Impact of Biochar on Agricultural (Maize) Production in Bungoma County, Kenya

Experimental Plots during April – August 2022

A project of Biochar Pamoja and Woodgas International

Four-Page Summary Report Released 14 October 2022

Full Twenty-Six-Page Report Released 14 October 2022

Find both reports at **Woodgas International**: https://woodgas.com/resources

THE DEMONSTRATION PLOTS REPORT:

1. INTRODUCTION:

Corn (Zea mays L.) provides basic diet to millions of people in Kenya. Total land area under corn production is about 1.5 million hectares, with an annual average production estimated at 3.0 million metric tons, giving a national mean yield of 2 metric tons per hectare. Typically, yields range from 4 to 8 T/Ha in the high potential highlands of Kenya, representing only 50% (or less) of the genetic potentials of hybrids. Highland maize varieties are grown on some 40-50% of the total maize area, representing 600,000 – 800,000 Ha.

Corn/Maize is the most important cereal crop in sub-Saharan Africa. It is a staple food for an estimated 50% of the population. It is an important source of carbohydrate, protein, iron, vitamin B and minerals. Africans consume maize in a wide variety of ways (porridges, pastes and beer). Green maize, fresh on the cob, is eaten baked, roasted or boiled. Every part of the maize plant has an economic value: the grain, leaves, stalk, tassel, and cob can all be used to produce a large variety of food and non-food products both for humans and animals.

Corn is also an important livestock feed both as silage and as crop residue, grain and is also used industrially for starch and oil extraction. In Kenya, it's an important food eaten in grains form, processed to produce maize flour to make a common meal called 'ugali', porridge, vegetable oils and sometimes fermented to produce alcohol to make local beer. Its remnants after harvesting are used as fodder and can be used to make silage when completely dried. Corn continues to be the most important staple food in Kenya.

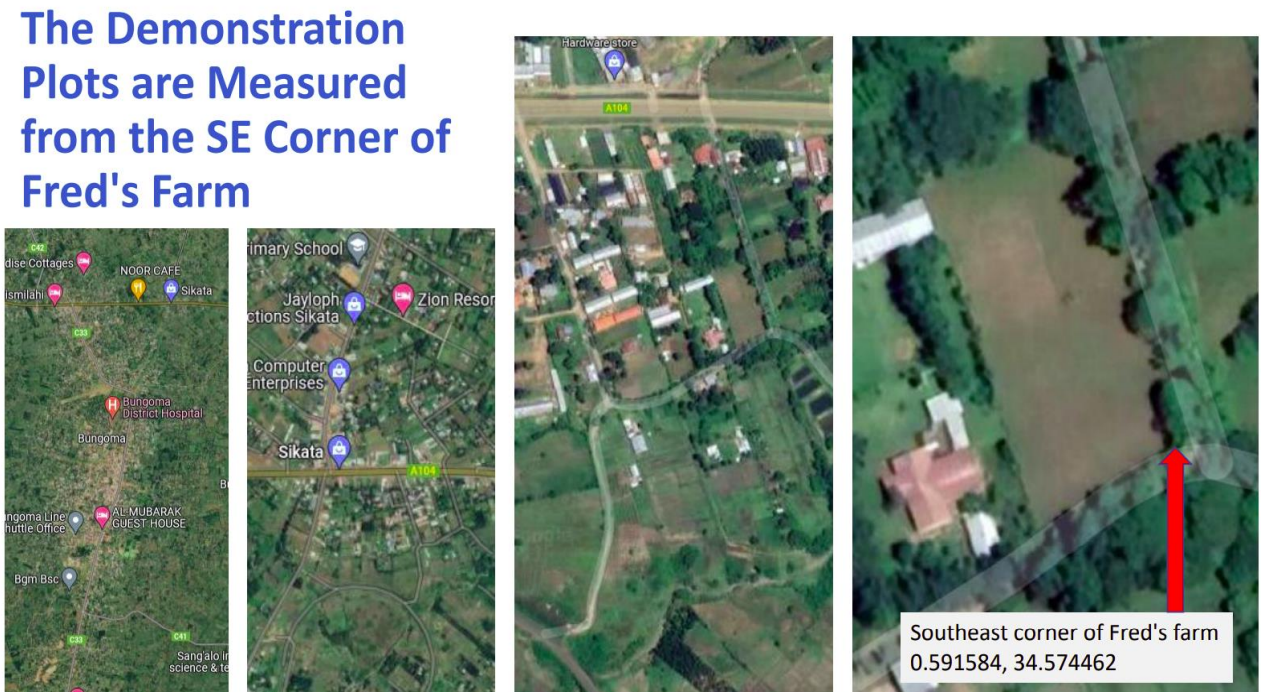
However, corn production has not kept pace with the population increase, although breeders and agronomists have exploited its genetic potential for yield. In sub-Saharan Africa corn is mostly grown by small-scale farmers, generally for subsistence as part of mixed agricultural systems. The systems often lack inputs such as fertilizer, improved seed, irrigation, and labor. Other constraints include drought, low soil fertility, pests and diseases.

1. LAND PREPARATION:

On 20th January 2022 we invited the Bungoma County Agricultural officer to conduct soil PH tests on a field belonging to Mr. Fred Namasakhe. We wanted to him to determine and indicate the poorest patch of land for us to set up our demonstration plots. We required a field containing little or no minerals. The soil tests showed that Eastern lower part along the perimeter fence didn't have any minerals at all. The soil here was very dry. There are trees and shrubs that dot the perimeter fence as hedge. Behind

it was a 4m path in between Fred's farm and his neighbor. The neighbor also has a perimeter hedge of fully grown trees and shrubs.

The first plough was done by an ox-drawn plough on 31st March 2022, early enough before the anticipated onset of rains to allow for weeds to dry and decompose before planting. We had Fred prepare his adjacent corn field at the same time to offer us better variations. Our initial plans to plant corn in two weeks did not materialize because of lack of rains then. On rain-fed agriculture early planting is essential as yields are greatly reduced by late planting. Planting is best done within the first two weeks of the onset of rainfall in highlands, while in lowlands, maize is best planted before the onset of rain for it to benefit from the scarce rainfall in these areas.



We measured and marked out six equal plots with dimensions of 20 feet by 10 feet (Approx. 6m by 3m) and provided footpaths of 2 feet (50cm) all around each plot in the field. Our entire working field was 21m by 7m. This was closely followed by a second till to prepare the plots to be ready for planting by ensuring the soil had a fine tilth and free of debris.



DEMONSTRATION PLOTS LAYOUT: **Star marks the SE corner**

Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6 ★
Biochar mixed with animal manure	Biochar mixed with Synthetic fertilizer - YARA MICROP	Biochar only	Synthetic fertilizer - YARA MICROP	Biochar with urine	Nothing added (This plot was slightly smaller, see notes.)

2. STAGES OF A CORN PLANT:

a. Seedling stage.

It is the initial stage of a corn plant with 2-4 leaves after the emergence. It takes 1-2 weeks' time after planting

b. Growth stage of maize.

Major growth stage of corn to a height equal to the knees (knee height). It takes a time period of about 35 - 40 days. First top dressing, last weeding and hoeing are all done at this stage.

c. Tasseling stage.

This is also referred as 'stage of male flower emergence' (pollen formation). This is formed after a corn plant has 15th leaves. A tassel should be done during this stage for good yields.

d. Silking stage.

This stage is also called as cob formation stage. In this stage, Gynoecia are developed. Generally, Cob also emerges between 7th to 11th leaves.

e. Milking stage of maize.

The development of blisters/ kernels starts after the completion of pollination and silks emerge at the upper end of the cob ear. The outer husk is green, and blisters appear to be milky. This is the best period to eat green corn/maize. cob ear.

PLANTING:

On 26th April 2022 we prepared 24 planting holes per row and 7 columns on Plots 1, 2, 3, 4, & 5. Optimal yields are realized if the correct number of plants per unit area are grown. Each planting hole got 1 corn seed. Every one of these plots got 168 corn seeds.

**** NOTE of exception of Plot 6: Space utilization on Plot 6 was affected by trees on two of its sides on the bottom Southeast corner of the farm. It could only accommodate 130 corn seeds. 130/168 =77.4% or approximately 25% fewer seeds were planted in Plot 6. Later calculations take this into account.**

We used the following to plant corn on the six demonstration plots; All corn seeds were planted manually with only one seed in each planting hole.

- Plot 1 (Biochar mixed with animal manure).
- Plot2 (Biochar mixed with synthetic fertilizer).
- Plot 3 (Biochar only).
- Plot 4 (Synthetic fertilizer).

- Plot 5 (Biochar with urine).
- Plot 6 (Nothing added).
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A bottle top full (25ml) of Yara Microp planting fertilizer with 'Promicro' (a smart nutrient technology) was put into every planting hole on Plots 2 & 4. It is a high quality blended NPK fertilizer developed to address key nutritional deficiencies, Sulphur and Zinc for higher yields. The synthetic fertilizer was mixed thoroughly with the soil to make sure that the fertilizer would not burn the corn seeds. Corn seeds were then placed on top of that mixture. Loose soil would then cover the planting hole.

All biochar dispersal was through a designated plastic cup measuring 237ml. Biochar charged on 25/01/2022 was used on Plot 1. We had prepared it by using 102.14Kgs of manure to charge 205.46Kgs of char. We had been maintaining a ratio 1:2 during all our animal manure charging. On Plot 2, a capful of raw biochar was put into all the planting holes and thereafter a bottle top full of synthetic fertilizer would be put on the biochar in the planting hole and mixed. Planting holes on Plot 3 got a cup full of raw biochar only while those on Plot 5 got biochar with urine. The biochar had been charged with human urine while in a char pile at the Ambassador 1 Farm of 24th December 2021 – 7th January 2022 that was stored at the Apartment. The amount of urine used on biochar was 20%. A capful of biochar would be placed at the base of a planting hole and covered with some little dirt, corn seeds would then be placed above the dirt and later covered with a loose soil cover at the top. On Plot 6, planting holes contained only corn seeds that were later covered with loose soil.

Corn grows in a wide range of zones with altitude ranging from 100-2900M ASL. This however depends on the maize variety. We purchased and planted certified corn seeds from Corteva Agriscience, Pioneer – PHB 30G19 that was highly recommended for areas around Bungoma.


YARA
MiCROP
Planting fertil
PROMICRO
CHAPA MELI


CORTEVA


PIONEER
SEED
MAIZE
CERTIFIED

3. FIELD OPERATIONS:

First weeding.

This was done on 23rd May 2022 to help the maize seedlings get relief from competition from weeds. If weeding is not done in good time, unnecessary weeds and plants compete for the same nutrients, light, water and space. These obstruct corn plants proper growth and decrease yields. It is recommended to do weeding 25-30 days after sowing. This enhances better production, growth and development of plants.

Gapping & Thinning (not done in the experimental plots)

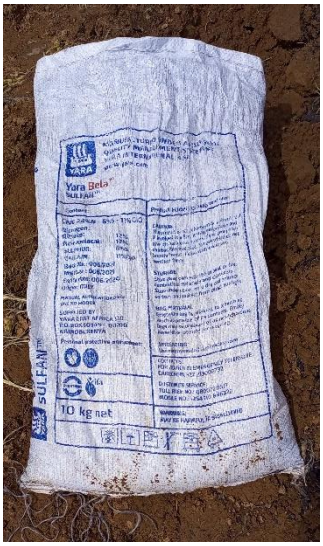
Gaping is done to replace ungerminated seeds immediately after germination is complete. Thinning is done when corn has grown to a height of about 15 cm by removing the weak and deformed seedlings. This leaves the desired number of seedlings per hole. Thinning is done just after the first weeding to help control competition for nutrition, water, and sunlight among plants. As a result, only the plant that develops well is left. These two activities were not conducted on the demonstration plots because we had planted a single corn seed per every planting hole.

Transplanting (not done in the experimental plots)

The removed corn plants during thinning are transplanted to a missing spot (planting holes that corn has not germinated) on a field. In case a missing spot is found, the transplanting is done after enough watering. The root of the maize plant should be pulled out with soil in the root because without it there might be no formation of a cob, or a kernel on the cob. This activity was not carried out on the demonstration plots.

Top dressing

The demonstration plots were top dressed on 25th May 2022. This was after the first weeding and the crops were about 45cm high. YaraBela SULFAN (26%n +35% SO_3), a compound Nitrogen and Sulphur fertilizer was used to top-dress corn plants on Plots 2 & 4. It's also referred as Ammonium Sulphate Nitrate (ASN). A bottle top full of synthetic fertilizer (ASN) was applied at the base of each plant in a ring about 15 cm away from the plant.

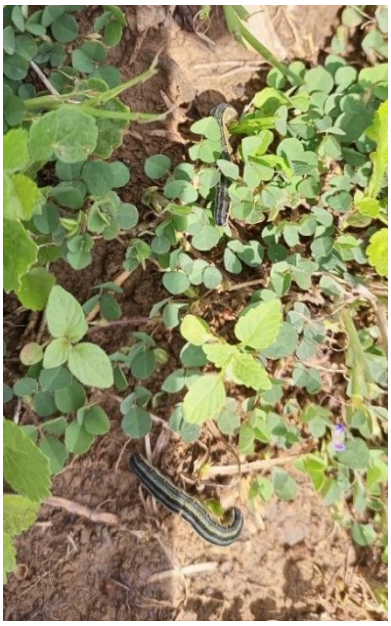


We used biochar charged on 25/01/2022. Dispersal was by the same designated cup. This biochar mixed with animal manure was used to top dress Plots 1,3 & 5. A capful of biochar would be placed at the base of a corn plant. Our plan was to top dress in two splits. 1st split 4 weeks after sowing and 2nd split just before tasseling. We could not do the second topdressing when the crop was at tasseling stage because of lack of rain.

Pests control:

We noticed on 21st June 2022 that our corn crop was attacked by Fall army worm. The affected corn plants had a mass of holes on leaves and larval frass. Fall army worm attacks corn crops at seedling, vegetative, flowering and fruiting growth stages. Its rapid spread and damage potential is devastating because it can cause up to 100% crop loss.

I purchased ALPHA DEGREE® 100EC 5ml/20L from Osho Chemicals and sprayed the insecticides that evening. This was an effective control because fall armyworms are nocturnal. We did not loose any of our corn crops.



Second weeding:

We did the second weeding on 23rd June 2022 after two days of adequate rain. The corn plants were at the knee height stage. Each nodal root of maize plant was covered with soil to prevent breakage of the stalk below the ear (plant lodging). At the same time of covering, we cleared drainage ways between each line of corn plants to help prevent root rot problems by plant lodging if it rained heavily. Unfortunately, the rains stopped just after we were through with the second weeding. A good field should be kept weed free till tasseling after which their presence might not cause crop loss.

Irrigation:

The corn plants at times experienced serious water challenges at the demonstration plots because of being rain dependent. Better maize production requires soils to have adequate moisture for 40-45 days from sowing. Soil moisture should also be maintained during the tasseling and kernel developing stage. Irrigation is necessary after the first weeding and during the tassel stage if the field goes dry.

4. MONITORING & EVALUATION:

The two tables below contain data recorded from the six-demonstration plot on 22nd June 2022 and 18th August 2022. They show the number of corn plants available during these set of dates and their heights.

TABLE 1.

Date: 22nd June 2022.						[Note p.6]]
Location	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 4**	**Plot 5**	**Plot 6**
Total number of corn plants	122	68	102	48	103	94
No. of corn plants below 1m. height	28	10	47	14	41	94
No. of corn plants between 1m – 1.5m height.	94	46	48	29	50	0
Number of corn plants above 1.5m height.	0	12	7	5	12	0

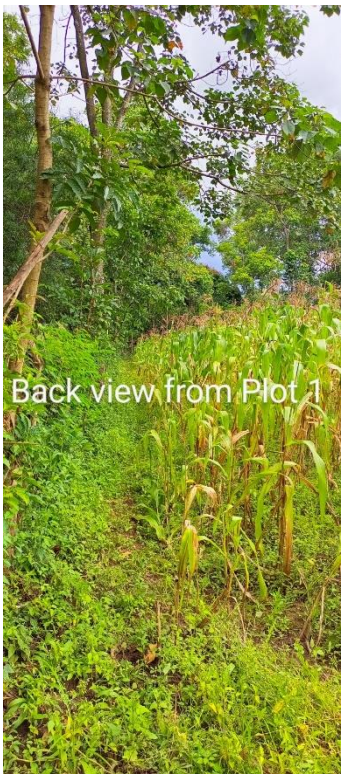
TABLE 2.

Date: 18th August 2022.						[Note p.6]]
Location	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 4**	**Plot 5**	**Plot 6**
Total number of corn plants	122	68	102	47	101	90
No. of corn plants above 2m height	76	47	54	31	47	0
No. of corn plants between 1.5m – 2m height.	36	16	39	14	40	30
No. of corn plant below 1.5m height.	10	5	9	2	14	60

These photos were taken on 30th June 2022 to show left and right variations on height in between two adjacent plots. The numbers indicate the demo plot number.

The corn crop on these two photos is of the same brand and was planted on the same date. The 1st photo has corn planted by Mr. Fred using synthetic fertilizer at the front and corn at the demo plots on the background. The 2nd photo shows the variations of both fields divided by a foot path that divides Mr. Fred and the demonstration plots. The photo has Fred's field to the left of the foot path and demonstration plots on the right. The 3rd photo shows the planting of corn on both fields.

These photos show an area along the perimeter on the Southeastern side of the demonstration plots. The fence has permanent trees and shrubs as part of the hedge. The hedge impacts corn plants as they competed for nutrients, water and adequate sunshine.



The two tables below show the tallest and the shortest corn plants on each of the six demonstration plots.

TALLEST CORN PLANT PER PLOT:

Date: 18th August 2022						[Note p.6]]
Location	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 4**	**Plot 5**	**Plot 6**
Height	240cm	278cm	286cm	280cm	287cm	195cm
Ear leaf width.	9cm	10cm	9cm	9.5cm	10.5cm	7.3cm
Ear leaf length.	130cm	160cm	138cm	126cm	123cm	107cm
No. of leaves.	12	15	14	15	16	14

SHORTEST CORN PLANT PER PLOT:

Date: 18th August 2022						[Note p.6]]
Location:	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 4**	**Plot 5**	**Plot 6**
Height	92cm	115cm	65cm	72cm	80cm	59cm
Ear leaf width.	4.1cm	6cm	4.3cm	4.8cm	5cm	3.3cm
Ear leaf length.	73cm	47cm	65cm	50cm	45cm	67cm
No. of leaves.	11	13	11	13	14	14

5. HARVESTING.


2m


Plot 1


1.
2.


2.
3.


3.
4.

Corn matures after 3-4 months especially for the short season varieties with others going up to 10 months or more. Harvesting can be done while the maize is green or when dry. We harvested our corn cobs manually by hand on 26th August 2022. The corn stalks were stacked around a tree to dry for use as biochar feedstock when they dry.

HARVEST RECORD:

Date: 26th August 2022						Note p.6]
Location:	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 4**	**Plot 5**	**Plot 6**
No. of corn plants	122	68	102	47	101	90
No. of cobs.	84	52	51	38	67	23
No. of empty corn plant stalks	38	16	51	9	34	67
Weight of kernels	7.35Kg	5.6Kg	3.7Kg	3.65Kg	5.45Kg	0.5Kg

The numbers indicated on the corn cobs piles of these photos show the demonstration plot from which the corn was harvested. **[Note p.6]**


Plot 1.


Plot 2.


Plot 3.


Plot 4.

[Note p.6]]

We shelled all the individual corn packages from the six demonstration plots manually soon after harvesting. We left out the shelled corn to dry out in the sun on six tarpaulin mats for over a week. The weight measurements were done on 7th September 2022.

The weights measurement were as follows;

Date: 7th September 2022						**[Note p.6]**
Location:	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 4**	**Plot 5**	**Plot 6**
Corn weight measurements	2.6Kg	1.95Kg	1.35Kg	1.30Kg	1.9Kg	0.20Kg


Plot 1


Plot 2.


Plot 3.


Plot 4.


Plot 5.

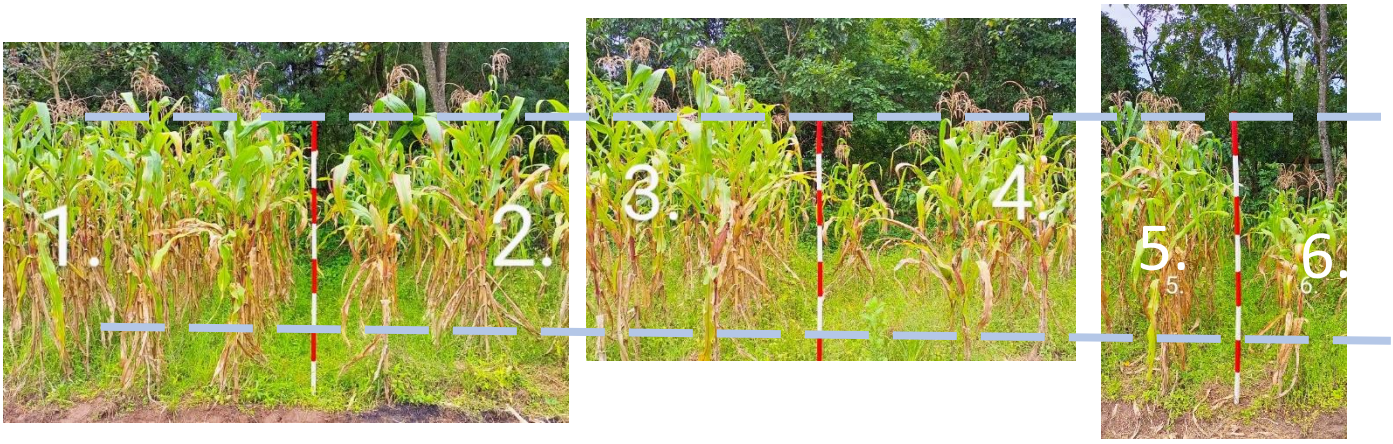

Plot 6.

	Biochar Manure	Biochar Fertilize	Biochar only	Fertilizer only	Biochar Urine	Control	Total
Plot Number	1	2	3	4	5	6	
Planted seeds	168	168	168	168	168	130	970
Germinated	122	68	102	47	101	90	530
Harvested cobs (ears)	84	52	51	38	67	23	315
Weight green no husks	7350	5600	3700	3650	5450	500	26250
Weight dry kernels (g)	2600	1950	1350	1300	1900	200	9300

Germinated/planted	73%	40%	61%	28%	60%	69%	55%
Cobs/germinated	69%	76%	50%	81%	66%	26%	59%
Cobs/planted	50%	31%	30%	23%	40%	18%	32%
Weight/cob (g)	88	108	73	96	81	22	83
Dry weight/cob (g)	31	38	26	34	28	9	30
Dry weight/planted (g)	15	12	8	8	11	2	10

[Note p.6 ABOUT Plot 6 applies to the raw numbers but not to the calculated proportionate values.]

Color code: Dark green = best of 6; light green = 2nd; Amber = 3rd & 4th; Orange = 5th; Red = worst of 6.



Interpretation:

The most important ratio is the bottom line: how much usable food is produced per planted seed in each plot.

Based on this single quantitative study, we must look for trends, not precise numeric results, especially because the control plot did very poorly. We must not dwell on the numerically true statement that "The biochar plus manure plot (#6) yielded 800% more grain compared to the control plot." Such statements would be misleading and

inappropriate because the results could be hugely impacted by unaccounted / unobserved factors.

However, without needing to do any fancy analysis, it is clear that the benefits of any kind of fertilizer or biochar alone are beneficial over the lack thereof.

Based on 8 g of dry kernels for every kernel planted, the benefits of biochar appear to be similar to the benefits of commercial fertilizer alone in this experiment.

The extra benefit of adding either fertilizer or urine to biochar is visually evident with an extra 40 to 45 percent increase in output.

We note that the best is plot 1. Manure with biochar nearly doubled the output vs using biochar alone. Unfortunately, we did not have a plot of manure only for comparison.

In conclusion, the results encourage us to continue our biochar efforts, seeking more experimental results and encouraging larger trials involving more farmers.

Reported by:
Gilbert Mwangi, Project Director for Biochar Pamoja, Bungoma County, Kenya.
Paul Anderson, PhD, Developer of RoCC kilns and sponsor of Biochar Pamoja.

Send correspondence to them at email: psanders@ilstu.edu

The four-page summary report and the full twenty-six-page report are available as downloadable PDF files from the resources page of the **Woodgas International** website (https://woodgas.com/resources) .