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Role of Carbon Sequestration to Mitigate the Global Environmental Changes

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Abstract

The process of absorbing and storing atmospheric carbon dioxide in order to slow down global warming and climate change is known as carbon sequestration. Carbon pools are another name for carbon reservoirs or storages. It may be caused by humans or by nature. The growing quantity of greenhouse gases (GHGs) in the atmosphere is decreased by the carbon sequestration process. The cultivation of crops, the creation of forests and public parks and gardens, and the use of biotechnological techniques to modify genes in order to obtain efficient genes that can significantly lower the amount of carbon in the atmosphere. More carbon dioxide can be absorbed from the atmosphere and global warming can be lessened with the use of biotechnological technologies for gene modification. This technology makes it simple for plants to absorb more carbon, which will contribute to an increase in plant biomass. Additionally, it aids in lowering poverty in the communities where these projects are implemented. Millions of people can profit from forestry projects on a social, economic, and local environmental level. The sole noteworthy advantage of improving carbon storage in the soil organic material is the removal of CO2 from the atmosphere.

Keywords: CO2; Greenhouse Gases; Global Warming; Carbon Sequestration; Forestry

Abbreviations:

GHGs: Greenhouse Gases; CCS: Carbon Capture and Sequestration; HRP: High Rate Ponds.

Introduction

The process of taking carbon out of the atmosphere and storing it in reservoirs is known as carbon sequestration. In essence, it is the process of absorbing carbon dioxide from the atmosphere and storing it in reservoirs to slow down climate change and global warming. The process of extracting carbon from the atmosphere and storing it in a reservoir is also referred to as this. These carbon reservoirs or storage facilities are also referred to as carbon pools, which describe a system or mechanism that has the ability to store or release carbon. It may be man-made or natural. Forest biomass, wood products, soils, and the atmosphere are a few examples [1]. The growing quantity of greenhouse gases (GHGs) in the atmosphere is decreased by the carbon sequestration process. It could be controlled by mitigating GHGs, especially carbon dioxide, by sequestering carbon into soil and vegetative cover (Figure 1). The major GHGs are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The concentration of CO_2, CH_4 and NO_2 in the atmosphere reduces their emission from the atmosphere [2]. It could also bring significant benefits to the local communities involved and consequently helps in reducing poverty at the same time. Forestry projects can bring social, economic and local environmental benefits to millions of people. Removing CO_2 from the atmosphere is the only significant benefit of enhanced carbon storage in the soil organic matter. When the soil is rich in nitrogen, microbes produce more carbon, leading to a greater release of CO_2 into the atmosphere. This release of CO_2 was also affected by the species and season [3]. In mechanism photosynthesis, wetland trees and other plants convert atmospheric CO_2 into biomass. Hence, carbon may be temporarily stored in wetlands as trees, plants and the other living materials, which feed upon them, and plant debris including fallen plant parts and animals, which feed upon them. The primary carbon dioxide source for many wetland plants is known to be atmospheric carbon dioxide, and its eventual demise and settling at the bottom of a marsh can have a significant impact on carbon sequestration. Wetlands are among the best ecosystems for storing soil carbon because of their ability to accumulate organic matter in the soil and sediment, which act as carbon sinks [4]. Carbon capture and sequestration (CCS) is now possible because to innovation and technology, but it is similar to waste management and requires large investment costs [3,4]. As a result, CCSU biotechnology has drawn increased attention in an effort to develop cost-offsetting value chains [5]. The C stored in the soil zone appears susceptible to enhanced degradation under the projected conditions of global climate change. Organic carbon plays a significant role in maintaining physical, chemical and biological properties of the soil. Hence, soil organic carbon is one of the most important indicators of soil quality. Higher level of organic carbon in the soil sustains higher productivity in any ecosystem [6-8].

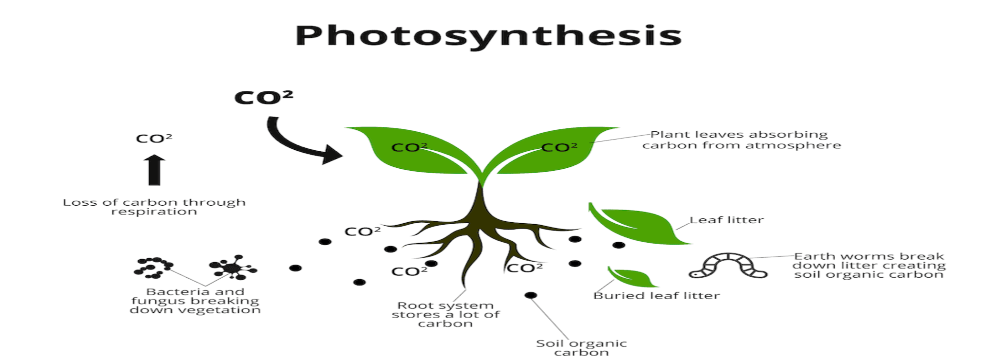

Figure 1: Carbon sequestration by plant.

Carbon Sequestration by Using Wetlands

Wetlands make up around 5% of the earth's land area and are dynamic, natural ecosystems that are characterized by waterlogged or standing water conditions for at least part of the year. Wetlands are found in all climatic zones, from the tropics to the tundra. Carbon sequestration is the long-term storage of carbon dioxide or other forms of carbon in oceans, soils, vegetation (especially forests), and geologic formations to either mitigate or defer global warming.

Productivity among wetlands varies depending on the type of the wetland, climatic condition and vegetation communities. Decomposition is a complex process that incorporates both anaerobic and aerobic processes, in addition to productivity. Wetlands are among the best ecosystems for storing soil carbon because of the rate and quality of organic matter entering the system, which causes organic matter to accumulate in the soil and sediment, acting as carbon sinks [9].

Mechanism of Carbon Storage in Wetlands

Wetland trees and other plants use the process of photosynthesis to transform carbon dioxide from the atmosphere into biomass. Wetlands can therefore temporarily store carbon in the form of trees, plants, and the living things that eat them, as well as trash like fallen plants and animals that eat them. The primary carbon source for many wetland plants is atmospheric carbon dioxide, and their eventual death, decomposition, and settlement at the bottom of the wetland can have a significant impact on C sequestration. This mechanism of storage through photosynthesis depends along the latitudinal gradient because vegetation growth is slower in high latitude wetlands with less sunlight, nutrients, and colder temperatures. Second, carbon-rich material that is carried by hurricanes, floods, or even drained from watershed sources is retained and stored. Numerous factors, including the wetland's topography and geological position, hydrological regime, plant species, soil temperature and moisture content, pH, and morphology, influence the balance between carbon input (the production of organic matter) and output (decomposition, methanogenisis, etc.) and the subsequent storage of carbon in wetlands [10].

Carbon Sequestration by Using Algae

The most significant CO_2 fixers in aquatic ecosystems are algae, which make up a significant portion of biomass in both freshwater and marine settings. These primary producers fill an important ecological niche by using photosynthesis to fix carbon into biomass. The ecological niche of algae is still not well known, nevertheless. Given our understanding of carbon storage, algae may be the undiscovered carbon sink. Major algal production facilities known as high rate ponds (HRP) effectively generate a lot of algae with little energy input [11]. Moreover, HRP could adapt ecological engineering concepts to mimic an ecosystem and might be an ideal choice for ecological study in the laboratory. This experimental setup is easy to manage and can simplify the complicated natural environment to obtain valuable data on the ecological niche of algae [12]. Figure 2 represent the process CO_2 sequestration and biomass conversion [13].

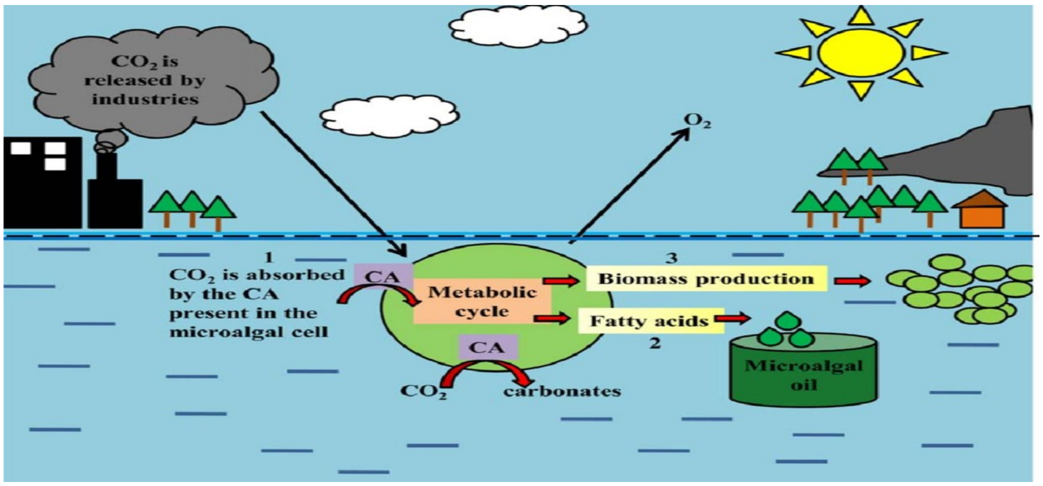

Figure 2: Carbon sequestration by algae and conversion into biofuel.

Carbon Sequestration by Terrestrial Plants

Terrestrial plants are widely acknowledged as a significant eco-tech option and fill a crucial niche in CO_2 capture. The main land use types include woods, brushlands, agricultural lands, and grasslands. We computed terrestrial plant uptake rates from the literature and contrasted them with reactor rates. The grassland did not contribute to the reduction of CO_2. Rice and other staple foods did not contribute to the sequestration of CO_2. Rice and grass performed similarly in fixing CO_2 since they belong to the same family (Poaceae) and order (Poales). Bananas and abaca in the genus Musa, family Musaceae, and order Zingiberales are examples of agricultural herbaceous plants (non-woody crops) that have negligible CO_2 absorption and no net CO_2 fixation. Compared to herbaceous crops, woody crops like coconuts were more effective at absorbing CO_2 [14]. According to estimates, shrubs and brushland have an 18.1% lower potential for CO_2 absorption than algae. The shrubs were Eudicots, woody perennials. Grass and shrubs coexisted in brushland. Shrubs were important because grass did not contribute to any CO_2 absorption. Because they all had woody plants, shrubs, brushland, and coconuts all showed comparable CO_2 readings. Compared to other terrestrial plants, forests absorbed more CO_2 (Figure 3). If we classified afforestation by geographic area, the equivalences of algal CO_2 uptake rates were as follows: (1) tropical zone: 13.8-79% in Philippines, (2) temperate zone: 9.9-30.1% in Europe, 5.1- 22.1% in North America, and 15.5- 20.5% in Australia.

Carbon Sequestration by Using Minerals

Mineral CO_2 sequestration is a process where atmospheric CO_2 is fixed in the form of carbonates. For carbonate ions to precipitate as carbonate minerals, a suitable counter ion should be present. The most common carbonate minerals on Earth contain Ca_{2+}, Mg_{2+}, Mn_{2+}, Fe_{2+}, or Sr_{2+} as counter ion [15]. These divalent cations, in addition to the alkalinity required for CO_2 conversion to carbonate ions can be considered as the main raw materials for the mineral CO_2 sequestration process. Alkalinity source for conversion of CO_2 to carbonate ions Mineral sequestration of CO_2 requires alkalinity to form carbonate ion (CO_3^{2-}) from the (CO_2) gas. Various sources of alkalinity have been suggested for CO_2 sequestration purposes. For example, alkaline solid residues from different industries such as steel slag [16], cement kiln dust [17], and fly ashes [18], have been identified as alkalinity sources. The quantity and distribution of these alkaline solid wastes is however limited on a global scale [19,20].

Carbon Sequestration by Using Soil

We brought issues like desertification, ozone depletion, global warming, decreased biodiversity, the demands of an expanding global population, and the necessity of a global agenda focused on sustainable development to the attention of the entire world [21]. Approximately 35% of the world's geographical surface is devoted to agriculture, more than any other human activity [22]. Agriculture releases a significant amount of greenhouse gases into the atmosphere due to its size and intensity [23]. It currently makes up around 25% of the CO_2, 50% of the CH_4, and 70% of the NO_2 that is released into the atmosphere by human activity worldwide. Nonetheless, farmers have some control over the quantity of these gases released due to the intensive management of farmlands. For example, by choosing different practices, it may be possible to reduce emissions. To assist absorb CO_2 released by fossil fuels and improve air quality, farmlands may actually be designed to absorb more gasses than they emit. Numerous studies have demonstrated that using C-conserving techniques, such as lowering the intensity of tillage, removing summer fallow, increasing the number of forages planted, and boosting residual inputs from greater yields, can frequently increase soil carbon in agriculture. The advantages of these methods differ depending on the climate, soil texture, soil taxonomy, and geographic location. Research conducted in central and eastern Canada, for instance, indicates that implementing reduced tillage does not always result in an increase in soil carbon [24].

Carbon Sequestration in Tropical Region

From broad, low-input subsistence production to intensive, highly established management systems, tropical agriculture is incredibly varied. All of the major soil types are used for agriculture, and warm climates with varying rainfall amounts are the key difference. Compared to temperate locations, tropical conditions have different limitations on agriculture's ability to sequester carbon. In the tropics, a significant amount of agriculture is subsistence-based, with poor yields and little production inputs. These systems frequently need for a large land base (shifting cultivation), and there is a strong need for different use of agricultural wastes (fuel, fodder, etc.). In contrast to most of the temperate zone, food demand exceeds supply in much of tropics and the agriculture land-base is expanding, resulting in large losses of biomass and soil C due to deforestation [25]. In the semi-arid tropics. This region includes parts of Central and South America (*e.g.*, Argentina, North-East Brazil) some parts of West, East and Southern Africa and some of the Indian sub-continent where annual precipitation averages is often employed to control shrub and tree cover and continuous heavy grazing can often lead to soil degradation. Often, the crop residues are not returned to the soil as it is either used for feed or fuel, and the manure is also used for fuel [26,27].

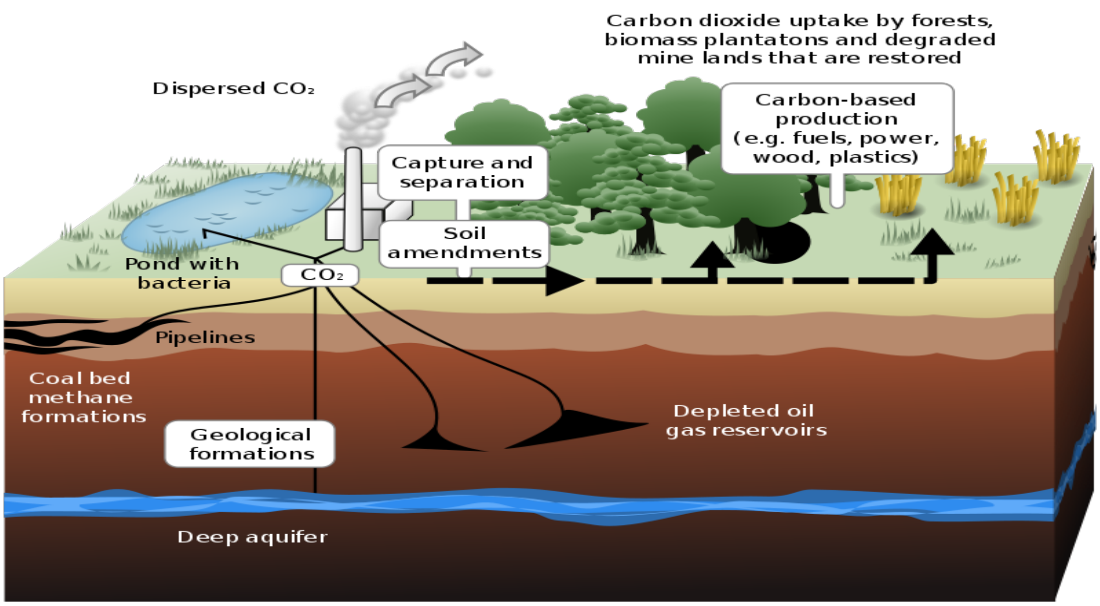

Figure 3: Carbon sequestration by geological and biological activities.

Carbon Sequestration by Agroforestry

By integrating trees into farms and the agricultural landscape, agroforestry—a dynamic, ecologically oriented system of managing natural resources—diversifies and maintains output for greater social, economic, and environmental advantages for land users at all levels. Despite the fact that agroforestry is not primarily intended for sequestering carbon, numerous recent studies have demonstrated that agroforestry contributes significantly to the storage of carbon and biomass in soil, both above and below ground [28]. For example *Populus* and *Eucalyptus* are two common tree species utilized in agroforestry in Haryana, India. According to a number of studies, agroforestry sequesters more carbon from biomass turnover in soils than traditional agriculture [29].

Carbon Sequestration by Using Biotechnology in Plants and Soil

Nearly every biological activity on the surface of the Earth depends on soils. Geologically speaking, weathering and erosion, which are governed by tectonic and climatic influences, control the amount of carbon stored in soils. Man-made activities are thought to be the primary causes of soil erosion at local and short-term scales. In addition to their functions in carbon cycling, soils support plant development in forestry and agriculture, mitigate flood risks, purify water, and preserve terrestrial biodiversity, among other vital ecosystem services. They are less labile because they store enormous amounts of decomposition-related carbon. It has been shown that single genes and genetic variants can alter root depth [30,31]. The biotechnological tools for alteration of gene can help in absorbing more carbon dioxide from the atmosphere and help to reduce the global warming. By using this technology, plants can easily absorb more carbon, which will help in increasing the plant biomass [32,33].

Conclusion

The management system and soil have a significant impact on carbon sequestration. The process of collecting CO_2 from the atmosphere and storing it in plant roots is known as carbon sequestration, and it contributes to the growth of plant biomass. One strategy to lessen the amount of carbon dioxide in the atmosphere and so slow down global warming is carbon sequestration. Wetlands, algae, minerals, soil, and agroforestry all contribute significantly to the sequestration of carbon. Millions of people can gain socially, economically, and environmentally locally from carbon sequestration. The sole noteworthy advantage of improving carbon storage in the soil organic material is the removal of CO_2 from the atmosphere.

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