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Carbon Sequestration In Soil and Vegetation - A Must Stride For Mitigating Climate Change

Yumnam Bijilaxmi Devi[1*] and Thounaojam Thomas Meetei[1]
[1]*Lovely Professional University, Phagwara, Punjab, 144411*
[*]*Corresponding author*

ABSTRACT

The gradual increase in the concentration of CO_2in atmosphere is observed by 31 % subsequently since 1750 from different anthropogenic practices like fossil fuel burning and changes in land use system causing considerable global warming. Worldwide population is facing the adverse effect of global warming due to emission of greenhouse gases to the atmosphere.Average surface temperature of Earthis expected to increase from a 1.3^{0}F over the last century to 3.2 to 7.2 degrees over the 21st century. Carbon sequestration is a practicewhere CO_2 is removed from the atmosphere and stored in the various carbon sinks like soil, vegetation, oceans etc.Entrapment or capturing carbon (C) from atmosphere and storing in different kinds of reservoirs is an important process to mitigate climate change which we simply understand as carbon sequestration. The stored carbon can be termed as carbon pools which has the capability to hoard/discharge C and can be altered by natural or anthropogenic practices. Wetland soil stores 14.5 % of the total soil carbon. Approximately 750 Mha of degraded land have been found to be having potential for afforestation, soil quality and nutrient enhancement. An area of 750 Mha terrestrial land has the capacity to store approximately 1.1 Pg C yr^{-1} with a sequestration prospective of 0.5 Mg ha^{-1}yr^{-1} as soil organic carbon and biomass of additional 1.0 Mg ha^{-1} yr^{-1}. By controlling the desertification in dry and semi-arid regions, an estimated potential of sequestering C accounts for 0.4 to 0.7 Pg C yr^{-1}. It has been proved all over the world that conversion of plough tillage to no-till or reduced till farming has the potential to improve C sequestration by 570 ± 140 Kg C ha^{-1} yr^{-1} in the next 40 to 60 years. C sequestration by agriculture process, forestry and land use systems have been recognized an impending choice to mitigate global warming as they have the great ability to store excess C from atmosphere. Less disturbance to the nature is becoming a major task in upcoming decades so that consequences of disturbing the nature is concealed. C sequestration will surely contribute to reducing C content in

the atmosphere thus help in mitigating adverse effects of nature like global warming, drought, salinity stress, desertification etc.

Keywords: global warming, greenhouse gases, stress, climate change

Introduction

Inter-governmental Panel on Climate Change (IPCC, 2007a) has reported an expected increase of the average surface temperature of Earth from a 1.3^{0}F over the last century to 3.2 to 7.2 degrees over the 21st century. The change in temperature will have many direct and indirect effects on farming, length of growth period, evaporation rate of soil, severe droughts, melting of ice etc. (EPA, 2008).Carbon dioxide (CO_2) being an important and major source of greenhouse gases which is causing global warming and climate change. Thus, entrapment or capturing carbon (C) from atmosphere and storing in different kinds of reservoirs is an important process to mitigate climate change which we simply understand as carbon sequestration.The stored carbon can be termed as carbon pools which has the capability to hoard/discharge C and can be altered by natural or anthropogenic practices. During pre - industrial area, the concentration of CO_2 was 280 ppm and it has reached an alarming level of 390 ppm in 2010 along with other greenhouse gases like nitrous oxide, methane etc. (IPCC, 2007b).Before, natural processes resulted in emission of C to the atmosphere and the rate of emission was also minimal but with increase in human population and technology development, the emission of C has tremendously increased due to anthropogenic processes like deforestation, industrialization, intensive farming, burning of biomass, animal husbandry etc. The C sequestration has the strong tendency to stabilize CO_2 along with other greenhouse gases to alleviate global warming. Some strategies have been defined by Schrag, 2007 for lowering CO_2emission into the atmosphere like dropping

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global energy use, sequestering C from different point sources, focusing on use of less C fuel. Since 1750 to 2003, the consequences of anthropogenic emissions of C was found to be 292 Pectagrams (Pg) (Holdren, 2008) due to combustion of fossil fuels and 136 Pg due to land use system changes, deforestation and expanding extensive cultivation on soil (IPCC, 2001).Presently, the scenario has worsened as the rate of C emission has increased tremendously*i.e* 8.3 Pg C emission per year by burning of fossil fuel and deforestation, soil cultivation and change in land use system has resulted in release of 1.6 Pg C per year (IPCC, 2007; WMO, 2014).Overall, the excess C released to the environment is absorbed by the atmosphere and oceans. Thus, it is now a must step to stabilize these C in other terrestrial sinks like soil and vegetation which will directly and indirectly improve the environment by trapping excess C from the atmosphere.

Mechanism of carbon sequestration

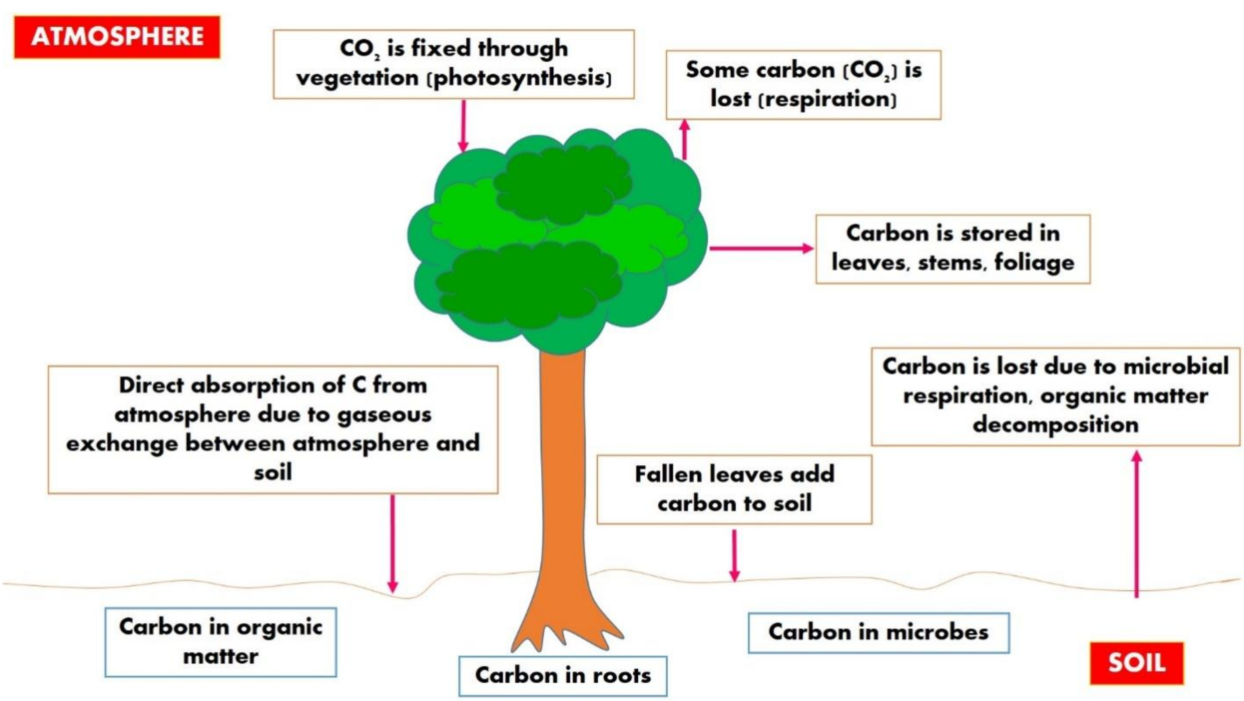

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Fig 1. Different processes showing pathway of carbon from atmosphere to vegetation and soil and vice versa

Carbon from atmosphere which was causing increase in global temperature of the Earth can be captured in plants through photosynthesis by vegetation and through exchange of gases by soil. Expanding vegetation over the area might be an important step towards storing excess CO_2 in the atmosphere which is the most common gas causing greenhouse effect. By lowering the release of C to the atmosphere, one can expect a good result in mitigating climate change due to global warming.

Main sources of carbon sequestration are soil, agroforestry, oceans, subterranean or geological sequestration. No doubt, oceans and subterranean regions are big source of carbon sink and it will be acting as an important source of carbon storage naturally but the other two sources *i.e* soil and vegetation can be altered to achieve more storage of carbon from atmosphere.

Indicators of climate change

Change in precipitation pattern, concentration of atmospheric CO_2, cyclonic recurrence, change in sea level, increase in temperature, melting of glaciers, change in acidity of the ocean, length of growing seasons, change in snow fall patterns, death due to extreme heat are some of the indicators of climate change due to excessive emission of greenhouse gases (Dhanwantri et al. 2014). The consequences of climate change can be imagined from the indicators and there is a must stride that one should follow to mitigate climate change.

Soil and carbon sequestration

There are three main constituents of terrestrial C sequestration: soils,wetlands and forests. Soil is one of the terrestrial sink of C in the world and is responsible for soil carbon pool. But these terrestrial carbon storage may encounter substantial change in amount of C stored due to

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various processes like fire, diseases, land use etc. The capability of terrestrial ecosystems to sequester additional C is ambiguous. The priorities of terrestrial carbon sequestration require optimum knowledge about different land use systems with its ability to sequester C. Forest and wetlands has more capacity to sequester C than crop and farm lands and may also enhance wildlife habitat and water quality but due to increasing demand of crop production, this process is limited to certain point. Nevertheless, conversion of forest and crop land to intensive cultivation might trigger increased CO_2 emission with low wildlife habitat and water quality.

Soil organic carbon (SOC) pools are degraded by different processes like erosion, nutrient loss, acidification, leaching, pollution etc. These changes are affecting the amount of C stored in the soil. Restoration of these degraded soil can give multi benefits like improving nutrient availability, water quality and decreasing CO_2 emission (Lal, 2008). Wetland soil stores 14.5 % of the total soil carbon (Dhanwantri et al. 2014). Approximately 750 Mha of degraded land have been found to be having potential for afforestation, soil quality and nutrient enhancement (Grainger, 1995). An area of 750 Mha terrestrial land has the capacity to store approximately 1.1 Pg C yr^{-1} with a sequestration prospective of 0.5 Mg $ha^{-1}yr^{-1}$ as soil organic carbon and biomass of additional 1.0 Mg ha^{-1} yr^{-1}. By controlling the desertification in arid and semi-arid regions, an estimated potential of sequestering C accounts for 0.4 to 0.7 Pg C yr^{-1} (Lal, 2001; Squires et al. 1995). It has been proved all over the world that conversion of plough tillage to no-till or reduced till farming has the potential to improve C sequestration by 570 ± 140 Kg C ha^{-1} yr^{-1} in the next 40 to 60 years (West and Post, 2002). Pacala & Socolow (2004) also predicted increase in potentiality of C sequestration of 0.5 to1 Pg C yr^{-1} by 2050 on 1600 Mha cropland with conversion of plough tillage to no-till farming. Availability of nitrogen is an important aspect to perform C sequestration in the soil (Paustian et al. 1997) and humification

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can be reserved by unavailability of major nutrients like N, P, S etc. (Himes, 1998). Therefore, nutrient management is also an essential need for sequestering C in the soil. Liebig et al. in 2002 have also observed improvement in SOC pool with increased N rate in the soil.

Vegetation and carbon sequestration

Carbon is a major source of plants body built up and various compounds made of C are released to the environment. More than 200 compounds have been reported to be released from plant roots as root exudates (Kuzyakov and Domanski, 2000). Secretion of these compounds is an important metabolic features of plant (Darrah, 1993). Around 20 to30 % of the total carbon assimilated in the soil is transferred through cereals and some amount of C is found in roots and utilized by microbial growth with some portions lost to the atmosphere due to respiration process (Gregory and Atwell, 1991). Pasture plants accounts for another 30 to 50% transfer of total C to soil and grasses transfer C from roots to faster than cereals (Kuzyakov et al. 1999).

There are two important sources of carbon assimilation in the soil *viz.* humification of organic matter and root exudates from plants. Both these processes results in assimilation of C in soil (Kumar et al. 2006). Photosynthates are transferring C internally through plants to soil. The gaseous exchange is totally dependent on gradation in pressure between atmosphere and soil air which is maintained continuously in the soil as in soil solution, plant roots, microbes and dead organic residues. Agroforestry can also add up social, economic and environmental advantages to the population (Clyde, 2012).

C sequestration to mitigate global warming

C sequestration by agriculture process, forestry and land use systems have been recognized an impending choice to mitigate global warming as they have the great ability to store excess C from atmosphere. Approximately 1 to 8 % weight is total soil is constituted by

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organic matter and it has the great capacity to store C upto 1600 Pg (Dakora and Phillips, 2000). Maintaining the optimum level of nutrients by proper nutrient management will eventually help boost up soil organic matter content as they are the major building blocks of plant. Increasing organic matter content not only helps to mitigate global warming, it will improve fertility level of the soil and ability to hold water by the soil thus reducing erosion lost and other related natural calamities. These processes will not only help mitigate the warming effect of the earth, it will also boost towards sustainability protecting our environment for future.

Role of Agriculture in mitigating climate change

Different agricultural practices affects the C sequestration as different type of vegetation and land use systems directly disturbs the amount of C stored in soil and plants (Johnson, 2008; Paustian et al. 2006).

1. **Conservation tillage**

   By following reduced tillage or no tillage, the disturbance to soil is greatly reduced with more capacity to absorb more C from the atmosphere in the soil (Baker, 2007). Some additional benefits includes reduced erosion, low labor requirement, water conservation, energy consumption etc.

2. **Improved cropping and cover crops**

   The loss of soil organic matter levels in the soils can be reduced by making compost, farm yard manures etc. which can be used for further nutrient application in the soil (LaSalle and Hepperly, 2008). Otherwise, the loss of these resources causes pollution in other parts of the soil where it has been accumulated without proper decomposition. The cover crops may help stability of the already stored C in the soil.

3. **Restoration of land and changing land use system**

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Restoration of land by changing land use system is a worthy step for assimilating more C from atmosphere. As converting marginal cropland to grass or trees increases carbon storage in the soil thus reducing gaseous emission having greenhouse effect.

4. **Irrigation and water management**

Improving irrigation and water management system in agriculture can help improve nutrient use efficiency of major nutrients like nitrogen, thus improving building of plant residues to absorb more C from the atmosphere.

5. **Nitrogen use efficiency (NUE)**

Increasing NUE can help in reducing nitrous oxide emissions. Use of slow release fertilizers, green manuring crops, organic manures etc. will no doubt improve NUE but also increase nutrient status and structure of the soil.

6. **Precision farming**

Precision agriculture or site specific farming is a farming management concept based on observation of the specific site, its variability in nutrient levels and crops. This will also help in conservation of water and nutrients to a certain limit which is needed by particular crop at particular time of its growth (Hinsinger, 1998).

Role of Forestry in mitigating climate change

Trees store carbon in its woody tissues and are more stable than the agricultural crops in storing C (Schlesinger, 1999). Growing more trees will help in absorbing excess C from atmosphere and it will also result in more production of organic matter thus assimilating more C in soil also through this. Forest also has a limit to store C so old carbon has a relatively greater ability to sequester C but not beyond its limit. Growing more trees will help in increasing the potentiality of the forest to capture more C with growing time (Schlesinger, 1999). However,

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instead of growing new trees, cutting and burning of trees are followed then it will eventually show its consequences in misbalancing C storage and cause emission of C from soil and the vegetation in long run. Use of woods for making furniture also act as C sink to a certain extent but to be safer side, one should always go for planting more with every tree down. Overall increasing the level of afforestation should be considered as utmost criteria for mitigating global warming in sustainable manner.

The consequences of degraded land results in low yield thus causing low C capture by the plants depleting C pools already present in the soil. In Sub-Saharan Africa content, negative nutrient balance is causing havoc in agriculture (Henoa and Baanante, 2006; Vitousek et al., 2009). Bioengineered crops and organic farming (Tester, 2009) can enhance the crop yield along with enhanced potentiality in capturing carbon while managing the environment judiciously.The approach of using current and innovative skills for sequestering C in soils (NRC, 2009) can improve the soil, its resilience and the environment as a whole (Walker and Salt, 2006).

Conclusion

Vegetation including both agricultural crops and trees acts as a stock for transmission of C from atmosphere to the soil via formation of many different organic carbon compounds like organic acids, amino acids, phenolic acids etc. Some amount of C is also internally transferred through vegetation to the soil thus acting as another important sink of C.The deposits through plants have the prospective for a better impact to long-term soil carbon than surface soil. Carbon components in the soil and plants also affect agriculture by reducing pH, nutrient mobilization and microbial growth. Therefore, management of these sinks needs a complete focus in present scenario in order to lessen the negative impact of greenhouse gases emitted to the atmosphere. Less disturbance to the nature is becoming a major task in upcoming decades so that

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consequences of disturbing the nature is concealed. C sequestration will surely contribute to reducing C content in the atmosphere thus help in mitigating adverse effects of nature like global warming, drought, salinity stress, desertification etc.

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