microorganisms to increase efficiency of fertilization strategies.



Main soil properties of the field experiment that have been being determined in CS1, including methods used, are provided below:

- o **Texture** (Sedimentation analysis): Silty-clay (sand 122 g kg<sup>-1</sup>; silt 461 g kg<sup>-1</sup>; clay 417 g kg<sup>-1</sup>);
- o **pH** (Potentiometric determination in H<sub>2</sub>O and/or KCl/CaCl<sub>2</sub>): 6.8 in H<sub>2</sub>O and 5.6 in KCl
- o **Organic Carbon content** (Wet oxidation with potassium dichromate – Walkley and Black): 13.4 g kg<sup>-1</sup>
- o **Total Nitrogen** (Kjeldahl): 1.21 g kg<sup>-1</sup>
- o **Available Phosphorous** (Olsen with bicarbonate 0.5 M and pH 8.5): 32 mg kg<sup>-1</sup>
- o **Exchangeable Potassium** (Ba chloride, pH 8.1): 294 mg kg<sup>-1</sup>
- o **Cation exchange capacity** (Ba chloride, pH 8.1): 30 cmol<sup>+</sup> g<sup>-1</sup>
- o **Bulk density** (Cylindrical core method): 1.28 g cm<sup>-3</sup>

A brief qualitative description of the soil, based on the measured soil variables, is provided below:

#### **Texture:**

The sedimentation analysis reveals a predominantly silty-clay texture, indicating a mixture with higher proportions of silt and clay particles compared to sand. Although there is some sand present, this suggests a less balanced mixture, with a greater representation of finer particles in the soil composition.

#### **pH:**

The pH of the soil varied depending on the solution used for measurement. In H<sub>2</sub>O, the pH is 6.8, indicating neutral condition. In KCl, the pH is slightly lower at 5.6, suggesting a mild acidity when exchangeable acidity was considered. These pH values can influence nutrient availability and microbial activity in the soil.

#### **Organic Carbon Content:**

The soil shows a moderate-high content of organic matter, as indicated by the organic carbon content of 13.4 g kg<sup>-1</sup>. This abundance of organic carbon contributes to soil fertility, water retention, and overall soil structure.

**Total Nitrogen:**

The total nitrogen content is measured at  $1.21 \text{ g kg}^{-1}$ , suggesting a moderate nitrogen level in the soil. Nitrogen is a crucial element for plant growth and development, and its availability in the soil is vital for supporting plant nutrition.

**Available Phosphorous:**

The soil shows a moderate availability of phosphorous with  $32 \text{ mg kg}^{-1}$ , as determined by the Olsen method with bicarbonate at pH 8.5. Phosphorous is essential for root development, flowering, and fruiting in plants.

**Exchangeable Potassium:**

The exchangeable potassium content is relatively high, measuring at  $294 \text{ mg kg}^{-1}$ . Potassium is a key nutrient that plays a crucial role in various physiological processes within plants, such as water uptake and enzyme activation.

**Cation Exchange Capacity:**

The cation exchange capacity, measured at  $30 \text{ cmol}^+ \text{ g}^{-1}$ , indicates the soil's ability to retain and exchange essential nutrients for plant growth. A higher CEC value suggests better nutrient-holding capacity.

**Bulk Density:**

The soil exhibits a moderate bulk density of  $1.28 \text{ g cm}^{-3}$ , determined using the cylindrical core method. This density indicates a well-structured soil with a good balance between pore spaces and solid particles, promoting water movement and root penetration.

In summary, the soil is characterized by its silty-clay texture, slightly acidic to neutral pH, moderately rich organic carbon content, moderate levels of nitrogen and phosphorous, high exchangeable potassium, and a balanced bulk density.

### 3.2 Case Study 2: Lombardia, Italy. Boosting organic farming *via* regenerative agriculture (lead: UCSC), 3 SIRAM pillars (A, B)



In this case study, experimental activities (started in August 2022) aim to assess the increased soil fertility and crop productivity under cover crop treatments (especially for legumes as cover crops), as well as the lower N<sub>2</sub>O emissions and weed presence (especially for grasses as cover crops). Novel indicators of soil microbiological quality, based on the analyses of functional genes involved in nutrient cycling and in plant-growth promoting traits, are being developed.



Main soil properties that have been being determined in CS2, including methods used, are provided below:

- o **Texture** (Sedimentation analysis): Loam (sand 408 g kg<sup>-1</sup>; silt 432 g kg<sup>-1</sup>; clay 160 g kg<sup>-1</sup>);
- o **pH** (Potentiometric determination in H<sub>2</sub>O and/or KCl/CaCl<sub>2</sub>): 6.5 in H<sub>2</sub>O and 6.0 in CaCl<sub>2</sub>;
- o **Organic Carbon content** (Wet oxidation with potassium dichromate – Walkley and Black): 10 g kg<sup>-1</sup>;
- o **Total Nitrogen** (Kjeldahl): 1.10 g kg<sup>-1</sup>;
- o **Available Phosphorous** (Olsen with bicarbonate 0.5 M and pH 8.5): 66 mg kg<sup>-1</sup>;
- o **Exchangeable Potassium** (Ba chloride, pH 8.1): 118 mg kg<sup>-1</sup>;
- o **Cation exchange capacity** (Ba chloride, pH 8.1): 12 cmol<sup>+</sup> g<sup>-1</sup>;
- o **Bulk density** (Cylindrical core method): 1.35 g cm<sup>-3</sup>;

A brief qualitative description of the soil based on the measured soil variables is provided below:

#### **Texture:**

The sedimentation analysis indicates a loam texture for the soil, characterized by a well-balanced mixture of sand, silt, and clay particles. With sand at 408 g kg<sup>-1</sup>, silt at 432 g kg<sup>-1</sup>, and clay at 160 g kg<sup>-1</sup>, this loamy texture provides a favorable environment for plant growth and soil management.

#### **pH:**

The pH of the soil varied depending on the solution used for measurement. In H<sub>2</sub>O, the pH is 6.5, indicating a slightly acidic to neutral condition. In CaCl<sub>2</sub>, the pH is 6.0, suggesting a slight decrease in acidity compared to the H<sub>2</sub>O measurement when exchangeable acidity was considered. These pH values are within a range that supports nutrient availability and microbial activity.

#### **Organic Carbon Content:**

The soil exhibits a moderate organic carbon content of 10 g kg<sup>-1</sup>, contributing to soil fertility and structure. While not as high as in the previous Italian CS, this organic carbon level still provides essential organic matter for sustaining plant growth.

#### **Total Nitrogen:**

The total nitrogen content is measured at 1.10 g kg<sup>-1</sup>, indicating a moderate level of nitrogen in the soil. Adequate nitrogen is essential for supporting plant development and overall crop productivity.

**Available Phosphorous:**

The soil shows a relatively high availability of phosphorous with  $66 \text{ mg kg}^{-1}$ , as determined by the Olsen method with bicarbonate at pH 8.5. This higher phosphorous content can positively impact root development, flowering, and fruiting in plants.

**Exchangeable Potassium:**

The exchangeable potassium content is measured at  $118 \text{ mg kg}^{-1}$ , indicating a moderate level of available potassium. Potassium is essential for various physiological processes in plants, including water uptake and enzyme activation.

**Cation Exchange Capacity:**

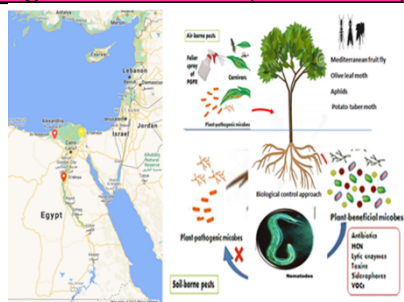
The cation exchange capacity is measured at  $12 \text{ cmol}^+ \text{ g}^{-1}$ , suggesting a moderate ability of the soil to retain and exchange essential nutrients. While lower than the previous Italian CS, this CEC value still indicates reasonable nutrient-holding capacity.

**Bulk Density:**

The soil exhibits a bulk density of  $1.35 \text{ g cm}^{-3}$ , as determined by the cylindrical core method. This is a well-structured soil, considering the soil texture, with a good balance between pore spaces and solid particles, promoting water movement and root penetration.

In summary, the field is characterized by a loam texture, slightly acidic to neutral pH, a moderate organic carbon content of  $10 \text{ g kg}^{-1}$ , moderate levels of nitrogen, higher phosphorous availability, moderate exchangeable potassium, and a balanced bulk density. These properties collectively contribute to a soil environment that is generally conducive to supporting healthy plant growth and agricultural productivity.

### 3.3 Case study 4: Al Minya, An Nubariyah and Salheya regions, Egypt. Organic agriculture farm (lead: ARC), 2 SIRAM pillars (B, M)



Activities in CS4 started in October 2022 and are focused on the following aspects: (1) promoting positive microbes-biomasses interactions as approaches for inducing aboveground (Mediterranean fruit fly, olive leaf moth, Aphids and potato tuber moth) and below ground (plant parasitic nematodes, bacterial and fungal pathogens) disease resistance; (2) Novel biopesticides

Main soil properties that have been being determined in CS4, including methods used, are provided below:

- o **Texture** (Sedimentation analysis): Clay loam;
- o **pH** (Potentiometric determination in  $H_2O$  and/or  $KCl/CaCl_2$ ): 8.11 in  $H_2O$
- o **Organic Carbon content** (Wet oxidation with potassium dichromate – Walkley and Black):  $6.8 \text{ g kg}^{-1}$ ;
- o **Total Nitrogen** (Kjeldahl):  $0.55 \text{ g kg}^{-1}$ ;
- o **Available Phosphorous** (Olsen with bicarbonate 0.5 M and pH 8.5):  $4.9 \text{ mg kg}^{-1}$ ;
- o **Exchangeable Potassium** (Ba chloride, pH 8.1):  $328 \text{ mg kg}^{-1}$ ;
- o **Cation exchange capacity** (Ba chloride, pH 8.1):  $15 \text{ cmol}^+ \text{ g}^{-1}$ ;
- o **Electrical conductivity** (Electrical resistance of a 1:2 soil:water suspension):  $0.95 \text{ dS m}^{-1}$ ;
- o **Bulk density** (Cylindrical core method):  $1.2 \text{ g cm}^{-3}$ .

A brief qualitative description of the soil based on the measured soil variables is provided below:

#### **Texture:**

The sedimentation analysis reveals a clay-loam texture for the soil, indicating a well-balanced combination of sand, silt, and clay particles. The specific proportions are not provided, but clay loam generally implies a mixture with a significant presence of clay, providing both water retention and good drainage.

#### **pH:**

The pH of the soil in  $H_2O$  is relatively high at 8.11, indicating an alkaline condition. This high pH may influence nutrient availability, and it is important to consider crops that are well-suited to alkaline soils.

#### **Organic Carbon Content:**

The organic carbon content is measured at  $6.8 \text{ g kg}^{-1}$ , indicating a low-moderate level of organic matter in the soil. While slightly lower than some other soils, this organic carbon level still supports microbial activity and nutrient cycling.

#### **Total Nitrogen:**

The total nitrogen content is relatively low at  $0.55 \text{ g kg}^{-1}$ , suggesting a lower overall nitrogen level in the soil. Nitrogen is essential for plant growth, and additional nitrogen need to be supplemented for optimal crop development.

**Available Phosphorous:**

The soil shows a low availability of phosphorous with  $4.9 \text{ mg kg}^{-1}$ , as determined by the Olsen method with bicarbonate at pH 8.5. Phosphorous is a crucial nutrient for plant development, so phosphorous supplementation may be necessary for certain crops.

**Exchangeable Potassium:**

The exchangeable potassium content is relatively high at  $328 \text{ mg kg}^{-1}$ , indicating a substantial availability of potassium. Adequate potassium is essential for various physiological processes in plants, contributing to overall plant health and productivity.

**Cation Exchange Capacity:**

The cation exchange capacity is measured at  $15 \text{ cmol}^+ \text{ g}^{-1}$ , suggesting a moderate ability of the soil to retain and exchange essential nutrients. This value indicates reasonable nutrient-holding capacity.

**Electrical Conductivity:**

The electrical conductivity of the soil is measured at  $0.95 \text{ dS m}^{-1}$ , suggesting non saline conditions. Higher values of salinity can represent a potential challenge for certain crops sensitive to salinity.

**Bulk Density:**

The soil exhibits a low bulk density of  $1.2 \text{ g cm}^{-3}$ , as determined by the cylindrical core method. This low bulk density suggests a well-structured soil with good porosity, facilitating water movement and root development.

In summary, the third field is characterized by a clay-loam texture, alkaline pH, a low-moderate organic carbon content of  $6.8 \text{ g kg}^{-1}$ , low levels of nitrogen and phosphorous, high exchangeable potassium, moderate cation exchange capacity, non-saline conditions, and a low bulk density of  $1.2 \text{ g cm}^{-3}$ . These properties collectively contribute to a soil environment that may require specific management practices to optimize crop production, especially considering the alkaline pH and lower nitrogen, organic carbon, and phosphorous levels.

### 3.4 Case Study 6: Catalonia, Spain. Regenerative practices on rainfed and irrigated arable agriculture (lead: IRTA). 2 Challenges, 3 SIRAM pillars (A, B, R).



Activities in CS6 started in October 2022 and are focused on the following aspects: (1) full assessment and application analysis of reduced tillage and dairy manure for increasing soil organic carbon and rainfed crop performance; (2) studying mechanisms by which cover crops and reduced tillage may increase use efficiency of nutrients and enhance soil quality.



Two field experiments are currently being involved in the CS6, thus initial soil properties for both fields are reported below.

Soil properties involving the field trial involving rainfed winter arable crops were assessed to a 40 cm depth except for soil texture, bulk density, SOC granulodensimetric fractions, and water holding capacity which were assessed to a 20 cm depth:

- o **Texture** (Sedimentation analysis): Loam;
- o **pH** (Potentiometric determination in  $H_2O$  and/or  $KCl/CaCl_2$ ): 8.3 in  $H_2O$ ;
- o **Organic Carbon content** (Wet oxidation with potassium dichromate – Walkley and Black):  $8.7 \text{ g kg}^{-1}$ ;
- o **Total Nitrogen** (Dry combustion with elemental analyser - Dumas):  $1.20 \text{ g kg}^{-1}$ ;
- o **Available Phosphorous** (Olsen with bicarbonate 0.5 M and pH 8.5):  $34 \text{ mg kg}^{-1}$ ;
- o **Exchangeable Potassium** (Ammonium acetate, pH 7.0):  $431 \text{ g kg}^{-1}$ ;
- o **Electrical conductivity** (Electrical resistance of a 1:5 soil:water suspension):  $0.19 \text{ dS m}^{-1}$ ;
- o **Bulk density** (Cylindrical core method):  $1.66 \text{ g cm}^{-3}$ ;
- o **Organic Carbon granulodensimetric fractions** (AFNOR):  $0.69 \text{ g C total-C}^{-1}$  (0.2-2 P);  $7.02 \text{ g C total-C}^{-1}$  (0.2-2 LI);  $1.97 \text{ g C total-C}^{-1}$  (0.05-0.2 P);  $14.7 \text{ g C total-C}^{-1}$  (0.05-0.2 LI);  $70.4 \text{ g C total-C}^{-1}$  ( $<0.05 \text{ T}$ );
- o **Water holding capacity** (Richard plates):  $7.8 \text{ g H}_2\text{O } 100 \text{ g}^{-1} \text{ dry soil}$ .

A brief qualitative description of the soil from the first field experiment is provided below, based on the measured soil variables:

#### **Texture:**

The sedimentation analysis indicates a loam texture for the soil, signifying a balanced mix of sand, silt, and clay particles. This type of soil texture is generally well-suited for a variety of crops due to its optimal combination of drainage and water retention.

#### **pH:**

The soil pH in  $H_2O$  is relatively high at 8.3, suggesting an alkaline condition. This alkalinity can influence nutrient availability, and it's important to consider crops that thrive in alkaline soils.

#### **Organic Carbon Content:**

The soil displays a moderate organic carbon content of  $8.7 \text{ g kg}^{-1}$ , contributing to soil fertility, microbial activity, and overall soil structure. This organic carbon level is beneficial for sustaining healthy plant growth.

**Total Nitrogen:**

The total nitrogen content is measured at  $1.20 \text{ g kg}^{-1}$ , indicating a moderate level of nitrogen in the soil. Adequate nitrogen is essential for supporting plant development and overall crop productivity.

**Available Phosphorous:**

The soil exhibits a moderate availability of phosphorous with  $34 \text{ mg kg}^{-1}$ , as determined by the Olsen method with bicarbonate at pH 8.5. This moderate phosphorous content supports essential plant processes, such as root development and flowering.

**Exchangeable Potassium:**

The exchangeable potassium content is notably high at  $431 \text{ g kg}^{-1}$ , indicating a substantial availability of potassium. Potassium is crucial for various plant functions and contributes to overall plant health and productivity.

**Electrical Conductivity:**

The electrical conductivity of the soil is relatively low at  $0.19 \text{ dS m}^{-1}$ , suggesting non-saline conditions. This is generally favorable for most crops, as high salinity can hinder plant growth.

**Bulk Density:**

The soil exhibits a high bulk density of  $1.66 \text{ g cm}^{-3}$ , as determined by the cylindrical core method. This high level of bulk density may impact water movement and root development, and appropriate management practices should be considered.

**Organic Carbon Granulodensimetric Fractions:**

The organic carbon granulodensimetric fractions provide insights into the distribution of organic carbon among different particle size fractions. The variations in carbon content among different fractions indicate the potential for diverse organic carbon turnover rates in the soil.

**Water Holding Capacity:**

The soil has a water holding capacity of  $7.8 \text{ g H}_2\text{O}$  per  $100 \text{ g}$  dry soil, indicating its ability to retain water. This is an important characteristic for supporting plant growth, especially during dry periods.

In summary, the described field is characterized by a loam texture, alkaline pH, moderate organic carbon content, moderate levels of nitrogen and phosphorous, high exchangeable potassium, low electrical conductivity, higher bulk density, diverse organic carbon granulodensimetric fractions, and a water holding capacity of  $7.8 \text{ g H}_2\text{O}$  per  $100 \text{ g}$  dry soil. These properties collectively suggest a soil environment that can support a variety of crops, but considerations should be made for the alkaline pH and higher bulk density.

Soil properties involving the field trial involving cover crops and maize as cash crop were assessed to a  $30 \text{ cm}$  depth except for soil texture, bulk density, SOC granulodensimetric fractions, and water holding capacity which were assessed to a  $20 \text{ cm}$  depth:

- o **Texture** (Sedimentation analysis): Sandy-loam;
- o **pH** (Potentiometric determination in  $\text{H}_2\text{O}$  and/or  $\text{KCl/CaCl}_2$ ): 8.3 in  $\text{H}_2\text{O}$ ;
- o **Organic Carbon content** (Wet oxidation with potassium dichromate – Walkley and Black):  $7.1 \text{ g kg}^{-1}$ ;
- o **Total Nitrogen** (Dry combustion with elemental analyser - Dumas):  $1.17 \text{ g kg}^{-1}$ ;

- o **Available Phosphorous** (Olsen with bicarbonate 0.5 M and pH 8.5): 9.1 mg kg<sup>-1</sup>;
- o **Exchangeable Potassium** (Ammonium acetate, pH 7.0): 71 g kg<sup>-1</sup>;
- o **Electrical conductivity** (Electrical resistance of a 1:5 soil:water suspension): 0.13 dS m<sup>-1</sup>;
- o **Bulk density** (Cylindrical core method): 1.38 g cm<sup>-3</sup>;
- o **Organic Carbon granulodensimetric fractions** (AFNOR): 0.76 g C total-C<sup>-1</sup> (0.2-2 P); 5.76 g C total-C<sup>-1</sup> (0.2-2 LI); 4.97 g C total-C<sup>-1</sup> (0.05-0.2 P); 12.2 g C total-C<sup>-1</sup> (0.05-0.2 LI); 76.3 g C total-C<sup>-1</sup> (<0.05 T);
- o **Water holding capacity** (Richard plates): 7.6 g H<sub>2</sub>O 100 g<sup>-1</sup> dry soil.

### **Texture:**

The sedimentation analysis indicates a sandy-loam texture for the soil, suggesting a mixture with a higher proportion of sand particles. This texture provides good drainage and aeration, which can be advantageous for certain crops.

### **pH:**

The soil pH in H<sub>2</sub>O is 8.3, indicating an alkaline condition. This alkalinity can influence nutrient availability, and consideration should be given to crops that are well-suited to alkaline soils.

### **Organic Carbon Content:**

The soil displays a low-moderate organic carbon content of 7.1 g kg<sup>-1</sup>, contributing to soil fertility and structure. While slightly lower than some other soils, this organic carbon level still supports microbial activity and nutrient cycling.

### **Total Nitrogen:**

The total nitrogen content is measured at 1.17 g kg<sup>-1</sup>, indicating a moderate level of nitrogen in the soil. Adequate nitrogen is essential for supporting plant development and overall crop productivity.

### **Available Phosphorous:**

The soil exhibits a relatively low availability of phosphorous with 9.1 mg kg<sup>-1</sup>, as determined by the Olsen method with bicarbonate at pH 8.5. Additional phosphorous supplementation may be necessary for optimal crop growth.

### **Exchangeable Potassium:**

The exchangeable potassium content is moderate at 71 g kg<sup>-1</sup>, providing a reasonable level of potassium for plant nutrient uptake. Potassium is important for various physiological processes in plants.

### **Electrical Conductivity:**

The electrical conductivity of the soil is low at  $0.13 \text{ dS m}^{-1}$ , indicating non-saline conditions. This is generally favourable for most crops, as high salinity can hinder plant growth.

**Bulk Density:**

The soil exhibits a moderate bulk density of  $1.38 \text{ g cm}^{-3}$ , as determined by the cylindrical core method. This suggests a balanced soil structure with good porosity for water movement and root development.

**Organic Carbon Granulodensimetric Fractions:**

The organic carbon granulodensimetric fractions provide insights into the distribution of organic carbon among different particle size fractions. The variations in carbon content among different fractions indicate the potential for diverse organic carbon turnover rates in the soil.

**Water Holding Capacity:**

The soil has a water holding capacity of  $7.6 \text{ g H}_2\text{O per } 100 \text{ g dry soil}$ , indicating its ability to retain water. This is an important characteristic for supporting plant growth, especially during dry periods.

In summary, the described field is characterized by a sandy-loam texture, alkaline pH, low-moderate organic carbon content, moderate levels of nitrogen and phosphorous, moderate exchangeable potassium, low electrical conductivity, moderate bulk density, diverse organic carbon granulodensimetric fractions, and a water holding capacity of  $7.6 \text{ g H}_2\text{O per } 100 \text{ g dry soil}$ . These properties suggest a soil environment that can support a variety of crops, especially those adapted to well-drained conditions and alkaline pH.

### 3.5 Case Study 7: Sidi Bouzid, Tunisia. Experimental farm of Olive trees and intensive crop production areas (leader: Dr. Hichem Hajlaoui CRRA). 2 Challenges, 4 SIRAM pillars (A, B, M, R)



Activities in CS7 started in October 2022 and are focused on the following aspects: (1) promoting the use of microbial biostimulants for enhancing plant resilience to biotic and abiotic stress; comprehensive assessment, (2) adoption of Regenerative agriculture practices (i.e., no-till plus cover crops) and beneficial microorganisms to enhance soil quality and functioning.



Two field experiments (focusing on tomato and on olive tree, respectively) are currently being involved in the CS7, thus initial soil properties (measured to 30 cm depth) for both fields are reported below.

Main soil properties of the tomato field experiment, including methods used, are provided below:

- o **Texture** (Sedimentation analysis): Sandy-loam (sand 762 g kg<sup>-1</sup>; silt 125 g kg<sup>-1</sup>; clay 113 g kg<sup>-1</sup>);
- o **Organic Carbon content** (Wet oxidation with potassium dichromate – Walkley and Black): 5.0 g kg<sup>-1</sup>;
- o **Total Nitrogen** (Kjeldahl): 0.43 g kg<sup>-1</sup>;
- o **Available Phosphorous** (Olsen with bicarbonate 0.5 M and pH 8.5): 3.64 mg kg<sup>-1</sup>;
- o **Exchangeable Potassium** (Ba chloride, pH 8.1): 791 mg kg<sup>-1</sup>;
- o **Electrical conductivity** (Electrical resistance of a 1:2 soil:water suspension): 2.03 dS m<sup>-1</sup>;
- o **Bulk density** (Cylindrical core method): 1.50 g cm<sup>-3</sup>;

#### **Texture:**

The sedimentation analysis reveals a sandy-loam texture, characterized by a predominant presence of sand (762 g kg<sup>-1</sup>), followed by lower proportions of silt (125 g kg<sup>-1</sup>) and clay (113 g kg<sup>-1</sup>). This texture suggests a well-drained soil with relatively large particles, making it suitable for crops that thrive in such conditions.

#### **Organic Carbon Content:**

The soil has a relatively low organic carbon content of 5.0 g kg<sup>-1</sup>. Enhancing organic carbon content can be considered to further improve soil fertility, foster microbial activity, and enhance overall soil structure.

#### **Total Nitrogen:**

The total nitrogen content is relatively low at 0.43 g kg<sup>-1</sup>, indicating a lower overall nitrogen level in the soil. Nitrogen is crucial for plant growth, and additional nitrogen may need to be supplemented for optimal crop development.

#### **Available Phosphorous:**

The soil shows a low availability of phosphorous with 3.64 mg kg<sup>-1</sup>, as determined by the Olsen method with bicarbonate at pH 8.5. Additional phosphorous supplementation may be necessary for supporting essential plant processes.

**Exchangeable Potassium:**

The exchangeable potassium content is notably high at  $791 \text{ mg kg}^{-1}$ , indicating a substantial availability of potassium. Potassium is crucial for various physiological processes in plants and contributes to overall plant health and productivity.

**Electrical Conductivity:**

The electrical conductivity of the soil is  $2.03 \text{ dS m}^{-1}$ , indicating a low level of soil salinity. This salinity level may impact plant growth on sensitive crops, and careful consideration should be given to selecting crops adapted to such conditions.

**Bulk Density:**

The soil exhibits a moderate bulk density of  $1.50 \text{ g cm}^{-3}$ , as determined by the cylindrical core method. This suggests a balanced soil structure, considering soil texture, with good porosity for water movement and root development.

In summary, the described field is characterized by a sandy-loam texture with high sand content, low organic carbon content, low levels of total nitrogen and available phosphorous, high exchangeable potassium, low salinity, and a moderate bulk density. These properties suggest a well-drained soil with potential challenges related to salinity and organic matter, and careful crop selection and management practices are recommended for optimal agricultural productivity.

Main soil properties of the olive tree field experiment, including methods used, are provided below:

- o **Texture** (Sedimentation analysis): Sandy-loam (sand  $671 \text{ g kg}^{-1}$ ; silt  $226 \text{ g kg}^{-1}$ ; clay  $104 \text{ g kg}^{-1}$ );
- o **Organic Carbon content** (Wet oxidation with potassium dichromate – Walkley and Black):  $6.4 \text{ g kg}^{-1}$ ;
- o **Total Nitrogen** (Kjeldahl):  $0.34 \text{ g kg}^{-1}$ ;
- o **Available Phosphorous** (Olsen with bicarbonate  $0.5 \text{ M}$  and  $\text{pH } 8.5$ ):  $3.46 \text{ mg kg}^{-1}$ ;
- o **Exchangeable Potassium** (Ba chloride,  $\text{pH } 8.1$ ):  $762 \text{ mg kg}^{-1}$ ;
- o **Electrical conductivity** (Electrical resistance of a 1:2 soil:water suspension):  $3.16 \text{ dS m}^{-1}$ ;
- o **Bulk density** (Cylindrical core method):  $1.35 \text{ g cm}^{-3}$ ;

**Texture:**

The sedimentation analysis indicates a sandy-loam texture, characterized by a notable presence of sand ( $671 \text{ g kg}^{-1}$ ), followed by silt ( $226 \text{ g kg}^{-1}$ ) and clay ( $104 \text{ g kg}^{-1}$ ). This texture suggests a well-drained soil with good aeration, suitable for a variety of crops.

**Organic Carbon Content:**

The soil has a low-moderate organic carbon content of  $6.4 \text{ g kg}^{-1}$ . While this value is not as high as in some other soils, enhancing organic carbon content can be considered to further improve soil fertility, foster microbial activity, and enhance overall soil structure.

**Total Nitrogen:**

The total nitrogen content is relatively low at  $0.34 \text{ g kg}^{-1}$ , indicating a lower overall nitrogen level in the soil. Nitrogen is a critical nutrient for plant growth, and additional nitrogen may need to be supplemented for optimal crop development.

**Available Phosphorous:**

The soil shows a low availability of phosphorous with  $3.46 \text{ mg kg}^{-1}$ , as determined by the Olsen method with bicarbonate at pH 8.5. This suggests that phosphorous supplementation may be necessary to support essential plant processes.

**Exchangeable Potassium:**

The exchangeable potassium content is relatively high at  $762 \text{ mg kg}^{-1}$ , indicating a substantial availability of potassium. Potassium is crucial for various physiological processes in plants and contributes to overall plant health and productivity.

**Electrical Conductivity:**

The electrical conductivity of the soil is  $3.16 \text{ dS m}^{-1}$ , suggesting low soil salinity. This level of salinity may pose challenges for some crops, and careful consideration of salt-tolerant varieties is recommended.

**Bulk Density:**

The soil exhibits a moderate bulk density of  $1.35 \text{ g cm}^{-3}$ , as determined by the cylindrical core method. This suggests a well-structured soil with good porosity, facilitating water movement and root development.

In summary, the described field is characterized by a sandy-loam texture, low-moderate organic carbon content, low levels of total nitrogen and available phosphorous, high exchangeable potassium, low salinity, and a moderate bulk density. These properties suggest a well-drained soil with potential challenges related to salinity and organic matter, and careful crop selection and management practices are recommended for optimal agricultural productivity.

## 2.6 Case Study 8: North, Center and Center South of Portugal, Surveillance on potato-growing soils (lead: UC), 2 Challenges, 3 SIRAM pillars (B, M, R)



Activities in CS8 started in October 2022 and are focused on the following aspects: (1) studying the potential of biological control by beneficial microorganisms' consortia in soils contaminated with phytopathogenic nematodes (PPN); identifying potato varieties resistant to PPN (2).



Several fields across Portugal were chosen for experimental activities, and initial soil properties were assessed in each. The main soil properties presented below are calculated as an average across all sampled fields to offer a comprehensive overview. Individual data for each field can be found in the attached Excel file (refer to the file by its name and location):

- o **Texture** (Sedimentation analysis): Sandy-loam (sand 744 g kg<sup>-1</sup>; silt 151 g kg<sup>-1</sup>; 105 g kg<sup>-1</sup>)
- o **pH** (Potentiometric determination in H<sub>2</sub>O and/or KCl/CaCl<sub>2</sub>): 6.34 in H<sub>2</sub>O;
- o **Organic Carbon content** (Dry combustion): 13.7 g kg<sup>-1</sup>;
- o **Total Nitrogen** (Extraction with calcium chloride): 0.22 g kg<sup>-1</sup>;
- o **Available Phosphorous** (Extraction with H<sub>2</sub>O, 1/5, p/v.): 15 mg kg<sup>-1</sup>
- o **Exchangeable Potassium** (Extraction with H<sub>2</sub>O, 1/5, p/v): 106 mg kg<sup>-1</sup>;
- o **Electrical conductivity** (Electrical resistance of a 1:2 soil:water suspension): 0.05 dS m<sup>-1</sup>.

### **Texture:**

The sedimentation analysis indicates an average sandy-loam texture, characterized by sand content of 744 g kg<sup>-1</sup>, silt at 151 g kg<sup>-1</sup>, and clay at 105 g kg<sup>-1</sup>. This texture suggests a well-balanced average soil with good drainage and aeration, making it suitable for a variety of crops.

### **pH:**

The pH of the average soil in H<sub>2</sub>O is 6.34, indicating a slightly acidic to neutral condition. This pH range is generally favorable for nutrient availability, and it accommodates a wide range of crops.

### **Organic Carbon Content:**

The soils, on average, have a moderate-high organic carbon content of 13.7 g kg<sup>-1</sup>, contributing to soil fertility, microbial activity, and soil structure. This relatively high organic carbon content is beneficial for supporting plant growth and nutrient cycling.

### **Total Nitrogen:**

The average total nitrogen content is measured at 0.22 g kg<sup>-1</sup>, indicating a low overall nitrogen level in the soils. Additional nitrogen supplementation may be necessary for optimal crop development, considering the lower nitrogen content.

### **Available Phosphorous:**

The average available phosphorous content is measured at 15 mg kg<sup>-1</sup>, indicating a moderate level. Phosphorous is an essential nutrient for plant growth, and supplementation may be necessary to support crop development.

**Exchangeable Potassium:**

The average exchangeable potassium content is measured at 106 mg kg<sup>-1</sup>, indicating a moderate availability of potassium. Adequate potassium is crucial for various physiological processes in plants and contributes to overall plant health and productivity.

**Electrical Conductivity:**

The average electrical conductivity of the soil is low at 0.05 dS m<sup>-1</sup>, indicating non saline conditions. This low salinity level is generally favorable for most crops, as high salinity can hinder plant growth.

In summary, the average soil across several fields in Portugal is characterized by a sandy-loam texture, slightly acidic to neutral pH, a moderate-high organic carbon content, low levels of nitrogen, moderate phosphorous availability, moderate exchangeable potassium, low electrical conductivity, and overall, a well-balanced soil structure. These properties suggest a soil environment that is generally conducive to supporting a variety of crops with appropriate nutrient management practices.