Abstract

This study highlights the key mechanistic insights that sustain the ecological restoration benefits of biochar (BC) and its relevance to sustainable environmental management. It recognizes the significant impact of specific feedstock types and pyrolysis conditions on the efficiency of BC. The research will aim to address existing gaps by providing a systematic review of the potential benefits of the use of BC in environmental restoration. The methodology consists of a comprehensive review of recent literature on the impacts of BC on several characteristics of agricultural sustainability, such as its capability to increase nutrient availability, facilitate microbial activities, help restore water quality and enhance crop growth. The results show that the use of BC produces a net negative carbon footprint, a reduction in heavy metal pollution, and improved overall soil condition and ecological health. BC acts as a multipurpose resource for the production of bioenergy, waste minimization, and enhancing carbon storage in the context of bioenergy production. The efficacy of BC in restoration of ecosystems and the sustainable management of natural resources is further enhanced by advanced production techniques, including customized pyrolysis processes and activation methods. In addition, the research highlights gaps in the existing research and recommends upcoming research directions to deepen the understanding of the applications of BC. In conclusion, the present review emphasizes the significance of feedstock types and pyrolysis conditions in BC studies and highlights the significant benefits of BC in promoting environmental sustainability. Nevertheless, further research and risk assessment is needed to promote the safe and sustainable use of BC, as it also raises concerns about potential effects on human health in agricultural environments.