Protocol for Field Survey

Guidelines for Field Surveyors on Soil Sample Collection and Field Assessment of Agricultural Lands in Africa

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Acronyms

AU	African Union
CAA	Cultivated Aquatic Area
CMTA	Cultivated and Managed Terrestrial Area
CS	Country Supervisor
CSV	Comma separate values
EU	European Union
FNSSA	Food and Nutrition Security and Sustainable Agriculture
FYM	Farmyard manure
GPS	Global Positioning System
GPX	GPS eXchange format
IITA	International Institute of Tropical Agriculture
ISRIC	International Soil Reference and Information Centre
KML	Keyhole Markup Language
LCCS	Land Cover Classification System
ODK	Open Data Kit
PSL	Proposed Sampling Location
PSU	Primary Sampling Unit
QR	Quick response
SIS	Soil Information System
SDMT	Survey Data Management Tool
SNV	Semi-Natural Vegetation
SOTER	Soil and Terrain databases
SP	Service Provider
SP-ID	Sampling point identifier
SS-ID	Soil Sample Identification
SSU	Secondary Sampling Unit
SWC	Soil and Water Conservation
TSU	Tertiary Sampling Unit
VQC	Visual Quality Control
WP	Work package

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Preface

The Soils4Africa project aims to build an open-access Soil Information System (SIS) for Africa that will allow for monitoring of soil quality. A set of key indicators of soil quality have been identified and they will be assessed using field data to be collected from 20,000 sampling sites spread across the African continent, using standard protocols and operating procedures for data collection that allows for repeated assessment and monitoring of soil properties and soil quality. This soil information system will become part of the knowledge and information system of the EU-AU Partnership on Food and Nutrition Security and Sustainable Agriculture (FNSSA) and will be hosted by an African organisation with the requisite capacity to manage the system. This system will inform decision making on policies and interventions towards sustainable agricultural intensification in Africa. The field campaign that is planned to take place from January 2022 to June 2023 will provide the baseline data for future monitoring of soil conditions.

The Soils4Africa project has seven (7) work packages which are all interconnected. Work package one (WP1) deals with project coordination, communication, and dissemination. WP2 is dedicated to stakeholder engagement and the identification of the relevant soil indicators. WP3 covers the design of the soil information system. WP4 focus on the field campaign and capacity building for sample collection and field observation, WP5 deals with the laboratory analyses of all soil samples collected in WP4. WP6 is responsible for the IT infrastructure and building the SIS and for capacity building on managing and maintaining the SIS. Finally, WP7 centres on the ethical aspects of the project including data privacy and environmental protection.

The project will collect soil samples and make field observations for agricultural land only. Agricultural land in this context refers to arable land, permanent crops and permanent pastures[1]. Arable land includes land under temporary crops, temporary meadows for mowing or pasture, land under market and kitchen gardens and land temporarily on fallow (less than five years). Permanent crops area includes land cultivated with crops that occupy the land for long periods (cash crops such as cocoa, coffee and rubber); land under flowering shrubs, fruit trees, nut trees and vines, but excludes land under trees grown for wood or timber, while 'permanent pastures' refers to land used permanently (five years or more) for herbaceous forage crops, either cultivated or growing wild (wild prairie or grazing land). In the end, the project will have a system in Africa that will enable the monitoring of soil quality in relation to intensification of agricultural use, so that threats to soil resource and opportunities for sustainable intensification could be identified.

This deliverable refers to the protocols and instructions for conducting the field campaign and consist of two documents. One is the protocol for the field survey, or the instructions for the field surveyor. The second document is the protocol for field survey management, in other words, the instruction for the country supervisor. The protocol for the field survey is a standard protocol that applies to all the surveys that are conducted for this project across Africa, such that results for one region, or the

[1] https://www.fao.org/faostat/en/#data/RL

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other are comparable. The protocols need to be strictly adhered to. The instructions for management of the survey are more general and allows for some flexibility in the implementation of the protocol and to adjust to the conditions in the region and country where the survey is implemented.

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1 Introduction

The soil information system for Africa requires information on land use and land cover, terrain condition, soil properties and land management. The data collected in the field (field observation) and the results of soil analysis will be used to assess soil quality. Land use and land cover measurement will include field observations on the type of vegetation, the current use of the land, purpose of the farming activities and crop types, and field distribution patterns. Data on soil surface and terrain condition will include slope, soil erosion, soil drainage, stoniness, and soil depth. A set of both physical and chemical properties defined in the deliverable "D3.3 Detailed guidance for fieldwork" will be determined in the laboratory using the soil samples collected. Field observation will also be made on land management and the data will include presence or absence of soil conservation measures, use of mineral fertilizers or manure, irrigation or any other practices employed by the farmers for the management of the land. A set of soil parameters, such as particle size distribution, pH, organic carbon content, carbonate content, total nitrogen content, extractable (available) phosphorus content and extractable (exchangeable) potassium content), is considered as the minimum information needed to support the quantification of soil quality from an agricultural perspective. Detailed explanations of each of the soil parameters as indicators of soil quality are contained in *D3.1 Methods for deriving selected soil quality indicators* (Moinet et al., 2021).

In the Soils4Africa project, a suitable sampling design has been formulated. The details are provided in the deliverable "D3.2B Soils4Africa Sampling design". The document defined the approach for selecting sampling locations and D3.3 Detailed guidance for fieldwork (Huising et al., 2021) provides the guidelines on which this protocol for field for field survey is developed. The Soils4Africa project will, in practice, be the first assessment of soil quality across Africa using a uniform and standard methodology. The protocols for the field data and soil sample collection provides for a standard method for the observations in the field and for the collection of the soil samples, such that repeated measurement and monitoring of the soil properties is possible.

There are several protocols that will be/are developed for the various types of activities in relation to the field campaign and that cover different aspects of the survey. Beside the protocol for the field survey per se, which is covered in the present document, there is a protocol for sample preparation and processing. There is a protocol for sample shipment, and a protocol for soil analysis that will be done locally. There is a protocol for the management of the field campaign that provides instructions for the country supervisor on how to organize and manage the field campaign in his/her country. The latter is the subject of the second document that is part of this deliverable. It will be presented as a separate document.

The present field protocol, or instructions for the field surveyor, provide the rules and instruction for the field survey that is planned to be conducted in the period from January 2022 to June 2023. It will provide the baseline data for the monitoring of soil quality, and which includes assessment of both permanent and dynamic soil features. For future assessment the protocol will need to be adjusted to focus on the more dynamic soil properties for the purpose of monitoring purpose. However, none of the soil properties are truly static or permanent and are subject to change depending on

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the change process. For each of these properties there is a different time horizon and consequently a different temporal resolution that allows for the monitoring of change. However, this is not of relevance to the present protocol.

This protocol is for making field observation and soil sample collection on agricultural land. It is intended for use by the field survey teams or surveyors as a training material and as a reference document in field, during the field survey. There will be additional training material available to further explain the instructions on particular aspects and elements of the protocol. This field survey protocol is the reference document for the field surveyor, and he/she needs to fully understand the instructions given. At the same time this document is intended for the field supervisors and country coordinator who have to manage the campaign within their country and who have to support the field surveyor in conducting their task. The country supervisor needs to have an even more profound understanding of the protocol and methods presented. Likewise, the regional hub coordinator needs to be fully abreast with protocol and instructions for the field survey, carrying the ultimate responsibility for the campaign within their African sub-region.

The protocol is presented as outlined below:

- Preparations and materials for fieldwork
- Safety and Security issues
- Navigating in the field
- Rejection of a secondary or tertiary sampling unit
- Layout and sampling procedure
- Soil sample collection
- Labelling
- Land and Soil surface characterization
- Landform and terrain observations
- What to do in special situations
- Protocols for making observations on land use and land cover

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2 Preparations for fieldwork

Proper and adequate preparation is vital towards a successful field survey. Preparations for the field work entail, firstly, downloading all reference and instruction materials (protocols etc.) and studying them. Then, downloading of the sampling locations to be surveyed and planning your itinerary and survey and getting all required materials needed for the field work. The preparation for the field survey may require some time, especially getting and preparing all materials required, such that a start should be made with the preparation as soon as a job has been assigned to you. And the time needed for the preparation should be included in the planning for the field survey. For example, QR codes will be used to for soil sample identification (SS-ID). These QR codes need to be generated and printed before going to the field. Furthermore, all tools that are used in the field need to be tested. Also, you should practice using the tools, such that no time is wasted in the field finding out how it works. All that requires time. Ensure you get a waterproof bag to protect equipment such as smartphones, GPS and others, and documents in case of rain.

Plan your itinerary using Google Maps or other similar apps to also get an idea on how much time you will spend in the field. You are strongly advised to print out the maps with sampling point locations for the different primary sampling units (PSUs) separately. This becomes handy as a reference for navigation to sampling points in the field and/or to make annotations on of where the car has been parked from where you have been further tracking on foot, for example. Or, to make annotations of observations in the field, or to make notes on the points already covered.

All data recording, in principle, is done using electronic means. Install ODK-collect (see instructions below) on your smart phone, download the form (see below instructions how to download the form) and ensure it is working properly. The smartphone battery should be fully charged before leaving to the field and you need to have a fully charged reserve battery, power bank or a second phone as backup if you will be staying for consecutive days in the field. Make sure you have reserve batteries for the GPS. Other recommended apps should be downloaded and practiced with, to make sure you're not taken by surprise in the field to find out that the app is not working, or that you do not know how it works. Upload coordinates of the sampling units and the backup locations to the GPS device, or to the smartphone when using MAPS.ME. Use GPS waypoint manager, or MAPS.ME to navigate in the field.

The surveyors should ensure they have received the accreditation letter which will be provide by the country supervisor. The letter is necessary for the surveyor to explain and justify his mission and to present it to the farmer or landowner, or local authorities when needed. Make sure that before you leave to the field that you have spoken with the Country Supervisor (CS) or possibly Field Supervisor (FS) assigned to you and have gone through all the preparations you have made and get approval to start the survey activities.

Observe general rules with respect to weather conditions. When it is raining soil sample collection cannot be done, and therefore also not recording of associated observations in the field. It is left to the surveyor to make the call whether to go to the field, but in case of isolated showers, for example, it is very well possible to conduct the field survey. Make sure you have protective clothing.

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Listed below are the equipment and materials needed for the fieldwork with their specifications.

2.1 Materials and equipment

Item	***Specifications/Quantity***	***Sample***	***Remarks***
Accreditation letter			To be provided by the country supervisor
Suitable vehicle(s) for transportation in the field.	4x4 car / saloon car, motorbike	 	A vehicle, or means of transport, is needed to reach the area (PMU) where the sampling points are located. Type of vehilce, 4wd or 2wd, depends on the condition of the roads. If motorable roads can't bring you close to the sampling locations, consider hiring a motobyke that is often avaialbe locally at little cost. (It will save a lot of time).
Smart phone	Android Version 9.0 or higher, 4GB RAM or more - with all required apps such as barcode scanner and MAPS.ME as indicated in this manual		The smartphone is used as a data recording device and is essential to have. Don't use cheap chinese brand phones, because features like 'location' may not work properly. At least ensure that all required services are workng properly (like 'location' and barcode scanning services). Preferably have a back up smartphone. It is essential you have 2 smartphones if you are going to use your phone as a means of navigation in lieu of a handheld GPS device. Make sure you can power your phone for a longer period of time (use backup battery, powerbank, or other)
ODK field forms loaded onto the smartphone and print out for back up			ODK-collect is the primary means of data recording in the field. Instructions on how to access the forms is given below. Having a printed

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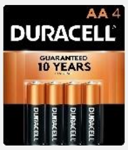
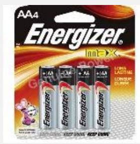
			version of the ODK form is useful for data recording if, for one reason or other, you cannot use your smartphone in the field. The data can be entered online at a later stage (contact your CS). You will be able to download the PDF version of the ODK from the SDMT
Permanent markers and pens plus writing pad			You need writing materials as back up if electronic recording device does not work. Markers are needed for writing the labels on the sample bags, to mark the soil augers at 20 and 50 cm.
Handheld GPS device			Handheld GPS device will be the recommended tool for navigation in the field (the last mile) to reach the designated sampling locations. Alternative solution is the use of MAPS.ME (see below)
Batteries for GPS	AA batteries	 	You need an AA size battery. This should be dry cell or alkaline battery. Ensure you load the batteries into the GPS device and also have at least 2 pairs as spare before going to the field
MAPS.ME App	[Android Apps on Google Play]		MAPS.ME is an app for navigation like google maps. It allows to download maps on your phone so you have them as reference for navigtion in the field. Coordinates of the sampling locations are uplaoded and displayed on the map. The app will be used for this project as an alternative app for navigation in the field in the absence of a handheld GPS device.

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Power bank for Smartphone	10000MAh		The power bank provides additional power support for your smartphone. If you have a smartphone with a strong and fully charged battery, you may not need to carry a power bank along to the field but it is advisable to have one in case of any eventualities
Sturdy plastic **and** paper or cloth sample bags	About 30 cm by 26 cm, or 1-litre bag, both for the plastic as the cloth or paper bag; number of bags: 1 plastic bag and 1 other bag per soil sample; cloth bag should have cord to close the bag	 	Each sample is going to do double-bagged. The sample goes into the plastic bag and then the plastic bag is bagged with a cloth bag or papper bag to provide sturdiness
Labels/barcode	QR codes printed on 300gsm A4 paper		There is a section in the ODK form where you will scan a QR code for the sample ID (SS-ID). After scanning place the QR code tag in between the bags. The QR codes are in duplicate, do not separate them. The barcodes will be provided by the CS (either in electonic form or printed). If to be printed use quality paper 300gsm to make the labels more sturdy
Plastic pouches	Ziploc plastic pouches small; Size: 5 x 7 cm		The pouches are used to put the QR codes in (in duplicate). Ziplock plastic ouches are used to protect the labels getting moist or wet.
Stapler	Handheld stapler		Can be any type or brand, but if available a handheld stapler is preferred to be used in the field; it is used to seal the sampling bags. Make sure you have enough staples.

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Standard soil auger	Edelman type auger; combi type, 7cm ∅		The Edeleman type auger is the standard and preferred tool for soil sample collection for this project. It will be provided by the CS when required. The soil auger soil be marked at 50cm and 10cm with either permanent marker or tape.
Spade	standard size with the bottom flat rather than being pointed		The spade is used as alternative for, or as supplementary to the soil auger for sample collection (not for soil depth measurement). Sample collection for the 0-20 cm especially may be easier with spade in certain circumstances (very sandy or very clayey soils)
Pipe/cylinder	The mouth edge should be sharp (needs to be sharpened); diameter around 7cm		Pipe, or cylinder should be used only if a soil auger is not avaiable; to be used for soil sample colelction and not soil depth measurements; a pipe should be preferred over a spade for sample collecton at 20-50cm. The pipe needs to be marked using tape at 20 cm and 50 cm.
Hammer/mallet	A big size – Carpenter's hammer		Needed only if you are using a pipe for soil sampling; the mallet is used to hammer the pipe down the soil.
Plastic buckets	Two 10-litre buckets, with different colours		You will need 2 plastic buckets of different colours for soil sample mixing in the field. Ensure you label the buckets: One as "TOPSOIL" and the other as "SUBSOIL"
Jute bags	Size: 50kg bags; The number of bags is dependent on the number of samples to be carried (not more than 30-40 samples per bag).		You need the jute bags to carry the soil samples in the field and for transportation and later shipping to the lab. The number of bags depends the weigth you want tocarry per

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			bag. (Thirty (30) soil samples may weigh already 20 kg).
A box to store and transport the samples			Serves as possilbe alterantive to jute bags for carrying and shipping the soil samples (is not the preferred and recommended option)
Measuring tape	The tailor type measuring tape (tape rule)		Any type or device that can be used to measure 20 cm, 50 cm, and 100 cm on the soil auger (and on pipe or spade when applicable) to mark these points such that soil depth can be measured for soil sample collection and soil depth measurement.
Knife	One blade of about 20cm		A straight knife is needed to remove the soil samples from the auger or to slit the soil on the spade
Hand trowel	One (1)		Hand trowel is needed for mixing the soil samples in the buckets -making of composite soil sample
Appropriate wears			Safety shoes/boots, jungle boots, and raincoat, Appropriate clothing for the type of work and weather conditions are necessary.

2.2 Loading sampling location coordinates into handheld GPS device

If the surveyor will be using a GPS for navigation in the field, all the locations of the sampling points assigned to the surveyor needs to be uploaded to the GPS device. The list of points together with their coordinates will be provided by the CS and will be available through the SDMT. Depending on the GPS device, the coordinates need to be in a specified format (though very much standardized across the various brands) and may therefore require conversion. Instructions are provided below. Call in the help of the CS in case you need any help in this

2.2.1 File conversion and uploading files onto the GPS device

The file in which the coordinates of the sampling points are provided is a CSV file (a comma separated values format). If you have received the coordinates as an MS Excel file (.XLSX), for one reason or other, you need to convert the MS Excel file to a CSV file

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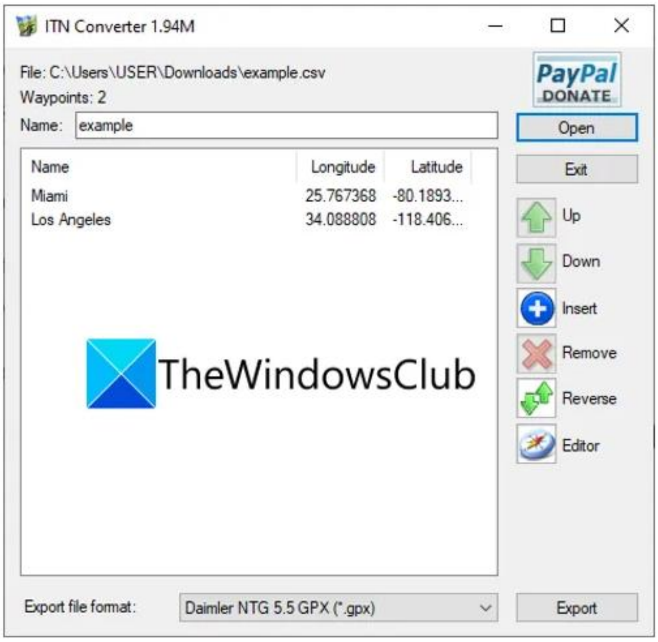
before you can convert to GPX or KML format. In MS Excel safe the file as 'csv' file (Go to 'File', select 'Safe As' and then select the CSV option under 'File Format:', specify the location where to safe the file and safe).

GPX stands for GPS eXchange Format, while KML is an acronym for Google Earth's Keyhole Markup Language format. Both these file formats are standard GPS file formats that are used to store and exchange GPX data including waypoints, routes, tracks, etc. You have been given coordinates of the sampling points in a csv file and want to convert it to GPX so that you can upload it into a GPS handheld device. To convert a csv file to GPX, you can use third-party software like GpsPrune, RouteConverter, ITN Converter, and more. These are free downloadable, open-source programs. You can also use a free online service that supports csv to GPX conversion, without having to download and install the program. However, below the example is given for 'ITN Converter', which need to be installed on your computer. Instructions are provided how subsequently the file conversion to GPX or KML is done (on a Windows Computer).

ITN Converter

ITN Converter lets you convert a csv file to different versions of a gpx file, including gpx Garmin MapSource, GPS eXchange, and Garmin Nüvi. Here are the main steps to convert a csv file to gpx or kml formats using this free software:

1. First, download and install this software (https://itn-converter.software.informer.com/)
2. Click on the 'Open' button and browse and import the source CSV file.
3. Next, you can edit the longitude and latitude information as per your requirement.
4. After that, select output format to GPX or KML.
5. Finally, press the Export button to start the GPS file conversion.
6. Once the conversion is done, power the GPS device and connect to the computer and transfer the file into the GPS device using the cable that comes with the GPS device.



2.2.2 Manual loading of points into handheld GPS device

You may need to enter the coordinates of the points you have been assigned into your handheld GPS device particularly if for one reason or the other you lose the already saved points in the field. Do the following to manually enter the coordinates one after the other.

1. Power on your device and wait while it searches for a signal. Press the menu button to access the main menu.
2. Press the "Select" button to move to and select "Mark Waypoint."

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3. Select the "Location" field and select the coordinates you want to enter (Make sure the coordinates are in the same format used by the GPS. If not in the same format, you can change the coordinates format under "Position format" in "Settings" on your GPS device).
4. Press "Done" when you have finished entering the fields. Make any other changes you desire, such as notes or elevation, and click "Done" or "Go" (depending on your device) to save the changes.

2.3 Loading of the coordinates of sampling points into Google Maps app

Displaying the sampling point locations in Google Maps, is in first instance intended for the planning of your trip; to know where all the points are located and subsequently planning your route. We assume you are familiar with using Google Maps for this purpose.

Google maps can be used for navigating in the field but requires internet coverage/access in the area to be surveyed. In case of good internet access this a very useful option because it allows you to access the satellite imagery data that Google Maps provides, which may be very helpful for your orientation in the field. It may also show roads and tracks that can be followed to navigate to the sampling points whilst in the field. It is essential you have internet access (and data bundles) on your phone to enjoy this service.

If no internet access can be guaranteed, the alternative is to print images of Google Maps of the areas to be surveyed, with the sampling point locations displayed, and take these to the field for orientation. In this case the sampling points are displayed in Google Maps on your computer and maps are printed out (using a screen dump, for example). To be of use in the field, the scale of the maps (printouts) needs to be such that prominent landscape features can be clearly recognized. For that purpose, it is advised to zoom into the various PMUs and print out maps for each PMU separately. You can request the CS to provide you with a link to file that contains the sampling points in Google Maps. Click on the link and it will take you to Google Maps app. In case you want to access these points on your phone for navigation in the field, ensure that you have the app on your phone (though the app comes installed on all android devices). For using on your computer, click the link on your computer and it will take you to Google Maps displaying all the sampling points assigned to you.

2.4 Downloading MAPS.ME app and uploading sampling locations' coordinates

1. First download and install MAPS.ME app on your phone (you need internet access). You will be able to do this using the Play Store on your phone (https://play.google.com/store/apps).
2. Click to open MAPS.ME.
3. Click on the 3 horizontal bars
4. Click on ☰ and then select "Download Maps".
5. Click on the "Find map" bar and type in the name of your country, e.g., Ghana.

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6. Click Download. In this way you have successfully downloaded your country map. You only need to do this once. Ensure your location is enabled on your device. You can do this on the settings of your phone.
7. Select ☰ and choose "Terrain" as map layer.
8. Also, download the file containing the coordinates of the sampling locations and save on your phone (you need internet access for this). You will receive the file as an email attachment from your Country Supervisor or their designates. The file will be in KML format. If the file is in csv format, convert to KML according to the instructions given in section 2.2 above.
9. Click to open the KML file containing the coordinates of the sampling locations which you have saved on your phone. Click on the file, some options to open the file will pop up (depending on the types of apps you have installed on your phone)
10. Click on open with MAPS.ME. The app will open, and a message will pop "Bookmarks loaded successfully! You can find them on the map or on the bookmarks Manager". The message will disappear in less than 20 seconds.
11. The points will be displayed by their name, which will be coordinate of the sampling point. To change the name of the sampling point to the sampling point ID such that the points are displayed by their name, rather than by their coordinates, you edit the name of sampling points:
12. Select ☆ in the menu bar and click the file name to open.
13. All the points in the file will be displayed by the coordinates as name. Select the ⋮ for "more" at the far right end of the point that you want to change the name off.
14. A menu will pop up and select "Edit"
15. A new screen will appear with the Name, Set and a placeholder where you can add "Your Description"
16. Select the name (click on the name, which are the coordinates at this point still)
17. Delete the coordinate and enter the sampling point ID corresponding to this particular point.
18. Click on SAVE (to save the changes)
19. Repeat step 12 to 17 for all points in the file.
20. Go back to the main menu and you see all the points displayed by their sampling point-ID (SP-ID)

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3 Safety and Security issues

Security during field work is an important issue. Care and due consideration must be taken to guarantee the safety of lives and property.

- It is important that at least two persons be in a group (2 persons per service provider) for the purpose of security and to aid or help one and another where and when necessary.
- Familiarize yourself with the security conditions in the area where the survey is to be conducted. If there are major concerns, please report to the country supervisor.
- The surveyor (SP) shall take action to eliminate, minimize, avoid, or report any hazards of which they are aware and follow safety and health instructions where and when applicable.
- Ensure you get consent of the community leader, village head or their representatives when applicable before sampling in the field. (At least announce your presence in the area and explain your purpose.) When in the field at the sampling location, if you encounter the farmer, farm or plantation manager ensure you get their permission. Fill the farmer Consent ODK form and in this form the farmer or the community leader would be able to provide his/her name (name in full) and append their signature. Where consent is denied, please use the back-up locations already provided.
- Security can often be provided at local or community level at a limited cost (like vigilantes, and will be most useful as they often know the farmers)
- Areas that require more than 1 hour of walk to access, restricted areas, unsafe areas should be excluded from the survey. In this case, make use of the available back-up sample locations.
- The accreditation letter provided should be always with you during the field work. In most instances it will be helpful to introduce yourself to the local authorities (community leaders) to inform them about the purpose of the soil survey you are conducting.
- It is generally helpful to assess how close you can get to any particular sampling location by car (safely), because this will affect how quickly surveys can be conducted and also reduce security risk (e.g., getting lost).
- As part of security measures, please ensure you have the following before going into the field:
    - Telephone number of the Country supervisor
    - Telephone number of security personnel around the area you want to work
    - Telephone number of a trusted relative/family who knows about your mission
    - Join the dedicated WhatsApp group for the Soils4Africa project (There is a group created for each country)
    - Telephone number of the local authorities or head of at least one community/town closest to your sampling area (optional)

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4 Navigating in the field

How to navigate in the field is important. It directly impacts on the effectiveness and efficiency of the work. The number of sampling points that could be done per day is directly related to mastery in field navigation. This section explains how to navigate with your phone in the absence of a handheld GPS device, and how to properly navigate in the field using handheld GPS device. There are several options to do this ranging from the traditional method of using topographic maps to the modern GPS navigation methods. In this protocol the focus is on the use of the modern GPS navigation methods. These include the use of GPS handheld device, Google Maps app and MAPS.ME app. It is important to load the sampling points into any device or app that will be used for field navigation. Instructions on how to load the points have been provided in section 2.2.2.

4.1 Navigating using a handheld GPS device

Navigating using handheld GPS device follows the same steps irrespective of the type of GPS device. Now that you have loaded all points assigned to you on the GPS device, travel to a known location closest to the point. Switch on the GPS device as soon as you are about to be in doubt of your direction. An example of how to navigate using Garmin Etrex 10 device is provided below. The GPS can be used while still in the car to indicate the direction and distance to a point, but the instructions are intended particularly for navigating in the field when on foot or going by motorcycle.

1. On the GPS device, scroll to "Waypoint Manager" and select the waypoint manager

2. Select any of the points you wish to go to (Advisable to do the points closer to you first)
3. A new page will appear with the 'Go' highlighted and showing the coordinates of the point. Select the "Go" and follow the arrow (move in the direction the arrow points). Direction and distance to the point are indicated. If the distance is still large it is advised to find and use existing foot paths that bring you nearer to the point and navigate directly to the point, traversing the fields, when the point is in sight (within 50 – 100 m, for example)

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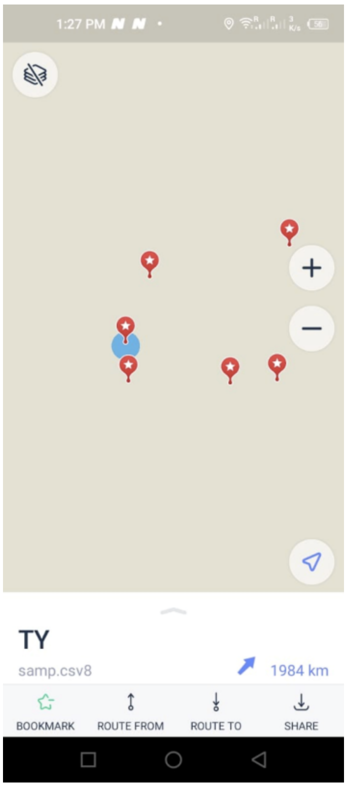
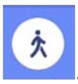
4. You can use the arrow keys on the device to zoom in and out for ease of navigation. Your device will either make a sound (Arrive at the point) or read "0 m" when you are at the point for sampling. Please take the soil samples as soon as the distance to the point is 10 m or less.

4.2 Navigate in the field using MAPS.ME app

1. Open the MAPS.ME app
2. Select  in the menu bar and click the file name to open
3. Select the point you want to navigate to. A screen will appear as in the example below (left)



4. Click on "Route To". A line connecting your location with the selected point appears (see the picture above, right), select Car  or walk .
5. Select car if you are far away from the point (>500 m) and the distance is motorable otherwise select . A start bar will appear, click on "START" and begin navigating. Follow tracks in the field rather than cutting through the bushes. The app will indicate whether you are getting any closer.

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4.3 Navigating using Google Maps app

1. On your phone or tablet, turn on your GPS (put "location" on)
2. Let Google Maps access your current location and audio speakers
3. On your Android phone or tablet, open the Google Maps app '.
4. Search for a place or tap it on the map.
5. In the bottom left, tap **Directions**. If you touch and hold the button instead, you'll start navigation and can skip steps 4-6.
6. **Optional:** To add additional destinations, go to the top right and tap More < ⋮ › and select **Add stop**. You can add up to 9 stops. When you are finished, tap **Done**.
7. Choose one of the following (preferably choose the walking mode while in the field):
   a. Driving:
   b. Transit:
   c. Walking:
   d. Rides:
   e. Cycling:
8. If other routes are available, they will be shown in gray on the map. To follow an alternate route, tap the grey line.
9. To start navigation, tap Start. If you see "Searching for GPS," your phone is trying to get a GPS signal. When in or near a tunnel, parking garage, or other location where there's no GPS signal the GPS device might not receive any signals and will not be able to determine your location.
10. To stop or cancel navigation, go to the bottom left and tap Close ✕.

4.3.1 Use Google Assistant's Driving mode

Assistant driving mode helps you get things done while you navigate with Google Maps. With Assistant driving mode you can read and send messages, make calls, and control media with your voice, without leaving Google Maps navigation.

Turn on or off Driving mode in Google Maps:

1. On your Android phone or tablet, open the Google Maps app .
2. Tap your profile picture or initial › Settings › **Navigation settings** › **Google Assistant settings.**
3. Turn on or off **Driving mode**.

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5 Rejection of a secondary or tertiary sampling unit

The sampling design is a hierarchical design consisting of three stages. The primary sampling units (PSU) represent two by two (2x2) kilometre spatial units from which several secondary sampling units (SSU), of one (1) ha in size, are randomly selected, and for each SSU there are several tertiary sampling units (TSUs) identified of 25m^2 each. For each SSU, one (1) TSU needs to be sampled. However, for reasons specified below certain points may not qualify or might not be suited to take samples. For that purpose, alternative sampling points (TSUs) are identified for each SSU. For each PSU four (4) SSU are supposed to be sampled, but because an individual SSU may not qualify as a valid sampling unit, alternative SSUs are likewise identified and that serve as back-up sampling locations.

For each SSU there are three (3) TSUs sequentially numbered 1, 2 and 3. The first point needs to be considered first for sample collection and data recording. If it is not possible to sample this point/plot due to any of the situations specified below, then the plot is discarded, and the second point is considered. The same consideration is made and when rejected the third location provided should be considered. When all three sampling points are rejected by consequence the corresponding SSU is rejected.

Given the small size of the SSU (one ha) possible restrictions may well apply to the whole SSU rather than to individual TSU, and this might be easily overseen or observed when in the field. In such case the SSU is then discarded and an alternative (back-up) SSU is selected. For each PSU, seven (7) SSUs are identified and these SSUs are sequentially numbered. The surveyor should in principle consider the first four (4) listed SSUs. The surveyor can start with any of those four SSUs. If the SSU is rejected, the next on the list is considered. That is the SSU with sequential number 5. Then any other of the first 4 SSUs is considered and when this SSU does not qualify the net in line, that is the SSU with sequential number 6 is selected. And this is repeated until all the 7 SSUs have been taking into consideration. If all the SSUs have been rejected the PSU is discarded/rejected as per consequence.

Soil samples are collected only on the designated sampling point location, which is reached if you are within 10m distance from the specified location. If the point is not suited for sampling, the surveyor cannot move a short distance in some random direction and take any other point, unless in specific situation and following procedures as described in section 9.

The surveyor is to record the reason for the rejection of the designated sampling point using the ODK form. The user will be requested to specify the current location and give the distance and direction to the proposed sampling point location, if not at the specified location, and to take a picture in the direction of the proposed sampling point location.

Below are the various options the surveyor can chose from to indicate the reason for the rejection of either the SSU or the TSU. The various reasons are categorised into four groups/classes

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Attribute: Reason for rejecting sampling unit (Code: SPrej)

Category	*Code*	*Details*
Restricted access	**RA**	
	RA01	• Fenced off areas used for other purposes than for agriculture (e.g., airports and other public services)
	RA02	• National parks and other protected areas
	RA03	• Private estate/farm with access being denied
Security challenge	**SC**	
	SC01	• Areas officially recognised as insecure areas
	SC02	• Local security threats area
	SC03	• Presence of wild animals in an area
Inaccessible terrain	**TI**	
	TI01	• Dense impenetrable vegetation
	TI02	• Swamps and other wetland areas
	TI03	• Obstacles in the terrain (e.g., streams, escarpments)
Non-cultivated managed land	**NCL**	
	NCL01	• Private gardens
	NCL02	• Sport fields
	NCL03	• Religious camps
	NCL04	• Park and Parklands
	NCL05	• Managed lawns
Miscellaneous land use	**MLU**	
	MLU01	• Alluvial land - Areas of unconsolidated alluvium recently deposited and subject to frequent changes
	MLU02	• Badlands - steep to very steep barren land, with active geological erosion, also rough broken land
	MLU03	• Beaches
	MLU04	• Blown-out land - Area with most of the soil material removed by wind - extreme degree of erosion
	MLU05	• Colluvial land: Unconsolidated recent colluvium - heterogeneous deposit of soil material, rock fragments
	MLU06	• Ditches and spoil banks - ditches and rock waste banks and dumps from excavations
	MLU07	• Dumps - Area of uneven accumulation or piles of waste rock, including tailings
	MLU08	• Marsh - Periodically flooded areas with grasses, cattails, rushes or other
	MLU09	• Oil-waste land: Accumulation of liquid oily wastes
	MLU10	• Pits and Open excavations from which soil and underlying material has been removed
	MLU11	• Rock land - Area having rock outcrop and very shallow soil (rock outcrop between 25 - 90%)

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MLU12	• Rock-outcrop Exposure of bare rock
MLU13	• Swamp - Naturally wooded areas which are covered with water most of the time
MLU14	• Stony land - Areas with enough stones and boulders to submerge other soil characteristics
MLU15	• Shifting sands

The project has procedures for excluding sampling units, especially PSUs, in areas of known security challenges or with restricted access (like national parks or other protected areas) and these sampling units will not be part of the list of sampling points offered to the surveyor. But areas with local security challenges are often less known and that information might reach the surveyor only when he is in the field. In such cases, the surveyor will reject the SSU or even PSU even before progressing to the locations in the field and will subsequently not be able to record the reasons for rejection while in the field filling the ODK forms. in such cases the Surveyor will contact the CS to explain the reasons why the sampling units will not be surveyed and if the CS agrees, he/she will confirm the decision by flagging the sampling points in the SDMT to be excluded from the survey.

Similarly, points located in areas of restricted access, like airports, will have been identified during the stage of validation of the proposed sampling locations and will thus not be included in the list of sampling point forwarded for surveying. But not all these cases can be adequately identified at that stage and may become apparent only when in the field. Similar procedures apply if the decision is to exclude those points even before having visited that particular area in the field: the CS needs to confirm the decision not to include those points and will make the corresponding annotation in the SDMT.

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6 Soil sample collection

This section describes the general layout of the sampling plot, provides instruction how the samples are taken using the various tools (auger, spade and pipe), and provides instruction for the bagging and labelling of the soil samples.

6.1 Layout of the sampling plot

A Soils4Africa sampling plot measures 25 m^2. In this sampling plot, soil samples are taken at four (4) sub-locations according to the configuration in the Figure below. One sub-sample is taken at the centre of the plot and the other three sub-samples are taken on the circle with a radius of about 2 m from the centre point at equidistance from each other. The 2 m is measured by taking three steps from the centre point (these are normal steps; small people need to stretch a little to reach the approx. 70 cm per step). Thus, sub-samples are collected in form of a Y-frame.

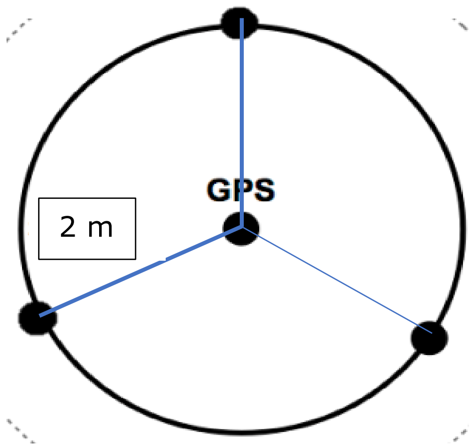

Figure 1. Configuration of the sampling plot

Soil samples are taken at two depths: 0-20 cm (topsoil sample) and 20-50 cm (subsoil sample). Topsoil samples from the four sub-locations are collected in the bucket labelled 'TopSoil", and thoroughly mixed. The four (4) subsoil samples are also bulked and thoroughly mixed using the bucket labelled "SubSoil" to provide for one composite subsoil sample (see the section on how to make composite samples). Sample collection can be done with an auger, spade, or pipe or corer, depending on which one you have but the use of an auger is preferred.

In case of soil depth restrictions, samples are still taken if it is possible to gather enough soil from at least two of the four sub-locations. In practice this means that you must be able to auger to at least 10cm within the soil layer. That is to 10cm from the soil surface for the topsoil sample and that is to 30cm depth at least for the subsoil sample. The depth restriction need to be indicated at all time, so as not to create any confusion with the interpretation of the results from the soil analysis.

6.2 Soil sample collection

6.2.1 Sample collection using an auger

1. Clear the point of litter or any vegetation

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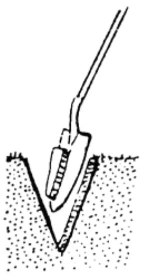
2. Put the auger straight down and auger vertically downward, avoid the auger from slanting sideways.
3. Collect topsoil sample from the centre of the plot and put in the bucket for the topsoil.
4. When augering the subsoil, make sure that soil from the surface (topsoil) that has fallen into the auger hole is not included in the sample to be collected. This is prevented by always removing the upper one third part of the soil in the auger and discard the soil. This is done every time subsoil is collected.
5. Do not overfill the auger when taking the subsoil sample as this will distort the volume of the auger hole. To avoid this, empty the auger regularly at depth increments of 10 cm (20-30 cm, 30-40 cm, and 40-50 cm).
6. Preferably collect the topsoil samples for the 4 subsampling locations first, before collecting the subsoil samples for the 4 subsampling locations. Clean the soil auger before taking the subsoil samples.
7. Pool (composite) topsoil samples from each subplot into one bucket and do the same for subsoil (in the bucket labelled “subsoil”).
8. Mix the soil thoroughly in the buckets using the trowel.
9. Take about ~500g for each composite sample – topsoil and subsoil; that is two topped hands full of soil for each composite sample and place it in a plastic bag. Tie the bag with a knot or use the stapler to close the bag. Put the plastic bag with the topsoil sample in the bucket for topsoil samples and put the plastic with the subsoil sample back in the bucket for the subsoil samples; label as described in section 6.4.
10. Clean the soil auger before moving to the next sampling location using grass or leaves that you find at the sampling site.

6.2.2 Soil sample collection using a spade

1. Clear the point of litters or any vegetation. Do this by hand (pull out the weeds if needed); do not use machete or spade, because you risk of removing topsoil (You can cut the vegetation to get access to the site, but to cut the vegetation at the actual point of sampling)
2. Dig a V –shaped hole with the spade
3. Slice a 3 cm thick layer from one side. Remove vegetation and litter
4. Trim the sides of this layer leaving 3 cm in the middle
5. Put the soil in the bucket
6. Clean the excess soil from the spade
7. Repeat steps 2-6 for the other 3 subsampling locations
8. Mix the 4 subsamples with the trowel
9. Take 500g and put in a plastic bag and close with a tie. Put the plastic bag with the sample bag in the bucket for the topsoil
10. For collecting the subsoil samples first dig a hole of 50x50cm and 20cm deep at each of the subsample locations.



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11. For each hole thus created repeat steps 2 to 6 but now digging a V-shaped hole from 20 cm to approximately 50 cm deep.
12. Repeat steps 8 and 9 to make one composite sample for the subsoil.
13. Clean the spade before taking samples at the next sampling site

6.2.3 Soil sample collection using a pipe/cylinder

1. Clear the point of litters or any vegetation.
2. Mark out 20 cm and 50 cm on the pipe.
3. Insert the pipe straight into the soil to a depth of 20 cm using the hammer.
4. Remove the pipe and empty the sample into the topsoil bucket
5. If the soil is very wet and sticky or clayey you will need to apply some pressure, knocking the mallet on the side of the pipe to empty the pipe. In case this does not work use the knife to empty the pipe.
6. After removing the topsoil return the pipe into the hole (where the 0- 20 cm was collected) and push down the pipe to a depth of 50 cm with the aid of a mallet on the top-end of the pipe
7. Remove the pipe and empty the content into the subsoil bucket as described in step 5. Make sure the soil is spread in the bucket when the pipe is being discharged such that the topsoil that is in the pipe is discharged latest and can be removed from the bucket.
8. First do the sampling of the topsoil for each of the subsampling locations before sampling the subsoil at each of the locations.
9. Clean the pipe as good as is possible before moving to the next site for sample collection.

6.3 Labelling and bagging

Bagging and labelling is an important aspect of quality assurance and needs to be properly done to make sure that the soil samples are correctly identified also in the further process of handling and analysis of the samples. Such that results of the sample analysis are not attributed to the wrong samples. The sample from each bucket goes into a different bag. The bucket used for the collection of the topsoil samples should be the same for all sampling points. The same applies for the bucket used for the sub-soil sample. And this should not change from one location to the other, or from one day to the other, in order not to create any confusion.

6.3.1 Bagging

The samples collected should be double bagged, using a plastic bag as inner bag for containing the moisture and a cloth or paper bag to provide strength or sturdiness to prevent the plastic bag from tearing. The inner bag needs to be closed by either tying or by stapling, depending on the type of plastic (if thick and hard it needs to be stapled). The label (the soil sample ID) is put in between the inner and outer bag (ensure the barcode is scanned before it is put in the bag). The outer bag (cloth or paper) needs to be closed as well. For the paper bag a stapler is best used. The cloth bag is tied with the cord that comes with it (otherwise fold and staple). a rope.

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6.3.2 Labelling

1. Scan the barcode with the smartphone into the appropriate section on the ODK form.
2. Insert the QR/barcode in between the inner and outer bag.
3. On the outer bag, write the sampling point ID legibly and indicate "T" for topsoil samples and "S" for subsoil samples. Write with a permanent marker.
4. The soil sample ID consists of a 2-letter country code and random sequence of alphanumerical characters which can be either in lower or upper case. The bar code comes in duplicates (two of the same QR codes on the same piece of paper) and should also be put as a duplicate soil sample ID in the sampling bag. The SS-IDs are provided (made available) to the surveyors. When provided as separate laminated duplicate codes they can be added as they are. If they are printed only (not laminated) the duplicate bar code needs to be put into the small plastic pouch (zip file) and sealed/zipped to prevent it from getting wet and then put into the sampling bag. Instruction for generating the QR codes are provides in the "Instructions for the Country Supervisor"

6.5 Leaving the site

When the work is done, please leave the site neat and clean. The auger hole (pit) needs to be closed and left in a condition as close as possible to before opening the pit (before augering). Try to get the soil back into the pit/hole, such that animals do not easily steps in the hole and break their leg. Please make sure that no plastic, paper or other material is left at the site!

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7 Field observations on soil and site characteristics

Field observation data are to be collected from the sampling locations. Observations are made on soil properties (e.g., soil depth, stoniness, soil drainage), on soil surface characteristics (soil erosion by water and wind, stoniness), on the land and terrain (landform, slope). For making the observations either of the four sub-sampling locations can be used. If the center point in the plot layout is not suited (e.g., because of depth restrictions, stones in the profile, or other) and of the other sub-sampling locations can be tried to make a valid observation. The specific observations to be made per each category are outlined below.

7.1 Soil depth determination

Soil depth is determined with the aid of an auger. Soil depth is registered at that point where restrictions are observed to augering to further depth even when applying considerable force. This can be because of hitting rock, because of gravel and stones or because of any type of hard pan (iron pan, dense clay layer, plough pan or other).

Auger until you find any restrictions. Apply considerable force to confirm that is not possible to go any deeper. Note the depth at which the restrictions are observed. Depth classes are defined according to the classification system given in the table below. This classification is adapted from RECARE 2018 Europe's soil research hub. The 20cm and 50cm mark on the soil auger help to determine the depth class. The auger itself is 120cm, so 20 cm below the handlebar the 100cm mark is located. Record the depth class and indicate the cause of the restriction in the ODK form. If there are no restrictions within the 120 cm depth, select "very deep" on the ODK form.

Attribute: Effective Soil Depth (Attr. Code: SDE)

Code	Depth (cm)	Indicator
SD1	0 – 25	Very shallow
SD2	25 – 50	Shallow
SD3	50 – 100	Moderately deep
SD4	100 – 120	Deep
SD5	>120	Very deep

In case you have only a spade or pipe at your disposal you can still record the soil depth class whether it is "SD1", "SD2", or "SD3". There is an option in the ODK form to indicate that no auger was available such that it is not possible to distinguish between depth classes "SD3", "SD4" and "SD5".

Type of soil depth restriction (Attr. code: SDRN)

The nature of the restriction making it impossible to auger any deeper is indicated. This can be because of hitting solid rock or rotten rock (layer consisting of rock fragments dominantly, with varying size of the rock fragments but can be as small as gravel), in which case the depth is the actual soil depth. It can also be cause of any cemented or compacted layer (horizon) within the soil profile that cannot be penetrated by the soil auger. In this case, the nature of the cementation of compaction

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is provided. This can be cementation by iron in case of an iron pan or hardened plinthite, or by clay (compacted horizons with high clay content), or by mechanical and action and ploughing (abrupt transition to compacted layer at 20- 30 cm depth that cannot be attributed to cementation or abrupt increase in clay content). We have included accumulations of iron and manganese concretions which occur in many soils. It may not completely make further augering impossible, but it will restrict rooting if the layer is made of these nodules almost completely. It is often classified as 'nodular', and it then includes concretions formed from lime/carbonates. If groundwater is found within the 120 cm it is also considered rooting or effective soil depth restriction and is recorded. Finally, an option is provided for when the nature or type of the restriction is not known.

Attribute: Soil depth restriction nature (code: SDRN)

Causes	**Code**
Bedrock or rotten rock (with dominant stones or gravel)	BRR
Iron pan or hard plinthite	Fe
Pisoplinthites (Fe and Mn concretions)	FeMn
Strong compaction or hard clay	Clay
Plough pan/Mechanical	PP
Ground water	GW
Not known	NK

7.2 Soil texture, colour, stoniness, and presence of mottles

Observations on soil texture, colour of the soil matrix, stoniness and presence of mottles is done for the soil layers 0-20cm, 20-50cm and 50-120cm. The soil texture is specified only in general terms, and since the texture is in principle determined in the lab it is used for cross referencing mainly:

- Sandy
- Loamy
- Clayey
- Silty

The soil colour refers to the colour of the soil matrix and the colour of mottles, if present, are not recorded. For sake of convenience, the dominant colour of the soil when moist is indicated:

- Blackish
- Blueish/greenish or greyish
- Brownish
- Reddish
- Whitish
- Yellowish

Stoniness is recorded in terms of stoniness class, based on the estimated volumetric content of gravel or stones:

- None
- Very few (0-2%)
- Few (2-5%)

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- Common (5-15%)
- Many (15-40%
- Abundant (40-80%)
- Dominant (> 80%)

Mottles are only recorded by their presence (Y/N) and serves mainly to countercheck with the drainage class presented in the next sections

7.3 Soil drainage class determination

Soil drainage is a natural process by which water moves across, through and out of the soil as a result of the force of gravity. Soil drainage class is determined by looking at visible signs within the soil profile that indicate that the soil is saturated with water for at least a considerable and significant period during the year. The presence or absence of mottles is used as an indicator of soil drainage. Mottles are spots or blotches of different colour, generally grey or orange, interspersed with the dominant soil colour. They occur as the results of oxidation/reduction processes in the soil. Under water saturated conditions, no air is available, and reduction of the various elements and compounds (especially iron – Fe) will take place resulting in greyish colours. Where the soil is subsequently drained (at least for part of the year, oxidation takes place resulting orange and reddish colours.
The picture below shows a typical pattern of mottles in the soil. However, the mottles themselves cannot be observed clearly in the soil that is removed using a soil auger, but the discolorations can be seen clearly. It helps to break up the clump of soil that you take out of the auger. So, while augering to determine soil depth, the soil that is taken out at the various depth layers should be inspected for mottles and/or clear discolorations. The drainage class is determined based on observations on the prevalence of mottles and the depth at which they occur according to the specifications given in the Table below.

Picture 1 Soil ped with clearly visible mottles

Attribute: Soil Drainage class (Code: SDrain)

Code	Class	Description/specification
D0	Very poorly drained	Water table remains at or on the surface for considerable time of the year, greater part of the time

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		Visible sign: You find water on the soil surface after 24 hours of rain; the soil matrix has greyish colours
D1	Poorly drained	Water removed slowly and remains wet for larger part of the time; water table at or near surface for considerable part of the year; high water table or slow permeable layer in soil profile or seepage Visible sign: You find many mottles in the topsoil
D2	Imperfectly drained	Water removed slowly to keep it wet for significant periods; mottles below 15 cm or evidence of gleying directly below A horizon; requires drainage to make suitable Visible sign: You find few mottles on the topsoil but increasingly within the subsoil
D3	Moderately well drained	Uniform colour in A and upper B horizon, with mottling in the lower B and C horizons Visible sign: You find mottles only in the subsoil beyond 20 cm depth, but few
D4	Well drained	Uniform colour no mottles. Water removed readily but not rapidly. May be gley mottled deep in the C horizon or below 120 cm depth. Visible sign: You find very few mottles only in the subsoil or no mottles at all, but the soil is not excessively drained
D5	Excessively drained	Water removed rapidly, little horizon differentiation sandy and porous soils Visible sign: No mottles within the soil and the soil is completely sand or loamy sand

7.4 Soil erosion

Erosion that is caused by water movement at the soil surface (runoff) is classified into three classes: sheet, rill and gully erosion. Sheet erosion occurs if the soil is removed and transported over the surface as a sheet of water. It is difficult to detect, especially if the land has been worked. However, stone pedestals are a visible sign of (sheet) erosion that may be observed even if even if rills and gullies are not observed. The erosion occurs where the soil is loosened by the impact of raindrops and washed away by surface runoff, while the soil protected by stones or other does not erode and thus results in pedestals. Also included as type of erosion are 'stone pavements', which may

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occur as the result of deflation (soils containing stones in their profile and stones being accumulated of at the soil surface as result of soil being blown out or washed away from the soil surface, which has taken place for a prolonged period of time). But even for soil that have been worked you still find a high concentration of stones on the soil surface. Visible signs for rill erosion are clearer, as they are for gully erosion. Though it may be difficult to see whether these are signs of active erosion or results from past events. Off-site effect of water erosion may be deposition of the sediment and it is included as a separate category
Another class of erosion is that which is caused by the action of wind. It is just recorded whether there are visible signs of wind erosion and those may be related to either or both soil material removed and soil material deposited. Shifting sands, which is a form wind erosion is not included in the list. It is one of the miscellaneous land uses that does not qualify as agricultural land and sampling points in such areas are rejected. Salt deposited by wind erosion is included as a separate category.
The options to choose from for recording of soil erosion are given in the table below

Attribute: Soil erosion category (Code: SECat)

Code	Title	Definition	
WE00	No erosion	No visible signs of erosion are observed	
WE01	Rill erosion	A rill is a linear depression or channel in soil that carries water after recent rainfall. The channels are not more than a few cm deep (max 3 to 4cm). They are removed and not visible on land that has been tilled or ploughed. The rills point in the same directions and distance between consecutive rills can be up to meters	
WE02	Gully erosion	Gully erosion is a deep depression or channel in a landscape, looking like a recent and very active extension to a natural drainage channel. It is a consequence of water that cuts into the soil along the line of flow. In contrast to rills, they cannot be obliterated by ordinary tillage.	

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WE03 Stone pedestals

Soil under a small stone or boulder is protected from the impact of rain drops, whereas the soil surface surrounding that stone is not, and where the soil is slowly washed away, resulting in pedestals that are easily observed.

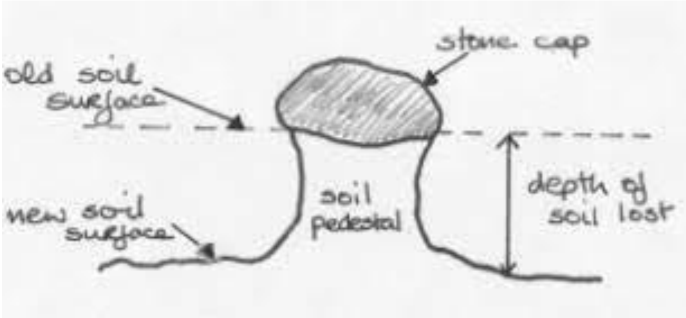

Figure 1 Drawing explaining the origin of stone pedestals (source: M. Stocking)

Picture 2 Illustration of stone pedestals (source John F. Williams); in the field isolated stonepedestal are observed generally.

WE04 Stone pavement

If soils have stones within their profile, these stones will emerge at the soil surface upon removal of the topsoil by erosion, resulting in a stone pavement, sometimes referred to as desert pavement or armour layer. Mostly different stages of deflation are observed rather than the surface being completely paved. It will still be recorded as such when observed. Even when the land is ploughed it may still be observed.

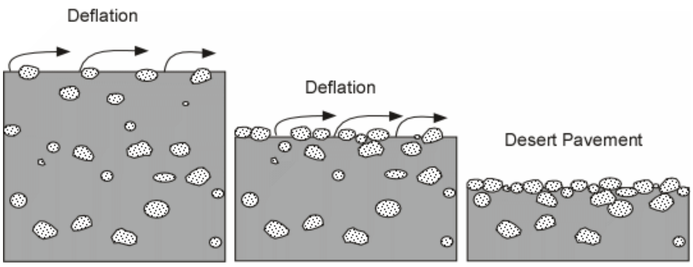

Figure 2 Picture explaining the process of desert pavement formation (source Tulane Univ.)

Picture 3 Exaple of armoured layer (courtesy: Tim McCabe USDA/NRCS)

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EWSM	Wind erosion Y/N	Visible signs of wind erosion are blown out land, looking as if the soil surface has been abraded and/or fine sand deposited in the wind shadow of plants or other small obstacles.
EWSD	Salt deposition	Deposition by wind, not salt flats or plains resulting from salt lakes that are not classified as agricultural land

7.5 Soil surface sealing and crusting

Soil surface sealing results from slaking of soil surface components or may result from sedimentation or deposition and results in a compacted surface layer with reduced porosity. We talk about sealing when no drying and hardening has taken place and of crusting when drying and hardening has taken place. No distinction is made between the different type of crusting, whether soil crust, chemical (salt) crust of biological crust, or to the process involved. It is just recorded whether there are clear signs of surface sealing or crusting. The accumulation of salt at the surface (cover percentage, and type of salt) is also not recorded, even though the presence of salt in the soils is an important consideration in soil quality monitoring for arid or semi-arid regions. For agricultural land, these observations are not considered that relevant and difficult to measure accurately. Further information on salt content and salinity will be accessed through the lab analysis of the samples.

Attribute: Soil surface sealing and crusting (SSSCrust)

Code	Description	Illustration
Y/N	Notable presence of surface sealing (crust) Y/N	 (source: http://soilquality.org/indicators/soil_crusts.html)

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7.6 Surface toniness

Stoniness records the percentage of the soil surface occupied by stones. There are different size classes of stones, from gravel to boulders, but the size class is not recorded (the photo taken of the soil surface will indicate the size class). However, you have to adjust the window of observation to the size class to be able to make a correct estimate of the surface area percentage. The large stones require a large area to be considered (a circular area with radius of 10m or more). The chart below (Figure 3) provides the guide to estimate surface cover percentages based on which the stoniness class is determined according to specifications in the below. The stoniness class is only recorded if there are stones, boulders, and large boulders.

Stoniness class

0 No stones: surface cover of less than 0.01%. There are not enough stones to interfere with tillage.

1 Slightly stony: soil surface covered: 0.01 - 2%; enough stones to interfere with tillage, but not to make it impracticable (e.g., stones of 36cm diameter with an average distance of 10m gives 0.1% surface cover).

2 Stony: surface area cover percentage: 2 - 5%; makes tillage impractical, but still possible when tillage by hand depending of the size of the stones and can be used for pasture or other crops (tree crops).

3 Very stony: surface area covered: 5 - 15% Makes use of any kind of machinery impractical except for handheld tools.

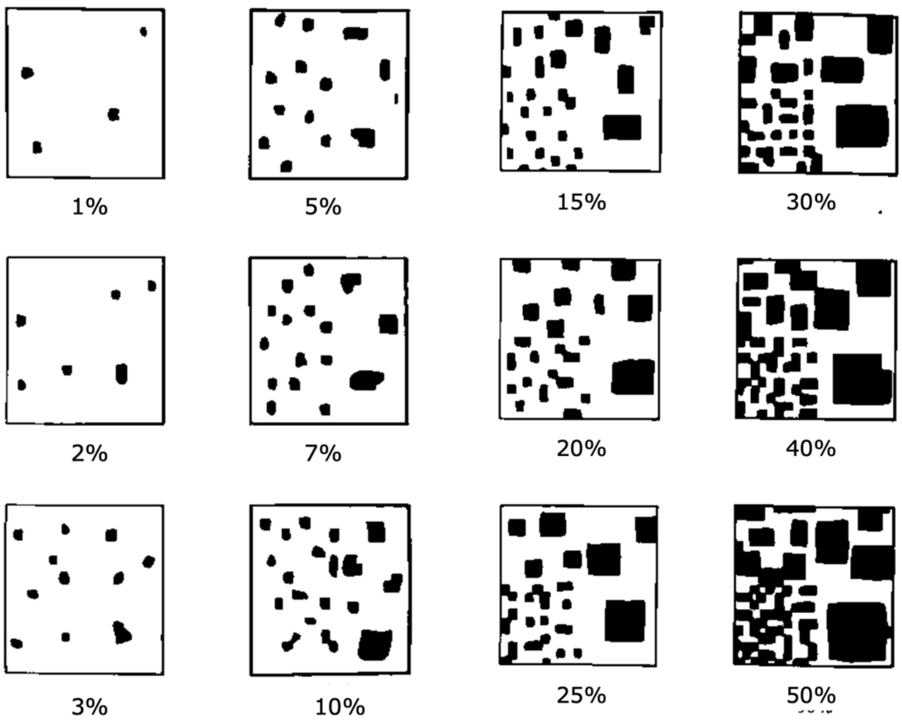

Figure 3 Graphs depicting cover percentages to be used as reference for estimating ground cover percentages in the field

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4 Extremely Stony: surface area covered >15%

(Classes adapted from Soil survey Manual -USDA and in alignment with the FAO guidelines for soil description)

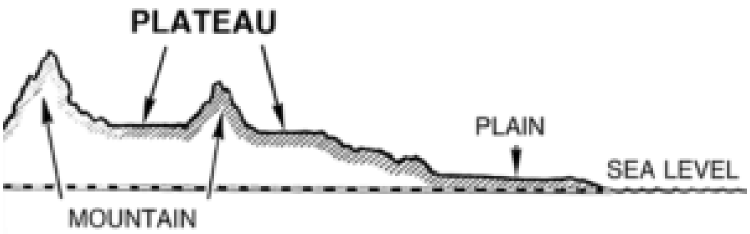
7.7 Landform and slope class

This section provides information on how to describe the general landform and how to describe the slope. For the description of the landform a large window of observation is used, that extends beyond the point of observation and even beyond the SSU, applying often to the whole PSU. Distinction is made between land that is generally level, sloping land and land with steep slopes that refers to mountainous area. For the sloping land further distinction is made according to the slope steepness class and according to orientation of the slopes (in case of ridges where the slope orientation is in two opposite directions in general).

Landforms refer to the shape of the land surface, without considering the genetic origin or the process responsible for their shape. Using the SOTER approach, below are the various categories. The class is assigned based on visual assessment and considering the physical environment. The figure below helps to explain the difference between a plain and a plateau. Gently sloping land/terrain has slopes not exceeding 10%, whereas moderate sloping terrain has sloped generally not exceeding 15%. Steep land has slopes that may exceed the 30%. The codes are provided for the development of the SDMT, and these will be used for entering the data on the DK forms.

Attribute: Landform (Code: LandF)

Code	Landform	Subcategory
LP	Level land	Plain
LL		Plateau
LD		Depression
LV		Valley floor
SE	Sloping land	Escarpment zone
SH		Hilly landscape; undulating to rolling terrain
SP		Dissected plain
SV		Low or medium gradient valley



Slope class: The topography is described by the slope class; that is the range in slope percentage that the dominant slope within the 1-ha window of observation falls within. The 1-ha window of observation can be taken as the circular area with a radius of 50 to 60m approximately. It does not refer to the slope at the specific location of the sampling point. The surveyor needs to practice in the visual assessment of the slope percentage. For practical purpose, to estimate the slope percentage you walk down

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the slope until you are at eye height level with the point where you started from, estimate the distance to that point and divide your height (m) by the distance (m); multiply by 100 and you get the percentage. The following slope classes apply:

Attribute: Slope class (code: SlpCls)

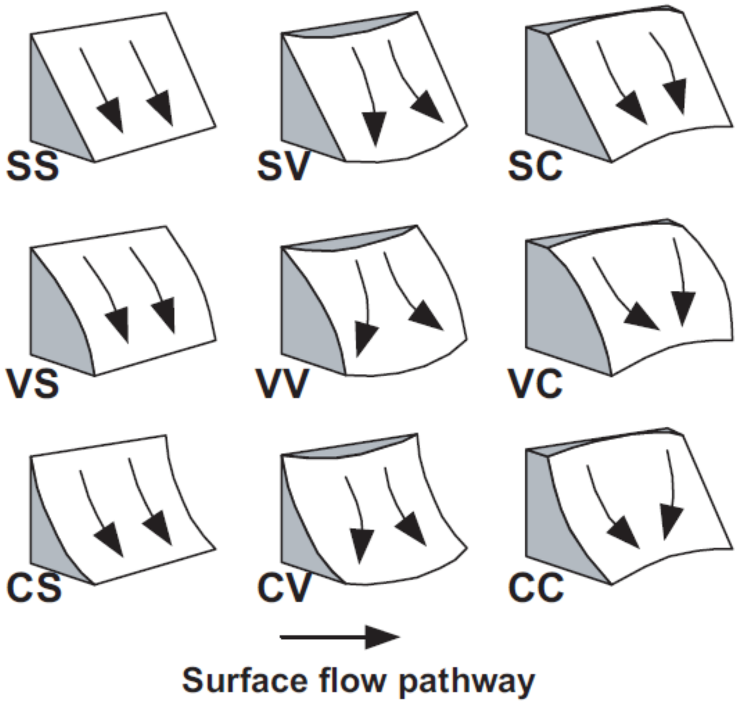
Code	Class	Slope percentage
0	Flat to almost flat	0 – 0.5%
1	Very gently sloping	0.5 – 2.0%
2	Gently sloping	2 – 5%
3	Sloping (undulating and gently rolling terrain)	5 – 10%
4	Strongly sloping (rolling terrain)	10 – 15%
5	Moderately steep (hilly terrain)	15 – 30%
6	Steep (very hilly or strongly dissected terrain)	30 - 60%
7	Very steep (very hilly and strongly dissected terrain)	>60%

Slope form and pathway: The slope form refers to the general shape of the slope in both the vertical and horizontal directions (See the figure below), and pathways indicate whether the slopes are converging or diverging. The graph below (FAO 2006, Guidelines for soil description) show the combination of both together with the codes for each of the categories.

Attribute: Slope form and pathway (code: SlpFP)

Slope forms and surface pathways (from FAO 2006 guidelines for soil description)

- SS – Straight-Straight
- SV – Straight-Convex
- SC – Straight-Concave
- VS – Convex-Straight
- VV – Convex-Convex
- VC – Convex-Concave
- CS – Concave-Straight
- CV – Concave-Convex
- CC – Concave-Concave



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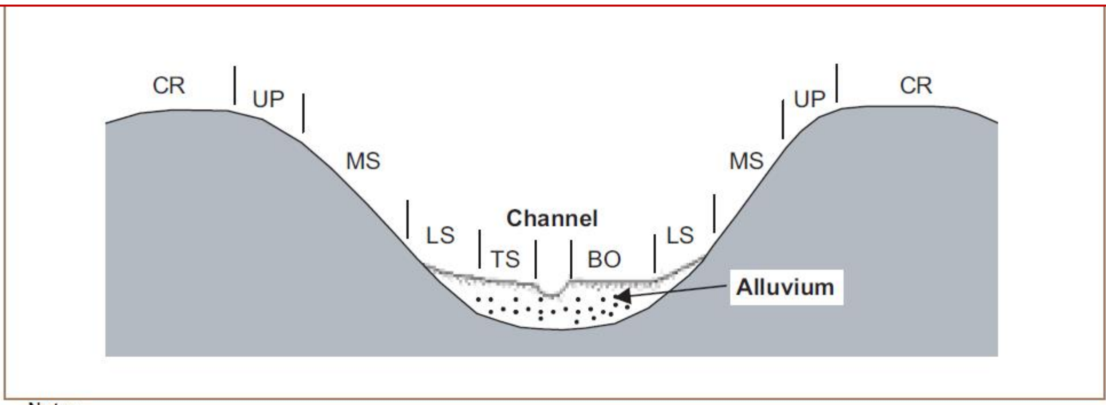
<u>Slope position:</u> The relative position of the site within the land should be indicated. The position affects the hydrological conditions of the site (external and internal drainage, e.g., subsurface runoff), which may be interpreted as being predominantly water receiving, water shedding or neither of these.



Note:

Position in undulating to mountainous terrain
CR = Crest (summit)
UP = Upper slope (shoulder)
MS = Middle slope (back slope)
LS = Lower slope (foot slope)
TS = Toe slope
BO = Bottom (flat)

Position in flat or almost flat terrain
HI = Higher part (rise)
IN = Intermediate part (talf)
LO = Lower part (and dip)
BO = Bottom (drainage line)

Slope positions in undulating and mountainous terrain (FAO 2006 guidelines for soil description)

7.8 Pictures of the soil surface and terrain

As part of the field observations three pictures are expected to be taken, to get additional pictorial data of the soil surface characteristics, the land use and land cover characteristics and the landform. The first picture is a vertically downward picture of the soil surface. Use a pencil, knife, booklet or jotter as reference for determining the scale. This picture will enable us to verify the surface characteristics of the soil as against what is filled into the form. The second picture is taken slanting downwards such that the furthest part still to be seen on the picture is 20 to 30 m away at least. Picture should be taken in the direction perpendicular to the slope direction. The third picture is taken in horizontal direction and likewise perpendicular to the slope direction. It serves to give an idea of the terrain and landscape.

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8. Protocol for making observations on land use, land cover and land & water management

In this section the instructions are provided for the observations on land use and land cover. Because observations are made in the context of agricultural land and for the purpose of soil quality assessment, the land cover observations mainly serve to determine soil cover. Furthermore, observations are made on land and crop management, providing information on land use intensity which is important for the interpretation and evaluation of changes in soil condition and soil quality. Observations on land management includes soil conservation measures and practices. Observations are also made regarding water management in terms of measures to increase water supply to the crop (e.g., irrigation).

8.1 Observations on land use

8.1.1 Observation unit (scale and window of observation)

Observations on land use are made on a different scale from the scale at which observations are made on the soil or soil profile (i.e., the TSU, or the circular sampling plot encompassing 25m^2). Rather the secondary sampling unit (SSU) provides for the window of observation for land use and land management practices. However, a 1-ha area might be difficult to oversee in some cases, and therefore the area of about 1000m^2 in size, surrounding the sampling point location may be used as window of observation for practical purposes. This corresponds to a circular area with a radius of 17.8, let's say about 20m.

8.1.2 Main land use class

For the Soils4Africa project the observations are made for the agricultural domain only. That means that the area belongs to primarily vegetated area, which according to the definition of the Land Cover Classification System (LCCS) of the FAO is the area with a vegetative cover of at least 4% for at least two months of the year. If these minimum requirements are not met the sampling point is not recognized as a valid sampling location and should have been rejected following criteria specified in chapter 5. The land use can then belong to one of the three main land use categories only, and the main land use category is the first that needs to be determined. The main land use categories are the following:

- Cultivated and Managed Terrestrial Area (CMTA): This class refers to areas where the natural vegetation has been removed or modified and replaced by other types of vegetative, artificial cover that requires human activity to maintain and manage it. This can be any kind of crop, but also includes 'agricultural grassland' that has been sown, that is intensely grazed and/or mowed.
- Semi-natural vegetation (SNV): This refers to vegetation that is not planted but influenced by human actions and that may result from grazing, selective logging, or regenerative vegetation on previously cultivated areas. It includes areas of secondary regrowth during fallow periods in shifting cultivation systems.
- Cultivated aquatic (CAA) or regularly flooded areas: This includes areas where an aquatic crop is planted, cultivated, and harvested, generally referring to

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paddy rice, tidal rice or deep-water rice. Irrigated cultivated areas are excluded from this class but included in the Cultivated and Managed Terrestrial Areas.

For each of these main land use categories a different set of attributes are considered that serve as classifiers for the land use class, and for which the attribute values are recorded in the field

8.1.3 Dominant life form (Cultivated and Managed terrestrial area [CMTA] and Cultivated aquatic [CAA])

The dominant life form only applies to CMTA and to CAA, though in the latter case you will only find graminoids (e.g., rice) as the dominant life form in practice.

The dominant life form is the life form of the uppermost canopy layer and of the crop that is the most relevant economically (the crop that represents the main purpose of the farming activities). For example, in a shaded coffee plantation, the dominant life form is "tree", being the life form of coffee, irrespective of whether the shade trees are commercially exploited as well, or whether there is an undergrowth, or whether a second crop (intercrop) is grown with some economic value. The options are the following:

1. Tree: Trees are defined as plants with a well-defined woody stem that is taller than 3m when full grown. In general, the criterion for distinguishing between tree and shrub life form is a height of 5 m. However, if the plant is smaller than 5m (but taller than 3m) but has the distinct physiognomy of a tree then it is still classified as tree.
2. Shrub: A shrub is a woody plant with persistent woody stems, but not with one defined main stem. It does not grow taller than 5m.
3. Herbaceous – Graminoids: Herbaceous plants are plants without a persistent stem or shoots and lacking a firm structure. Graminoids are herbaceous grasses and narrow-leafed grass-like plants. It includes cereals, grasses, rice, reeds and bamboos. Bamboos, though officially a graminoid, is classified under shrubs because of its physiognomy.
4. Herbaceous – Non-Graminoids: Includes all broad-leaved herbaceous plants and non-graminoid herbaceous plants. It can be subdivided into the following categories of crops: 1. herbaceous, 2. Bananas and other tree-like herbaceous plants, 3. cover crops, and 4. hops and other perennial herbaceous vines.

8.1.4 Purpose and crop type

For all the above the dominant life forms the purpose for which the crop is grown is indicated, which at the same time determines the crop type. They are divided into two main categories: Food crops and Non-food crops. The following crop types are defined.

1. Cereals
2. Fibre crops
3. Fodder plants
4. Fruits
5. Semi-luxury foods (tea, cocoa, coffee and nuts)
6. Oil crop
7. Pulses
8. Roots and Tubers
9. Vegetables
10. Other crops (e.g., rubber)

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11. Nursery stock

8.1.5 Spatial aspect (field size and spatial distribution)

The spatial aspect, because it refers to field size and pattern only applies to CMTA and CAA. We include two classifiers under the spatial aspect; that is field size and spatial distribution pattern. Both these classifiers imply other aspects, like mechanisation and cropping intensity for example, and provide relevant data for the information on land use intensity. The scale of the observation is smaller (window of observation is larger); that is, it applies to a considerable larger area than the unit of observation for the above-mentioned observations. It can refer to an area of 1 km^2 or larger, if that can be overseen from the point where the observation is made. Field size and field pattern can be easily verified from high resolution satellite imagery.

8.1.5.1 Field size

The size is specified in acres as well as in hectares (approximate corresponding area in ha). For reference, a football pitch measures about one and a half acres (the area between the lines demarcating the football pitch) and with the immediately surrounding land that goes with it, it covers about 2 acres. The field size class is given for the dominant field size, assuming a more or less even distribution of the field size in the area.

Attribute: Field size (Code: FldSz)

Class name	***Size range (acres/ha)***	***Class code***
Very small	Less than 1 acre (< ± 0.4 ha)	(1)
Small	Less than 2 acres (< ± 0.8 ha)	(2)
Somewhat small	2 to 5 acres (± 0.8 ha to ± 2 ha)	(3)
Intermediate	5 -12 acres (± 2 ha to ± 5 ha)	(4)
Large	More than 12 acres (> ± 5 ha)	(5)

8.1.5.2 Field distribution pattern

The field distribution pattern is defined by the percentage of cultivated field and by the arrangement and shape of the fields. If fields are of the same shape and arrange in a regular pattern it indicates that there is a certain organisation in place, like is the case with irrigation schemes or plantations, and it is indicative of a more intensive land use system generally. In the same way, when field are not continuous it indicates a lower cropping intensity and lower intensity of land use. Field occupying less than 50% of the area indicates that other land use and land cover types are present and dominant within the area.

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Attribute: Field pattern (Code: FldPn

Class	***Description***	***Class code***
Structured and planned field pattern	Contiguous fields; > 70% – regular pattern	(1)
Unstructured continuous field pattern	Contiguous fields; > 50% – irregular pattern and shape	(2)
Clustered fields	Fields: 20 – 50%; clustered – irregular pattern and shape	(3)
Scattered fields	Fields: < 20%; scattered	(4)

8.2 Land cover characteristics

8.2.1 Ground cover percentage of the structural vegetation layers

The land cover characteristics are described by the ground cover percentages for each of the structural layers of the vegetation. It applies, in first instance, to the "semi - natural vegetation" main land use category but will likewise be used for the other main land use categories, especially the cultivated and managed terrestrial areas, where trees as part of the agricultural landscape are so characteristics for the Soudan savanna and other tree savanna zones in Africa, for example

The cover percentage or cover class is specified for each of the different life forms and including bare soil (percentage of the area where soil surface is exposed). The following specification are given for the different life forms:

- Trees (> 15 m)
- Trees (3 m – 15 m)
- Shrubs (0.3 m – 5 m)
- Herbaceous (0.03 m – 3 m)
- Bare soil (vegetation absent)

For estimating cover percentage use the graphs provided in Figure 3 as reference. The ground cover classes are defined as follows:

Attribute: Structural Vegetation Layer Ground Cover (Code:SVLGCov)

Class name	***Range (percentage)***	***Class code***
Absent	0 - 1	(0)
Scattered	1 - 4	(1)
Sparse	4 - 15	(2)
Very open	15 - 40	(3)
Open	40 – 65	(4)
Closed	> 65	(5)

8.2.1 Signs of grazing

We treat 'grazing' as part of the land use and land cover assessment because 'grazing' identifies the purpose for which the land is being used, including land in open range. Open range land is land that is not being managed with often the implication that the land is being overgrazed and degraded. In other situations, 'grazing' would be an

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aspect of land management. Therefore, signs of overgrazing have been included in the observations on grazing. For these observations the window of observation is widened, beyond the soil sampling plot. Signs of grazing, in as far as this relates to grassland with livestock grazing and infrastructure present in the field, is included to cater for those situations in which the land is cultivated and managed, to distinguish between grassland that is used as hayfield only and that which is being grazed.

Parameter	**Description**	**Code / Response**
Signs of grazing	Relates to signs of an area being used for grazing or to signs of impact of grazing. Either one of the following: ➢ Where animals (livestock) are out in the field grazing ➢ When there is infrastructure for grazing of cattle or other livestock: Fences, drinking troughs, stables, or sheds. ➢ Droppings/faeces are seen (often concentrated), left over from fodder – feeding operation ➢ Signs of poaching by livestock (removal of grass or vegetation), spots of trampling and compaction of the soil are visible.	Y/N
Signs of overgrazing	Either one of the following: ➢ Short grass height over large areas ➢ Frequent observation of areas of bare or poached ground ➢ Large amounts of dung ➢ Frequently uprooted vegetation	Y/N

8.3 Land and Crop Management

In relation to land management data is collected in reference to the land preparation; information on crop management is in relation to the use of input. Both provide information on land use intensity, though not very specific. For these two classifiers the information can be obtained by observation in the field. Other aspects of land preparation, like land clearing, and crop management, like pest and disease management, are not included because these data cannot be obtained from visual assessment in the field alone.

8.3.1 Land preparation

For land preparation visible signs of ploughing will be recorded, and, if visible, the direction of ploughing. The signs might refer to land that has been ploughed in the past or to recently ploughed fields. In land that has been previously cultivated, but where we find secondary regrowth, signs of the land having been ploughed might still be visible and is indicative of agricultural use in the past (and therefore belongs to 'agricultural area'). Whether the ploughing has been done manually, by animal traction or using a tractor can be observed by the distance between the plough ridges and the pattern, whether regular and straight or whether irregular and not straight and will be visible for the trained eye. Also, it is easy to find out what is common practice in the area, and the surveyor will indicate the most likely option.

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Land preparation in case of smallholder farming in Africa generally means that the land has been ploughed leaving ridges on which the crop is planted. In case a seedbed has been prepared, (possible in case of commercial and mechanized farming operations) the ridges might not be visible anymore. In that case you still enter 'signs of field recently tilled'. The planting lines might not be indicative of the directions of ploughing, and the direction of the planting lines is entered as the 'Direction of ploughing'.

The direction of ploughing is to provide information on practices for soil conservations and could as such also be grouped under that category of observations

Parameter	***Description***	***Code / response***
Signs of ploughing/tillage	➢ No visible signs of tillage ➢ No-till ➢ Signs of tillage in the past: ridges visible forming a pattern, but ridges less pronounced/flattened ➢ Signs of field recently tilled: patterns of ridges clearly visible that form a pattern	(0) (1) (2) (3)
Direction of ploughing	➢ Not applicable ➢ Along contours ➢ In slope direction, tangent to contour	(0) (1) (2)
Tillage mode	➢ Not applicable ➢ Manual (hoe) ➢ Animal traction (buffalo, bullock, cow, horse, mule/donkey) ➢ Mechanical (tractor)	(0) (1) (2) (3)

8.3.2 Use of inputs

With the use of inputs reference is made to the use of fertilizer (both organic and inorganic) only. It is sometimes difficult to recognise the visual signs of the various types of inputs that might have been used, or there might not be any visible signs at the time when the survey is conducted. In that case we may assume that the common practice for the area might also be applied in the field where the point/unit of observation is located, if the land use and crop observed at that point is consistent with the crop for which the practice applies. Crop residues, if they are left in the field, are readily observed for crops like maize, sorghum, millet, etc., and it is also quite common to use the crops residue in certain regions. The same for the use of farmyard manure, it might be quite common in certain regions. It can be observed by heaps of manure they put on the field and that they will spread out before planting. It will still be visible in field with a standing crop as remnants of the manure that have not been decomposed and worked into the soil. Likewise, for use of inorganic fertilizers, it is difficult to spot in the field, but the practice is most likely used, when it is a common practice for that area. And if the surveyor is from that area s/he will know and will indicate the most likely option.

Parameter	***Options***	***Code / Response***
Signs of input use	No visible signs	Y/N
	Crop residues	Y/N

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Green manures and/or compost	Y/N
Manure (FYM, cattle manure, chicken manure, etc.)	Y/N
Inorganic fertilizer	Y/N

8.4 Water management/ irrigation

Water management applies to the 'cultivated and managed terrestrial areas'. It does not apply to the (semi-)natural vegetation areas and for the cultivated aquatic areas the water management is inherent in this type of land use and does not need to be further specified. This section deals with cultural practices related to water supply to the crop. First it is indicated whether you have a rainfed system, a post-flooding system or makes use of an irrigation system. The post-flooding is when the land is being cultivated after is has been flooded, with the crop making use of the residual soil moisture. It generally is found in river flood plains and not in artificially flooded areas. Obviously, it can only be observed at the right time when the water has subsided. However, a surveyor that is familiar with the cultural practices within the area, will know. For irrigated systems, this may refer to fully irrigated systems or to systems intended for supplementary supply of water, in addition to the water supplied by rain. Water harvesting is not explicitly included as a separate option as a technique for water management but is inherent in the choices for type of irrigation and source of irrigation. For example, half-moon or zaï systems make use of (cone-shaped) pits to harvest water and is a specific from of surface irrigation, even though it is part of rainfed agriculture. It could be made explicit if it is considered an important technique and much applied practice in certain regions. much-applied cultural practice.

Parameter	***Description/ options***	***Code/ response***
Water supply	Rainfed	(1)
	Post-flooding/ residual moisture	(2)
	Irrigated	(3)
Type of irrigation	Surface / gravity (can be by use borders, basins, furrow, corrugation (i.e., parallel ridges and grooves, wild flooding, etc.)	(1)
	Sprinkler (different types of sprinklers: central pivot, fixed set of sprinklers, travelling gun irrigation system, etc.)	(2)
	Drip irrigation (trickle, dribble, or localized irrigation in which the water trickles onto or into the soil near the plant)	(3)
	Not applicable	(4)
Delivery system	Canal	(1)
	Ditch	(2)
	Pipeline	(3)
	Other / not identifiable	(4)
	Not applicable	(5)
Source of irrigation	Well (groundwater)	(1)
	Pond/lake/reservoir (still water)	(2)

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Stream/canal/ditch (running water)	(3)
Lagoon / wastewater (wastewater)	(4)
Other / non identifiable	(5)
Not applicable	(6)

8.5 Soil and water conservation

Recording of soil and water conservation measures apply to the cultivated and managed terrestrial areas and to 'cultivated aquatic and temporary flooded' areas. For example, paddy rice fields can be found in completely terraced terrain, though not very common in Africa. Also, for the semi-natural vegetated areas that is used for grazing and therefore part of agricultural land, measures for controlling erosion may have been taken. This might refer to stone lines, that might even originate from the time the land was cultivated. Distinction is made between vegetative and structural measures. Vegetative measures make use of planting barriers (vegetative strips), life fences and wind barriers, whereas structural measures involve mechanical work to modify the slope, construct banks, dig ditches, and other measures that change the physical appearance of the land surface. Conservations measures that have to do with agronomic practice and farming methods are not included, because these are difficult to observe directly in the field.

(See: https://infonet-biovision.org/EnvironmentalHealth/Introduction-soil-conservation-measures for pictures).

Classifier/Attribute	Options / Attrib. Values	Code / Value
Conservation Measure	No conservation measures	(0)
	Vegetative in nature	(1)
	Structural	(2)
Type of Conservations Measure	Stone line	(1)
	Bench terrace	(2)
	Graded terrace	(3)
	Contour bunds	(4)
	Graded bunch	(5)
	Drains, ditches, and furrows (for retention of water and/or soil)	(6)
	Grass strips (vegetated strips)	(7)
	Not applicable	(8)

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9.0 What to do in special situations

9.1 Sampling a cultivated farm with prominent ridges or heaps

In a cultivated land with prominent ridges, the topsoil mainly the 0 -20 cm depth has already been scooped up to make the ridge or heap. The furrow of the ridges therefore represents the subsoil (20 cm depth downward). This is true especially when the ridge is fresh, that is, the ridge was made recently. As time passes, part of the topsoil will be washed down into the furrow by raindrop impacts thereby creating another thin layer of topsoil in the furrow. Under this condition sample the soil as follows:

- Sample the heap/ridge as the topsoil (0-20 cm)
- To get the subsoil, sample the furrow as the subsoil taking the surface of the furrow at the point 20 cm only if the heap is fresh or recently made.
- If the heap is not fresh or it was not made recently, then drill out the first 10cm layer on the furrow and discard. Then drill down to 40 cm on the mark on the auger. This represents the 20-50cm depth of the soil which is the subsoil sample.

9.2 Sampling point at border between fields or at the transition of one land use type to the other.

A sampling point may be located at the edge of a field or just between, or it may be at the edge of the road, or track. The general rule is that any sampling point should be located at minimum 5 meters from the edge of the field (field boundary). Therefore, in such cases move the point 5 meters into the field. In case the proposed sampling location falls on a road, within a compound, or other, move to the field that is closest by, but should be within a 25 m distance. In case a point falls exactly between two fields or on a point where the neighbouring fields are at the same distance, the "look north" rule applies. From the proposed sampling location, we look north and the field that is found in that direction will be sampled.
Similar considerations apply when at the exact proposed sampling location, a rock is found, or there is a tree or any object that prevents from taking soil samples. In such case you may relocate the sampling point location, moving north in first instance and remain within 25m distance from the original point, and if the land use and land cover characteristics remain the same. If not, search a point in the same field and with the same land use characteristics as for the original sampling location.

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ANNEX A. Proposed coding system for the land use and land cover classes

A Main Land Use class

Cultivated & Managed Terrestrial Area	A11
Semi-Natural Vegetation	A12
Cultivated Aquatic Area	A21

B Dominant Life Form (A)

Trees	A1
Shrub	A2
Herbaceous	A3
- Graminoids	A4
- Forbes	A5

C Purpose (crop category)

Cereal	B1
Root and Tuber	B2
Pulses and Vegetables	B3
Fruits and Nuts	B4
Fodder crops	B5
Beverage and stimulants	B6
Industrial	B7
Wood and timber	B8
Fibre and structural mat.	B9

D. Spatial Aspect

1. Field size

Very small	S1
Small	S2
Intermediate	S3
Large	S4

2. Distribution

Structured and continuous	S5
Continuous and unstructured	S6
Clustered	S7
Scattered	S8

E. Land cover; cover of main vegetation strata

Absent	C6
Scattered	C5
Sparse	C4
Very open	C3
Open	C2
Closed	C1

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F1. Signs of Grazing YN
F2. Signs overgrazing Y/N
Tillage and Land preparation
- Signs
  - No signs/no-till P1
  - Signs tillage past P2
  - Signs recent tillage P3
- Ploughing direction
  - Along contour S1
  - Tangent S2
- Tillage type
  - Manual T1
  - Animal traction T2
  - Mechanical T3
  - Not applicable T4

Input use
- No input I0
- Crop residues I1
- Green manure/cove crops I2
- Manure I3
- Inorganic fertilizer I4

Water management
- Water supply
  - Rainfed W1
  - Post flooding W2
  - Irrigated W3
- Irrigation type
  - Surface/gravity W31
  - Sprinkle W32
  - Drip W33
- Delivery channel
  - Canal D1
  - Ditch D2
  - Pipeline D3
  - Other D4
- Source of water
  - Well V1
  - Pond V2
  - Canal/Stream V3
  - Lagoon/ wastewater V4
  - Unidentifiable V5

Soil and Water Conservation (SWC)
- General type
  - No conservations measures U0
  - Vegetative measures U1

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Structural measures	U2
Specific type	
Stone line	U50
Bench terrace	U21
Graded terrace	U22
Contour bunds	U31
Graded bunds	U32
Drains / ditches	U41
Grass strips	U11
Not applicable	U60

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