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Impact of Climate Changes on Soil Properties

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Abstract

Climate change is expected to have a vigorous impact on soils and its ecosystems due to increase in temperature and changes in precipitation (amount and frequency), thereby altering the biogeochemical and hydrological cycles. The several phenomena associated with climate change and anthropogenic activity affecting the soils. The increase in atmospheric CO_2 concentration, growth rates, water-use efficiency of crops and natural vegetation in so far as other factors do not become limiting. However, scarcity of water may prevent water existence used for irrigation. Increasing damage to the land, or land degradation, will occur in the form of soil erosion, desertification, salinization, or loss of peat soils, further influencing on the capability of soils to support the needs of agriculture.

Introduction

The task of producing adequate food, fibre and feed to meet ever-increasing demand has now become even more challenging to sustain the agricultural productivity with dwindling natural resources and ecological constrains. In future, agricultural production may be severely constrained by other emerging threats to agricultural production like increasing climatic variability and number of biotic factors due to climate change which is mainly caused by human activities.

There are three aspects of climate change that are important from the agriculture point of view:

• Increase in greenhouse gas concentration, particularly CO_2 levels.

• Rise in temperature.

• Increased climatic variability.

Soils are directly linked to the atmospheric/ climate system through the carbon, nitrogen, and hydrologic cycles. Because of this, changed climate will have an effect on soil processes and properties. Recent studies indicate at least some soils may become net sources of atmospheric C, lowering soil organic matter levels.

What is Climate Change?

Current and predicted pattern of global climate change are a major concern in many areas of socioeconomic activities, such as agriculture, forestry, etc., and is a major threat for biodiversity and ecosystem function. Climate change is a result from emission of greenhouse gases (e.g. CO_2, CH_4, & N_2O, etc.) in the past century that will cause atmospheric warming. The effects have become particularly obvious over the last 30 years in the natural environment and it will affect all level of life, from the individual, population species community and ecosystem to the Eco-region level.

The main issue that every country, private sector, institutions, etc. must face is how to adapt the future changes in climate that will occur. Agriculture is one of the sectors, which are both sensitive to global warming (e.g. through, atmospheric temperature, precipitation, soil moisture, sea level and humidity) and contributes to climate change.

Causes Climate Change

Due to increasing world population and industrial development there is an increased emission of GHGs. Use of fossil fuels, deforestation, burning and decay of biomass, etc., leads to higher atmospheric CO_2 concentration, which currently is around 388 ppm and predicted to increase to approximately 470-570 ppm until year 2050.

Climate change can result from natural processes and factors and more recently due to human activities through our emissions of greenhouse gases. Examples of natural factors include,

• Changes in the sun's intensity.

• Volcanic eruptions, or slow changes in the Earth's orbit around the sun.

• Natural processes within the climate system such as changes in ocean current circulation.

However, the current global aim is to tackle climate change resulting from human activities whose greenhouse gas emissions are changing the composition of the earth's atmosphere. The External Link Intergovernmental Panel on Climate Change (IPCC) state that;

"Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic (produced by humans) greenhouse gas emissions."

Examples of human activities contributing to climate change include;

• Carbon dioxide emissions through burning fossil fuels such as coal, oil and gas and peat.

• Methane and nitrous oxide emissions from agriculture.

• Emissions through land use changes such as deforestation, reforestation, urbanization, and desertification.

• This rise in greenhouse gases has increased the amount of energy being trapped in the climate system. The consequences of this are most clearly evident in the global temperature records, which show that, on average, the global temperature has increased by 0.8 degrees centigrade (°C) above pre-industrial levels. Continued emissions at or above current levels would cause further warming and result in changes in the global climate system during the 21st century that would very likely be larger than those observed during the 20th century.

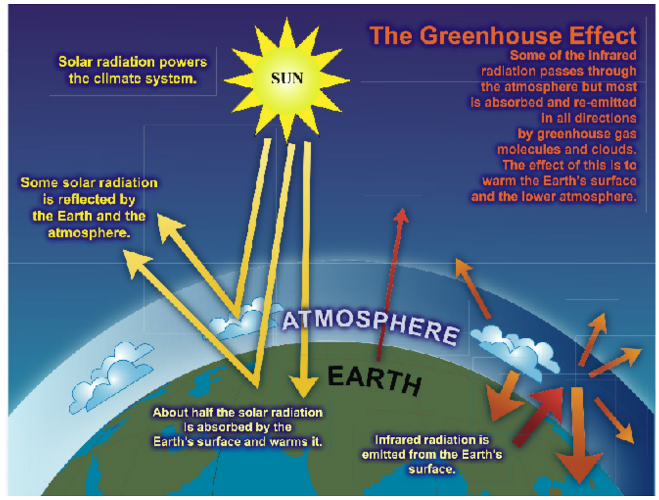

Figure 1: The greenhouse gas effect (Source: IPCC, 2007)

Influence of Climate Change on Soil Properties

Climate change can occupy a very big impact on soils the activities and functions that soil performs. In agriculture, climate change will affect crop production as changes in soil, air temperature and rainfall affect the capacity of crops to reach maturity and their potential harvest. As the climate heats up, decreases in the amount of water available may be made up primary by irrigation.

Physical Properties of Soil

The physical properties and processes of soil affect soil health by altering water movement through soil, root penetration in soil and water congestion. Important soil physical properties that affect soil health due to impact of climate change are as follow.

Soil Texture

Soil texture is the relative proportion of sand, silt and clay in a soil. It has direct impact of climate change. The four potential climate scenarios (Arid, Semi-arid, Sub-humid and Humid) have great impact on important soil processes as the texture differentiation in the soil profile.

Soil Structure and Aggregate Stability

Aggregate stability, the resistance of soil aggregates to external energy such as high intensity rainfall and cultivation is determined by soil structure as well as a range of chemical, biological properties and management practices. It can also be used to measure soil erosion and management changes. A decline in soil organic matter levels lead to a decrease in soil aggregate stability, infiltration rates and increase in susceptibility to compaction, run-off furthermore susceptibility to erosion.

Bulk Density

Bulk density is routinely assessed to characterize the state of soil compactness in response to land use and management. Bulk density in general negatively correlated with soil organic matter (SOM) or soil organic carbon (SOC) content. The loss of organic carbon from increased decomposition due to elevated temperature may lead to increase in bulk density and hence making soil more prone to compaction *viz.* land management activities and climate change stresses from variable and high intensity rainfall and drought events.

Infiltration and Plant Available Water

The water availability for plant growth and important soil processes are governed by a range of soil properties including porosity, field capacity, lower limit of plant available water (thus excluding osmotic potential), micro pore flow and texture. Plant available water capacity has been used as part of integrative soil health tests to assess management impacts.

Soil Temperature

The soil temperature regime is governed by gains and losses of sun radiation at the surface, the process of evaporation, heat conduction through the soil profile and convective transfer via the movement of gas and water. However, soil temperatures will also be affected by the type of vegetation occurring at its surface, which may change itself as a result of climate change or adaptation management.

Chemical Properties of Soil

Soil pH

Soil pH is a function of parent material, time of weathering, vegetation and climate. It is considering as important indicators of soil. Soil pH has thus been included in integrative soil tests to evaluate the impacts of land use change and agricultural practices. However, these drivers of climate change will affect organic matter status, C and nutrient cycling, plant available water and hence plant productivity, which in turn will affect soil pH.

Soil Organic Carbon

Soil organic carbon (SOC) is almost widely used indicators of soil. It is associated with many chemically and physically desirable attributes including high biological activity, nutrient availability, soil physical structure, water holding capacity and aeration. SOC is also important for its potential role in contributing to climate change mitigation. It is also play the role of microbial activities, when increase the temperature than effect on the organic carbon level.

Electrical Conductivity

Soil electrical conductivity (EC) is a measure of salt concentration. It can inform trends in salinity, crop performance, nutrient cycling and biological activity. Increasing temperatures and decreasing precipitation increase the electrical conductivity under climate change scenarios. The dynamics of soluble salts concentration in soils from four climatic regions (Mediterranean, Semi-arid, mildly arid and Arid) and found a non-linear relationship between the soluble salts content and rainfall with sites that received <200 mm rainfall contained significantly high soluble contents and vice versa.

Sorption and Cation Exchange Capacity

Sorption and cation exchange capacity (CEC) are highly influenced properties of soil particularly the retention of major nutrient cations Ca^{2+}, Mg^{2+}, K^{+} and immobilization of potentially toxic cations Al^{3+} and Mn^{3+}. These properties can thus be useful indicators of soil health informing of a soil's capacity to absorb nutrients as well as pesticides and chemicals. Since CEC of coarse-textured soils and low-activity clay soils is attributed to that of SOM, the increasing decomposition and loss of SOM due to elevated temperatures may lead to the loss of CEC of these soils. It may result in increased leaching of base cations in response to high and intense rainfall events, thus transporting alkalinity from soil to waterways.

Biological Properties of Soil

Microbial biomass, gross N mineralization, microbial immobilization, and net N mineralization under elevated CO_2 show a high degree of variability. However, rates of soil and microbial respiration are generally more rapid under elevated CO_2, indicating that enhanced plant growth under elevated CO_2 increases the amount of C entering the soil, thereby stimulating soil microbial activity. Soil microorganisms are often C-limited and therefore, increased C availability stimulates microbial growth and activity. Given the important roles played by fungi in organic matter degradation, nutrient cycling, plant nutrition, and soil aggregate formation, shifts in fungal communities might have a strong impact on soil functioning. Furthermore, lower N availability at elevated CO_2 may, in part, explain these increases in fungi, as fungi tend to have a higher C/N ratio than bacteria and so have a lower demand for nitrogen than bacteria have Bacteria and fungi, the initial consumers of soil organic matter, are themselves substrates for a multitude of tiny predators and grazers, including protozoa, nematodes, and arthropods, which comprise the soil food web.

Fertility of Soil

In the economic approach to fertility, parents have a finite set of resources and preferences over various outcomes, as with any other decision. They use these resources to achieve the best possible outcome attainable within their economic constraints. Measurement of extract-able nutrients may provide indication of a soil's capacity to support plant growth; conversely, it may identify critical or threshold values for environmental hazard assessment. Nutrient cycling especially N is intimately linked with soil organic carbon cycling and hence drivers of climate change such as elevated temperatures, variable precipitation and atmospheric N deposition are likely to impact on N cycling and possibly the cycling of other plant available nutrients such as phosphorus and sulphur.

Conclusion

Soils are part of the C and N cycles and C and N are both important components of soil organic matter, the organic matter content of soils will be influenced by climate change. It is the inhabitants of developing countries who are least prepared to cope with a changing climate and with potential soil degradation due to climate change; developed countries are better equipped to mitigate those changes and cope than developing countries are However, the site specific management practices for soil and water conservation, crop improvement and integrated nutrient management needs to be identified to overcome impact of climate change on physical, chemical and biological properties of soil.

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