Chapter 1
Carbon Cycle in Response to Global Warming

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Abstract Global warming is a crucial problem in the whole world since the nineteenth century. There are several reasons responsible for global warming. Most considerable from them are anthropogenic activities. Through a variety of human activities, greenhouse gases are continuously released into the atmosphere which resulted in raised Earth temperature. Various greenhouse gases are emitted into the atmosphere. Most common of them are CO_2, methane, nitrous oxide, SO_2, and ozone. CO_2 emission usually occurred naturally by plants in dark, through human respiration and the natural carbon cycle. But, due to anthropogenic activities, the significant amounts of CO_2 are released into the atmosphere which is above the normal threshold limit. High concentrations of CO_2 caused Global Warming. Global warming, in turn, disrupts natural carbon cycle which releases more CO_2 into the environment. Thus, this cycle is continuously running with disastrous effect on the natural earth's environment. Natural carbon cycle normally occurred by the degradation of SOC (soil organic carbon) by a variety of microbes and other chemical reactions which then released CO_2 in the atmosphere. But, due to the decline of organic carbon in the soil, a huge amount of CO_2 is being released into the environment. This process has disastrous effects on not only humans but also on plants and

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S. Fahad et al. (eds.), *Environment, Climate, Plant and Vegetation Growth*,
https://doi.org/10.1007/978-3-030-49732-3_1

other wildlife. This chapter reveals the effects of global warming on the natural carbon cycle which is the prime concern of today's studies.

Keywords Climate change · Greenhouse emission gases · Methane, nitrous oxide · Temperature

1.1 Introduction

Carbon is one of the most important elements of the periodic table. In nature, the major Carbon reservoirs are atmosphere, ocean, plant, soil and fossil fuels. Carbon keeps flowing among these reservoirs. If Carbon concentration is disturbed in one reservoir it automatically affects the carbon concentration of other reservoirs. Higher carbon concentration in the atmosphere results in an increase in the global temperature. However, Carbon is not the enemy as it is very essential for life on earth. It is necessary for soil health. Photosynthesis is driven by CO_2. The micro-organisms play an important part in converting the carbon compounds into stable, life-giving organic compounds (McDonough 2016). The processes of decomposition and fossil fuel combustion releases the CO_2 into the atmosphere again. The increased CO_2 concentration in the atmosphere has increased as a result of deforestation, industrialization, transportation and current human lifestyle which resulted in a global climate shift (Adnan et al. 2018; Akram et al. 2018a, b; Aziz et al. 2017; Habib ur et al. 2017; Hafiz et al. 2016, 2019; Kamran et al. 2017; Muhammad et al. 2019; Sajjad et al. 2019; Saud et al. 2013, 2014, 2016, 2017; Shah et al. 2013; Qamar-ur et al. 2017; Wajid et al. 2017; Yang et al. 2017; Zahida et al. 2017; Fahad and Bano 2012; Fahad et al. 2013, 2014a, b, 2015a, b, 2016a, b, c, d, 2017, 2018, 2019a, b).

In 2013, IPPC (Intergovernmental Panel on Climate Change) reported an increase in the global mean surface temperature of 0.8 °C from 1880 to 2012 with an increase of about 0.72 °C from 1951 to 2012. Global warming is a major problem which is leading to climate change in most of the countries throughout the world. The crucial factors responsible for global warming include disastrous human activities. Changes in the environment now exceeded the limits of natural divergence. Human activities lead to the release of greenhouse gases in the environment through a variety of sources which ultimately increase the environment's temperature, commonly known as global warming (Wheeler and Watts 2018). Species are now forced to pass through more rigorous selection pressures and will require more adaptation to persist in the environment which will ultimately affect the evolution of the organisms (Monroe et al. 2018a). It has been estimated that at the end of the current century there will an increase of 3 °C in temperature if the current trends continue. Efforts are now being made to somehow limit the global warming around 1.5 °C above pre-industrialization but serious efforts are required to do so (Monroe 2018b). Scientists have now accumulated experimental evidence to prove human involvement in global climate change like ozone depletion, pollution, etc. (Santer et al. 2018). The ozone layer has an important role in maintaining the normal temperature of the ecosystem. The continuous release of greenhouse gases above certain limits depleted the ozone layer which ultimately leads to the global warming (Santer et al. 2018). This chapter aims to provide insights about natural Carbon cycle and its response to global warming.

1.2 The Carbon Cycle

The biogeochemical cycle through which carbon is exchanged among carbon reservoirs like biosphere, pedosphere, hydrosphere, and atmosphere of the Earth is called the Carbon Cycle (Fig. 1.1). In nature, carbon is the main component of the biological compounds as well as the minerals e.g. limestone. The carbon is among the important cycles on the earth which make it sustainable for life. It provides a description of the carbon recycling, re-usage, sequestration and release from the sinks.

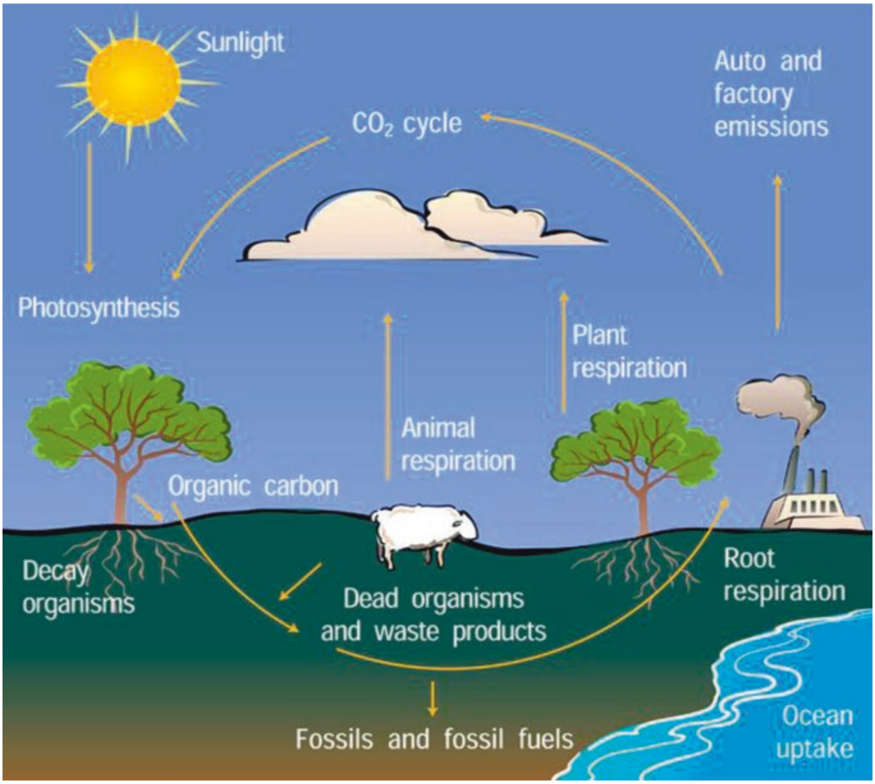

Fig. 1.1 Global Carbon Cycle

Overall, there are five carbon pools: the aquatic pool is the huge one among pedologic, geologic, atmospheric and biotic pools (Fig. 1.2). All these pools are connected with each other and carbon flow between them.

Carbon dioxide concentration was low in atmosphere before industrial development. One study revealed that CO_2 concentration was approximately 280 ppm before industrial development. After industrial development, in 2008 concentration raised up to 384 ppm (Tans et al. 1990). Human activities and isolation of CO_2 from sea water and land have 50% contribution in increased level of CO_2 (Menon et al. 2007; Raupach et al. 2007). Inland waters have major role in CO_2 emissions. Inland water includes natural ponds, rivers, streams, wetlands and reservoirs. No doubt they cover only 1% of earth but they have significant contribution in CO_2 emissions as compared to terrestrial and marine ecosystem (Richey et al. 2002; Cole et al. 2007; Tranvik et al. 2009; Battin et al. 2008; Harris et al. 2012). 0.6 pg carbon buried inside water inlands per year (Richey et al. 2002). It is equal to 20% of carbon which is thought to be buried inside soil and terrestrial ecosystem. Carbon buried inside sediments over thousands of years (Richey et al. 2002; Einsele et al. 2001). Some stable carbon buried inside sediments may reach lithosphere. Due to deficiency of oxygen in inland water as compared to oceans inhibits decomposition of sedimentary carbon and further its emission into atmosphere. This whole process is well presented in (Fig. 1.3). Organic carbon mobility from terrestrial ecosystems to inland water resources is an attention grabbing situation which is responsible for climate change (Battin et al. 2009). To understand carbon seclusion primary step is to find out where this process occurs. After this it is necessary to understand processes that maintain and enhance it. For instance, when soil erosion occur it create a path by which carbon move from land to inland water resources. However, reservoirs, sea water maintain their sediments and bounded carbon (Richey et al. 2002; Battin et al. 2008). They also block carbon movement from water to other inland

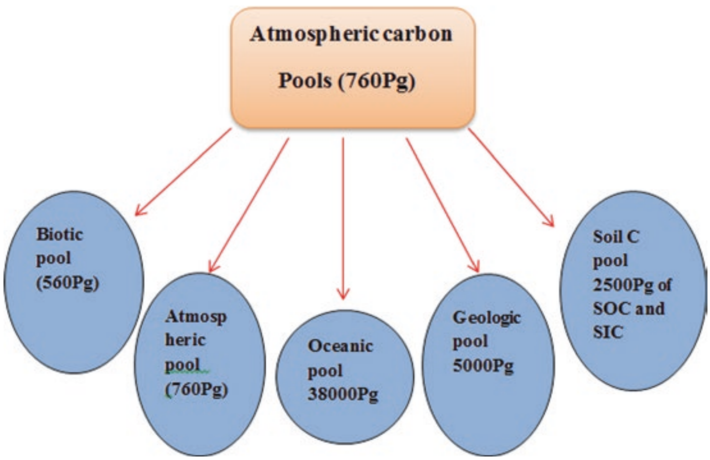

Fig. 1.2 Five worldwide carbon pools. Biotic, Atmospheric, Aquatic, Geologic and Pedologic

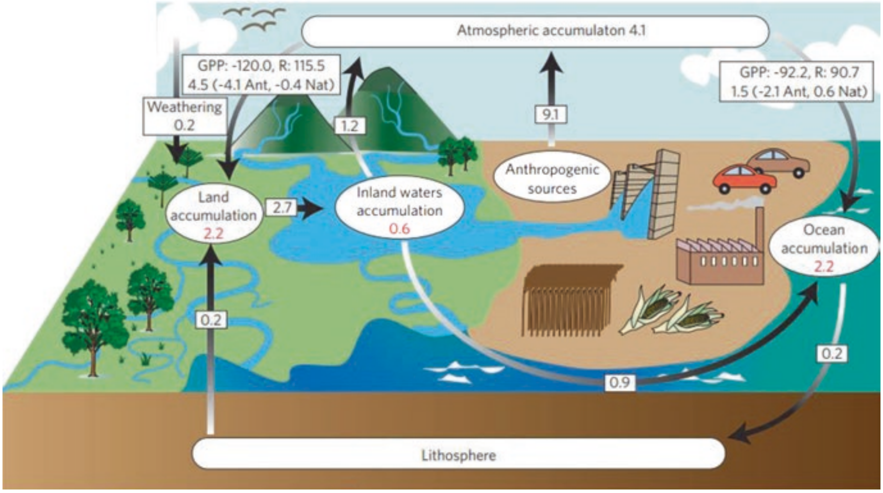

Fig. 1.3 "Abundant carbon cycle" (Battin et al. 2009). The symbolic diagram represents net carbon flow from inland water resources (Richey et al. 2002), and from anthropogenic activities (Raupach et al. 2007). It also includes carbon influx before the industrial development (Menon et al. 2007). Black values represent carbon influx among carbon pools and rate of change in carbon flow represented by red values. This figure also reveals total carbon flow from atmosphere to land and water resources, anthropogenic activities responsible for carbon production and total usage of carbon by organisms depend on photosynthetic process. Ecosystem respiration (R) and Gross primary production (GPP) are poorly constrained (Luyssaert et al. 2008; Del Giorgio and Duarte 2002). CO_2 produced by human activities intake by sea water also include in this net carbon flow (Menon et al. 2007). Influx of carbon from lithosphere represents discharge of CO_2 into firm basins and flow of carbon from lithosphere to land show abrasion of elevated sedimentary rocks also represented in diagram (Menon et al. 2007)

water resources. Furthermore, it is unclear till yet that either sediment's burial resulted in net increase of carbon seclusion or sea water and land responsible for it (Harden et al. 2008). Land use alterations can worsen the effects of inlands outgassing on climate. Inland's water carbon when mineralized then released as CO_2 in atmosphere. But, other lakes, ponds, rivers also release methane (CH_4) into atmosphere. CH_4 is also greenhouse gas and absorb more heat than equal amount of CO_2. Hence, it also has major role in higher temperature of atmosphere. Reservoirs created for hydrolytic power plants and agriculture also released methane into atmosphere (Richey et al. 2002). So, inland water resources responsible for carbon seclusion, its release into atmosphere and resulting warm environment.

1.3 Global Warming

From the mid of the nineteenth century, human activities have disturbed the biogeochemical cycles like the global carbon cycle with an unnatural increase in the Carbon Emission and other greenhouse gases like methane, nitrous oxide, etc. which resulted in increased average global temperature. The temperature rise resulted in soil degradation, agricultural land productivity loss, desertification, biodiversity loss, ecosystem degradation, freshwater resource reduction, ocean acidification and depletion of stratospheric ozone. Global warming will ultimately affect agricultural resources through reduced water availability, alteration, and shrinking of arable land, increased pollution, and toxic substance accumulation in the food chain (Srivastav 2019). The atmospheric Carbon Dioxide (CO_2) concentration increased from 277 parts per million (ppm) to 405 ± 0.1 ppm in 2017 which indicates a continuous rise in the atmospheric CO_2 concentration since the beginning of the industrial era (Alshboul and Lorke 2015). Before industrialization, the atmospheric CO_2 increase was mainly because of deforestation and other land use activities (Alshboul and Lorke 2015). However, after industrialization, fuel combustion became the primary source of anthropogenic emissions to the atmosphere. Since 1750, human beings are responsible for the release of 555 pentagrams of Carbon in the atmosphere which increased the atmospheric CO_2 concentration to a record level in 800.000 years (Battin et al. 2009). The human activities which are somehow involved and can disturb the natural phenomenon are referred to as anthropogenic activities (Barnes et al. 2019). With an increased level of CO_2, temperature rises which give rise to sea level as a result of thermal expansion which results in temporary changes that usually very rapid. The reason behind this is the change in ocean circulation (Flückiger et al. 2006). Environmental warming is responsible for the decrease in rainfall (Allen and Ingram 2002) which ultimately affect water supply for living organisms. Significant decrease in rainfall occurred in some areas including southern Africa, parts of southwestern North America and Mediterranean (Burke et al. 2006). Due to the melting of glaciers and ice pools water drained into the sea and its level raised up. Antarctica and green lands ice pools/ice sheets also melted due to the warm atmosphere and have observed in many areas. One recent study proved ice sheets raised sea level up to 1–2 m. However, one other study suggested that air rather than warm atmosphere responsible for rapid glaciers melting. CO_2 emission has already imparted irrevocable effects on the planet. Further carbon dioxide discharged into the atmosphere through various anthropogenic activities would contribute to more irreversible catastrophic effects on the environment.

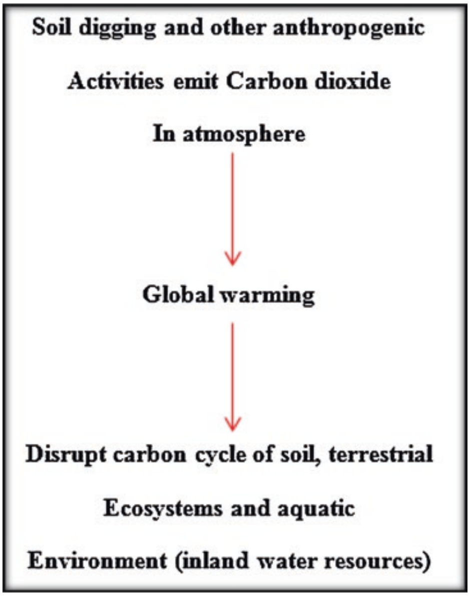

Fig. 1.4 This fig shows the flow of carbon in the atmosphere. Various anthropogenic activities e.g. digging, deforestation, biomass burning, and soil erosion emit CO_2 in the atmosphere which results in global warming. Global warming, in turn, disrupts natural carbon cycle/carbon pool resulting in enhanced CO_2 emission in the atmosphere. In this way, CO_2 concentration get increase day by day in an atmosphere

1.4 Effects of Global Warming on the Carbon Cycle

As discussed above, that increase in CO_2 in atmosphere accelerates global warming (increase in earth's temperature) which in turn disturbs carbon cycle. Terrestrial ecosystems and inland water resources produce more CO_2 under warming as illustrated in (Fig. 1.4). Here we discuss the effects of global warming on the biogeochemical carbon cycle.

1.5 Global Warming and Soil Properties

1.5.1 Soil Respiration

The CO_2 released from microbial activity along with the CO_2 released from plant respiration is known as Soil Respiration. This flux is the second largest carbon flux on Earth (Smith 2002). Despite the fact that the dynamics of this flux are not clearly understood (Watson et al. 2000), the scientists have reached the conclusion that climate change especially the Global warming is affecting the soil respiration flux and its rate. As compared to the atmosphere, the Earth's soil store about twice the Carbon. Over time the carbon concentration releasing from the soil to the atmosphere is increasing (Prentice et al. 2001) but the degree to which Global warming is affecting the carbon flux from soil to atmosphere is the current topic of investigation for many Scientists (Rossati 2017). Observations indicate that soil surface heterotrophic to soil respiration has been increased from 0.54 to 0.63 between 1990 and 2014. It was also noted that both heterotrophic respiration and soil respiration to gross primary production has increased over time. From a study, it was concluded that global heterotrophic respiration is rising in response to climate change (Peters et al. 2017). This suggests that climate-driven losses of soil carbon are currently occurring across many ecosystems, with a detectable and sustained trend emerging at the global scale.

1.5.2 Soil Carbon Feedback

Carbon Cycle feedback to global warming is a poorly understood concept (Change 2013). Experiments suggest that carbon feedback will play an important role either in accelerating or slowing down climate change (Stocker et al. 2013) but the magnitude and of this feedback cannot be predicted. The potential switch of the terrestrial biosphere from carbon sink to Carbon source depends on temperature sensitivity trend of soil organic matter decay (Buttigieg et al. 2016) and complex carbon-nitrogen interactions for the understanding of which as long term field-based experiments are required (Peters et al. 2017).

1.5.3 Soil Organic Matter

Wetlands, permafrost, and peatlands have a high stock of organic carbon as compared to mineral soil on the earth surface (Moftakhari et al. 2017). They make the largest carbon stock globally. Permafrost and peatlands are mostly present at parallel surfaces where the temperature is mostly higher (Hassol 2004) Soil's organic matter stock resulted from a balance between input and output resources below the ground as shown in (Fig. 1.5). Inputs come from roots and leaf debris. Output sources resulted from CO_2 outflow from the soil. Methane outflow and leaching of other organic matter are also significant. Microbial decomposition of organic matter and soil respiration are responsible for the presence of carbon in the soil. These processes rely on temperature and also require water. Carbon dioxide is the main product of organic carbon's breakdown in the soil. Similarly, dissolved organic carbon, dissolved inorganic carbon, aquatic particulate organic components, and methane are also significant transports in soil. Recent extreme weather conditions like heatwaves, droughts, storms, etc. which are caused due to global warming can be a reason for carbon sinks destruction and cause a net loss of carbon from Carbon Stocks releasing CO_2 to the atmosphere (Madakumbura et al. 2019). Extreme weather events can trigger immediate or time-lagged ecosystem responses like mortality, fires or insect infestation (Dai 2011). This indicates that a small shift in the weather conditions can reduce carbon concentration in the sinks and may give positive feedback to climate changing.

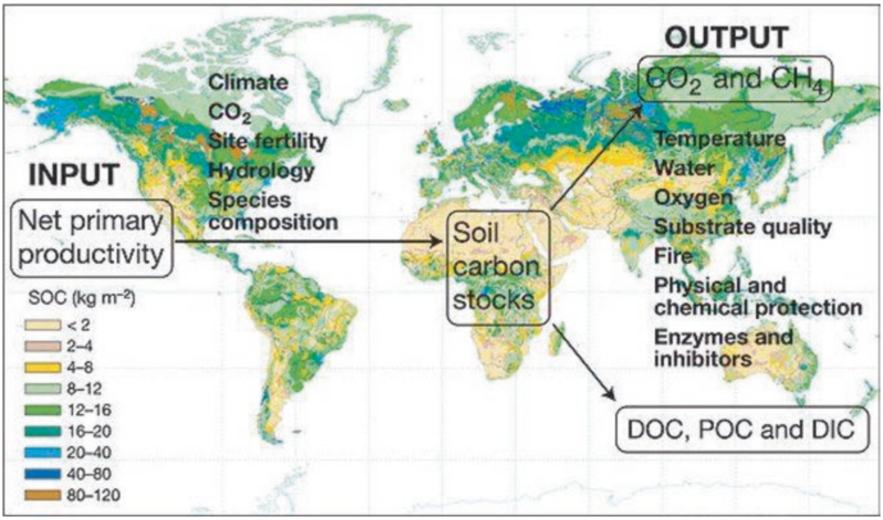

Fig. 1.5 Factors affecting input and product of soil's carbon, highly obtrude over worldwide carbon map

1.5.4 *Microbial Decomposition*

The soil microbial species responsible for the decomposition of organic soil material are the cause of 50–70 Pg Carbon emission into the atmosphere annually that is approximately 7.5–9 times of the Carbon emissions caused by human activities. The decomposition process is sensitive to the constant climate change due to global warming as it affects the global carbon cycle. Many scientists are interested in researching the impacts of global warming factors on the microbial decomposition activity the interspecific interactions also have a great impact but they give rare importance (Raich and Potter 1995). The combination of global change factors alleviated the bottom-up limitations on fungal growth, stimulating enzyme production and decomposition rates in the absence of soil animals. However, increased fungal biomass also stimulated consumption rates by soil invertebrates, restoring microbial process rates to levels observed under ambient conditions. Our results support the contemporary theory that top-down control in soil food webs is apparent only in the absence of bottom-up limitation. As such, when global change factors alleviate the bottom-up limitations on microbial activity, top-down control becomes an increasingly important regulatory force with the capacity to dampen the strength of the positive carbon cycle-climate feedbacks (Crowther et al. 2015).

1.6 Future Perspectives

The carbon cycle is responsible for the circulation of CO_2 in the atmosphere. Anthropogenic activities are greatly responsible for the disturbance of the Global Carbon Cycle. In-depth study of biogeochemical Carbon Cycle can provide a better understanding of continuous climate change and its effects. New observational methods and experimental ideas are needed to achieve this aim. Various studies indicated that the decline in the soil concentration results in higher atmospheric carbon concentration. In soil organic carbon misplacement is mostly because of the alterations in the soil's composition and structure. Increased soil concentration will also lead to increased CO2 emission from the soil. So, carbon sequestration from the soil is a leading pathway to mitigate climate change. More research work is needed to counter the large scale carbon emissions. Management practices, precautionary measures should be taken to minimize the disastrous effects of human activities on soil structure. Land misuse should be minimized and restoration processes must be carried out for better crop production and to avoid/minimize soil erosion. Some issues related to the carbon cycle and carbon sequestration from soil should be addressed which are as following:

1. Which ecosystem has large carbon concentrations and how to identify it?
2. RMP (recommended management practices) for carbon sequestration from farmland and other soils.
3. What are better processes for soil carbon sequestration, their cost-effectiveness, and their precision and accuracy?
4. Association between soil and water's procedures in response to greenhouse gases.
5. What would be outcomes of any changes in the global carbon pool?
6. How features and quantity of soil organic carbon effect air water and soil's quality?
7. What will be expenses of carbon isolation from soil under various conditions like vegetation, water, and soil management implementations?

All these issues should be clearly understood in order to control and limit the disastrous effects on climate. More research work is required for understanding carbon scattering in various ecosystems, its contribution to global warming and the procedures to minimize climate changes.

1.7 Conclusion

The carbon cycle is a natural cycle that maintains the carbon flow among different reservoirs. Carbon circulation occurs in soil, terrestrial ecosystems, aquatic areas and within inland water resources. Carbon stock is present in the soil as soil organic carbon which is decomposed by various microbes and other chemical reactions. Some of the carbon is utilized by the plants and remaining is released into the atmosphere. Due to continuous changes in global temperature, carbon cycle became disrupted. The carbon concentration of soil is declining as more and more of the soil organic carbon is becoming a part of the atmosphere. The release of CO_2 exceeding the threshold limit raised the global temperature which resulted in global warming. Global warming further affects the Carbon cycle which causes an increased emission of CO_2 in the atmosphere. Anthropogenic activities are a major source of greenhouse gases. Greenhouse gases enhance the Earth's temperature. There are various greenhouse gases like SO_2, CO_2, nitrous oxide, ozone, and CFCs. CO_2 is one of the enormously discharged gas into the atmosphere. Naturally, carbon dioxide discharges into the atmosphere through plants, humans and animal's respiration, soil respiration and through natural carbon cycles from terrestrial and aquatic ecosystems. Various anthropogenic activities like tropical deforestation, land misuse, biomass burning, soil erosion, and industrial development discharge a huge amount of CO_2 in the atmosphere which results in increased temperature which melts glaciers and causes flooding. Global warming has disastrous effects not only on the lives of human beings but also on animals and plants. The density of animals got is changing globally due to climate change as they move toward the areas with a more favorable environment. Plants characteristics, development time, growing time is also changing with climatic changes. Since soil's carbon is responsible for the huge discharge of CO_2 into the atmosphere so one way to mitigate climate change is to isolate/sequester carbon from the soil. Land use in a better way by implementing suggested management instruction can have considerable results for soil's carbon sequestration. Soil's carbon sequestration not only decrease the emission of CO_2 discharge into the atmosphere but also maintains a natural carbon pool. It betters soil quality and magically enhances biomass yield. So, carbon isolation from the soil is the best way to diminish temperature alterations and to improve soil quality which is a natural homeland for plants and other living organisms.

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