6 Facts About the Role of Soil Health in Climate Change Mitigation

Climate change tremendously impacts every aspect of the environment, including the soil and its components. Soil health changes as it interacts with various aspects of our climate. For instance, heat waves lead to dryness in the soil. And changes in rain patterns can erode the soil structure.

However, most of us don't realize that soil also significantly impacts climate change, primarily related to carbon dioxide and nitrous oxide. Soil can store more carbon than the atmosphere. A large expanse of agricultural land can become a carbon sink, a storage for carbon stocks and other forms of greenhouse gases. However, there is a thin line between releasing soil carbon back into the environment and changing climate.

This article explores the relationship between soil carbon, health, and climate change. We will examine the characteristics of healthy soils and explore the properties that influence soil's chemical and biological activities and its ability to store soil carbon.

What makes soil healthy?

We can define soil health as the ability of soil to facilitate the growth of plants and animals. Healthy soil also maintains and enhances water and air quality and supports human health. The soil is an important ecosystem that supports all other life forms and performs multiple essential functions.

The soil controls the flow of rain, rainwater, snowmelt, or irrigation water. Water flows in and through the soil ecosystem. It sustains the diversity and productivity of plants and animals.

Plants wouldn't exist without healthy soil, and animals and humans wouldn't have anything to feed them. Soil structures provide stability for plant roots and human structures [1].

Another function of the soil is to filter potential pollutants. The microbial community in the soil filters, detoxifies and immobilizes organic and inorganic matter. The soil also stores nutrients like carbon dioxide, nitrogen, and phosphorus [1].

Components of healthy soil

Now that we have established the functions and importance of the soil, what are the components of a healthy soil?

The biological, chemical, and physical processes of soil are interdependent. Everything must be in sync to make the soil healthy. The chemical processes in the soil give plants the micro, macro, and secondary nutrients needed for growth. Fertile soil has sufficient nutrients to sustain the growth of other organic matter. It is free from harmful chemicals like pesticides, heavy metals, and other contaminants [2].

The physical processes of the soil include water availability and drainage. It also includes soil structure, aggregate stability, and compaction. These processes in healthy soils lead to adequate soil depth for plant roots to thrive. Healthy agricultural soils also have good water storage and drainage.

The soil's biological processes happen close to the soil's surface, where more of the soil's organic matter is found. There are three types of organic matter in healthy agricultural soils. They are living, dead, and very dead soil organic matter [2].

Living organic matter is roots, earthworms, nematodes, bacteria, fungi, mites, moles, and other organisms. These organisms decompose other organic materials; cycle nutrients. Also, they influence plants and other living organisms in the soil. Dead organic matter includes freshly dead organic materials and crop residues. It is a source of energy and nutrients for living soil organisms that consume it [2].

You can also refer to dead organic matter as active organic matter. It can mineralize nutrients for plants, aggregate soils, and form humus. Very dead organic matter, also called humus, refers to adequately decomposed organic materials. It acts as a support system for soil chemical processes during land use. It can store carbon and has a high water storage capacity. Also, humus has high negative charges that hold nutrients together in the soil [2].

Healthy soils are rich in all these organic matters and resistant to degradation. They also possess the ability to recover quickly from climate events like erosion, flooding, drought, hurricanes, etc.

Fun Fact: a teaspoon of rich soil contains up to one billion bacteria, thousands of protozoa and nematodes, and several yards of fungal filaments [3].

Ways Climate Change Affects Soil Health

Climate change affects the productivity of land management practices by disrupting the biological and chemical processes of the soil. Climate change triggers a change in the temperature and precipitation patterns. This change affects carbon, nitrogen, and hydrology cycles and severely impacts soil weathering [4]. Let us examine the soil properties affected by the climate crisis.

Biological Properties Affected by Climate Change

Climate change affects soil microbial biomass. Research conducted on soil samples showed a reduction in the soil microbial biomass. Researchers exposed the soil sample to simulate climatic warming experiments for a long time.

Precipitation influenced the bacterial phyla, leading to changes in the population of *Proteobacteria* and *Acidobacteria* in the soil. There were more *Proteobacteria* in wet soil because they required anaerobic conditions for metabolism. However, *Acidobacteria* were abundant in dry soil because they preferred aerobic conditions for metabolism.

The temperature response of soil respiration is a critical link between climate change and the carbon cycle. Research shows soil respiration responds to changes during seasonal rainfall. It changes according to various global and regional climate models [5].

Chemical Properties Affected by Climate Change

Climate change affects the up to 6 chemical properties of soils. These properties include:

1. soil pH,
2. rate of acidification,
3. electrical conductivity,
4. salinization, and
5. plant nutrients.

The soil pH is the most important property of soil and is easily influenced by vegetation type, weather severity, and plant material type. The pH in most soils does not change rapidly from the drivers of climate change. However, the drivers of climate change influence nutrient cycling, plant water, and plant productivity. This cumulative influence will then impact the soil pH. According to research, the soil pH reduces as it moves from higher to lower elevations [5].

Reduced precipitation leads to decreased downward filtration and leaching. Climate change determines the productivity of major vegetation. It also determines the decomposition rate of litter deposits. All these little actions go a long way to influence soil acidification indirectly. Increased temperatures, varying precipitation, and atmospheric nitrogen deposition notably impact the nutrients available to plants. The cycling of nitrogen, sulfur, phosphorus, and organic carbon nutrients in the soil also affects the atmospheric deposition of nitrogen [5].

For instance, vegetation's response to drought reduces nitrogen in the soil. This leads to the weakening of positive feedback between nitrogen and carbon dioxide cycles in the soil. The soil's structure is affected by electrical conductivity linked with salinity, crop performance, nutrient cycling, and bioactivity levels [5].

Facts about soil carbon sequestration’s ability to mitigate climate change?

1. Research shows that agricultural soils can help with climate change mitigation.

Soils store two to three times more carbon than the atmosphere. Some land management practices used to improve soil health also aid the reduction of greenhouse gas emissions in the environment. There are three elements with the climate change mitigation potential connected to soil carbon sequestration.

These elements are:

1. Mineral soils in peatlands can sequester carbon when re-wetted.
2. The preservation of existing arable land has the potential to sequester carbon.
3. Reducing greenhouse gases is connected with fertilizer usage because of improved nutrient and crop rotations [5].

2. Unsustainable agricultural practices reduce soil's ability to hold carbon.

Over time, soil carbon sequestration reduced significantly because of intense land use. Unsustainable agricultural practices like peat land drainage, intensive crop rotations, removal of crop residues, and livestock farming contributed to reducing soil carbon storage. As global greenhouse gas emissions rise, soil carbon sequestration reduces, speeding up climate change in the environment [5].

3. Peatlands, croplands, and grasslands have a high potential for climate change mitigation.

The peatlands across the European Union have climate mitigation potential ranging from 48 to 57 million tons of carbon annually. European peatlands store five times more soil carbon sequestration capacity than tree storage. While this is great, removing carbon dioxide from the atmosphere can become problematic.

In Germany, peatlands can store up to 10 million tons of carbon. The agricultural soils of croplands and grasslands in the European Union have the climate mitigation potential of 23 to 58 million tons of carbon [5].

4. Peatlands contain organic soils with at least 30% of high organic matter.

Peatland soils contain 30% organic matter. However, due to drainage, 30% of its soil carbon enters the atmosphere as greenhouse gas emissions. Croplands and grasslands occur on mineral soil globally. The majority of the soil contains lots of organic materials. The soil carbon on grazing lands enters the atmosphere because of tillage, fertilization, harvest, drainage, and grazing activities [5].

5. Peatlands hold about 2,363,48 Gt of carbon dioxide.

Research shows that peatlands hold about 2,363,48 Gt of carbon dioxide. Unfortunately, about 15% of these lands experience soil disturbance. People often drain them for forestry, peat extraction, cropland, or pasture.

Drained peatland releases all its stored greenhouse gases into the atmosphere, making Europe the second largest region with high greenhouse gas emissions rates. Europe released 220 million tonnes of greenhouse gas emissions in 2017 [5].

Germany is the top emitter of organic carbon and other greenhouse gases. The country has 1.3 million hectares of organic soil as of 2019. However, they drained 98% of the land, releasing 53 million tons of CO_2 into the atmosphere.

Researchers projected the peatlands would save 10 million tons of carbon annually by 2050 if the government takes steps to protect and rewet them. The gas emissions from Germany should be reduced to almost 12 million tons yearly by 2050 [5].

6. Abandoning peatlands and rewetting them allows them to hold up to 42 million tons of carbon.

Leaving European peatlands alone can hold 42 million tons of carbon by 2030. Another way for peatlands to save soil fertility and prevent global warming is by avoiding peat extraction. Avoiding peat extraction limits carbon emissions by 9 million tons [5].

Also, peatland rewetting is an effective climate mitigation. Depending on the previous land use, you can save almost 30 tons of soil carbon per hectare annually. However, researchers are still determining its ability to store more carbon.

Soil management systems that promote climate change mitigation

We must improve soil health to reduce the harmful gases released into the atmosphere through human activities. Besides mitigating climate change, improved soil health means global food security. Soils are essential to food production. There are three climate-friendly soil management systems. They are land use change measures, peatlands and organic soil re-wetting, and agricultural management measures.

Land use change measures include converting land with food soil and water quality to grassland. It also involves the prevention of land usage for unsustainable activities. Converting lands with high soil fertility to regenerative agricultural lands is an efficient method of using soil ecosystem services. This system also works best for open pasture, agroforestry, and mixed crop-livestock systems [5].

In previous paragraphs, we mentioned how much carbon rewetting peatlands would remove from the atmosphere. Rewetting peatlands or organic soils increases the waterbeds of drained soils. It can also reestablish water-saturated areas. This soil management method also requires changing the uses of the land before restoring the landscape water regime.

Agricultural management measures involve changing the management of the farmland. Farmers should endeavor to plant cover crops and practice crop rotations. Planting cover crops prevents soil erosion and promotes water retention and nitrogen fixation. Crop rotation helps manage weeds and pests on lands. Farmers should include forage and grain legumes in their rotations to maintain soil health [5].

Also, farmers can use optimized grazing methods, green manuring, mulching, conservation tillage management, and manure to improve soil fertility. Contour farming and reduction of soil compaction also work well. Soil compaction reduces the pore space in soils. It also reduces the soil's water infiltration, drainage, and air movement rate [5].

Soil compaction makes the soil structure poor. It causes waterlogging and drought during wet seasons [6]. No-tillage management promotes minimal to no soil disturbance at all. It saves carbon from the atmosphere and prevents soil erosion.

Conclusion

We need to be well aware of the impacts of climate change on every aspect of the environment and how to ensure climate mitigation. Climate change affects the very foundation of life that supports most life forms. Soils support most living organisms and sustain human life; they can also store carbon from the atmosphere.

Adequate soil health management takes us several steps ahead of preventing global warming. Farmers and agriculturalists should practice different ranges of cropland and grassland management to reap the benefits of food production and save soil carbon.

However, there are limitations to how much carbon soil carbon sequestration can save. The limitations and uncertainties surrounding carbon farming are because of climatic conditions, heterogeneity of soils, and existing soil organic carbon. Sequestering carbon can also be very expensive because of the processes of measuring, monitoring, reporting, and verifications involved.

Restoring degraded soils and preserving major ecosystems might save Earth from climate change's woes. Combining sustainable and regenerative agriculture practices and living an eco-friendly lifestyle will do the environment a lot better.

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