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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27 November 2024

Intro & Acknowledgements

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

Teachers & Mentors

Outline

- 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?

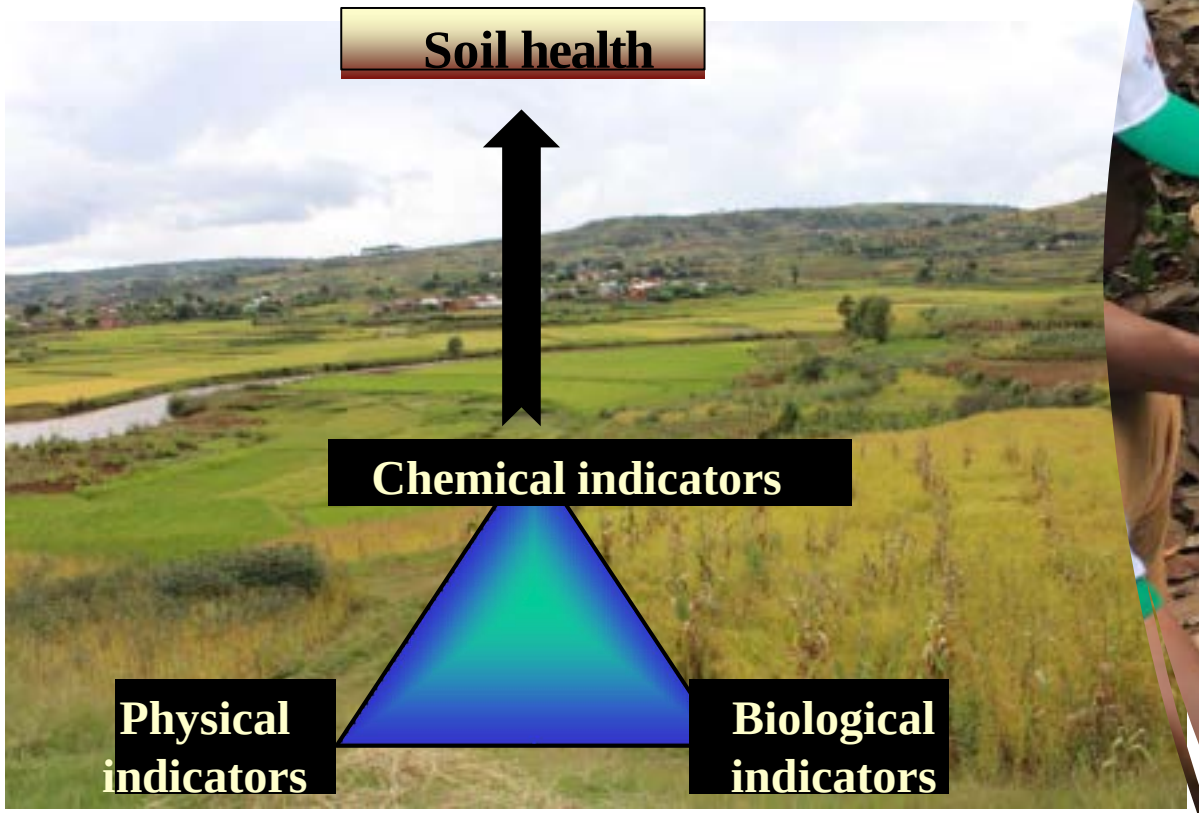

Table 1. A limited listing of soil attributes or properties which can be estimated from basic input variables using pedotransfer functions or simple models.

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)	Parkin et al., 1996
Plant/microbial activity or pollution potential	Soil pH + EC	Smith and Doran, 1996
Soil productivity	BD, AWHC, pH, EC, and aeration	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., 1992

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!

- **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
Physical		
Texture	Retention and transport of water and chemicals; Modelling use, soil erosion and variability estimate	% Sand, silt, and clay; Less eroded sites or landscape positions
Depth of soil, topsoil, and rooting	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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Depth of soil, topsoil, and rooting	Estimate of productivity potential and erosion; Normalizes landscape and geographic variability	cm or m; Non-cultivated sites or varying landscape positions
Infiltration and soil bulk density (SBD)	Potential for leaching, productivity, and erosivity; SBD needed to adjust analyses to volumetric basis	minutes per 2.5 cm of water and Mg cm^{-3}; Row and/or landscape positions
Water holding capacity (water retention characteristics)	Related to water retention, transport, and erosivity; Available H_2O: calculate from SBD, texture, and OM	% (Mg cm^{-3}), cm of available H_2O 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
Chemical		
Soil organic matter (OM) (total organic C and N)	Defines soil fertility, stability, and erosion extent; Use in process models and for site normalization	kg C or N ha-30 cm; Non-cultivated or native control
pH	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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pH	Defines biological and chemical activity thresholds; Essential to process modelling	Compared with upper and lower limits for plant and microbial activity
Electrical conductivity	Defines plant and microbial activity thresholds; Presently lacking in most process models	dS m^{-1}; Compared with upper and lower limits for plant and microbial activity
Extractable N, P, and K	Plant available nutrients and potential for N loss; Productivity and environmental quality indicators	kg ha^{-1} 30 cm; Seasonal sufficiency levels for crop growth

Doran and Parkin, 1994 and Larson and Pierce, 1994

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
Biological		
Microbial biomass C and N	Microbial catalytic potential and repository for C and N; Modelling: early warning of management effects on OM	kg N or C ha^{-1} 30 cm; Relative to total C and N or CO_2 produced
Potentially mineralizable N (anaerobic incubation)	Soil productivity and N supplying potential; process modelling;(surrogate indicator of biomass)	kg ha^{-1}- 30cm d^{-1}; Relative to total C or total N contents
Soil respiration, water content, and temperature	Microbial activity measure (in some cases plants) process modelling; estimate of biomass activity	kg C ha^{-1}- d^{-1}; Relative microbial biomass activity, C loss vs. inputs and total C pool

Doran and Parkin, 1994 and Larson and Pierce, 1994

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

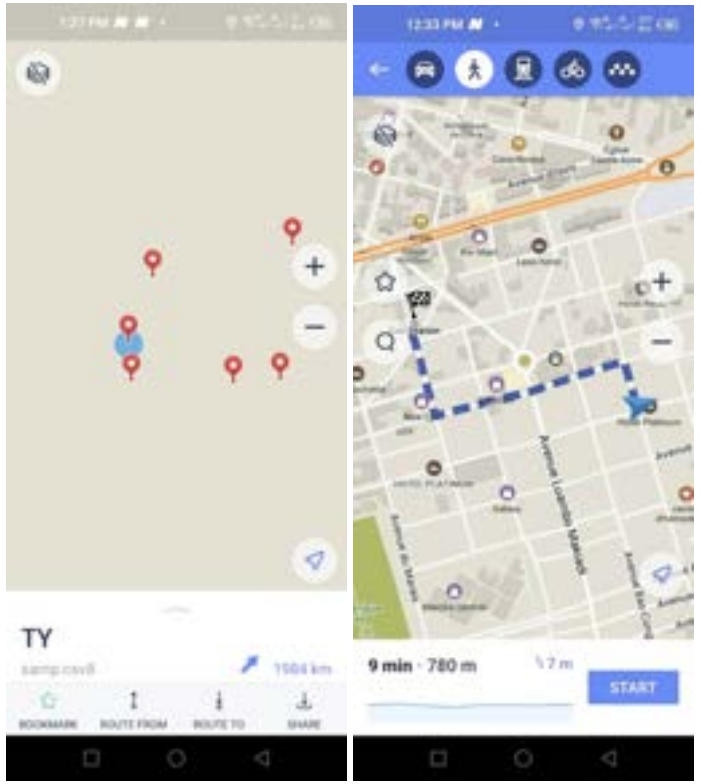
Using Maps.me for navigation

- 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

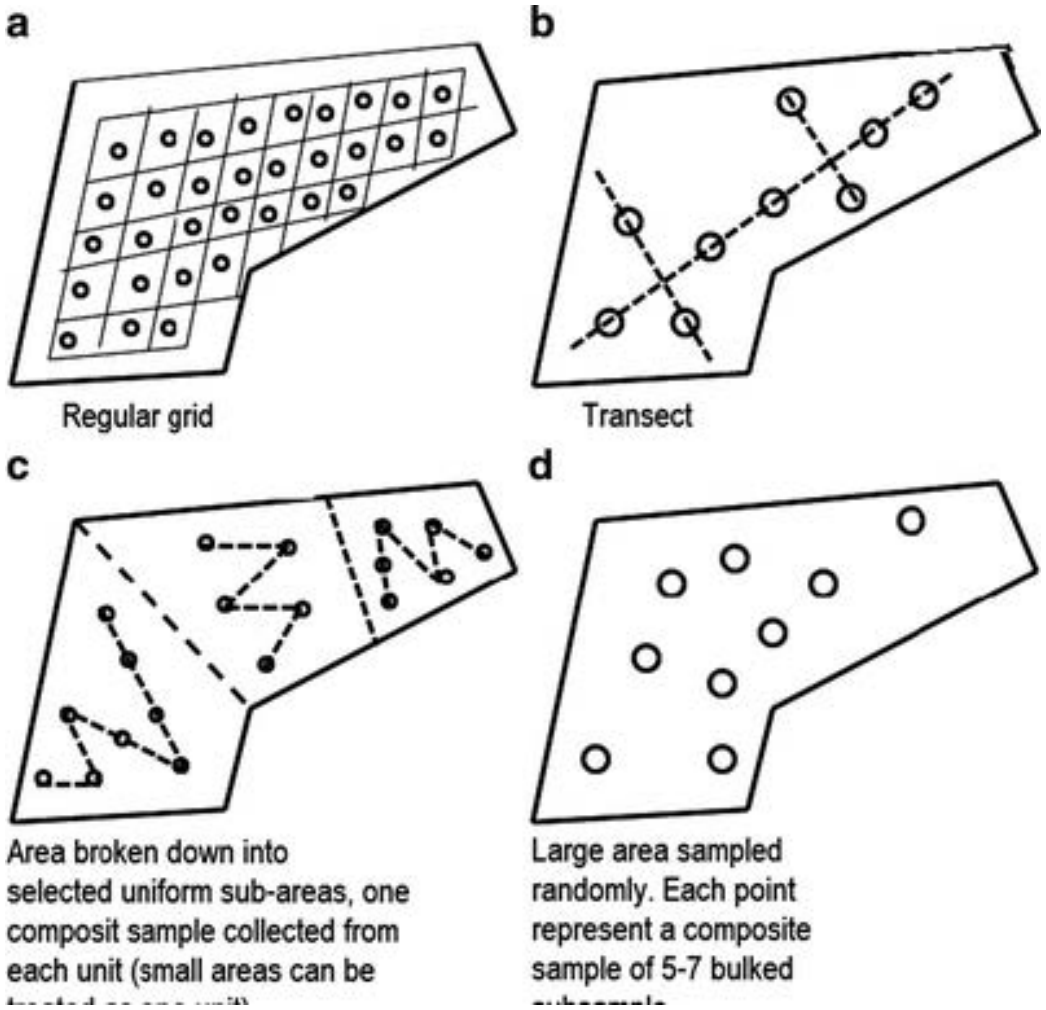
Maps.me

Software

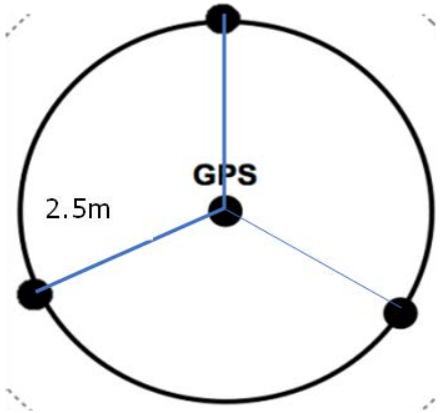


Sampling methods

- 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

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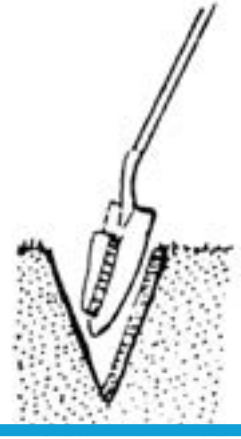
https://www.youtube.com/watch?v=qgjAImbXgXs&list=PLB4Kg_AOaGwGLT9iY77wgm_CMNTA3xtvA&index=4

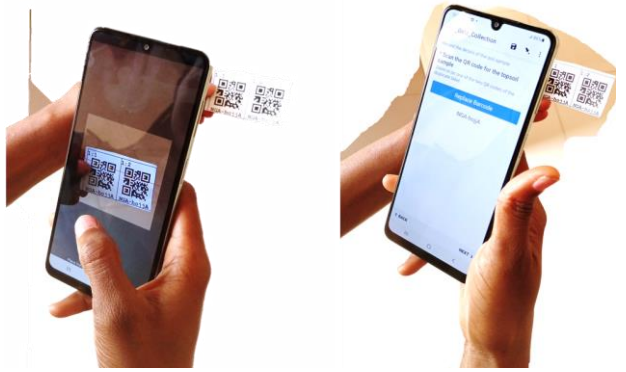


Soil sample collection

- 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?



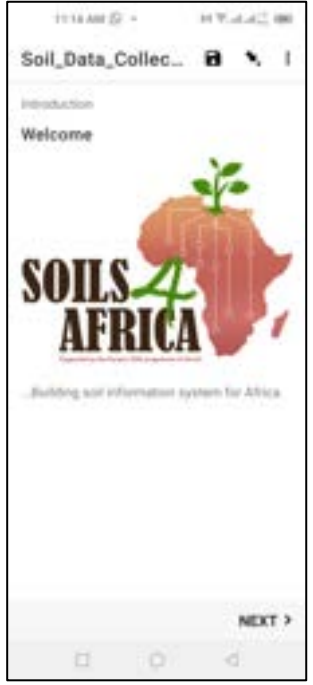
https://tag.qed.ai/

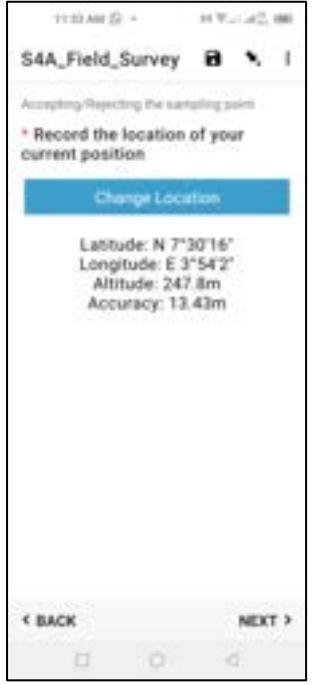
Field observations and assessment

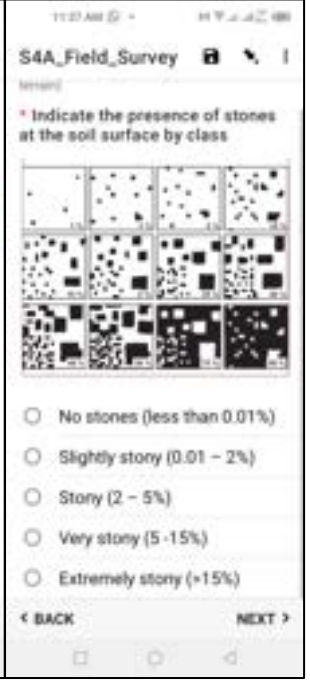
- -Electronic data recording
  - Moving proforma to ODK digital forms
- Advantages of the digital systems-
  - Efficient data recording
  - Improves data quality
  - Ensure FAIR data

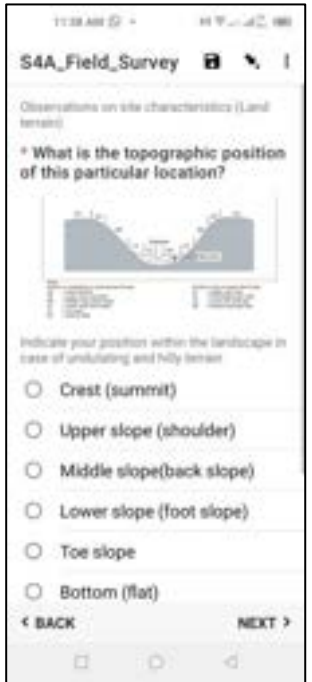
OPEN DATA KIT

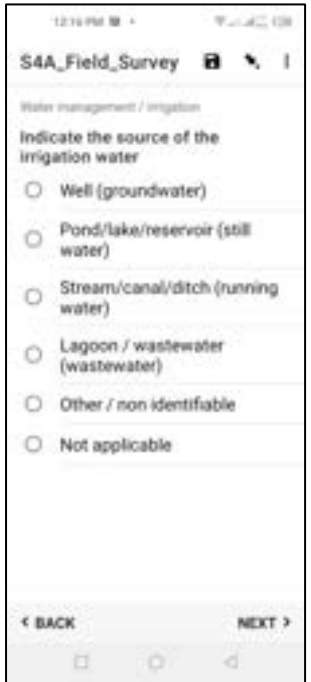
Electronic forms for data capture

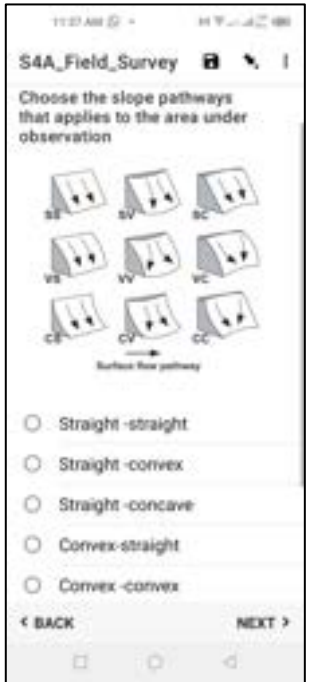


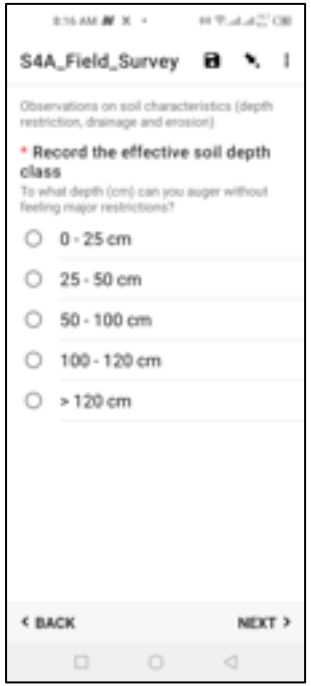


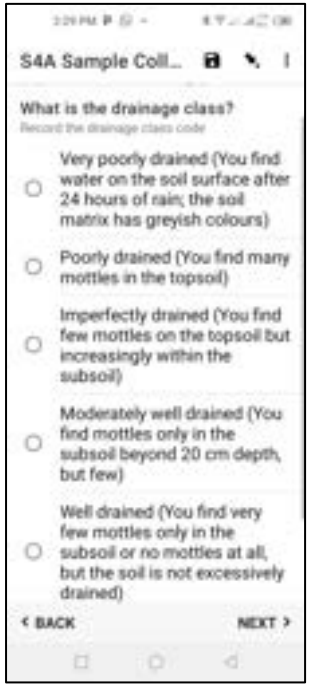












Monitoring Soil health

- 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:

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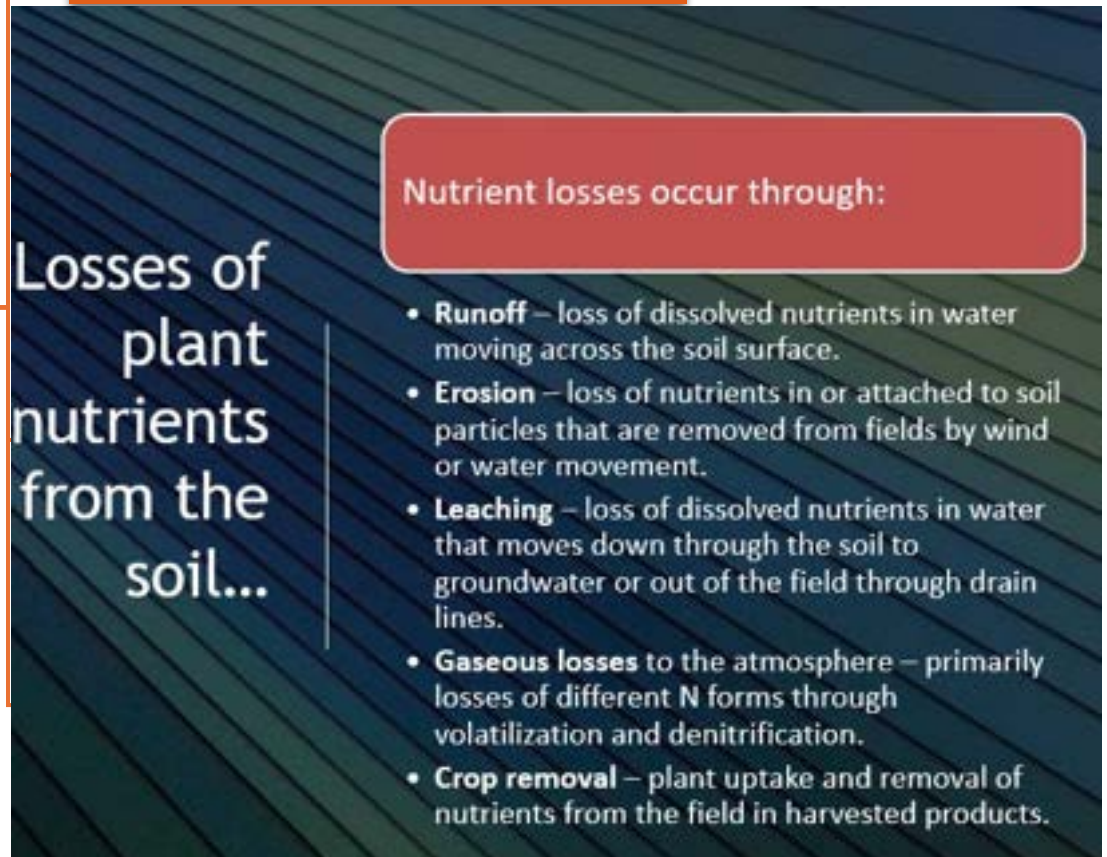

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The primary challenges in sustaining soil health are to:

- Reduce nutrient **losses**
- Maintain or increase nutrient **storage capacity**
  - Soil organic matter management
    - Use of soil amendments
    - Use of cover crops
    - Improved land use systems
    - Nutrient management
  - Soil pH management
- Promote **recycling** of plant nutrients
- Apply additional nutrients in **appropriate amounts**

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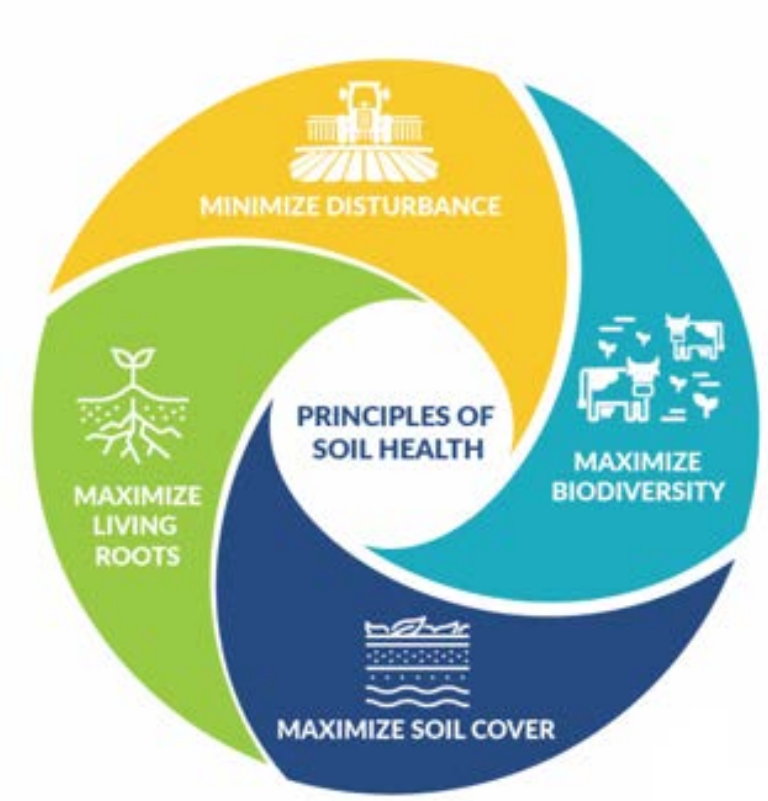

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Conclusion and recommendations

- 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...

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.

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

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