

Carbon Sequestration: An Essential Salvager to Mankind

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INTRODUCTION

Rising atmospheric CO₂ concentrations resulting from rapid industrialization, extensive fossil fuel combustion, land-use changes, and deforestation have significantly intensified global warming and climate change. Increased greenhouse gas emissions have led to rising global temperatures, altered precipitation patterns, frequent extreme weather events, and ecological imbalances. In response to these challenges, carbon sequestration has emerged as a crucial climate mitigation strategy aimed at capturing and storing atmospheric carbon dioxide for long periods (IPCC, 2023). Carbon sequestration occurs through both natural and artificial processes by storing carbon in various reservoirs such as forests, agricultural soils, oceans, wetlands, and geological formations. Forest ecosystems play a major role by absorbing CO₂ through photosynthesis and storing it in biomass and soil organic matter. Similarly, soil carbon storage through sustainable land management practices enhances soil fertility while reducing atmospheric carbon levels. Technological approaches such as geological sequestration further contribute by storing captured carbon underground. Thus, carbon sequestration not only helps mitigate climate change but also supports biodiversity conservation, ecosystem stability, sustainable land use, and overall environmental sustainability.

Importance and Purpose of Carbon Sequestration

Carbon sequestration plays a vital role in mitigating climate change by reducing atmospheric CO₂ concentrations and limiting the greenhouse effect. It helps maintain balance in the global carbon cycle by transferring excess carbon from the atmosphere into long-term storage reservoirs. In addition to climate regulation, carbon sequestration improves environmental health by enhancing soil quality, conserving biodiversity, preventing land degradation, and supporting ecosystem stability.

It also contributes to sustainable development by promoting resilient ecosystems, sustainable land management practices, and long-term environmental security (Lal, 2008). Natural ecosystems such as forests, wetlands, mangroves, grasslands, and agroforestry systems function as important carbon sinks by absorbing and storing carbon in plant biomass and soils through photosynthesis. Among these, mangroves and wetlands are particularly efficient due to their high carbon storage capacity in both vegetation and sediments. Alongside natural methods, technological approaches including carbon capture and storage (CCS) systems capture CO₂ emissions from industries and power plants and store them in deep geological formations, thereby reducing industrial carbon footprints and supporting global climate mitigation efforts.

Uses of Sequestered Carbon

Sequestered carbon provides multiple environmental, economic, and industrial benefits beyond climate change mitigation. In forest ecosystems, stored carbon supports sustainable timber production by promoting biomass accumulation while simultaneously maintaining ecological balance. Carbon stored in soils improves soil fertility, enhances organic matter content, increases water-holding capacity, and supports agricultural productivity. Additionally, carbon-rich ecosystems contribute to biodiversity conservation by maintaining habitats, improving ecosystem resilience, and supporting wildlife populations (Smith, 2016). From an industrial perspective, captured carbon can be utilized in various value-added applications such as synthetic fuel production, chemical manufacturing, and industrial feedstocks, reducing dependence on fossil resources. Carbon sequestration also supports carbon credit markets, where carbon storage activities generate economic incentives through emission trading mechanisms and climate finance initiatives. Furthermore, Carbon Capture, Utilization and Storage (CCUS) technologies

enable the conversion of captured CO₂ into useful products including construction materials such as concrete and cement additives, as well as chemicals, polymers, and other industrial products, thereby promoting a circular carbon economy and sustainable development.

Trees Suitable for Carbon Sequestration

Tree species possessing rapid growth rates, high biomass production, dense wood, extensive root systems, and long-life spans exhibit greater carbon sequestration potential due to their ability to absorb and store large amounts of atmospheric CO₂ in both aboveground and belowground biomass. Deep root systems further enhance carbon storage by increasing soil organic carbon accumulation and improving long-term carbon retention. Species with dense wood are particularly efficient because they store more carbon per unit volume of biomass. Several tree species are recognized for their high carbon sequestration capacity. Examples include Giant Sequoia and Coast Redwood, which are among the largest and longest-living trees with exceptional biomass accumulation. Mangrove species also serve as highly efficient carbon sinks due to their ability to store large amounts of “blue carbon” in sediments and roots. Commercial and multipurpose species such as Teak, Poplar, Douglas fir, and Bamboo also demonstrate significant sequestration potential because of their rapid growth and biomass production. In addition, several Indian native hardwood species contribute substantially to long-term carbon storage and support sustainable forestry and climate mitigation initiatives.

Challenges and Limitations

Despite its significant potential, carbon sequestration faces several technical, economic, and environmental constraints that limit large-scale implementation. High installation and operational costs associated with carbon capture technologies, along with substantial energy requirements, remain major barriers to widespread adoption. Geological

storage systems also involve potential risks such as CO₂ leakage, which may affect long-term storage security and environmental safety. Land availability and competition for agricultural production, urban expansion, and conservation purposes can restrict the establishment of large-scale afforestation and sequestration projects. In addition, limited storage capacity in suitable geological formations and the need for continuous monitoring, verification, and maintenance increase the complexity of carbon sequestration programs. Policy limitations, inadequate regulatory frameworks, and insufficient financial incentives further hinder implementation and investment. Biological carbon sequestration methods, including forestry, afforestation, reforestation, and soil carbon management, also require extended time periods before measurable impacts become visible because carbon accumulation occurs gradually over years or decades. Therefore, long-term planning, sustained management, and integrated policy support are essential for

achieving effective carbon sequestration outcomes.

CONCLUSION

Carbon sequestration is an effective climate mitigation strategy that integrates environmental conservation with sustainable development. Expanding forests, improving carbon capture technologies, and strengthening policy frameworks can enhance long-term carbon storage and support global climate goals.

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