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BIOCHAR: A MULTIFACETED APPROACH TO REVITALIZING INDIAN AGRICULTURE AND COMBATING CLIMATE CHANGE

Dushyant Dipakkumar Champaneri

Young Professional II, Precision Farming Development center
Soil and Water Management Research Unit
Navsari Agricultural University, Navsari, Gujarat
Corresponding Email: dushyant6194@gmail.com

Abstract

Biochar, a carbon-rich material derived from the pyrolysis of biomass, holds promise as a transformative tool for Indian agriculture. Its ability to improve soil properties—such as pH, cation exchange capacity, water retention, and nutrient availability—addresses the critical issues of soil degradation and declining crop yields exacerbated by unsustainable farming practices and climate change. India, with its vast agricultural landscape and abundant biomass resources, is poised to benefit significantly from biochar application. However, the adoption of biochar technology faces challenges, including high production costs, lack of awareness, and the need for standardized production processes. Government support, investment in research, and the development of robust value chains are essential to overcoming these barriers. By enhancing soil health, increasing crop productivity, and sequestering carbon, biochar offers a multi-faceted solution to climate change and food security. This article explores the current status of biochar use in Indian agriculture, its benefits, challenges, and future prospects.

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Introduction

Biochar is a stable, carbon-rich material produced from the thermochemical conversion of biomass under oxygen-limited conditions (pyrolysis). It possesses a porous structure with a high surface area, and its physicochemical properties are influenced by the feedstock and pyrolysis conditions. Biochar has been shown to influence soil properties, including pH, cation exchange capacity, water retention, and nutrient availability. Biochar is an indispensable tool in the fight

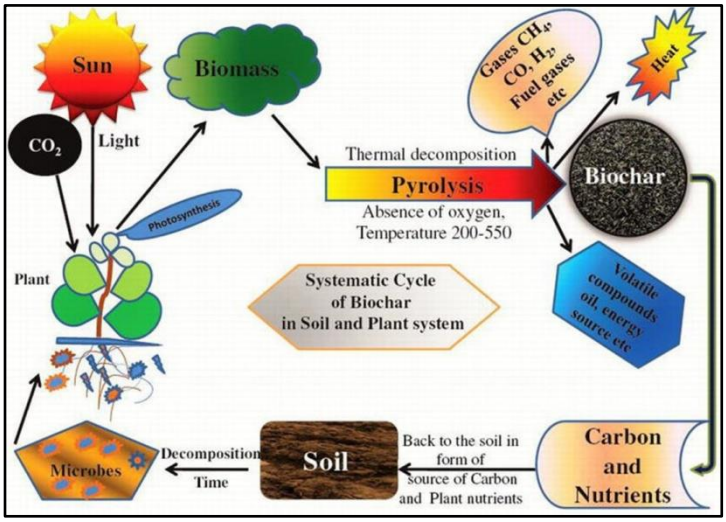

Figure 1: The cyclical and renewable characteristics of biochar (Allohverdi et al., 2021)

against the dual threats of climate change and agricultural degradation plaguing India. The relentless onslaught of anthropogenic climate change, manifested in increasingly severe droughts and unpredictable weather patterns, has pushed agricultural systems to their limits (Champaneri & Patel, 2021). Simultaneously, decades of unsustainable farming practices have depleted soil fertility, leading to declining crop yields and a growing reliance on chemical fertilizers(Champaneri et al., 2021). These interconnected challenges have culminated in a complex web of problems that threaten food security and environmental sustainability.

Biochar emerges as a beacon of hope in this challenging landscape. By transforming organic waste into a stable carbon-rich material, it offers a multi-faceted solution. Its capacity to enhance soil structure, boost water retention, and liberate essential nutrients creates a fertile ground for robust plant growth. Moreover, biochar's remarkable ability to sequester carbon from the atmosphere provides a powerful weapon against climate change(El-Naggar et al., 2019). As the world grapples with the urgent need to reduce greenhouse gas emissions, biochar offers a tangible pathway to carbon capture and storage. The cyclical and renewable nature of biochar is depicted in Figure1 (Allohverdi et al., 2021).

India, with its vast agricultural lands and abundant biomass resources, stands at a pivotal moment. Embracing biochar technology can revitalize rural economies, safeguard food supplies, and contribute to global climate action. By investing in research, development, and widespread adoption of biochar, India can pioneer a sustainable agricultural future that nourishes both people and the planet. This article explores the current status of biochar use in Indian agriculture, highlighting its benefits, challenges, and future prospects.

Biochar Production in India

India boasts a rich tapestry of biomass resources, including an abundance of agricultural residues, forest byproducts, and livestock manure. These organic materials present a promising foundation for the production of biochar, a carbon-rich substance with potential applications in agriculture and environmental management. However, despite this abundant raw material base, the current state of biochar production in India remains relatively nascent. While a handful of dedicated facilities have emerged, their operations are primarily confined to small-scale production and experimental endeavours (Anand et al., 2022).

Several challenges impede the large-scale adoption of biochar production within the country. A significant hurdle is the limited awareness among farmers, policymakers, and the general public about the benefits and potential of biochar (Panwar et al., 2019). Additionally, the absence of standardized production processes and quality control measures creates uncertainties for both producers and end-users. Moreover, the relatively high production costs associated with biochar, compared to traditional soil amendments, pose a financial barrier to widespread adoption(Mishra et al., 2023).

To unlock the full potential of biochar production in India, concerted efforts are required. Government support through policies, incentives, and research funding can catalyse the growth of the biochar industry. Investing in research and development is crucial to optimize production processes, enhance biochar quality, and explore new applications. Furthermore, establishing robust value chains that connect biochar producers with end-users is essential to create a sustainable market for this valuable product. By addressing these challenges and capitalizing on the opportunities, India can position itself as a global leader in biochar production and utilization.

Biochar and Soil Health

Biochar has demonstrated a profound influence on soil health, with numerous studies highlighting its beneficial effects. One of the primary mechanisms is through improving soil physical properties. Biochar's porous structure contributes to enhanced soil aeration, water infiltration, and retention. Consequently, it can mitigate soil compaction and erosion, enhancing overall soil structure (Mukherjee & Lal, 2013).Biochar also impacts soil chemical properties. It can increase soil pH, which can benefit acid soils by improving nutrient availability(Sharma, 2024). Moreover, biochar's high cation exchange capacity can contribute to nutrient retention, reducing leaching losses(Batista et al., 2018). However, the effect on nutrient availability is complex and can vary depending on biochar type, soil properties, and nutrient forms.

While the positive impacts of biochar on soil physical and chemical properties are well-documented, its influence on soil biological properties is still under investigation. Some studies suggest that biochar can stimulate microbial activity and enhance soil organic matter content(Yang et al., 2023). However, the effects on microbial communities can be complex and dependent on various factors, including biochar type, application rate, and soil conditions.

In conclusion, biochar has the potential to significantly improve soil health by enhancing physical, chemical, and biological properties. However, the specific impacts can vary depending on numerous factors, and further research is needed to fully understand the mechanisms involved and optimize biochar applications for different soil and agricultural conditions.

Biochar and Crop Productivity

Biochar has the potential to enhance crop productivity through various mechanisms. By improving soil conditions and nutrient availability, biochar can promote root growth, water uptake, and nutrient acquisition by plants. Several studies have reported increased yields of various crops, including rice, wheat, and maize, following biochar application.

Many researchers observed increased crop yields in various agricultural systems following biochar application(Lehmann, 2007). This enhancement is often attributed to improved water retention, nutrient availability, and soil structure, which collectively create a more favourable environment for plant growth. However, the impact of biochar on crop productivity can vary depending on factors such as biochar type, application rate, soil properties, and climatic conditions. Some studies have reported inconsistent or even negative effects on crop yield(Bo et al., 2023). Therefore, it is essential to carefully consider these factors when applying biochar to agricultural lands.

While the potential benefits of biochar for crop productivity are evident, further research is needed to optimize its application and maximize its positive impacts. By conducting long-term field trials and exploring interactions with other agricultural management practices, scientists can refine our understanding of biochar's role in sustainable agriculture.

Biochar and Climate Change Mitigation

Biochar emerges as a potent ally in the battle against climate change, acting as a formidable carbon sink. This dark, porous material, derived from the pyrolysis of biomass, possesses a remarkable ability to sequester carbon from the atmosphere and store it within the soil for extended periods. By transforming organic matter into a stable carbon-rich form,

biochar prevents the release of carbon dioxide, a primary greenhouse gas, back into the atmosphere.

The escalating concentration of atmospheric carbon dioxide, underscores the urgent need for climate change mitigation strategies. Biochar emerges as a promising solution by offering a pathway to sequester carbon dioxide in the form of stable carbon within soils(Lehmann, 2009).This carbon sequestration capability transforms soils into carbon sinks, contributing to the reduction of greenhouse gas (GHG) emissions. The benefits of biochar extend beyond carbon dioxide sequestration. It also plays a role in mitigating nitrous oxide emissions, another potent GHG (Repo et al., 2011). Feedstocks rich in nitrogen, such as animal manure and sewage sludge, can contribute to nitrous oxide reduction when converted into biochar. The benefits of biochar is displayed in Figure 2 (Allohverdi et al., 2021).

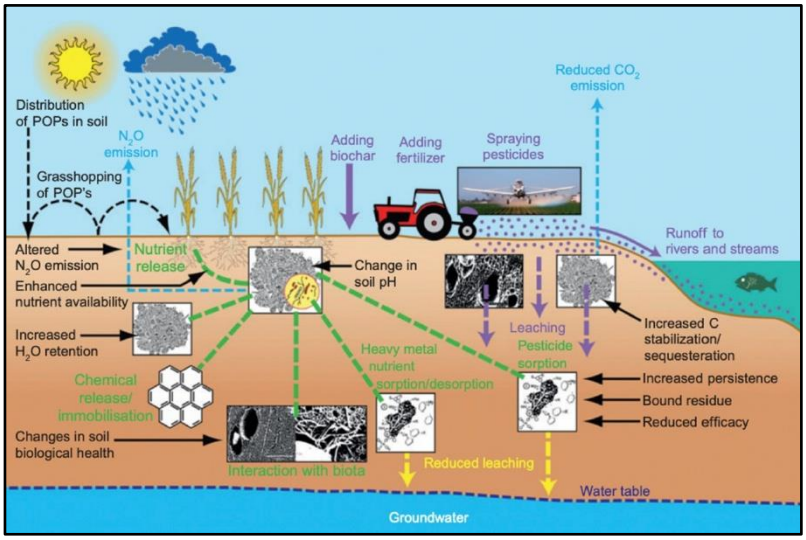

Figure 2: Wide range of advantages offered by biochar (Allohverdi et al., 2021)

To fully assess biochar's climate change mitigation potential, it is crucial to consider its entire lifecycle, including production, persistence, and degradation in soil. Studies have demonstrated significant reductions in carbon dioxide emissions through biochar application. For example, research in China showed a 47-57% reduction in carbon dioxide emissions from rice and maize fields after biochar amendment (Stavi & Lal, 2013). While biochar production itself involves energy consumption and associated emissions, the net effect is often a reduction in GHG emissions when biochar is applied to agricultural soils. Moreover, biochar's ability to improve soil quality, enhance crop yields, and contribute to water purification further amplifies its environmental benefits.

By understanding the complex interactions between biochar, soil, and the atmosphere, researchers and policymakers can optimize the use of this promising technology to mitigate climate change and create a more sustainable future.

Challenges and Future Prospects

Despite the promising potential of biochar, several challenges hinder its widespread adoption in Indian agriculture. These include high production costs, lack of awareness among farmers, and limited availability of quality biochar.

(i) Economic Viability

The economic feasibility of biochar production and application remains a significant hurdle to widespread adoption. While the environmental benefits are substantial, the financial viability of the process is essential for its long-term sustainability. Production costs, including feedstock acquisition, energy input for pyrolysis, and equipment depreciation, often outweigh the immediate returns from biochar sales .Moreover, the development of effective value

chains and markets for biochar products is crucial to ensuring a consistent revenue stream for producers.To address these challenges, innovative approaches are necessary. Diversifying biochar products, such as biochar-based fertilizers or soil amendments, can enhance market value. Additionally, exploring co-product generation, such as bio-oil or syngas, can improve the overall economic viability of the biochar production process. Government support through subsidies, tax incentives, and research funding can also play a pivotal role in reducing production costs and stimulating market demand(Keske et al., 2020).The role biochar plays in the circular economy model showed in Figure 3 (Allohverdi et al., 2021).

(ii) Knowledge Dissemination

Effective knowledge transfer and capacity building are essential for the successful implementation of biochar technologies. There is a clear need to bridge the gap between researchers and practitioners to ensure that the latest findings and best practices are translated into practical applications. Extension services, farmer training programs, and demonstration projects can play a crucial role in disseminating information about biochar production, application, and benefits (Chan et al., 2007). Moreover, fostering collaboration between researchers, policymakers, and farmers is essential for addressing knowledge gaps and identifying priorities for future research. Building strong partnerships can help to create a supportive environment for biochar adoption and innovation.

(iii) Policy Framework

A supportive policy environment is critical for accelerating biochar adoption and realizing its full potential. Government policies can play a significant role in creating incentives for biochar production and use, as well as in addressing potential challenges. Carbon pricing mechanisms, such as carbon taxes or cap-and-trade systems, can provide economic incentives for carbon sequestration through biochar (Chan et al., 2007). Additionally, regulations and standards for biochar production and quality assurance are necessary to build consumer confidence and facilitate trade.

Investing in research and development is another crucial policy component. Government funding can support research to improve biochar production technologies, evaluate its environmental impacts, and develop new applications. By creating a favourable policy framework, governments can stimulate investment in the biochar sector and accelerate its contribution to sustainable agriculture and climate change mitigation.

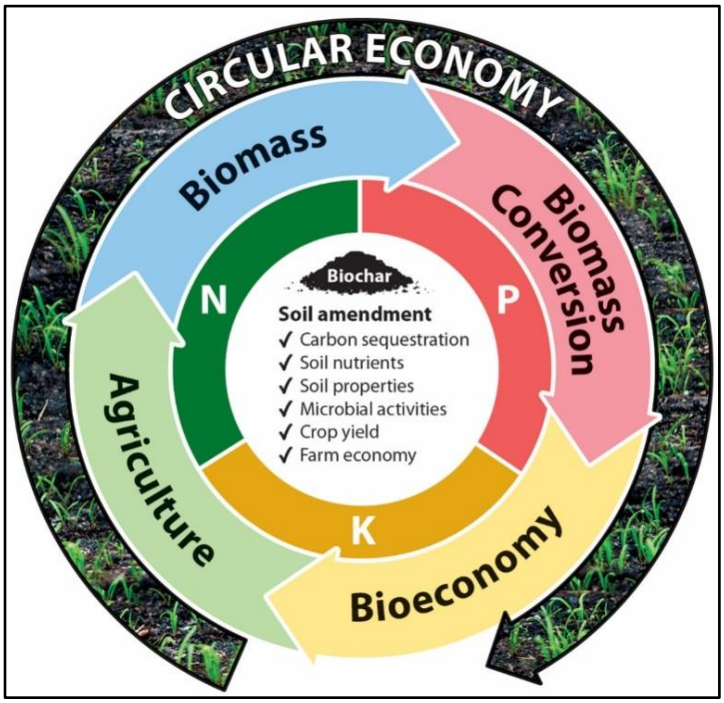

Figure 3: Circular economy of biochar (Allohverdi et al., 2021)

Conclusion

Biochar stands as a beacon of hope in addressing the intertwined challenges of climate change and agricultural degradation in India. Its potential to enhance soil health, boost crop productivity, and sequester atmospheric carbon offers a sustainable pathway for revitalizing Indian agriculture. Despite the current limitations in awareness, production capacity, and economic viability, targeted efforts by government and private sectors can unlock the full potential of biochar. By investing in research and development, promoting knowledge dissemination, and establishing supportive policy frameworks, India can lead the way in biochar technology adoption. This will not only safeguard food security but also contribute significantly to global climate action, creating a resilient and sustainable agricultural future for the nation.

References

Allohverdi, T., Mohanty, A. K., Roy, P., & Misra, M. (2021). A review on current status of biochar uses in agriculture. *Molecules*, *26* (18), 5584. https://doi.org/10.3390/molecules26185584

Anand, A., Kumar, V., & Kaushal, P. (2022). Biochar and its twin benefits: Crop residue management and climate change mitigation in India. *Renewable and Sustainable Energy Reviews*, *156*, 111959. https://doi.org/10.1016/j.rser.2021.111959

Batista, E. M. C. C., Shultz, J., Matos, T. T. S., Fornari, M. R., Ferreira, T. M., Szpoganicz, B., De Freitas, R. A., & Mangrich, A. S. (2018). Effect of surface and porosity of biochar on water holding capacity aiming indirectly at preservation of the Amazon biome. *Scientific Reports*, *8*(1), 10677. https://doi.org/10.1038/s41598-018-28794-z

Bo, X., Zhang, Z., Wang, J., Guo, S., Li, Z., Lin, H., Huang, Y., Han, Z., Kuzyakov, Y., & Zou, J. (2023). Benefits and limitations of biochar for climate-smart agriculture: A review and case study from China. *Biochar*, *5*(1), 77. https://doi.org/10.1007/s42773-023-00279-x

Champaneri, D. D., & Patel, N. K. (2021). Photo selective shade net: An effective tool to reduce the impact of global warming and pesticide residues in vegetable production: A review. *Agricultural Reviews*, *43*(2), 135–144. https://doi.org/10.18805/ag.R-2363

Champaneri, D. D., Patel, N. K., Desai, C. S., & Desai, D. H. (2021). Efficacy of Novel Organic Liquid Nutrient and Novel Plus Organic Liquid Nutrient on quantitative traits of Indian bean [Lablab purpureus (L.) Sweet]. *International Journal of Plant & Soil Science*, *33*(17), 105–115. https://doi.org/10.9734/ijpss/2021/v33i1730555

Chan, K. Y., Van Zwieten, L., Meszaros, I., Downie, A., & Joseph, S. (2007). Agronomic values of greenwaste biochar as a soil amendment. *Soil Research*, *45*(8), 629. https://doi.org/10.1071/SR07109

El-Naggar, A., El-Naggar, A. H., Shaheen, S. M., Sarkar, B., Chang, S. X., Tsang, D. C. W., Rinklebe, J., & Ok, Y. S. (2019). Biochar composition-dependent impacts on soil nutrient release, carbon mineralization, and potential environmental risk: A review. *Journal of Environmental Management*, *241*, 458–467. https://doi.org/10.1016/j.jenvman.2019.02.044

Keske, C., Godfrey, T., Hoag, D. L. K., & Abedin, J. (2020). Economic feasibility of biochar and agriculture coproduction from Canadian black spruce forest. *Food and Energy Security*, *9*(1), e188. https://doi.org/10.1002/fes3.188

Lehmann, J. (2007). A handful of carbon. *Nature*, *447*(7141), 143–144. https://doi.org/10.1038/447143a

Lehmann, J. (2009). Biological carbon sequestration must and can be a win-win approach: An editorial comment. *Climatic Change*, *97*(3–4), 459–463. https://doi.org/10.1007/s10584-009-9695-y

Mishra, R. K., Prasanna, J., Narula, A., Chistie, S. M., & Naik, S. U. (2023). Production and beneficial impact of biochar for environmental application: A review on types of feedstocks, chemical compositions, operating parameters, techno-economic study, and life cycle assessment. *Fuel*, *343*, 127968. https://doi.org/10.1016/j.fuel.2023.127968

Mukherjee, A., & Lal, R. (2013). Biochar Impacts on soil physical properties and greenhouse gas emissions. *Agronomy*, *3*(2), 313–339. https://doi.org/10.3390/agronomy3020313

Panwar, N. L., Pawar, A., & Salvi, B. L. (2019). Comprehensive review on production and utilization of biochar. *SN Applied Sciences*, *1*(2), 168. https://doi.org/10.1007/s42452-019-0172-6

Repo, A., Tuomi, M., & Liski, J. (2011). Indirect carbon dioxide emissions from producing bioenergy from forest harvest residues: Indirect emissions of harvest residue bioenergy. *GCB Bioenergy*, *3*(2), 107–115. https://doi.org/10.1111/j.1757-1707.2010.01065.x

Sharma, P. (2024). Biochar application for sustainable soil erosion control: A review of current research and future perspectives. *Frontiers in Environmental Science*, *12*, 1373287. https://doi.org/10.3389/fenvs.2024.1373287

Stavi, I., & Lal, R. (2013). Agroforestry and biochar to offset climate change: A review. *Agronomy for Sustainable Development*, *33*(1), 81–96. https://doi.org/10.1007/s13593-012-0081-1

Yang, X., You, M., Liu, S., Sarkar, B., Liu, Z., & Yan, X. (2023). Microbial responses towards biochar application in potentially toxic element (PTE) contaminated soil: A critical review on effects and potential mechanisms. *Biochar*, *5*(1), 57. https://doi.org/10.1007/s42773-023-00255-5