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Carbon Farming: A Climate-Resilient Approach for Achieving the Goal of a Green Economy

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Abstract

Carbon farming is a climate-resilient approach that plays a pivotal role in achieving the goal of a green economy. As the world faces the challenges of climate change and its far-reaching impacts, carbon farming offers a transformative pathway to mitigate greenhouse gas emissions and enhance climate resilience. At its core, carbon farming focuses on sequestering carbon dioxide (CO_2) from the atmosphere and storing it in agricultural soils and vegetation. Through a combination of sustainable land management practices, such as conservation agriculture, cover cropping, crop diversification, agroforestry, and organic matter incorporation, carbon farming promotes increased soil organic carbon content. This not only reduces the concentration of CO_2 in the atmosphere but also enhances soil health, water retention, and nutrient cycling. By harnessing the potential of agricultural lands to sequester carbon and promoting sustainable practices, carbon farming offers a viable and scalable solution to combat climate change, enhance agricultural resilience, and foster a more sustainable and prosperous future for generations to come.

Introduction

The Green Revolution, which began in the mid-20th century, brought significant advancements in agricultural technology and practices, leading to a substantial increase in global food production. The introduction of high-yielding crop varieties, synthetic fertilizers,

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pesticides, and modern irrigation systems resulted in remarkable gains in crop yields, helping to alleviate hunger and poverty in many parts of the world. However, the Green Revolution also had its share of harmful impacts on the environment, society, and the long-term sustainability of agricultural systems (Babu *et al*., 2020). The intensive use of chemical fertilizers and pesticides during the Green Revolution has led to widespread environmental degradation. These chemicals often leach into water bodies, causing pollution and harming aquatic ecosystems. Additionally, the continuous application of fertilizers has resulted in nutrient imbalances in soils, leading to reduced soil fertility and long-term degradation (Torralba *et al*., 2016). The focus on a few high-yielding crop varieties during the Green Revolution has led to the neglect of traditional and locally adapted crop varieties. This shift towards monoculture farming has contributed to the loss of agricultural biodiversity, making crops more vulnerable to pests, diseases, and changing climatic conditions. The introduction of modern irrigation systems during the Green Revolution has resulted in the overexploitation of water resources. Excessive groundwater pumping has led to the depletion of aquifers in many regions, causing water scarcity and posing a threat to the sustainability of agriculture. Intensive tillage practices, common during the Green Revolution, have accelerated soil erosion, leading to the loss of fertile topsoil. Moreover, the emphasis on high-input agriculture has led to a decline in the incorporation of organic matter into the soil, negatively impacting soil structure and nutrient cycling. The use of chemical pesticides in the Green Revolution has raised concerns about human health and safety. Prolonged exposure to these chemicals can lead to various health issues for farmers and consumers, including respiratory problems, skin conditions, and even cancer. The intensive agricultural practices promoted by the Green Revolution, such as increased greenhouse gas emissions from synthetic fertilizer use and deforestation for agricultural expansion, have contributed to climate change (Baumber *et al*., 2019). Furthermore, the loss of biodiversity and soil degradation reduce the resilience of ecosystems to climate impacts. Carbon farming emerges as a climate-resilient and transformative approach towards a green economy (Niles *et al*., 2015). By harnessing the potential of agricultural lands to sequester carbon and promoting sustainable practices, carbon farming offers a viable and scalable solution to combat climate change, enhance agricultural resilience, and foster a more sustainable and prosperous future for generations to come.

Concept and definition of Carbon Farming

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The concept of carbon farming aligns with broader sustainability goals, such as the United Nations' Sustainable Development Goals (SDGs), particularly SDG 13 (Climate Action) and SDG 15 (Life on Land). By enhancing carbon sequestration, it contributes to the global efforts to limit global warming and combat climate change. Carbon farming refers to a set of land management practices and agricultural techniques aimed at sequestering atmospheric carbon dioxide (CO_2) into soils and vegetation, thereby mitigating climate change and enhancing climate resilience. The primary goal of carbon farming is to enhance carbon sequestration and minimize carbon emissions, thereby creating a carbon-neutral or even carbon-negative balance in the agricultural system.

Tactics of carbon farming

It involves various strategies, such as increasing soil organic carbon content, promoting agroforestry, reducing greenhouse gas emissions from agricultural activities, and adopting sustainable agricultural practices that optimize carbon capture and storage. Several methods and techniques are employed in carbon farming to achieve this-

1. **Agroforestry:** One of the primary benefits of agroforestry is its ability to sequester large amounts of carbon dioxide from the atmosphere. Trees are highly efficient at photosynthesis, where they absorb CO_2 and convert it into biomass (Torralba *et al*., 2016). As trees grow, they store carbon in their leaves, stems, and roots. Agroforestry systems integrate trees with crops or livestock, providing an opportunity to sequester carbon not only in the tree biomass but also in the soil. Agroforestry systems create a favorable environment for increased soil carbon storage. Tree roots release organic matter into the soil, providing a nutrient-rich substrate for soil microbes. This stimulates microbial activity and increases the incorporation of carbon-rich organic matter into the soil, thereby enhancing soil carbon content. Agroforestry practices help prevent soil erosion and degradation. Trees act as windbreaks and reduce the impact of heavy rainfall, protecting topsoil from erosion. This preservation of soil structure and health allows for better carbon retention in the soil. Integrating trees in agricultural landscapes enhances biodiversity by providing habitat for various plant and animal species. Biodiverse ecosystems are more resilient to environmental stressors and contribute to increased carbon storage. Beyond carbon sequestration, agroforestry can provide economic incentives for farmers. The integration of trees

with crops or livestock can diversify income streams and increase overall farm productivity. Additionally, farmers may have access to carbon markets and receive payments for the carbon sequestered on their land.

2. **Cover Cropping:** It involves planting specific crops, such as legumes or grasses, during fallow periods or between main crop cycles. Dense cover crops can suppress weed growth, reducing the need for herbicides and minimizing soil disturbance during weed control. This practice contributes to the preservation of soil carbon by avoiding unnecessary disruption of the soil profile. When cover crops are incorporated into the soil or left as organic residue on the surface, the stored carbon becomes part of the soil's organic matter. Many cover crops, particularly legumes, have the ability to fix atmospheric nitrogen into a form that can be utilized by plants. This natural nitrogen fixation reduces the need for synthetic fertilizers, which are energy-intensive to produce and can contribute to greenhouse gas emissions. Integrating cover crops into crop rotations contributes to crop diversity. A diverse crop rotation can make agricultural systems more resilient to pests, diseases, and changing climatic conditions, reducing the need for chemical interventions (Baumber *et al*., 2019). Cover cropping can offer economic advantages to farmers by enhancing long-term soil fertility, reducing input costs, and potentially improving crop yields in subsequent seasons. Cover cropping enhances the resilience of agricultural systems to climate change impacts. Improved soil health and structure resulting from cover cropping help mitigate the effects of extreme weather events, such as heavy rainfall or droughts, by increasing the soil's water-holding capacity. By promoting healthier soil and reducing the use of synthetic inputs, cover cropping can indirectly reduce greenhouse gas emissions associated with conventional agriculture. Moreover, cover crops themselves capture CO_2, offsetting some emissions during their growth. Overall, cover cropping is an effective carbon farming practice that not only sequesters carbon but also enhances soil health, biodiversity, and climate resilience. By incorporating cover crops into agricultural systems, we can move closer to achieving the goal of a green economy that promotes sustainable and climate-resilient agriculture.
3. **Conservation agriculture:** It is a sustainable farming approach that involves a combination of practices aimed at preserving and enhancing soil health, minimizing

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soil disturbance, and optimizing natural processes in agricultural ecosystems. Conservation agriculture (CA) plays a crucial role in carbon farming and contributes to achieving the goal of a green economy by maintenance of soil cover through practices like cover cropping and mulching. By keeping the soil covered with plant residues or living plants, CA reduces soil erosion and promotes the sequestration of carbon in the soil. The organic matter from crop residues and cover crops is gradually incorporated into the soil, increasing soil carbon content over time (Niles *et al.*, 2015). CA advocates minimal soil disturbance and reduced tillage. Traditional plowing releases carbon stored in the soil into the atmosphere as CO_2, accelerating global warming. By minimizing tillage, CA preserves soil carbon, leading to increased carbon sequestration and improved soil structure. CA encourages crop rotation and diversification, which contribute to higher carbon storage in the soil. Different plant species have varied root structures and carbon input rates, leading to a more balanced and diverse soil carbon profile. CA practices, such as the use of cover crops, help improve water infiltration and water retention in the soil. Adequate moisture levels enhance microbial activity, promoting the breakdown of organic matter and carbon sequestration. CA fosters biodiversity by providing habitat and food sources for beneficial organisms such as earthworms and beneficial insects. Biodiverse ecosystems enhance soil health and contribute to higher carbon sequestration rates. The overall reduction in emissions of GHGs can contribute to climate change mitigation efforts. CA builds climate resilience by enhancing soil structure and water retention capacity. Improved soil health and moisture management make agricultural systems more resilient to extreme weather events, such as droughts and heavy rainfall. By adopting CA practices, farmers can effectively contribute to carbon farming, promoting soil carbon sequestration, and reducing greenhouse gas emissions. CA aligns with the principles of a green economy by promoting sustainable and climate-resilient agriculture, making it a vital strategy in achieving a greener and more sustainable future.

4. **Crop Rotation and Diversification:** Monoculture farming can lead to soil degradation and reduced carbon sequestration. Crop rotation and diversification are essential components of carbon farming that contribute significantly to achieving the

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goal of a green economy. These practices involve alternating the types of crops grown on a piece of land over time and incorporating a variety of plant species within the same farming system **(Newton *et al.*, 2020)**. Crop rotation and diversification offer numerous benefits for carbon sequestration, soil health, biodiversity, and sustainable agricultural practices. Different plant species have varying root structures and carbon input rates. When a diverse range of crops is grown in a rotation sequence, the root exudates and organic matter inputs into the soil also vary. This diversity leads to a more balanced and consistent carbon input into the soil, enhancing carbon storage. During crop rotation, specific plants, such as legumes, have the ability to fix atmospheric nitrogen into the soil through symbiotic relationships with nitrogen-fixing bacteria. The added nitrogen benefits subsequent crops in the rotation, promoting higher biomass production and, consequently, increased carbon sequestration in the soil. The presence of diverse root systems in crop rotation enhances soil aggregation and aeration, improving the soil's physical properties and water-holding capacity. Well-structured soils allow for better water infiltration and reduced runoff, which further supports plant growth and carbon sequestration. It also reduces soil erosion by providing continuous plant cover throughout the year. As crops are grown in a sequence, the fields are rarely left bare, mitigating the risk of soil erosion from wind and water. The continuous plant cover preserves the integrity of the soil structure, preventing the loss of topsoil and carbon-rich organic matter. By incorporating a variety of plant species, crop rotation and diversification promote biodiversity in agricultural landscapes. Biodiverse ecosystems support a wide range of organisms, including beneficial insects, pollinators, and soil microorganisms. Biodiversity conservation in agricultural systems also fosters ecological resilience, making the farming system more adaptable to climate variability and disturbances. It contributes to climate resilience by reducing the risk of crop failure and maintaining productivity under varying climatic conditions. When facing extreme weather events like droughts or floods, having a diversity of crops provides a buffer against total crop loss. Diverse crop rotations often result in higher overall yields compared to monoculture systems. This increased productivity can lead to improved farm income and economic stability. Moreover, by reducing the dependence on specific crops, farmers can diversify their income sources and decrease the vulnerability to market fluctuations. By adopting these sustainable agricultural approaches, we move closer to realizing a greener and more sustainable future.

5. **Organic Farming:** It is a sustainable and environmentally friendly agricultural approach that prioritizes soil health, biodiversity, and the responsible use of natural resources. Organic farming practices have a direct impact on carbon sequestration and the reduction of greenhouse gas emissions, making it a vital strategy for mitigating climate change and fostering a more sustainable and climate-resilient future (Babu *et al*., 2021). Organic farming focuses on building and maintaining healthy soils through the use of organic matter, such as compost and cover crops. This enhances soil organic carbon content, as organic matter is rich in carbon compounds. As organic materials are added to the soil, they decompose gradually, releasing carbon, which becomes sequestered in the soil in the form of stable humus. By avoiding the use of synthetic fertilizers and chemical pesticides, organic farming also promotes the growth of soil microorganisms that contribute to carbon sequestration. These microorganisms break down organic matter and transform it into stable organic carbon compounds, locking carbon in the soil for extended periods. By avoiding these chemical inputs, organic farming reduces the overall carbon footprint associated with conventional agriculture, making it a crucial strategy for mitigating greenhouse gas emissions. Organic farming emphasizes the importance of biodiversity in agricultural ecosystems. Promoting organic farming practices can play a pivotal role in achieving the vision of a greener, more sustainable and climate-resilient future, aligning with the principles of a green economy. As consumers, supporting organic products and advocating for sustainable farming practices can further drive the adoption of organic farming methods, benefiting both the environment and the global effort to combat climate change.
6. **Livestock Management:** Livestock, such as cattle, sheep, and goats, are significant contributors to greenhouse gas emissions, particularly methane (CH_4) and nitrous oxide (N_2O). However, with proper management practices, livestock farming can become a sustainable and climate-friendly activity that supports carbon sequestration, reduces emissions, and fosters a more sustainable and environmentally conscious

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agriculture sector. Implementing rotational or managed grazing practices allows for better land utilization and promotes healthy pasture growth. When livestock graze intensively in one area, they may overgraze the vegetation, leading to soil erosion and a decrease in carbon stored in the soil. Rotational grazing, on the other hand, allows pastures to recover and regrow, increasing plant biomass and carbon sequestration in the soil. Well-managed pastures with healthy vegetation have deeper root systems, which enhance soil carbon storage and improve soil health. Livestock emit methane during the digestion process, mainly through enteric fermentation in the rumen. However, the type of feed and diet composition can influence methane emissions significantly. Including high-quality forages and legumes in livestock diets can reduce methane production compared to diets that rely heavily on grain and concentrated feeds. Manure management is another critical aspect of livestock farming that can contribute to carbon farming. Manure is a source of methane emissions when it decomposes anaerobically. However, by implementing proper manure management practices, such as composting, aerobic digestion, or methane capture, methane emissions can be significantly reduced (Viaene *et al.*, 2016). Healthy and well-managed livestock tend to be more productive, leading to reduced environmental impacts per unit of output. By providing proper nutrition, housing, and healthcare for livestock, farmers can enhance their overall productivity and reduce the number of animals needed to meet the same production goals. This, in turn, can lower the overall carbon footprint of livestock farming.

7. **Biochar Application:** Biochar is a carbon-rich form of charcoal produced through a process called pyrolysis, which involves heating biomass (such as agricultural residues, wood, or organic waste) in a low-oxygen environment. This ancient practice has gained renewed interest in recent years as a potent tool for carbon farming and achieving the goal of a green economy. Biochar application offers numerous benefits for carbon sequestration, soil health, and sustainable agricultural practices. It is a stable form of carbon that can persist in the soil for hundreds to thousands of years. When biochar is applied to the soil, it acts as a long-term carbon sink, effectively sequestering carbon dioxide (CO_2) from the atmosphere. By locking carbon in the soil, biochar contributes to reducing greenhouse gas concentrations in the atmosphere,

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helping to mitigate climate change. When biochar is incorporated into the soil, it provides a porous and stable matrix for organic matter to bind to. This creates a more favorable environment for soil microbes, which break down organic matter into stable forms of carbon, contributing to long-term carbon storage. Biochar has a high surface area and cation exchange capacity, which allows it to adsorb and retain nutrients in the soil. When biochar is applied to agricultural fields, it can help reduce nutrient leaching, making essential nutrients more available to plants. This improves soil fertility and nutrient-use efficiency, leading to higher crop yields with potentially reduced fertilizer requirements. Biochar application can indirectly lead to reduced greenhouse gas emissions (Rodrigues *et al*., 2021). Biochar-amended soils have improved structure and stability, making them more resilient to soil erosion. The stable structure prevents soil loss during heavy rainfall, reducing the risk of soil degradation and maintaining carbon storage in the soil. Encouraging the adoption of biochar in various sectors of the economy can significantly contribute to building a more sustainable and climate-friendly future.

8. **Wetland Restoration:** Wetlands, such as marshes, swamps, and bogs, are highly effective carbon sinks and play a crucial role in sequestering carbon dioxide (CO_2) from the atmosphere. Human activities, such as drainage, agriculture, and urban development, have led to the degradation and loss of wetlands worldwide. Restoring these valuable ecosystems not only helps combat climate change through carbon sequestration but also provides a myriad of environmental benefits. Wetlands are among the most efficient carbon sinks globally. When wetlands are restored, they return to their natural state, enabling them to accumulate and store carbon from the atmosphere. Wetland soils have high organic content and low oxygen levels, creating conditions conducive to carbon sequestration. As plants and organic matter decay in the waterlogged soil, carbon is incorporated and stored for extended periods, effectively reducing atmospheric CO_2 concentrations. Peat lands, a type of wetland, are particularly important for carbon sequestration. Peat is formed from partially decayed organic matter that accumulates over thousands of years in waterlogged environments with limited oxygen. Restoring degraded peat lands prevents further decomposition and drainage, preserving the stored carbon and preventing CO_2 release

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into the atmosphere. Wetlands have the unique ability to regulate methane emissions. Blue carbon refers to carbon stored in coastal and marine ecosystems, primarily in mangroves, salt marshes, and sea grass beds. Restoring these coastal wetlands is a significant component of blue carbon projects, where carbon sequestration is quantified and monetized. Participating in blue carbon initiatives allows wetland restoration projects to generate revenue through carbon offsetting and contribute to the green economy (IPCC 2022). As we recognize the value of wetlands in carbon farming and climate change mitigation, restoring these ecosystems becomes an essential component of global efforts to transition to a more sustainable and climate-resilient economy.

Conclusion

By integrating climate-friendly practices that sequester carbon, reduce emissions, enhance soil health, and promote biodiversity, carbon farming offers a sustainable and holistic approach to agriculture. The potential of carbon farming extends beyond mitigating climate change; it contributes to climate resilience, water management, and economic opportunities for farmers. By aligning with the United Nations Sustainable Development Goals and supporting global efforts to limit temperature rise, carbon farming becomes a crucial tool in the fight against climate change. Collaborative efforts from governments, businesses, farmers, and consumers are essential to foster widespread adoption and accelerate the transition to a green economy. In embracing carbon farming, we embrace a future that values environmental stewardship, sustainable agriculture, and climate resilience. By harnessing nature's power to combat climate change, carbon farming presents a beacon of hope for a greener, healthier, and more sustainable for future generations.

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