Biochar for Soil Fertility

Experiments in making charcoal using the invasive weed Lantana camara in and around the Mudumalai Tiger Reserve.

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March 2011
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Background

As a part of converting the unwanted *Lantana camara,* a highly invasive weed from the Mudumalai Tiger Reserve area in Tamil Nadu into “greener” biochar, studies were performed to analyse the feasibility of using household stoves and bigger reactors to produce the charcoal and then biochar.

The model we are attempting to create is to have communities, at a household level, to start making and using biochar. For long term continued sustainability we as an NGO cannot indefinitely play a supporting role to ensure biochar is produced and used. Communities have to have ownership over the process, and must genuinely feel that it is useful for them.

In keeping with this objective, The Shola Trust has first tried to ensure (1) we have a good working stove/pyrolysis unit for communities to use at both a household and and village level (2) that biochar is indeed good for agriculture.

These are largely the two main lines of work we have been working on so far. As these come to a close, we hope to then get communities involved and that the idea will grow virally among 100s of households across the region.

Three charcoal producing stoves were used in these studies: Anila stove and Sampada stoves, as well as a modified version of the traditional stove. These stoves serve a dual purpose: they can be used for daily cooking and at the same time they can use up the surplus heat energy during the cooking process to produce charcoal, which can later be converted into biochar by mixing it with the compost and manure into the soil. Bigger kilns were used to study the feasibility of using them to produce charcoal at a larger, village level scale than the household stoves. Like the stoves, two types of bigger reactors were used for the studies. In all 5 cases – 3 stoves and 2 reactors – charcoal was successfully obtained. Conversions of 25% - 30% were obtained during these studies.

This report also addresses the design to test the soil fertility by using biochar. We have identified three locations and each location will be divided into 4 plots. All the plots will have the same external inputs, the only different parameter will be the fertilizers added. This way we are hoping to get substantial results for using biochar to improve soil fertility.

We are extremely grateful to the RH Southern Trust for the financial support extended to this project.

Household charcoal production

Anila Stove

Construction

The Anila biomass gasifier stove used for the experiments was designed and built by Professor Ravikumar, Mysore University, India.

The Anila stove consists of two chambers (pictures overleaf):

1) The gasifier chamber – filled with light biomass to be converted into charcoal
2) The combustion chamber - filled with fuel wood to provide energy for cooking and the pyrolysis process.

There are 10 mm holes punched around the inner walls of the gasifier chamber to let in the gasses released through pyrolysis, into the combustion chamber and the ventilation cone also has 10 mm holes punched in them to let in oxygen supply to aid in combustion.

Working

1) The stove is first turned upside down to fill the gasifier chamber with light biomass. Depending on the density of the materials used, roughly about 1 kg of biomass - Lantana twigs, dried leaves, paddy husk, dried coconut shells, etc. - can be added into the chamber. Then the ventilation cone and the closing plate are placed in that order and are clamped shut tightly.
2) The stove is now turned the right side up. The combustion chamber can hold anywhere between 750 gms to 1.5 kgs of fuel wood depending on the size and bulk density of the fuel wood used.
3) The stove is lit from the top and burns continuously for 45 to 80 mins depending on the amount of fuelwood filled. It was observed that, on an average 1 kg of fuel wood burns for about 50 – 55 minutes.
4) As the fuel wood burns (Fig. 3) from the top to the bottom, the temperature increases to around 400 °C, the biomass starts turning into charcoal by releasing volatile gases. These gases enter the combustion chamber aiding in the combustion process. Since the gases are burnt in the combustion chamber, the process releases very little smoke.

Multiple experiments were conducted using the Anila stove with different kinds of biomass filled in the gasifier chamber. Rice husks, dried coconut shell, dried Lantana twigs and dried leaves were used as biomass for the experiments. It was found that while complete charring of 1 kg of Lantana was achieved only partially charring of dried coconuts and rice husks took place under identical experimental conditions. This discrepancy in the charring process is due to the density differences of the different types of biomass. The fibrous nature of Lantana twigs aids in Lantana getting charred much more easily than the other types of biomass tested in this study.

Experiments were also conducted to increase the efficiency of the stove in terms of more effectively utilizing the extra heat (energy) which is produced during the pyrolysis of the biomass in the stove. By inserting a copper tube inside the combustion chamber, we were aiming to tap the extra heat produced to heat water while you could cook in the stove above. Figure 5 shows the schematic of the setup.

One end of the copper tube is connected to a water tap, in this case a plastic bucket with a siphon. This source of water needs to be higher than the stove in order to enable flow due to gravity and thereby eliminate the need for a pump. The other end falls into a collecting vessel. When the tap is turned on, as the water flows through the pipe it gets heated by conduction in the combustion chamber and comes out as hot water in the collecting vessel.

The output volume and the outlet temperature of the hot water can be varied by changing the flow rate of the water in the tube thereby changing the residence time of the water in the coil for a given length and diameter of the copper tubing used.

In this study, it was observed that with 1 kg of fuel wood and 1 kg of light biomass approximately 32 litres of hot water was obtained from the copper coil and 35 litres of water was heated on top of the stove, which in total gives around 67 litres of hot water. Also, 300 grams of charcoal was obtained from the biomass in the gasifier chamber.

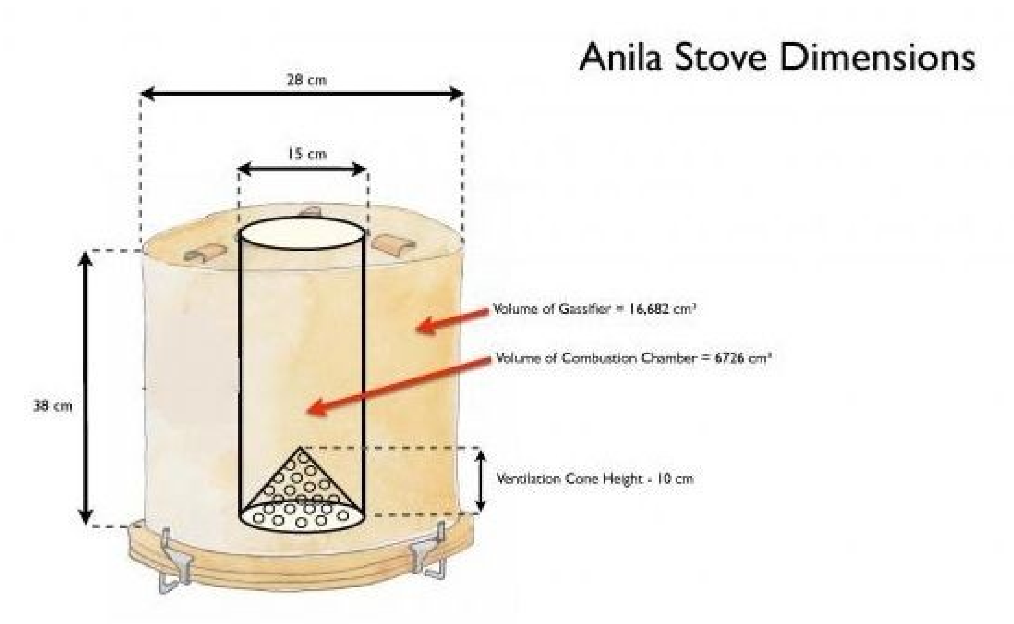

Fig 1: Anila Stove dimensions

Fig 2: Upside down Anila stove, for loading biomass to be charred

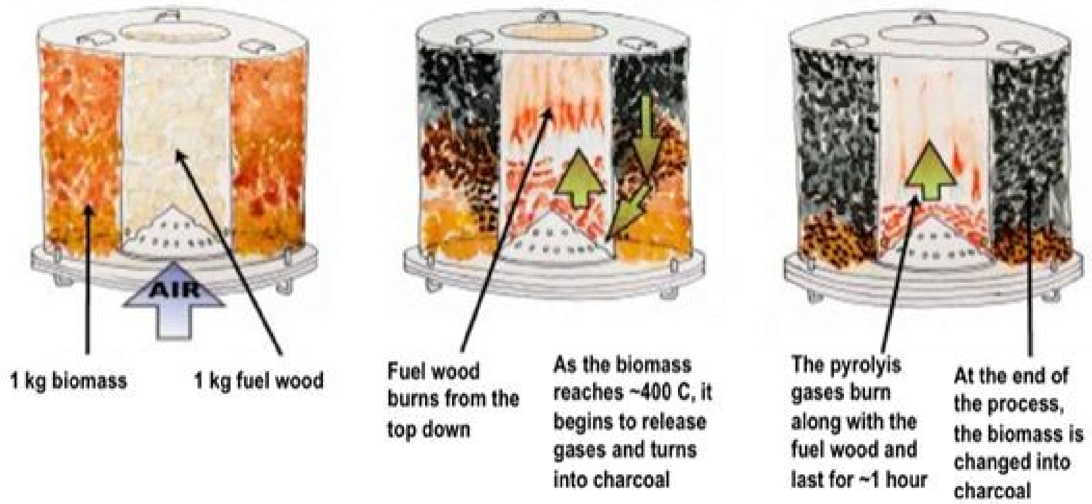

Fig 3: Working of the Anila Stove

Fig 4: Partially charred coconut husk and dried leaves

Fig 5: Completely charred Lantana twigs

Fig 6: Schematic of the copper coil water heating set up

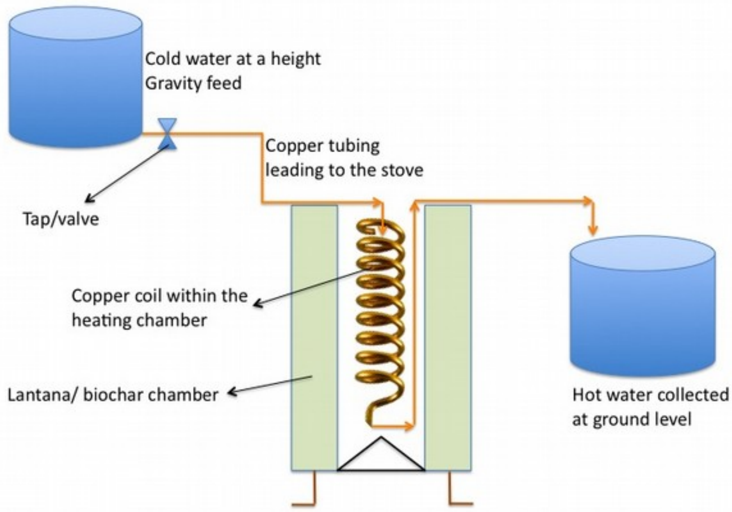

Fig 7: Copper coil inserted inside the combustion chamber of the Anila stove

Fig 8: Photograph of the copper coil water heating set up

Sampada Stove

The Sampada Stove (charcoal producing stove) is one of the many improved “green” cook stoves that was designed and developed by Appropriate Rural Technology Institute (ARTI), an organisation based in Pune, India.

Construction

The Sampada stove consists of two parts:

1) A Pyrolysis chamber where fuel wood is added and burned from the top. This chamber can hold about 500grams to 1kg of fuel wood depending on the density of fuel wood used.
2) The bottom of the can has holes drilled in them for letting in air through the bottom. The central tube has holes at the top for oxygen supply from the top.
3) A stainless steel portion with provisions to keep vessels for cooking. This portion covers the pyrolytic chamber.

Working

The operation of the Sampada stove is explained in this section. Figure 11 shows the cross-section of the Sampada stove.

1) At least 500 grams of fuel wood needs to be added so that the flames come out of the stove. It has been observed, for best results that the standard size of wood needs to be as shown in Fig 12. Average length of wood pieces – 15cm; Maximum length of wood pieces – 22cm.
2) Igniting the fire can be done from the bottom or from the top. Performance is not hindered in any way here unlike the Anila stove, which needs to be lit only from the top.
3) Once the fire gets going, the second part- a stainless steel covering is put over the first combustion can (Fig 13 and 14).
4) The fire can be kept going by adding fuel wood from the top. On full charge of about 1 kg of fuel wood, the stove will be in operation for about 50 -55mins.
5) Once the cooking is over, the burnt wood is emptied into an airtight can, shutting off the air supply completely. This prevents the wood from being turned into ash and once the contents in the can are cooled, charcoal remains.

Experiments conducted with the Sampada stove have shown that not all waste biomass can be used in this stove. Hard wood with at least 12cm/3cm is necessary to keep the fire going. Thin twigs of Lantana camera, rice husks, dried leaves etc. cannot be used.

Fig 9: The two major parts of the Sampada stove

Fig 10: Getting started with the Sampada stove

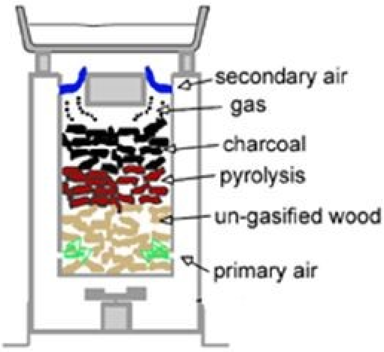

Fig 11: Working of the Sampada Stove

Fig 12: Typical fuel wood size for use in the Sampada stove

Fig 13: Firing up the Sampada stove

Fig 14: Sampada stove in operation

Fig 15: Airtight can aiding in the charring process

Modified Traditional Stove

This stove is designed by Dr. N. Sai Bhaskar Reddy, Founder and CEO of Geoecology Energy Organisation (GEO) which is based in Hyderabad. Dr. Sai made a three day visit to The Shola Trust and the main objective was to design a stove which would be best suited for the cooking and eating patterns of local people. Based on his observations, Dr. Sai designed a cook stove which is very similar to the traditional stoves but is more efficient in

1) Fuel wood consumption
2) Visibly less smoke
3) Increased charcoal yield

Construction

These stoves are constructed using easily available locally available raw material - bricks, clay, mud and cow-dung.
Around 50 bricks are needed for the construction of these stoves. Mud or clay is available in plenty around the villages itself. The construction cost including transportation of bricks, mason charges and labour is about Rs 400 per stove.

Working

There are twin fire places for cooking simultaneously (which people prefer). The fuel wood is placed in the slot provided for it. Fire moves up to the first pot, some of the flames are deflected to the second pot providing enough heat to cook simultaneously on both pots. A chimney to channel the smoke out is not necessary as the extra chimney effect is caused by the second pot, the total length travelled by the left over combustible gases is greater due to second pot, there is greater chance that all the gases are combusted in the two pot stove.

We have installed these stoves in 2 households in Srimadurai area. At the end of this month, we will know the feedback of the families which are using these stoves. But overall, people are happy with these models as they are very much like their traditional designs but more efficient, less smokey, consume less wood and easy to construct and repair with local material.

Fig 16: Dr Sai with the The Shola Trust team

Fig 17: The stove lit up

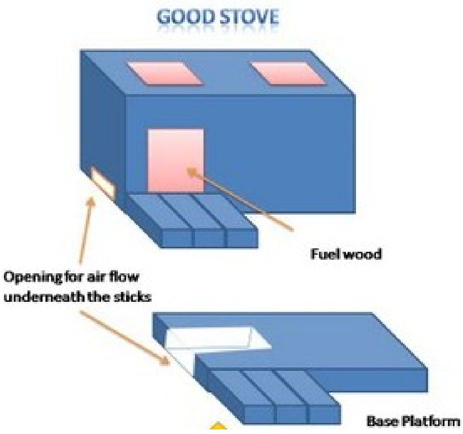

Fig 19: Schematic view of the stove

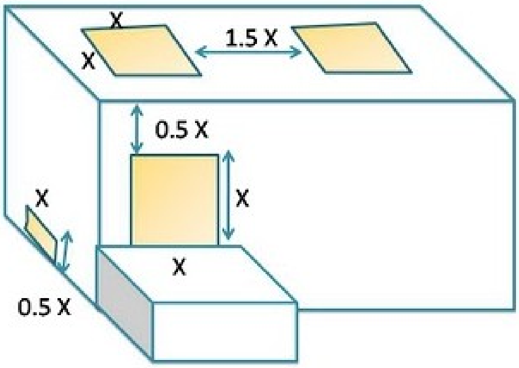

Fig 18: Dimensions of the stove

Fig 20: Stoves installed at 2 household in Srimadurai Area

Comparison:Anila and Sampada stoves

Particulars	Anila	Sampada	Traditional Design
Height/ Length	40cms/30cms	34cms/24cms	28cms/55cms
Weight	Portable, but reasonably heavy	Portable and light	Fixed, cannot be moved.
Cost	Rs 2500	Rs 1200	Rs 400
Filling procedure/ Starting procedure	1) Turn the stove upside down	Fill the stove with 1kg of hard biomass	Place the fuel wood/sticks at the slots provided for them.
	2) Fill the outer ring with about 1kg biomass		
	3) Turn the stove around ride side up		
	4) Fill stove with 1 kg of hard biomass		
	Most complicated of all the stoves	Less complicated than Anila Stove	Similar to their traditional habits of using stoves. So least complicated
Total biomass/filling	2kgs	1kg	Continuous – biomass added as and when required
Type of biomass	1kg of hard wood + 1 kg of any available light biomass	1kg of hard wood only. No use of light biomass	Hard wood. No use of light biomass
Time ignited for	60 - 75 mins/ full filling	45-50 mins/full filling	Till fuel wood lasts
Charcoal produced	30% of weight stuffed into the outer ring	30% of dry weight of the 1kg hard biomass	20% of fuel wood burned
Ignition	From the top only	From anywhere	From anywhere
Obtaining charcoal	Charcoal can be obtained at the end of 60 - 75 mins	1) The stainless steel container needs to be lifted	1) Charcoal needs to be taken out of the slot provided for it.
		2) Hot coal in the combustion chamber to be emptied into another airtight box	2) Water needs to be sprayed to prevent charcoal from turning into ash.
		3) Once all the smoke is released and cooled, the charcoal can be removed	
	Least complicated of all	Most Complicated	Reasonably complicated
Flame control	No	No	No

Larger scale Charcoal production

Double Barrel Pyrolysis Unit

We are on the search for an effective charring kiln. As a first step towards this search, we fabricated our own double drum pyrolytic reactor.

Construction

The pilot plant mainly consists of 3 parts:

1) The outer drum – This is a 200 litre drum. This drum has holes at the bottom of it which act as air slots for oxygen supply.
2) The inner drum – This is a 117 litre drum. The inner drum has small 10mm holes in the bottom of it to allow the volatile gasses to escape out.
3) An air tight lid and a chimney – The dimensions of the lid and chimney are given in figure 16.

Working

1) First the inner drum is filled with biomass. The biomass used was mostly small wood pieces and wood shavings obtained from a nearby saw mill as they were dry and easily available. In our trials we filled 13 kgs of biomass into the inner drum (max capacity of roughly 20 kgs). Even though multiple trials were done with different weights, the best results were obtained using 13 kgs of biomass. The lid is then shut tight and the drum is placed inside the big drum.
2) About 13 kgs (1:1 ratio) of fuelwood is filled inside the big drum. Care should be taken that it is evenly spread out around the inner drum.
3) The drum is then ignited from the top. During the studies it was observed that when the fuelwood is ignited from the bottom, there was more smoke than normal generated in the kiln and the charring efficiency was also markedly lower. When lit from the bottom, the lower portion of the barrel gets ashed up during combustion and in the process the unburned fuelwood gets pulled down thereby depriving the biomass in the top half of the inner chamber direct heat from the burning fuelwood.
4) Once the fire gets going, the lid and the chimney are placed and sealed tightly. The below figure shows the gasifier when it has been lit.

As the wood in the outer drum burns, the temperature increases and at about 400 ºC, volatile gases from the inner drum escape through the holes provided below leaving behind charcoal. In our experiments, we have gotten about 80% of the wood in the inner drum to turn into charcoal. The efficiencies considerably reduced when the fire was lit from the bottom.

In the above model, 1:1 ratio of biomass to fuelwood was used. It was found in our studies that roughly about 30% of biomass (by wt %) was converted into charcoal. About 3.5 kgs of charcoal was obtained from 26 kgs (13 kgs biomass + 13 kgs fuelwood) of total wood used.

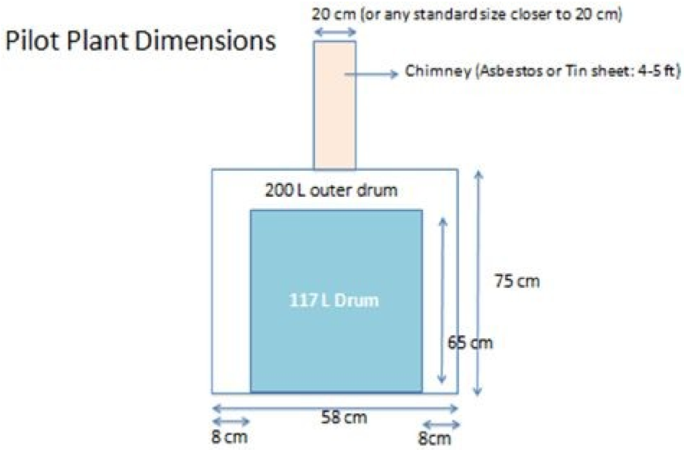

Fig 21: Dimensions of the double drum charring kiln

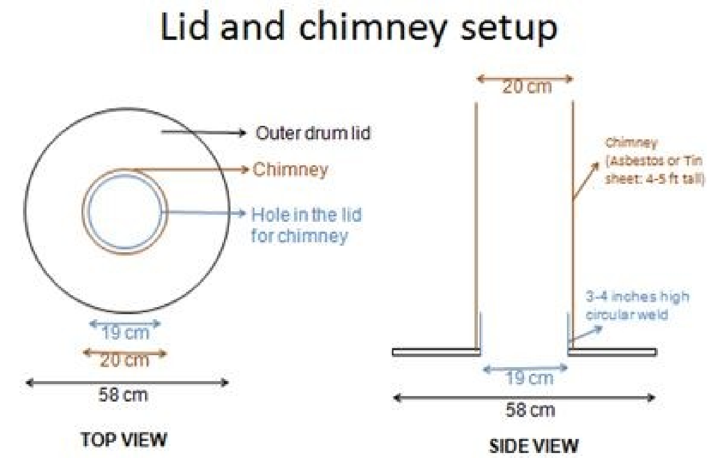

Fig 22: Chimney and lid dimensions of the pilot plant

Fig 24: Double barrel pyrolytic reactor in operation

Fig 25: Charcoal obtained from the double barrel reactor

Fig 23: Small wood pieces and shavings used in the pilot plant experiments

Single Barrel Pyrolysis Unit

As the efficiency of the above model is low, we also tried the single barrel model developed by ARTI.

Construction

The single barrel reactor effectively consists of two parts –

1) One 200 litre steel barrel used as biomass pyrolyser – thirteen 1 cm holes were punched at the bottom and 12 holes at the sides to allow oxygen supply into the barrel.
2) Lid and chimney are shown in figure 22.

Working

1) The 200 litre barrel is placed over 3 bricks, so that there is air supply to the holes at the bottom. The barrel is filled with biomass. The weight of biomass to be filled inside the barrel depends on the kind of biomass used. Approximately 6 kgs of sugar cane trash or 5 kgs of cardboard paper or 20kgs of Lantana or any other hard wood can be filled in the barrel. The variation in the weights of the biomass is due to the different bulk densities of different biomass.
2) Once the barrel is filled, the biomass is ignited from the top. Once the fire catches on, the lid and the chimney is placed over the barrel and sealed tightly using the clamps provided. A figure of the gasifier when it is lit is shown below.
3) At the end of about 15 mins to 1 hour (depending on type of biomass used), the lid is opened and the charcoal is emptied into an airtight collection barrel. If this barrel is not air tight, then there is a risk of charcoal re-igniting and turning into ash.

At Gudalur, experiments were conducted using wood shavings as biomass inside the single barrel reactor. About 8 kgs of wood shavings were pyrolyzed inside the 200 litre drum. After about half an hour we opened the lid to find only about 50% of the biomass turned into charcoal.

More experiments need to be conducted in this single barrel kiln with different biomass to calculate the efficiency of the model and compare it with the double barrel reactor. Comparison data between the two types of reactors will be provided in the next report.


Fig 26: ARTI's single barrel kiln


Fig 27: Lid and chimney atop the barrel


Fig 28: Filling the barrel with biomass


Fig 29: Wood shavings inside the single barrel reactor

Single Barrel Closed Pyrolysis Unit

Construction

Retort Kiln: It consists of a standard 200 litre oil drum which has had the bottom removed and has been mounted horizontally onto a hand-fabricated angle iron stand. The 2” bunghole which was on the top is now at the “back,” and an L-shaped section of 2” galvanized pipe has been routed from the bunghole to the underside of the drum so that it runs parallel to what was once the side. 1/2” holes have been drilled every 5 inches along the length of the pipe. The former bottom which was removed has been modified into a tight fitting lid for the front of the barrel.

Heat Retention Structure: A surrounding containment structure of sand/cement bricks has been constructed in order to retain the heat within the system and to increase safety. Several red clay roofing tiles were placed under the drum in order to prevent heat loss to the ground and to form a base so that ash and char can more easily be removed. A makeshift top of aluminium and a cement sheet has been used for the roofing.

Working

Initial Fire Preparation: The heat to start the self-sustaining gasification feedback loop is generated by creating a large fire underneath the drum with Lantana. It is important to fully and thoroughly stuff the area underneath the drum with fuel wood before starting the fire, as time, heat, and wood will be wasted by starting the fire small and attempting to gradually build it up. Also the wood should be evenly dispersed and built up underneath the drum so that all areas are heated evenly.

Charcoal Feedstock Loading: The wood which will be converted to charcoal is loaded into the drum. Pieces of wood that go into the drum should be 20 to 30 cm in length, with a maximum diameter of 5 cm. The largest pieces are placed on the bottom, with smaller pieces placed on top. This will allow the initial gasification to come from the larger, harder to char pieces, and after this threshold is crossed the remaining smaller pieces will more easily give off their gases and be converted to charcoal. After placing in the drum, The lid is put on and closed tightly with the crossbar and wing nuts. The area where the drum and lid meet is sealed with a mix of mud and cow dung to prevent gas leakage from this area; otherwise it can take much more energy to start the feedback loop.

Final Preparation: At this point the side and back walls and top should is in place. A large space at bottom-dweller is left open when constructing the front wall so that the fire can be lit and additional wood can be added. After building the wall, use a cow dung/mud mixture to seal any obvious gaps in the structure; alternatively it can be fully sealed for maximum heat retention.

Firing: The wood under the drum can now be set on fire. In ideal conditions gasification will start in about 20 to 30 minutes. When gasification starts, obvious flames will shoot out of the holes in the pipe and a loud roaring sound will be heard. The wood will fully give of its gases in a period of 10 to 20 minutes depending on the amount and density of the wood, and it will be finished when there are no more flames coming out of the pipe.

Removal: In order to have multiple batches processed in one day, it is necessary to remove the charcoal from the drum while the drum and the system are still hot. For easier loading and unloading, a wire mesh cage that is just slightly smaller than the drum is constructed so that feedstock can be placed inside while vertical, closed on the top, then turned horizontal and slid into the drum. This makes it easier to unload from the drum after charring. Water is immediately sprayed onto the hot charcoal so it does not catch fire.

Fig 30: Our welding team who fabricated the unit

Fig 31: Lantana feedstock loading

Fig 32: Single Barrel Closed Pyrolysis Unit

Fig 33: Final Preparation

Fig 34: Flames shooting out of the holes

Fig 35: Heat retention structure made up of concrete brick built around the drum

Fig 36: Wire mesh cage for holding feedstock, this makes it easier to load and unload the drum

Fig 37: Making charcoal in Chembakolly village

Feedstock

Since the objective is aimed at Lantana eradication, only Lantana wood is used for firing and as feedstock for charcoal. As Lantana is extremely bulky, it takes a lot of time and labour to bring it to the site where we are making charcoal. As of now, the process is completely manual. 2 people work the entire day and bring in about 140 kgs of Lantana. At 4rs/kg of Lantana brought in, it costs us Rs 560/day for raw materials. In our first phase, we are looking at bringing in Lantana for 10 days a month, 1200 – 1400kgs and make around 400kgs of charcoal a month. Once this process is streamlined, we can look at increasing the volumes.

Fig 38: Manually collecting and weighing Lantana

Soil Fertility Trials

We have identified three locations to conduct field trials to test the effect of biochar on soil fertility. The raw material used to make charcoal is primarily dried wood. We have started with taking soil samples of all the locations and plots before adding the fertilizers. For this cycle of experiments we will need about 120 kgs of charcoal. The charcoal making process is going on using the single barrel and double barrel gasifiers. Charcoal produced is being mixed with compost (1:1 ratio) and kept aside in sacks. These will be spread on the field after two weeks. The quality of charcoal and compost are kept the same for all three locations for this cycle of experiments.

Fig 39: Beds being prepared for soil fertility trials

Experiment Design

For the first cycle of experiments, we have selected 3 different locations and each of these locations will be divided into 4 plots. All 3 locations will have irrigation through pipes and the water supplied to each plot will be monitored/kept the same. All other external inputs will be kept the same except for the kind of fertiliser used. The size of each plot is 200 sq ft.

Plot Allocations –

1. Plot 1 – Soil (Control)
2. Plot 2 – Soil + Compost
3. Plot 3 – Soil + Charcoal
4. Plot 4 – Soil + Compost + Charcoal (1:1 ratio)

The compost used was as per as 4T/acre. So for each plot about 20kgs of fertilizer is needed. For plot 4, 10kgs of compost will be mixed with 10kgs of charcoal.

Seed sowing (beans) was done in December. Each plot was monitored and watered equally. Around 160 seeds were sown in each of the plots. The germination rates were as follows

Plot	Seeds Germinated
Plot 1(Soil)	55
Plot 2 (Soil + Compost)	76
Plot 3 (Soil + Charcoal)	95
Plot 4 (Soil + Compost + Charcoal)	110

Further monitoring was not possible as there was a pest attack on the plants, killing almost all of them. Another key observation was the moisture contents of the plots. Plots 3 and 4 were evidently more moist than the other 2 plots. But for the next cycle, we are looking at convincing a few farmers to try out biochar in their own fields. If they think it is helpful, then they themselves will propagate the use of biochar.

Field Sites

Previous activities on the above selected sites are different for the different locations. Location 1 has been agriculture land with rice being grown in the previous cropping cycle. The area surrounding the sites are agriculture lands too with rice mainly being grown. Location 2, which is a school's backyard had never been used for agriculture. The area surrounding the experiment sites have only been recently cleared up so the level of degradation is low. Location 3 was agriculture land where vegetables were being grown some years ago but currently left fallow. This patch is surrounded be coffee and ginger plantations.

The predominant soil type in the Gudalur valley area is found to be clayey soil. Soil samples taken from the locations were sent to a soil testing lab for analyses. Both the top soil and the bottom soil analyses was done. The analysed data for location 1 is given below. We are awaiting data for the other two samples.

Soil Characteristics -

- Soil Type – Clayey
- Composition and Laterite – 85% Gravel, 15 % Soil
- Water holding capacity – 42.80%

Soil analysis results

S. No	pH	EC(dSm-1)	OM (%)	N (%)	P (ppm) (%)	K (ppm) (%)
Top Soil	5.39 (SA)	0.03 (N)	3.0 (L)	0.15	12.1 (M)	31.0 (L)
Bottom Soil	5.21 (SA)	0.03 (N)	2.4 (L)	0.12	4.6 (M)	20.2 (L)

Where SA – Strongly Acidic, N – Normal, L – Low and M – Medium.

Summary and Conclusion

This report aims to briefly describe/document some of the work done around experiments with Lantana, biochar/charcoal, and more efficient fuel stoves, within the overarching aim of using Lantana as a resource so it could be cleared from the forests. The broad conclusion from this project is that communities here in the Nilgiris are not likely to take to biochar or charcoal in a significant way because:

- It is very hard to change people's attitudes, beliefs and behaviour. They all believe for example, that fire should come around the pot, but most modern fuel efficient/charcoal producing stoves aim to keep the combustion chamber somewhat contained to be able to control the combustion and not waste heat. They prop up the vessels on stones above the stove, and completely negate the careful design and intended working of these stoves!
- Charcoal is a highly useful product in villages – for starting fires from scratch, for cleaning teeth, for washing utensils, mixing with cow dung to paste of floors and walls etc. While they are all keen to make charcoal they also use it up themselves, and there is very low probability of them burying it to improve soil fertility.
- There is no real shortage of fuelwood in the region, and so there is a limited push/motivation for communities to switch to Lantana or even consider more efficient stoves. They are happy with what they are using.

Despite these limitations, we believe many of these experiments may be useful in other regions, and this document is an attempt to focus on the technical elements of the stoves and the experiments done, in case anyone wants to try and replicate it in other regions.

To summarise the key takeways:

1. On the small scale village stoves, the more sophisticated Anila and Sampada stoves produce a better charcoal yeild, but they cost more and are not easily available at a local level. A modification of the traditional stove may therefore work better, even if the charcoal production is lower. There are a slew of newer and more high-tech stoves being developed by various research institutions across the country, but it may be wiser to adapt on improve on traditional stoves for large usage/uptake by local communities.
2. There are also a number of opportunities to make charcoal at a slightly larger, village level scale, and both designs we experimented with produced reasonable results. However, the whole economy around charcoal needs to be studied arefully first, or there is likely to be a limited uptake by communities. At this scale, the economics do not easily work out to pay for the wgaes of people to make the charcoal, and perhaps even larger scale units that employ 3-5 people but produce 10-20 times the volume of charcoal need to be exprimented with. These units exist, and we are currently looking into them.
3. We conducted very preliminary experiments into the improved soild fertility and water retention, which produced very promising results particularly in terms of water retention in the soil, but unfortunately we were not able to complete these experiments for more significant results.

We hope there remains to be an interest in Lantana and biochar, to use it at wider scales.

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