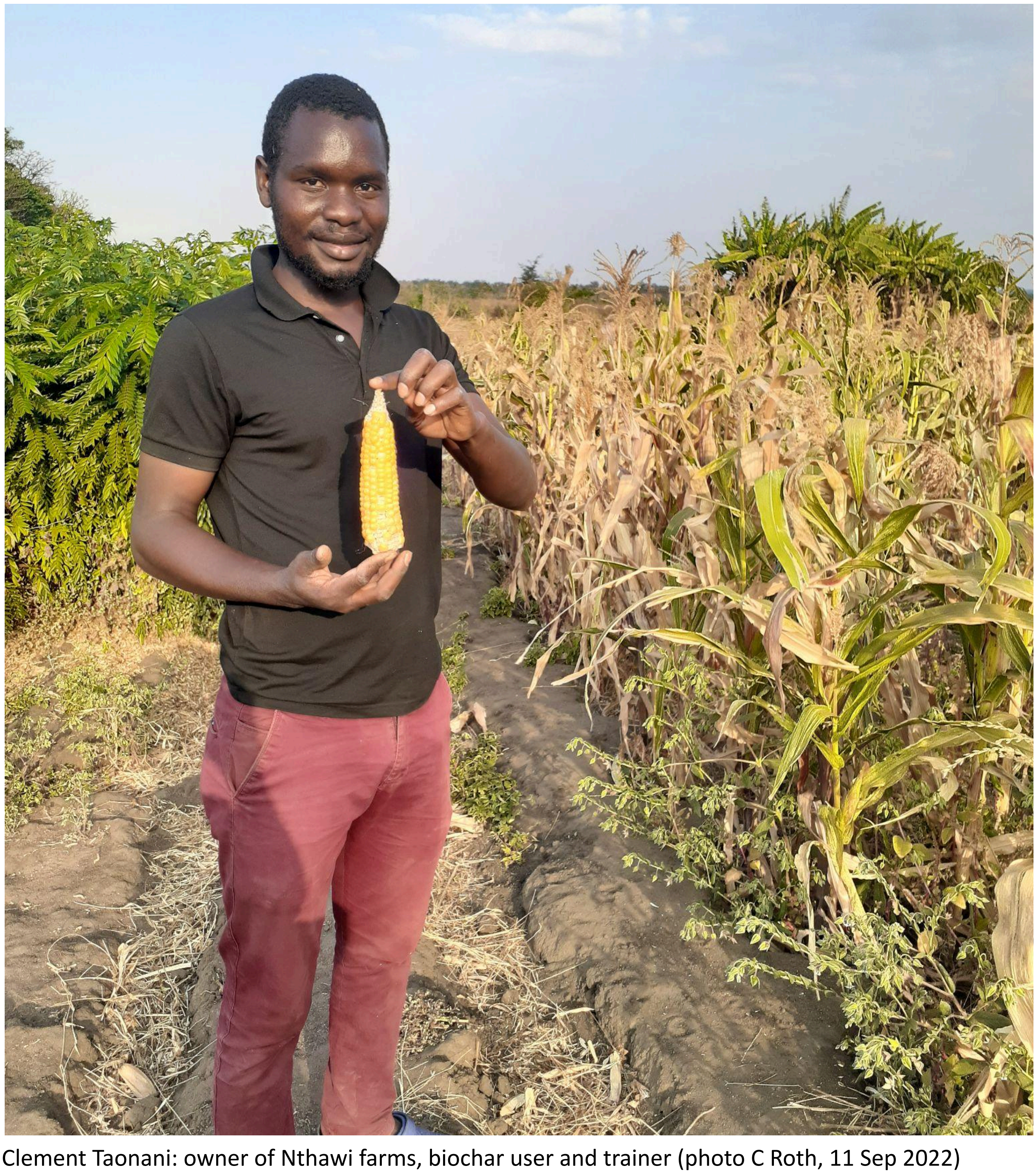
Report on trials to make biochar by top-lighting large piles of maize stover above ground on Nthawi Farms near Lilongwe (Malawi)

in the time from August to September 2021
Client: Kevin Mclean, Sun24
Report drawn up by
christa-roth@foodandfuel.info



Clement Taonani: owner of Nthawi farms, biochar user and trainer (photo C Roth, 11 Sep 2022)

Abstract

Third-party verification of trials at Nthawi Farms near Lilongwe in the Central Region of Malawi confirmed that making biochar from farm residues like maize stover by burning large piles lit at the top can have many advantages:

- High yield of nearly 25% of char, at least in calm wind conditions
- It has a nearly smokeless burn when piled up and lit from the top
- The char can be quenched with available soil from the field and does not require (scarce) water
- Advantages of top-down burn pile compared to the drum-charring method:
  - It does not require the input into a drum or other container to char the maize stover
  - It reduces time and labor to cut the stover into smaller sizes to fit into the drum
- Advantages of top-down burn pile above ground compared to making biochar in a trench:
  - it reduces labor to dig the trench and move the stover to the trench. The burn pile can be made anywhere directly at the source of the stove, e.g. on the field.
  - burning one pile top-down can reduce the time to feed the stalks into the fire in a trench from 1 hour to 15 minutes.
  - It does not require an iron-sheet to quench the char, as it is sufficient to simply shoveling soil from the field on the embers.

The amount of biochar that can be made per hectare varies according to the plant density, the survival rate, and the overall plant Growth determined by the variety, amount of fertilizer, rainfall pattern, soil acidity etc. yet some early conclusions can be drawn:

Biochar could become a game changer in Malawi in many ways:

- It is estimated that the biochar made from one hectare of maize stalks can fertilize three hectares of maize the following season.
- Biochar could contribute greatly to **improve food security** of the nation.
- As the trials at Nthawi farm indicate, the use of charged biochar can (at least partially if not entirely) **substitute industrial fertilizer and reduce the need for costly imports** of the commodity. This could reduce the enormous financial burden and strain
  - for the farmers to save 30 USD per one 50 kg bag of fertilizer (unsubsidised cost as per 2021 in Malawi)
  - on foreign exchange of the Affordable Input Program including subsidies of fertilizers by the Government of Malawi
- Biochar can contribute to **climate change mitigation**:
  - it is a very easy, cost efficient and safe way of **carbon capture and storage** at scale: biochar sequesters carbon from the atmosphere and stores it in the soil, while increasing plant yields and resilience.
  - The technique of lighting a burn pile from the top also **reduces the amount of climate relevant emissions** of smoke and particulate matter. Farmers in Malawi often clear their fields by burning the residues as they lie on the ground. This leads to incomplete combustion and smoldering fires that cover entire areas in smoke. Burning piles from the top does not require any additional inputs other than training and awareness creation and it can be done by every farmer in Malawi.
- Biochar also has an important role for **climate change adaptation** as it reduces the vulnerability of (not only) smallholder farmers to climate change, as biochar buffers the availability of water and nutrients for the plants thus increasing the resilience of plants to droughts and floods that have become more frequent with climate change in recent years.

Objective of the Mission

Kevin McLean from Sun24 has cooperated with Clement Taonani from Nthawi Farms (ca. 20 km west of Lilongwe, the capital of Malawi) for a while Kevin found Clement through the WarmHeart Worldwide network and engaged him to do several trials with the top-down burnpile method to make biochar from maize stalks on his farm. Kevin approached me early August 2021 and asked for a third-party verification of the data reported by Clement. I first engaged my Malawian colleague Owen Mbilizi to witness biochar making whilst I was not in Malawi and then went several times to Nthawi farms for his own observations and verification visits from 29.8.-20.9.2021.

Background Nthawi Farms

Nthawi farms currently comprises 26 acres of farmland that extends into a valley with wetlands and water sources for irrigation. Clement started with biochar in 2019 after attending a training by Warm Heart Worldwide on how to make biochar with both the drum and the trench method. He makes his biochar mainly from maize stalks and maize cobs. Clement used the trench method exclusively until Kevin McLean introduced the top down burn to him in July 2021. Now he uses the top down burn exclusively He no longer uses a trench, but instead makes piles above ground of 60 kg of maize stover right in the field, which he then lights from the top and quenches with soil from the field to extinguish the fire and stop the combustion of the char into ash. There are many advantages of the top down burn over the drum method: It does not require the input into a drum or other container to char the maize stover and it reduces time and labor to cut the stover into smaller sizes to fit into the drum. There are also advantages of top-down burn pile above ground compared to making biochar in a trench: it reduces labor to dig the trench and move the stover to the trench. The burn pile can be made anywhere directly at the source of the stove, e.g. on the field. It also saves time as the stalks do not have to be fed continuously into the fire. With the trench method, feeding fuel can take an hour, while burning the pile in one go lit at the top can take less than twenty minutes including the quenching. It also does not require an iron-sheet to quench the char, as it is sufficient to simply shovel soil from the field on the embers.

Clement then takes the biochar quenched with soil from the field to his compound and charges it with a mixture of urine and manure from his own animals. He keeps a variety of animals (pigs, chicken and various other fowl, guinea pigs, rabbits etc.) in pens and stables and collects their excrement in the beddings from plant material from his own farm. Clement now uses urine from humans and animals to charge his biochar.

Clement no longer lets the biochar and urine "ferment" for two weeks. He just pours a 20 l container of urine over about 120 l of biochar and lets the residue liquid flow away. This is easier and just as effective in charging biochar.

Whatever surplus biochar he does not use on his own farm, he then bags into empty maize bags (designed for 50 kg maize) and sells it to customers at ca. 10 USD.

When he applies biochar on his own farm, he puts one handful of the mixture into each planting hole for maize etc. and a bit more for plants with larger planting holes like bananas.

In the 2020/2021 season he grew a local maize variety on 10 acres only with compost and his own biochar mix, without any inorganic fertilizer. He harvested 700 bags of 50 kg= 35,000 kg of shelled maize grain. Assuming the figures are correct, this would equal a yield of 3,500 kg/acre or 8,648 kg/ha[1]. Normal maize yields of local varieties grown without fertilizer on smallholder farms in the Central region of Malawi average around 1,200 kg/ha, while commercial yields of hybrid maize seed with fertilizer range between 6,000 – 8,000 kg/ha. This would mean that the biochar mixed with compost, manure and urine could raise smallholder farmer’s yields of local maize to the level of

[1] 1 acre = 0.4046 ha = 4,046 square meters, or 1 ha = 2.471 acres

commercial farms. These figures should be confirmed in the next growing season, but it can already be concluded that biochar has an enormous potential to increase the yields of the staple crop maize substantially and thus contribute to the food security of the nation.

Third-party verification carried out by Christa Roth in August-September 2021 in Malawi

These were the major research questions to be confirmed and checked for plausibility:

1. *The amount of biochar made from a defined area of maize*
2. *The quality of the resulting biochar*

The first point was operationalized into the confirmation of the following specific metrics to be measured, counted or weighed:

a) The weight of the maize stalks in one pile in kg
b) The number of maize stalks in one pile / weight of one stalk in kg
c) The area of upright maize stalks needed to make one pile / planting pattern
d) The dry weight of biochar yield from one pile in kg

The second point was addressed through visual inspection.

Results from various field trips carried out from 20.8.-16.9.2021

1) The amount of biochar made from a defined area of maize

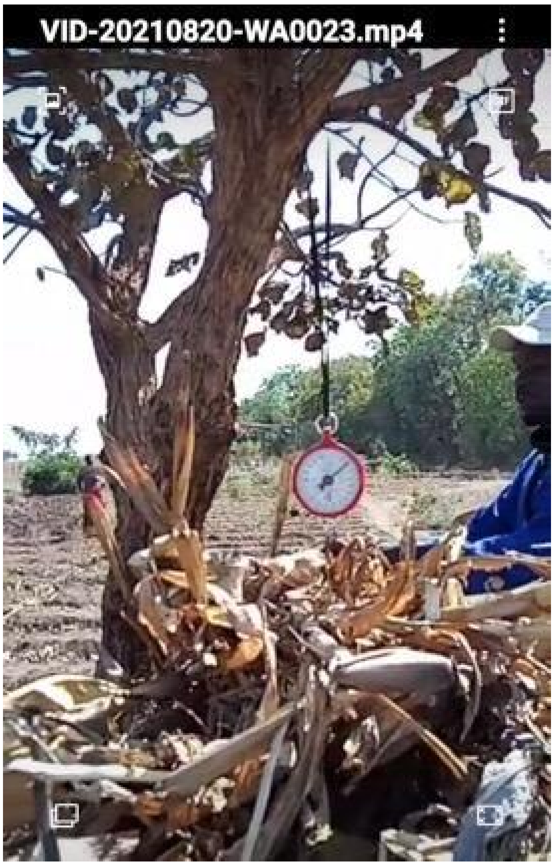
a) The weight of the maize stalks in one pile:

This was easy to quantify: Clement and his workers normally pick up an armful of maize stalks that they can carry on their heads to take to the site of the burn pile. They normally make a pile of 4 bundles.

Whilst I was not yet in Malawi, my Malawian colleague Owen Mbilizi went on 20th August to witness the process of making biochar top-lighting a pile of maize stalks above ground. He documented this in videos and I took screenshots for the purpose of this report.

For the sake of the quantification in the trials each bundle of maize stalks was first tied with a thin rubber band to hook it on a hanging scale (analogue hanging scale with a 100 kg capacity and 500 g resolution markings) tied on a branch of a tree. Those bundles had rather consistent weights between 14.5 and 15.5 kg, as far as the accuracy of the scale allows correct readings.

Clement then piled up 4 bundles to make one pile ready to burn. It can be assumed that each pile normally has an average weight of 60 kg. It is around 1 m high and covers a footprint of ca 1x2 m. When making biochar from maize stalks he always uses this type of pile, but he would normally not tie the bundles and weigh them if it were not for reporting purposes on request of Sun24.
Photos from burning a pile on 12th September 2021 are shown further below.

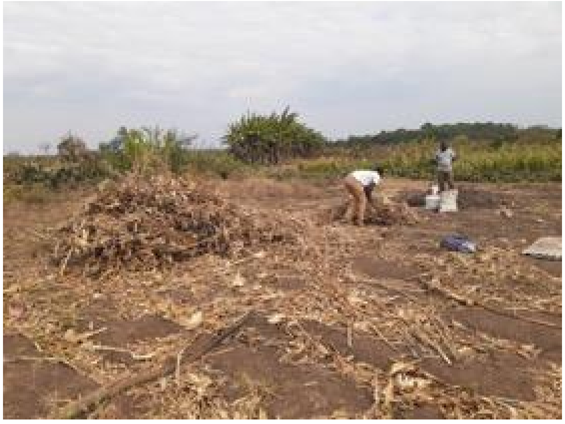
	
from video on 20th August: one bundle of maize stalks for carrying on the headload	Bundle weighed on an analogue hanging scale = 15 kg. (orginal Videos by Owen Mbilizi)

b) The number of maize stalks in one pile / weight of one stalk

This was more tricky to determine: Clement had previously reported that he counted 84 maize stalks weighing 12 kg, (equivalent to 143 g per stalks) so that one burn pile of 60 kg would contain about 420 stalks that were taken from a pile of upright standing stalks left to dry out properly, which is a common practice in Malawi.

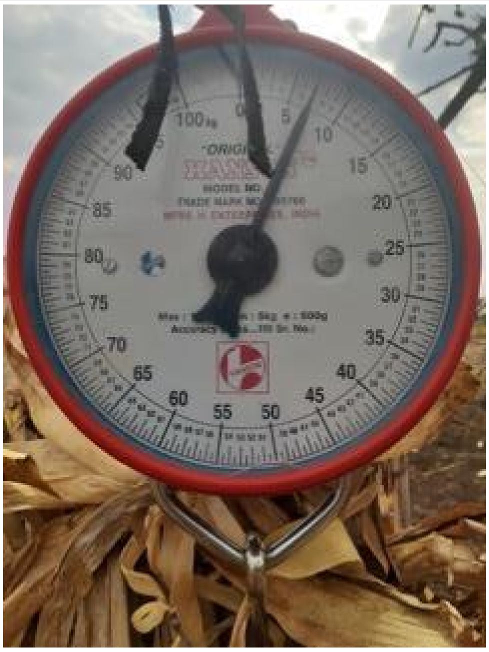
But when I first came on site on 29th August, this was about 3 months after the harvest and the stalks had been cut, carried by hand from the original location and piled up loosely on an empty field that had not yet been repurposed to grow other crops. Some stalks were broken and it was difficult to determine accurately which parts made up the biomass that had come from one single maize plant. A lot of biochar had been made already and we were looking at the last remainders of the harvest.
In consultation with Kevin McLean after the first visit, we agreed to weigh whatever we could under the circumstances. We agreed with Nthawi farms to do the weighing at the next possible date in the schedules and settled on 6. September 2021.

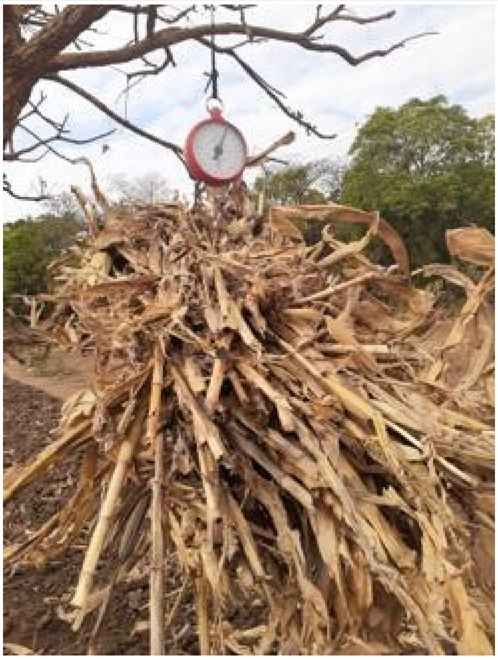
On 6th September we tried our best to make bundles of 100 stalks each and weigh them to determine an average weight per dry stalk. We compiled 7 bundles of 100 stalks weighing mostly between 6.5 and 7 kg, with one outlier bundle #7 weighing 8.5 kg. A possible explanation for that heavier bundle could be that the stalks at the bottom of the storage pile were more intact as the ones on top. We put the leftovers of broken stalks and leaves in bags for weighing purposes to come up with a pile.



6. September 2021: Remaining stock of maize. Counting 100 stalks to make a bundle to weigh.

The total remainder of the original pile assumed to have been 700 plants – 7 bundles and the remaining debris filled in bags for weighing.





Weighing 100 stalks on a hanging scale = 7 kg
The weight of 5 out of 7 bundles was rather consistently between 6.7 and 7 kg.

Weight of biomass attributed to 700 maize plants

Bundle	1	2	3	4	5	6	7	Total kg
Kg of bundle of 100 stalks	7	6.5	6.7	7	7	6.8	8.5	49.5
Kg bags filled with debris	4.7	4	3.5	3	3.5			18.7
Total kg of raw material for the burn pile from 700 plants								68.2
(equivalent to average 97 g per plant)								

We only counted the number of stalks of the entire bundles and assumed that the total dry biomass that we weighed could be allocated to 700 maize plants originally. 68.2 This would make 97 g per plant. From this we concluded that 1 dried maize stalk could be assumed to weigh roughly 100g. This result does not entirely match the previously reported figure by Clement of 143 g per stalk. This metric would need to be confirmed in the next season with another trial earlier in the year. For now as a conservative estimate the 100 g per maize stalk could be used to extrapolate figures.

c) The area of upright maize stalks needed to make one pile / planting pattern

The main challenge was that the main maize harvest was long over. The only maize standing in the field was one little plot that was still under production. Some plants had been taken out already, harvesting the green maize cobs for sale as the green cobs are a popular snack, either roasted or boiled. The fresh stalks were used for fodder and bedding for the animals on the farm. Despite the fact that the field was already incomplete, we also would not have been able to take it down prematurely and also have needed to wait until the stalks would be dried out, so we agreed to use this plot to give us the theoretical yield following the planting pattern and extrapolate the number of stalks per area and the data of the estimated weight per stalk as elaborated in the previous paragraph.

The plot in question was 15 x 15 m, giving a total area of 225 square meters.
The maize was planted in 34 rows on 33 ridges, totaling 1,122 planting stations.
Divided by 225 square meters this would correspond to 5 planting stations per square meter.
Equivalent to 50,000 planting stations per hectare.
The total number of plants available might be lower as this also depends on the germination and survival rates of the maize. The weight per stalk also depends on seed variety, soil conditions, fertilizer applied, rainfall patterns, damage from roaming animals etc.

Extrapolating from Nthawi farms to the regular smallholder farmer in Malawi is also not straight forward, as the planting pattern at Nthawi is rather dense with the distance between ridges and between the planting holes only 45 cm, while in normal smallholder conditions the pattern of 90 cm between the ridges is common as well as a distance between planting stations on the ridge of 60 cm, compensated by the practice that often 2-3 seeds are planted in one planting station.

This means that for smallholder conditions it is more prudent to calculate with a maximum of 2 plants per square meter. In reality this will be rather lower and will have a high variability, making estimates rather difficult.

d) The dry weight of biochar yield from one pile

This was nearly impossible to determine during normal operations, as the biochar is normally quenched by shoveling soil on it. Converting the 60 kg pile of dry maize stalk at an expected yield of 25% of char from the raw material would give 15 kg of pure char.

Yet, the biochar-soil mixture of a burn-pile of 60 kg of maize stalk could weigh over 40 kg, so it was clear this could not only be char. As it was impossible to separate the char from soil after cooling, another method had to be found to get as close as possible to the dry weight of biochar yield. Quenching with soil or water was out of the question, so the only option was to quench by depriving the hot char from air while still hot to avoid that the char would burn into ash.

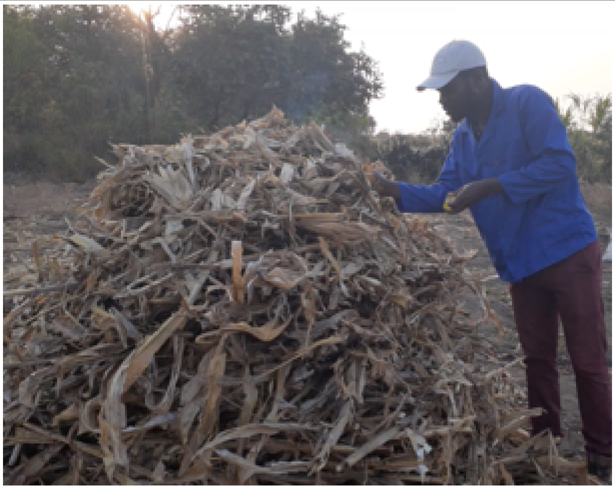
To do that we agreed to borrow ideas from the trench method, but make the pile on top of a rather square pit to simulate the usual burning above ground, then let the glowing char fall into the pit and cover it with iron-sheets to keep the air out.

On 31. August Clement did a trial using this method without me being able to witness: from 60 kg of dry maize stalk he obtained 17 kg of char. The weight of 17 kg of char came from the not so accurate hanging scale, but it would translate into a conversion of 28,3% of char from the raw material. I did not see the resulting char and recommended to apply caution and repeat the trial.

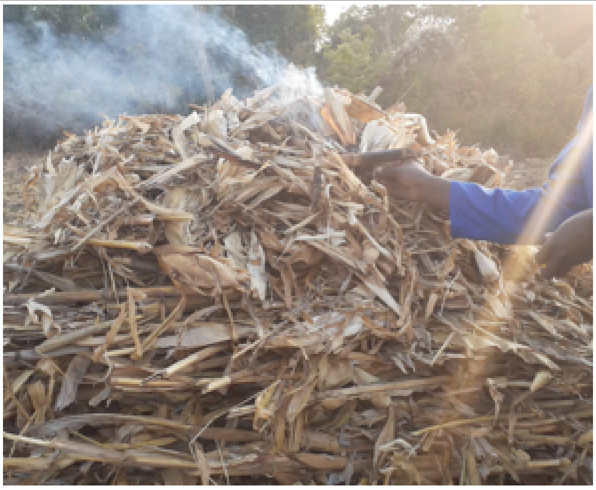
On 1.9. Clement obtained 14 kg of char from 45 kg of stalk. When I inspected the char on 6.9., there was hardly any dirt, the charcoal looked dark-black, mostly properly charred and rather lightweight. The conversion rate was 31% which seemed rather high, which I attributed to the fact that there was some yellow material still uncharred or in the transition to torrefied in different shades of brown that was definitely heavier than the char.

We agreed to repeat the exercise in my presence the following week: We had a pile of 68.2 kg from the quantification exercise weighing the 700 remaining stalks on 6. September as described under paragraph 1 b). There was rather strong wind in the days following the 6th, which would have distorted the potential yield of char as more char would be converted to ash and thus lost. So weather conditions only allowed us on the early morning of the 12th September to burn the pile without too much wind. The photos show the process:

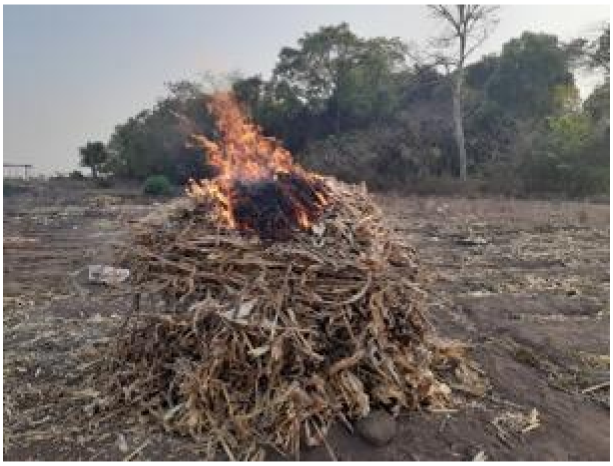
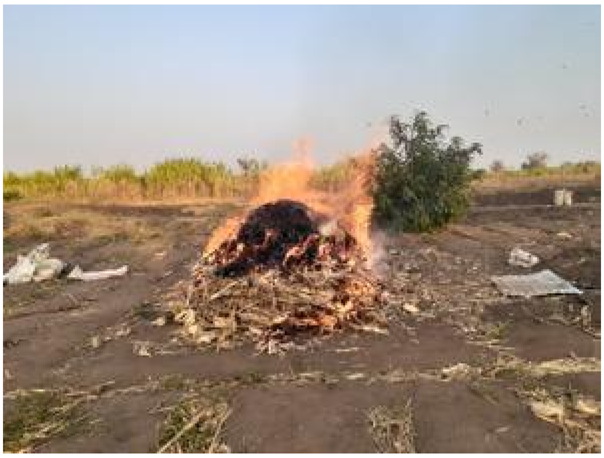
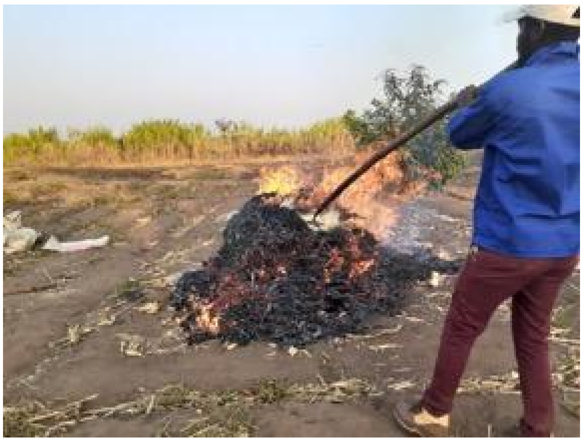
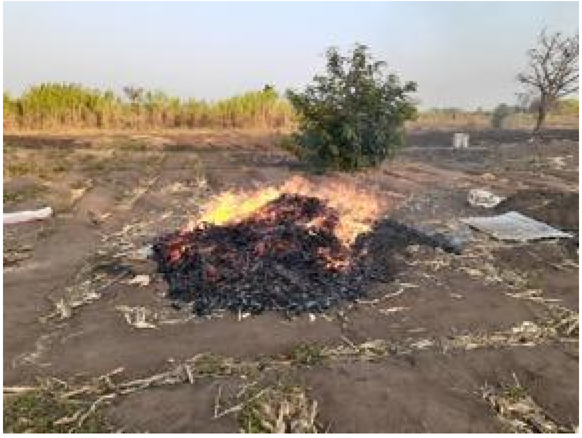
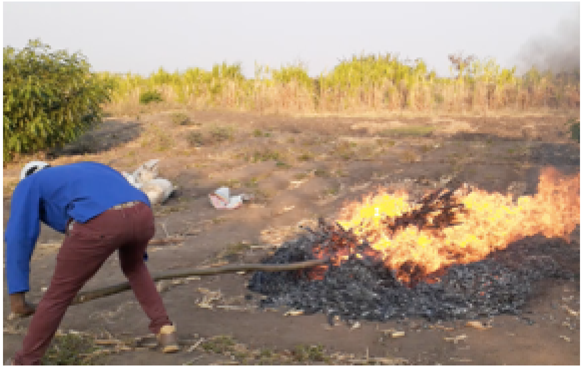
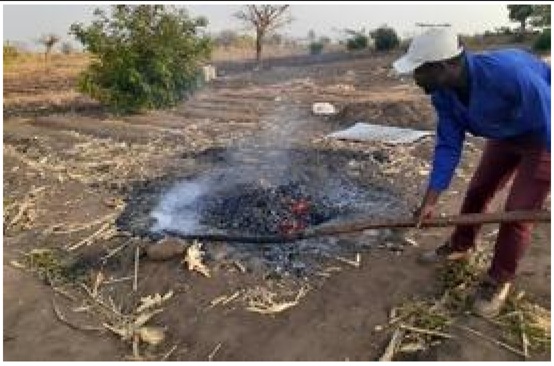
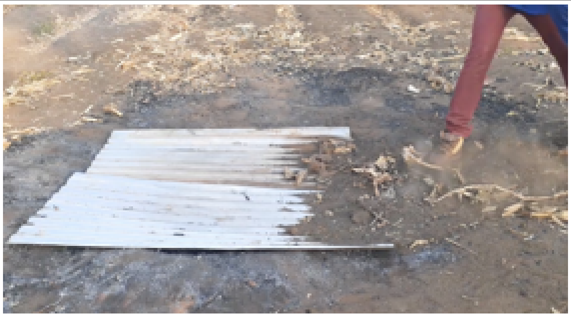
At 6:27 AM we started to pile up the 68.2 kg maize stalk to get the burn pile ready to light.
At 6:29 the pile was lit on the top, and it took 4 minutes for most of the pile to burn down, mostly without smoke. At 6:33 Clement started to stir the pile with a long wood to allow the centre of the pile as well to burn up into char. At 6:42 the burn process was finished and he started covering the pit with ironsheet for quenching. So the total process from piling to quenching took 15 minutes, which is considerably less time than feeding a similar amount of stalks in a trench continuously for one hour.

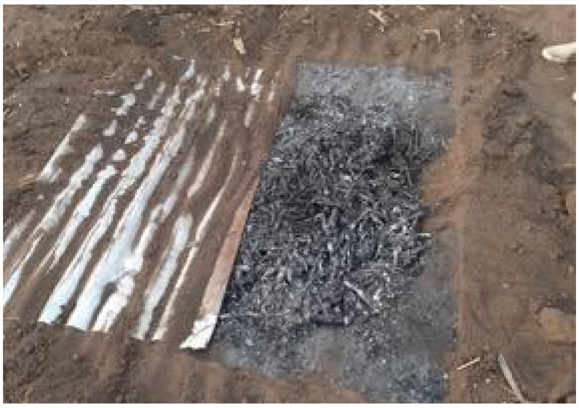
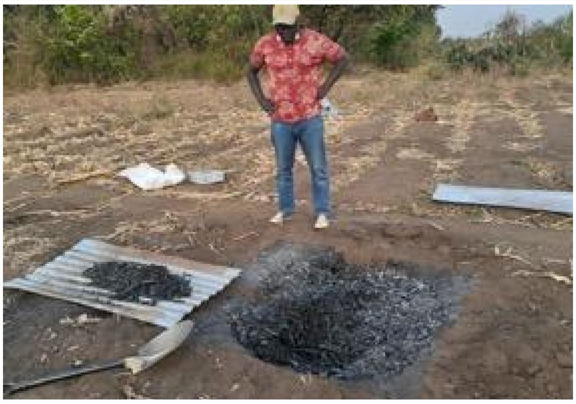


6:28 at sunrise in the cold: pile ca. 1.5 m high, ready to light. No wind



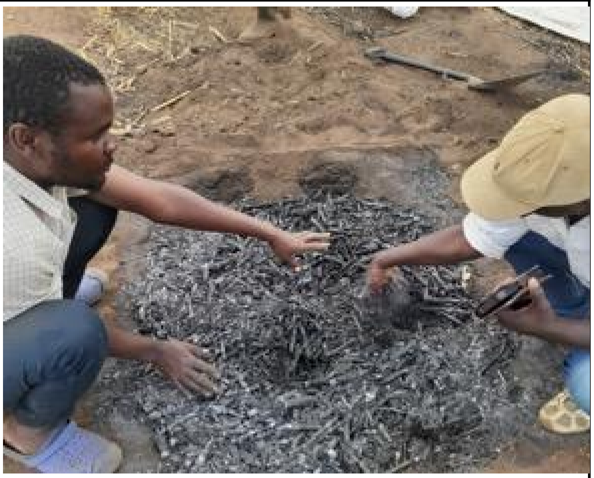
6:29 fire lit on the top, smoking while still cold until a flame is fully established

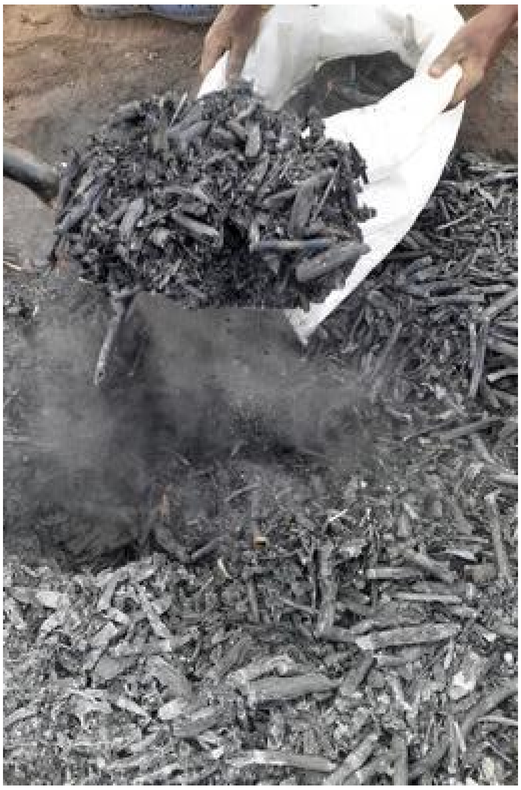
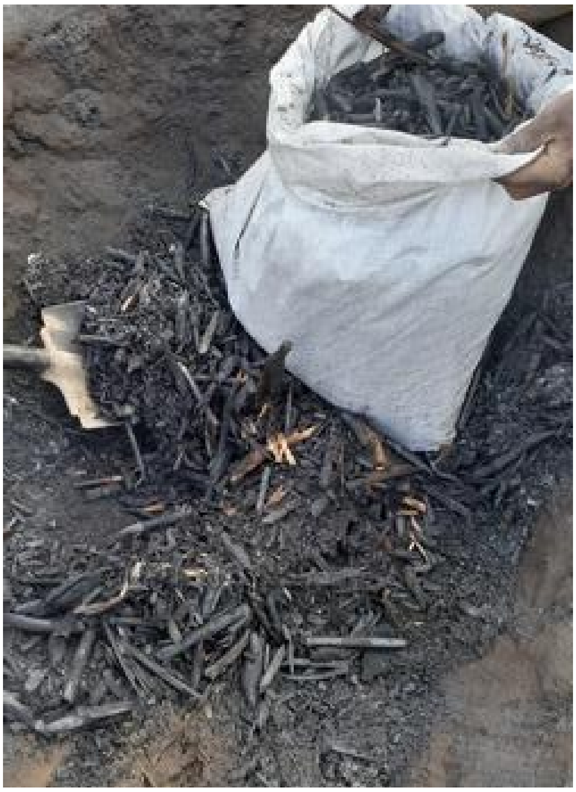
<table>
<tr><td></td><td></td></tr>
<tr><td>6:30 fire catches on and burns smokeless</td><td>6:32 wind picks up, pushing flames a bit sideways, creating some smoke at the tip</td></tr>
<tr><td>
6:33 Clement starts stirring the pile</td><td>
6:35 pile has shrunk and most biomass remaining uncharred is in the centre where the flames show</td></tr>
<tr><td>
6:37: every time raw biomass is stirred up and starts burning when in contact with the air, the yellow flames revive</td><td>
6:42 no more uncharred biomass in the pile, flames died down, all char moved into the pit with the stick, tip of stick started smoldering</td></tr>
<tr><td></td><td></td></tr>
</table>

<table>
<tr><td>6:43 ironsheets place on top immediately and soil shovelled on to seal the inside from air</td><td>6:53 All char covered and well sealed and protected from air as well as lose soil</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">16:53 uncovering the pit with the biochar to find that it was still too hot on the bottom so that it started glowing and burning when it came in contact with air.</td></tr>
</table>

We then came back in the afternoon of the same day to find out that the char in the pit was still too hot so we had to cover the pit back up. The biochar would have partially turned to ash if we had dug it up, and we would not have been able to put it in bags or other containers for weighing.

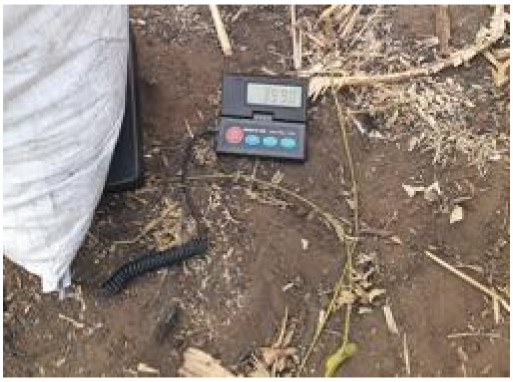
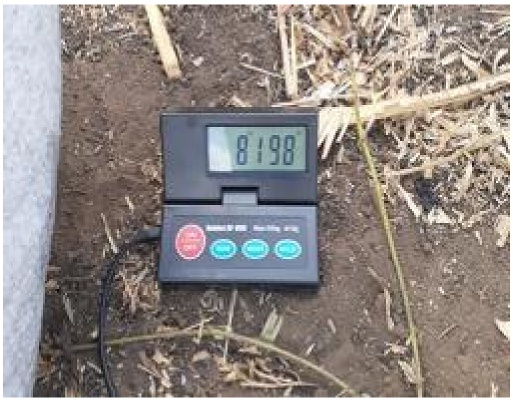
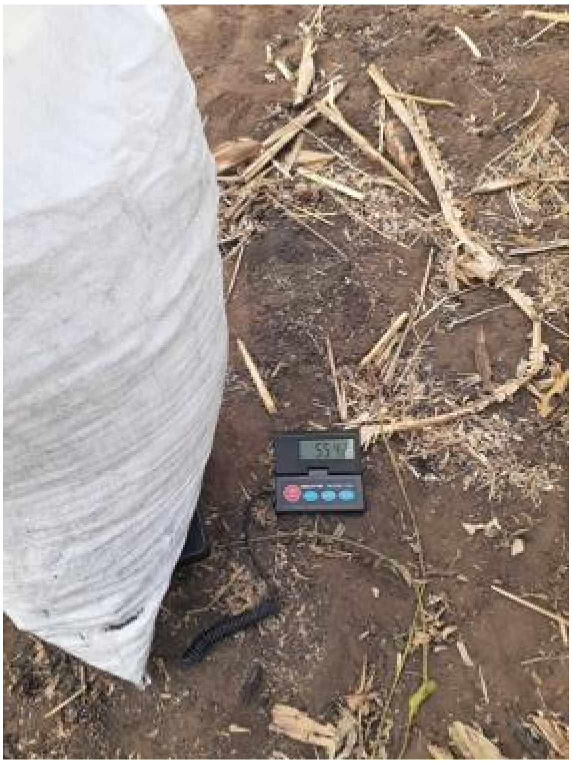
We decided to give it more time to cool and came back on the 7th September in the afternoon:

<table>
<tr><td></td><td></td></tr>
<tr><td>We confirmed that the bottom had cooled off. Then we assessed the quality of the char:</td><td>Some grey-white colour indicated that on the top of the pit some char had burnt to ash</td></tr>
</table>

	
Transferring the biochar carefully in a bag, So that no dirt would get mixed in there	On the very bottom of the pit we found some uncharred stalk pieces, but otherwise everything was well charred.

We filled the char in three bags whereof the first two bags had the same volume but different weights, while the third bag was less volume but more weight. All bags were weighed on a digital platform scale with 50 kg capacity and 1 g resolution. The total weight came up to 17.83 kg of biochar from 68.2 kg raw input:

- Bag 1: 3,990 g with the lightests charcoal from the top of the pit.
- Bag 2: 5,542 g from the middle of the pit
- Bag 3: 8,198 g from the bottom, including some not completely charred material
-

 	
Weighing the three bags on a platform scale	

This makes a conversion rate of 26.14 % of dry weight of biochar from dry weight of maize stalk. This is within the range of the char yield of a good TLUD gasifier like the drum also used to make biochar. This trial confirms that without the investment into a drum or digging a trench, biochar can be made in high quality without compromising the quality applying the top-lit burn-pile method.

For scientific purposes we wanted to be as accurate as possible in the measurements, but in practical terms the potential harvest of biochar is less relevant for a farmer. On a real farm there will never be an exact figure. What is more important is the estimate by Clement, that the biochar that can be potentially harvested from an area of maize could serve to apply biochar in the next season for an area three times as big.

Conclusions:
From reports by Clement it seems that the pit underneath the pile is good for measuring purposes but not needed in the practical day-to-day making of biochar. He had similar results when he made biochar by just burning a pile above ground. Minimal gains in more char yield seem not to justify the extra effort of digging the pit, which also can become an obstacle for farmwork in the field.

Thus I conclude that the method of a top-down burn of a pile of maize stalks above ground does work. It seems to be the simplest and resource-efficient method to make biochar, both regarding material input and human resources of labor and time. We just don't know yet how efficient that needs to be seen with replication in different settings over time.

Kevin McLean suggested as next experiments to burn longer rows of stalk at once instead of various individual piles. A first trial by Clement in October 2021 with 600 kg of stalk piled in one long row on the neighbors farm looks promising. To be continued after the next harvesting season.

2 The quality of the char

The quality of the char is somehow related to the bulk volume of the char: the lighter the char, the more surface area it has inside as more carbon molecules are removed at higher temperatures. Hugh McLaughlin (oral quote) recommends the 'soap test' to get and indication of the quality of the char: when char is crumbled between the tips of the fingers and one needs to apply soap to remove the residues, the char did not reach a high temperature and it is heavier due to tars recondensing on the char. filling the pores that provide the living habitat for the soil microbes that help to increase the soil fertility.

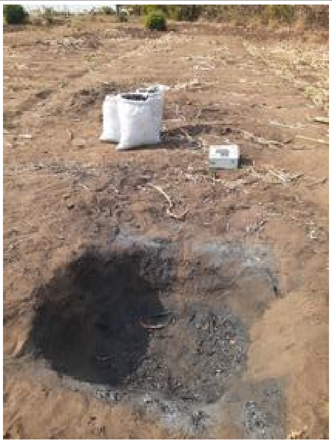
If only dust remains on the fingertips, that can be removed with water, the char probably reached temperatures above 400 ° Celsius, which is beneficial for soil fertility. Optimum charring temperatures seem to be between 400 and 600° C.

The number of bags of biochar from one pile is actually less relevant than the mass (in kg) of char harvested and the quality of the char.

From the trials on 12/13 September we got some interesting observations regarding the bulk volume (meaning the weight per l of volume of char). There is an inverse relation of volume to mass of char depending on the 'quality of the biochar', which can be interpreted in different ways.
For climate mitigation the weight of the char that is sequestered into the ground is an important metric, while for soil fertility the type of char is more important.

We observed substantial differences between the 3 bags of biochar that we harvested carefully from the pit to avoid contamination with dirt: Bag 1 and 2 had the same volume but different weights. Bag 1 was the most lightweight which came from the top of the pit. It contained mostly what fell into the pit last and came from the top of the burn pile that had been exposed longest to the fire and probably at the highest temperatures, thus the most lightweight char which is the most recommended for biochar. Bag 2 from the middle had the same volume as bag 1 but weighed 1.5 kg more. The least volume was in bag 3, yet it weighed 8.1 kg, probably due to the partially uncharred material from the bottom of the pile. Only for some torrefied and not fully charred material in bag 3 soap had to be applied to clean the fingers afterwards. all other material seemed to have reached temperatures above 400° C.

Uncharred material in the biochar mix to be applied to a field is not a problem. According to Kelpie Wilson (oral quote) it is a good food for soil microbes and adds to increase the fertility of the soil.

	
Carefully emptied pit on13th Sep: hardly any char left in the pit, no dirt scraped up	3 bags: 2 bags with same volume but different weights - right: bag 1 with 3.99 kg, Bag2 on top 5.5 kg, left: bag 3 with less volume but 8.1 kg due to partially uncharred material.

Some material from bag 3 was compared to similar pieces from uncharred maize: it shows that the pieces keep their shape but they reduce in size by about 40-50%, depending on the degree of carbonisation.

	
Before and after comparison: shrinking 50 percent in volume, 75% in mass	Very good quality char from maize stalks in bag 1: lightweight, brittle, easy to crush to powder

	Biochar quenched with soil and mixed with manure and urine, a bag sold at ca. 10 USD

Timeline of events in 2021 in Malawi

Date	Event / Action
3. Aug	First request by email from Sun24 to Christa Roth and request for third-party person to report on activities on biochar making at Nthawi farms near Lilongwe, Malawi, discussions vial email, suggestion to engage Owen Mbilizi
14. Aug	Contact established between Kevin McLean and Owen Mbilizi, agreement on tasks and conditions via email and threeway whatsapp call 1 hour
19. Aug	Owen visits Clement to look at the farm and make biochar, too much wind, but weighing stalks - each bundle of maize stalks ca. 15 kg, the compile 4 piles of 15 kg = 60 kg of dry maize stover
20. Aug	Owen visits Clement to finally make biochar and cover with dirt harvesting bags in darkness
21. Aug	Owen goes back to confirm reading of weights : Initial report 60 kg dry maize stover yielding 43 kg biochar
28. Aug	Christa in Malawi, inspecting biochar bag from Nthawi in Lilongwe, discussions on email on potential yields to triangulate figures reported by Nthawi (initial report 60 kg maize stover yielding 40 kg biochar)
29. Aug	Christa and Owen visit Nthawi farms to see quality and quantity of biochar on site
1 Sep	Christa and Owen visit Nthawi farms to try make char too windy
6. Sep	Christa counting stalks and weighing
10 Sep	Christa to Nthawi, too much wind
11 Sep	Christa to Nthawi, too much wind
12 Sep	Christa to Nthawi, burning the pile early morning, coming back in afternoon with Owen to weigh char, but still too hot
13 Sep	Christa and Owen visit Nthawi to harvest biochar
14 Sep	Conversation with Kevin
16 Sep	Last visit of Christa to Nthawi farms before leaving the country
	Report compilation

About the author:

As FOODandFUEL consultant, Christa Roth advocates for the availability and affordability of appropriate fuels and end-user devices for different household energy needs, especially for vital cooking energy. She shares her extensive field experience (25 years in the field worldwide but a focus on Africa) in Food and Biomass Fuel Security and carbon-negative biochar-making cooking solutions e.g. in ‘Stove Camps’ around the world to enhance sustainable access to renewable household energy solutions for the target groups in need.

Christa is well known in the international biochar scene.

Her fascination with biochar goes back to 2007 when she started working with Paul Anderson (aka Dr TLUD) on Top-lit up-draught TLUD devices that can also make biochar. After meeting Kelpie Wilson (wilsonbiochar.com) in Oregon at Aprovecho stove camp in 2009, she learned how to make and use biochar. Christa accompanied Kelpie in Germany on a tour to meet great researchers on biochar like Prof Claudia Kamman, Pyreg demonstration site etc.

The close cooperation with Hugh McLaughlin (All Biochars are Not Created Equal, and How to Tell Them Apart), Paul Anderson and Tom Miles brought a deep-dive into biochar and lead to the first edition of the GIZ-HERA Manual on Microgasification- Cooking with gas from biomass in 2011, to which Hugh and Paul contributed the science and many other experiences and Kelpie contributed a chapter on biochar.

In the following years Christa presented carbon-negative cooking solutions on various biochar-related events e.g. BayCEER in Bayreuth (How many *sausages* can you grill in the process of *making*. 30g of *biochar*). Christa became a co-organiser and instructor of various 'Stove and CHAB camps' for Combined Heat and Biochar, e.g. in 2011 with Paul Anderson at Makerere University in Uganda and at Zamorano University in Honduras (for which the gasification manual was translated into Spanish) at Trentino in Italy (with Dale Andreatta) in 2012 in Amhurst (Massachusetts USA, with Hugh McLaughlin, Tom Reed, Paul Anderson), Glücksburg (Germany 2015), to mention a few.

From 2011-2012 she led a TLUD gasifier field trial and assessment on biochar potential in Malawi together with Paul Anderson, during which the TChar concept was developed.

In 2014 she authored the Micro-gasification manual 2.0 with updated biochar chapters.

In 2015 she started biochar field work in Malawi with Alliance One Tobacco, developing the of 'amazing biochar makers' and continues the journey with Pyxus Ltd.

At the conference for Pathways to Cleaner Cooking 2050 in Wexford (Ireland) in 2019 she presented biochar-making cooking options and the potential paradigm shifts for charcoal production, urban cooking fuels and climate change mitigation&adaptation, Carbon Capture and Storage etc.

In 2021 she was approached by Kevin McLean from Sun24 for a third-party verification of the top-down burn pile method to make biochar from maize residues in the field.