Biochar for Carbon Enrichment in Soils and GHG Mitigation

Content

1 Global Frame

Global demand for food production is continuously increasing with a growing global population. At the same time, global food production is challenged by ongoing land degradation and climate change. Nearly 1/4 of the world's landscapes are considered to be degraded, while rising temperatures and changes in precipitation patterns are likely to further increase the risk of land degradation (IPCC, 2019). Without the implementation of measures to protect and restore soils through sustainable land management (SLM), continuous degradation will have serious consequences on soil and its ecosystem services, such as producing food and fiber, supporting nutrient and water cycling, and providing the largest terrestrial carbon sink (Chotte et al., 2019).

SLM generally provides multiple benefits related to soil and agriculture, such as enhancing resilience of agricultural systems, maintaining or enhancing food production, enhancing soil capacity to buffer against degradation processes, improving nutrient cycling, and protecting and sequestering soil organic carbon (SOC) (Gabathuler, Liniger, Hauert, & Giger, 2009). With proper management using SLM, carbon sequestration in soils and vegetation can contribute to climate change mitigation through negative and prevented emissions (IPCC, 2014), as well as adaptation by impeding land degradation and providing multiple co-benefits for food security and biodiversity (FAO, 2020; IPBES, 2018; Sykes et al., 2020). During the past five years there has been an increase in the development of an enabling political-instrumental environment that would support the adoption of SLM practices that support SOC protection and sequestration . From a climate change perspective, this is illustrated through the Paris Agreement (United Nations, 2015) the Koronivia Joint Work on Agriculture (KJWA) (UNFCCC, 2018), and the Intergovernmental Panel on Climate Change (IPCC) Special Report on Climate and Land (IPCC, 2019) under the UNFCCC. In terms of land degradation, the UNCCD has set Land Degradation Neutrality (LDN) by 2030 as its main target. LDN is also the goal of Sustainable Development Goal (SDG) 15.3 with its indicator 15.3.1 ("proportion of land that is degraded over total land area") which

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consists of three sub-indicators and metrics[1] that includes SOC (Orr et al., 2017).
The 4 per 1000 Initiative, founded alongside the Paris Agreement in 2015, aims to increase SOC sequestration through the implementation of agricultural practices adapted to local environmental, social and economic conditions. Specifically, the initiative focuses on encouraging the transition towards agriculture that is productive, highly resilient, based on appropriate land and soil management, creating jobs and income, and therefore supporting sustainable development.

a large mitigation potential., especially in tropical countries (Griscom et al., 2020).
According to the IPCC's Special Report on Climate Change and Land, the AFOLU sector is essential for Carbon Dioxide Removal (CDR) from the atmosphere. CDR will be in any scenario necessary to reach the 1.5°C target of the Paris Agreement.
The geoengineering technology of Bioenergy production and Carbon Capture and Storage (BECCS) is one popular CDR technology. The IPCC evaluates its potential removal between 0.4 and 11.3 billion tons of

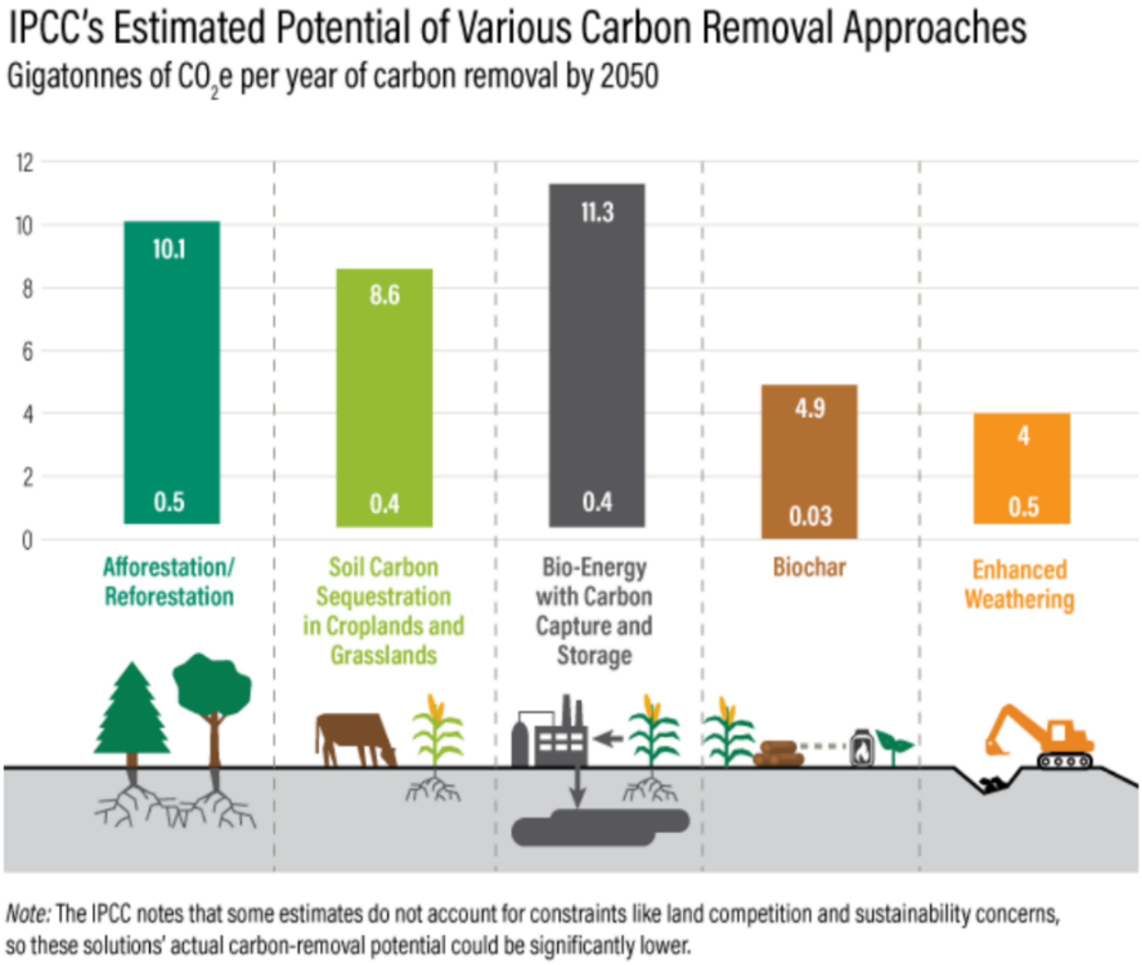

Figure 1 IPCC's estimated potential of various CDR Approaches (GtCO2e yr-1)
Data source: IPCC Special Report on Climate Change and Land. Chart by World Resources Institute

The Agriculture, Forestry and Other Land Use (AFOLU) sector is one of the biggest emitters of greenhouse gases (GHG), with unsustainable land uses contributing 10-12 GtCO2e[2] per year (ca. 25% of global emissions). About half of this is due to agriculture, which is also the most vulnerable sector to climate change (IPCC, 2019). Yet, the land sector, holds

carbon dioxide equivalents (CO_2e) per year. BECCS targets to capture the emissions of bioenergy combustion or biofuel conversion and to store them in geological formations.
Besides BECCS, different options from the AFOLU sector are among the most promising CDR options (Figure 1). They, in contrary to BECCS, store the atmospheric carbon dioxide within the landscapes.

[1] The three sub-indicators (and associated metrics) for SDG indicator 15.3.1 are: land cover (land cover change), land productivity (land productivity dynamics), and carbon stocks (soil organic carbon stocks)

[2] 1 GtCO2e = 1 000 000 000 tCO2e (metric tons carbon dioxide equivalent)

They include: Afforestation/reforestation with a potential removal between 0.5–10.1 billion tons of carbon dioxide equivalents (CO_2e) per year ($GtCO_2e$ yr–1), soil carbon sequestration in crop- and grasslands with a potential removal between 0.4 to 8.6 GtCO2e yr–1, and biochar application with a potential removal between 0.03 to 4.9 $GtCO_2e$ yr–1. Furthermore, enhanced rock weathering is listed with a potential removal between 0.5 to 4 $GtCO_2e$ yr–1 (Jia et al., 2019; Rogelj et al., 2018).
The wide range of the IPCC's estimation reflects the persistent scientific uncertainty concerning the effect of practices that enhance the soil organic carbon content (Levin, 2019). In comparison to other CDR options with a large mitigation potential, an increased soil organic carbon (SOC) content has no adverse impacts on other global challenges (Jia et al., 2019).

SOC protecting or sequestering activities, policies and targets related to agriculture are included in 28 first Nationally Determined Contributions (NDCs) submitted to the Paris Agreement. However, solely three of those quantified indicators for SOC (Wiese-Rozanova et al., 2020). Thus, regardless of the great potential of SOC, their integration in the NDCs remains limited. Constraints to include SOC into NDCs do often exist due to pre-existing challenges on inter alia: measurement, reporting, and verification (MRV), monitoring SOC changes over time and linking those to management practices, and the identification and tracking of relevant measures at the national level (Wiese-Rozanova, Alacantara-Shivapatham, Wollen-berg, & Shelton, 2020).
However, several options to enhance the SOC content exist. Besides the implementation of agroforestry systems or conservation agriculture, one way to support the SOC formation is through the amendment of biochar to the soil, as it can stabilize organic matter (Jia et al., 2019). Furthermore, Biochar itself has implications on climate change mitigation as shown in the previously mentioned IPCC's report as well.
A recently published study by *Bossio et al., 2020* has assessed the greenhouse gas removal potential of various soil-based natural climate solutions. Here, with a potential annual removal of 1.1 billion tons CO_2e, Biochar application has been placed as the second-largest soil-based natural solution, just after afforestation and avoided forest conservation with a potential of 1.2 billion tons of CO_2e per year (Bossio et al., 2020).

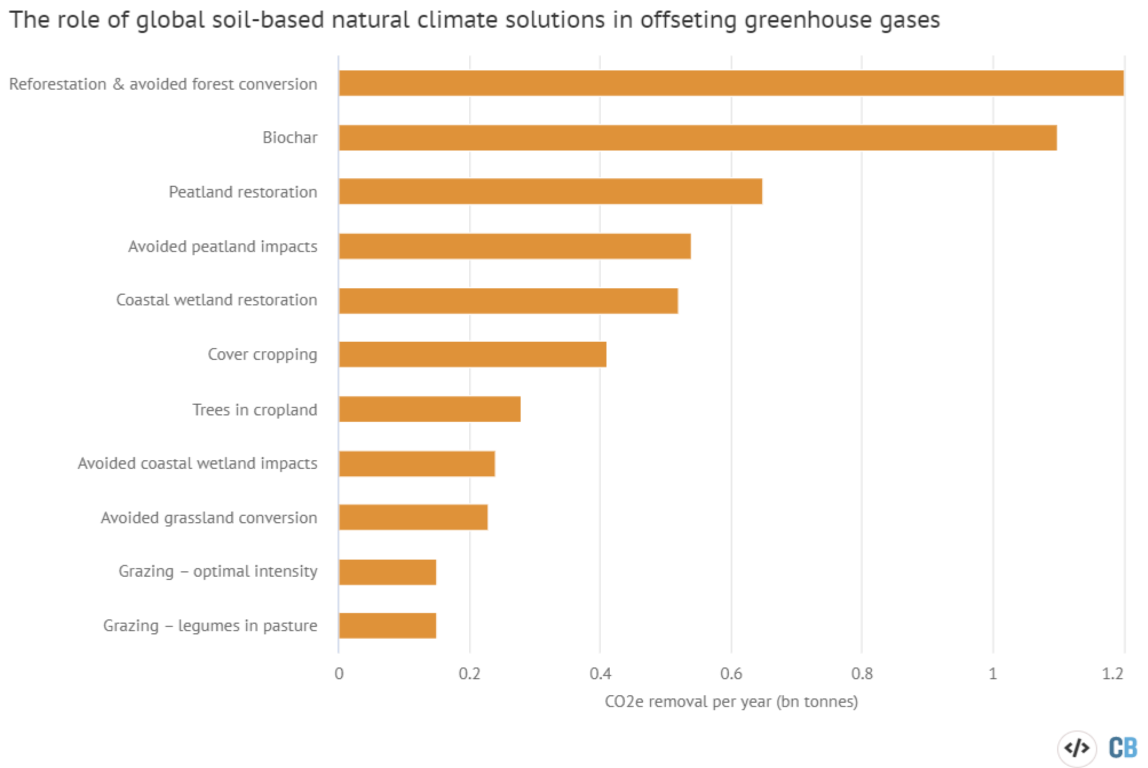

Figure 2 :The global greenhouse gas removal potential of different soil-based natural climate solutions. Data source: Bossio et al. (2020). Chart by Carbon Brief

Biochar application as one soil management option offers, besides its great mitigation potential, several advantages for agriculture but can also contain risks. Therefore, we want to introduce you in the following pages to this promising option to enhance soil health and fight climate change.

2 Biochar in practice

2.1 Biochar: Production and properties

Biochar is pyrogenic carbon. It is defined by the European Biochar Foundation as "a porous, carbonaceous material that is produced by pyrolysis of plant biomasses and is applied in such a way that the contained carbon remains stored as a long-term C sink or replaces fossil carbon in industrial manufacturing. It is not made to be burnt for energy generation." (EBC, 2012).

Pyrogenic carbon is a natural constituent of soil organic matter in many soils around the world. It occurs naturally in soils as a product of incomplete combustion in forest fires. But it can be found as well as an amendment in historically modified soils, such as the highly fertile black anthrosols (Amazon or African black soils), or modern agricultural soils for which it was specifically produced as biochar in pyrolysis systems (Bier, 2019).

Several types of technologies to produce biochar exist and range from non-investment solutions like self-dug Kon-Tikis to big industrial plants. The technologies differ in their amount of investment, manual work, technological construction, biochar yields, and its quality necessary for different purposes.

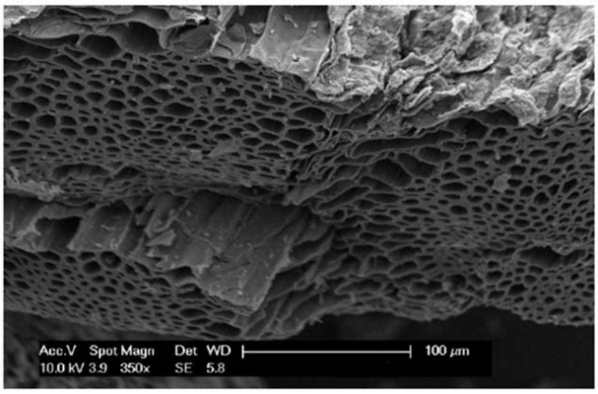

Figure 3: Electron micrograph scan of a sugarcane bagasse biochar (magnification of 350×)
©Eggleston and Lima 2015

Depending mainly on the biomass feedstock, biochar contains between less than 35% and more than 90% of organic carbon. For example, pyrolyzed straw has a carbon content between 40% and 50% and pyrolyzed wood has one between 70% and 90%. The biochar quality depends to a large extent on the pyrolysis temperature, which is between 350°C and 1000°C (EBC, 2012). Due to its stable aromatic carbon structures that are formed during the pyrolysis, biochar can be hardly decomposed by microorganisms and thus remains in the soil for a long term (more than 100 years) and is therefore considered as a carbon sink.

The shape of biochar reminds of a solid structure sponge with a large internal surface area, reaching up to 350-400 m^2 per gram (Figure 3). This property allows biochar, when incorporated in the soil, to adsorb and retain water, ions, and minerals and thus functions as a slow-release structure for nutrients (Schmidt. H.-P., 2016).

The biochar's pH is mostly basic, and thus has a liming effect in acidic soils (Scholz et al., 2014).

2.2 The impact of biochar as a soil amendment on the climate

As described previously, biochar has a large potential for climate mitigation. The potential is attributed to different factors.

The most essential and direct implication of biochar on climate change is probably carbon storage and stabilization. Here, the mitigation effect of biochar is mainly the difference between the emissions associated with the production and decomposition of biochar and the emissions which would be derived from the decomposition of the original feedstock without the pyrolysis process, including methane and nitrous oxide emissions. The rate of decomposition of the biochar depends on several factors. One main factor is the ratio between labile and recalcitrant carbon in the composition of the biochar, which depends on the feedstock and the pyrolysis technique. Other factors affecting the decomposition rate are the climate and the soil conditions. Furthermore, there are indirect factors that contribute to the emission balance, including the utilization of the syngas by-product of the pyrolysis process for renewable energy, and GHG-reductions in the agricultural sector resulting from biochar application. Moreover, biochar has the potential to reduce the need for fertilizers and could, therefore, reduce emissions related to its application and production (Scholz et al., 2014). The highly porous structure of biochar retains water, organic compounds, and chemicals, stabilizes them in the soil and slows down the leaching of mobile nutrients, which reduces soil emissions, such as nitrous oxide, and supports the accumulation of SOC and the formation of humus (Blanco ‐ Canqui, Laird, Heaton, Rathke, & Acharya, 2020; Kammann et al., 2015; Schmidt. H.-P., 2016). Moreover, biochar is likely to address growth constraints of plants, which will lead to higher above and below plant biomass and hence to more stored carbon (Jeffery et al., 2017; Thomas & Gale, 2015).

2.3 Biochar for agricultural productivity

Without further incentives, farmers will hardly adopt climate mitigation methods.
Biochar is more than a sole climate mitigation method and can deliver this as a bonus because it has a positive impact on food production. With its property to act as a carrier material that is neutral to basic pH, biochar is particularly beneficial in sandy, acidic, and low-nutrient soils and in environments where heavy rainfall occurs. This is often the case in tropical countries (Bier, 2019; Jeffery et al., 2017; Schmidt. H.-P., 2016).
Multiple field trials on the effect of biochar on agricultural productivity have been undertaken in the last years, most of them using application rates between 10 to 50 tons per hectare (Schmidt et al., 2015). The found increases in crop productivity differ mainly according to the climate. In a recent literature review, *Robb, Joseph, Abdul Aziz, Dargusch, & Tisdell, 2020* found an average yield growth (% ha^{-1}) of 3,09% per metric ton of biochar in tropical climates, whereby in temperate zones the average yield growth was found to be only a modest 0.71%.
Bearing in mind that the formation of highly fertile black anthrosols was not due to the presence of pure biochar, but rather to the amendment of biochar mixtures with nutrient-rich organic matter, field and pot trials combining biochar with compost and/or manure are increasingly carried out in the last years. The trials indicate a synergy between the highly porous and recalcitrant biochar and nutrient-rich organic substrates. The combination with nutrient-rich organic substrate valorizes the biochar's potential to act as a carrier for nitrate, phosphate, and other nutrients needed by plants (Kammann et al., 2015; Schmidt et al., 2015). *Schmidt et al., 2015* demonstrated that mixing cow-manure compost with urine-loaded biochar resulted in an increase in pumpkin yield of over 300% compared to treatment with compost and cow-urine alone and an 85% increase compared to a compost and biochar-only treatment.
To extract the nutrients captured by the biochar, plant roots and their symbionts must be in sufficiently close contact with the nutrient-laden biochar particles. It is therefore more efficient to apply the nutrient-enriched biochar in the root zone rather than distributing it evenly throughout a field by sprinkling or tilling. This is similar to the application of other soil fertility amendments, such as cow manure or urea fertilizers (Bier, 2019; Schmidt et al., 2015).
Biochar can additionally enhance the efficiency of mineral fertilizer. For this, the fertilizer should be diluted in water until saturated and absorbed by the biochar. This can be helpful in environments where organic fertilizer are insufficient and cannot optimally reach the crops' nutrient requirements (Bier, 2019; Schmidt, Pandit, Cornelissen, & Kammann, 2017).
Schmidt et al., 2017 applied nutrient-enriched biochars (biochar-based fertilization) in 21 field trials at low rates of 0.5-2 tons per hectare into the root zone of 13 different crop species in Nepal. The biochars were enriched with organic or chemical fertilizers. It was demonstrated that the crop yields considerably increased compared to the control treatments with the same fertilization amount and type but without biochar. Furthermore, it was shown that organic nutrient-enrichment of biochar was consistently more effective than enrichment with chemical fertilizers. These findings corroborate with the findings of the recently published study by *Pandit et al., 2020*. They found that the application with cattle urine enhanced biochar increased the yield of banana in a agroforestry based system by 41 percent compared to the treatment with mineral NPK fertilizer.
Besides a greater yield, several other beneficial effects have been observed: the predictability of the yield enhances, the germination time reduces, the cropping seasons lengthen, and the crop's resilience to drought improves. It is important to note, that these observed effects vary depending on the environmental circumstances and biochar amounts applied (Scholz et al., 2014).
Besides being beneficial for crop production, biochar could be used in livestock systems as well. Scientific research on the effects on biochar in fodder is still scarce. However, the experiences made so far indicate that fed biochar has positive effects on blood value, toxin adsorption, digestion, feed efficiency, meat quality, and as well on greenhouse gas emissions. The biochar should be offered to the livestock as a free-choice supplement. In this form, the animals themselves can choose when and how much to consume (MEFT / GIZ Bush Control and Biomass Utilisation project, 2020; Schmidt, Hagemann, Draper, & Kammann, 2019).

2.4 Biochar Adoption

2.4.1 Economic feasibility

Despite significant evidence demonstrating the positive manyfold effects of biochar on the environment, the adoption worldwide has not been as fast as one might wish. This is mainly since it is often not clear if the application of biochar is economically feasible.
The economics of biochar systems depend on numerous factors that are specific to the farmers' circumstances. Parameters that can be directly quantified include the capital and operating costs of the stove or kiln, the cost of the biochar feedstock and the transportation, manual labor, the price of the biochar and

the crop, the savings from reduced agricultural inputs, and the price of pyrolysis co-products such as bio-oil or heat if they are harvested. However, the quantification of parameters, such as enhanced indoor air quality or improved food security, is more difficult, as they are often not monetized. Furthermore, the environmental benefits of biochar application, like climate change mitigation, are (mostly) not rewarded (Robb et al., 2020; Scholz et al., 2014).
To clarify under which circumstances biochar projects are financially feasible, *Robb et al., 2020* performed a comprehensive review including 33 publications. Out of these, 70 scenarios with different characteristics have been extracted and analyzed. The characteristics included the Gross National Income (GNI), the climate, the yield inclusion (whether it was included or not), the crop value, and the technology scale and focus (whether it was focusing on biochar or the coproduct). The scenarios have been aggregated into higher- and lower-income countries orientating on the classifications of the World Bank. In this way, 50 of the scenarios have been performed in higher-income countries and 20 in lower-income countries, which are generally in the tropical and subtropical latitudes. They found that of the 70 reviewed scenarios, 27 scenarios have been financially feasible in terms of the biochar net value, including the revenue of coproducts. Of those, 19 scenarios have been feasible just due to the agronomic net value of the biochar application (excluding coproducts). These 19 scenarios shared several characteristics: They were mostly implemented in tropical (17 of 19), lower-income countries (16 of 19), using small decentralized pyrolysis technology (16 of 19), and focusing on crop yield improvement (19 of 19) in higher-value crops (10 of 19) or cereal crops (9 of 19) as the only source of project value (16 of 19). The authors concluded that “Biochar's cost constraints are overcome in small-scale farming on tropical soils in lower-income countries”, which became also the title of their review.
However, having in mind that particularly in the Global South the biochar application stands in competition to its selling as charcoal, the most attractive option for the smallholder farmer might still be to sell the biochar as fuel, despite the biochar’s agronomic potential. This decision will be influenced by the price of the charcoal and the farmers' financial liquidity, as it can be assumed that the farmer will rather prefer the selling of the biochar as charcoal than investing the biochar into crop production.

2.4.2 Voluntary carbon markets

One option discussed to further boost the attractiveness of biochar projects among farmers is its integration into voluntary carbon markets (VCM). The generation of carbon credits through the application of biochar and their sale holds the potential to reward the farmers for their climate mitigation service and, thus, enhance the feasibility and competitiveness of biochar projects.
(Robb et al., 2020) have analyzed in the previously described review the sensitivity of the scenario’s financial feasibility to carbon prices. They found that of the 70 scenarios, a carbon price of 16 USD, which is achieved under the European Union emission trading system (ETS), increases the number of viable scenarios from 27 to 31. A relatively high carbon price of 77 USD, which is the average price of the Finland carbon tax, increases the viable scenarios from 27 to 44. They concluded that the financial feasibility does not generally depend on high carbon prices, but that it is generally unlikely that the global carbon markets develop to the extent that infeasible scenarios are made feasible by carbon pricing. The European Biochar Industry Consortium (EBI) criticizes the current design of the carbon market to balance net sinks and emissions against each other. The prices of C-sink projects are far above the current prices for emission certificates, however, C-sink projects are needed in all scenarios to reach the 1.5° target of the Paris Agreement (Bier et al., 2020; IPCC, 2019).
Besides well-designed carbon markets, reliable methodology to quantify the GHG emission reductions, and sequestration benefits that result from the implementation of biochar projects are needed for the successful integration. Currently, none of the leading voluntary carbon offset registries, like Verra or Gold Standard, has an approved methodology for the implementation of biochar projects. Carbon Gold has submitted in 2009 its methodology “General Methodology for Quantifying the Greenhouse Gas Emission Reductions from the Production and Incorporation into Soil of Biochar in Agricultural and Forest Management Systems” to the Verified Carbon Standard (VCS) of Verra (Carbon Gold, 2009). However, it is not approved by Verra and needs to be further developed. It is listed by Verra as inactive. In 2013, the International Biochar Initiative, the Climate Trust, The Prasino Group, and Carbon Consulting submitted their “Methodology for Biochar Projects” to the American Carbon Registry (ACR). However, the methodology was also not approved and is classified as inactive. The peer reviewer stated that the scientific literature does not provide sufficient evidence of the stability of soil carbon sequestration in fields treated

with biochar (American Carbon Registry). Now in 2020, none of the big registries, but the European Biochar Certificate (EBC), developed and ensured by the Ithaka Institute, provides for the first time a methodology "Certification of the carbon sink potential of biochar" to independently certify biochar based carbon sinks. The certification is currently available to all EBC certified producers and through cooperation with the International Biochar Initiative (IBI) to North American producers based on the IBI certificate. The partnering with other biochar organizations to provide the C-sink certification in Australia, Asia, and Africa is in the process (EBC, 2020). However, as the Kon-Tiki and other low tech pyrolysis technologies own the risk to emit uncontrolled CH4-emmisions, the certification is only available to technically advanced pyrolysis plants.

2.4.3 Standards for policy support

Besides being crucial for the possible inclusion of biochar into the VCM, the certification of biochar helps to increase political support. Standards are necessary to ensure compliance with programs and policies and can provide a basis for future regulations. Those can be in the form of commercial financial incentives, such as grants, loan guarantees, or tax credits or in the form of non-financial policy support. Non-financial policy programs help a business maintain resilience rather than setting direct financial incentives. For example, a fertilizing material program which includes biochar can leverage market demand and raise public awareness for the benefits of biochar (Pourhashem, Hung, Medlock, & Masiello, 2019).

As many countries lack in supporting policies on biochar and as it is uncertain whether working frame conditions for the integration of biochar projects in carbon markets are established and if yes when this will be the case, project developers should seek alternative forms of financial value creation rather than relying on carbon markets (Robb et al., 2020). This could happen through, for example, the cascading use of biochar, such as the first use in animal husbandry and then as second use as a soil amendment, or the further development and integration of biochar-based fertilizer and the adaptation of them to specific soil and crop constraints.

3 Actor and processes mapping

Biochar projects are implemented around the globe by various development cooperation organizations Also, there are several universities implied in the implementation and research on biochar. During the last two decades, many regional biochar groups have been formed. The International Biochar Initiative (IBI) is providing an overview of the regional groups and is interested in showcasing new activities. The IBI was formed in 2006 at the World Soil Science Congress and provides a platform for fostering stakeholder collaboration and standards to support biochar systems that are safe and economically viable. It is listing several biochar case studies implemented in the global south on their website.

A strong partner of the IBI is the Ithaka Institute. The Ithaka Institute is a non-profit research foundation and is a leading research collaboration for carbon sequestration and cycling through agronomic methods. It developed the Kon-Tiki flame curtain pyrolysis, established the European Biochar Certificate and found the Biochar Journal which is the first international journal entirely dedicated to biochar and carbon intelligence. It has offices in Switzerland, Germany, USA, and Nepal.

4 Literature recommendations

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Schmidt, Hans-Peter; Pandit, Bishnu Hari; Cornelissen, Gerard; Kammann, Claudia I. (2017): Biochar-Based Fertilization with Liquid Nutrient Enrichment: 21 Field Trials Covering 13 Crop Species in Nepal. - A detailed study showing the effects of on-farm prepared organic and mineral **biochar-based fertilizers** on different crops.

Schmidt, Hans-Peter; Hagemann, Nikolas; Draper, Kathleen; Kammann, Claudia (2019): The use of biochar in animal feeding - This review summarizes the state of knowledge up by evaluating 112 relevant scientific publications on the topic of biochar as a **feed supplement.**

Robb, Samuel; Joseph, Stephen; Abdul Aziz, Ammar; Dargusch, Paul; Tisdell, Clement (2020): Biochar's cost constraints are overcome in small-scale farming on tropical soils in lower-income countries - A comprehensive review on biochar's **financial feasibility** including various biochar project scenarios.

MEFT/GIZ Bush Control and Biomass Utilisation project (2020): Biochar from Namibian Encroacher Bush. Practical Guidelines for Producers - This brochure is a **practical guide** for biochar production and application. It takes the reader through the production process step-by-step and provides useful information for anyone interested in the topic

5 Case study on biochar

Restoring grasslands and increasing climate resilience: Biochar production in Namibia

The Bush Control and Biomass Utilisation (BCBU) Project is a bilateral project implemented by GIZ since 2014 on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ) and the Namibian Ministry of Environment, Forestry and Tourism (MEFT). In order to achieve the project's aim of improving the utilisation of bush biomass from restored rangelands, BCBU promotes different value chains, such as wood chips for energy production, bush-based animal fodder, barbecue charcoal as well as biochar.

Figure 6: Bush encroachment has severe impacts not only on livestock farming due to the reduction of the carrying capacity of rangelands, also Namibia's indigenous wildlife is negatively affected by the impenetrable thickening of bushes. ©Colin Lindeque

Namibia faces the challenge of bush encroachment in previously open semi-arid savannah ecosystems, especially in the central north of the country. It is estimated that more than 45 million ha of grassland is bush encroached, entailing negative effects on groundwater recharge, leading to a decline of biodiversity and reducing the productivity of the affected areas on a massive scale. The phenomenon, provoked amongst others by poor rangeland management and climate change, has grown to a problem that causes a severe adverse impact on the country's economy. Furthermore, the mere removal or poisoning of the bushes is a cost-intensive activity that can only be afforded by few farmers in the country. At the same time, bush encroachment results in a sustainably harvestable amount of biomass of over 400 million tons. Therefore, the BCBU Project follows a value addition approach, which enables farmers to turn the problem into an opportunity by utilising the accumulating biomass and thereby diversifying income streams. Since 2014, the project fosters animal fodder, wood chips and barbecue charcoal to become well-established value chains - biochar was the next reasonable step to take from there for the BCBU Project to enhance local value addition.

Even though the use of biochar does not have an agricultural tradition within the Namibian farming community, there are a number of socio-economic and ecological factors that make Namibia a relevant place for both production and application of biochar: A) high quantity of excess woody biomass available that is suitable for high quality biochar, B) both subsistence and commercial agriculture playing a major role in the Namibian economy, C) poor, coarse soils with low nutrient and water holding capacity and D) landscapes that are prone to extreme weather phenomena such as droughts and floods.

Biochar in the Namibian agricultural context does not only have a potential as a soil enhancer but also as an animal feed additive. Biochar, when consumed by livestock as a free choice supplement, is an ideal product

Figure 7: Biochar as a free-choice supplement for chicken. ©GIZ/ Tim Brunauer

for Namibia's large cattle farming industry as it can adsorb pathogens from the animals' stomachs, reduce the methane emissions and improve the overall growth rate.
The BCBU project started its activities on biochar in 2018 when entering a cooperation with a local university on probing new promising bush-biomass-based value chains for Namibia. After encouraging preliminary results, the project called for a first public roundtable on biochar to facilitate exchange among stakeholders and to outline the status quo of biochar in Namibia. The high interest for further discussions on the topic among participants of the roundtable lead to the establishment of thematic working groups.

Figure 8: Biochar application for horticulture in Namibia ©GIZ/Tim Brunauer

Thereafter and guided by the working groups, the BCBU Project's approach to establish the value chain in Namibia can be broken down into three main areas of action.

Firstly, the project acknowledges that the lack of understanding and knowledge is one of the main barriers (inter-)nationally that prevents famers from using biochar and thus puts a strong focus on awareness raising, outreach and capacity development. In light of that and together with Namibian sector organisations and academia, a biochar brochure was developed as a practical hands-on guideline for production and application. Hereby, international best practices are condensed and adapted to local circumstances in order to provide step-by-step instructions for farmers. Furthermore, a series of public events for farmers, entrepreneurs and the media were scheduled to create awareness for biochar in the country.

Secondly, the project supports Namibian academia to conduct practically-oriented research on various aspects of biochar, such as ideal feedstock composition, fertilizers and inoculates, adaption of low-budget technologies to local circumstances as well as application in the field. In conjunction with the efforts on awareness raising above, certain parts of the research trials are implemented with farmers and are meant to serve as showcases. Apart from that, biochar samples produced in a Kon-Tiki kiln from encroacher bush were sent to a German laboratory to test its properties and its overall suitability for international accreditation. The analysis revealed that the Namibian biochar is of excellent quality for all kinds of possible fields of application and would fall under the highest classification of the European Biochar Certificate standard ("feed quality").

Thirdly, economic viability of the value chain remains a central issue for farmers. The project's attempt to answer the question is threefold and related to the type of use. A) There is large potential for self-sustaining local application to enhance crop and livestock production. The different technologies that are locally available, allow biochar production also with a minimal investment and make it suitable for large-scale production for commercial application on crop fields as well as small-scale production for personal use in Namibia. B) Due to the close to infinite amount of available biomass, export is a potential second option for Namibian biochar to make it a viable value chain. International demands for biochar have been on a steady rise in the past years. Together with international networks and partners, export markets are currently explored to define if there are opportunities for Namibian commercial producers. C) The project also screens the potential of biochar to be eligible for being subsidised by international climate funding.

Figure 9: Namibian research partners work also on technologies that are adapted to the needs and habits of the people. Here a TLUD stove that produces biochar as well as heat for cooking. ©Dr. Ibo Zimmermann

So far, there have been some few entrepreneurs that look into biochar from a commercial perspective in Namibia and some farmers that produce biochar with either Kon-Tiki kilns or Top Lit Up-Draft Gasifiers for own horticultural use. Due to the immense Namibian livestock industry, slurry from cattle farming has been widely available and used for conditioning of the biochar before applying to the soil. Also, chicken manure has been proven to be equally effective and been mixed in a 4:1 ratio with biochar and kept moist in large drums for 14 days to ensure charging and inoculation before applying to the soil.

Namibian biochar production is still at an infancy stage, but with private sector, academia and government already on board, biochar has the potential to become a main pillar in Namibia's effort to adapt to climate change and strengthen the resilience of rural, agriculture-dependent communities.

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