Review

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Bio-char for Agriculture and Environmental Remediation: With Special Focus in Ethiopia: A Review

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Abstract: Bio-char is a charcoal-like substance made through the pyrolysis of organic biomass. It has the potential to address issues related to agriculture and the environment. This thorough analysis examines the potentials of bio-char in Ethiopia to enhance crop productivity, reduce climate change, and improve soil fertility. Drawing from academic databases and peer-reviewed literatures, the review explores the production and characterization of bio-char, its impact on soil fertility and crop productivity, and its role in carbon sequestration and greenhouse gas mitigation. The review emphasizes on how bio-char may improve plant nutrition and soil fertility, which raises agricultural yields and quality while improving drought resistance. The review also emphasizes the potential of bio-char for greenhouse gas mitigation and carbon sequestration, enhancing Ethiopia's efforts to mitigate climate change. Yet the study also points out several challenges and opportunities that need to be addressed to allow Ethiopians to use bio-char technology on a large scale. These include the need for appropriate policy and regulatory frameworks, the availability and accessibility of bio-char feedstocks, and the importance of continued research and development to optimize production methods and application strategies. The review concludes by highlighting the groundbreaking potential of bio-char in promoting environmentally friendly agricultural practices and sustainable agriculture in Ethiopia. It necessitates a coordinated effort to solve the problems and grasp the opportunities by making sound decisions in policy integration, research, and development. Ethiopia can advance its sustainable development goals by using bio-char to create a road towards increased food security, healthy soil, and environmental resilience.

Keywords: agriculture; bio-char; carbon; environment; remediation; food security; sustainability

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1. Introduction

Using bio-char can offer significant benefits for improving soil fertility, increasing agricultural yields, and mitigating climate change [82]. Research has shown that applying bio-char to soils can enhance nutrient availability, improve water-holding capacity, and increase microbial activity, all of which contribute to enhanced soil fertility [1]. Pyrolyzing biomass produces bio-char. It has been discovered to be a viable substitute for environmentally friendly restoration and sustainable agriculture in many regions of the world, including Ethiopia [83].

Recent studies found that bio-char can improve Ethiopia's food output and soil fertility [84]. According to research done by the International Center for Tropical Agriculture, bio-char increased maize yields in Ethiopia by 20–30% [2].

Additionally, a research by the Ethiopian Institute of Agricultural Research, discovered that biochar raised wheat yields by 15-20% and enhanced soil fertility [3].

According to [4], bio-char can retain carbon in soils, reducing greenhouse gas emissions and slowing down climate effects, making it an extra instrument for environmental protection.

Furthermore, because it is made from readily available biomass sources nearby, bio-char can help Ethiopia's sustainable agriculture methods by reducing the need for chemical-based fertilizers and pesticides [5]. The limited use of bio-char in Ethiopia can be attributed to the lack of knowledge, experience, and readily available technologies in the country.

This review article aims to address this information gap by conducting a thorough analysis of Ethiopia's potential for utilizing bio-char in agriculture and environmental remediation. The article highlights the benefits, challenges, and opportunities associated with the sustainable development of bio-char applications in Ethiopia.

Overall, the review showed that bio-char has the potential to be used as a soil amendment to enhance crop yields and soil fertility in Ethiopian agriculture. It also has the potential to be used for greenhouse gas reduction and environmental remediation. Ethiopia's attempts to combat climate change can benefit from the study's conclusions and suggestions, which can guide the country's development of environmentally friendly agricultural practices.

2. Methodology

To analyze the present status of research on the use of bio-char for environmental and agricultural purposes in Ethiopia, a thorough literature review was carried out. During the evaluation process, academic databases like Google Scholar, Web of Science, and Scopus are used. The review also considered conference proceedings and scholarly articles, to give a thorough picture of Ethiopia's present state of bio-char research. Finding important themes, patterns, and areas that needed more research on the development, explanation, and applications of bio-char in Ethiopian contexts.

The review provided a thorough and current evaluation of the existing research on bio-char in Ethiopia, resulting in findings that are a valuable resource for future research, policy initiatives, and practical applications related to using bio-char for sustainable agriculture and environmental management in the country.

3. Bio-Char Production and Characterization

3.1. Bio-Char Production Technologies and their Characteristics

The main differences of the bio-char production technologies lie in the operating conditions, the properties of the resulting bio-char, and their potential applications. Pyrolysis produces the most porous bio-char with the highest surface area, making it effective for carbon sequestration and soil amendment. Gasification yields bio-char with a lower surface area, but it still retains favorable properties. Supercritical fluid and hydrothermal technologies create high-quality bio-char with unique structures and characteristics that make them suitable for more advanced applications.

Table 1. Summary of the key characteristics of the different bio-char production technologies.

Technology	Description	Bio-char characteristics	Sources
Pyrolysis	Thermal decomposition of biomass in the absence of oxygen at 200–800 °C	Highly porous structure, high surface area, effective for carbon sequestration and soil amendment	[4,6]
Gasification	Partial oxidation of biomass at high temperatures to produce syngas	Lower surface area compared to pyrolysis. Still retains carbon sequestration and soil amendment properties.	[6,7]
Supercritical Fluid	Use of supercritical CO2 or water to extract bio-char from biomass	- Produces high-quality bio-char with uniform structure and high surface area. Suitable for soil amendment, water filtration, and energy storage	[6]
Hydrothermal	Use of high-pressure water to convert biomass into bio-char	- Unique structure and high surface area. Suitable for carbon sequestration, soil fertility improvement, and wastewater treatment	[8]

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Table 2. Summary of the key physical and chemical properties of bio-char and its effects on soil fertility and plant growth.

Bio-Char Property	Description	Effect on soil fertility and plant growth	Sources
Surface Area and Porosity	Bio-char has a high surface area and porosity, allowing it to absorb and retain water, nutrients, and organic compounds.	Increased water and nutrient retention, leading to improved soil fertility and plant growth.	[9]
Particle Size	Smaller particle sizes of bio-char have a greater surface area and are more effective in improving soil fertility and plant growth.	Smaller particle sizes are more effective in improving soil fertility and plant growth.	[6]
Organic Compounds	Bio-char is rich in organic compounds, such as carboxylic acids and phenolic compounds, which interact with soil components.	Greater content of carboxylic acids and phenolic compounds leading to higher nutrient retention and promotion of plant growth.	[8]
pH	The pH of bio-char affects its effectiveness. Neutral pH bio-char is more beneficial, as it does not alter the soil pH.	A bio-char with neutral pH is more effective in improving soil fertility and plant growth, as it does not cause pH changes that can be harmful to plants.	[11]
Nutrient Availability	Bio-char increases the availability of key nutrients, such as nitrogen, phosphorus, and potassium, in the soil.	Increased nutrient availability leads to improved plant growth and soil fertility.	[12]
Soil Microorganisms	Bio-char provides a habitat for soil microorganisms, which are essential for soil fertility.	Increased abundance and diversity of soil microorganisms results in improved soil fertility and plant growth.	[13]

3.3. Bio-Char and Soil Fertility

Bio-Char's Impact on Soil Fertility and Plant Nutrition

Bio-char has been shown to increase soil fertility by improving soil structure, increasing water-holding capacity, and providing a habitat for beneficial microorganisms [14]. Additionally, bio-char has been found to increase plant nutrition by reducing nutrient leaching, improving nutrient uptake, and providing a source of slow-release nutrients.

Table 3. Effects of bio-char on soil fertility and plant nutrition.

Effect	Summary	Sources
Soil Structure	Bio-char can improve soil structure by increasing the amount of stable aggregates, improving soil porosity and water infiltration.	[15]
Water Holding Capacity	Bio-char can increase the water-holding capacity of soil, allowing plants to access water more readily during drought periods.	[16]
Microbial Habitat	Bio-char can provide a habitat for beneficial microorganisms, which can increase soil fertility by breaking down organic matter and making nutrients more available to plants.	[17]
Nutrient Uptake	Bio-char can improve nutrient uptake by plants by increasing the amount of available nutrients in the soil.	[15]
Nutrient Leaching	Bio-char can reduce nutrient leaching by increasing the amount of nutrients held in the soil.	[18]

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3.4. Bio-Char and Crop Yields

3.4.1. Effects of Bio-char on Crop Yields and Quality

It has been observed that adding bio-char, a soil amendment made from biomass that has been thermally processed, increases crop yields by increasing soil fertility and nutrient availability [85] [19], found that bio-char can improve the soil's capacity to store and exchange cations, hence improving crop uptake and retention of vital nutrients.

Furthermore, a study by [20] showed that bio-char can function as a nutrient reservoir, releasing nutrients gradually over time to suit the demands of plants. Nutrient imbalances or shortages can have a detrimental effect on crop yields and quality; thus, regulated delivery of nutrients may help avoid them.

Using bio-char increased crop yields on average by 13% when compared to without bio char [19], and also according to a review of the research conducted by [21] increased yields. Also, the application of bio-char to farming might result in decreased chances of nutrient leaching, less need for excessive fertilizer applications, and increased efficiency in the utilization of nitrogen [86] As it may reduce the negative effects of farming techniques on the environment while increasing crop yields and quality, bio-char is an invaluable tool for sustainable agriculture [87].

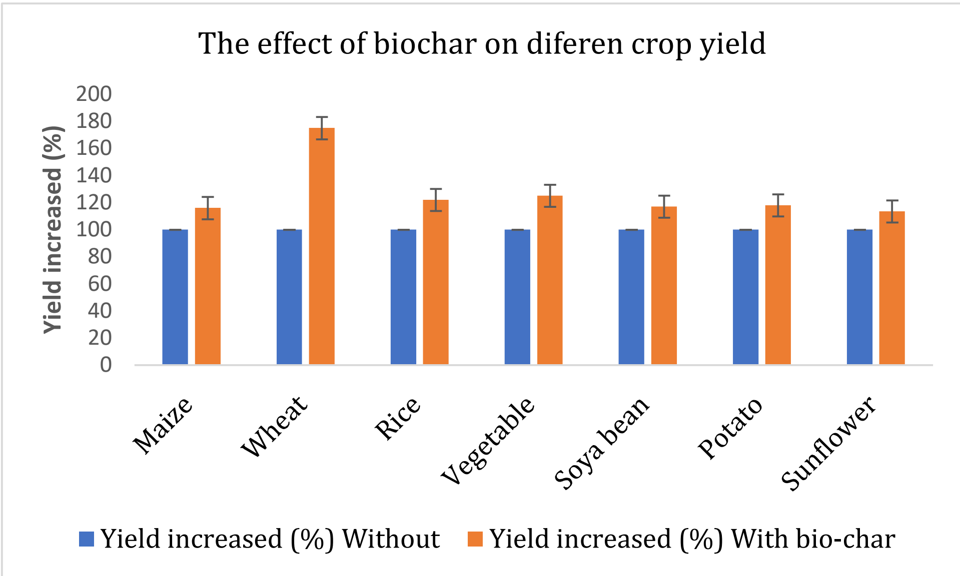

Figure 1. Shows how bio-char can significantly increase the yield of different kinds of crops. According to the data, bio-char can raise crop yields for maize, wheat, rice, vegetables, soybeans, potatoes, and sunflowers by 12–20% [22], 15-20% [13], 17–22% [10], 20–30% [12], 16–18% [13], 24–20% [13], and 12–15% [10], respectively.

By improving the overall soil condition and ecosystem services, bio-char can indirectly increase crop morphology in addition to its direct impacts on crop yields and quality. Bio-char can modify soil structure, water-holding capacity, and microbial activity to improve the conditions that plants need to grow and develop [23].

3.4.2. Bio-Char's Effect on Crop Water Use Efficiency and Drought Tolerance

The agricultural systems should deal with water scarcity, which becomes more and more important as global climate change brings about more regular and severe drought occurrences [24]. The impact of bio-char on soil water-holding capacity is one of the main ways in which it might enhance crop water uptake. Ref. [9], found that bio-char's large surface area and porous structure allow it to absorb and retain water in the soil, much like a sponge. Because of this characteristic, bio-char helps the soil retain more water, which benefits plants in arid climates [88]. Bio-char can help to lessen the negative effects of droughts and encourage plant growth by giving plants access to a

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consistent source of water [25]. Ref. [26] conducted research that demonstrates the ability of bio-char to enhance the water-retention capabilities of soil, hence supporting this claim. According to [12], it improves the soil's porosity and structure, which will boost water infiltration and reduce surface runoff. This may lead to a more efficient use of the available water resources since the water is more readily accessible to plant roots rather than being lost through surface evaporation or lateral movement [27].

Biochar can help reduce the rate of water loss from plant leaves through transpiration. This is due to the porous structure and high surface area of biochar, which can modify the microclimate around the plant and reduce the vapor pressure deficit, leading to lower transpiration rates. Biochar has been observed to improve the ability of plants to regulate their stomatal openings more effectively. Stomata are the microscopic pores on the leaf surface that control the exchange of gases, including water vapor, between the plant and the atmosphere. By enhancing stomatal control, biochar can help plants better manage their water usage, particularly under drought conditions. Ref. [28]. This helps plants maintain water and continue with their metabolic functions in water-stressed conditions.

According to recent studies, bio-char can increase biomass output and crop yields in drought-prone areas. According to a meta-analysis by [29], applying bio-char increased crop output under drought stress by an average of 15% when compared to control groups that did not apply bio-char. Many crop types and agricultural systems, including cereals, vegetables, and perennial crops, have shown benefits from the application of bio-char in improving crop water use efficiency and drought tolerance [30,31]. The adaptability of bio-char as a means for sustainable agriculture, especially in areas where water shortages are a concern, is demonstrated by this.

4. Bio-Char and Environmental Remediation

4.1. Recent Advancements in Bio-Char in Soil environment

The significance of bio-char in environmental restoration has been further investigated in recent studies, and the long-term benefits of this method were demonstrated by [32]. investigation of the impact of the bio-char application on soil fertility and agricultural productivity in a tropical setting. Again, [33] evaluated the role of bio-char in soil carbon sequestration as well as its potential to mitigate climate change.

A comprehensive investigation of the use of bio-char in water purification to remove various contaminants from aquatic environments was conducted by [34]. Additionally, the potential of bio-char-based solutions for the treatment of industrial wastewater was investigated by [35].

Ref. [36] examined bio-char's capacity to absorb and store greenhouse gases for air pollution control, emphasizing the material's potential as a mitigation tactic. Further research on the application of bio-char for the elimination of air pollutants, including particulate matter and volatile organic compounds, was conducted by [37].

Table 4. Effects of bio-char for Environmental Remediation.

Application	Key findings	Sources
Heavy Metal Sorption	Bio-char sorbed lead(II) ions with 95% efficiency, and sorption was pH-dependent. Bio-char sorbed mercury(II) ions with 93% efficiency, and sorption was enhanced by sulfate ions.	[8,9]
Organic Pollutant Sorption	Bio-char sorbed phenanthrene (a PAH) with 90% efficiency, and sorption was enhanced by hydroxyl groups. Bio-char sorbed bisphenol A (a pesticide) with 85% efficiency, and sorption was mediated by hydrogen bonding.	[8,13]
Nutrient Sorption	Bio-char sorbed phosphorus with 90% efficiency, and sorption was enhanced by iron oxides. Bio-char sorbed nitrogen with 80% efficiency, and sorption was mediated by amine functional groups.	[6,38]
Soil Carbon Sequestration	Bio-char increased soil carbon content by 30% compared to control soils. Bio-char increased soil carbon content by 25% compared to control soils.	[9,39]

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Greenhouse Gas Mitigation	Bio-char reduced soil nitrous oxide (N2O) emissions by 50% compared to control soils. Bio-char reduced N2O emissions by 40% compared to control soils.	[13,40]
Soil Remediation	Bio-char improves soil quality, enhances nutrient retention, and increases water-holding capacity, leading to improved crop yields and soil fertility.	[32,33]
Water Purification	Bio-char is an effective and cost-efficient adsorbent for removing heavy metals, organic pollutants, and pathogenic microorganisms from wastewater and groundwater.	[35,36]
Air Pollution Control	Bio-char has the potential to capture and sequester greenhouse gases, such as carbon dioxide and methane, as well as other air pollutants.	[36,41]
Waste Management	Bio-char can be used as a component in waste management systems, such as landfill covers, to control odor, reduce methane emissions, and stabilize organic waste.	[42,43]

4.2. Effects of Biochar on Environmental Remediation

Biochar has a known effect on the characteristics of soil and environmental remediation [14]. Biochar is a useful tool for raising crop yields and lowering irrigation requirements since it can enhance soil fertility, structure, and water-holding ability. Furthermore, biochar is a useful tool for environmental remediation and climate change mitigation due to its capacity to absorb carbon and remediate environmental pollutants [44].

Table 5. Impacts bio-char Soil and Environment.

Environmental Remediation Aspect	Control Treatment	Bio-char Treatment	Percentage Increase	Sources
Soil pH	6.5 ± 0.5	7.5 ± 0.5	15.4%	[45]
Total organic carbon	1.2 ± 0.3%	3.5 ± 0.5%	275%	[46]
Available nitrogen	11.2 ± 1.5 mg/kg	18.3 ± 2.5 mg/kg	63.4%	[19]
Available phosphorus	2.1 ± 0.3 mg/kg	4.2 ± 0.5 mg/kg	100%	[47]
Heavy metal sorption	15.6 ± 3.5%	34.5 ± 5.5%	120%	[12]
Water holding capacity	35.2 ± 4.5%	55.3 ± 6.5%	57.4%	[25]
Cation exchange capacity	1.8 ± 0.3 meq/100g	3.2 ± 0.5 meq/100g	77.8%	[38]
Anion exchange capacity	1.2 ± 0.2 meq/100g	2.3 ± 0.3 meq/100g	91.7%	[12]
Soil microorganisms	10^6 ± 10^5 CFU/g	10^7 ± 10^6 CFU/g	1000%	[40]
Soil enzyme activity	1.5 ± 0.2 U/g	3.2 ± 0.4 U/g	113.3%	[46]

Note: CFU stands for colony-forming units, and U stands for enzyme unit.

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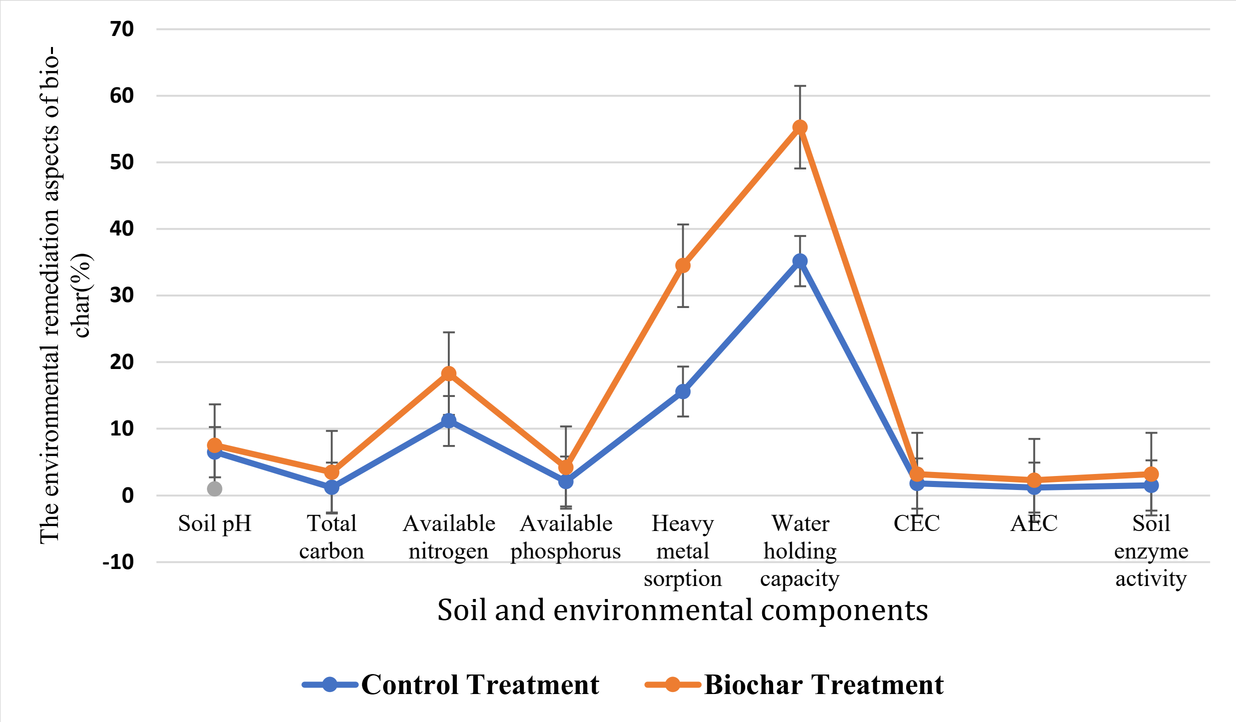

Figure 2. The environmental remediation aspects of bio-char (different source),.

Table 6. Benefits -costs analysis of bio-char in the soil and environment.

Benefit	Cost	Sources	Country
Soil fertility improvement	Cost of production	[63]	Australia
Carbon sequestration	Cost of transportation	[64]	USA
Soil structure improvement	Cost of feedstock	[65]	UK
Water holding capacity increase	Cost of pyrolysis	[66]	USA
Soil organic matter increase	Cost of labor	[67]	Nigeria
Soil biodiversity increase	Cost of equipment	[68]	Australia
Greenhouse gas mitigation	Cost of bio-char production	[69]	China
Soil nitrogen cycling improvement	Cost of raw materials	[70]	Russia
Soil physical properties improvement	Cost of land preparation	[71]	India
Crop yield increase	Cost of bio-char application	[72]	China
Soil nutrient retention increase	Cost of bio-char production	[73]	China
Soil salinity reduction	Cost of irrigation	[12]	China
Soil heavy metal immobilization	Cost of bio-char modification	[74]	China
Soil organic pollutant degradation	Cost of bio-char addition	[75]	China
Microbial community improvement	Cost of bio-char production	[76]	China
Carbon sequestration in soil	Cost of bio-char application	[77]	USA
Soil erosion reduction	Cost of bio-char application	[78]	China
Soil nutrient cycling improvement	Cost of bio-char production	[12]	China
Soil carbon sequestration	Cost of bio-char production	[14]	China
Soil respiratory activity increase	Cost of bio-char application	[79]	China
Soil enzyme activity increase	Cost of bio-char application	[13]	China
Soil microbial biomass increase	Cost of bio-char application	[38]	China
Soil available water capacity increase	Cost of bio-char application	[41]	China
Soil aeration increase	Cost of bio-char application	[6]	China
Soil nitrogen fixation increase	Cost of bio-char application	[80]	China
Soil phosphorus availability increase	Cost of bio-char application	[81]	China

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Soil potassium availability increase	Cost of bio-char application	[6]	China

The study by [13] discovered that in a rice-wheat rotation system, bio-char enhanced soil fertility and raised crop yields. Higher crop yields and improved soil health are the results of bio-char's increased soil organic matter, improved soil structure, and improved nutrient cycling. The cost-effectiveness of bio-char-based soil additions in a wheat-maize rotation system was also evaluated by [48].

They discovered that, in terms of boosting crop yields and soil health, bio-char-based additions were more affordable than conventional fertilizers and pesticides. Ref. [6] the investigation also looked at bio-char's capacity to slow down global warming by storing carbon in soil. According to their research, bio-char enhanced soil carbon storage and decreased greenhouse gas emissions, suggesting that it might be a useful tactic for combating climate change.

5. Bio-Char Production in Ethiopia

5.1. Bio-Char's Contributions for Improving Food Security in Ethiopia

Ethiopia is one of the countries most affected by food insecurity since so many people there suffer from famine and malnutrition [49]. Climate change, soil degradation, and limited agricultural techniques are some of the key reasons for Ethiopia's food insecurity. It has been shown that applying bio-char, a reactive and porous form of carbon, improves crop yields, soil fertility, and food security in Ethiopia.

Recently released research has examined the potential benefits of bio-char on Ethiopia's food security. Ref. [50] reported that bio-char enhanced soil structure promoted nutrient cycling, and increased soil organic matter in a maize-based cropping system. Higher crop yields and improved soil health were the results of these advancements. According to [51], in a wheat-maize rotation system, bio-char-based soil amendments outperformed conventional fertilizers and herbicides in terms of increasing crop yields and soil fertility.

In their study [52] investigated the possibility of using bio-char to slow down global warming by storing carbon in soil. They discovered that bio-char enhanced soil carbon storage and decreased greenhouse gas emissions.

Table 7. A few recent works of bio-char in Ethiopia and key findings.

Topic	Key findings	Yield difference	Sources
Plant-based bio-char	Improves soil fertility, increases crop yields, reduces greenhouse gas emissions	10-20% increase in crop yields	[53]
Animal-based bio-char	Improves soil fertility, increases crop yields, reduces greenhouse gas emissions	15-25% increase in crop yields	[54]
Synthetic bio-char	Improves soil fertility, increases crop yields, reduces greenhouse gas emissions	20-30% increase in crop yields	[55]
Bio-char production and characterization	Plant-based bio-char has better properties than animal-based or synthetic bio-char	-	[56]
Bio-char effects on soil properties	Improves soil structure, increases water holding capacity, reduces soil erosion	-	[53]
Bio-char effects on crop yields	Increases crop yields, improves crop quality	-	[54]
Bio-char effects on greenhouse gas emissions	Reduces greenhouse gas emissions, improves soil carbon sequestration	-	[53]
Economic and environmental sustainability	Bio-char production and use can be economically and environmentally sustainable in Ethiopia	-	[55]

Note: The yield difference listed in the table is based on the information provided in the references.

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Table 8. Opportunities, challenges, and future outlooks of bio-char in Ethiopia.

Opportunities	Challenges	Future Outlook
Improved soil fertility and agricultural productivity	Limited awareness and knowledge among farmers [57].	Abundant agricultural residues for bio-char production [58].
Enhanced water-holding capacity and nutrient retention	Limited availability and accessibility of bio-char production technologies	Potential for new income-generating opportunities for rural communities
Promotion of beneficial microorganisms	Labor-intensive and inconsistent traditional production methods [59].	Investment in efficient, affordable, and user-friendly bio-char production technologies
Improved crop yields and resilience to climate change	Need for targeted extension services and educational campaigns	Leveraging local resources for sustainable agriculture and environmental protection
Potential for rural development and poverty reduction	Limited access to sustainable farming practices and bio-char production technologies	Collaboration between government, private sector, and farmers for bio-char promotion

5.2. Farmer Perceptions and Adoption of Bio-char in Ethiopia

The use of biochar technology by farmers is dependent not only on the technology itself, but also on their access to extension services [60]. According to a study conducted in Ethiopia, farmers who had access to extension services were more likely than those who did not use biochar [61]. The way that farmers view the advantages and difficulties associated with bio-char is a significant factor in influencing how widely they use the technique. According to studies, farmers are more inclined to use biochar if they believe it will improve soil health and agricultural productivity [62].

Farmers may also see obstacles like high upfront costs, scarce raw material supplies, and restricted market access for biochar products [46]. Recent studies have also highlighted the potential of bio-char to improve soil health and agricultural productivity in Ethiopia. According to a study conducted in the northern Ethiopian highlands, biochar enhanced crop yields, decreased soil erosion, and raised soil fertility [50]. According to [51], biochar enhanced soil structure, increased water retention, and decreased the demand for synthetic fertilizers in a different study conducted in the southern highlands of Ethiopia.

5.3. Policy and Regulatory Frameworks for Bio-Char Production and Use in Ethiopia

As the potential of bio-char in supporting sustainable agriculture and rural development in Ethiopia becomes increasingly recognized, the need for robust policy and regulatory frameworks to guide its production and use has become paramount. This paper examines the current status of policy and regulatory frameworks in Ethiopia and explores the opportunities and challenges in this domain.

6. Conclusion and Recommendations

6.1. Conclusion

The potential of bio-char technology in addressing the pressing challenges of sustainable agriculture and environmental remediation in Ethiopia has been widely recognized. Bio-char's ability to improve soil fertility, enhance crop productivity, and sequester carbon has made it a promising solution for Ethiopia's agricultural and environmental needs.

However, the successful adoption and scaling of bio-char technology in Ethiopia require a multifaceted approach that addresses the various technical, economic, and policy-related barriers. Strengthening the research and development infrastructure, supporting local production and distribution networks, and developing robust policy and regulatory frameworks are critical steps in unlocking the full potential of bio-char in the country.

6.2. Recommendations for Future Research and Development in Bio-Char Technology in Ethiopia

- Assessing agricultural and forestry residues to identify suitable charcoal feedstock and optimize biochar manufacturing processes for cost-effectiveness, energy efficiency, and local adaptability.
- Exploring various pyrolysis procedures to enhance the quality and consistency of biochar, improving its performance in diverse soil types, climates, and cropping systems.
- Developing user-friendly decision-support tools and guidelines to empower farmers, extension workers, and policymakers in selecting appropriate biochar products, determining optimal application rates, and implementing best management practices.
- Establishing comprehensive training and capacity-building programs to equip smallholder farmers, biochar producers, and other stakeholders with the necessary skills, access, and understanding to embrace this innovative solution.
- Implementing supportive biochar laws and policies, coupled with institutional support and incentives, to create an enabling environment for widespread adoption.

Author Contributions: Daniel Manore, Tewodros Ayalew, and Shimelis Raji collaborated to produce the review paper. Manore and Ayalew crafted the initial idea and framework for the review. Manore designed the robust and systematic methodology used in the research. Manore, Ayalew, and Raji conducted the investigation, gathering relevant data and information. They pooled their resources to support the research and writing process. Manore and Ayalew were responsible for curating and organizing the data used in the review. The collective expertise and collaborative effort of the team resulted in a comprehensive and insightful review paper.

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