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SOIL CARBON SEQUESTRATION TO MITIGATE CLIMATE CHANGE AND FOOD INSECURITY

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ABSTRACT
Climate change caused by increased temperature and atmospheric carbon-di-oxide concentration has brought the global food insecurity. The natural global carbon cycle has been disturbed with increased human induced CO_2 emission. Soil carbon sequestration is a major means to overcome this concern by transferring the atmospheric CO_2 into soil for long term use by means of proper land use and agronomic practices. The prime object for the effort is to slow down the rapid rise of carbon dioxide in the atmosphere. Upon sequestering the atmospheric CO_2 in to the soil, the atmospheric CO_2 level get reduced and beside this, soil organic carbon releases nutrients for plant growth, promotes the chemical, biological and physical properties of the soil, and acts as a buffer against harmful substances which ultimately enhances the crop production. Soil organic carbon is part of the natural carbon cycle, and the world's soils holds around twice the amount of carbon that is found in the atmosphere and in vegetation. Organic carbon gets assimilated within the plant system through photosynthesis using carbon dioxide from the air and water. The vegetative parts, animals, human and other living beings after death return to the soil where they are decomposed and recycled. It increase agricultural production with enhanced soil physical, chemical and biological properties and facilitate environmental benefits leading to improved food system stability to fight world hunger.

Introduction

Current trends point to continued human population growth beside climate change increase the pressure on improving the capacity of agricultural system to produce food and fiber without further sacrificing the regional and natural resources. Climate change has immense effects on agriculture and therefore human hunger currently and in the decades ahead (Trevors, 2015). The global surface temperature because of climate change has increased by 0.88ºC since the late 19th century, and 14 out of the 15 warmest years on record have occurred in 21st century. According to IPCC the earth's mean temperature is projected to increase by 1.5–5.88ºC during the 21st century. In addition to the sea-level rise of 15–23 cm during the 21st century, there have been notable shifts in ecosystems and frequency and intensity of occurrence of wild fires. These and other observed climate changes are reportedly caused by emission of greenhouse gases (GHGs) through anthropogenic activities. Historically, land-use conversion and soil cultivation have been an important source of greenhouse gases (GHGs) to the atmosphere (West and Marland, 2002). It is estimated that they are still responsible for about one-third of GHG emissions. The increase in atmospheric concentration of CO_2 by 31% since 1750 from fossil fuel combustion and land use change necessitates identification of strategies for mitigating the threat of the attendant global warming (Keith, 2009). There is a strong interest in stabilizing the atmospheric abundance of CO_2 and other GHGs to mitigate the risks of global warming.

There are about 850 million undernourished people in the world today. That means one in nine people do not get enough food to be healthy and lead an active life. Hunger and malnutrition are in fact the number one risk to health worldwide— greater than AIDS, malaria and tuberculosis combined. Food security is the situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life. Simply, food security is defined as the ability of people to secure satisfactory food. It is the outcome of food production system processes all along the food chain. Climate change will affect all four dimensions of food security: food availability, food accessibility, food utilization and food systems stability. *Food availability*; Changes in climatic conditions have already affected the production of some staple crops, and future climate change threatens to exacerbate this. Higher temperatures will have an impact on yields while changes in rainfall could affect both crop quality and quantity. *Food accessibility*; It covers access by individuals to sufficient resources (Entitlements) to gain proper foods. This dimension is affected by the higher food prices resulted from decreased crop yield, loss of income because of the potential increase in damage to agricultural production etc. *Food stability;* The climatic variability produced by more frequent and intense weather events can upset the stability of individuals' and government food security strategies, creating fluctuations in food availability, access and utilization. *Food utilization;* Climate-related risks affect calorie intake, particularly in areas where chronic food insecurity is already a significant problem. Changing climatic conditions could also create a vicious cycle of disease and hunger. Nutrition is likely to be affected by climate change through related impacts on food security, dietary diversity, care practices and health.

Before human-caused CO_2 emissions began, the natural processes that make up the global "carbon cycle" maintained a near balance between the uptake of CO_2 and its release back to the atmosphere (Prentice, 2001). However, existing CO_2 uptake mechanisms (sometimes called CO_2 or carbon "sinks") are insufficient to offset the accelerating pace of emissions related to human activities. Atmospheric concentrations of carbon dioxide can be lowered either by reducing emissions or by taking carbon dioxide out of the atmosphere and storing in terrestrial, oceanic, or freshwater aquatic ecosystems. There are several technological options for sequestration of atmospheric CO_2 into one of the other global pools. These can be grouped into two broad categories: abiotic and biotic sequestration. The abiotic sequestration involves the oceanic injection, geological injection, and scrubbing and mineral carbonation whereas; the biotic sequestration involves oceanic sequestration, terrestrial sequestration and secondary carbonates. Terrestrial sequestration (sometimes termed "biological sequestration") is typically accomplished through forest and soil conservation practices that enhance the storage of carbon (such as restoring and establishing new forests, wetlands, and grasslands) or reduce CO_2 emissions such as reducing agricultural tillage and suppressing wildfires (Sauerbeck, 2001).

Soil carbon sequestration

Soil is a large reservoir of carbon, with about 60% organic carbon in the form of soil organic matter (SOM), and the remaining inorganic carbon in the form of inorganic compounds (e.g., limestone, or $CaCO_3$). It is estimated that SOM stores about twice as much carbon as the atmosphere, and about three times more than forests and other vegetation. Soil carbon sequestration is getting more interest of both scientific and civil sector. Soil carbon sequestration implies transferring atmospheric CO_2 into long-lived pools and storing it in soil securely for long term to either mitigate or defeat global warming and avoid dangerous climate change so it is not immediately re-emitted. Simply we can say that soil carbon sequestration is the process of transferring carbon dioxide from the atmosphere into the soil through crop residues and other organic solids, and in a form that is not immediately reemitted. Therefore, soil C sequestration means increasing the soil organic carbon (SOC) and soil inorganic carbon (SIC) stocks through judicious land use and recommended management practices (Table 1. and Figure 1.).Soil carbon storage is a vital ecosystem service, resulting from interactions of ecological processes. Human activities affecting these processes can lead to carbon loss or improved storage. The transfer or "sequestering" of carbon helps off-set emissions from fossil fuel combustion and other carbon-emitting activities while enhancing soil quality and long-term agronomic productivity. Soil carbon sequestration can be accomplished by management systems that add high amounts of biomass to the soil, cause minimal soil disturbance, conserve soil and water, improve soil structure, and enhance soil fauna activity (Post and Kwon, 2000; Gregorich, *et al*, 2001; Carter, 2002). Continuous no-till crop production is a prime example (Baker *et al*, 2006).

Management practices	Effect
Minimum or zero tillage	Reduced carbon loss
Erosion control i.e. contour cultivation	Reduced carbon loss
Addition of organic matter (compost, manure, crop residues)	Enhanced carbon input
Cover crops	Reduced carbon loss/ Enhanced carbon input

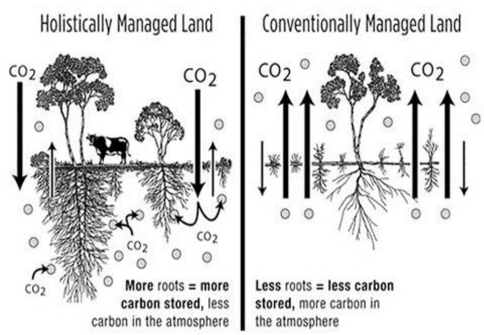

Table 1 and Fig. 1. Soil carbon sequestration in agricultural system with management practices.

How is carbon sequestered into soils?

Soil organic matter originally comes from atmospheric CO_2 that is captured by plants through the process of photosynthesis. When plants die and decompose, some CO_2 is sequestered in the soil, while some is released back to the atmosphere. The primary way to sequester carbon in the soil is to add organic soil amendments such as compost or animal manures (Schlesinger, 1999). Soil organic matter is a complex of carbon compounds, and includes everything in or on the soil that is of biological origin (Franzluebbers *et al.*, 2001). It includes plant and animal remains in various states of decomposition, cells and tissues of soil organisms, and substances from plant roots and soil microbes. Organic carbon in the form of humus, the dark, spongy organic matter in soils, is highly resistant to soil microbial decomposition. It can be stored in the soil for hundreds to thousands of years, while other SOM (e.g., partially decomposed plant residues) can be quickly released as CO_2 back into the atmosphere.

Paybacks of soil carbon sequestration

In addition to reducing current atmospheric CO2 levels, increasing soil carbon sequestration can provide other benefits for soil quality, the environment, and agricultural production:

- Increased agricultural productivity.
- Increased water use efficiency, due to reduced moisture loss from runoff, evaporation, deep drainage below the root zone.
- Increased water holding capacity.
- Reduced fertilizer (N, P) needs over the longer term.
- Improved soil structure.
- Increased infiltration capacity.
- Increased soil fertility.
- Improved soil health resulting in higher nutrient cycling and availability.

Ways of soil carbon sequestration increment

The following management practices can increase soil carbon sequestration and help mitigate climate change:

1. Add organic soil amendments such as compost, animal manure, biosolids, and organic mulch.
2. Grow bio-energy crops which are grown specifically for their fuel value to make biofuel (e.g., switch grass) on marginal lands.
3. Add biochar to the soil. Biochar is a microbially resistant carbon substance which is produced by heating organic wastes such as crop residues or wood chips in the absence of oxygen by a process called pyrolysis.
4. Leave crop residues on the soil without open burning.
5. Practice organic, biological, or biodynamic farming or gardening methods (management practices that restore, maintain, and enhance ecological balance).
6. Adopt no-till or minimum till to avoid mechanical disturbance of the soil.
7. Adopt crop rotations with cover crops in the rotation cycle.
8. Shorten or eliminate summer fallow periods.

9. Apply agronomic rates of nitrogen fertilizers to increase soil fertility and crop production.
10. Switch from single crop farming to more diverse practices such as pasture, crop and pasture rotation, inter-cropping (growing two or more crops close to each other), pasture cropping (sowing crops such as cereals into pastures), and agroforestry (combining trees or shrubs with crops or pasture).
11. Enhance biological nitrogen fixation through the use of legume crops such as alfalfa.

Conclusion

The atmospheric carbon-dioxide increased significantly after the post industrialization in 1860s, more especially in recent decades because of the burning fossil fuels, changes in land use pattern, and cultivation of the land for food production and projected to continue increasing if appropriate action is not taken at time.This increased poses a significant threat of global climate change. Therefore, in this context, soil carbon sequestration is one of the appropriate, flexible and possible ways to reduce the atmospheric carbon-dioxide levels and to store the captured carbon in to the soil for long term. Soil organic matter has the capacity to store the carbon about twice as much carbon as the atmosphere, and about three times more than forests and other vegetation. Through this process CO_2 from the atmosphere is removed through plant photosynthesis, and storage as long-lived, stable forms of soil organic matter that is not rapidly decomposed. The increased carbon stock in soil acts as a source of several plant nutrients which subsequently accelerate the plant growth and development and ensures the good food production to overcome inhabitants hunger and malnutrition.

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