SOIL CARBON NOTES / POLICY BRIEF

THE ROLE OF SOILS IN RESILIENCE TO CLIMATE EXTREMES AND CLIMATE CHANGE FOR FOOD AND WATER SECURITY

THE SCIENTIFIC CONTEXT FOR POLICY ACTION

Ensuring sustainable food production and the provision of safe and nutritious food for healthy diets, while adapting to the accelerating climate crisis and degrading environment, is important for every modality and scale of agricultural production systems. From large-scale market-oriented commodity farms to small local producers, it is simply essential for food and nutrition security as well as for water security. Future-proof food production systems should be environmentally resilient, economically viable and socially acceptable.

Soil is crucial for producing the staple crops feeding most of the world's population. Soil is transformed by agricultural management, particularly those practices that directly affect soil structure, soil organic matter and carbon content, soil fertility, and biodiversity. This has consequences for environmental quality and human health.

To increase soil organic matter or at least avoid or reduce its loss and soil degradation, agricultural systems that build soil biological activity, organic carbon, and soil structure, while sustaining food, fiber and bioenergy production, must be promoted. Solutions may vary and depend on the activity, regional social and economic conditions and ecosystem characteristics. Nature-based solutions, such as agroforestry, agroecology, and regenerative agriculture, are some of the examples and are the basis for the development of region- or even site-specific solutions.

Healthy soils with high organic carbon levels maintain ecological functions and provide ecosystem services as they can better cycle and retain moisture and nutrients, thus being resilient to extreme weather events and less vulnerable to erosion, disease, and pests. This helps sustain productivity and promotes climate change adaptation of agroecosystems.

BACKGROUND

The years of 2022 and 2023 have been notable for intense and extreme weather events globally with devastating impacts for many regions on agricultural and forestry production. In 2022 South America faced one of the worst droughts in history, mainly affecting countries such as Brazil, Argentina and Chile. The lack of rain compromised agricultural production, leading to significant losses in grain, fruit and vegetable crops. That same year several regions in Asia, including India, China and Bangladesh, and in Australia were hit by heavy rains and devastating floods. In large areas of Asia agricultural infrastructure such as irrigation and food storage systems were destroyed which had a significant impact on the production of rice, a staple food in the region. Particularly intense tropical storms and hurricanes affected the Caribbean in 2023, damaging greenhouses and irrigation systems, making it difficult for agriculture to recover. Banana plantations, sugar cane and other crops important to the local economy were widely affected. Also in 2023, an unprecedented fire season in Canada directly affected agriculture, destroying farms and livestock, while poor air quality due to smoke and ash negatively affected not only human health but plant health and crop productivity. An extreme heat wave worsened by water scarcity hit Europe in this same year, resulting in record temperatures in several countries, causing significant damage especially in southern European regions where heat-sensitive crops such as olives and grapes were affected.

The vulnerability of food, fibre, biomass and bioenergy production to climate variability and extreme events is linked to water access and ecosystem health as well as management strategies to improve natural and agroecosystem resilience through targeting the healthy functioning of soils. Additionally, in the context of one health, the impact of soil goes beyond agriculture, soil health being a relevant factor for the abundance and spread of diseases (Wasan and Wasan, 2023). Moreover, soil health is underpinning both planetary and human health (Koppittke et al., 2023) and is thus crucial for the resilience of human societies to tackle global crises including pandemics (Rumpel et al., 2022).

The principles underpinning management approaches such as agroforestry, agroecology and regenerative agriculture are broadly consistent with the understanding that high soil organic matter (and, consequently, soil organic carbon) supports strong plant growth, stable crop and pasture yields, higher water retention and drought resilience. While the ecological and agronomic outcomes of different farm management practices vary between regions, there is a clear scientific consensus supporting policy actions that increase sustainability and resilience of agricultural systems through an ecological transition, while also contributing to climate change mitigation through soil carbon sequestration.

RECENT RESEARCH

Agroecosystem resilience to climate change, soil health and soil organic carbon are interrelated. The resilience of agricultural landscapes can be enhanced by improving soil resilience (Neher et al., 2022), which is defined as the soil's ability to recover and adapt to disturbances or stresses, such as extreme weather events, intensive agricultural practices, or pollution. A resilient soil can maintain its ecosystem functions and services, such as the ability to retain water, provide nutrients to plants, filter pollutants and store carbon. Soil organic carbon is key to soil resilience (Liptzin et al., 2022), underpinning sustainable development goals including human health (Rumpel et al., 2022).

There is strong information on soil management practices and agricultural systems that can increase soil carbon, biodiversity and enhance soil biological processes, thus contributing to regenerating or maintaining soil health and key soil functions, contributing eventually to soil resilience.

Plant water availability and biological processes, such as plant growth and soil microbiological activities that lead to organic matter input, are strongly linked (Vedere et al. 2022). Agricultural practices that focus on managing and conserving water resources and selecting pasture and crop species better adapted to available soil water levels will help to maintain and increase soil organic carbon and improve resilience to climate variability (Bracken et al; 2023; Goswami et al., 2023). Soils with higher organic carbon content can reduce the sensitivity of crop yield to climate variability, leading to both higher productivity and yield stability (Qiao et al. 2022).

Evaluating soil and farm resilience is, a challenging task. Soil resilience can be assessed by describing potential and actual soil functions (Kibblewhite et al., 2008).

However, while comprehensive and integrative strategies (Neher et al., 2022), new microbial approaches (Fierer et al., 2021) and indicators (Mendes et al., 2019, 2021; Chaer et al., 2023) are improving, monitoring "climate smart" agriculture is a complex issue. The organic matter content of soil provides a simple measure that is a key integrating indicator of soil health, and is accessible to most farmers (Koppittke et al., 2022; Rumpel et al., 2022).

IMPLICATIONS

Research suggests that soil health can be improved by implementing sustainable agricultural systems and management strategies contributing to enhancement of soil organic carbon and microbial functioning with positive effects on many ecosystem services derived from soil. Healthy soils provide a positive environment for plant growth in a variety of conditions. This requires the development and implementation of environmentally sound, economically feasible, and socially and culturally acceptable farming practices, that are able to provide multiple benefits for the environment and for rural communities with no negative impacts (Rumpel et al., 2023).

However, transitioning to climate-resilient agricultural systems can be challenging. For example, in the case of farm-based households limited livelihood strategies and insufficient capital may be available to invest in adaptation strategies (Pereira et al., 2018). In other cases, limited information and poor access to agricultural extension services can be also prohibitive (Rai et al., 2018).

Due to the importance of soil health and soil resilience for the adaptation of agricultural systems and farms to climate variability as well as for the one health of communities, some initiatives already exist to include soils in agriculture related policies like the EU Farm to Fork strategy (Montanarella and Panagos, 2021), mainly related to climate change, environmental protection, and food quality. Others, like Brazil's Low Carbon Emission Agriculture Plan, promote the adoption of sustainable agricultural systems and practices to accelerate the transition of agriculture to systems with enhanced adaptation capacity (Brasil, 2021).

RECOMMENDATIONS

Observing the role of soils in the resilience of agricultural systems to climate extremes and climate change for food and water security, and realizing the urgent need for actions to increase the adaptation capacity of agricultural systems, based on the above explanations, we strongly recommend to:

- Develop recommendations for regionally adequate and culturally acceptable climate-resilient land use and agriculture practices, guided by scientific evidence, and giving special consideration of those that enhance soil carbon and soil health as soil is the basic natural resource underpinning the climate resilience of agroecosystems and rural communities and, therefore, food security.

- Develop support programmes, including financial and technical resources and communication materials, to help transition to climate-resilient agriculture.
- Develop a framework of carefully selected early warning indicators for the monitoring and evaluating soil, agricultural system and farm resilience to detect continued vulnerability and allow timely corrective measures.
- Develop educational strategies to improve the understanding of soil and its functions as being the basis of human existence on planet Earth among stakeholders and the general public.

FURTHER ACTIONS

Examples of complementary measures that are important in reinforcing positive impacts in a framework of actions include:

- Contributing to the implementation of the "4 per 1000 Strategic Plan 2050";
- Implementing the 2020-2030 Plan of Action of the International Initiative on Soil Biodiversity Conservation, led by FAO and the Global Soil Partnership;
- Actively supporting the Global Soil Biodiversity Observatory, launched during COP15, to gather crucial scientific data on soil biodiversity and ecosystem services;
- Adhering to regional soil governance strategies like the the European Union's 2030 soil strategy that specifies safeguarding, rehabilitation, and sustainable management measures.

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