Chapter

Enhancement of Soil Health Using Biochar

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Abstract

Over the years, the carbon-rich biochar has been used for the purpose of environmental conservation and reservation. Typically produced from varieties of materials ranging from sewage, farm produce, energy crops and agricultural waste or residues, the properties usually considered in the application of biochar include the chemical composition, porosity and stability. Contemporarily, the use of biochar has extended to its utilization in the industry, agriculture, forestry, and the natural environment. Soil fertility depends on the holistic process of managing the soil and likewise maintaining a robust biodiversity. This process involves the application of natural carbon-rich materials like biochar as soil amendments. The rapid absorption tendency of biochar, both on organic and inorganic materials has contributed immensely to the removal of excess antimicrobials from the environment. Biochar has been known to be a good enhancer of the soil due to its rich content of carbon and other nutrients good enough for the soil. Other striking effects of biochar on the soil and environment include the enhancement of the uptake of nitrogen, improvement of the soil structure, mitigation of greenhouse gases, conservation of the environment and enhancement of soil microbial community.

Keywords: biochar, soil fertility, soil enhancement, soil properties, wastes, soil carbon

1. Introduction

Biochar is a carbon-rich stable solid biomass in form of humus which is produced either from sustainable waste particles buried in the soil or through pyrolysis of plant or animal biomass under different temperature conditions. The nature and efficiency of the plant biomass used in biochar production depend on the type and the characteristics of the soil from which the plant biomass was developed [1]. The stability of organic matter in soils is determined by its ability to resist microbial and/or chemical decomposition, through chemical transformations and physical interactions with soil minerals. The sequestration of carbon and carbon dioxide reduction are being gradually achieved in recent years through the use of biochar. Biochar also help in the reduction of wastes and removal of the same from the environment. It actually comprise of organic carbon with low expectancy of degradation [1, 2].

Biochar has been in hunt for so many decades till now. Over the years, it has been used for the purpose of environmental conservation and reservation. Today, the use of biochar has extended to its utilization in the industry, agriculture, forestry, and the natural environment. It has also been used for the purpose of heavy metal digestion, pollutant immobilization as well as a supplement to composting and methane fermentation process [1, 3]. Recently, biochar is being used in pyrolytic filtering of tar and also in the production of hydrogen [3].

The presence of organic matter and nutrients in biochar is vital because the nutrients provide basic mineral supplements for the soil. Therefore, the amendment of soil with biochar increases the soil's pH, cation-exchange capacity (CEC), total nitrogen, organic carbon and conductivity. It has been reported that the fate and toxicity of heavy metals have been reasonably reduced due to the amendment of soil with biochar [4]. Furthermore, the porosity, large surface area and absorbance potential have made biochar a medium for soil nutrient improvement. Likewise, biochar also acts as a suitable habitat for soil microorganisms to thrive, alongside the support by roots of leguminous plants that aid the symbiotic relationships between the microorganisms and the plants [5].

Biochar has also been known to decrease the tensile strength of the soil because of its porosity and ability to create air pores within the soil, thus reducing soil compaction. With this development, biochar can be used as a sustainable tool for agricultural soil development. High crop yields can be produced with the use of biochar without necessarily depleting essential nutrients from the environment [6].

2. Biochar properties that enhance environmental safety

Biochar can be produced from varieties of materials ranging from sewage, farm produce, energy crops and agricultural waste or residues. Other materials used for biochar include forest wastes like conifer barks, sawdust pellets, paper and moss. After biochar is produced, the quality of the biochar is determined by the assessment of certain properties possessed by the biochar product [7, 8].

The properties usually considered at the post-production stage of biochar include the chemical composition, porosity and stability. However, at the point of production, the chemical composition can be manipulated by the type of substrate used in the biochar preparation and the composition of the substrate determines the chemical composition of the biochar itself [3, 9].

Typically, biochars contain stable organic compounds where the carbon content may be within the range of 50 to 90% and volatile content at 10 to 50% [2, 10]. Biochar seldom undergo microbial degradation because of their carbonized nature and their pH. Some of the properties of biochar are shown in **Table 1**. These properties determine the level of biochar quality. The temperatures of the pyrolytic processes at the point of production of the biochar are also indicated.

The pH is either neutral or alkaline. The alkaline pH sometimes results from the biomass pyrolysis of high temperature. The increase in the temperature of the soil containing the biomass has a resultant effect on the alkalinity of the biomass [10]. However, at lower temperatures, high ion-exchange biochars are produced. The cation exchange capacity which determines nutrient absorption indicates a rise in temperature at every rise in the cation exchange capacity of the soil biomass [11]. It is as a result of these physicochemical properties that make biochars qualify as good soil carbon sequesters and soil remediation agents [3, 12]. Furthermore, soil types that are supplemented with biochar have a very high degree of absorption.

Biochar has a predominantly condensed aromatic structure that is known to be highly resistant to microbial decomposition. The porosity of the biochar adds to the water retention capacity of the soil and increases the soils ability to form aggregates [13]. **Figure 1** describes the porous nature of a typical biochar.

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Feedstock for biochar production	pH	Carbon (g/kg)	Nitrogen (g/kg)	Carbon/ nitrogen ratio	Phosphorus (g/kg)	Potassium (g/kg)	Ash (%)	CEC (mEq/100 g)	Pyrolysis temperature (°C)
Acacia bark	7.4	398	10.4	38	—	—	—	350	260–360
Coconut bark		690	9.4	73	—	—	3.38	—	500
Corn	—	675	9.3	73	—	10.4	—	400	350
Corn	—	790	9.2	86	—	6.7	—	670	600
Green waste	6.2	680	1.7	400	0.2	1	—	228	450
Peanut shells	—	499	11.0	45	0.6	6.2	—	—	400
Pecan shells	7.6	834	3.4	245	—	—	3.8	640	700
Pecan shells	—	880	4.0	220	—	—	—	—	700
Rice slaw	—	490	13.2	37	—	—	9.54	—	500
Sewage sludge	—	470	64	7	56	—	35	—	450
Sugarcane bagasse	—	710	17.7	40	—	—	4.34	—	500
Eucalyptus wood	7.0	824	5.7	144	0.6	—	0.23	286	350
Oak wood	—	759	1.0	759	—	1.1	—	400	350
Oak wood	—	884	1.2	737	—	2.2	—	120	600

Source: Saletnik et al. [1].
NB: The biomass with suitable pH for biochar was highlighted. Other biomasses are more acidic, thus less suitable. Most emphasis was based on suitable pH and pyrolysis temperature while the CEC (cation exchange capacity) of the suitable biomass was determined.

Table 1.
Selected properties of biochar and the respective temperatures of pyrolytic processes.

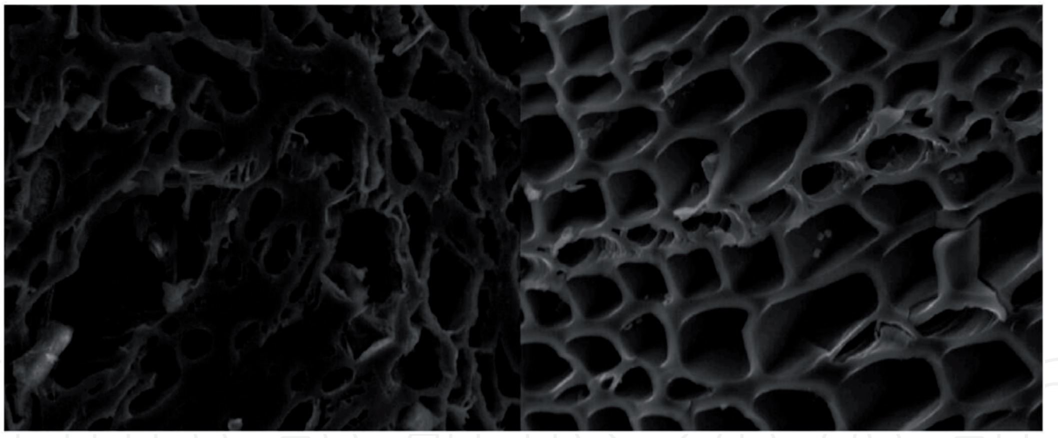

Figure 1.
The porous nature of biochar (Burrell et al. [14]).

3. Production processes of biochar and biochar efficiency

Biochars could be made either by burying organic waste particles in the soil or from pyrolysis of selected types of waste and fuel under different temperature conditions ranging from 260°C to about 600°C [4, 14]. When wastes are buried under the soil, for example wooden debris, sewage, sawdust and other similar wastes, they are placed in a shallow garden bed of 1–2 feet, smoked and covered with soil of up to 1 inch [12]. The waste material is thereafter left to char before the fire is put out. This leftover material referred to as biochar, is used in the improvement of soil composition. Likewise, the pyrolysis process involves the anaerobic digestion of biomass, usually between 260°C to about 600°C [4, 13–16]. These wastes could be regarded as raw materials for the pyrolytic process of making biochar. Thus, these waste materials are major constituents in the chemical and structural properties of biochars. Example of the raw materials for the pyrolytic process is categorized into three groups which include the following:

- Coal: charcoal can be made from coal to produce biochar. Apart from coal, charcoal can be made from peat, wood and petroleum. One of the common raw materials for charcoal is coal. The presence of solid coal increases the efficiency of the production of good biochar [17]. However, coal could also be used as a fuel material for the pyrolytic process.

- Biomass: example of biomass is wood, plant debris and organic matter. Biomass is one of the most important raw materials for pyrolytic production of biochar. It could be homogenous or heterogeneous in composition, and could either have a high or low humidity. The biomass could either be strongly bonded or loose in structure [4, 7].

- Sewage sludge: examples of these are tyres.

The composition of the raw materials determines the structural and chemical properties of the biochar. The processes involved in the biochar production through gasification procedures should be reviewed occasionally to avoid difficulty in the production of biofuel. The type of bioreactor and range of products should also be simplified enough to allow for the efficiency of the production process and technological reliability.

The high temperature enhances the production of hemicelluloses and depolymerization of celluloses in the biofuel production. The collisions alongside the high level of temperature are effective enough to prevent dehydration reactions; unlike the low temperature rates where the collisions always produce dehydration reactions [18]. Similarly, the fast and slow heating rate affects the product efficiency and volatility of the carbonated material. A slow heating rate has been shown to reduce the rate at which volatile substances from the production materials escape into the atmosphere causing more secondary reactions take place; while the fast heating rate increases volatility of volatile compounds thereby less secondary reactions take place [19]. Thus, more secondary reactions definitely result into high grade biochar production.

However, the most important properties are the chemical and physical properties. The raw materials with high lignin content have a very high tendency of producing efficient biochar but at relatively moderate temperatures. Furthermore, biomass materials that are relatively volatile produce efficient and large amount of pyrolitic gas and biofuel [20]. Furthermore, the amount of moisture in the raw materials for biochar determines the speed of the process of heat transfer and the distribution of products.

4. Soil fertility and biochar soil amendment

Soil fertility is a condition whereby a particular soil is physically, chemically and biologically stable with the required ecosystem intact without disrupting it. The state of complete functioning of the ecosystem is still intact in a soil termed to have the soil quality. There must be favorable interactions between the abiotic and biotic elements of the soil's ecosystem and still serve the purpose of crop production for sustainability [21]. A soil may have a complete ecosystem, yet not serving the purpose of crop production. Thus, soil fertility depends on the holistic process of managing the soil and at the same time keeping a robust biodiversity. Part of this process is through the application of natural carbon-rich materials like biochar as soil amendments [22]. The natural organic material added to the soil should fulfill the conditions of sustaining life, increasing biodiversity, keeping good water and air quality, beneficial to human health, as well as sequestering carbon.

5. Application of biochar and environmental safety standards

Legal standards, ab initio have been set on environmental matters, part of which includes biochar. Biochar in many countries is regarded as waste or fertilizers which have been guided by regulations and legal statements. Although, biochar may not appear in the legislation of many countries, even in the European Union (EU), but the law and regulations about waste control is in the offing of the constitutions of many nations across the world; though a few have gone beyond implementation.

In reality, biochar is considered as waste, but in several literatures, it is usually considered as a by-product of carbonization. Waste, according to the EU, is defined as any product that is supposed to be discarded or any substance the holder proposes to discard. The Waste Act of the EU therefore specifies that any waste that undergoes a recycling process and meet the following conditions may not be regarded as waste. These conditions are:

- If the specified waste is commonly used for certain purposes

- If the product is being traded in the market or has market value

- If the product meets the standard and specific requirement set out for the application of such product to the environment [23, 24]

- If the product itself or the use of it does no harm to the environment and to the people directly or indirectly affected by the product or its use

- If the use of the product does not cause long-term defects on the living and nonliving entities in the environment [6, 22]
  Biochar may also be classified as a by-product if it meets the above conditions.

Furthermore, other conditions whereby biochar cannot be regarded as waste are:

- If it is certain that the biochar can be reused

- If the biochar can be used without any further processing or manipulation

- If the biochar is an integral entity of the manufacturing process

- If the use of the biochar will not constitute an environmental nuisance or health hazard [25]

Apart from the existence of biochar as a by-product, it could also portray the picture of a product if it has been produced as the major product from the biomass raw material specifically designed for the process of that biochar production. Thus, the Waste Act is less concerned about the concept of using the biochar as product or by-product since biochar is not specifically mentioned in the Waste Act. The only country that has specific regulations about biochar is the Switzerland where biochar is permitted to be used in agriculture [26]. There is the European Biochar Certificate (EBC) which is recommended by the EU but only Switzerland has included the certification in their law in the use of biochar [7].

However, in Poland, the use of biochar as fertilizer or for the amelioration of soil must be preceded with the completed and signed approval form from the Ministry of Agriculture and Rural Development with the exception of the use of biochar for research purposes [25].

6. Applications of biochar for soil sustainability

In the face of declining soil infertility, climate change and human anthropogenic activities have made situation worse. However, several organic products have been introduced as part of the palliatives to lessen soil burden. Among these products is biochar which has been used as a popular choice for remediation of soil. Application of biochar to the environment is not detrimental because biochar samples have been found to contain several polycyclic aromatic hydrocarbons that are environmentally friendly. Pollutant compounds and toxic chemicals are yet to be found in the feedstocks used in the production of biochar [27].

However, acceptable proportions and amounts of biochar need to be determined through approved methods and environmental risk assessment so that the addition to land and aquatic bodies will be safe for the environment. The type of soil also needs to be considered to determine if specific physicochemical property of biochar is required for specific type of soil. The carbon sequestering potential of the biochar product is important for the determination of the amount of carbon sequestered for the purpose of evaluating the greenhouse gas effects and mitigating global warming [28, 29]. The Clean Development Mechanism (CDM) of the Kyoto Protocol is a model for the approval of materials involved in waste management. If biochar is approved by the CDM, then there is certainty of global commercial use. Fewer studies have been done to support the use of biochar when some studies have been skeptical about its use due to the ignorance of the interactions that take place between biochar and the soil. Therefore, there is need for innovations to create models that will be required for the assessing locations and soil types to determine the biochar-soil-climate interactions [19, 29].

7. Soil enhancement tendencies of biochar

Biochar has been effective on the soil in recent years through the evaluation of the soil quality after application to the soil. It has been observed that after application to the soil, the soil nutrients have been retained and soil quality improved. As earlier mentioned, the porous nature of the biochar, among other qualities has made the product to be a good soil conditioner and enhancer in recent years [30]. Some of these physicochemical properties exceptional of biochar will be discussed in details in this chapter.

7.1 Absorption tendencies of biochar

Biochar has been found to be a very good absorbent for the removal of excess pharmaceutical components from the environment. The kinds of pharmaceuticals that have been found to be removed by biochar are glyphosate, ibuprofen, atrazine, acetaminophen, and caffeine [9, 16, 31]. The excess release of pharmaceuticals into the environment has been a major risk factor for the resistance of microorganisms to antimicrobials. The rapid absorption tendency of biochar has therefore contributed immensely to the removal of these excess antimicrobials from the environment [10]. Toxins and unwanted drugs from the gastrointestinal tract have been shown to be reduced to reasonable amounts by biochar [11, 23, 29].

Furthermore, biochar has also been used to remediate waste fruit candy extract using deionized water as solvent with the aim of reusing the candy waste for the production of organic acids. The electrostatic interaction between polar and non-polar groups enhances the adsorption potential on organic substances by biochar. **Figure 2** reveals the mechanism of adsorption of organic substances by biochar. However, the adsorption of inorganic substances like heavy metals by biochar or activated carbon involves mechanisms like ion exchange, precipitation, cationic anionic metal attraction [29–31]. **Figure 3** shows the mechanisms of inorganic substance adsorption by biochar.

7.2 Soil amelioration of biochar

Biochar has been known to be a good enhancer of the soil due to its rich content of carbon and other nutrients good enough for the soil. Prior to the addition of biochar to soil, plant growth has not been optimum; but after the addition of biochar, the rate of growth of the plants on the same soil has been with optimum yield. A major advantage of biochar for soil amelioration is cost effectiveness and efficient process of application [32].

However, the feedstocks used in the production of biochar determine its efficiency and nutritive value. It also determines the proportion of the micro and macro-nutrients present in the biochar which resultantly affects the interactive patterns between the carboniferous biochar and organic as well as inorganic particles in the soil [29].

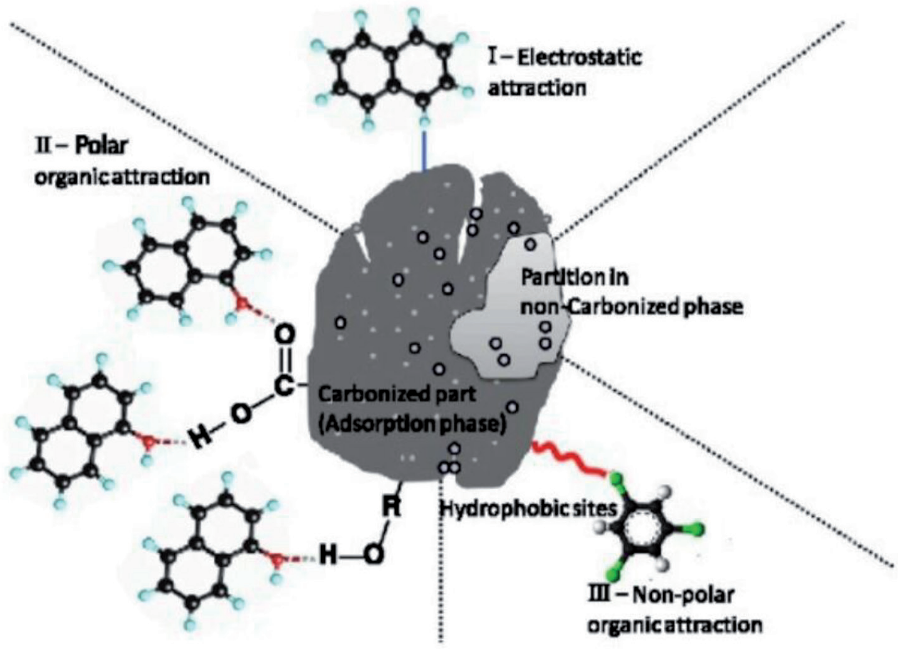

Figure 2.
Mechanism of adsorption of organic substances by biochar [31].

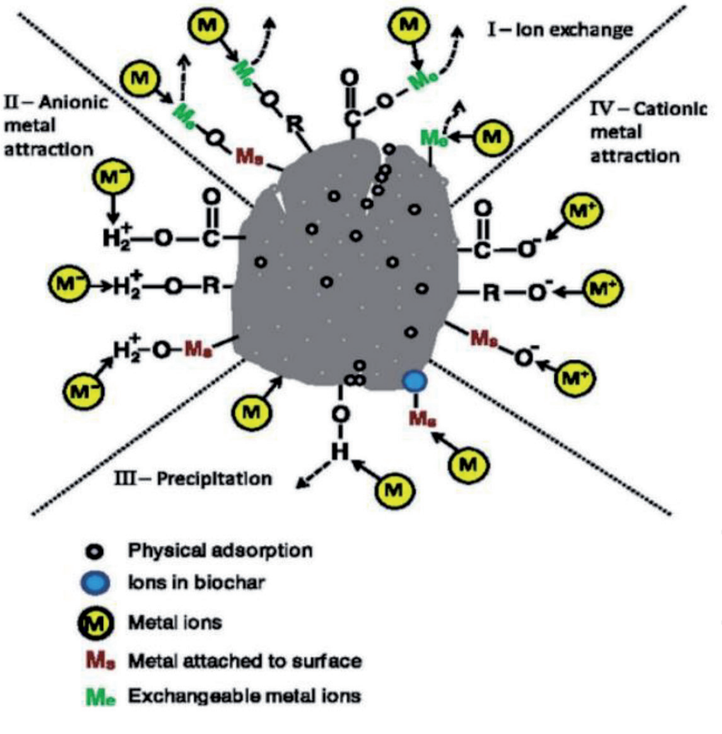

Figure 3.
Mechanism of inorganic adsorption by biochar [31].

Biochar from wood, poultry litter and cattle manure was discovered to produce the highest yield in cowpea, radish and maize plantations, respectively [28–31]. Certain characteristics of biochar that facilitates the enhancement of the soil includes its nature of rejecting biodegradation which makes it to spend more time within the soil for proper and effective carbon sequestration, thus making it an effective moderator for carbon dioxide in the soil. However, the presence of biochar in the soil tends to increase the amount of biogenic substances in the soil. Nonetheless, substances like phosphorus and potassium are bonded and chelated with biochars to avoid excess leaching of these substances into the environment [33]. The ion-exchange properties of biochars also enable the exchange and replacement of organic and inorganic substances that helps to complete the biogenic and geogenic cycles.

Additionally, biochar is a booster for the silicon cycle by supplying biogenic silica, also known as phytoliths into the soil. Likewise, it also helps in balancing the phosphorus and nitrogen cycle by the ion-exchange storage of phosphorus and nitrogen respectively in their compound forms [34]. Thus, when ammonia and ammonium compounds are trapped in the soil by biochars, it reduces the process of the formation of nitrous oxides, thereby reducing the emission of greenhouse gases into the atmosphere. Furthermore, by trapping more nitrogen in the soil, it increases the productivity rate of nitrogen-fixing bacteria in the soil, thereby increasing soil yield [35].

Biochars also increase the pH of the soil due to the presence of carbonized compounds like calcium carbonate [23, 30]. This may not be too beneficial in temperate regions where the soil pH is always tending toward the right side of the scale; but in the acid tropical soil regions, biochars are mostly used to regulate the pH of the soil. Due to the physical porous nature of biochars, they also affect the physical structure of soils thereby affecting the soil's retention capacity [36]. Therefore, such a soil is able to retain water at a very high rate but at the same time, forms aggregates and increases the capacity to resist erosion. **Figure 4** shows how soil enhancement can be achieved through biochar addition. Thus, with the combined effect of porosity and carbonization, biochar-in-soil is a favorable substrate for microorganisms to thrive on in the soil. *Nitrobacter* and *Nitrosomonas* spp. are suspected to thrive better in such biochar-laden soils due to the presence of trapped nitrogen by biochar [2, 4, 33]. Subsequently, there would be high microbial stimulation and efficient nitrogen mineralization in that soil.

7.3 Enhanced nitrogen fertilizer

Fertilizers and water need to be supplied increasingly as food and agricultural practices keep increasing. The rate at which population increases demands that more food should be supplied; hence, more fertilizer is needed. Over the years, the supply of nitrogen has been insufficient and mismanaged; thus, there is need to improve the supply of nitrogen and device affordable means of sustaining the

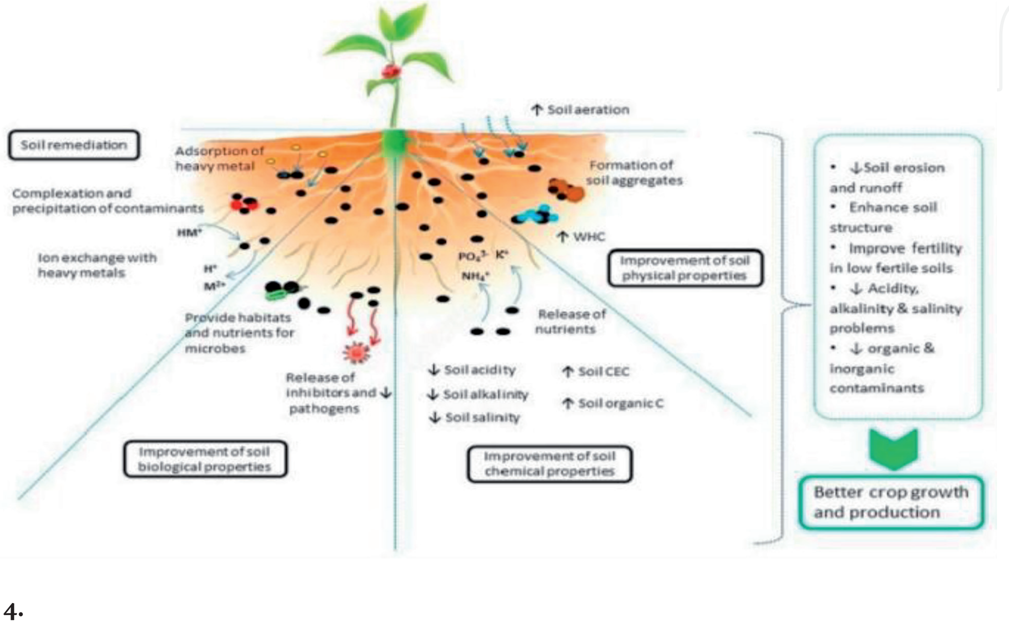

Figure 4.
Soil enhancement through biochar addition [35].

supply [15, 19]. Plants normally do not utilize more than 50% of the soil nitrogen; therefore, adequate technology should be invented in order to build the mechanism that would increase nitrogen uptake in plants. Part of these measures is the introduction of biochar into the soil to encourage the uptake of nitrogen from pure organic sources [18, 30].

The addition of biochar to soil increases the pool of nutrients and the volume of nitrogen available to plants. Organic amendment of soil provides the soil with nutrients like nitrogen, phosphorus and potassium [29, 33–35]. Therefore, biochar addition to the soil enhances improved supply of nutrients to plants and to the soil.

7.4 Soil structure improvements of biochar

Biochar amendments into the soil improves soil's nutrients and structure due to the high porosity of the biochar, leading to the formation of well-structured aggregates that enhances soil's water holding capacity. In tropical regions and areas with low rainfall, the addition of biochar to the soil improves the water retention capacity in the dry season [2, 13, 34]. The tensile strength of the soil increases as a result of accumulation of more organic matter. This forms a strong structure for the plant roots to adhere to. The strong adherence improves the soil ecosystem because the bonding of the soil aggregates prevents erosion and displacement of the top-most layers of the soil [11]. Thus, this overall soil structure improvement proves the evidence of the advantage of the physicochemical attributes of biochar to prevent adverse soil conditions caused by earth's geogenic and climate activities, thereby mitigating climate change [12, 36].

7.5 Biochar and mitigation of greenhouse gases

Biochar possess interesting properties like the presence of high-stable carbon necessary for the carbon capturing. The high stability of biochar carbon therefore gives biochar products an edge over other additives and conditioners. Thus, with the effective sinking of carbon from the soil, it regulates the presence of carbon dioxide in the atmosphere [29, 30]. Likewise, this property of biochar stability increases the turnover rate and half-life of biochar in the soil for more number of years. However, the mitigation of other greenhouse gases other than carbon dioxide by biochar has still not been investigated. Therefore, further research needs to be carried out to evaluate the effectiveness of biochar in regulating other greenhouse gases [33]. Also, effective measures of evaluating the emissions of these gases must be considered with the aim of saving up the greenhouse gases pertaining to the emission trading schemes [17, 18, 37].

Also, the use of plant and animal wastes for biochar is a means of preventing the emission of methane and nitrous oxide gas from landfills, which are potent greenhouse gases.

7.6 Biochar in environmental conservation

Biochars effect in environmental conservation deals with waste management, soil remediation and energy conservation. Animal wastes and biomass from agricultural produce can be processes under certain environmental conditions using pyrolysis [1, 10, 34]. The emission of greenhouse gases from wastes is reduced if the plant and animal biomass is processed into biochar [20].

Another major advantage of biochar for environmental conservation is the use of biochar as renewable fuel. The incineration of carbonized products can be processed into biochar which releases lesser amounts of inorganic materials into the environment because carbonized materials are purely organic [36].

The process of pyrolysis could however alter the extent of release of non-carbon materials like chlorine into the environment. However, the nature of the biomass determines the amount of chlorine released during the process of biomass conversion into biochar during pyrolysis. If the chlorine and other inorganic substances are formed continuously, it leads to the formation of sludge in fuel-burning boilers but with the carbonization of fuel, the sludge formation disappears. Thus, because the carbonization happens inevitably during biochar production, the process of production of biochar is a key process in solving the problem of sludge production [29].

Therefore, it is re-iterated that the type, properties and processes of feedstocks used for the formation of biochar is a potent determinant of the nature and effectiveness of the biochar [16, 36].

7.7 Biochar in enhancing soil microbial community

Biochar application to the soil has been found to increase the soil's physicochemical conditions, more especially rate of carbon sequestration and the overall soil fertility [22]. For example, biochar from wood waste was used to amend the soil on which wheat crops were planted in Tuscany, Italy. The soil samples were collected after 3 months of biochar amendment and was analyzed the pH, total organic carbon, microbial biomass, mean substrate-induced respiration and other parameters. It was observed that only the pH and the mean substrate-induced respiration had significant changes after 3 months of amendment, but after 14 months the effect was not pronounced [22, 37]. The result reflects the perking up of the activities of soil microorganisms after treatment with biochar.

Furthermore, biochar has an averagely neutral pH ranging from 6.2 to 7.6 (**Table 1**) and majority of microorganisms, especially soil microorganisms thrive well at this pH. Only a few microorganisms are acidophilic and alkanophilic. This therefore increases the chance of more microbial activities in a biochar-amended soil [24, 37].

Likewise, the porous nature of biochar is obviously an advantage for soil aeration, a good condition for soil aerobes. However, there are also anaerobic organisms (that do not require the presence of oxygen to survive) in the soil. In a condition where the soil aerobes use up the total oxygen in the soil, it provides a good ambience for soil anaerobes to thrive. The porous biochar also increases soil water retention capacity. However, chances of soil water-logging are possible, but the tendency of biochar to form aggregates reduces the chances of soil erosion [38].

The chemical properties of biochar also increase the microbial population in the rhizosphere region of the soil, which is popularly known as the rhizosphere effect [26, 36]. Furthermore, the overall effect of biochar enhances the growth of plants that release vitamins and amino acids from their roots and tissues. These nutrients subsequently increase microbial metabolism and increased microbial products yield.

In a biochar-amended tobacco-planting soil in China, rice-straw biochar was used to enhance the soil. Indigenous microorganisms present in the soil were bacteria of the phyla Proteobacteria, Actinomycetes and Acidobacteria; while the predominant fungal phyla were Ascomycota, Zygomycota and Basidiomycota [23, 35]. **Figures 5** and **6** shows that among these groups, only the Actinomycetes bacteria group and the Ascomycota fungal group respectively reduced in proportion after the addition of biochar while the remaining bacterial and fungal groups increased in proportion after the biochar treatment. Other soil fungal groups that exhibited increased proportion include the Zygomycota and Glomeromycota phyla [25, 38].

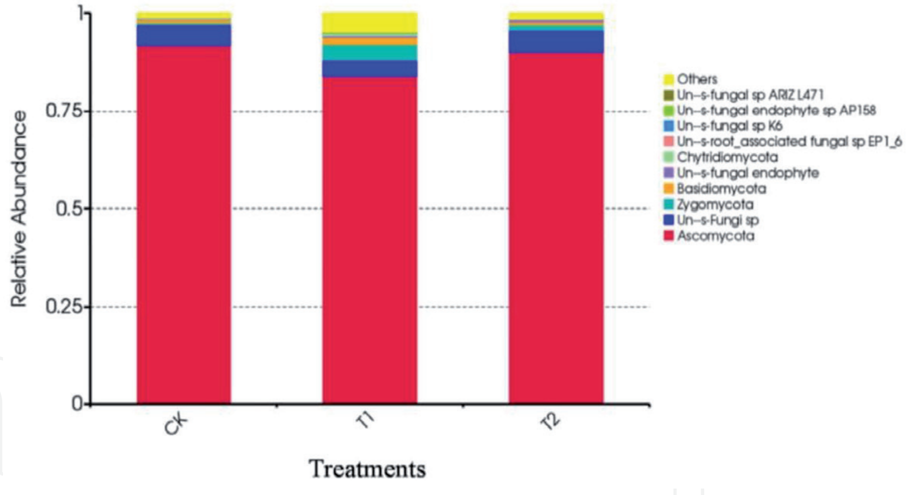

Figure 5.
Proportions of soil bacteria after biochar treatment [36]. CK = un-amended treatment; T1 = 2250 kg/ha biochar-amended treatment; T2 = 4500 kg/ha biochar-amended treatment.

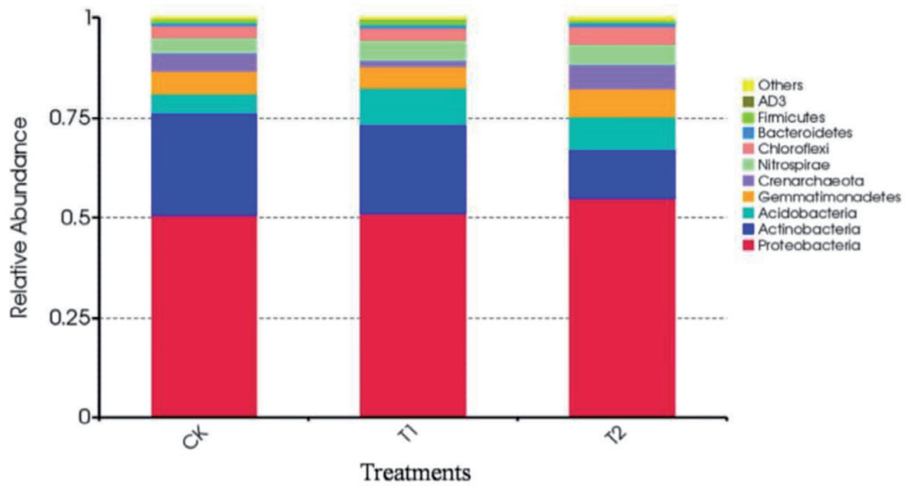

Figure 6.
Proportions of soil fungi after biochar treatment [36]. CK = un-amended treatment; T1 = 2250 kg/ha biochar-amended treatment; T2 = 4500 kg/ha biochar-amended treatment.

8. The implications of amending soils with biochar

Biochar is a natural soil booster and has recorded high success rates over the years in some parts of the world. In some regions including Africa, biochar has been found to yield positive results although some negative results were reported, for example due to improper incorporation of biochar into soil blends which fosters soil erosion [39]. Biochar has been found to balance soil pH, absorb pollutants, improve soil moisture and increases soil aeration. However, there are other economic importance attached with the use of biochar, these include the geographical distribution of the effective use of biochar [38, 39].

Biochar has not been known in some parts of the world due to lack of research, negligence and cultural practices. Another major implication of biochar application is contamination which is of high economic importance. The kinds of cattle manure used in biochar production could be contaminated with non-soil infectious microorganisms, heavy metals or may be denatured due to the high temperature of pyrolysis [40].

Excessive removal of feedstock from biochar raw material and production processes could lead to usage of biochar devoid of adequate organic nutrient constituents. Inadequate improvisation of biochar, for example the use of straw alone, or in inadequate amounts, will also have a negative effect on the soil. Earthworm survival is always put in doubts as well as the soil ecosystem niche that ensures overall soil health [40].

9. Discussion

Soil has been one major source of habitat for plants and animals. However, the anthropogenic activities of humans have contributed to the depletion of natural resources and nutrients from the soil. In a rescue mission to curtail the devastation of land and soil, biochar have been introduced for both agricultural and commercial purposes. Digestion of wastes in less amounts of oxygen at high temperature produces high quality biochar. The high temperature explains the pyrolysis process which is usually more than 200°C anaerobically [4, 41–43]. Biofertilizers and organic fertilizers have served as appetizers to the soil over the years. Recently, other forms of soil amendments have been procured for soil improvement. The soil amendments generally have a low cost and easy accessibility. An example of these soil amendments includes biochar.

Biochar is environmentally friendly and has a high binding capacity that allows the soil to adhere to biomolecules and absorb nutrients. Biochar is globally known to becoming a means of sustainable amendment of soil and means excavating heavy metals from the soil [44]. Although, biochar is produced from different biomass sources, but biochar produced from carbonization of organic wastes produces amended soil types with high carbon sequestration [45]. The quality of biochar depends on the pyrolysis conditions and raw materials, while the efficiency of biochar not only depends on the pre-production parameters but also the post-production and application procedure of the biochar; which include the type of soil under amendment and the amount of biochar applied [46]. In the process of pyrolysis of biomass, biochar is produced. There are new innovations that need to be applied when producing biochar. For example nanotechnologies and large scale model production are among the recent methods that need to be explored for adequate and mass production of biochar [15, 44, 47]. The temperature of pyrolysis, the particle size and residence time are factors that determine the end product of biomass conversion into biochar. These factors determine the state and half-life of the biochar product [48]. Biochar is a good soil and plant health promoter because it helps to retain the nutrients in the soil through its absorbent power thereby enhancing overall plant growth [49].

10. Conclusion

The physicochemical property of biochars is key to the enhancement and remediation of the soil. The porous structure and high carbon content are important factors for conservation and sustainability of the soil. A combination of the above properties and the ion-exchange characteristic is symbolic for carbon sequestration, immobilization of heavy metals, and removal of pollutants from the soil [28]. Wastes are used to generate biochars with specific processes like pyrolysis under certain parameters. Biochar is potent enough to trap excess carbon dioxide from the environment but studies have not been seen with regards to mitigating other greenhouse gases. Thus, further research needs to be carried out to evaluate the effectiveness of biochar in regulating other greenhouse gases. Also, effective measures of evaluating the emissions of these gases must be considered with the aim of saving up the greenhouse gases pertaining to the emission trading schemes.

Thus, as a substance of good physicochemical parameter, addition of the carbon-rich biochar to soil enhances the physical, chemical and biological properties of the soil. The enhancement includes the total organic and inorganic carbon, nitrogen, phosphorus and potassium. For agricultural purposes, the soil with added biochar has high crop yield. Therefore, biochar is recommended for most agricultural practices due to cost effectiveness and easy application techniques.

Furthermore, the effect of biochar on soil microbial community is significant considering the increase on the soil bacterial and fungal community with a higher increase in the later. Thus, biochar simultaneously enhances both the soil nutritional status and the soil microbial structure.

However, commercial use of biochar has not been widely accepted due to regulations backed by the law and bias about the fact that biochar is just a waste. Therefore, applications of biochar should be considered using efficient processes with the assurance of environmental safety so as to encourage the schools of thought that are tendentious about the safety of biochar application.

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