Bush Control and Biomass Utilisation Project

Beyond Bush

Biochar

from Namibian Encroacher Bush




Practical Guidelines for Producers

german cooperation
DEUTSCHE ZUSAMMENARBEIT

Implemented by
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

NAMIBIA UNIVERSITY OF SCIENCE AND TECHNOLOGY

BUSH
BIOMASS UTILISATION BY SUSTAINABLE HARVEST

NCA
Namibia Charcoal Association

N-BiG
Namibia Biomass Industry Group

Introducing the **Bush Control and Biomass Utilisation** Project

Namibia is affected by bush encroachment on a massive scale. The phenomenon currently affects up to 45 million hectares of farmland in 11 of the country's 14 political regions which amounts to up to 50 per cent of Namibia's land area. Bush encroachment has reduced the country's rangeland production capacity by up to two thirds in the past decades. It has further resulted in a loss of biodiversity and limited groundwater recharge on the affected areas.

Despite the negative impacts, **the encroacher bush is an enormous natural resource,** estimated at more than 400 million tonnes of sustainably harvestable biomass. Measures to combat bush encroachment create opportunities for the Namibian economy, such as the use of the resource for power generation and value chain development in other sectors. Bush thinning therefore offers the potential to increase agricultural productivity, economic growth, employment and energy security without competing with food production.

Taking these opportunities into account, the **Bush Control and Biomass Utilisation (BCBU) project** aims to promote the sustainable utilisation of bush biomass, thereby contributing to rangeland restoration and economic development in Namibia. The bilateral project is commissioned by the **German Federal Ministry for Economic Cooperation and Development (BMZ)** and is implemented by the **Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH** in cooperation with of the **Namibian Ministry of Environment, Forestry and Tourism (MEFT)** from 2018 until 2021.

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WHAT IS THIS BROCHURE ABOUT?

Adding value to encroacher bush and utilising it for a variety of products such as animal fodder, wood chips or charcoal has proven effective as a means to countering bush encroachment and achieving additional socio-economic benefits in Namibia. Biochar from bush biomass is yet another opportunity.

This brochure is a practical guide for biochar production and application in Namibia. It takes the reader through the production process step-by-step and provides useful information for anyone interested in the topic.

With kind contributions from Namibia Charcoal Association (NCA) and Namibia Biomass Industry Group (N-BiG), this brochure is an outcome of the collaboration between the GIZ Bush Control and Biomass Utilisation Project (BCBU) and the BUSH Project of Namibia University of Science and Technology (NUST).

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Biochar and Bush Encroachment in Namibia

Bush encroachment provides a great opportunity for Namibian farmers to utilise excess bush biomass. Besides well-established value chains, such as charcoal, wood chips or animal fodder, the production and application of biochar presents another good option for Namibian land users to counter bush encroachment.

It looks just like charcoal. But it is something a bit more special: Biochar. Any type of Namibian woody bush species can be used to produce this interesting product.

Different feedstock (left) and different products (right): Animal feed (back), biochar (middle) and charcoal (front) neither compete for the same feedstock nor for the same market.

Biochar Production

- only requires simple machinery and can be produced easily on-farm for own agricultural use or for commercialisation.
- strengthens a diverse year-round utilisation of bush biomass.
- targets different markets than barbecue charcoal and thus complements charcoal from an off-take perspective. Biochar markets internationally are booming, and demand is rising.
- can be produced from any type of Namibian encroacher species.
- plays a completive role in a more holistic approach to bush control and biomass utilisation. While charcoal and wood chips are extractive value chains, the use of biochar is inherently additive and promotes a better nutrient cycle for the soil, especially when used on the site it was produced on.
- complements the production of barbecue charcoal or animal fodder as biochar is easily produced from fine and medium sized bush fractions, which are typically too big for animal fodder and too small for charcoal production.

An Introduction to Biochar

Biochar is a solid material that can be obtained when biomass is carbonised under limited supply or absence of oxygen. The production process resembles the burning of regular charcoal.

What is Biochar?

Biochar is a form of black carbon that is similar to but also distinctly different from barbecue charcoal. It is an interesting material for farmers and agricultural practitioners worldwide due to its resistance against humification and mineralisation, its porous texture with a large inner surface and its adsorptive and absorptive capacity.

The adsorptive capacity of biochar refers to its capability to make gases, liquids or dissolved solids (temporarily) adhere to its surface. The absorptive capacity is the biochar's capability to take in (or "absorb") substances into its own volume, comparable to a sponge.

Usage of Biochar

The production process resembles the burning of regular charcoal, but other than charcoal that is produced for braaing, biochar is used differently, amongst others for the following three purposes:

Soil Enhancement

The application of biochar can positively influence the physical, chemical and biological properties of soils and thereby boost their productivity.

Biochar can realise its full potential under environmental conditions that are prevalent in Namibia – nutrient poor soils and low or irregular rainfall. Soils which are treated with biochar to increase soil organic carbon are more resilient to extreme weather phenomena such as droughts and flooding, can hold more water and can deliver improved agricultural yield.

Animal Health

Even though the use of biochar as a livestock feed supplement is a rather recent development, there is already proof of its benefits for animal health. When supplemented correctly, ideally as a free-choice additive, biochar has shown to improve digestion, increase growth rates, improve overall health, vitality and appearance, reduce methane production of cattle, and increase milk protein and fat in cattle.

Due to its stability and resistance against digestion and decomposition, the utilisation of biochar as an animal feed supplement has cascade effects if the manure is applied on the land.

Biochar can be applied on crop fields to permanently improve soil properties and sequester carbon.

Carbon Sequestration

The soil application of biochar has impacts on a wider scale since it has the potential to positively affect the world's climate. Applying biochar into soils can fix additional carbon for thousands of years and thus presents a solution to encounter global climate change. It is estimated that 1 kilogramme of biochar applied to soil is able to sequester approximately 3 kilogrammes of CO_2.

While the first two applications for soil and animal health can create an immediate surplus for the farmer, the storage of carbon in the form of biochar has benefits beyond the farm level. Financing models for the utilisation of biochar in this regard are discussed in the market chapter of this brochure.

COMPARING BIOCHAR AND CHARCOAL

	Biochar	Charcoal
Application	• Soil enhancement • Animal health • Carbon sequestration	Heat generation for barbecuing ('braaiing')
Burning Technology	• Kon-Tiki kiln • TLUD stove • Retort	• Charcoal kiln • Retort
Burning Temperature	ca. 700 °C	ca. 450 °C
Production Steps	**1.** Burning **2.** Quenching **3.** Crushing **4.** Charging* **5.** Inoculating* *only for soil application	**1.** Burning **2.** Sieving
Ideal Feedstock	Any encroacher species, diameter of 1-4cm 	Any encroacher species, diameter of 5-18cm 
Ideal Product Size	Thin twigs (before crushing) or granulate, powder (after crushing) 	Chunks 
Texture	porous	solid
Hazardous Residues	low	medium
Specific Surface Area	>300 m^2/ g	<190 m^2/ g

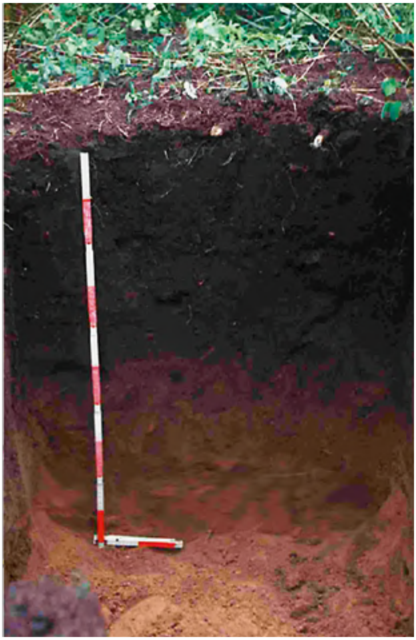
The History of "Black Soils"

Using carbonised biomass for soil enhancement is certainly not a new idea. As a counter measure against soil degradation, societies have come up with a smart solution: carbonised biomass, conditioned with kitchen waste, bones, urine and other nutritious additives were incorporated into the soil.

A famous historic use of biochar can be found in the Amazon Basin of South America – the "terra preta" which means "black soil" in Portuguese. Pre-Columbian societies recognised the generally poor characteristics of the soils of the tropical rainforest and included carbonised biomass in their soils.

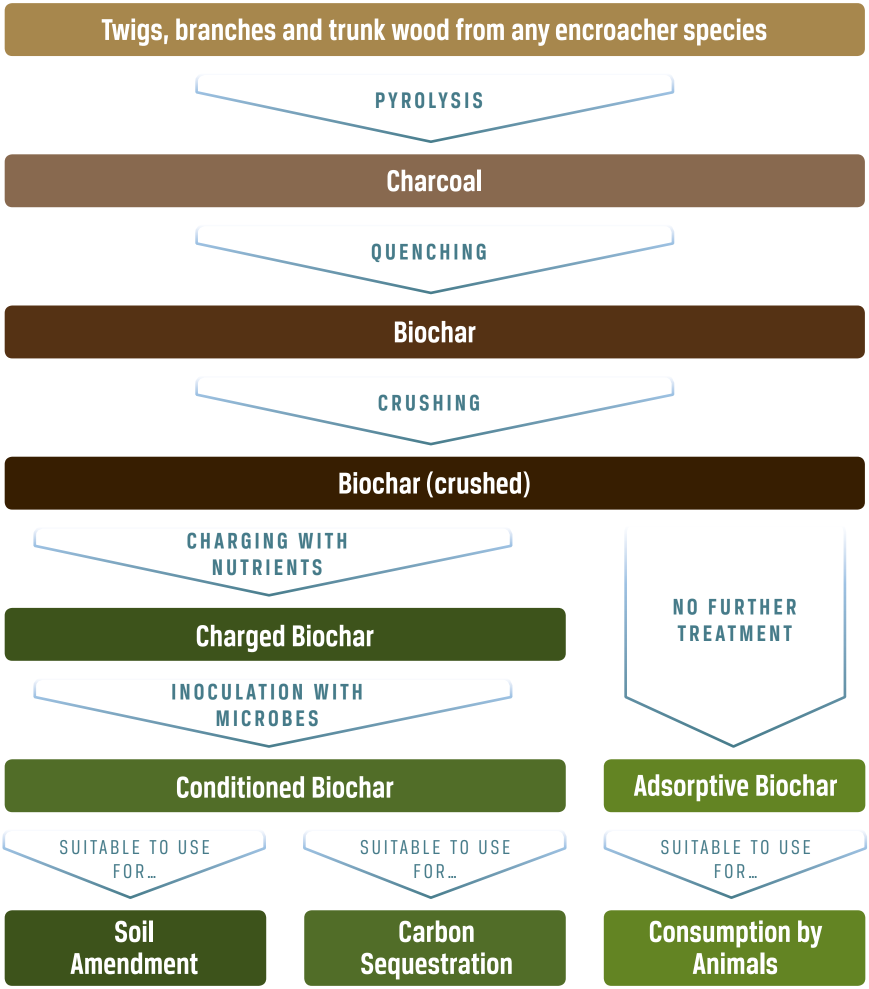
The fact that more than 2000 years later the carbon in terra preta still verifiably improves soil health on site is a clear indication of the long-term benefits of biochar.

Although less documented, Western and Southern Africa too has soils to which biochar has been added, presumably by farmers centuries or millennia ago and recently scientists discovered the first evidence of "terra preta" in Asia, on the Indonesian island of Borneo.



A typical soil profile of the tropical rainforests on the left side with a rather infertile Ferralsol compared to fertile, carbon rich terra preta on the right side. © Prof. Dr. Bruno Glaser

ALL RELEVANT STEPS OF THE BIOCHAR PRODUCTION PROCESS



The choice of feedstock biomass for biochar production depends on local availability of material. Biochar can be produced from crop residues, manure, wood, or wastes from agro-processing industries. All species of Namibian encroacher bush can be utilised.

Production of Biochar

Harvesting bush, setting up the burning operation, supervising the burning process, quenching and crushing are the main production steps for biochar.

Harvesting

The different harvesting methods can be divided into three main approaches: 1) manual, 2) semi-mechanised and 3) mechanised harvesting. All methods have their strengths and weaknesses, depending on the desired production output.

All harvesting operations should adhere to the Namibian forestry regulations and a harvesting permit from the Directorate of Forestry (DoF) has to be obtained. Details can be found in the brochure "Forestry and Environmental Authorisation Process for Bush Harvesting Projects" from the De-bushing Advisory Service (DAS), available for download at www.dasnamibia.org/download.

Only selective bush thinning will lead to successful restoration of rangeland. Therefore, it is important that the environmental impacts are always considered.

OVERVIEW OF HARVESTING METHODS

	Example	Description	Cost
MANUAL		**Tools include:** Axes, machete / panga, backsaw Low skill requirements but knowledge is needed on the type of bush to be harvested. **Output:** One worker can harvest roughly 1 t/day. This includes the chopping into small pieces suitable for biochar production.	**Labour:** NAD 180-220/t direct labour costs per harvester **Equipment:** NAD 250 worth of equipment per worker; lasts approx. 3 working months
SEMI-MECHANISED		**Tools include:** Brush cutter, chain saw, bosvreter Skills are required for safe use of equipment and maintenance. Knowledge is needed about the type of bush to be harvested. **Output:** Roughly 4 t/ day per worker. This includes chopping into small pieces suitable for biochar production. Semi-mechanised harvesting requires that workers only work 5-6 h/ day with these tools as they need maintenance. Workers also get tired and thus handling the tools becomes dangerous.	**Labour:** Min. NAD 50/t direct labour costs **Equipment:** NAD 10,000/ power tool, incl. spare parts; NAD 10 per working hour of operation for fuel and oil consumption. Power tools last for >1 year if well cared for. Chains and blades must be sharpened daily and exchanged after approx. 3 months of continuous production. For rental options of semi-mechanised harvesting equipment, please contact N-BiG.
MECHANISED		**Equipment includes:** Front end loader, loggers or excavators. In addition, manual or semi-mechanised equipment is needed to chop the bush into small pieces suitable for biochar production. **Output:** Roughly 4 h/ day. Depending on the technology, an output of 16-24 t/ day can be expected for harvesting, excluding chopping the bush into a suitable size.	**Labour/ Equipment:** NAD 230-780/hr of operation on a rental basis (not incl. labour, fuel and maintenance costs) or NAD 615-2080/ ha (incl. labour, fuel and maintenance). Purchasing new equipment (costs between NAD 500,000 and NAD 1,000,000) is not advisable for biochar production, unless a business model has been defined. For rental options of mechanised harvesting equipment, please contact N-BiG.

Setting Up the Burning Operation

Site Preparation

Since there is a risk of fire spreading, an area of at least 5 metres around the kiln must be cleared of any flammable material. Especially in the dry season, it is important to be vigilant against veld fires.

As water is required for the quenching process of biochar, it is advisable to set-up the biochar burning site in the vicinity of water access points in order to avoid unnecessary transportation between the different treatment steps. Note that the quench water can be re-used for quenching. Only periodic top-ups are needed.

Workers

- Protective clothing is required, especially safety boots, gloves, overalls, FFP2 safety masks.
- All employees must be treated according to the applicable laws in Namibia, e.g. the Labour Act.

Feedstock

All Namibian encroacher species are suitable to produce biochar. Species with harder wood, such as sickle bush *(Dichrostachys cinerea)* can generally yield good biochar quality, but may be a bit more difficult to crush later on if thicker pieces of wood are used during the burning process. An overview of all relevant Namibian encroacher species can be found on the DAS website under www.dasnamibia.org/download.

Even though the feedstock should be fairly dry when used for biochar production, the Kon-Tiki technology requires only the initial wood to be dry enough to light a fire from. Afterwards, even fresh wood can be added, as it will rapidly be dried by the intense heat from below. Nevertheless, when fresh wood is used an increase in smoke emission should be expected.

In general, bush wood of any size that fits into the technology used for production can be converted to biochar, including thicker stems as

NAMIBIAN GUIDELINES ON CHARCOAL PRODUCTION

As long as there are no specific biochar regulations in the Forest Act, producers have to stick to regulations for normal charcoal production, which include (but are not limited to):

1. Trees with stem diameter of more than 18 cm at ground level may not be removed unless approval is granted.
2. An area of at least 5m around the kiln for production must be cleared of any flammable material.
3. No protected species must be removed unless special permission is granted.
4. All employees must be treated according to all applicable laws in Namibia.
5. Kilns must be guarded at all times.
6. Firefighting equipment must be on site at all times.
7. Burning may not be done within 1 km to the nearest house or dwelling.

The ideal feedstock for biochar has a diameter of 1-4cm and thus does not conflict with animal feed or charcoal feedstock.

well as thin twigs. However, bushes with a stem diameter of more than 18 centimetres at ground level are not allowed to be harvested in Namibia by law and must therefore not be used for biochar production unless special permits were granted. In order to avoid extensive crushing of the product later on, diameters between 1 and 4 centimetres are ideal.

An improved output can be achieved if input material of a similar size and moisture content is used.

If the biochar is used as an animal feed additive, it is not recommended to use feedstock from chemically treated bushes (chemical bush thinning) as the agents may cause harm to the livestock.

The Burning Process

High temperatures are needed to produce high quality biochar. Temperatures of around 700°C are helpful to drive out hazardous residues such as Polycyclic Aromatic Hydrocarbons (PAH) from the char. A traditional charcoal kiln only reaches temperatures of ca. 450°C which makes it less suitable for biochar production of an acceptable quality.

The conversion rate from wood to biochar lies between 3:1 and 4:1, similar to barbeque charcoal. Variations depend on the technique used. For an output of 1 kilogramme of dry biochar, an input of 3-4 kilogrammes of dry bush biomass is required.

With the technologies introduced below, temperature and air supply adjust automatically. A wind shield may be needed if wind interferes.

Choosing the right kiln technology is critical. Kiln technologies that are recommended for the

Wood is added from the top of the kiln.

Kon-Tiki kiln with an inlet for direct water supply and swivel technology for easier handling.

If no kiln is at hand, biochar can also be produced in a hole in the ground.

Namibian context are the Top-Lit Updraft (TLUD) stove for small-scale production, the Kon-Tiki kiln for medium-scale production, and the Industrial Retort Kiln for large-scale production. Alternatively, a hole of appropriate shape and size could be dug in the ground for much lower cost, but the quality of biochar would likely be lower, and quenching would waste water or require use of sand.

Kon-Tiki Kiln

This kiln was specifically designed to produce biochar. Its upwardly open shape has been field-tested in Namibia as well as on an international level. Different designs exist and all of them can yield satisfactory results for all types of biochar. The production capacity of this technology is scalable and can range from small kilns to very big models, depending on the demand of producers.

It can take 3 hours to produce roughly 100 kilogrammes of biochar in a standard Kon-Tiki kiln or 4 hours in a large Kon-Tiki kiln with an output of more than 300 kilogrammes.

For a standard size kiln of $1m^3$ prices can range around NAD 7,500. A large Kon-Tiki kiln with an intake of up to $3m^3$ of biomass costs approximately NAD 22,000. Kon-Tiki kilns can be produced on demand by several manufacturers in Namibia, see contact list at the end of this brochure.

KON-TIKI BURNING PROCESS*

Step 1

Build a stacked chimney of dry bush in the middle of the kiln. It should be about three-quarters of the kiln height.

Step 2

Ignite the stack on top with some tinder. Once the top rows of the stack burn well, it creates a train that pulls air down the sidewalls of the kiln and back up through the middle of the wooden chimney. After about 10 minutes, burning wood falls down from the top and ignites the base as well, burning from the bottom of the stack to the top. After another 5 to 10 minutes the stack collapses and spreads evenly on the bottom of the kiln, creating a hot bed of embers. The surface covers with white ash.

Step 3

Once the surface of the ember is covered with white ash, a layer of bush biomass should be added, covering the ember evenly but not too thickly.

Step 4

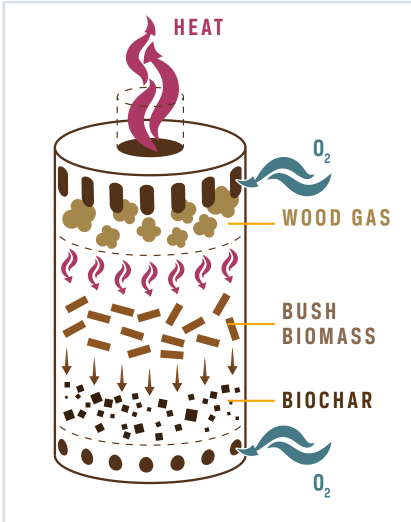
When this new layer also gets coated with white ash, the feedstock has reached the right temperature and pyrolysis will continue even without flaming combustion. It is now time to add the next layer of bush biomass. This will maintain a powerful flame front above the pyrolysing material to consume oxygen, to combust the smoke and thus to protect the biochar.

Step 5

This process is repeated for all the subsequent layers of bush every 5 to 10 minutes until quenching. Consequently, working with the Kon-Tiki requires the constant presence of a person to add new layers of biomass. If one waits too long, the char starts to oxidise, which reduces the yield and increases ash production. Take care not to lay on too much too fast as this will weaken the flame, reducing its ability to capture the fumes and allowing smoke to escape. Generally, the kiln should not be filled with bush biomass higher than 10 centimetres from the top edge. Ensure that the last few layers of bush consist of thinner material that can pyrolyse faster.

* The description of the burning process is based on SCHMIDT, H.P., TAYLOR P. (2014): Kon-Tiki – the re-democratisation of biochar production. For further information please see the link provided on page 34.

TLUD gasifier for small scale biochar production



Principle functioning of a TLUD stove.
©GIZ/ Christa Roth (adapted)

Top-Lit Updraft (TLUD) Gasifier

The TLUD micro-gasifier is also specifically designed to produce biochar. But unlike with the much bigger Kon-Tiki kiln, it is possible to use its excess heat at the same time, e.g. for cooking or boiling of water, making it a suitable household solution.

This technology is also a good option for anyone who wants to test the production of quality biochar for own small-scale use before venturing into an up-scaled or commercial production.

In a TLUD stove, thin twigs can be converted to approximately 1 kilogramme of biochar in 10 minutes and larger bush wood may take 30 minutes to produce roughly 3 kilogrammes of biochar.

TLUD stoves usually have a capacity of 30 litres and costs less than NAD 1,000. Commercial manufacturers still need to be identified, but due to its comparably simple design, any metal working business should be able to assist, even if using only hand tools.

TLUD BURNING PROCESS

Step 1

Remove the top part of the stove and loosely fill up to about two thirds of the inner drum of the stove with bush biomass.

Step 2

Place some kindling on top of the fuel, replace the top part of the stove and set the kindling alight.

Step 3

Now you can place a pot with food or water over the flames and wait until the biomass is fully pyrolysed.

Retort kilns are also used for charcoal production

Industrial Retort Kiln

Large retort kilns can be suitable for biochar production if the achievable temperature is adjustable and beyond 600°C.

A retort heats indirectly and the fire does not come into contact with the wood. The advantage of a retort is that there is very little risk of the wood turning into ash and therefore biochar can be made out of very fine materials.

If biochar is produced commercially in large quantities, retort kilns are the most suitable technology. However, this is the most expensive option and procurement should only be considered if a commercial uptake of the final product is guaranteed.

Quenching of biochar with a hose in a Kon-Tiki kiln

Inlet for quenching from the bottom

Quenching

The term quenching refers to the production step that terminates the burning process through the application of water to the hot biochar. It is the first production step that clearly distinguishes biochar from barbecue charcoal.

By applying water to the char in the kiln/ stove right after the last layer of biomass is sufficiently pyrolysed, the quenching helps to clean the product, increases the pore volume of the biochar and thus makes it more receptive for nutrients and microbes than conventional charcoal. As soon as the water encounters the hot coals, it turns to steam. The 600-700°C steam rises through the char bed and not only makes for a slow quench, but also partially activates the biochar at the same time.

Depending on the technology that is used for burning, the water can either most effectively be applied from the bottom through an inlet, which blasts steam through the whole batch of biochar or less effectively applied from the top, e.g. by means of a hose. In this case, the steam blasting is optimal only in the upper layers of biochar. The amount of water that is needed depends on the size of the kiln as well as on the amount of biochar therein.

Ideally, enough water is added to soak also the last layers of biochar.

Generally, normal tap water is used for quenching. Nonetheless, if the biochar is to be used for soil application, dissolving fertilisers into the quench water is considered more beneficial than mixing fertiliser into the biochar after the burn. It achieves better penetration into the biochar's pores during quenching.

The quench water can remain in the kiln for several hours.

Quenched biochar in a Kon-Tiki kiln

With a Kon-Tiki kiln, the water can be drained out to separate it from the biochar with the help of an outlet/ tap on the bottom of the kiln. The quench water can be reused for further quenches. It only needs to be topped up after each cycle.

With a TLUD stove, the lid of the stove can be lifted off once it has cooled down and the biochar can be poured out.

In a Kon-Tiki kiln, the biochar will be sufficiently cool to handle after approximately an hour, while a TLUD stove cools much faster and can be handled after approximately 10 minutes.

Note: Biochar can alternatively be quenched with sand, but unlike water this fails to clean out the biochar's pores and requires sieving to separate out the sand. Furthermore, there are indications that the alkaline quench water can be diluted and used as a beneficial tonic for application on fruit and vegetable plants. Quench water is diluted with normal water in a 1:10 ratio and then applied weekly to the leafs of the crops or to the soil .

TIP

Capture and re-use quench water, either for further quenching cycles or for application on fruit and vegetable plants.

Crushed biochar can be as small as powder or granulate

Crushing

Large chunks of biochar can be crushed into smaller pieces after quenching, possibly to granulate size, for improved applicability. Some farmers use a hammer mill, other options include a cement mixer with a few round stones, or a roller press.

For crushing, biochar must be of the correct moisture content to prevent dust when too dry or avoid turning into a sticky paste when too wet. This is usually achieved by crushing about a day after quenching.

After burning, quenching and crushing, the produced biochar is generally ready for application as a feed additive. However, in order to avoid adverse effects, there are a few more steps necessary in case the biochar is used for soil enhancement.

Use of Biochar for Soil Enhancement

Using biochar for soil enhancement is relevant for both small scale horticulture as well as medium to large scale commercial and organic agricultural production.

Biochar can improve the holding capacity of soil for moisture, nutrients and beneficial microorganisms due to its specific properties.

Absorption Capacity: Biochar is extremely porous and has a specific surface of more than 300 m^2/g*. Due to this high porosity, biochar can absorb up to five times its own weight in water, including the nutrients dissolved therein. This property is referred to as the absorption capacity of biochar and can, depending on the type of soil and climate, halve the required water for irrigation. Especially in those areas of Namibia that face regular water scarcity, biochar can be a useful tool to optimise agricultural production.

Cation Exchange Capacity (CEC) indicates the capacity of a soil to hold exchangeable cations. A high CEC increases the soil's ability to hold onto essential nutrients and provide a buffer against soil acidification. Soils with higher organic matter tend to have a higher CEC whereas sandy soils rely heavily on the high CEC of organic matter for the retention of nutrients. Most Namibian soils have a notoriously low CEC which could be raised with the use of biochar. A sandy soil's CEC could also be raised by addition of clay, but biochar has the advantage of also raising the soil's anion exchange capacity (AEC).

Habitat Creation: As biochar adsorbs nutrients, microorganisms find ideal habitats in and around the char. This benefits the entire microbial revitalisation of the soil and thus the potential for symbioses between microorganisms and plant roots.

Conditioning of Biochar

Freshly produced biochar is sterile and porous. If added to soil in this state, it will typically absorb nutrients and water from the surrounding soil, decreasing their availability to plants during the first months or years after application. The biochar will only be charged naturally at a very slow rate.

Biochar is not in itself a fertiliser, but rather a potential carrier for nutrients and a habitat for microbial communities. In order to bring its soil enhancing properties to effect on a short-to medium-basis, it is therefore important to condition the biochar by charging it with nutrients and by inoculating it with beneficial microorganisms before its application.

*As a comparison: a regular tennis court has a size of around 260m^2.

Charged and inoculated biochar – ready for soil application

There is no catch-all solution for successful charging and inoculation of biochar, but the following principles should be adhered to:

- The charging time should be at least 14 days.
- There must be enough moisture to dissolve the nutrients and recharge the pores of the biochar.
- The greatest possible variety of organic (carbon-based) nutrients should be made available.

CONDITIONING

refers to the process of preparing biochar for soil application. Conditioning biochar consists of two steps: **1) charging** the biochar with nutrients, either before or after burning and **2) inoculating** the biochar with microorganisms after the burning process. Depending on the production method used, both processes can practically be merged to take place at the same time.

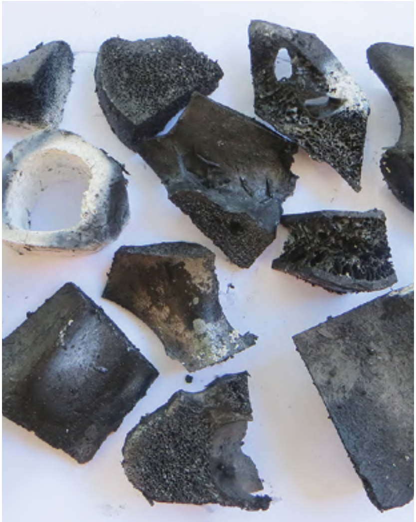
Charging with Bones

If available, animal bones can be used to charge the biochar with calcium and phosphorous. In order to charge the biochar with bone minerals, you add approximately 10 per cent of dry bones during the burning process to the kiln/stove.

If charged with bones, the biochar should ideally still be inoculated with microorganisms before applied to the soil.

Charging with Fertilisers

Fertiliser efficiency increases when mixed with biochar as leaching of nutrients is significantly reduced. Approximately half of the conventionally calculated amount of fertiliser may be required when combined with biochar. It is ideal to use fertilisers that contain a variety of nutrients. The fertiliser is put in a container (e.g. a drum), dissolved in a sufficient amount of water and then mixed with biochar. Biochar is then added until the entire fertiliser is soaked by the char. In



Bones can be added during the burning process if the biochar is meant to be used for soil enhancement.

addition to NPK – nitrogen (N), phosphorus (P) and potassium (K) – fertilisers, organic liquid fertilisers are a good alternative for charging biochar. Urine slurry is ideal, especially in a farming setting, where it is usually readily available.

When charged with fertilisers, the biochar should ideally still be inoculated before soil application to ensure microbial colonisation.

Charging and Inoculation with Compost

Adding biochar to compost is ideal: Microbial life is high in compost, nutrients are already built into complex organic compounds and the finished substrate comes very close to the humus of the soil.

When adding biochar to ripe compost, both are well mixed in a ratio of 1:1. The mixture should be done at least 2 weeks before incorporation into the soil and turned at least twice and thoroughly moistened during this time.

The compost itself can also be made with chipped encroacher bushes and biochar could be mixed in before composting.

Charging and Inoculation with Manure

A mixture of different types of manure is preferable to a single type. Experts advise to store the manure first for a while and to ensure a high straw content. The ratio of biochar to manure should be about 4:1. The mixture should be prepared at least 14 days in advance, kept moist and turned several times before entering the soil.

Alternatively, in an intensive livestock farming system, e.g. in a feedlot or kraal, biochar can be used as litter on the floor. It will then be crushed by hooves while being mixed with dung and urine. Such kraal applications will also help the ground in the kraal to dry out more quickly after rain, and the biochar will help adsorb and reduce the bad smells.

Charging and Inoculation with Bokashi

While conventional composting relies on aerobic bacteria, bokashi composting uses lactic acid bacteria in an anaerobic environment. Organic matter is fermented. Biochar can be beneficial in this process as its high surface area offers a habitat for more bacteria and as it can bind ammonia and thus reduce bad odours that would otherwise attract flies. The combination of biochar and bokashi is especially suitable where the focus is on breaking down non-compostable food waste such as meat or dairy or human manure.

Application into the Soil

Inoculated biochar should be kept moist. It is therefore easiest applied during the rainy season or during irrigation.

The conditioned biochar can be sprinkled on top of the soil, worked in the soil superficially or added selectively to the respective plant holes. A further recommendation is to layer the top of the soil with a compost and biochar mix. Applying powdered biochar to the surface might cause wind loss if the biochar is not sufficiently moist.

Ideally, the application of biochar into the soil is done before sowing or planting. The depth of the biochar application can be adapted to the type of crop that is planted, depending on their characteristic to root deeply into the soil or not.

When biochar has been used as litter in a kraal, it can be removed and added to crop fields. Crops can also be sown directly onto the old kraal site if it has not been stocked excessively.

The recommended amounts of biochar that should be added to the soil can vary widely, depending on the prevailing soil, climate and crops as well as the combination with other applied soil enhancers. Even though there are no indications that serious adverse effects occur if large amounts of biochar are applied to the soil, the additional benefits per unit area will cease at some point.

To a great extent, biochar is recalcitrant to decomposition in soil. Therefore, biochar is applied as a once-off investment from which benefits are likely to rise over the first few years before stabilising for decades or centuries thereafter.

Favourable results have been obtained with rates of 5 to 15 tonnes of biochar per hectare,

but also much higher rates of up to 50 tonnes have been reported with positive effects. The exact amount of biochar that is applied in a defined area should be guided by local environmental conditions and agricultural parameters and be weighed against cost-effectiveness considerations.

In order to find the right amount and frequency of application, adaption by "trial-and-error" during the initial testing phase can make sense.

TIPS FOR BIOCHAR APPLICATION

- Losses of biochar due to wind and water erosion are reduced when biochar is thoroughly incorporated into soil. Please note that ploughing and soil mixing are not desirable in all cropping systems.
- The costs are kept low when the use of biochar is integrated into routine field operations.
- Perennials: Biochar can be top-dressed on perennial vegetation for example around food trees.
- Horticulture: Biochar could be applied while transplanting in the field or mixed with topsoil and other amendments when building raised beds.
- Trees: Biochar should ideally be applied to an area of soil that tree roots will eventually utilise to take up nutrients.

Use of Biochar as a Feed Additive

It is one of the oldest remedies for digestive disorders in humans and livestock alike. When biochar is added to the animal's menu, positive effects on toxin adsorption, digestion, blood values, feed efficiency, meat quality, and greenhouse gas emissions can be observed.

It is important to mention that there are risks associated with feeding biochar to animals if done incorrectly. Unlike its application for soil enhancement, biochar should not be conditioned with nutrients and microbes if used as a feed additive, but be fed pure.

Ideally, the biochar is offered as a free-choice supplement, leaving it up to the animals to decide when and how much to consume. If mixed with other supplements and fed to the whole herd, biochar is likely to harm those animals which do not have toxins in need of adsorption in their digestive tracts, as the biochar may adsorb valuable nutrients.

If biochar is supplemented as a feed additive in an extensive livestock farming system and first consumed by livestock, the rangeland's soil can also benefit from cascade effects due to the biochar's stability and resistance against digestion and decomposition.

While systematic scientific research of the effects of biochar in fodder is still scarce, the practice is spreading rapidly due to good experiences of farmers. Observed effects of biochar in animal feed include:

- ➜ High adsorption capacity for a variety of different toxins like mycotoxins (such as mould fungi in stored feed), pesticides (especially glyphosate which currently contaminates most of the feed produced from genetically modified maize, rapeseed and soybean), plant toxins, as well as toxic metabolites or pathogens.
- ➜ Redox activity: A well-balanced animal feed regime should contain multiple electron mediating substances. Biochar acts as a non-toxic electron mediator with the result that redox reactions may take place more efficiently. This is assumed to increase feed intake efficiency.

BIOCHAR AND BUSH-BASED ANIMAL FODDER

Biochar has the potential to play a complementary role in combination with bush-based animal fodder. Digesting bushes with high tannin contents prevents animals from accessing the desired proteins in the bush fodder. Biochar can adsorb tannins in the digestive tract and thus help the animals to use the feed more effectively.

A dairy cow feeds on crushed biochar offered as a free-choice supplement

- Reduction of methane emissions from ruminants which currently account for around 80 per cent of the total greenhouse gas emissions from the livestock sector.

Feed Quality Biochar

Biochar which is considered suitable for animal feed additives has to adhere to higher quality standards than biochar for soil application. For instance, under the European Biochar Certificate, biochar can only be certified as "feed grade" if a number of conditions are met. These include:

- Only biochar from natural, untreated trunk wood is permitted as feed grade. Consequently, Namibian encroacher bush is very well suited.

- Carbon content must be higher than 80 per cent of dry matter. In (non-representative) tests conducted by the Namibia Biomass Industry Group, only Namibian biochar produced in the Kon-Tiki Kiln reached this threshold and is therefore recommended.

- If the required production temperature of 700 °C is not reached, a critical amount of so called Polycyclic Aromatic Hydrocarbons (PAHs) can form during the burning process. These are a potential risk for human and animal health as well as for the environment. For feed grade biochar, the total content of the PAH pollutants must be under 4 mg/kg. Biochar samples produced in a Kon-Tiki kiln in Namibia met this threshold in N-BiG tests.

Market Perspective

As there is an existing international market for the product and as it is suitable specifically for application in the poor, sandy soils that are prevalent in Namibia, biochar has a great potential both for on-farm usage as well as commercialisation.

International Biochar Standards

For commercial markets, biochar usually needs to acquire international certifications proving it adheres to certain standards. This gives consumers all over the world certainty that the traded biochar has the desired effects.

Even if the biochar is produced for own use, adherence to principal standards is advisable to avoid unforeseen consequences or adverse impacts.

Internationally, two main certification bodies for biochar exist – the International Biochar Initiative (IBI) Biochar Standard as well as the European Biochar Certificate (EBC). In general, their standards are similar, but IBI only certifies biochar produced in the USA and Canada.

Certification

EBC certification requires an initial on-site examination as well as subsequent batch certifications. Initial on-site certification can cost around NAD 20,000 (excl. travel expenses; indicative cost only) but may vary based on circumstances. Currently, only bio.inspecta AG from Switzerland is registered to certify biochar producers with the European Biochar Certificate.

Testing of Samples

A detailed analysis of biochar testing on the parameter of the EBC can be done currently by two independent laboratories in Germany, Eurofins Umwelt Ost GmbH as well as Ruhr Lab GmbH. The testing can cost around NAD 15,000 per sample (excl. freight costs; indicative cost only).

In 2019, N-BiG facilitated an initial testing of Namibian biochar samples in order to determine the suitability of bush biomass for biochar production. For the burning process, mostly Red-thorn *(Acacia reficiens)* as well as Black-thorn *(Acacia mellifera)* were used.

The results indicate that biochar from Namibian encroacher bush produced locally in a Kon-Tiki kiln can meet the highest international standards of the EBC (feed char). The results as well as the thresholds for different EBC quality standards are depicted in the table on the next page..

By 2021, the Namibian University of Science and Technology (NUST) will have established laboratory capacities in Windhoek to facilitate the testing of biomass samples for any public and private entity. Even though not yet accredited for international standards' certification, NUST will be able to test the most crucial parameters for biochar.

European Biochar Certificate

The EBC standard differentiates between biochar that is fed to livestock ("feed" quality) and biochar that is used for soil application ("basic" and "premium" quality).

EBC THRESHOLDS AND NAMIBIAN KON TIKI KILN TEST RESULTS (2019)

	EBC thresholds			Namibian Kon-Tiki Kiln Test Results (2019)
	Basic	Premium	Feed	
Carbon content (dry mass) in %	> 50		> 80	85.4
Molar H/Corg ratio	< 0.7			0.17
Molar O/Corg ratio	< 0.4			0.052
pH	< 10			7.9
Heavy metal thresholds in g/t dry mass:				
Lead (Pb)	< 150	< 120	< 10*	2
Cadmium (Cd)	< 1.5	< 1	< 1*	0.2
Copper (Cu)	< 100			7
Nickel (Ni)	< 50	< 30		1
Mercury (Hg)	< 1			0.07
Zinc (Zn)	< 400			11
Chromium (Cr)	< 90	< 80		1
Arsenic (As)	< 13		< 2*	0.8
Polycyclic Aromatic Hydrocarbons (PAH) in mg/kg dry mass	< 12	< 4		0.2
Polychlorinated Biphenyl (PCB) in mg/kg dry mass	< 0.2		Stricter thresholds apply	-
Dioxins in ng/kg dry mass	< 0.2			-
Furans in ng/kg dry mass	< 20			-
Benzo-a-pyren in µg/kg			< 25	0.1
Fluorene in g/t dry mass			< 150*	0.1

*based on 88% dry mass

Quenched biochar in a Kon-Tiki kiln after the quench water has been drained off from the bottom.

Global Perspective

The global market estimates for biochar vary considerably between sources, ranging from USD 285 million to 1.48 billion in 2018, with volumes estimated between 355,000 and 395,000 tonnes in 2017/18.

This significant variation continues within the forecasts, whereby it is expected that the global market value will increase to between USD 870 million and 3.8 billion by 2024/25.

Conservatively speaking, the global market value was worth NAD 5.4 billion in 2018, with expected growth of around 12 per cent per annum. This places the current value at about NAD 6.3 billion in 2020. It is expected to grow to roughly NAD 11.1 billion by 2025.

Market Drivers and Trends

The main driver of the strong growth forecast for biochar is the rising demand for organic foods, which is driven by environmental awareness of consumers. Another factor for increased growth in biochar demand is declining soil fertility and subsequent reductions in crop yields across the world, linked to factors such as deforestation, reliance on chemical fertilisers and other current agricultural practices.

Growth in demand is foreseen to continue in future, largely due to increasingly strict environmental regulations, the positive effects of biochar on carbon sequestration and the subsequent climate adaptation benefits of improved soil fertility.

International Markets

Even though biochar is not yet produced and used on a large scale in Namibia and a local market does not yet exist, countries such as China, India, Japan, Mexico, and Brazil produce significant amounts of biochar through mainly small and medium-scale production systems. Large-scale manufacturers are typically concentrated in North America and Europe.

North America has historically been the largest market for biochar and it is expected to witness continued growth in line with the increasing demand for organic foods and meat products. Its market share in value is estimated at 52 per cent of the global market. The United States account for the largest market share within the region. Awareness of biochar is high in this region as compared to others, with the agricultural sector having a generally good understanding about biochar and its benefits. The availability of large amounts of forestry waste is one of the key factors fuelling market growth in this region.

Europe is the second largest market, led by the United Kingdom, France, and Germany. The growth of the European market is mostly due to the increased consumer awareness about biochar application, rising product demand for organic products, stringent environmental regulations, and growing use of biochar in animal feed applications. These factors are expected to keep growing the European biochar market in the coming years.

The **Asia Pacific** market is also expected to witness extremely high growth, primarily due to the large and developing agriculture, food, pharmaceutical, and clinical sectors in those economies, with emphasis on China and India. China is the third largest organic food producing country in the world. Japan, Australia, New Zealand, and South Korea are also key markets within this region.

The other markets, including **Latin America**, the **Middle East**, and **Africa** are anticipated to experience moderate growth in the future, owed largely to the noteworthy investments in biochar by international companies, as well as improving economic conditions.

To find out more about international markets and access to them, kindly get in touch with the Namibian Biomass Industry Group (N-BiG) or the Namibian Charcoal Association (NCA).

Biochar at Krumhuk Farmer's Story

Just south of Windhoek, at Farm Krumhuk, Mareike Voigts is experimenting with biochar production. "I had already heard about biochar during my studies. Our cooperation with Dr. Ibo Zimmermann from NUST then created the opportunity to produce biochar on the farm," she explains.

At Farm Krumhuk, biochar is used to enhance the soil for crop production.

At Krumhuk, it is the gardening team that is responsible for biochar. The production starts with two people driving out into the veld with a bakkie to collect dry wood, mainly *Acacia mellifera*. It takes the team about half a day to collect the 300 kilograms required for a burn.

Then they cut pieces of 30 centimetres length and once 10 to 15 kilograms are ready, they stack this wood in the Kon-Tiki kiln, light it and continue preparing the rest of the wood for burning.

"With this kiln, you add new wood every 15 to 20 minutes. One person can handle this task easily," Mareike says. "But they have to be diligent and watchful. You do not want the wood to turn into ash."

After 4 hours the kiln is fully burned down. 300 kilograms of bush produce around 150 kilograms of moist biochar. To stop the burn, the char is quenched with around 200 litres of water. This water can be collected, diluted and used to water plants for which it acts as a fertiliser.

The biochar itself needs to be dried before it is milled. At Krumhuk, it mostly dries in bags for a week, but it could also be spread out in the morning and then milled in the afternoon.

After milling comes inoculation. Mareike uses compost tea which she also produces at Krumhuk from ripe compost, molasses and salt.

As a rule of thumb, 8 kilograms of char need 2 kilograms of manure and 5 litres of compost tea. The mixture is left for 48 hours in a bucket or wheel barrow. "You want aerobic conditions but nicely moist."

Krumhuk uses the biochar in their certified organic horticulture production. The inoculated char gets sprinkled onto the soil and then worked in with a rotating hoe.

"We consider it a long-term investment into healthy soils and prevention of diseases," Mareike points out.

RESEARCH ON BIOCHAR AT NUST

The NUST BUSH project does wide research on various aspects of biomass harvesting, processing and utilisation from encroacher bush. Biochar research activities are implemented in cooperation with Ovitoto Community, Farm Krumhuk, Farm Humulus and Cheetah Conservation Fund.

Research focus includes:

- productivity of crop fields that were treated with biochar
- conditioning of biochar
- development of Kon-Tiki kilns
- biochar as a free-choice supplement for livestock

NAMIBIA UNIVERSITY OF SCIENCE AND TECHNOLOGY

BUSH BIOMASS UTILISATION BY SUSTAINABLE HARVEST

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Ministry of Environment, Forestry and Tourism (MEFT) - Directorate of Forestry 3rd Floor, Government Office Park Luther Street Private Bag 13306 Windhoek NAMIBIA Phone: +264 61 208 7111 www.met.gov.na	DoF is the responsible Namibian authority to issue harvesting permits for bush that are necessary in order to produce biochar. MEFT is also the responsible authority to issue the environmental clearance for large scale harvesting activities.
Namibia Biomass Industry Group (N-BiG) Cargo City 5 Von Braun Street Southern Industrial Windhoek NAMIBIA Phone: +264 61 242 949 E-mail: info@n-big.org www.n-big.org	N-BiG is an industry organisation that aims to serve and grow the Namibian biomass industry through information, capacity development, applied research and development and active membership support.
Namibia Charcoal Association (NCA) Shop 3 20 St. George's Street Otjiwarongo NAMIBIA Phone: +264 67 304 220 E-mail: info@ncanamibia.com www.ncanamibia.com	NCA is a non-profit voluntary membership association that strengthens the charcoal industry and supports the needs of its role-players.
Namibia Science and Technology (NUST) Innovation Design Lab 10 Haydn Street Windhoek NAMIBIA Phone: +264 61 207 2728 E-mail: estrydom@nust.na www.bush.nust.na	NUST's BUSH project conduct research on the topic of biochar production and application. BUSH has cooperated with several farmers to create knowledge on the potential of biochar. From 2021 onwards, NUST will have laboratory testing capacities in place.

INTERNATIONAL CERTIFICATION

bio.inspecta AG Ackerstrasse 5070 Frick SWITZERLAND Phone: +41 62 865 63 00 E-mail: service@bio-inspecta.ch www.bio-inspecta.ch	bio.inspecta AG is currently the only entity that is entitled to certify biochar producers with the European Biochar Certificate.
Eurofins Umwelt Ost GmbH Niederlassung Freiberg Gewerbegebiet Freiberg Ost Lindenstraße 11 09627 Bobritzsch-Hilbersdorf GERMANY Phone: +49 3731 2076 – 500 Mobile: +49 172 9224 436 E-mail: info_jena@eurofins.de www.eurofins.de	Eurofins Umwelt Ost GmbH is a Germany based laboratory that is qualified to test biochar on all relevant chemical properties for the European Biochar Certificate.
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EQUIPMENT AND BIOCHAR SUPPLIERS

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Inventec 16 West Street Otjiwarongo NAMIBIA Phone: +264 67 307 489 Email: info@inventecnam.com www.inventecnam.com	Manufacturer of Kon-Tiki kilns.
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* For an updated contact list of stakeholders, technology providers and biochar suppliers, please visit www.dasnamibia.org

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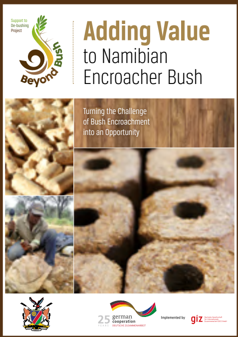

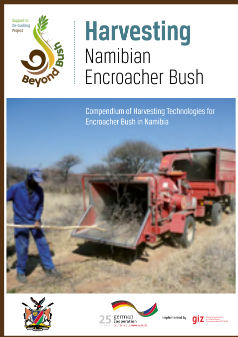

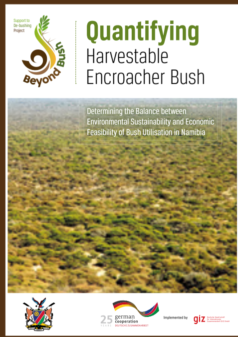

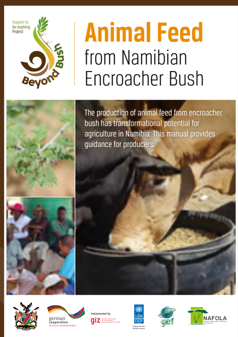

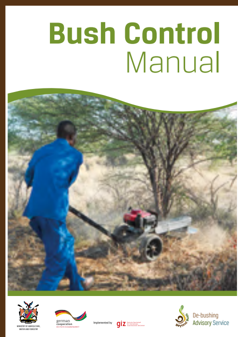

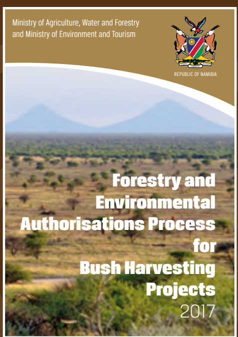

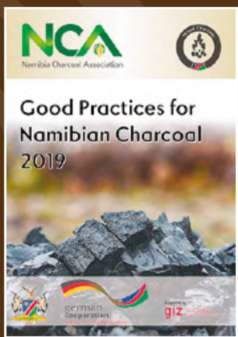

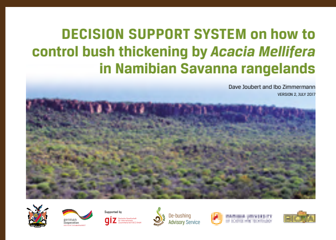

Bush Control
and Biomass
Utilisation
Project

Beyond Bush

Biochar enhances soil health and fertility and is therefore popular in organic agriculture. As consumer demand for organic food rises, biochar markets will boom.

Namibian farmers can produce biochar from encroacher bush, thereby restoring rangelands. The product can be sold or used on-farm.

This brochure explores production methods as well as areas of application and provides an overview of international market development.