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Biochar: An all-natural solution for Agriculture, Environment and Climate action

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Introduction:

Biochar is a rapidly evolving, sustainable waste management and soil improvement solution with a broad array of applications in the fields of agriculture, environment, and climate action. Biochar is a type of charcoal produced by pyrolyzing biomass in the absence of oxygen and is used as a soil amendment. "The solid material produced as a result of the thermochemical conversion of biomass in an oxygen-limited environment" by burning agricultural waste in pits or trenches (covering burning biomass with soil) The production method is known as pyrolysis. The efficacy of biochar is determined by its source (hay, pine cones, or sludge), particle size, pyrolysis temperature (higher temperatures burn off more nitrogen), the quantity used, and whether it is applied on the soil's surface or integrated into the soil.

The quantity and quality of biochar are affected by the feedstock and pyrolysis conditions. They have heterogeneous physical and chemical properties that can increase the efficacy of remediating polluted soils, increase

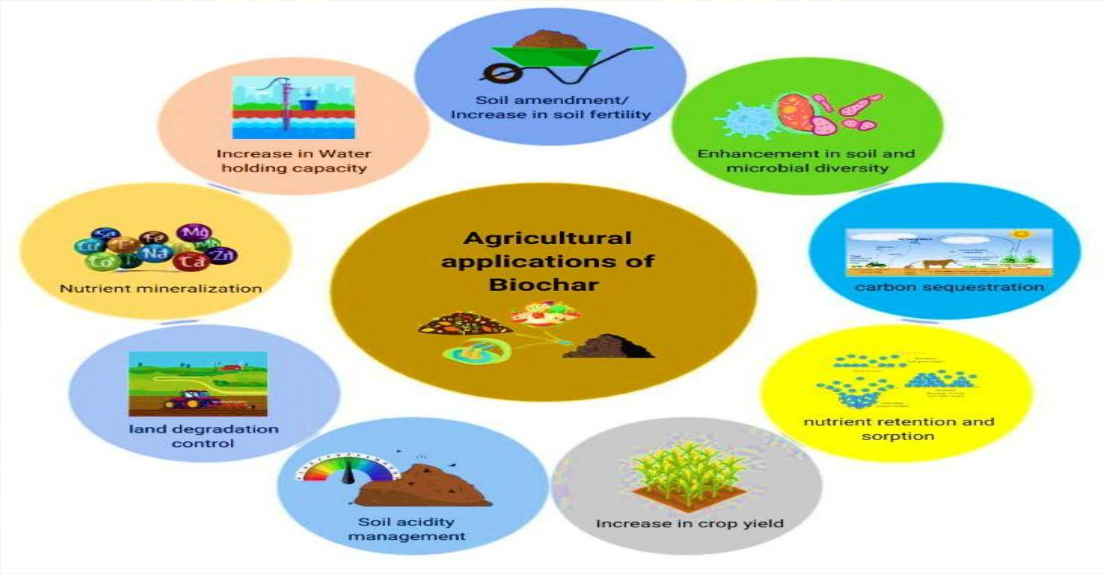

Fig. 1: Diagrammatic representation of Agricultural applications of Biochar

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photosynthesis, improve carbon sequestration, reduce greenhouse gas emissions, control soil erosion, reduce the island effect, etc. The application of biochar significantly improves the soil's physical health, which incorporates water temperature, texture, structure, density, and air, among other factors. The addition of biochar to sandy clay soil enhances aggregate stiffness, thereby increasing the soil's water-holding capacity, especially under drought conditions.

Similar to agricultural limestone, biochar operates as a soil lime agent. Because it is dependent on pyrolysis temperature, residence duration, and raw material, it is evident and verified that not all biochar is alkaline by nature. The utilisation of biochar in the soil promotes both cost-effective soil amendment and long-term carbon sequestration. The application of biochar to soil has the dual benefits of fostering low-cost soil amendment and long-term carbon sequestration. Biochar is typically added to manage nutrients rather than provide them. After application, biochar can bind nutrients, particularly micronutrients. Since more microorganisms thrive in nutrient-rich and higher-pH environments that can metabolise phosphorus, nitrogen, and carbon, increasing the biochar concentration increases the microbial diversity in the soil.

The biochar-captured phosphorus can be used as crop fertilizer. Biochar can be used to recycle dairy wastewater, among other emerging applications for the substance.

Fig. 1: Diagrammatic representation of Environmental applications of Biochar

Various binding mechanisms affect the availability of Fe and Mn in biochar-amended soil. Due to reduction and desorption processes, the amount of Mn and Fe available in the soil increases as the pH drops, and charcoal's biochar's ability to raise soil pH can significantly reduce Mn and Fe bioavailability. Since it immobilises heavy metals and organic contaminants, biochar amendment is a promising approach for soil contamination remediation. Biochar can stabilise and reduce Cd, Cu, Ni, Pb, and Zn bioavailability through enhanced sorption (ion exchange, surface complexation, and electrostatic attraction) and chemical precipitation. The biochar quantity, amendment rate, placement, soil type, and pollutant type influence the efficacy of biochar-assisted soil remediation. Activated biochar, like activated charcoal, may be used in water and wastewater treatment to absorb contaminants such as pesticides, heavy metals, and pathogens while also restoring nutrients. Biochar has the potential to reduce the bioavailability and effectiveness of organic and inorganic soil contaminants. Biochar enhances the retention of soil and water, lowering irrigation costs and fertiliser consumption while also regenerating degraded soils. Biochar as a soil amendment lasts longer and does not need to be applied every year, making it more cost-effective than agricultural fertilisers.

Burning on an open field has detrimental environmental effects, making the disposal of agricultural wastes a worldwide problem. In agricultural countries such as India, where a significant amount of agricultural waste is generated, The use of biochar as a specially formulated amendment is a viable solution to the anticipated challenges in the ecological and agricultural sectors. The conversion of biomass and animal waste into biochar for agricultural use is a profitable and cost-effective waste valorisation approach. By shifting from slash-and-burn to slash-and-char agricultural practises and adopting a decentralised strategy, residues can be processed on-site into biochar by cooperative production units comprised of each farmer or group of farmers operating a kiln. In addition, through promoting biochar knowledge through educational and demonstration activities, Biochar is more resistant to microbial degradation than regular (uncharred) organic matter due to its refractory nature. Due to biochar's recalcitrant nature, it remains in the soil for 1,000 to 10,000 years and helps to enhance soil carbon stock.

The pyrolysis of biomass yields two basic products: syngas and oil. These products can be used to generate renewable, clean energy. Syngas is mostly used in the pyrolysis process, either as a source of heat during the drying phase or in the kiln itself. The discovery and use of bio-resources, which involves the application of biotechnology to develop innovative bioproducts of economic importance, is referred to as "bio-economy." Biochar is a valuable bioproduct (profitable in bio-oil production) that may be utilized in agriculture, industry, and the energy sector. As a result, biochar production creates new revenue options for small farmers. Some studies have established that carbon dioxide sequestration payments are crucial to biochar profitability. Biochar can be fostered by instituting a CO_2 sequestration payment policy, so the landowners would find it advantageous to utilize charcoal to cultivate high-return cash crops, which will help combat climate change.

Biochar has played a leading role in sequestering carbon dioxide from the atmosphere into the soil, ramping up agricultural productivity, reducing greenhouse gas emissions and global warming, reducing the bioavailability of environmental contaminants, lowering nutrient leaching losses in the soil, and, as a result, becoming a value-added product that emphasizes the bio-economy. However, technical and practical barriers to large-scale biochar application have been reported, and the priming effect should be further explored. Global standardization in production technology and quality control is yet to be developed, despite those facts, biochar has proven to be an intriguing sustainable solution for soil health, climate action, and eco-friendly assets.