



# Soil Science Society of Nigeria

## Monthly Soil Talk Lecture Series –November Edition



### A Comprehensive Approach to Measuring, Monitoring, and Managing Soil Health

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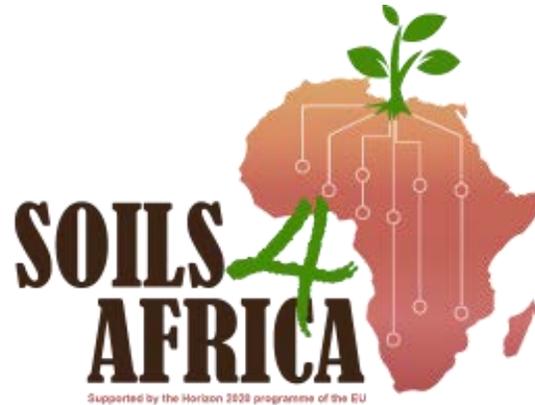


# Intro & Acknowledgements

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B.Agric (Hons) Soil Science and Land Mgt. (FUNAAB)  
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RSS –NISS  
FAO INSOILFER Technical WP1



**Teachers & Mentors**

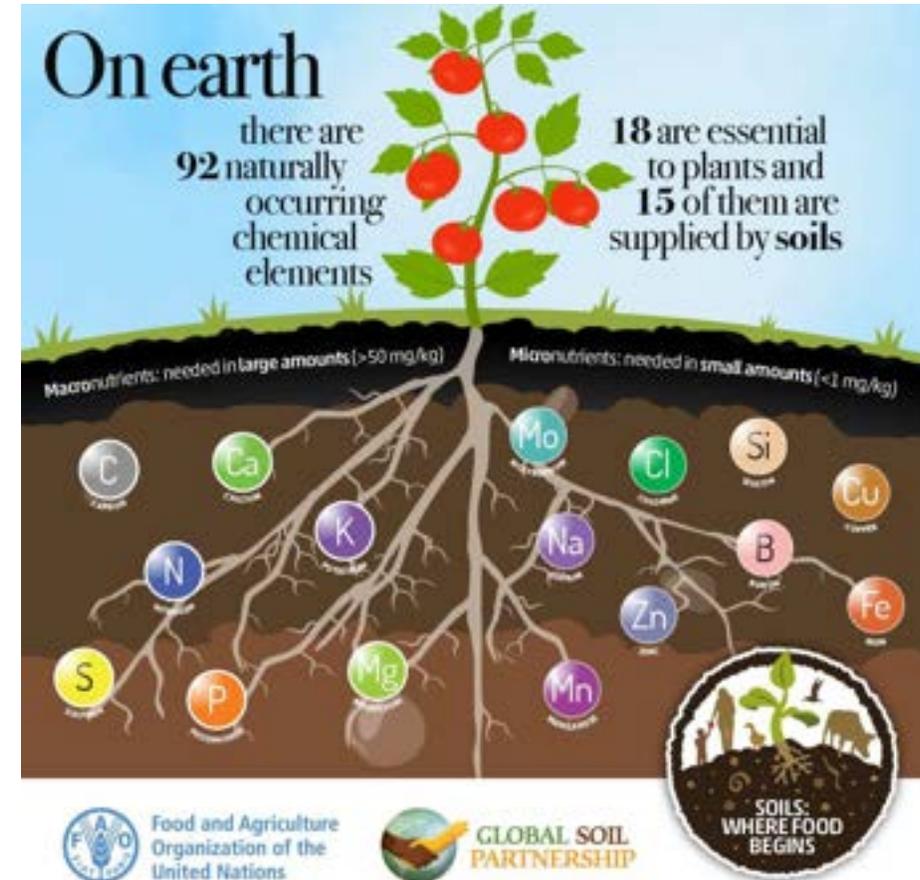
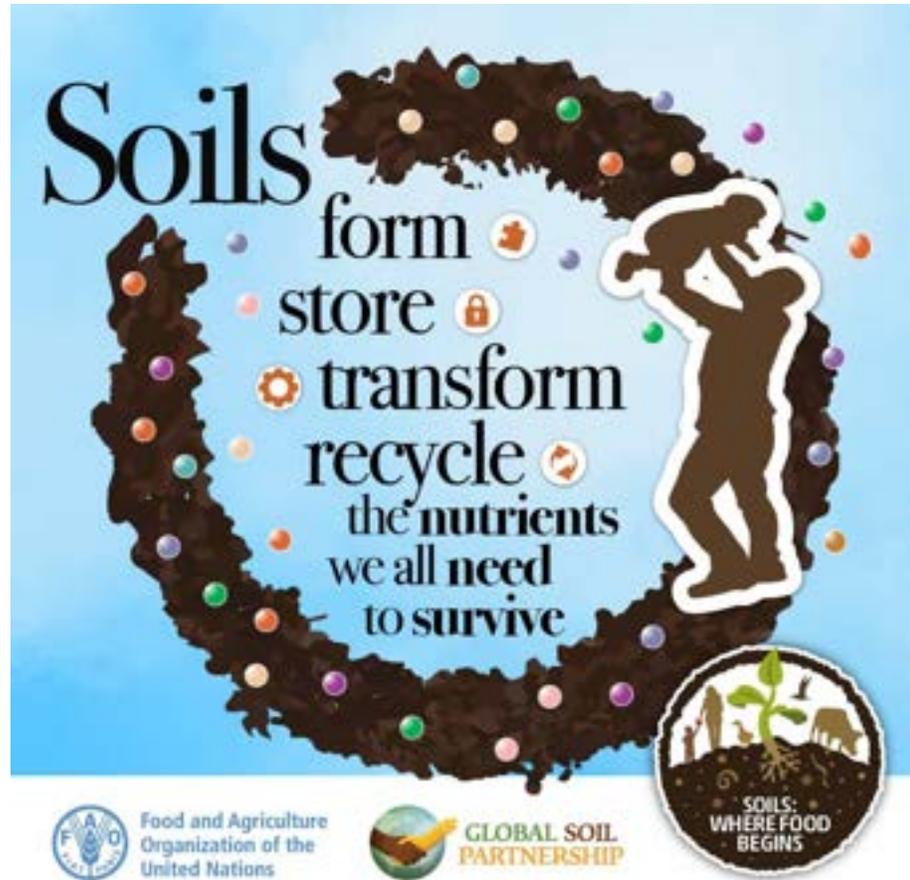
# Outline

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- Relevance of soil in sustainable development
- The concept of soil health
- Why –measuring, monitoring, and managing soil health?
- How can we measure soil health?
- Soil health indicators
- Challenges in measuring soil health
- Proposed minimum dataset for soil health measurement
- Protocols and tools –including new tools for soil health assessment
  - Field navigation
  - Sampling frame/methods
  - Sampling depth
  - Field observations and assessment -electronic data recording
- Monitoring soil health
- Principles to manage soil health
- Conclusion and recommendations



# Relevance of soils to sustainable development



# The concept of Soil Health

- Soil health is defined as the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans.

## Soil performs five essential functions:

- Regulating water: Soil helps control where rain, snowmelt, and irrigation water go. Water flows over the land or into and through the soil.
- Sustaining plant and animal life: The diversity and productivity of living things depends on soil.
- Filtering and buffering potential pollutants: Soil minerals and microbes are responsible for filtering, buffering, degrading, immobilizing, and detoxifying organic and inorganic materials, including industrial and municipal by-products and atmospheric deposits.
- Cycling nutrients: Carbon, nitrogen, phosphorus, and many other nutrients are stored, transformed, and cycled in the soil.
- Providing physical stability and support: Soil structure provides a medium for plant roots. Soils also support human structures and protect archeological treasures.



# Why –measuring, monitoring, and managing soil health?

This theme highlights the importance of accurate soil data and information for:

- Understanding soil characteristics
- Making informed decisions about sustainable soil management
- Supporting food security
- Harnessing the potential of soil to support agriculture
- Storing carbon
- Preserving biodiversity



# How can we measure soil health?



Soil health



Chemical indicators

Physical indicators

Biological indicators

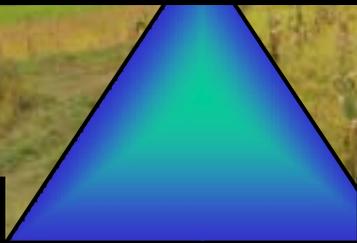


Table 1. A limited listing of soil attributes or properties which can be estimated from basic input variables using pedotransfer functions or simple models.

Soil attribute or property	Basic input variables	Reference
Cation exchange capacity	Org. C+ clay type and content	Larson and Pierce, 1994
Water Retention Charac. (AWHC)	% sand, silt, clay, + org. C + BD	Gupta and Larson, 1979
Hydraulic conductivity	Soil texture	Larson and Pierce, 1994
Aerobic and anaerobic microbial activity	WFPS as calculated from BD and water content	Linn and Doran, 1984 Doran et al., 1990
C and N cycling	Soil respiration Soil temperature + WFPS	Parker et al., 1986
Plant/microbial activity or pollution potential	Soil pH + EC	Smith and Doran, 1996
Soil productivity	AWHC, pH, EC, and texture	Larson and Pierce, 1994
Rooting depth	BD, AWHC, pH	Larson and Pierce, 1994
Leaching potential	Soil texture, pH, org. C Hydr. cond., CEC, depth	Shea et al., 1982

Abbreviations: AWHC, available water holding capacity; BD, soil bulk density; EC, soil electrical conductivity; WFPS, water-filled pore space.

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# ...managing soil health is complex!

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- **Lack of consensus** on a key performance indicators (KPIs) of soil health; what constitutes soil health.
- Some key indicators of soil health (e.g., soil organic carbon) **change slowly** ('slow variables')
- **Measurement at scale** of changes in key indicators is usually difficult (high variability).
- Changes in soil health do not come with immediate and visible benefits; **incentives are needed** for farmers to invest in soil health.
- **Policy frameworks** largely ignore soil health.



# Table 2. Proposed minimum data set of physical indicators for soil health

Indicators of soil condition	Relationship to soil condition and function: Rationale as a priority measurement	Ecologically relevant values/units; Comparisons for evaluation
<b>Physical</b>		
<b>Texture</b>	Retention and transport of water and chemicals; Modelling use, soil erosion and variability estimate	% Sand, silt, and clay; Less eroded sites or landscape positions
<b>Depth of soil, topsoil, and rooting</b>	Estimate of productivity potential and erosion; Normalizes landscape and geographic variability	cm or m; Non-cultivated sites or varying landscape positions

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<b>Depth of soil, topsoil, and rooting</b>	Estimate of productivity potential and erosion; Normalizes landscape and geographic variability	cm or m; Non-cultivated sites or varying landscape positions
<b>Infiltration and soil bulk density (SBD)</b>	Potential for leaching, productivity, and erosivity; SBD needed to adjust analyses to volumetric basis	minutes per 2.5 cm of water and $\text{Mg cm}^{-3}$ ; Row and/or landscape positions
<b>Water holding capacity (water retention characteristics)</b>	Related to water retention, transport, and erosivity; Available $\text{H}_2\text{O}$ : calculate from SBD, texture, and OM	% ( $\text{Mg cm}^{-3}$ ), cm of available $\text{H}_2\text{O}$ per 30 cm : Precipitation intensity

Doran and Parkin, 1994 and Larson and Pierce, 1994

# Table 3. Proposed minimum data set of chemical indicators for soil health

Indicators of soil condition	Relationship to soil condition and function: Rationale as a priority measurement	Ecologically relevant values/units; Comparisons for evaluation
<b>Chemical</b>		
<b>Soil organic matter (OM) (total organic C and N)</b>	Defines soil fertility, stability, and erosion extent; Use in process models and for site normalization	kg C or N ha <sup>-30</sup> cm; Non-cultivated or native control
<b>pH</b>	Defines biological and chemical activity thresholds; Essential to process modelling	Compared with upper and lower limits for plant and microbial activity

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<b>pH</b>	Defines biological and chemical activity thresholds; Essential to process modelling	Compared with upper and lower limits for plant and microbial activity
<b>Electrical conductivity</b>	Defines plant and microbial activity thresholds; Presently lacking in most process models	dS m <sup>-1</sup> ; Compared with upper and lower limits for plant and microbial activity
<b>Extractable N, P, and K</b>	Plant available nutrients and potential for N loss; Productivity and environmental quality indicators	kg ha <sup>-1</sup> 30 cm; Seasonal sufficiency levels for crop growth

# Table 4. Proposed minimum data set of biological indicators for soil health

Indicators of soil condition	Relationship to soil condition and function: Rationale as a priority measurement	Ecologically relevant values/units; Comparisons for evaluation
<b>Biological</b>		
<b>Microbial biomass C and N</b>	Microbial catalytic potential and repository for C and N; Modelling: early warning of management effects on OM	kg N or C ha <sup>-1</sup> 30 cm; Relative to total C and N or CO <sub>2</sub> produced
<b>Potentially mineralizable N (anaerobic incubation)</b>	Soil productivity and N supplying potential; process modelling;(surrogate indicator of biomass)	kg ha <sup>-1</sup> - 30cm d <sup>-1</sup> ; Relative to total C or total N contents
<b>Soil respiration, water content, and temperature</b>	Microbial activity measure (in some cases plants)  process modelling; estimate of biomass activity	kg C ha <sup>-1</sup> - d <sup>-1</sup> ; Relative microbial biomass activity, C loss vs. inputs and total C pool

# Protocols and tools – including new tools for soil health assessment

- **Field navigation**

- How to navigate in the field is important.
- It directly impacts the effectiveness and efficiency of the work.
- The number of sampling points that could be done per day is directly related to mastery of in-field navigation.



Maps.me

Software ⋮

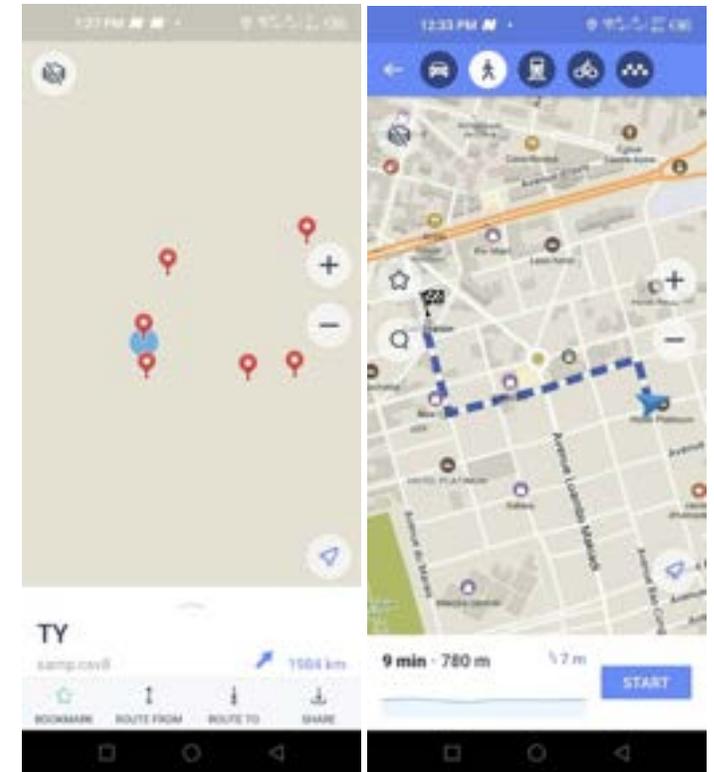
# Using Maps.me for navigation

- Advantages
  - Freely accessible
  - Provide more functionality than GPS handheld device
  - User friendly
- Accessible via Google PlayStore
- Transfer the KML file to your smartphone and open the file with MAPS.ME (select the MAPS.ME option provided when opening the file)
- <https://cgspace.cgiar.org/server/api/core/bitstreams/7a9a173f-034d-4888-a147-5856b98cd43c/content>



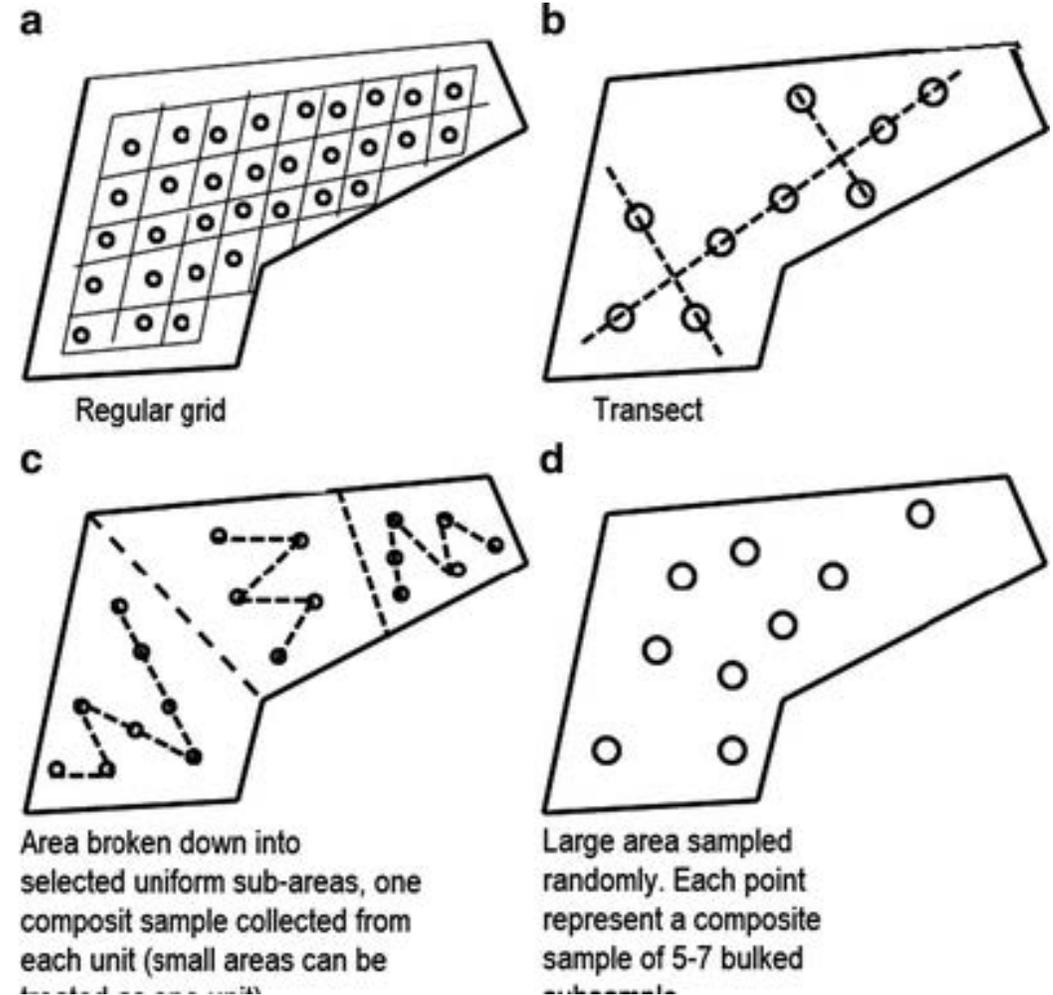
Maps.me

Software ⋮



# Sampling methods

- What guides the selection of our sampling methods/design?
  - Area under consideration
  - Purpose of study –
    - Baseline assessment /traditional soil survey
    - Carbon monitoring
    - Monitoring of agronomic gains
    - Site-specific recommendations, etc.

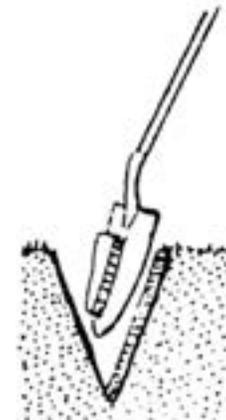
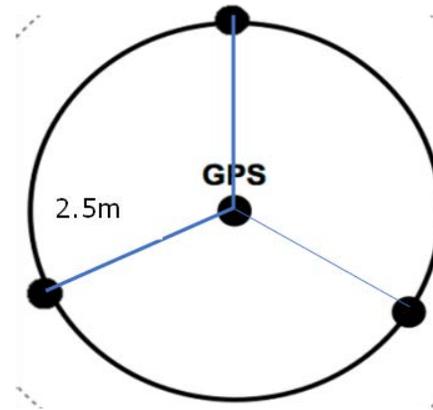


# Soil sample collection

- Tools – auger, spade, pipe
- Taking composite sample

[https://www.youtube.com/watch?v=Subl4V4FrQk&list=PLB4Kg\\_AOaGwGLT9iY77wgm\\_CMNTA3xtvA&index=3](https://www.youtube.com/watch?v=Subl4V4FrQk&list=PLB4Kg_AOaGwGLT9iY77wgm_CMNTA3xtvA&index=3)

[https://www.youtube.com/watch?v=qgjAlmbXgXs&list=PLB4Kg\\_AOaGwGLT9iY77wgm\\_CMNTA3xtvA&index=4](https://www.youtube.com/watch?v=qgjAlmbXgXs&list=PLB4Kg_AOaGwGLT9iY77wgm_CMNTA3xtvA&index=4)



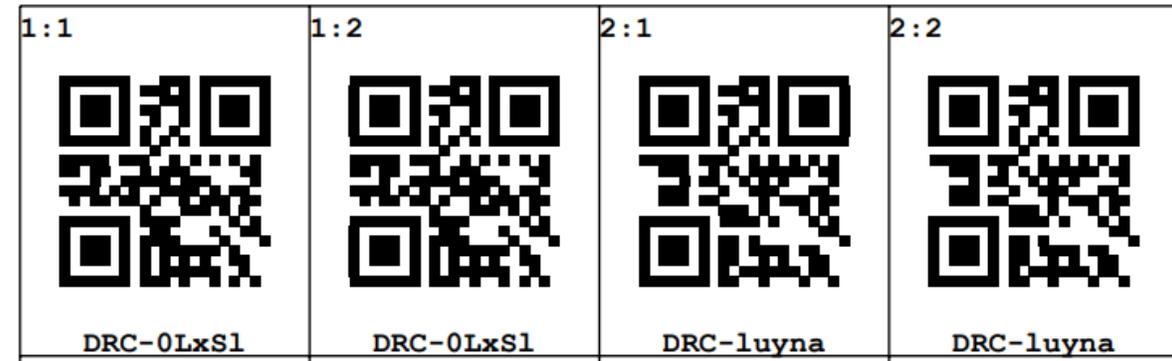


## Soil sample collection

- Soil sampling depth
  - Topsoil 0 – 20 cm or 0 – 15 cm?
  - Subsoil 15 – 30 cm or 20 – 40 cm or 20 -50 cm?

# Sample labeling –QR code

- QR/Bar coding system for identification of the soil samples (could be used throughout the process from sample collection to lab analysis and reporting)
- Verification and quality control check to be part of the process (procedures for quality control is built-in)
- How do I create QR for my project free of charge?



<https://tag.qed.ai/>

# Field observations and assessment

- Electronic data recording
  - Moving proforma to ODK digital forms
- Advantages of the digital systems-
  - Efficient data recording
  - Improves data quality
  - Ensure FAIR data

Field No.	Location	Coordinate	Vegetation	Date	Observer											
11201	Forest area	08.024757 003.281188	Natural or forest island													
Elevation	Parent no. (soilment complex or Physiographic Unit)		Program/upper slope													
Slope Angle	North facing slope	% Slope	Land use	Soil type	Drainage type											
Surface of	Covered with refuse	Cracks	Stones	Rocks												
Remarks	Dump site, deep soil from over sandy clay loam															
Depth (cm)	Colour	Texture	Structure	Concentrations		Condition	Course material		Roots		Pores					
0-10	Mb10	S	None	Grade	Moisture	Size (mm)	Shape and Amount (%)	Moisture	Size (mm)	Shape	Amount	Size (mm)	Abundance	Type	Size (mm)	Abundance
11-20	Mb10	S	None	MB	MB	MB	MB	MB	MB	MB	MB	MB	MB	MB	MB	MB
21-30	Mb10	S	None	MB	MB	MB	MB	MB	MB	MB	MB	MB	MB	MB	MB	MB
31-40	Mb10	S	None	MB	MB	MB	MB	MB	MB	MB	MB	MB	MB	MB	MB	MB
41-50	Mb10	S	None	MB	MB	MB	MB	MB	MB	MB	MB	MB	MB	MB	MB	MB



## Electronic forms for data capture

Soil\_Data\_Collec... | 11:08 AM

Introduction  
Welcome



...Building soil information system for Africa

NEXT >

S4A\_Field\_Survey | 11:03 AM

Accepting/Rejecting the sampling point

\* Record the location of your current position

Change Location

Latitude: N 7°30'16"  
Longitude: E 3°54'2"  
Altitude: 247.8m  
Accuracy: 13.43m

BACK < NEXT >

S4A\_Field\_Survey | 11:03 AM

Accepting/Rejecting the sampling point

\* Provide the ID of the designated sampling point (SP-ID)

BACK < NEXT >

S4A Sample Coll... | 1:09 PM

Record the details of the soil sample

\* Scan the QR code for the topsoil sample of layer 1 (0-20 cm)

Zoom in on one of the two QR codes of the duplicate label

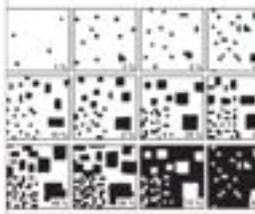
Get Barcode

BACK < NEXT >

S4A\_Field\_Survey | 11:07 AM

Record

\* Indicate the presence of stones at the soil surface by class



No stones (less than 0.01%)  
 Slightly stony (0.01 – 2%)  
 Stony (2 – 5%)  
 Very stony (5 -15%)  
 Extremely stony (>15%)

BACK < NEXT >

S4A Sample Coll... | 1:08 PM

Observations on grazing

Relates to signs of an area being used for grazing or to signs of impact of grazing

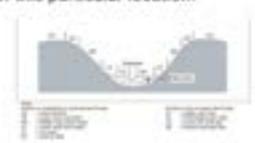
	Yes	No
Can you see if the land is used for grazing?	<input type="radio"/>	<input type="radio"/>
Do you find any infrastructure for grazing of cattle or other livestock?	<input type="radio"/>	<input type="radio"/>
Do you find livestock droppings or any signs of poaching?	<input type="radio"/>	<input type="radio"/>
Do you find short grass height over	<input type="radio"/>	<input type="radio"/>

BACK < NEXT >

S4A\_Field\_Survey | 11:08 AM

Observations on site characteristics (Land terrain)

\* What is the topographic position of this particular location?



Indicate your position within the landscape in case of undulating and hilly terrain

Crest (summit)  
 Upper slope (shoulder)  
 Middle slope(back slope)  
 Lower slope (foot slope)  
 Toe slope  
 Bottom (flat)

BACK < NEXT >

S4A\_Field\_Survey | 12:16 PM

Water management / irrigation

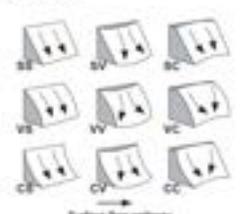
Indicate the source of the irrigation water

Well (groundwater)  
 Pond/lake/reservoir (still water)  
 Stream/canal/ditch (running water)  
 Lagoon / wastewater (wastewater)  
 Other / non identifiable  
 Not applicable

BACK < NEXT >

S4A\_Field\_Survey | 11:07 AM

Choose the slope pathways that applies to the area under observation



Straight -straight  
 Straight -convex  
 Straight -concave  
 Convex-straight  
 Convex -convex

BACK < NEXT >

S4A\_Field\_Survey | 8:16 AM

Observations on soil characteristics (depth restriction, drainage and erosion)

\* Record the effective soil depth class

To what depth (cm) can you auger without feeling major restrictions?

0 - 25 cm  
 25 - 50 cm  
 50 - 100 cm  
 100 - 120 cm  
 > 120 cm

BACK < NEXT >

S4A Sample Coll... | 2:29 PM

What is the drainage class?

Record the drainage class code

Very poorly drained (You find water on the soil surface after 24 hours of rain; the soil matrix has greyish colours)  
 Poorly drained (You find many mottles in the topsoil)  
 Imperfectly drained (You find few mottles on the topsoil but increasingly within the subsoil)  
 Moderately well drained (You find mottles only in the subsoil beyond 20 cm depth, but few)  
 Well drained (You find very few mottles only in the subsoil or no mottles at all, but the soil is not excessively drained)

BACK < NEXT >

S4A\_Field\_Survey | 8:08 AM

You are at the end of S4A\_Field\_Survey.

Name this form  
S4A\_Field\_Survey

Mark form as finalized

Save Form and Exit

BACK <

# Monitoring Soil health

Monitoring can only be done through the indicators

A standard protocols and SOPs for field campaigns and lab analysis

A baseline assessment of the indicators is crucial

A standardized and unified database is required

Future assessment should respect baseline assessment protocol

# Principles to Manage Soil Health

This involves management practices to maximize nutrient cycling and nutrient-use efficiency.

Nutrient management can be defined as “efficient use of all nutrient sources”.

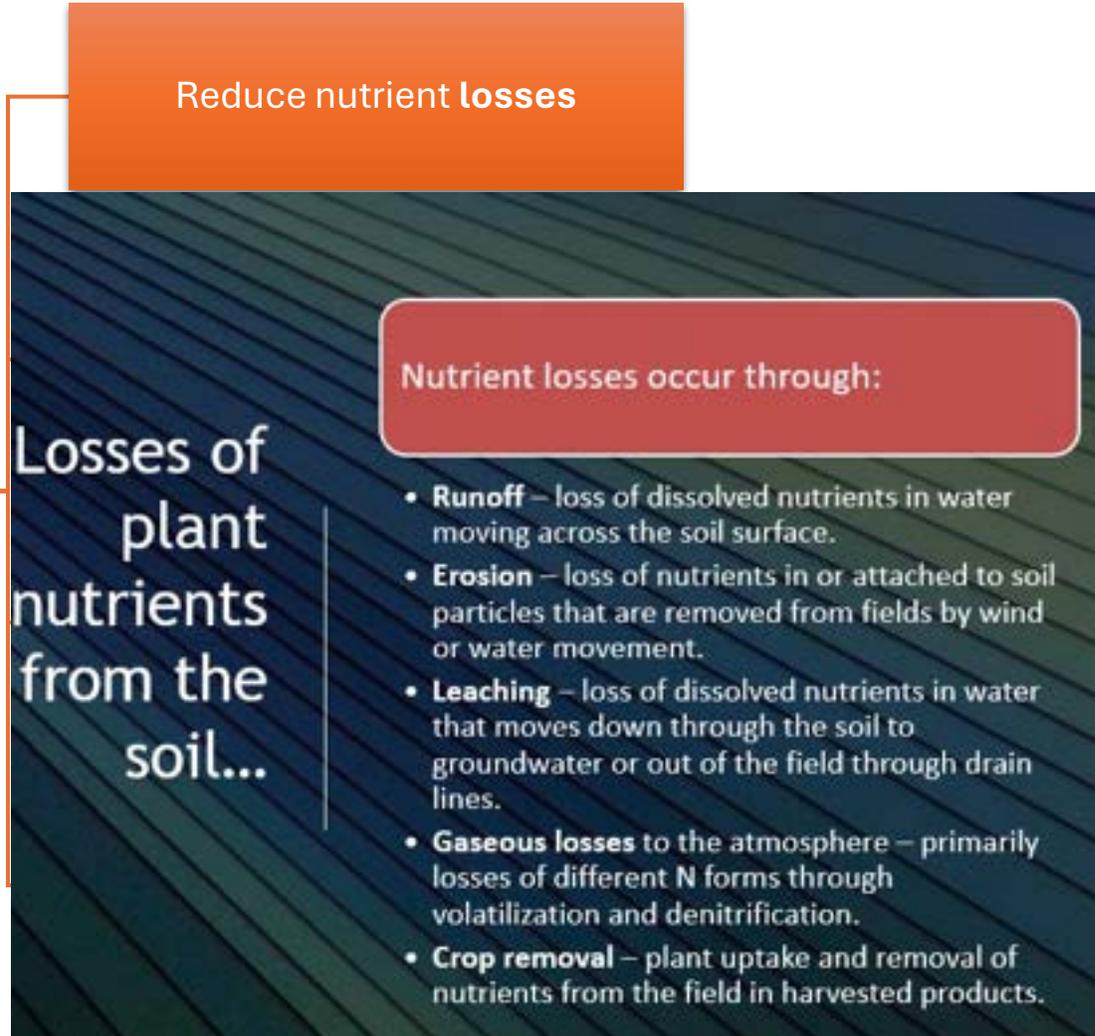
The primary principles of managing soil health are to:

# Principles to Manage Soil Health

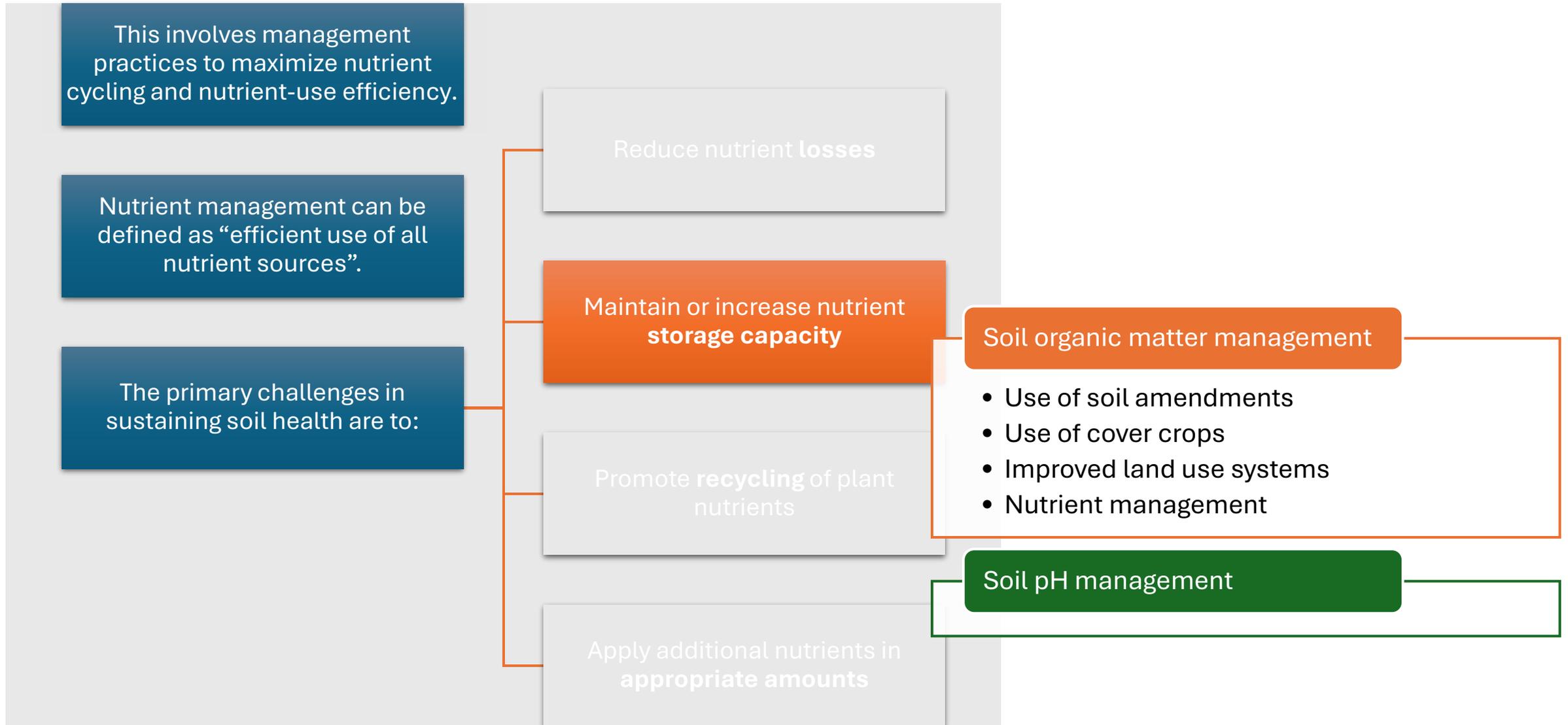
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# Principles to Manage Soil Health



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The primary challenges in sustaining soil health are to:

Reduce nutrient losses

Maintain or increase nutrient storage capacity

Promote **recycling** of plant nutrients

Apply additional nutrients in appropriate amounts



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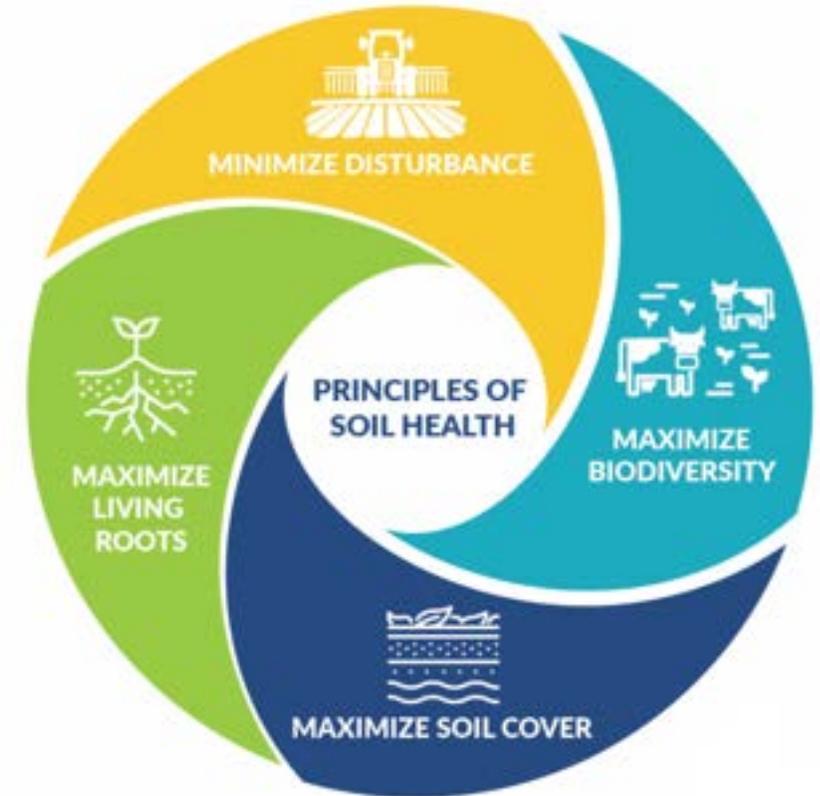
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- Maintain or increase nutrient **storage capacity**
- Promote **recycling** of plant nutrients
- Apply additional nutrients in **appropriate amounts**



# Conclusion and recommendations

- Enhancing soil health, minimizing environmental degradation, and promoting sustainable agrifood systems depend on effective strategies for measuring, monitoring, and managing soil health.
- Coordinated development of standards for soil health at national level (SSSN) and by interest groups involved in agriculture, the environment, resource conservation, and economics, to assess sustainability changes with time.
  - Establishment of reference guidelines and thresholds for indicators of soil health that enable identification of relationships between soil measures and soil function – climate, soils, land use, topography and management systems
  - Identification of appropriate scales of time and space for assessment of soil health
  - Development of standardized protocols for sampling, processing and analysis



# Conclusion and recommendations...

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Develop practical approaches and tools for farmers, researchers, and extension workers to assess soil health on-site.



The challenge before us is to develop holistic approaches for assessing soil health that are useful to producers, specialists, and policymakers in identifying profitable agricultural and land-use management systems that will sustain our soil resources for future generations.



**IITA**  
*Transforming African Agriculture*



**Treat soils and hearts  
carefully, it takes much time  
to heal them.. they are  
difficult to recover... ..and it is  
almost impossible to make  
them the same again...**

## Thank you

**Samuel A. Mesele PhD**

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mob. 09062927833

