

## Carbon Sequestration through Biodiversity Restoration

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### INTRODUCTION

Climate change has become one of the biggest environmental issues globally due to the increasing levels of greenhouse gases, such as carbon dioxide. The increase in carbon dioxide has contributed significantly to global warming, weather patterns, and environmental degradation. Among various strategies for mitigating climate change, carbon sequestration through biodiversity restoration has become a viable option. The strategy is not only helpful in mitigating climate change but also brings ecological balance, fertility, and sustainable development. Biodiversity restoration can be defined as a process that involves improving biodiversity, ecosystem structure, and ecological functions. When biodiversity is restored, it can store more carbon dioxide from the atmosphere through various natural sinks.

### Concept of Carbon Sequestration

Carbon sequestration is the process of capturing atmospheric carbon dioxide and storing it in long-term reservoirs to mitigate climate change. It occurs naturally through photosynthesis, where plants absorb CO<sub>2</sub> and convert it into organic matter.

### Types of Carbon Sequestration

1. **Biological Sequestration** – Storage of carbon in vegetation, forests, grasslands, wetlands, and agricultural soils.
2. **Geological Sequestration** – Storage of carbon in underground geological formations.
3. **Oceanic Sequestration** – Absorption and storage of carbon in oceans and marine ecosystems.

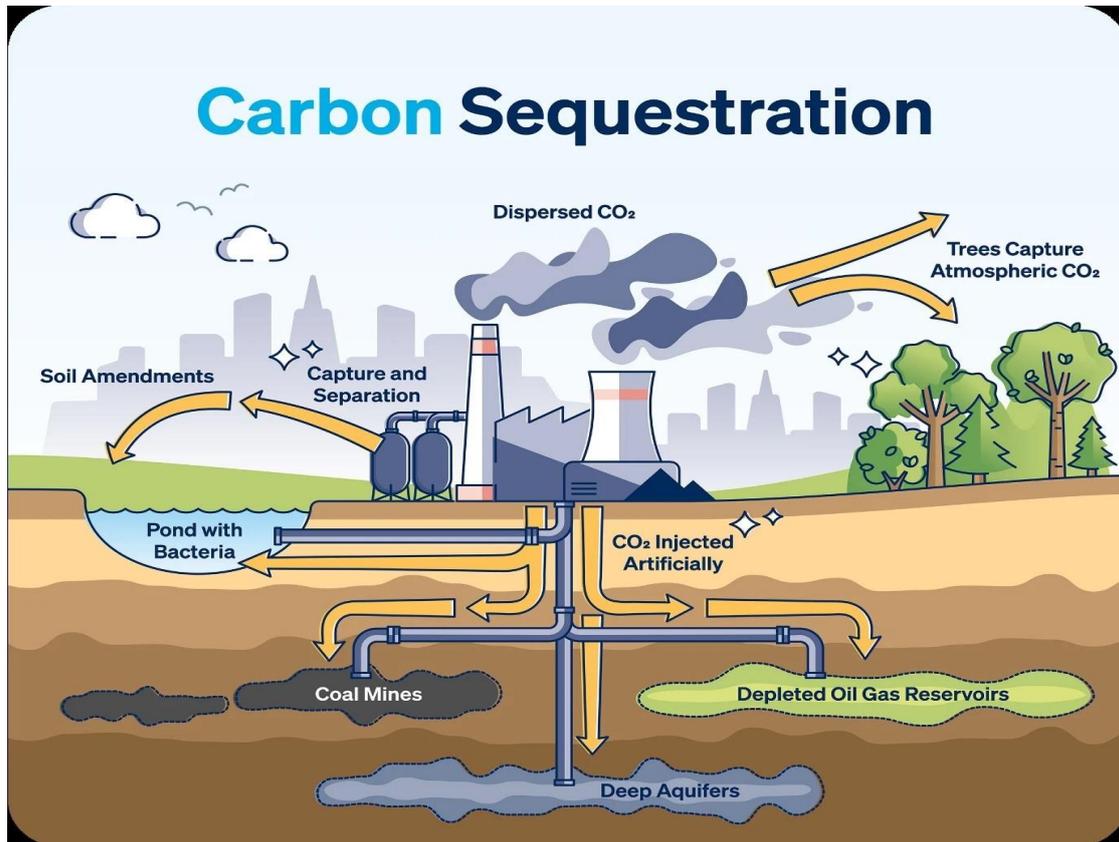
Among these, biological sequestration is considered the most environmentally friendly and cost-effective approach, especially when integrated with biodiversity restoration.

### Understanding Biodiversity Restoration

Biodiversity restoration involves rehabilitating degraded lands and ecosystems to their natural or near-natural state. It includes increasing plant and animal species diversity, improving soil health, and restoring ecosystem processes such as nutrient cycling and water regulation.

Major restoration strategies include:

- Reforestation and afforestation
- Grassland restoration
- Wetland rehabilitation
- Agroforestry development
- Soil microbial restoration
- Native species reintroduction



Mechanisms Source: <https://mahabal.com/>

### of Carbon Sequestration in Restored Ecosystems

#### 1. Photosynthesis and Biomass Accumulation

Plants absorb atmospheric CO<sub>2</sub> during photosynthesis and convert it into carbohydrates. This carbon becomes part of plant biomass, including leaves, stems, roots, and woody tissues. Forests and diverse vegetation systems accumulate large amounts of carbon over time.

#### 2. Soil Organic Carbon (SOC) Formation

When plants shed leaves, roots, and other residues, organic matter enters the soil. Soil microorganisms decompose this material, forming soil organic carbon. Healthy soils act as

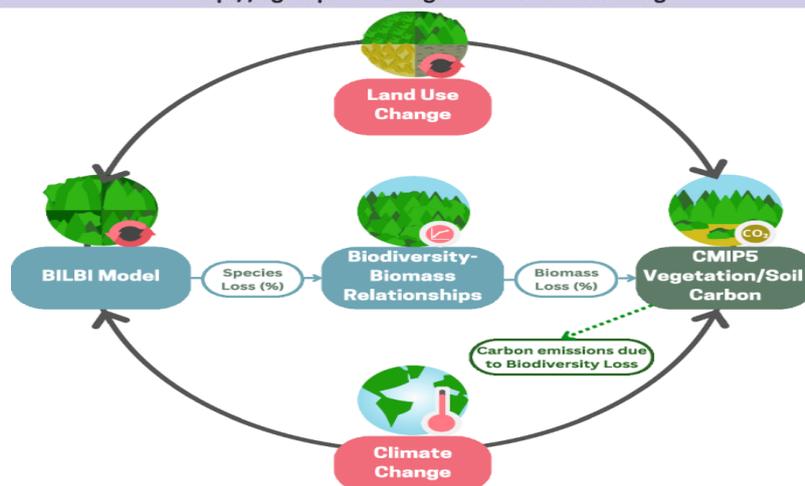
major carbon sinks and store carbon for long periods.

#### 3. Belowground Carbon Storage

Deep-rooted plants store carbon in subsoil layers where decomposition is slower. This enhances long-term carbon stability and reduces the risk of carbon release.

#### 4. Microbial and Fungal Activity

Soil microorganisms, including bacteria and fungi, play a crucial role in carbon stabilization. Mycorrhizal fungi improve root growth and increase carbon transfer to soil. Microbial processes convert organic matter into stable humus, enhancing carbon retention.



Source: <https://www.nature.com/>

## Role of Different Ecosystems in Carbon Sequestration

### Forest Ecosystems

Forests are the largest terrestrial carbon sinks and play a central role in global carbon cycling. Through photosynthesis, trees absorb atmospheric carbon dioxide and store it in trunks, branches, leaves, and roots. Restoration of degraded forests significantly enhances carbon storage in both aboveground biomass and forest soils. Mixed-species forests generally sequester more carbon than monoculture plantations due to greater structural complexity, complementary resource use, and stronger ecological interactions among species.

#### Benefits of forest restoration include:

- Increased carbon storage
- Improved biodiversity conservation
- Enhanced watershed protection and groundwater recharge
- Regulation of local and regional climate

### Grassland Ecosystems

The significant portion of the stored carbon in grasslands is hidden below the surface in the form of dense root systems. Unlike forests, where stored carbon is in the form of biomass, in the case of grasslands, stored carbon is in the form of soil organic matter. Restoring native grasses will increase soil organic carbon, soil structure, and reduce soil erosion. Grasslands are very resilient to drought conditions, making them stable long-term carbon sinks.

### Wetland Ecosystems

Wetland ecosystems, including peatlands and mangroves, are considered to be very efficient natural carbon sinks. Wetland ecosystems, including those covered in peat and mangroves, are considered very efficient natural carbon

sinks. This is because of the low rate of decomposition of organic matter, as they are usually flooded. As a result, they are able to store large amounts of carbon for long periods of time. Restoring these ecosystems will help in storing more carbon, reducing flood risks, as well as providing habitats for different species of plants and animals.

### Agroforestry Systems

Agroforestry integrates trees with crops and livestock within the same land management system. This approach enhances biodiversity and promotes carbon sequestration in both woody biomass and soil. Trees in agroforestry systems capture atmospheric carbon while improving soil fertility through litter fall and root interactions. Additionally, agroforestry improves farm productivity, increases resilience to climate stress, diversifies income sources, and supports sustainable agricultural development.

### Importance of Soil Biodiversity

Soil biodiversity is essential for carbon sequestration and ecosystem sustainability. The soil habitat harbors a vast diversity of organisms, including bacteria, fungi, protozoa, earthworms, nematodes, and arthropods. These organisms interact with each other through complex food webs. The microorganisms play a crucial role in decomposing plant and animal residues. In this way, they convert organic matter into stable soil organic carbon. In this process, carbon is converted into microbial biomass and humus, where it can be stored for a long time.

For example, mycorrhizal fungi are microorganisms that play a crucial role in increasing root growth. These fungi are essential for transferring more carbon from plants into the soil. Earthworms are important because they help

to aerate the soil and increase its aggregation. In this way, they help to stabilize carbon within soil aggregates.

Soil biodiversity is essential for improving soil fertility, carbon sequestration, nutrient availability, and sustainable agriculture. In addition, it makes the soil more resilient to environmental stresses such as drought and land degradation.

### **Carbon Sequestration in Agricultural Landscapes**

One of the most promising areas for increasing the potential for carbon sequestering is the agricultural landscape, especially when managed in a sustainable and biodiversity-based manner. Croplands have the potential to act as efficient carbon sinks if managed in an appropriate manner. This includes an increase in soil organic carbon and a decrease in greenhouse gas emissions.

The main practices for this purpose are crop diversification, which increases biomass production and root diversity; cover crops, which provide additional organic residues; and conservation tillage systems, which avoid excessive tillage of the land. Organic farming systems improve the quantity of organic matter in the soil through the use of compost and manure. Integrated nutrient management involves a balance of organic and inorganic sources of nutrients. Bio-fertilizers are also an effective tool for increasing microbial activity in the soil.

### **Environmental Benefits**

The environmental benefits of biodiversity restoration in the context of carbon sequestration are numerous. These benefits promote a balanced state of the environment and the climate. Carbon sequestration through biodiversity restoration is a powerful tool in the fight against climate change. Carbon dioxide is a greenhouse gas. The increase in plant cover in the context of biodiversity restoration promotes the sequestration of a considerable amount of atmospheric CO<sub>2</sub>. This is a direct approach towards the mitigation of climate change.

Biodiversity restoration also promotes soil conservation through the enhancement of soil cover. The increase in plant cover protects the soil from erosion caused by wind and surface runoff. The soil structure is also improved in the context of biodiversity restoration. The enhancement of soil structure promotes the conservation of water. Diverse ecosystems are

also more resilient in the context of environmental shocks such as droughts, floods, and extreme temperatures. Biodiversity promotes the sustainability of the ecosystem.

### **Socioeconomic Benefits**

Beyond environmental improvements, biodiversity restoration generates important socioeconomic benefits. Healthy ecosystems enhance agricultural productivity by improving soil fertility and water availability. Increased crop yields and diversified production systems can raise farmer income and reduce economic vulnerability. Restoration projects also create employment opportunities in tree planting, land management, and conservation activities. By supporting sustainable livelihoods and strengthening food security, biodiversity restoration contributes to rural development. Active community participation and the integration of local knowledge are essential for ensuring long-term success and equitable resource management.

### **Challenges**

However, biodiversity-based carbon sequestration is still confronted with numerous ecological, economic, and institutional challenges. For instance, deforestation and rapid land use change continue to contribute to the loss of natural carbon sequestration potential, especially in tropical and subtropical ecosystems. Habitat conversion and biodiversity loss are consequences of increased agricultural development, urbanization, and infrastructure development.

Another major challenge confronting biodiversity-based carbon sequestration is the fact that there is still inadequate awareness and technical knowledge among farmers, land managers, and policymakers regarding the potential benefits of biodiversity restoration. In addition, high restoration costs, including those of planting materials, labor, fencing, and maintenance, may discourage land restoration, especially among small-scale land managers. Climate change and extreme weather conditions, including drought, floods, and fires, may also compromise biodiversity restoration and its potential for carbon sequestration.

### **Policy Framework and Global Initiatives**

Global efforts to promote biodiversity restoration and carbon sequestration are supported by major international agreements and scientific bodies. The United Nations Framework Convention on Climate Change (UNFCCC) provides a global

framework for addressing climate change and promoting mitigation strategies, including nature-based solutions. The Intergovernmental Panel on Climate Change (IPCC) offers scientific assessments and policy recommendations on carbon management and ecosystem restoration. The Convention on Biological Diversity (CBD) focuses on conserving biological diversity and promoting sustainable use of natural resources.

### Future Perspectives

Future strategies for improving carbon sequestration through biodiversity restoration should incorporate an integrated and forward-looking strategy. The strategy should emphasize landscape restoration, where forests, grasslands, wetlands, and agricultural lands are restored as a single unit. This strategy can significantly enhance ecological connectivity, biodiversity corridors, and carbon sequestration.

The promotion of climate-smart agriculture is important for balancing productivity with environmental sustainability. Climate change mitigation practices that can help farmers maintain high levels of soil organic carbon, reduce emissions, and build resilience against climate change impacts should be integrated.

Technology can play a vital role in improving the assessment, verification, and tracking of carbon sequestration through digital monitoring tools such as remote sensing and Geographic Information Systems (GIS). These tools can help enhance transparency.

The emergence of carbon credit markets can help farmers receive incentives for maintaining carbon sinks. Community-based conservation strategies can help incorporate local participation, ownership, and benefit sharing.

### CONCLUSION

Carbon sequestration through biodiversity restoration is a powerful, nature-based solution for mitigating climate change. By restoring forests, grasslands, wetlands, and agricultural ecosystems, we can enhance carbon storage

while improving biodiversity, soil health, and ecosystem services.

This approach offers environmental sustainability, economic benefits, and social resilience. Therefore, biodiversity restoration should be prioritized as a central component of global and national climate change mitigation strategies.

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