A Guide for Soil Biology Training

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About Nature Positive Agriculture

Nature Positive Agriculture initiative offers a sustainable food production system that meets the demands of the growing population as well as facilitates the necessity of environmental restoration, and biodiversity conservation thereby improving soil, land, and water by scientifically supported solutions. Nature positively implements and equitably supports food and livelihoods on the ground through a transformative change, initiating at the farm and community level, mainstreaming the research pathways and solutions in the smallholder agricultural systems. While working and implementing solutions with CGIAR and non-CGIAR partners including decision-makers, the initiative also accounts for true food cost, targets the policy realignments, and incentives for a higher adoption rate of nature-positive solutions. Finally, the initiative aims to protect, manage, and restore natural ecosystems, enhance soil biodiversity, mitigate climate change, and shift overall food systems to a net nature-positive way. Nature-positive agriculture delivers pathways through various interventions including:

- implementation of nature-friendly soil management practices such as applying manure and compost for soil conservation
- use of cover crops and crop rotation for minimizing erosion and pest and disease influence
- focus on below-ground soil biodiversity
- blending of nature-friendly farming practices as the systems approach

What do you mean by Soil Health?

Soil health corresponds very much to human health and refers to its capacity to work with the full ability for sustaining productivity, below and above-ground biodiversity and enhancing other ecosystem services including natural resources and promoting plant and animal health.

Healthy soils are efficient in utilizing the in-house inputs. They produce more with fewer external input supplies. A typical example includes the presence of essential nutrients and organic matter in it with rich amount of below-ground biodiversity whereby healthy soils transfer the required/ optimum amount of nutrients from soil to crops. Thus, it's important to say that healthy soil produces more crops per unit of external resources supplied. Healthy soils also have greater efficiencies to protect crops from extreme conditions of abiotic/ biotic stresses such as drought, temperature shocks, flooding, unpredictable pests and disease attack. These soils have inherent capacity to fight against pests and diseases are generally referred as suppressive capacity of soils. Both healthy and suppressive soils recommend five basic principles to maximize its ability to perform and produce more in healthy and sustainable manner.

Soil Health Principles

To improve soil health and maximize it's efficacy one should consider moving from inside to outside focusing on various compartments.

1. Roots that are alive

The rhizosphere, which refers to the region around the plant roots, is an essential area for microbes in the soil due to the secretion of root exudates, nutrient cycling and plant growth. Rhizosphere (region around the plant roots) is an ideal place for microbes in soil which secretes root exudates. Root exudates is the term used to the compounds produced by plant roots such as sugars, carbohydrates and organic acids and act as source of food and energy for the soil life. Root exudates play a crucial role in providing nourishment and energy for the diverse microbial community present in the soil. Active roots also support living biomass in soil, a nutrient dense space for protozoa, bacteria, fungi and numerous other life in the rhizosphere.

Benefit of active roots:

- improved soil infiltration through maintaining soil aggregation and pore spaces
- Enhanced uptake of soil nutrients
- Increased crop resilience against erosion caused by water and wind

Interventions to enhance rhizosphere biology can include implementing cereal-legume systems that complement each other. This can lead to a more diverse microbial community in the soil, benefiting plant growth and nutrient cycling. Additionally, below ground soil biodiversity isolation and screening can help identify and utilize specific microorganisms that promote soil health.

2. Diversity of plants

The diversity of plant plays a crucial role for proper functioning of the environment. Different crops releases their own unique root exudates, which support life in the soil. By incorporating various approaches to enhance diversity, such as planting different crops, rotating crops, and intercropping, farmers can establish healthy and sustainable farming systems.

Benefit of increasing on-Farm diversity- increasing the diversity of crops on a farm offers several advantages, including:

a) Disease control- a diverse crop system can disrupt disease cycles, leading to healthier crops and improved growth.
b) Weed suppression- planting diverse crops can help suppress the growth of weeds, reducing the need for herbicides.
c) Habitat for soil microorganisms- variety of crops provide habitat for beneficial soil microorganisms, promoting soil health and fertility.
d) Erosion prevention- by increasing plant diversity, erosion caused by water and wind can be minimized, protecting the soil and preventing nutrient loss.

e) Organic matter enhancement- increasing on-farm diversity contributes to the accumulation of organic matter in the soil, which improves soil structure, water retention, and nutrient availability.

Interventions to enhance diversity: to optimize crop diversity on a farm, various interventions can be implemented, including:

a) Crop diversification- planting a wide range of crops and varieties with different growth habits, nutrient requirements, harvesting seasons and different function.
b) Crop rotation- rotating the crops grown in a particular field over time. This helps break pest and disease cycles, conserve soil nutrients, and minimize the buildup of pathogens.
c) Agroforestry: introducing essential multipurpose trees and fruit trees could improve the soil health by providing additional organic matter, nutrient and preventing erosion. Furthermore, these trees also serve as shelter and feeding source for various valuable insects and animals play crucial role in maintaining a balanced ecosystem. They may act as pollinators for crops, contribute to natural pest control, or assist in nutrient cycling.

By implementing these interventions, farmers can effectively promote plant diversity and create sustainable farming systems.

3. Minimize farm disturbance

Mechanical and chemical disturbance on farms have significant impacts on the soil structures, resulting in various changes that affect the overall health and productivity of the soil. These disturbance can alter the infiltration capacity, water holding capacity, and soil biological life. Minimizing tillage allow the ground biomass (plant materials and crop residues) to remain on the top layer of soil. This approach, along with reduced tillage and the presence of above-ground biomass, contributes in several positive outcomes:

a) Maintaining the soil structure for long term productivity- by leaving the biomass on the surface, it acts as a protective layer that helps to prevent erosion and compaction. This preservation of soil structure is vital for sustaining long-term productivity and ensuring healthy crop growth.
b) Improve pore spaces in soil and enhancing water infiltration- the presence of the above-ground biomass helps to promote the creation and maintenance of pore spaces in the soil. These pores allow for better water movement and infiltration, reducing the risk of waterlogging and improving overall water management on farms.
c) Retaining soil moisture at optimum levels- the ground biomass acts as a natural mulch, helping to regulate soil moisture by reducing evaporation and suppressing weed growth. This assists in maintaining optimal moisture levels essential for plant growth and minimizing water stress.
d) Supporting soil life and biological processes- the presence of above-ground biomass provides a habitat and food source for a diverse range of soil organisms, including beneficial microbes, earthworms, and insects. This encourages a thriving soil ecosystem and enhances essential biological processes such as nutrient cycling and organic matter decomposition.

Interventions include:

- minimizing the use of heavy farm machineries

- practicing no-till or reduced-till farming methods
- utilizing cover crops to protect the soil surface
- implementing crop rotation to prevent soil depletion

4. Cover top layer of soil

Crop mulching is a technique that involves covering the top layer of soils with crop residue left on ground after harvest. One can also use plant residues from forests systems that are rich in organic matter. Covering the top soil helps to:

a) Reduce evaporation rates- the reduced evaporation rates helps to maintain adequate moisture levels for both the soil and the crops. This is particularly beneficial in dry or arid regions where water availability is limited.
b) Regulates soil temperature throughout the year- by providing a protective layer, it minimizes temperature fluctuations, ensuring that the soil remains at an optimal temperature for plant growth and development.
c) Protect soils against erosion caused by wind and water- the crop residue acts as a physical barrier, preventing the soil from being washed away or blown off by strong winds. In doing so, it helps to retain essential nutrients within the soil, preventing them from being lost through erosion.
d) Suppress weed growth- the layer of residue acts as a natural weed barrier, preventing weed seeds from germinating and competing with the desired crops for resources such as water, sunlight, and nutrients. This reduces the need for manual weed control and allows the crops to thrive without unnecessary competition.

Interventions include:

- enhancement of ground biomass such as crop residue management
- cover crops

Fig 1: Practice of diversifying crops, crop mulching and crop residue management for multi farm benefits

5. Integration of livestock

The integration of livestock in agricultural systems, particularly through grazing, plays a crucial role in arid and semi-arid regions. This practice not only supports the functioning of ecosystems but also provides numerous benefits for soil health, crop growth, and biodiversity.

The key advantages of integrating livestock is:

a) balancing soil organic matter
b) enhancing soil bulk density and soil biodiversity
c) recycling of soil nutrients
d) increase the diversity of soil organisms, such as earthworms and microbes, which contribute to nutrient cycling and improve overall soil fertility.
e) improve soil fertility, resulting in healthier crops and reduced reliance on chemical fertilizers.
f) providing habitat for beneficial insects such as pollinators and predators of pests. These insects play a vital role in maintaining a balanced ecosystem and promoting the health of crops

Interventions include:

- balanced integration of livestock with the available grazing resources to prevent overgrazing. Monitoring and managing animal stocking rates is crucial to maintain the ecological balance of the system.
- on farm manure utilization strategies should be implemented to effectively manage and utilize the nutrients present in livestock waste. Practices such as composting or proper application of manure to fields can maximize the benefits while minimizing the risks of nutrient runoff or environmental pollution.

Fig 2: Soils with poor (on the left) and good organic matter (on the right)

The below five basic principles of soil make it as living system:

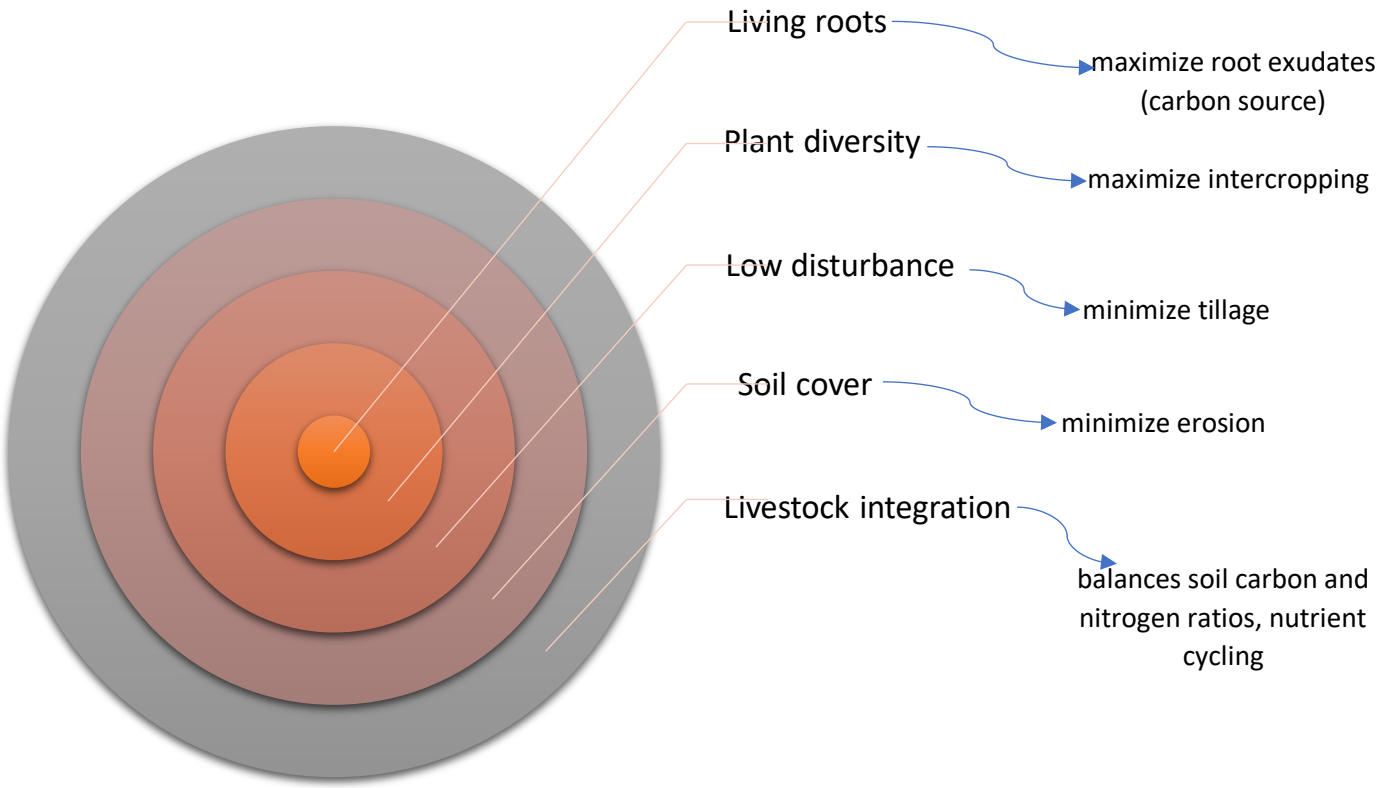

Fig 3: Soul of infinite life (SOIL) as a living system (adopted from COP in Soil health, Nature+ Alliance of Bioversity International and CIAT)

Soil Biology: on farm testing

A home of numerous macro and microflora, soils are crucial for healthy planet. These macro and microflora influence soil fertility, nutrient mobilization and recycling, direct interaction with plants and thus responsible for crop productivity. Several microorganisms are responsible for fixing nitrogen in soil, mobilization of insoluble nutrients such as Phosphorus and protecting crops from pests and diseases. The manual describes the soil biology components that farmers can visualize and test on farm. Once farmer's are trained, this manual can help them to relate their soil health conditions and to decide and select crops, applying the right inputs at the right time and quantity, follow good management practices and interventions when required. Our focus is on soil health biological indicators, agronomic and management characteristics are covered by training manual on- Soil health strategies for Sorghum systems in Kenya (Kinyua et al., 2023) and global Community of practice on soil health in Nature+ (Kaushal et al., 2023).

Healthy soils- test yourself

This section allows you to learn and decide about the soil in terms of what is required for making your farm more productive, sustainable, and economical stable for future generations. The techniques are available in order to test your farm with locally available inexpensive resources. The simple interventions can be addressed at each step before, at sowing, during growth season and post crop harvest management practices. Below are some on farm techniques that allow you to test and improve the conditions of your farm without additional resources or much laboratory inputs.

pH:

Step 1. Take 50 g of soil samples (deep about 15 cm) from 4-5 randomized (different corners and center) places of farm and mix them together in a container

Step 2. Divide this composite soil sample into half in another two different containers each having at least 50 g of soil

Step 3. Add 100-125 ml of Lemon juice to container 1, occurrence of gas bubbles indicates alkalinity of soil, with a pH of 8 or higher. In this case, locally available resources such as compost or peat can be applied to make it neutral (ideal for the farm soil)

Step 4. Add 100-125 g of baking soda to container 2, occurrence of gas bubbles indicates acidity of soil which is 6 or lower. In this case, locally available resources such as lime or well composted manure can be applied to increase to bring it neutral (ideal for the farm soil)

Step 5. No reaction in any of the above two steps indicates soil is neutral (around pH 7) which is perfect for any crop cultivation

Soil type:

Step 1. Take handful of moist (not wet) soil from farm and gently press it by closely hand palm and then open to observe

Step 2. If the soil remains in its original shape and stick to the hand palm, this indicates the clay soil which is good for holding water and nutrients but not for releasing them for the uptake of plants

Step 3. If the soil gets fragmented into pieces, this indicates sandy soil which is not ideal for retaining water and nutrients in it

Step 4. If the soil disintegrates without losing it's shape, it indicates loamy soil which is perfect for any crop cultivations

Soil drainage capacity:

Step 1. Choose good and flat location of your farm, make as trench of 15 cm width X 30 cm depth in soil

Step 2. Pour water in the trench until water touch the ground level (fill water up to the top of trench)

Step 3. When the water gets drain fully, repeat step 2 (fill water up to the top of trench) and observe the time taken for second drainage

Step 4. If the water completely gets drained in less than 4 hours, the soil has good absorption capacity and is perfect for any crop cultivations, more than 4 hours means poor drainage

Earthworms test:

Step 1. Collect the soil sample from your farm, where the soil is moist but not wet

Step 2. Make as trench of 30 cm width X 30 cm deep in farm and place the collected soil near the trench on a piece of large paper

Step 3. Start shifting the soil slowly from the piece of paper into the trench with your hands while you count the earthworms

Step 4. If you found more than 5 earthworms, this indicates good soil enough to support earthworms population

Earthworms casting:

Step 1. The process refers to vermicompost making that includes digging a trench (if not can be considered in a container) and placing a mesh or loose wire bin type of structure in the trench

Step 2. Add fine shredded waste- kitchen waste, crop residue and cow dung slurry mixed in layers. Spray water to keep the enough moisture in trench and add earthworm

Step 3. Cover the trench with crop residue, observe and rotate the piles regularly and if require spray water to keep consistent temperature in trench

Step 4. When the food waste/ crop residue turned into compost, harvest the casting and repeat the process with more shredded waste, no need to add earthworms again as they live, work and reproduce in the trench

Step 5. The process can also be done in open space in a farm as raised beds and earthworms presence and movement can be observed with improving soil structure, pore space which adds aeration, increase water holding capacity of soil.

Organic matter presence test:

Step 1. Collect handful of soils each from cultivated and other non-cultivated field (barren land). This is also a farmer led test that determines organic matter and soil biology as indicator of good soil health

Step 2. Place two soils samples on two sperate wire mesh structures which are inserted on the top of two different glass jars

Step 3. Start filling the jars with water through soil in submerged process

Step 4. If you found soil holds together, this is an indication of good organic matter presence in soil (dark brown to black) and if soil disintegrates that indicates lower organic matter and thus poor soil biology