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EVALUATING THE ROLES OF BIOCHAR IN CLIMATE CHANGE MITIGATIONS AND SOIL AMENDMENTS; A REVIEW

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Abstract

Highly degraded semi-arid regions could be potential crop production areas to meet the ever increasing food and beverages demands of the growing population. The major production challenges this region faces are water scarcity, soils and biodiversity loss due to prolonged drought, erosions and leaching. These make farmers to depend on supplementary irrigation and commercial fertilizers for crop production and the conditions are even worsened with change in climate. In the past, organic amendments and polymers such as polyacrylamides (PAM) were used to improve soil physiochemical properties and protect soils from erosion but to no avail. The aim of this paper was to review different scientific research findings on the potential value of

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Biochar in green house gas sequestration, and Soil Amendment in particular in sites under serious degradation. Many scientific findings (170) published in brochures; journals, abstract, and thesis on biochar potentials on soil nutrient cycling, green house gas sequestration, and soil/land rehabilitation with methodology that can be reproduced were reviewed and synthesized. We found out that Biochar has proven potentials to improve soil physical, biological and chemical properties hence boosting soil fertility and productivity and as well as sequester carbon dioxide from the atmosphere-biosphere pool and transferred it to soil. Biochar also remained a promising solution to energy. With good extension service packaging, biochar can be effectively adopted as solutions to soil degradation and pollution.

Key words: biochar, climate change mitigation, green house gases (GHG) sequestration, soil properties, Carbon.

1 Introduction

The three most important inter-related problems facing the global community today that need urgent address; climate change, Soil/Land degradation and pollution as well as achieving global food and nutrition security. This is because of increase in industrialization, urbanization, population and reliance on rain fed agriculture which makes people vulnerable to climate events (McCarthy and Brubaker, 2014). Semi Arid regions of Ethiopia are mainly situated in the lowlands of South, East and North of Ethiopia and occasionally leeward sides of the highland. The region covers about 63% of the total land area (World Bank, 2013; UNDP, 2014). The region suffers food insecurity and poverty where about 10% of the population lives in abject poverty, silent and deep hunger (Oxfam, 2012). The chronic poverty and food insecurity have been linked to climate change especially rainfall variability, high temperature; (Brown et al, 2011;FDRE, 2011) and occasional floods example in Awash (Demeke etal, 2011, Omondi, 2014); meanwhile the non climatic forces being increment in population pressure, economic development, soil/land degradation and war (Biazen and Sterk, 2013). Increase in temperature

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variability has greatly influences evapotranspiration, relative humidity and genetic erosion (Conway and Schipper, 2011).

2 Climate change: Is the long-term statistical deviation of climate overtime atmospheric conditions from its long-term average conditions naturally or induced by human activities. While Climate on the other hand represents average weather and the range of extremes compiled over many years (more than 30 years) (IPCC, 2007). Climate is a factor in the natural environment which directly or indirectly affects the lives and livelihoods of people globally. The IPCC (2014) reported global total GHG emission increase of about 10% between the years 2000-2010. Human influence directly or indirectly was ascribed to be a major contributor of climate Change through increased emissions of greenhouse gas (GHG) like carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and Fluorinated gases (F-gases); changes in the ability of terrestrial ecosystems to serve as carbon sinks, damage on biodiversity as well as reduction in water quality and global mean sea level rise (IPCC, 2014). According to the IPCC (2014), CO_2 emission is the main anthropogenic GHG emission with 76% and other GHG contributed only 24% with CH_4 (16%), N_20 (6.2%), F-gases (1.6%) to the total GHG emissions; Industrial processes and fossil fuel combustion contributed 78% of the total CO_2 emissions to the overall GHG. The global economic sectors evaluation report showed high contribution of CO_2 from Energy sector (47%) followed by industry (30%) as direct human influence, meanwhile the indirect contributions were still through energy sector (35%), agriculture forests and other land uses (24%), industries (21%). And it was concluded that economic and population growth increase amplifies the CO_2 net emissions from fossil fuel combustion to the GHG pool which later results in increase global warming (IPCC, 2014). Climate change influence on agricultural production varies according to location; but generally there is change in seasons, Floods, drought, extremities in temperature-cold or heat which has affected agricultural productivity either positively or negatively (Beddington et al., 2011). The long-term impacts of climate change remains unsatisfactorily addressed, but it is estimated that the poor smallholder farmers stand higher chances of being adversely affected by this threat (Nelson et al., 2010). Different studies have documented the links between agriculture and climate change and it is believed that agriculture has a key role to play in the global efforts to address both the mitigation and adaptation to climate change (Beddington et al., 2011). But addressing climate change requires new move to crops and animal production technology development that more clearly address ecosystem health and resilience,

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action and impacts that can be realized at scale (IPCC, 2014). Despite, the need to increase in agricultural yield production, there is need to adapt practices and technologies that are self-sustaining, energy efficient and make use of natural renewable energy sources other than depending on external inputs that is by employing the principles of smart sustainability production. Biochar has a great potential to mitigate climate change and enhance increase sustainable food and beverage production than conventional methods of production (Zheng et al, 2010).

3 Biochar

Biochar is a carbon-rich product obtained by heating biomass in a closed system under limited supply of oxygen (Zheng, et al, 2010). Biomass materials like livestock manures, sewage sludge, crop residues and composts are subjected to slow thermo-chemical pyrolysis which convert them to charcoal-like materials (biochars) applied to soils as an amendment (Busscher et al., 2011). Biochar represents a stable form of carbon and thus provides an intriguing potential carbon storage strategy as a soil amendment and its value as such would likely increase as social and regulatory interest in carbon dioxide sequestration increases because of the longevity of carbon in the soil (Suzette,et al, 2010). The Biochar majorly differs from charcoal (or char) in that; Charcoal is produced with the purpose for fuel use while biochar is produced with the intent to be added to soil as a means of sequestering carbon dioxide and enhancing soil quality (Seassey, 2013). In production of charcoal some of the gases may be lost to the atmosphere together with oils and tar as smoke, which may contain the greenhouse gas (GHG) nitrous oxide (N_2O) as well as methane. Meanwhile in controlled pyrolysis in biochar production, oil can be condensed or combusted with tar in the vapour form, to utilize its energy value (Peter et al, 2010).

3.1 The origin of biochar

Much of the interest in biochar comes from studies of Amazonian soils at the River Basin known as Terra Preta de Indio that appear to have been amended with biochar, with significant improvements in soil quality and positive effects on crop yields. The soil was said to have higher levels of carbon and organic matter measured 70 and 150g/kg times respectively higher than the surrounding soils (Lehmann et al., 2004). These soils were also superior in essential plant elements like phosphorus, calcium, sulfur and nitrogen accompanied with high cation exchange

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capacity (CEC) and a neutral pH in comparison to the oxisol soils neighbouring the Terra Preta soils (Lehmann et al, 2006). The modified chemical properties of the Terra Preta soils resulted in fruitful arable land where it naturally did not exist; they are further prolific than adjacent soils and have been productive close to hundreds of years (Glaser et al., 2001; Lehmann, 2007).

3.2 Biochar production

According to Zheng et al (2010), Biochar production goes through several thermo-chemical changes like; pyrolysis, gasification, and hydrothermal conversion to make biochar.

Pyrolysis engages the heating of biomass in the absence of oxygen and the end products are;

a) Biochar,

b) Bio-oil,

c) Syngas.

Modern pyrolyzers have the ability to utilize volatiles for the production of bio-oil and syngas.

G**asification** is a thermochemical process in which organic matter is burnt with limited oxygen to produce Syngas as a main product and biochar as a byproduct.

Hydrothermal conversion primarily focuses on using wet biomass to generate bio-oil and biochar as a byproduct. This process makes Biochar to be used directly to make a replacement for pulverized coal as a fuel (Zheng et al, 2010).

There has been a noticeable variation in the carbon content of biochar produced from different organic material used. Collins (2008), showed carbon content (from slow pyrolysis) ranging from 61% to 80%, the highest being from wood pellets. Woody feedstocks (bark, wood pellets) have superior carbon content than herbaceous feedstocks. In relation to this, roughly 0.61 to 0.80 metric tons of carbon (or 2.2 to 2.93 metric tons of CO_2) is sequestered for every ton of biochar applied to the soil (Collins, 2008).

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Table 1: Selected characteristics of six biochars (slow pyrolysis at 500°C) analysis.

Source of biochar	% Biochar Characteristics					
	C	**N**	**S**	**C:N**	**C:S**	**pH**
Switch grass	60.5	2.06	0.20	30	350	9.4
Digested fiber	66.7	2.23	0.30	30	228	9.3
Peanut hull	70.6	1.74	0.04	41	1203	9.6
Bark (UGA)	74.5	0.34	0.03	220	2833	7.6
Softwood bark	77.8	0.44	0.06	176	1482	8.4
Wood Pellets	80.0	0.14	0.04	588	1855	7.4
Activated	87.3	0.47	0.80	186	114	9.1

Source: Collins (2008).

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3.3 Factors affecting the Quality of Biochar for Soil Amendment and Carbon dioxide Sequestration

- **The pyrolysis process** affects the qualities of the biochar produced and its potential value to agriculture in terms of soil performance or in carbon dioxide sequestration (David and John, 2013). When the pyrolysis process is done rapidly within short time, more bio-oil is produced than biochar and vice versa (David and John, 2013).
- **Temperature and time** the biomass takes in the pyrolysis kiln; Additional increase in temperature of 100^{o}C results in corresponding 41gC kg^{-1} of biomass used (Cheng et al. 2006). As pyrolysis temperature increases from 350 to 600^{o}C, feedstocks lost 60 - 70% of total N. Usually, low pyrolysis temperatures below 400°C yield acidic biochar, while increasing pyrolysis temperatures of between 450°C and 850^{o}C produce alkaline biochar (Cheng et al. 2006). Temperature also influence the CEC potentials of Biochar produced in that low pyrolysis temperature increases the anion exchange potentials meanwhile high temperature increases the Cation exchange (Lehmann 2007).
- **Feedstocks and Biomass types used** determines the nature of the product; High nutrient rich biomass generate high quality biochar very rich in available plant element nitrogen, phosphorus, potassium, and other nutrients similar to that of commercial fertilizer (Covell et. al, 2011).

3.4 Methods of Application of Biochar into the Soil

Biochar placement in the soils is influenced by the production form; they are produced in powdered or pellets form (Blackwell et al, 2007). The following methods of placements have been used;

- **Top soil assimilation**

This is the placement of biochar on top soil surface alone or in mixture with manure at a depth of 0-30cm. moistening the biochar during soil application is very essential to minimize the loss of biochar from wind and water erosion (Blackwell et al., 2007).

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- **Depth application**

Depth application of biochar has been described mostly as 'deep-banded' application Deep mould board ploughing essentially results in temporary 'depth application', although horizontally continuously subsequent mould board ploughing and cultivation will then further homogenize the biochar distribution through the topsoil (Blackwell et al., 2007).

- **Top-dressing**

Here thin layer of fine powdered biochar is evenly spread on top of the soil surface and left unturned. This form of application is being considered mainly for those situations where mechanical incorporation is not possible for instance, no-till systems, forests, and pastures (Blackwell et al, 2007). An obvious drawback is the risk of erosion by water and wind, as well as human health (inhalation) and impacts on other ecosystem components (surface water, leaf surfaces, to mention but a few). Both topsoil assimilation and top-dressing can be applied frequently depending on the farmers wish yearly or after some few years. For specific effects on soil, for example nutrient availability (from a feedstock like poultry manure) or liming effect, a more frequent application may be more beneficial to the soil and/or less detrimental to the environment (nitrate leaching) (Blackwell et al, 2007).

3.5 Role of Biochar in Climate Change Mitigation

Biochar is one potential strategy amongst many actions that need to be taken concurrently to address climate change impacts globally (Guant and Cowie, 2009). Biochar was rated as the best geo-engineering option to reduce Carbon dioxide (Lenton and Vaughan, 2009). Biochar slow down the carbon cycle with significant carbon management. Carbon dating of charcoal has shown some Carbon material to be over 1500 years old, fairly stable, and a permanent form of carbon dioxide sequestration (Lenton and Vaughan, 2009).

According to Spokas et al (2009), the use of biochar in soils not only leads to a net sequestration of Carbon dioxide, but as well decrease emissions of other greenhouse gases like N_2O and CH_4. The emissions of CO_2, CH_4 and N_2O from soil are controlled by soil physical properties such as moisture content, aeration, porosity, organic matter (OM) content which could both be biotic

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(microbial response) or abiotic (mineralization or decomposition of SOM) (Laird et al, 2010). The existence of Terra Preta proved that soil organic carbon (SOC) improvement further than the maximum capacity (determined by environmental factors) is possible if done with intractable carbon form like biochar. The CO_2 respiration was comparatively lower than the neighbouring soils (Steiner *et al.* 2004). Carbon stabilized in biochar represents approximately 75% of C in the feedstock, stable over 100 years; these volume composition enables 1ton of biochar application to sequester 2.06 tons of carbon dioxide of total annual CO_2 (David and John, 2013). Therefore, the transformation of labile plant organic matter into biochar through pyrolysis not only reduce CO_2 emissions from energy production, but biochar additions to the soil constitutes a net withdrawal of carbon dioxide from the atmosphere (David and John, 2013).

According to Guant and Lehmann (2008), the three main products of pyrolysis: liquid (bio-oil), solid (biochar), and gas (syngas), can influence the global carbon (C) cycle in two ways that is to say;

- All three pyrolysis products (syngas, bio-oil and biochar) may be used as an energy source that can displace fossil energy use.
- The biochar amended soils can become a durable sink of soil organic carbon

Gaunt and Cowie (2009), projected that diverting 1% of annual net plant uptake of CO_2 into biochar would mitigate nearly 10% of current anthropogenic CO_2 emissions.

Lehmann et al. (2006) estimated that low-temperature pyrolysis of biomass combined with the capture of gas and liquid products for bio-energy production and soil application of biochar could sequester the equivalent of about 10% of the annual fossil-fuel emissions. Bio-oil and syngas may displace 25% of the fossil fuel use annually and biochar C sequestration of about 10% of the average annual CO_2 emissions (Laird, 2008).

Increased N_2O emissions have been identified following the application of nitrogen fertilizers, incorporation of crop residue and application of liquid organic wastes and bio-solids in reclaimed lands (Palumbo *et al.* 2004). A 50% reduction in N_2O emissions was observed from soybean plots and almost complete suppression of CH_4 emissions from biochar amended (20 Mg ha^{-1}) acidic soils in the Eastern Colombian Plains (Rondon et al, 2005).

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Yanai, et al (2007), observed an 89% reduction in N_2O production of rewetted clay loamy soils up to 78% water filled space containing 10% biochar compared to soils without biochar. Case et al (2012), observed a 98% reduction of N_2O emission on sandy loam soils amended with biochar from hardy wood and concluded that it can be useful in mitigating global warming. A significant reduction in N_2O production was also found by Spokas *et al.* (2009) in a Minnesota agricultural soil.

3.6 Contributions of Biochar in Soil Amendment

Agricultural land use acts as a source and/or sink of Carbon depending on its effect on soil and plant processes (IPPC, 2007; Stavi and Lal, 2013). Photosynthesis by plants partly offset the impact of carbon dioxide emissions resulting from continuous commercial fertilizers use in nutrient supplementation for crop production. Biochar may be use to correct the imbalances in soil nutrient thus it's of particular interest to agronomists and farmers (Pratt and Moran 2010). Biochar may be blended with composts, mycorrhyzae, digestates, urine and other cultures to make it richer in nutrients and provide food for the already existing microbes in the soil (Sai, 2014). Biochar blend is given different names such as Biochar compost, Biochar, Geochar, Terra preta but a few to mention. The combination of Biochar and Fertilizers gave significant yield increase of up to 250% yield (Van et al, 2007; Sai, 2014). Biochar is an acid-neutralizing material for highly weathered soils. Experimental evidence shows that wood biochar not only improved the chemical and biological properties of the soil, including increasing soil pH, CEC, BS, and microbial activity, but also improved the physical properties of the soil, such as Bd, Ksat, aggregate stability, and erosion resistance.

- **Water Holding Capacity (WHC)**

According to Sun and Lu (2014), biochar significantly boost water retention of soils. Karhu et al (2011) mentioned that biochar application could increase WHC by 11% due to surface area and charge characteristics. Ammal and Heyden (2014) also found that biochar addition increased soil moisture content especially in sandy and silty soils. This signifies the amended soils ability to reduce rain water losses and as well reduced irrigation water needs for crop production.

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- **Soil Nutrients**

Biederman and Harpole (2013) analyzed the results of 371 independent studies. This meta-analysis showed that the addition of biochar to soils resulted in increased aboveground productivity, crop yield, plant potassium (K) tissue concentration, soil phosphorus (P), soil potassium (K), total soil nitrogen (N), and total soil carbon (C) compared with control conditions. However, the variability in crop production increased with application rates. Biochar surfaces adsorb plant elements hence minimizing nutrient loss by leaching. This enhances fertilizers use efficiency (Laird et al, 2010). Application of biochar accelerates nutrients uptake by plants (Major et al., 2009). Minimum fertilizers application rate is required with band application of biochar (Blackwell et al, 2009). This lowers production costs in sustaining high crop yield.

- **Cation Exchange Capacity (CEC).**

Significant increase in the CEC has been reported with increase in the amount of exchangeable cations in biochar amended soils mostly for elements like Calcium, Potassium, Magnesium and Phosphorus. According to Lehmann (2007), CEC of soils amended with biochar increases with time increment; the longer the time given for abiotic oxidation the higher the CEC of that soil and vise verses. Biochar has a greater ability to absorb and retain cations in an exchangeable form than other forms of soil organic matter due to its greater surface area, and negative surface charge. Increased CEC was highly observed in sandy soils (Liang et al. 2006). This implies ability to hold essential nutrients and release it slowly as required by plants for over long time. This quality reduces fertilizers application rate.

- **Soil biodiversity and microbial activities**

Increased soil organic carbon concentration resulting from biochars application generates conducive soil micro climate attractive to soil biota (Sai, 2014). There was also observed increase in soil microbial biomass especially Rhizobia and Arbuscular mycorrhizal in soil amended with Biochar as biochar acts as habitat for mychorrhizal fungal hyphae (Biederman and Harpole, 2013). Similarly, biological nitrogen fixation increases through biochar application due to increased rhizobia nodulation (Biederman and Harpole, 2013).

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- **Soil pH**

There is significantly positive linear correlation between biochar-treated soil pH and biochar pH ($r^2 = 0.46$, $p < 0.05$). Mineralisation of biochar over time produces carboxylic groups on the edges of the aromatic core, increases the reactivity of black carbon in soil. This can be a good tool to improve nutrients use efficiency and moisture in drastically disturbs soils in Arid and semi Arid areas (Glaser *et al.* 2001).

- **Surface area and porosity**

A long-term soil column incubation study indicated increase in specific SA of an amended clayey soil from 130 to 150 m^2g^{-1} when biochar derived from mixed hardwoods was applied at rates of 0 to 20 g kg−1 (Laird et al,2010). The higher the total porosity (micro- and macro-pores) the higher is the soil physical quality since micro-pores are involved in molecular adsorption and transport while macro-pores affect aeration and hydrology (Atkinson et al, 2010).

- **Bulk Density (BD)**

In a 3-year field study, application of biochar amendment decreased the BD of 0–7.5 cm soil layer by 4.5 and 6.0% for 0.23 kg m^{-2} and 0.45 kg m^{-2} application rate, respectively (Chen.et al, 2011). Zhang.,et al, (2012), also observed a decrease in BD rate of 9.4 (± 2.2%) in a 2-year field study of soils amended with biochar.

- **Soil Structure**

According to Liu et al. (2012), application of biochar (5%) rate encourages good soil particles aggregation and structure stability. Biochar application at a rate of 2.5% and 5% decreased soil loss by 50% and 64% respectively (Jien and Wang, 2013). Good soil structure stability and aggregates maintain soil in situ and as well balanced physical, biological and chemical functioning of soils (Cantón et al, 2009).

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- **Sorption of Heavy Metal**

According to Cao et al. (2009), biochar because of the high content of Ash, is able to adsorb at least 85% of the Lead (Pb) , 50% of Arsenic (As), 70% of Cadmium (Cd) from solution at pH range (5-7) reacting with ash present in the biochar, and also to direct surface sorption AC 15% on biochar surface. The metal adsorptions are possible because of high ion exchange capacity. Presence of biochar in the soil cause breakdown of phenanthrene to a form less toxic (Zhang et al., 2012).

- **Water Purification**

Biochar positively charged surface strongly adsorb agrochemicals and pollutants onto their surfaces there by reducing Eutrophication and pollution. Soil structure aggregation and stability reduces siltation of water bodies by soil debris (Novak et al., 2009; Sai, 2010).

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Table 2: Effects of biochar from different feedstocks on soil properties

Country	Soil Types	Feedstock	Pyrolysis Temperature	Application Rate	Factor	Impact	Remarks	Source
Nigeria	Ultisol	Hardwood	350°C	6.25 t/ha	Cation Exchange Capacity	11% increase	After 2 Years	Mbah et al., 2017
Zambia	Aeolian Sand	Wood stocks	400°C	4 t/ha	Cation Exchange Capacity	2-9% increase	After 1 year	Cornelissen et al., 2013
USA	Spodosol	Hard wood Residues	Not available	0.25Mg m^{-3}	Cation Exchange Capacity	5 % increase	30 weeks	Kristin, 2011
Taiwan	Paleudults	White lead wood waste	700°C	5w/w	Bulk Density	1.42 mg m^{-3}-<1.15 Mg m^{-3} decrease	After 105 days	Jien and Wang, 2013
Nigeria	Ultisol	Hardwood	350°C	6.25 t/ha	Bulk Density	1.53-1.44g/cm^3 decrease	After 2 years	Mbah et al., 2017

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USA	Sandy loam	Hardwood (Red oak)	500°C	6% w/w	Bulk Density	1.43g/cm^3-1.30g/cm^3 decrease	After 91 days	Andress et al., 2013
Taiwan	Paleudults	White lead wood waste	700°C	5w/w	Stability Structure	64% reduction in soil loss	After 105 days	Jien and Wang, 2013
Finland	Silty loam	Birch (hardwood)	400°C	9 t/ha	Soil water Holding capacity	11% increase	After 8 weeks	Karhu et al., 2011
Zambia	Aeolian Sand	Maize Cob	400°C	4 t/ha	Plat Available Water	17- 21% increase	After 1 year	Cornelissen et al., 2013
India	Loamy sand	Rice Husk	900-1100°C	1 t/ha	CO_2	0.9-1% Sequestration	After 4 years	APN, 2009.
Canada	Sandy		800°C	50 g/kg^{-1}	CO_2	77% increase Sequestration	After 84 days	Bekele et al., 2015
China	Not available	Maize cob	500°C	200.34 Mt	CO_2	441.31Mt Sequestration	After 2 months	Stoyle, 2011
Japan	Typic Hapludand	Municipal Biowaste	700°C	10 wt%	N_2O	89% decrease emission	After 120 hours	Yania et al., 2007
Minnesota	Waukegan silt loam	Mixed Saw dust	500°C	60 w/w	N_2O	74% reduction in production	After 5 days	Spokas et al., 2009

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Minnesota	Waukegan silt loam	Mixed Saw dust	500^{o}C	10 w/w	CH_4	60% reduction in production	After 5days	Spokas et al., 2009
Finland	Silty loam	Birch (hardwood)	400^{o}C	9 t/ha	CH_4	96% decrease emission	After 8 weeks	Karhu et al., 2011
Columbia	Oxisol	wood	Data Not available	20 t/ha	Soil pH	pH 3.80-4.27 Increased	After 4 years	Major et al., 2010
USA	Spodosol	Hard wood Residues	Not available	0.25Mg m^{-3}	Soil pH	pH3.9-6.8 increase	30 weeks	Kristin, 2011
USA	Waukegan Silt loam	Macadamia nutshell	550^{o}C	22 t/ha	Soil pH	pH 5.9-7.0 increase	Within 2 Years	Nooker, 2014
Switzerland	Sandy	Swine manure	800-900^{o}C	2 t/ha	Soil Carbon	17.6-68.8% increase	After 500 days	Rogovska, 2011
USA	Spodosol	Hard wood Residues	Not available	0.25Mg m^{-3}	Soil Carbon	79 % increase	30 weeks	Kristin, 2011
Columbia	Oxisol	wood	Data Not available	20 t/ha	Soil available plant nutrients	Increased; Ca=101-320%, Mg=64-217%, Mn=136-342%, Mo= 573-860%	After 4 years	Major et al., 2010

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3.7 Biochar Loss from the Soils

Wind loss

Biochar in fine powdered form is easily blown away by wind during application time. In the biochar field trial in Québec, Canada; it was estimated that 2% of the material was lost loading the spreader, 3% was lost during transport, and 25% was lost during spreading, leading to a total loss of approximately 30% (Blackwell et al, 2009).

Minimizing wind loss

According to Blackwell et al (2009), biochar loss by wind can be minimized in the following 3 ways;

a. Do not apply biochar in strong wind; wait when the weather conditions is favourable. Very fine powdered form of biochar should be applied when the soils moisture is averagely high for good bonding.

b. Very fine powdered biochar should be evenly mixed with water or manure before application to avoid it being carried away by wind.

c. Use biochar formulation like pellets, prills or mix biochar with compost or manure.

Water erosion

The factors such as very high rainfall intensity, steep terrain encourages biochar loss (Major et al. 2010)

Minimize biochar loss by water

Subsurface banding on steep slopes may be ideal when applying powdered form of biochar. Liquid slurries containing biochar could also be injected below the soil's surface (Sistani et al., 2009).

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3.8 Possible Risks of Associated with Using Biochar

Despite all the above positive unique qualities of biochar which can be exploited for carbon sequestration and soil amendments, there are some challenging risks that are associated with its use that needs further investigations and remedy. These challenging risks may include the followings among others;

- **Damage to soils:** Bulk application of powdered biochar in fields beyond the recommended quantity could cause soil compaction. Confidence in the evidence base: low (Peter et al, 2010).

- **Contaminants**: If the organic materials used contain heavy metals it may be retained in the ash after pyrolysis. Pyrolysis process may as well induce production of organic compounds called polycyclic aromatic hydrocarbons (PAHs) example benzo (a) pyrene which are carcinogenic and their content in food substances is strictly regulated (Lerda, 2009).

- **A possible ‘priming effect’:** Biochar may increase mineralization processes making it difficult to use organic mulch once applied (Wardle et al., 2008).

- **Effect of over liming with Biochar:** Altering agronomic soil pH through the addition of biochar may result in unfavorable shifts in above- and below ground flora.

4 Conclusion

Despite the adverse effects which may result from abuse of biochar use or choices of materials to kiln into biochar, biochar remain promising to the degraded soil and land and energy. Biochar application significantly improves not only the chemical and biological but as well the physical properties of the soil; the persistent characteristics of the biochar ensure long-term benefits for the soils and soil microbes. This attributes can be exploited to reduce land/soil degradation, lowering fertilizers and irrigation water needs in arid and semi arid regions. The long stable persistent nature of Biochar accompanied by its slow oxidation level in the soil also enhance effective climate change mitigation by sequestering Carbon dioxide, Methane and Nitrous

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oxides. Thus using biochar in climate mitigation since it can suit all farming systems (Organic, conventional, conservative). Since Biochar augment water and fertilizers use efficiency, supplementary fertilizers use would be of paramount in increasing crop yield however, soil analysis has to be done before application to determine the pyrolysis temperature for production, application rate, and supplementary fertilizers rate. There was a dearth of information on the duration Biochar integration takes into the soil before expressing its quality. Further study has to be done on the time biochar takes from the application to disintegrate into the soil to yield impact.

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