Rethinking Agriculture: Soil Health for Sustainable Farming in Africa

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Summary

Agricultural sustainability hinges on soil health. This article outlines the crucial role of soil health in agricultural sustainability by exploring the interconnected roles of agroecological practices, soil microorganisms and soil organic matter.

Agroecological practices, such as crop rotation, intercropping, agroforestry and cover cropping, build soil structure, water retention and soil fertility, and reduce the incidence of pests and disease pathogens. In addition, they importantly build soil organic matter and microorganisms. Soil microorganisms enhance soil fertility and plant nutrition uptake, which, in turn, is augmented by soil organic matter, thereby creating a symbiotic relationship that promotes overall soil health and productivity. The interconnectedness of these aspects of soil health create more resilient and productive agricultural systems. However, soil health is under threat by the over dependency on synthetic inputs and other conventional agricultural practices such as intensive tillage.

Policy interventions play a critical role in countering the over promotion of synthetic fertilizers and dispelling misconceptions about agroecology in Africa. Strengthening farmer capacities in soil health management and investing in research and innovation are essential for transitioning to sustainable agricultural systems. Emphasizing soil health as a fundamental pillar of agricultural sustainability is important to mitigate environmental degradation and ensure food security in the face of climate change.

Introduction

Agricultural sustainability hinges on the maintenance of soil health, a cornerstone of productive farming systems. However, soil health is neglected in favour of synthetic fertilizers because of productivity narratives that uphold synthetic fertilizers as the key ingredient in promoting "high productivity". Although synthetic fertilizers yield short-term gains in crop productivity (*See Figure 1 below),* their continuous application upsets the soil ecosystem, resulting in soil organic matter depletion (Tilman *et al.,* 2019; Gupta *et al.,* 2022). Additionally, synthetic fertilizers disrupt the delicate equilibrium of soil flora and fauna, leading to diminished nutrient availability and soil structure degradation over time (Bünemann *et al.,* 2018). This decline in soil biodiversity, including the depletion of beneficial microorganisms, poses a significant global concern as it undermines the resilience and sustainability of agricultural systems (Zhou *et al.,* 2020).

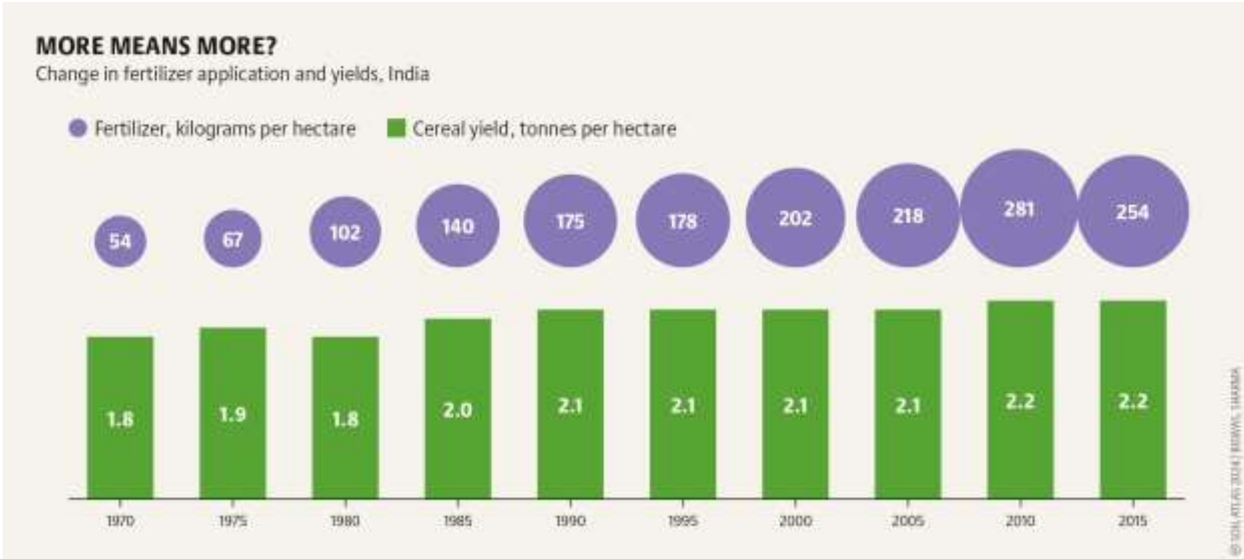

Figure 1: More fertilizer application does not mean an indefinite increase in yields.

The importance of soil health is relevant even as the political and corporate framing of synthetic fertilizers change. For example, in the last few years, "green" fertilizers have been fronted as better alternatives to fossil-based fertilizers. Green fertilizers are produced using green hydrogen, a renewable energy source. Thus, the output is thought to be carbon-neutral and better for the climate compared to fossil-based nitrogen fertilizer whose life cycle from production to application is responsible for more than two (2) per cent of global greenhouse gas emissions. However, the use of "green fertilizer" neither eliminates nitrous oxide emissions on the farm nor does it improve soil health.

For truly sustainable agriculture, we must move from spot improvements such as synthetic fertilizers to ecosystem-wide improvements that primarily include enhancing soil health. Soil health is a function of the complex interactions among soil organisms, organic matter and plant roots impacting nutrient availability, water retention and ecosystem resilience.

In this article, we explore the importance of soil health and why a shift away from sole reliance on synthetic fertilizers remains an imperative discourse for sustainable agriculture in Africa.

Soil Health and Sustainable Agriculture

Soil is not just a substrate for plant growth; it is a complex ecosystem essential for sustaining plant growth vigour, regulating water dynamics and sequestering carbon (Smith *et al.,* 2020). Recognizing soil as an important foundation for sustainable agriculture necessitates a shift towards practices that prioritize soil conservation, organic matter enrichment and microbial diversity conservation. The sections below discuss how agroecological practices, organic matter and microbial diversity safeguard soil health, mitigate environmental degradation and ensure the long-term viability of agricultural systems.

1. Agroecological practices

Agroecological practices encompass a range of sustainable farming methods that integrate ecological principles into agricultural systems. They include crop rotation, diversification, cover cropping, intercropping and agroforestry. These practices aim to enhance soil biodiversity, increase organic matter, contribute to soil fertility, and improve soil aeration and water infiltration.

Practices such as cover cropping and agroforestry hold the soil together to prevent erosion of precious and fertile topsoil. Intercropping facilitates the interaction between biological systems and crops making crops less susceptible to pests and disease and improving nutrient uptake (Yang et *al.,* 2020; Angon *et al.,* 2023). Crop rotation improves soil structure when plants with diverse root systems are rotated and fertility when regular crops are rotated with legumes. Cover crops, such as legumes and forages, play a vital role in moisture retention and weed suppression.

Other useful practices include contour farming and the use of strip crops (high-growing crops cultivated with low-growing crops), which benefit soils of lands with varying soil and slope characteristics.

These practices serve as natural shields against soil erosion by reducing the impact of raindrops, while also replenishing soil nutrients, thus promoting sustainable agricultural ecosystems (Yang *et al.,* 2020).

2. Soil Beneficial Organisms

Beneficial microorganisms in soil, including fungi, bacteria and protozoa (see Figure 2 below), constitute the backbone of soil ecosystems, driving essential processes such as nutrient cycling, organic matter decomposition and disease suppression (Wang *et al.,* 2022; Srivastava *et al.,* 2023). These organisms are increasingly being recognized for their key roles in agriculture, serving as eco-friendly alternatives to mineral fertilizers and chemical pesticides (Ortiz & Sansinenea, 2022). The microorganisms interact with plants to supply nutrients, control phytopathogens and stimulate plant growth, thereby contributing to improved soil quality and plant health. Genera like *Bacillus* have gained prominence in agriculture due to their diverse mechanisms as biofertilizers and biopesticides (Ortiz & Sansinenea, 2022). Mycorrhizae fungi, such as *ectomycorrhizal* and *endomycorrhiza*l fungi, extend root reach and facilitate nutrient exchange with plant roots, enhancing nutrient uptake (Bonfante & Genre, 2010). Bacteria, including nitrogen-fixing and phosphate-solubilising bacteria, also contribute to nutrient transformation and solubilisation - enriching the soil with accessible nitrogen and phosphorus (Giller *et al.,* 1998). Protozoa aid in nutrient recycling through predation and decomposition processes.

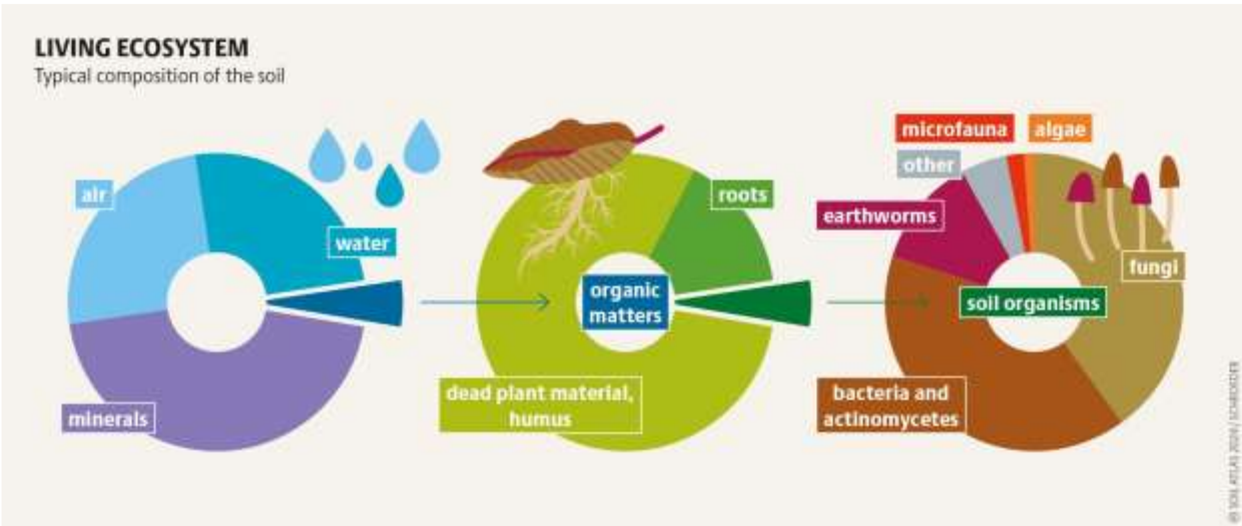

Figure 2: Typical components of a soil. *Source: Soil Atlas*[2]

Soil microorganisms play a crucial role in carbon stabilisation, as highlighted by Meena *et al*. (2017). They produce extracellular enzymes that break down complex organic molecules, facilitating the incorporation of carbon into soil organic matter (SOM) pools. Additionally, soil aggregates formed by microbial activity physically protect organic carbon from decomposition, contributing to soil carbon sequestration (Six *at al*., 2002).

Moreover, the composition and diversity of soil microbial communities influence carbon cycling processes. Fungi, bacteria and archaea each contribute uniquely to carbon turnover dynamics (Bardgett & van der Putten, 2014). For instance, mycorrhizal fungi form symbiotic associations with plant roots, enhancing carbon allocation to the soil through the exudation of root-derived carbon compounds (Phillips *et al*., 2013). Similarly, certain bacterial groups, such as *Actinobacteria* and *Proteobacteria,* are known for their ability to degrade recalcitrant organic matter, releasing carbon for microbial utilization (Schimel, 2018).

[2] Source: Bodenatlas 2024": www.boell.de/bodenatlas

As research advances in this field, there is growing optimism regarding the widespread adoption of beneficial microorganisms in agricultural practices. Indeed, by promoting microbial diversity, farmers can harness nature's power to enhance nutrient resilience and sustain soil fertility.

3. Soil Organic Matter

Soil organic matter (SOM) is the part of soil comprising dead plant materials and animal matter, all at varying states of decay. SOM may be humus, the more stabilized form which is the part that binds carbon found in soil aggregates. The non-humus component of the organic matter comprises a pool of nutrients that are released to a plant during a growing season.

Soil organic matter influences numerous biological, physical, and chemical soil properties. SOM influences ecosystem functions of soils including aggregation, nutrient exchange, water infiltration, moisture retention and supply of energy and food materials to soil organisms (Gurmu, 2019). Additionally, the availability of majority of plant nutrients is directly influenced by soil organic matter. Soil microorganisms decompose SOM, releasing the nutrients held in the organic materials. Plants cannot directly utilize the nutrients contained in soil organic matter (SOM). However, soil microbial community facilitates the conversion of these nutrients into simpler inorganic forms that plants can absorb. This process, called mineralization, is integral to the nutrient cycles that sustain agricultural systems (Lehman et al., 2020). Indirectly, SOM improves soil structure, water infiltration and water holding capacity, all of which lead to better plant health.

Practices such as the addition of compost, manure and cover cropping increase soil organic matter and its carbon content (Gerke, 2022). Minimum tillage protects soil organic matter by guarding against the breaking up of soil aggregates and oxidation of residues. Soils with rich organic matter are not only healthy and productive but also are important carbon sinks which could play a part in decreasing atmospheric carbon dioxide.

Impact of Conventional Agriculture on Soil Health

As described above, soil health is an interconnected link between soil organisms and organic matter, often modified by crop/soil practices such as agroecological practices. Thus, conventional agriculture can disrupt these linkages in ways that lead to the depletion of organic carbon, compromised soil structure and lost soil microbial diversity. For example, heavy tillage breaks soil aggregates and exposes soil organic carbon. Burning of crop resides, monocropping and reliance on synthetic fertilizers also decrease soil organic carbon (Shahane & Shivay, 2021). Crop rotations (or lack of) also influence the community of organisms around crops because organisms change with different crops.

Synthetic fertilizers reduce the diversity and abundance of soil microorganisms and may affect plant nutrient uptake (Montgomery & Bikle, 2021). For example, a decrease in mycorrhizae fungi influences crop uptake of zinc, which has consequences for diet nutrient diversity for humans/livestock feeding on the crops. Additionally, nitrogen-rich fertilizers may reduce plant defences through a reduction in the production of phenols and other phytochemicals. This compromises plant defences against pests and diseases resulting in poor yields or a higher use of synthetic pesticides. There is evidence that combining conservative tillage and cover crops increases organic matter and improves soil health (Montgomery & Bikle, 2021). These metrics improve further with diverse cropping systems and organic soil amendments that enhance organic matter and microbial biomass (Montgomery & Bikle, 2021).

This underscores the importance of prioritizing practices that support soil microbial communities, such as cover cropping, composting and reduced tillage (Kumar & Verma, 2019). Additionally, exploiting the potential of microbial communities enables farmers to optimize nutrient cycling, improve soil fertility and promote soil health and agricultural sustainability.

Thus, there is a need to champion an integrated and holistic approach that considers ecosystem-wide impacts rather than spot improvement through promoting the use of synthetic fertilizers.

Policy Direction

i. Challenging Synthetic Fertilizer Promotion with a Focus on Soil Health

There has been an aggressive promotion of synthetic fertilizers by industry players, both globally and at regional levels, which needs to be confronted with a specific emphasis on the implications for soil health. This involves advocating for policies that prioritize soil health as a fundamental pillar of agricultural sustainability, recognizing the long-term consequences of synthetic fertilizer use on soil fertility and farm production system resilience.

Encouraging governments to reconsider subsidies and incentives that promote the extensive use of synthetic fertilizers, and instead redirecting financial support towards agroecological practices that promote soil health, such as the use of compost or biofertilizers, cover cropping and crop rotation. Moreover, synthetic fertilizers create input dependency on farmers increasing their cost of production, which can be discouraged by such policy direction (Warui, 2023).

ii. Combatting Misconceptions about Agroecology and its Impact on Soil Health

Addressing misconceptions about agroecology and its potential to sustainably manage soil health and productivity. This involves advocating for research initiatives and policy interventions that highlight the benefits of agroecological approaches for enhancing soil health and promoting biodiversity.

Promoting farmer education and extension programs that showcase successful agroecological practices and their positive impacts on soil health, including increased soil organic matter, improved soil structure and enhanced nutrient cycling.

iii. Strengthening Farmer Capacities and Knowledge Sharing on Soil Health Management

Supporting capacity-building initiatives that empower farmers with the knowledge and skills needed to implement soil health management practices effectively. This includes investing in farmer education programs, extension services and participatory research initiatives that promote soil conservation, soil organic matter enrichment and integrated soil fertility management.

Promoting partnerships between research institutions, government agencies, civil society organizations, and farmers' associations to co-develop and disseminate context-specific soil health management strategies that take into account local agroecological conditions, socio-economic contexts and cultural preferences.

iv. Investing in Research and Innovation for Soil Health

Prioritising research funding for studies that explore the interactions between agricultural practices and soil health, with a focus on identifying sustainable soil management strategies that optimize soil fertility, carbon sequestration and environmental services provision.

Supporting innovation in soil monitoring technologies, farmer-to-farmer learning and farmer-led scientific enquiry to support agroecological farming systems that enable farmers to assess and improve soil health outcomes on their farms.

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