SoilFER APP FOR LOCALIZED CROP SUITABILITY

User's Guide

Last updated 23/07/2025

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BACKGROUND

The Soil mapping for resilient agrifood systems in Central America and Sub-Saharan Africa (SoilFER) project represents a unique framework designed to uncover critical soil data, offering key insights to inform policy decisions on crop suitability and fertilizer recommendations at both national and local scales.

The SoilFER App for localized crop suitability provides open-access geographic information on the suitability of opportunity crops identified by the Vision for Adapted Crops and Soils (VACS) for specific soil groups. The SoilFER App for localized crop suitability enables users to select the most suitable crops under specific soil types and land management conditions. This creates a solid foundation for sustainable agricultural planning and implementation.

SoilFER results on crop suitability are built on the foundation of the Agro-Ecological Zoning (AEZ) framework, developed in collaboration between the Food and Agriculture Organization of the United Nations (FAO), and the International Institute for Applied Systems Analysis (IIASA). The AEZ framework assesses natural resources to identify optimal agricultural land use options, contributing to several United Nations Sustainable Development Goals (SDGs).

INTRODUCTION

The SoilFER App for localized crop suitability is a web-based decision-support tool designed to enhance agricultural planning through geospatial data integration, crop modeling, and suitability assessments. It processes global soil, water, climate and crop data hosted on a centralized platform, leveraging the Agro-Ecological Zones (AEZ) modelling framework to provide science-based recommendations on crop selection and land management. The SoilFER App for localized crop suitability analyzes user-entered parameters related to soil, crop, and input management, and uses this information to extract the corresponding results from the SoilFER Geospatial Platform (see schematic workflow in figure below).

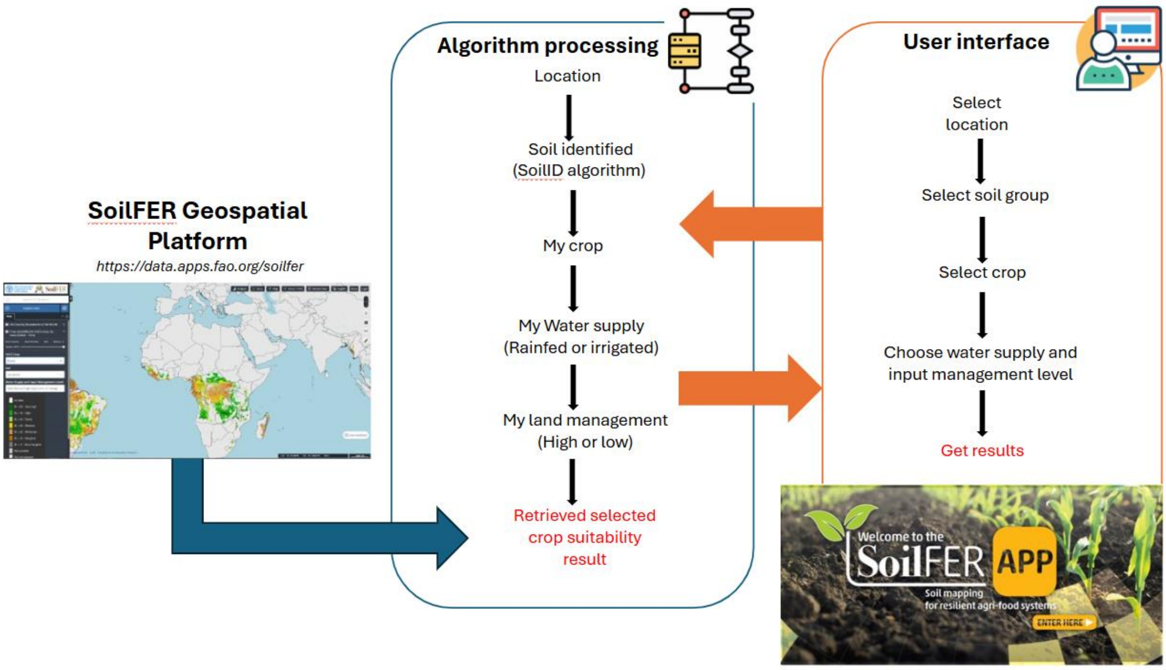


Figure 1. Schematic Workflow. The diagram illustrates the interaction between the user interface and algorithm processing in the SoilFER App for localized crop suitability.

The App is structured in different steps, each corresponding to a specific selection and interaction by the user:

i. Selection of the location

ii. Selection of the soil type

iii. Selection of the crop

iv. Selection of the water supply system and level of input management

SOILFER APP FOR LOCALIZED CROP SUITABILITY

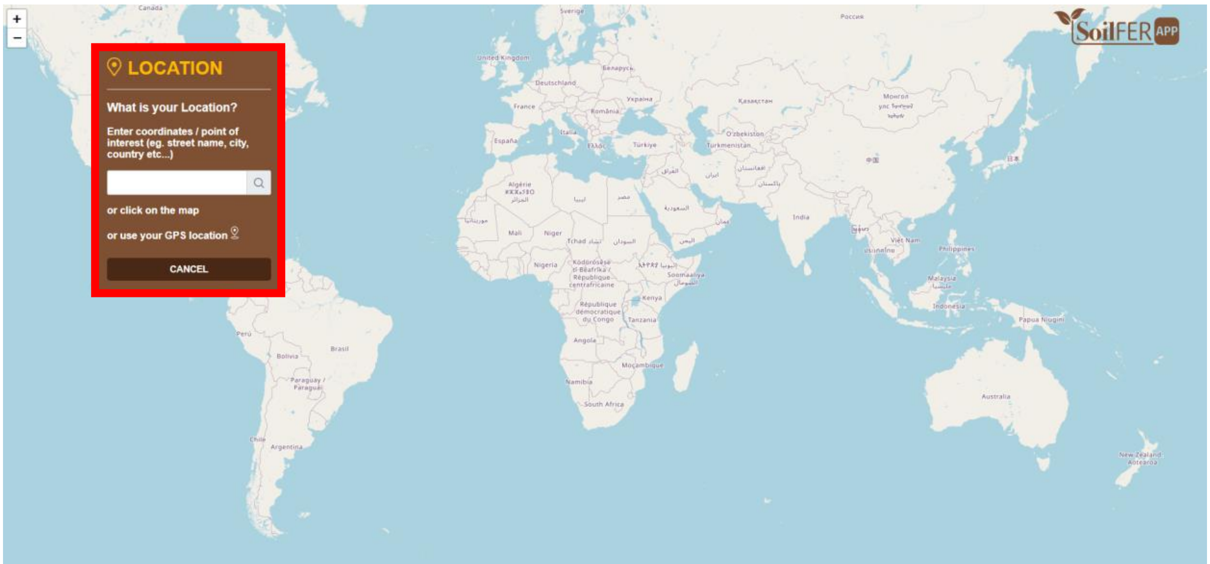
This section provides a structured, step-by-step guide on using the SoilFER App for localized crop suitability to obtain crop suitability and agro-ecological attainable yield values at a specific location. Through the interface, users can select key parameters such as location, soil type, crop, water supply, and level of input management.

Step 1. Location information

Area of interest

To select the area of interest the user can choose among the following options:

- Search bar: enter either an address or name of the city/neighborhood;
- Coordinates: enter latitude and longitude coordinates in decimal degree format;
- Click directly on the map;
- Use GPS location.



Mark sign

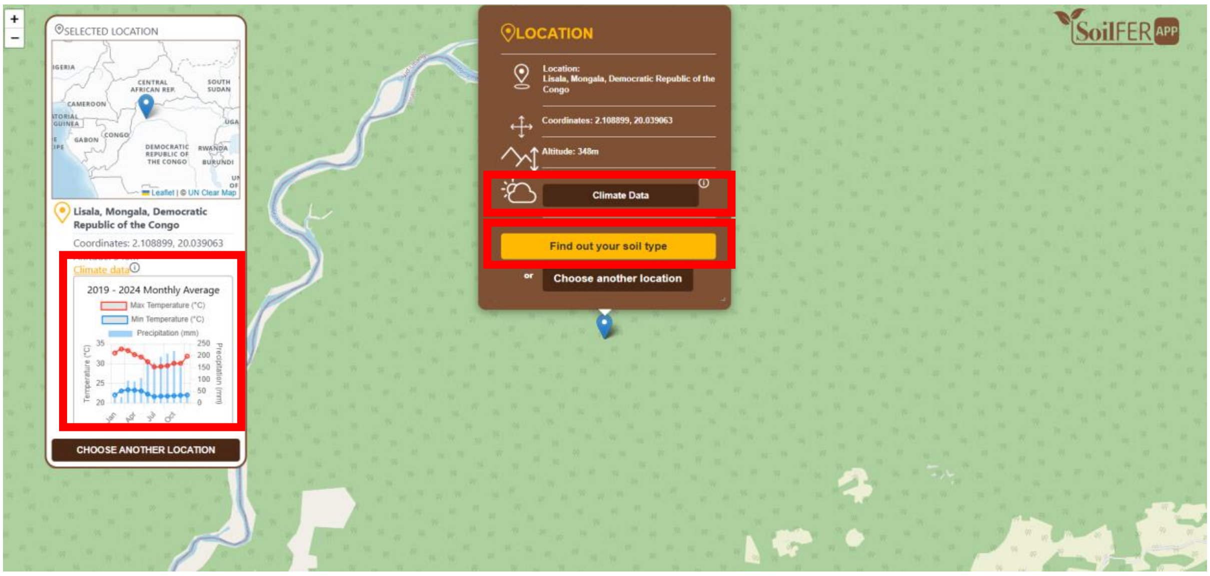
The selected location is marked with a placemark on the background map (see figure below). By clicking on the placemark, a pop-up window opens displaying information about the location, including its name, coordinates, altitude, and a button to access climate data for that location.

Climate information

Climate data are available for the selected location by clicking on the *"Climate data"* button. The App will display climate parameter trends averaged for each month over the last five years (2019–2024). The graph presents three key climate variables: (1) the red line with circles represents the maximum temperature (°C), (2) the blue line with circles represents the minimum temperature (°C), (3) the light blue bars indicate monthly precipitation levels (mm). By clicking on any of the variables in the legend, users can toggle data visibility to focus on specific climate trends. The historical weather displayed in the App is based on the daily surface meteorological data averaged each month for the last 5 years from the Copernicus Climate Change Service - ERA5 data.

While this visualization provides a general climate overview, crop suitability and yield calculations in the App rely on a more detailed set of climate variables, processed at a daily scale (refer to Global Agro-ecological Zoning (GAEZ v5) Model Documentation[1] for more information about the climatic input variables used in the model).

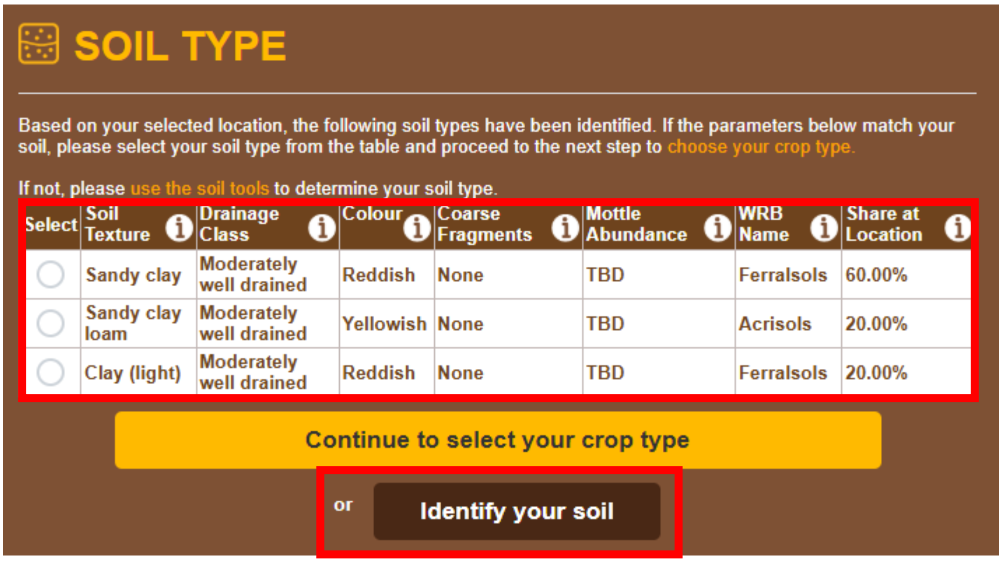
[1] GAEZ v5 Model Documentation accessible at https://github.com/un-fao/gaezv5/wiki



Step 2. Soil type

After selecting the location, users can proceed to determine the soil type by clicking on the placemark. By clicking on *"Find out your soil type"*, this will open a new window where soil classification details on the soil types for the selected area are listed.

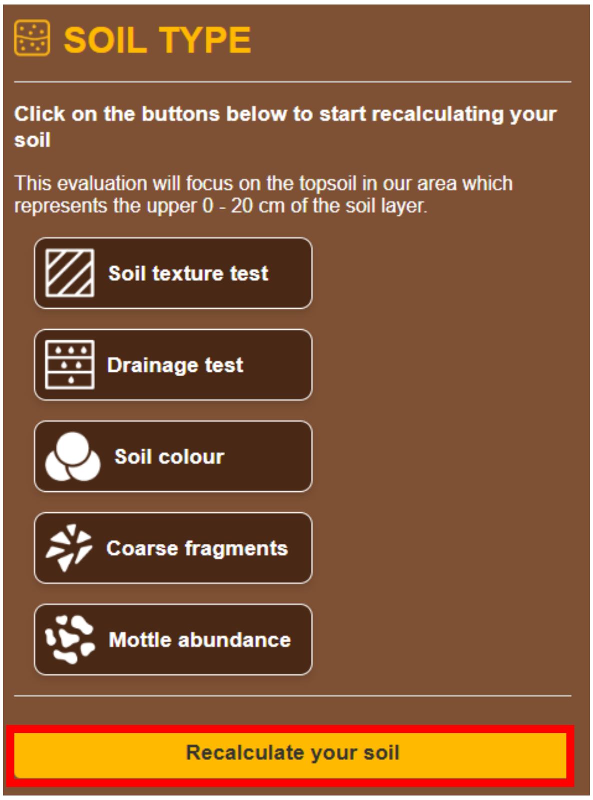
The soil types at the selected location, along with their specific parameters, are extracted from the Harmonized World Soil Database version 2 (HWSD v2) (FAO & IIASA, 2023) using the SoilID algorithm. For more information on how the SoilID algorithm functions, please refer to Annex I.



Once the soil type detection process is initiated, the App will display a table containing the general soil types based on the selected location. The table provides an overview of key soil properties, allowing users to verify and select the most appropriate soil type for further analysis. If the parameters listed in the table match user's soil conditions, the user can select the appropriate soil type and proceed to the next step by clicking on *"Continue to select your crop type"*.

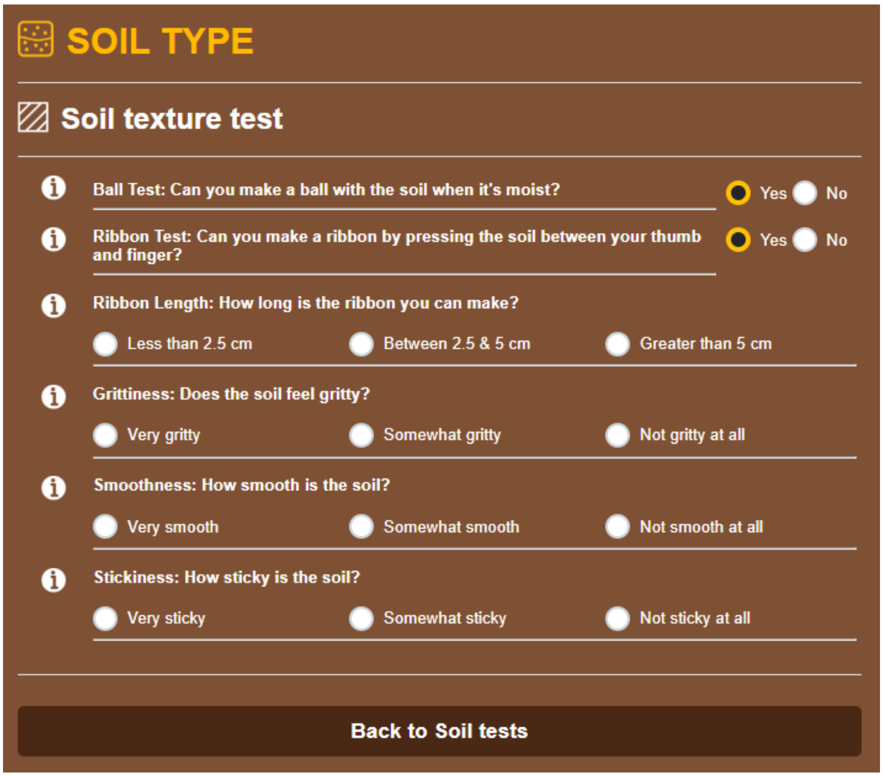
If the suggested soil types do not match user's field conditions, users can click on *"Identify your soil"* to refine the soil identification process. This option opens a window containing a list of five simple soil tests that users can perform easily without specialized tools. These tests assess texture, drainage, colour, coarse fragments, and mottle abundance, focusing only on the topsoil layer (0–20 cm).

Once the user completes the tests and makes their selections, the App's algorithm will recalculate and provide an updated estimate of the soil type at that location based on the input provided



Soil Texture test

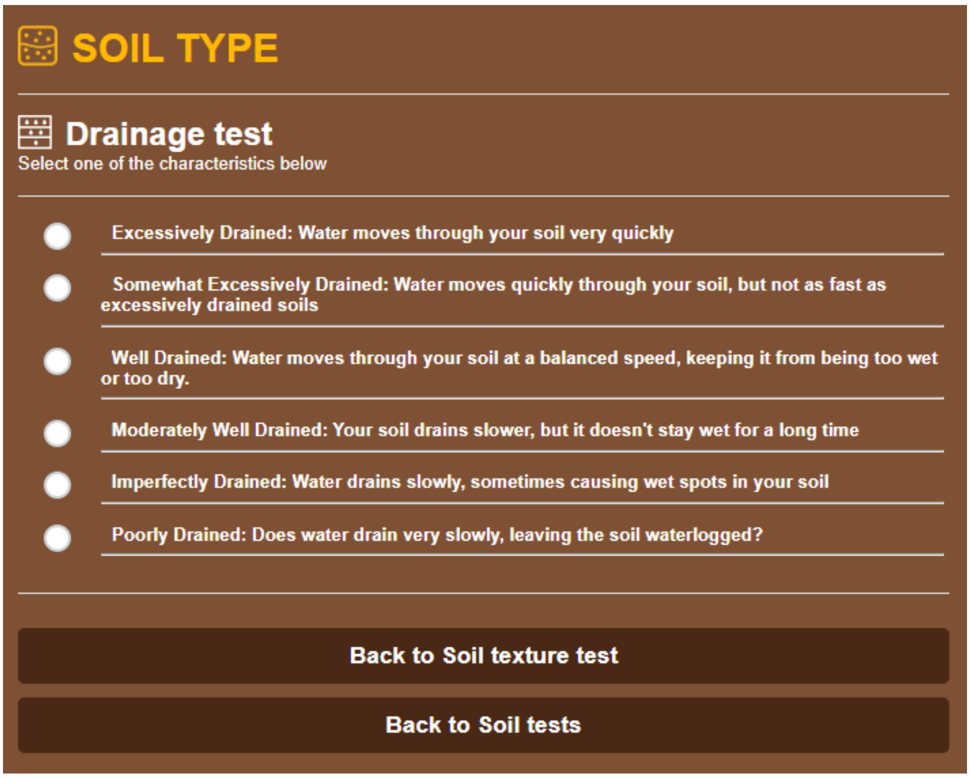
To determine soil texture, the App prompts users with two key questions about Ball Test and Ribbon Test. If both answers are "Yes", additional detailed assessments appear, including ribbon length, grittiness, smoothness, and stickiness. Users may select the most appropriate characteristics from the available multi-choice options to refine soil classification, ensuring a more precise identification of the soil type. Once a selection is made, users can either return to the Soil Tests or continue to the next test.



Drainage test

After completing the Soil Texture test, the App directs users to the Drainage Test. Users can select the most appropriate drainage characteristic that best describes the soil conditions.

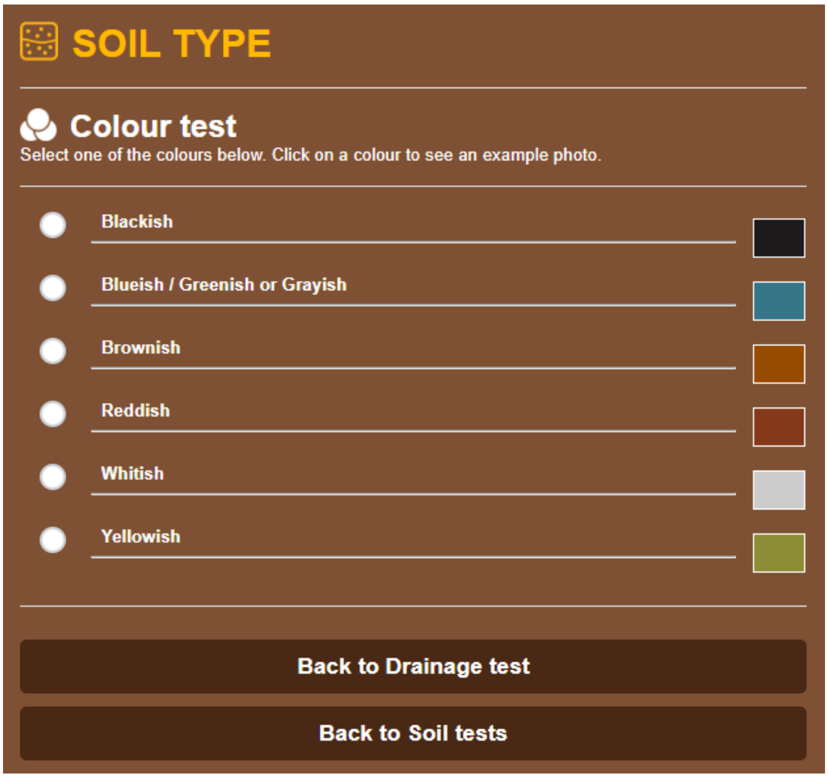
The available options include excessively drained, somewhat excessively drained, well drained, moderately well drained, imperfectly drained, and poorly drained. Once a selection is made, users can either return to the Drainage Test or continue to the next test.



Colour test

After completing the Drainage Test, the App moves on to the Colour Test, where users identify the dominant colour of the soil. Users can choose from a set of predefined colour categories that best match their sample. When a colour option is selected, the App displays an example photo to help guide the choice.

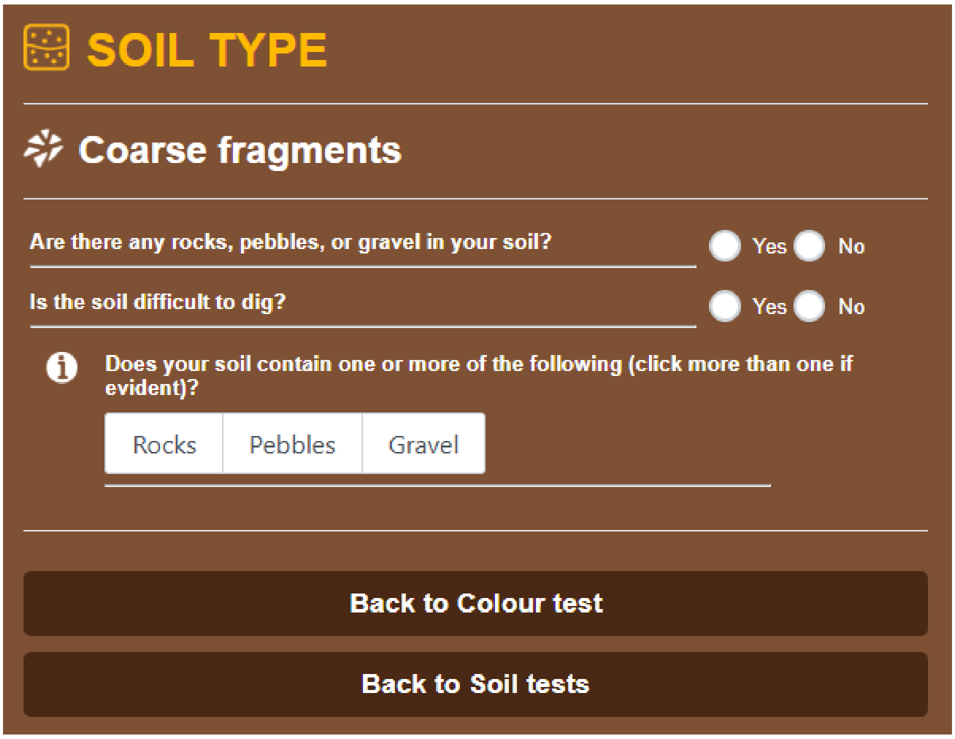
The available colour categories include: blackish, bluish/greenish or grayish, brownish, reddish, whitish, and yellowish. Once a selection is made, users can either return to the Drainage Test or continue to the next test.



Coarse Fragments test

After completing the Colour Test, the App advances to the Coarse Fragments test, where users evaluate the presence of rocks, pebbles, or gravel in the soil. Users indicate whether coarse fragments are present. If the answer is "Yes," additional fields appear, allowing users to specify the size of the fragments (small, medium, or large), the estimated percentage of soil containing them, and whether the soil is difficult to dig. Users may also identify any other relevant soil characteristics.

Once all selections are made, the App provides the option to return to the Colour test or proceed to the Mottle Abundance test.

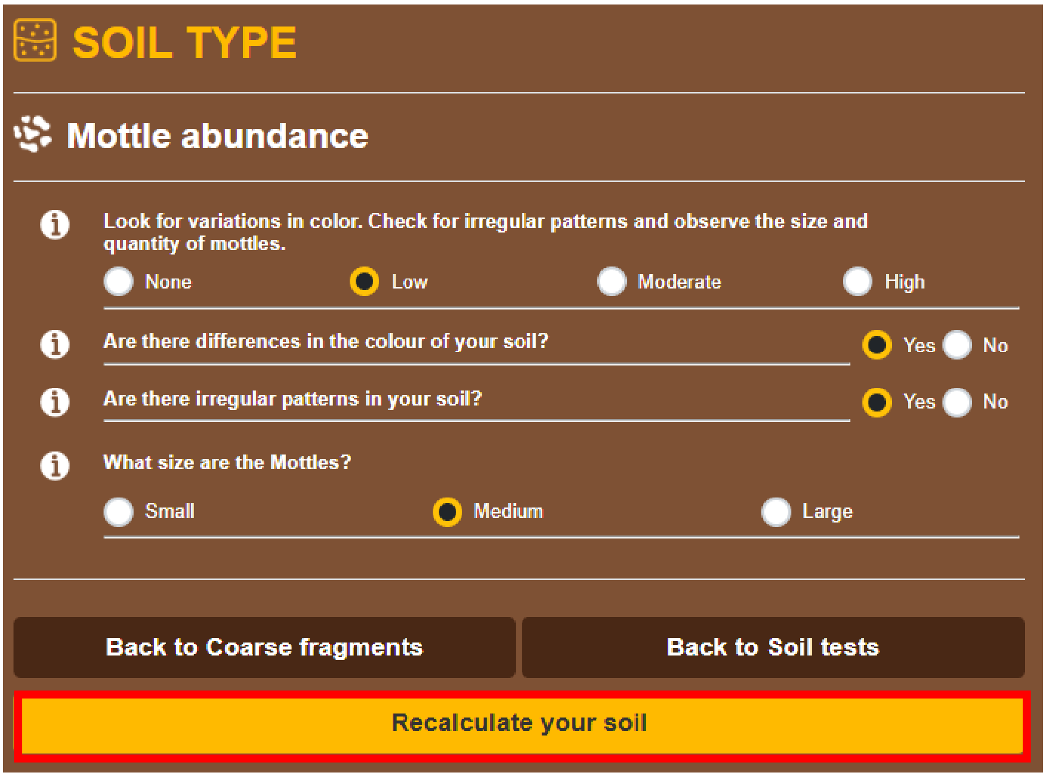


Mottle Abundance test

The Mottle Abundance test is the final step in determining the soil type. The Mottle Abundance test guides users in assessing variations in soil colour and patterns to identify the presence of mottles, which may indicate fluctuating water conditions or specific soil drainage characteristics.

The assessment begins by asking whether there are noticeable colour differences or irregular patterns in the soil. If "Yes" is selected for either, additional fields appear to specify the size of the mottles (small, medium, or large).

Once selections are complete, users can choose to return to the Coarse Fragments test or proceed to recalculate the soil classification based on all collected parameters.



Step 3. Crop type

Once soil type identification is complete, the App proceeds to the Crop Selection step. As shown in the figure below, users can choose a crop from a categorized list of opportunity crops and benchmark crops, each presented with both its common and scientific names.

Users can scroll through the list to find their crop of interest (e.g., maize (*Zea mays*)) and access additional information for each selection via the ECOCROP database[2], which offers insights into optimal growing conditions. The available results cover a selection of opportunity crops aligned with the Vision for Adapted Crops and Soils (VACS) and additional benchmark crops (see Annex II).

After selecting a crop, users click *"Continue to select your water and input management"* to proceed to the next step.

[2] The ECOCROP database is designed to collect and provide information on plants characteristics and crop environmental requirements for more than 2000 plant species, and it is used to determine the suitability of a crop for a specified environment. The ECOCROP database is available at https://ecocrop.apps.fao.org/ecocrop/srv/en/home

Step 4. Irrigation and farm management

In this step, users specify the irrigation practices and farm management level applied at the selected location. The section begins by asking whether irrigation is used on the farm.

Next, users specify the farm management level by selecting one of the following options:

- Low input: characterized by a small workforce, the use of traditional local crops, and minimal application of fertilizers or pest control measures.
- High input: involves a medium to large workforce, the use of high-yielding improved crop varieties, and the regular application of fertilizers and pest control.

If users are uncertain about their management level, they can complete a brief questionnaire to determine whether the system aligns more closely with low-input or high-input farming. The questionnaire assesses key aspects of farm practices, including:

- Farming goal – Subsistence (household use) vs. market-oriented (commercial production)
- Crop varieties – Traditional/local vs. high-yielding/improved
- Labour intensity – Manual labour vs. fully mechanized operations
- Fertilizer and nutrient use – No application vs. optimal application
- Pest, disease, and weed control – No chemical use vs. regular, optimized application
- Soil fertility management – Reliance on fallows vs. advanced soil management practices

Once selections are made, users proceed by clicking *"View Your Crop Suitability Results"*.

Step 5. Crop suitability report summary

This section provides an overview of the crop suitability and agro-ecological attainable yield results for the selected location, based on the specific combination of soil type, crop, irrigation, and farm management options. These results are based on the Agro-Ecological Zoning (AEZ) framework[3], developed jointly by the Food and Agriculture Organization (FAO) and the International Institute for Applied Systems Analysis (IIASA). The methodology is detailed in the GAEZ v5 Model Documentation. Global outputs, developed for selected opportunity crops in alignment with the Vision for Adapted Crops and Soils (VACS) and categorized by soil groups identified in the Harmonized World Soil Database (HWSD v2) (FAO & IIASA, 2023), are published and made available through the SoilFER Geospatial Platform[4].

In the SoilFER App for localized crop suitability, results are presented as:

- **Crop suitability index**, classified into defined suitability categories. More information on this dataset can be found at this link.
- **Agro-ecological attainable yield**, expressed in kilograms of dry weight per hectare (kg DW/ha) for each grid cell. More information on this dataset can be found at this link.

All results are tailored to the user's selected inputs for soil type, water availability, and input management, and are provided for both the exact location and a surrounding 10 km buffer zone.

In addition, a list of alternative suitable crops for that location, based on the same input conditions, is provided.

Users can download the results as a PDF report by clicking "*Download your detailed crop suitability report.*"

[3] GAEZ v5 Model Documentation accessible at https://github.com/un-fao/gaezv5/wiki
[4] SoilFER Geospatial Platform https://data.apps.fao.org/soilfer

PEARL MILLET SUITABILITY SUMMARY

Your crop suitability index is **10 < SI < 25**.
This means your crop has a **Marginal suitability** under selected conditions.

- SI > 85: Very high
- SI > 70: High
- SI > 55: Good
- SI > 40: Medium
- SI > 25: Moderate
- SI > 10: Marginal
- SI ~ 0: Very marginal
- Not Suitable

The average suitability index in a buffered area of 10 km is **Marginal**. This means your crop suitability is **the same as** the average suitability.

The attainable yield at your location is **93 kg/ha** (Dry Weight).

ALTERNATIVE SUITABLE CROPS

Considering your input parameters, this is the suitability of other crops at your location:

Biomass sorghum - *Sorghum bicolor*

55 < SI < 70 (Good)

Cassava - *Manihot esculenta*

55 < SI < 70 (Good)

Banana - *Musa spp.*

25 < SI < 40 (Moderate)

DOWNLOAD YOUR DETAILED CROP SUITABILITY REPORT

For more detailed information on crop suitability (metadata link) and attainable yield (metadata link), please visit the SoilFER Geospatial Platform at https://data.apps.fao.org/soilfer/

ANNEX I: SoilID algorithm

Introduction

Understanding soil characteristics at a local scale is essential for sustainable land use planning, soil fertility management, and climate-resilient agriculture. This analysis focuses on identifying and classifying soil types within defined areas of interest using spatial soil data and open-source geospatial tools. The results contribute to SoilFER's objective of enhancing national soil information and supporting evidence-based decision-making.

Data requirements

The implementation of this soil identification methodology relies on the integration of spatial datasets, tabular soil property databases, mapping platforms, and optional field validation tools. Each data component plays a critical role in ensuring the scientific rigor, spatial accuracy, and reproducibility of the soil classification output. The following subsections describe the required data sources and their respective functions within the workflow.

Geographic Coordinate for Area of Interest (AOI)

The entry point for the workflow is the definition of an Area of Interest (AOI), represented by a single geographic coordinate (latitude and longitude). This point defines the spatial center for all subsequent data extraction steps. The accuracy of the coordinate is essential, as it determines the spatial zone within which soil types will be analyzed and classified.

OpenStreetMap (OSM) Basemap

OpenStreetMap is an open-source global basemap that provides detailed geographic context, including roads, settlements, water bodies, and land-use features. OSM is used as the reference layer for selecting and visually verifying the AOI. This ensures that users can anchor their selection based on real-world features, enhancing location precision and contextual relevance.

Circular Buffer Zone

Once the AOI is identified, a circular buffer—typically with a radius of 10 kilometers—is generated around the point. This buffer defines the spatial extent from which soil data will be extracted. The use of a standardized buffer allows for consistent spatial units of analysis, enabling comparisons across different geographic contexts. All soil properties and proportions calculated within the workflow are constrained to this defined zone.

HWSD v2 Raster Dataset

The Harmonized World Soil Database version 2 (HWSD v2) raster dataset is a global soil information product developed by FAO and IIASA. The raster layer consists of pixels, each containing a Soil Mapping Unit (SMU) identifier that links to detailed soil information. Within the workflow, this dataset serves as the core spatial layer from which SMU distributions are extracted within the buffer zone. It provides the quantitative basis for calculating soil coverage and proportional dominance.

HWSD v2 Soil Component Database

Complementing the raster layer, the HWSD v2 soil component database is a tabular dataset containing descriptive and quantitative attributes associated with each SMU. Key fields used in this workflow include:

- HWSD2_SMU_ID – Soil mapping unit identifier
- WRB2 – World Reference Base for Soil Resources classification
- TEXTURE_USDA – USDA-based soil texture classification
- ROOT_DEPTH, DRAINAGE, COARSE – Key physical soil characteristics
- LAYER – Soil horizon depth (e.g., D1 for topsoil)
- SHARE and Adjusted_SHARE – Percentage contribution of each component within an SMU

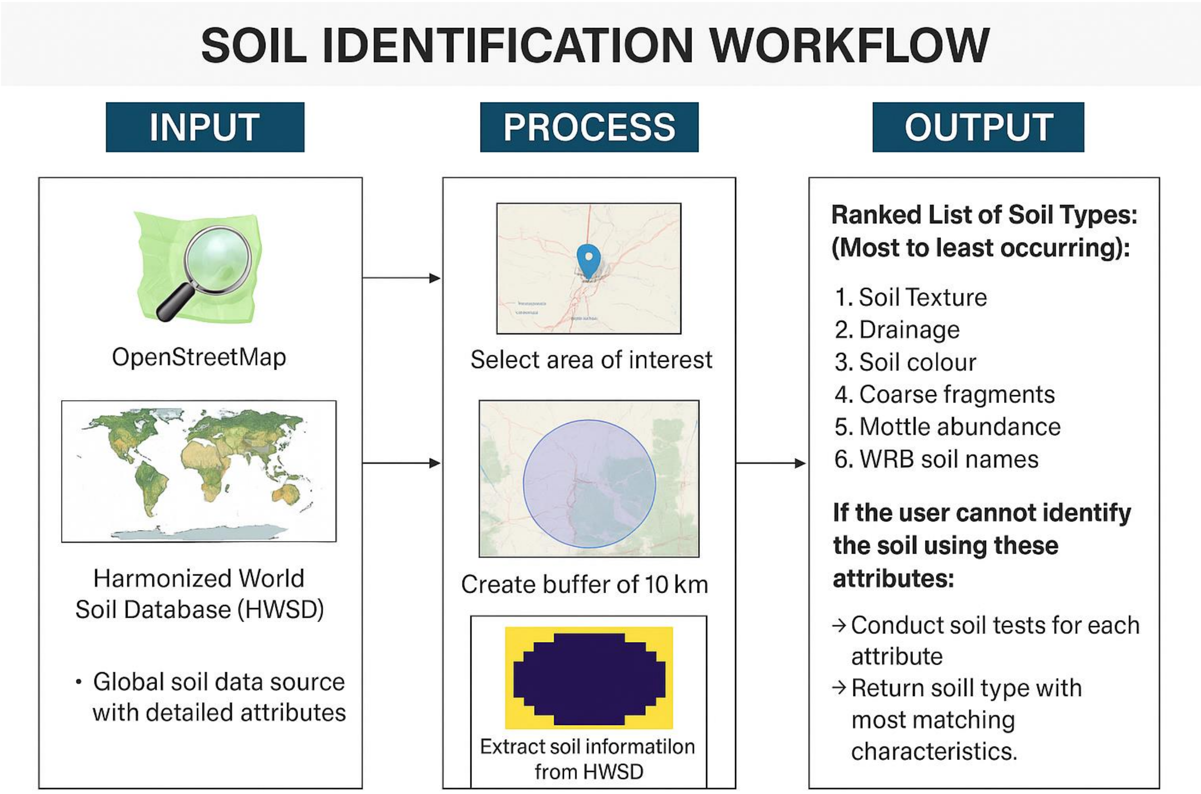
This database allows the user to retrieve soil properties for each SMU identified within the raster buffer zone and supports further analysis such as soil grouping and filtering.

Analytical Software and Processing Tools

LIBRARY	PURPOSE
GEOPANDAS	Vector data manipulation, buffer creation, CRS transformations
RASTERIO	Raster file reading, masking, pixel analysis
SHAPELY	Geometry creation and manipulation
NUMPY	Raster data analysis, frequency counts
PANDAS	Tabular data processing, filtering, and merging
MATPLOTLIB OR FOLIUM	Visualization of spatial results
PYPROJ	CRS transformations (especially for accurate buffering)

Methodology

The methodology presented in this workflow follows a systematic and structured approach for soil classification, combining spatial data extraction, quantitative analysis, and, where necessary, field validation. The workflow is designed to be both data-driven and adaptable to varying spatial contexts.



The process begins by defining a precise Area of Interest (AOI), which is specified by a geographic coordinate point (latitude and longitude). This location acts as the focal point around which spatial data will be extracted and analyzed. The AOI is buffered using a circular geometry, with a radius of 10 kilometers, to delineate the analysis boundary.

Once the AOI is established, the next step is to extract data from the HWSD raster layer. This involves masking the raster using the buffered AOI to isolate the soil mapping units (SMUs) present within that zone. Each SMU in the raster corresponds to one or more soil types stored in the HWSD tabular component database. The relative presence of each SMU is quantified by calculating the proportion of raster pixels associated with each ID, which gives a spatial representation of the extent of different soil units in the buffer.

The extracted SMU IDs are then matched with the HWSD soil component database to retrieve relevant soil attributes, including texture, World Reference Base (WRB2) soil type names, drainage, and other physical properties. At this stage, the data is filtered to include only top-soil values (Layer D1), and entries with missing or invalid data are excluded to ensure reliability.

Following data extraction there is an adjustment of the soil component shares using the adjusted share values. These are normalized within each SMU to account for overlapping soil types. The workflow then aggregates soil components by their WRB2 classification and computes the total adjusted share for each group.

The final step involves ranking the soil based on the cumulative adjusted share with the associated attributes. However, if the users cannot identify their soil based on the information provided then they are directed to conduct field validation. This involves five key soil tests which are texture, drainage, color, coarse fragment content, and mottling to empirically verify the characteristics observed in the spatial dataset.

This integrated methodology ensures that soil classification is both spatially comprehensive and grounded in field reality, providing a robust framework for supporting land-use decisions, agricultural planning, and ecological assessments.

ANNEX II: Crop list

CATEGORY	Crop Name	Scientific name
Opportunity Crops (Trees and Perennials)	Acacia	*Acacia holosericea/ Acacia colei/ Acacia sp.*
Opportunity Crops (Annuals/Biennials)	African eggplant	*Solanum aethiopicum/ Solanum macrocarpon*
Opportunity Crops (Trees and Perennials)	African Jujube	*Ziziphus jujuba/mauritiana*
Opportunity Crops (Annuals/Biennials)	African nightshade	*Solanum scabrum / Solanum nigrum*
Opportunity Crops (Annuals/Biennials)	African Rice	*Oryza glaberrima*
Opportunity Crops (Trees and Perennials)	Allanblackia/ tallow tree	*Allanblackia floribunda*
Opportunity Crops (Annuals/Biennials)	Bambara groundnut	*Vigna subterranea*
Opportunity Crops (Trees and Perennials)	Baobab	*Adansonia digitata*
Opportunity Crops (Trees and Perennials)	Bushmango	*Irvingia gabonensis*
Opportunity Crops (Trees and Perennials)	Cashew	*Anacardium occidentale*
Benchmark/Comparator Crop	Cassava	*Manihot esculenta*
Opportunity Crops (Annuals/Biennials)	Cocoyam/elephant ear	*Xanthosoma sagittifolium*
Opportunity Crops (Annuals/Biennials)	Cowpea	*Vigna unguiculata*
Opportunity Crops (Trees and Perennials)	Desert date	*Balanites aegyptiaca*
Opportunity Crops (Annuals/Biennials)	Finger Millet	*Eleusine coracana*
Opportunity Crops (Annuals/Biennials)	Fonio	*Digitaria exilis*
Opportunity Crops (Annuals/Biennials)	Grass pea	*Lathyrus sativus*
Opportunity Crops (Annuals/Biennials)	Groundnut	*Arachis hypogea*
Opportunity Crops (Annuals/Biennials)	Joseph's Coat/Amaranth (leaves)	*Amaranthus tricolor/ Amaranthus cruentus/ Amaranthus sp.*
Opportunity Crops (Annuals/Biennials)	Lablab/Bonavist (dry)	*Lablab purpureus*
Opportunity Crops (Trees and Perennials)	Locust bean	*Parkia biglobosa*
Benchmark/Comparator Crop	Maize	*Zea mays*
Opportunity Crops (Trees and Perennials)	Moringa/drumstick tree	*Moringa oleifera*

Opportunity Crops (Annuals/Biennials)	Mung bean/green gram	*Vigna radiata*
Opportunity Crops (Annuals/Biennials)	Okra	*Abelmoschus esculentus*
Opportunity Crops (Annuals/Biennials)	Pearl millet	*Pennisetum glaucum*
Opportunity Crops (Annuals/Biennials)	Pigeon pea	*Cajanus cajan*
Opportunity Crops (Trees and Perennials)	Plantain	*Musa balbisiana/Musa spp*
Opportunity Crops (Annuals/Biennials)	Pumpkin	*Cucurbita spp.*
Opportunity Crops (Annuals/Biennials)	Sesame	*Sesamum indicum*
Opportunity Crops (Trees and Perennials)	Shea	*Vitellaria paradoxa*
Opportunity Crops (Annuals/Biennials)	Sorghum	*Sorghum bicolor*
Benchmark/Comparator Crop	Soy	*Glycine max*
Opportunity Crops (Annuals/Biennials)	Sweet potato	*Ipomea batatas*
Opportunity Crops (Annuals/Biennials)	Taro	*Colocasia esculenta*
Opportunity Crops (Annuals/Biennials)	Tef	*Eragrostis tef*
Benchmark/Comparator Crop	Tomato	*Solanum lycopersicum*
Opportunity Crops (Annuals/Biennials)	Watermelon	*Citrullus lanatus*
Opportunity Crops (Annuals/Biennials)	Yams	*Dioscorea rotundata/ Dioscera dumetorum/ other subsp.*