Review on Suitability of Carbon Sequestration in Mango Orchards in Village of Garhfuljhar ,Chhattisgarh India.

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ABSTRACT

Carbon sequestration is an essential process in addressing climate change, which entails removing carbon dioxide from the atmosphere and storing it within ecosystems over time. This extensive review examines the carbon sequestration potential of tropical fruit trees, focusing on significant species such as *Mangifera indica* (Mango) and their different species. In tropical regions, fruit trees particularly demonstrate considerable carbon sequestration abilities through the accumulation of biomass in different parts of the plant. Various factors that affect carbon sequestration include solar energy, water supply, nutrient availability, thermal conditions, and components of the atmosphere. The review underscores the necessity of comprehending the physiological processes that drive carbon sequestration in fruit trees and their significance to sustainable farming. Fruit orchards are presented as robust carbon sinks, aiding in climate change mitigation, environmental conservation, and sustainable agricultural practices. Numerous studies regarding specific fruit crops like Mango, Banana, Guava, Sapota, and Avocado offer insights into their distinct carbon sequestration capacities and the factors that affect them. The evaluation of carbon sequestration potential involves assessing both above-ground and below-ground biomass, as well as soil organic carbon. The review concludes with suggestions for improving carbon sequestration capabilities, which include agroforestry strategies, soil management practices, and recognizing the impact of environmental factors.

Keywords: Carbon sequestration, Mango orchards, Mangifera indica, Chhattisgarh, Fruit tree biomass, Above-ground biomass, Below-ground biomass, Soil organic carbon, Climate change mitigation, Carbon sinks, Agroforestry, Sustainable farming.

INTRODUCTION

1.1 **Background and rationale** Carbon sequestration is a key strategy in combating climate change by capturing and storing atmospheric carbon dioxide (CO_2). Natural sequestration occurs in forests, wetlands, and oceans, where plants and soils absorb CO_2 through photosynthesis. Additionally, marine ecosystems, like phytoplankton and seagrass meadows, play a significant role in storing carbon over long periods. This biological process helps maintain a balance in global carbon cycles while enhancing biodiversity and ecosystem resilience.

Technological approaches, such as Carbon Capture and Storage (CCS), involve capturing emissions from industrial sources and storing them in geological formations underground. These methods aim to reduce the carbon footprint of fossil fuel-based industries while enabling a transition to cleaner energy systems. Advancing sequestration potential through improved land management, afforestation, and enhanced storage technologies is crucial for achieving net-zero emissions and mitigating the impacts of global warming.Chhattisgarh, situated in the little middle of India, offers a natural laboratory with its rich mosaic of ecological systems and agro-climatic variations, making it an ideal spot for investigating carbon sequestration. The state's complex tapestry—spanning tropical forests, wetlands, and diverse agricultural landscapes—naturally supports a robust carbon cycle. Multiple studies in the region, such as assessments of forest growing stocks near Bilaspur, have highlighted how these varied ecosystems serve as effective carbon sinks through natural processes like photosynthesis and biomass accumulation .

1.2 **Allingment in sustainable developement goals** Environmental Integrity and Climate Action (SDG 13 & SDG 15)-Carbon sequestration projects in Chhattisgarh, notably through compensatory afforestation, are critical for mitigating climate change and preserving native ecosystems. These initiatives involve planting perennial species with high biomass accumulation capacities that act as efficient carbon sinks, thereby reducing atmospheric CO_2 levels. By restoring degraded lands and enhancing forest cover, these projects reinforce ecological resilience and biodiversity. Such nature-based solutions directly support SDG 13 (Climate Action) by decreasing greenhouse gas emissions and SDG 15 (Life on Land) by promoting sustainable land management and ecosystem conservation (Ranjitha et al., 2024).

Economic upliftment and community development through carbon sequestration align with Sustainable Development Goal 8 (SDG 8), fostering decent work and economic growth. In Chhattisgarh, initiatives incorporating compensatory afforestation not only enhance carbon stocks but also generate green employment, boost local incomes, and contribute to the valuation of ecosystem services in economic frameworks such as the Green GDP (Das & Sharma, 2023). This holistic approach creates a positive feedback loop—economic benefits provide incentives for continued ecological restoration while sustainable practices lead to improved community well-being (Singh & Verma, 2024). Consequently, carbon sequestration serves as a catalyst for both SDG 8 and broader sustainable development, aligning environmental restoration with inclusive economic progress (Rao & Patel, 2022).

1.3 **Carbon Sequestration in Horticultural Systems** Carbon sequestration in horticultural systems leverages the perennial nature and deep-root architectures of many horticultural species to capture and store carbon both above and below ground; such systems—ranging from fruit orchards to integrated agroforestry models—accumulate substantial biomass over extended growth periods, while their active root networks foster soil microbial health and enhance organic matter stabilization, thereby improving soil fertility and biodiversity. When combined with sustainable management practices, these horticultural strategies not only reduce atmospheric CO_2 but also generate economic opportunities through mechanisms like carbon credits, making them a vital component of both climate change mitigation and sustainable agricultural d

2. SCOPE AND SIGNIFICANCE

2.1.Carbon Sequestration and Biomass Growth: Fruit trees absorb CO_2 from the air via photosynthesis and store it within their woody structures (trunks, branches, and roots). Because they are perennial and have longer life cycles, these trees can gather and hold carbon for long durations, making them effective long-term carbon storage solutions. This ability is especially significant in efforts to mitigate climate change (Rajan, Mirza, & Pandey, 2022).

2.2.Carbon absrption and BiomassAccumulation : Fruit trees absorb CO_2 from the air via photosynthesis and sequester it in their structural biomass, including trunks, branches, and roots. Their ability to live for many years and their perennial growth characteristics allow them to store and retain carbon for long durations, rendering these trees effective long-term carbon sinks (Köhl et al., 2017). This ability is especially significant for efforts aimed at mitigating climate change, as trees continue to accumulate carbon throughout their lifespan, contributing to global carbon balance (Wang et al., 2024).

2.3.Dual role in climate mitigation and food security: Fruit trees serve a dual purpose by capturing carbon and yielding fruits that enhance food security and provide income. The ability to produce both environmental and socio-economic advantages makes fruit orchards especially appealing in the formulation of climate-smart agricultural strategies. Studies conducted in areas like Ethiopia reveal that, in spite of their considerable capacity for carbon sequestration, fruit trees frequently remain overlooked in national carbon accounting systems (Gelaye & Getahun, 2023).

2.4.Economic Benefits through Carbon Markets: Fruit orchards, with their strong ability to sequester carbon, can be utilized to create carbon credits. This financial incentive promotes the implementation of sustainable management practices in orchards while enabling farmers and rural communities to gain financially from their role in lowering atmospheric CO_2 concentrations (Rajan et al., 2022).

2.5.Reformulating policy and climate finance: Creating straightforward, user-friendly approaches (like allometric equations) to estimate carbon stocks in fruit trees can enhance the accuracy of monitoring and reporting. This improved transparency is essential for accessing international climate finance and developing policy frameworks that encourage sustainable land management practices. Improved data and quantification techniques provide the necessary evidence to incorporate fruit-based systems into wider climate change and carbon trading initiatives (Gelaye & Getahun, 2023).

3. ROLE OF VEGETATION IN CARBON

Different kinds of vegetation are vital for capturing carbon by taking in and storing atmospheric carbon dioxide (CO_2), which helps lower greenhouse gas concentrations and alleviate climate change.According to,(Stoy et al., 2008) Forests, such as tropical rainforests, temperate forests, and boreal forests, serve as long-lasting carbon reservoirs, holding carbon within tree biomass and soil. Mangroves and wetlands excel at capturing carbon with their thick root systems, effectively minimizing CO_2 emissions. Grasslands, although not as dense, still store substantial amounts of carbon below ground through deep-rooted vegetation. Fruit trees like mango, apple, and citrus not only aid in carbon sequestration but also offer ecological and economic advantages, particularly when incorporated into agroforestry practices that boost soil carbon retention. Urban green areas, such as parks and rooftop gardens, capture CO_2 as well, enhancing air quality in urban environments and bolstering climate resilience. Protecting and increasing these types of vegetation is crucial for sustaining environmental health and addressing global warming.

4. CARBON SEQUESTRATION BY HORTICULTURAL SPECIES

Mango orchards are important for carbon sequestration, with various Mangifera indica cultivars showing different capacities for carbon storage. Research has indicated that mango trees capture carbon in both their biomass and the soil, thus aiding in long-term carbon storage.According to,(HY et al., 2008) The ability of mango orchards to sequester carbon is influenced by factors like tree age, planting density, and environmental conditions.Studies reveal that mature mango trees can absorb significant amounts of carbon, with some cultivars exhibiting higher sequestration capabilities than others. Moreover, incorporating mango orchards into agroforestry systems boosts soil organic carbon levels and enhances ecosystem stability. Employing sustainable management techniques, such as organic mulching and reduced soil disturbance, can further maximize carbon sequestration in mango orchards..(Ganeshamurthy, Ravindra, & Rupa, 2019)

5. AGROFORESTRY AND INTEGRATED HORTICULTURE SYSTEM

Agroforestry and integrated horticulture systems in villages across Chhattisgarh have successfully incorporated *Mangifera indica* (mango) to enhance both carbon sequestration and economic sustainability. Farmers in the region practice hortisilviculture, where*Mangifera indica* (mango) trees are intercropped with seasonal crops like wheat, pulses, and vegetables, improving soil fertility and biodiversity.According to, (Williams, 2019). Studies highlight that mango-based agroforestry systems in Bastar, Rajnandgaon and mahasamund districts contribute significantly to carbon storage, with mango trees acting as natural carbon sinks.According to,(Sinha & Prajapati, 2021) Additionally, traditional agroforestry models in tribal villages integrate mango with othermore varieties of the *Mangifera indica* (mango) ensuring long-term ecological balance. These systems not only yield fruits and timber but also benefit pollinator populations and soil microbes, making them essential for sustainable agriculture in Chhattisgarh.(Banik & Nema, 2024).

6. BIOMASS ESTIMATION TECHNIQUES

Estimating biomass for carbon sequestration in fruit trees combines scientific accuracy with practical usage, enabling both farmers and researchers to gauge the carbon stored in orchards.According to,(Panwar et al., 2022)A commonly utilized method is the application of allometric equations, which calculate tree biomass based on measurements such as diameter at breast height (DBH) and the height of the tree. For instance, research has created specific equations for mango (Mangifera indica) and avocado trees that use the mean diameter of primary branches (μDPB) to estimate above-ground biomass (AGB)(Nath et al., 2009). Another method involves remote sensing technology, where satellite imagery and LiDAR are employed to evaluate tree canopy size and density, facilitating extensive biomass assessments without the need for physical measurements. Furthermore, destructive sampling—in which sample trees are cut down to measure their biomass—is utilized to refine models, although this method is not the most sustainable. Analyzing soil carbon further enriches these techniques by evaluating organic carbon buildup in the soils of orchards, showcasing the role of fruit trees in long-term carbon storage. These approaches enable farmers to assess the carbon sequestration capabilities of their orchards, aiding in the advancement of climate-smart agricultural practices and carbon credit programs.(Wirabuana et al., 2019).

7. POLICY CONTEXT

Chhattisgarh has been actively incorporating carbon sequestration into its environmental strategies. The state has the capability to sequester more than 210 million tons of carbon through initiatives aimed at safeguarding forests and restoring tree cover (Shukla, 2024) . The Restoration Policy Dialogues 2024, organized by the state government in collaboration with organizations such as WRI India, examined policy alignment and scalable solutions for landscape restoration. Moreover, Chhattisgarh has become the pioneering state in India to associate its forest ecosystem with Green GDP, ensuring that carbon absorption and climate regulation are officially integrated into economic planning .(Kujur et al., 2021).In addition, efforts under MGNREGA have played a crucial role in enhancing carbon sequestration in rural regions, particularly in Shankargarh block, where 2,564 Integrated Natural Resource Management (INRM) structures have been established to boost carbon capture. These initiatives contribute to India's overall climate objectives and sustainable development plans.(Shukla, 2024)

8. PROBLEM IDENTIFICATION

8.1. Intoduction

Rural India finds itself at the crossroads of traditional farming methods and pressing climate change issues. The increase in atmospheric CO_2 levels, largely due to factors like deforestation, burning of agricultural residues, and intensive tilling, highlights the significant role that natural carbon sinks, such as soil and vegetation, could play in mitigation efforts. However, leveraging this potential is made difficult by the fragmented nature of smallholder agriculture in rural areas, where the focus often lies on immediate crop yields instead of long-term soil vitality (Thakur & Kalasariya, 2023).The decline in soil organic matter due to unsustainable agricultural methods not only reduces the soil's ability to sequester carbon but also negatively impacts crop production and the resilience of rural populations. The challenges are compounded by limited access to modern agricultural techniques and a lack of specific incentives and targeted policies, which hinder the uptake of advances like conservation farming and agroforestry (Lal, 2015). To tackle these issues effectively, it is essential to adopt a holistic approach that integrates scientific advancements with thorough socioeconomic strategies, ensuring that environmental gains lead to significant improvements in the livelihoods of rural communities.

9.REASEARCH GAPS IN RURAL CONTEXT

Fruit trees have significant potential as carbon sinks, yet research on their sequestration capabilities remains underdeveloped. Several key gaps exist in current literature, particularly regarding rural agroecosystems like Garhfuljhar.

9.1. Carbon Quantification by Species

While forests and perennial systems have been extensively studied, there is limited systematic research on the carbon sequestration potential of individual fruit species. Understanding biomass accumulation and soil carbon retention in various fruit species is essential to optimize their role in carbon management (Rajan, Mirza, & Pandey, 2022).

9.2. Optimization of Orchard Management and Propagation

Existing studies focus on general carbon sequestration strategies but lack tailored approaches for orchard management. Refining practices such as spacing, pruning, and intercropping to enhance carbon capture while ensuring sustainable production could yield meaningful advancements (Rajan et al., 2022; Sharma et al., 2021).

9.3. Integration of Traditional Knowledge and Land-Use Practices

Indigenous land-use strategies play a crucial role in rural agricultural systems, yet research seldom explores their synergy with modern carbon sequestration techniques. Investigating the relationship between traditional methods and contemporary climate strategies may lead to locally adapted sustainable solutions (Sharma et al., 2021).

9.4. Economic Feasibility and Carbon Credit Integration

Despite the potential for fruit-based systems to generate carbon credits, comprehensive economic analyses assessing financial viability, cost–benefit considerations, and farmer incentives remain scarce. Addressing these gaps is essential for promoting adoption in resource-limited villages like Garhfuljhar (Singh et al., 2024).

9.5. Influence of Local Environmental Factors

Current studies often generalize findings without accounting for variations in soil type, water availability, and microclimatic conditions. Locally specific field studies are necessary to determine how environmental factors impact carbon storage in fruit orchards (Das, Dhara, & Panda, 2020).

9.6. Long-Term Observations and Seasonal Variability

Most existing research provides only short-term insights into carbon sequestration, overlooking seasonal and annual fluctuations. Longitudinal studies are needed to assess dynamic changes in carbon stocks, particularly in regions experiencing environmental variability (Singh et al., 2024).

10. CONCLUSION

Mango orchards play a significant role in carbon sequestration, contributing to climate change mitigation through biomass accumulation and soil carbon storage. Studies indicate that different mango cultivars exhibit varying sequestration potentials, with some varieties demonstrating higher carbon retention capacities than others (Murali et al., 2022). The ability of mango trees to act as carbon sinks is influenced by factors such as orchard management practices, environmental conditions, and tree age (Rupa et al., 2022).Optimizing orchard management, including spacing, pruning, and soil conservation techniques, can enhance carbon sequestration efficiency while maintaining fruit productivity (Asaduzzaman et al., 2025). Additionally, integrating mango orchards into carbon credit systems may provide economic incentives for farmers, encouraging sustainable agricultural practices (Murali et al., 2022).Long-term studies are essential to assess seasonal and annual fluctuations in carbon stocks, ensuring accurate estimations of sequestration potential in different climatic zones (Rupa et al., 2022). Future research should focus on refining sequestration models, incorporating traditional land-use strategies, and evaluating the socio-economic feasibility of carbon trading in mango-based agroecosystems (Hasanuzzaman, Adhikary, & Shita, n.d.)

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