A friendly research project driven by SouthSouthNorth in collaboration with Abalimi Bezekhaya

Case Study: Testing the Use of Biochar in Food Gardens in the Cape Flats

Written by Freda Burden

2024

Table of Contents

Images:

This photo on the right as well as the photo on the left of the cover page show the Abalimi Garden Centre in Khayelitsha at the time of the study.

The photo on the right of the cover page is of the biochar used in the experiments.

All the images used in this report were taken by the author, Freda.

Collaborators

SouthSouthNorth

Non-profit Organisation

Supports national and regional responses to climate change through policy and knowledge interventions, partnerships and deep collaboration.

Abalimi Bezekhaya

Non-profit Organisation

Supports micro-farmers in the Cape Flats townships to grow vegetables organically with the purpose of encouraging food security and creating livelihoods.

Freda Burden

Researcher

Freda is a junior urban food systems researcher. She holds a PGDip in Sustainable Development and a BSc in Biochemistry, Genetics and English Literature.

Project Overview

The context of the biochar project in Kuyasa.

Abalimi Garden Centre Khayelitsha, 2023.

Biochar Project Context

SouthSouthNorth (SSN) launched an investigation to see whether biochar is an effective soil amendment that can improve the growth of vegetables in backyard and community gardens in Kuyasa, Khayelitsha. The biochar was a donation which SSN had sent to the Abalimi Garden Centre in Khayelitsha.

SSN have been implementing and testing the efficacy of technologies that can improve the quality of the lives of people in Kuyasa while mitigating climate change for many years. Check out the Kuyasa Clean Development Mechanism Project for more information.

The biochar testing project described in this report is an extension of this collaborative community development work.

Timeline

The project ran from 1 July 2023 until 31 April 2024.

Team

The following people worked together to steer this project:

Freda Burden | Independent Researcher
Babalwa Mpayipi | Abalimi Bezekhaya
Asiphe Mntuyedwa | Abalimi Bezekhaya
Aimee Tredoux | SSN
Carl Wesselink | SSN

Background: Biochar

What is it and what value does it hold?

What is Biochar?

Biochar is produced when organic matter is burnt in an oxygen-limited environment.

Function and Properties of Biochar

Research has shown that the properties of biochar and its effects on agricultural ecosystems vary largely depending on what it is made from, how it is produced, how it is applied and the context in which it is implemented.

In recent years biochar has attracted attention because when it is made and applied appropriately it offers the following advantages:

1. Improved Plant Production

Biochar can alter the physical and chemical properties of soil to improve factors like the soil's ability to hold water and transfer nutrients to plants. This means biochar can increase the agricultural productivity of soils, bolstering food security.

2. Climate Change Mitigation

The process of producing biochar locks carbon into very stable structures in which it can remain stored in the soil for thousands of years. As such, biochar can help ease the detrimental effects of climate change by trapping carbon and reducing soil greenhouse gas emissions.

Biochar in an African context:

Producing biochar is an ancient indigenous technique that has been used by agricultural communities in Africa for centuries.

In contemporary Africa, biochar might be able to serve as a cost-effective resource that farmers can use to improve the quality of soil and thereby improve their yields.

If farmers produce their own biochar it can function as a cheaper and more ecologically sound alternative to chemical fertilisers.

Background: Kuyasa

Exploring the social setting.

Context: An Unequal City

Kuyasa is a neighbourhood located on the Cape Flats, 30km outside of Cape Town's city centre.

The legacy of unequal apartheid-era policies and urban planning still shapes the lives of Cape Town's citizens. Residents of the Cape Flats live in settlements that were designed to marginalise communities of colour by locating them on the city's periphery, away from economic opportunities and quality public amenities.[5] These neighbourhoods are significantly under-serviced compared to the city's centrally located and historically white neighbourhoods.[5] Residents of these neighbourhoods are also more likely to be excluded from accessing nutritious food due to multiple, intersecting food security barriers.[2] In 2021, following exacerbated food insecurity brought about by the COVID-19 lockdown restrictions, the Kuyasa CDM project developer decided to use some of the carbon revenue earned from the sale of the project's carbon credits to set up food gardens in the area.

Given this context, the value of this research project lies in seeing whether biochar might be a resource that could improve food production in these gardens. If so, biochar might strengthen the capacity of the Cape Flats' soil to deliver ecosystem services to residents of the area while also sequestering carbon.

Biochar Testing Site 5, 2023.

Biochar Testing Site 6, 2023.

Background: The Cape Flats

Understanding the soil of the Cape Flats.

The Cape Flats Area

The Cape Flats is a 460 km^2 region of whitish sand that connects the Cape Peninsula mountain chain to the Southwestern Cape mainland.[1]

Plants indigenous to this sandy soil, the Cape Flats Sand Fynbos, are the most threatened vegetation type in Cape Town. Only 10% of this floral group remains.[7]

This sandy soil is very porous and permeable. Water which lands on the surface of the soil runs down towards the Cape Flats aquifer. The soil is also susceptible to erosion by wind and flooding.[1]

Existing research has shown that while the impacts of biochar on agricultural systems can be radically different, in sandy soils its effects are generally found to be positive. Mostly because it increases the soil's water and nutrient holding capacity.[3]

Biochar Testing Site 3, 2023.

Biochar Testing Site 5, 2023.

The pictures on the right (taken at two of the gardens in Kuyasa) show the sandy nature of the soil in the Cape Flats.

Overview of Method

How was this study conducted and its results obtained?

Aim of the Study

SSN donated 30 kilograms of biochar-based compost, made by a biochar producer in the Eastern Cape, to Abalimi Bezekhaya. Instead of immediately distributing this biochar to Abalimi's farmers, SSN recruited a researcher to do a preliminary investigation into the efficacy of the donated biochar in improving the growth and yield of food-bearing plants at gardens in Kuyasa.

Green pepper plants growing at experiment sites in Kuyasa, 2023.

Materials Used

According to a description provided by the supplier the following two 'types' of biochar were used in this study:

1. **Black Wattle Biochar**
This biochar was made from black wattle and then left outside exposed to natural elements for six months whilst being intermittently treated with manure and urine from a sheep kraal (enclosure).

2. **Black Wattle Biochar x Sheep Manure**
This being a pre-mixture of the biochar described above and composted sheep manure.

Black Wattle

Scientifically known as *Acacia mearnsii* is an invasive tree species in South Africa. It competes with and replaces indigenous grasslands and riverine species.

Additionally, the experiment required the planting of food crops that would develop to show measurable indicators of growth and yields in the short timeline set out for this study (four to eight weeks). **Yellow pepper, green pepper and tomato seedlings** were used because they fit this description and were available at the Abalimi Garden Centre.

Seedlings at the Abalimi Garden Centre, 2023.

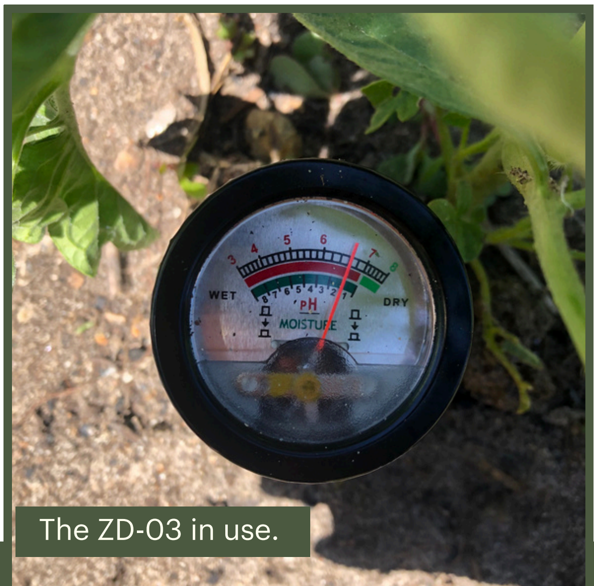
Equipment Used

Two very simple tools were used to set up the biochar test sites: a **shovel** and an up-cycled **1L yoghurt container**.

The shovel was used to dig up the soil and uniformly space out the seedlings before planting.
The yoghurt tub was used to measure the volumes of biochar and biochar x sheep manure mixture being added to the soil.

When collecting data from the experiment sites, once again only two tools were used: A **measuring tape** served to ascertain the heights of the plants. While an instrument called the **ZD-03** was used to attain indicators of soil pH and moisture content. The ZD-03 measures pH in the range of pH = 3 - 8 with a resolution of +/- 0.2. It measures soil moisture content on a scale from 0% to 80%. Further information about the ZD-03 can be found here.

In terms of data processing, **Google Sheets** was used to calculate — data averages and create the charts shown in the results section of this report.



The ZD-03 in use.

Method

Using Abalimi Bezekhaya's network of farmers, ten sites (five backyard gardens and five community gardens) were identified as suitable locations for setting up experimental planting patches where the development of seedlings growing in soil under the following conditions could be compared:

- Control soil
- Biochar-only treated soil
- Biochar and sheep manure pre-mixture treated soil

The control patches did not receive any soil amendments. At garden sites where the soil had already been treated with some type of humus: approximately 2kg (2 x 1L yoghurt tub scoopfuls) of only biochar and biochar x sheep manure pre-mixture were incorporated per square meter of soil, respectively. In gardens where the soil had not been pre-treated with humus: approximately 4kg (4 x 1L yoghurt tub scoopfuls) of only biochar and biochar x sheep manure pre-mixture were combined into every square meter of soil.

At each site an equal number of seedlings were planted in the three different soil treatments. Seedlings were planted half a shovel length (approximately 50cm) apart.

Biochar [left] and biochar x sheep manure pre-mixture [right] laying on top of the soil before being mixed in.

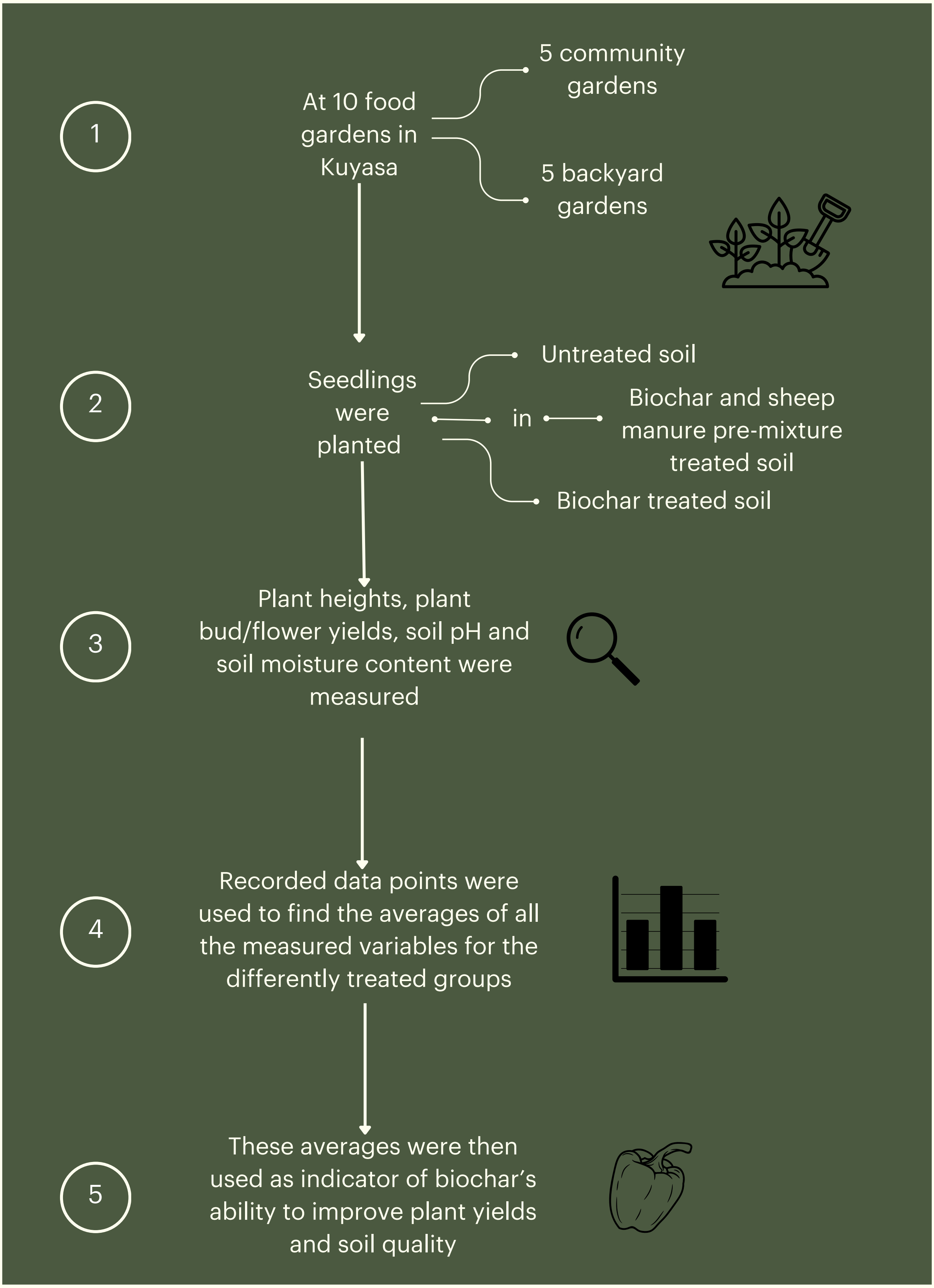
A newly planted biochar testing site.

As far as possible, the seedlings were planted in locations where they would receive uniform exposure to sunlight. Additionally, the gardeners overseeing the sites were asked to nurture all the seedlings equally.

In a period ranging from four to six weeks after planting the sites were revisited and the following metrics were collected: The heights of each plant were measured from the base of the stem to its highest point using the measuring tape. The visible number of buds and/or flowers on each plant was counted by eye. Using the ZD-03, two repeat readings for soil pH and for soil moisture content were taken in every control, biochar-only treated and, biochar x sheep manure pre-mixture treated soil patch.

These data points were then entered into Google Sheets and the mean plant heights, bud/flower counts, soil pHs and soil water contents were derived and used to make the graphs displayed in this report.

Flow Diagram Showing the Experimental Method



Results and Findings

Understanding the data.

Soil Moisture Content

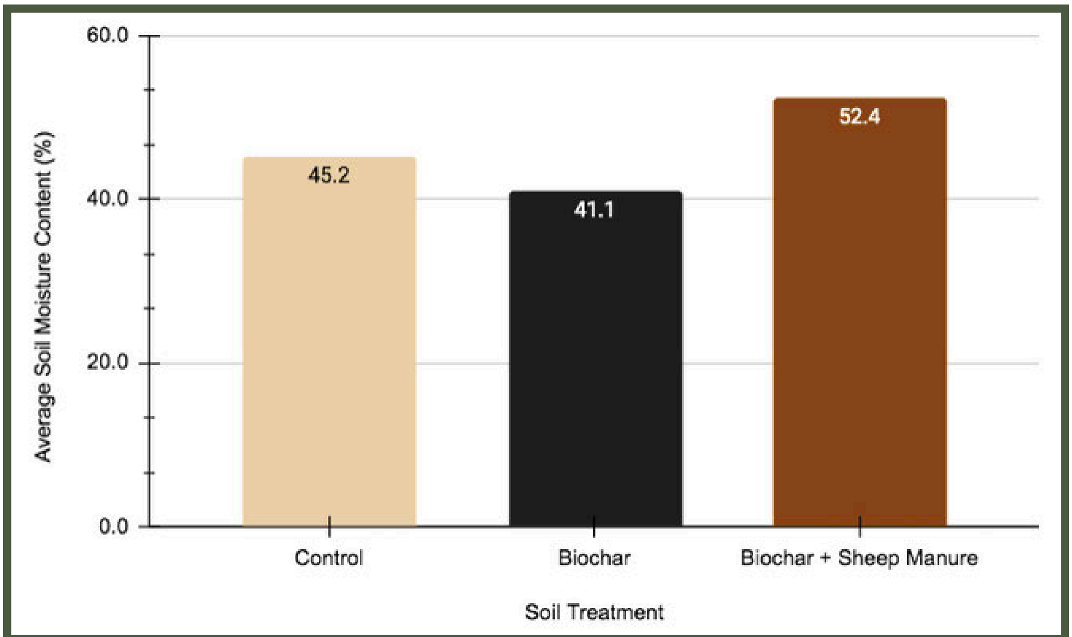


Figure 1: Shows the average soil moisture content of the differently treated soil patches.

Figure 1 shows that on average the biochar and sheep manure mixture treated soil patches had the highest soil moisture content at 52.4% followed by the control soil patches with 45.2%. Soil that had been treated with biochar only had the lowest average moisture content at 41.1%.

All of these average soil moisture content readings fall within a range of 11.3% indicating that there was not a drastic difference in soil water content between soils in the three different groups.

At the same time, the results suggest that the addition of the biochar and sheep manure treatment marginally increased the water content of the soil by 7.2%, while the biochar-only treatment marginally decreased soil water content by 4.1%.

This means that the study's results reflect that on average the addition of the donated biochar marginally decreased the detected water content of the soils of the gardens in Kuyasa. While the application of a mixture of biochar and composted sheep manure slightly increased the detected soil water content of the same gardens.

Biochar: A water container?

Under certain conditions biochar is known to increase the water holding capacity of soil. It might be that the porous nature of biochar and its capacity to bind and store water molecules means that it sequesters water within its structure making less water available in the area surrounding it and thus less detectable by the ZD-03.

Soil pH

What is pH?

It is a measure of the acidity or alkalinity of a substance. 0 being the most acidic and 14 being the most alkaline while 7, in the middle of the scale, is neutral.

What effect does soil pH have on plant production?

Soil pH affects the amount of nutrients and chemicals that are soluble in soil water and therefore the amount of nutrients that are available to plants. Some nutrients are more available under acidic conditions while some are more available under alkaline conditions.

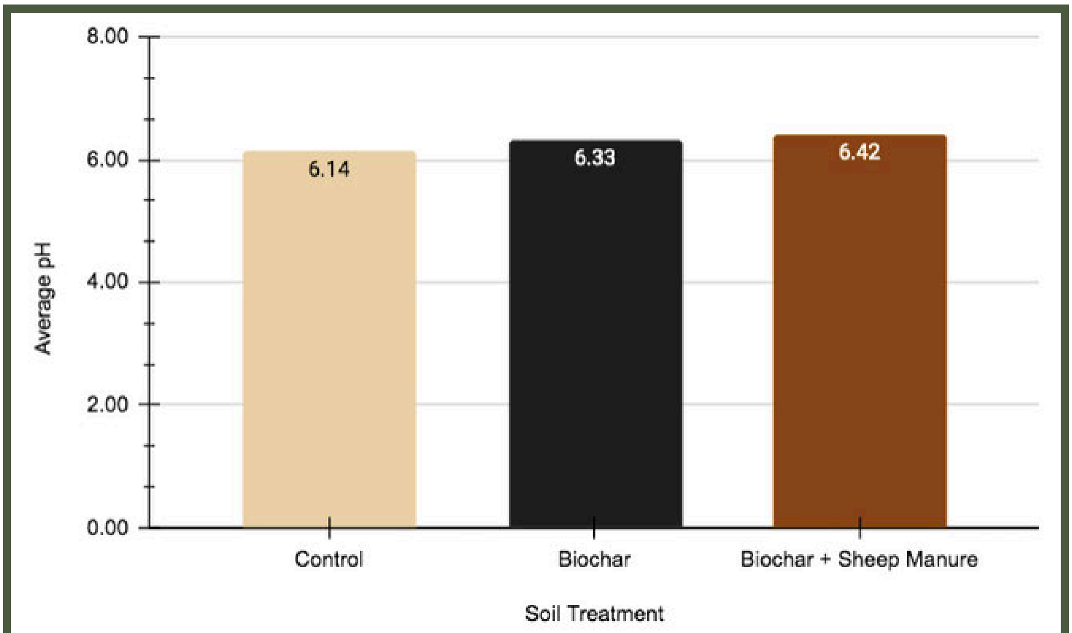


Figure 2: Shows the average pH of the differently treated soil patches.

Figure 2 shows that on average: the control soil patches yielded a pH=6.14, biochar treated soils had a pH=6.33 and biochar-sheep manure mixture treated patches had a pH=6.42.

While even subtle changes in pH can impact soil microbial ecosystems and how they function, the ZD-03 can only accurately detect pH changes in increments of pH=0.2. Therefore differences in pH smaller than this range cannot be considered noteworthy.

Given that the difference between the control and biochar treated samples was 0.19 and the difference between the biochar-only treated samples and the biochar-sheep manure mixture treated samples were 0.09 the results indicate that there was no noteworthy difference in the average pH of the different soils.

This means that according to the data derived from the study, addition of the donated biochar and biochar-sheep manure mixture had no measurable impact on the soil pH of gardens in Kuyasa as far as could be detected by the ZD-03.

Plant Heights

What does plant height indicate?

Plant height is a metric that can serve as an indicator of various aspects of a plant's well-being. Such as what developmental stage the plant is in, its overall health, how well it is adapted to the environment it is growing in and its potential productivity.

As is shown in **Figure 3**, data about the average heights of seedlings planted in the variously treated soils showed that the average height of plants in the control patches was 21.03cm, while that of the biochar only treated patches was 25.65cm and those growing in the biochar and sheep manure mixture was 25.40cm.

The results showed a marginal 0.25cm difference in the average height of plants growing in the treated patches. Yet, plants growing in soil treated with biochar only as well as those growing in soil treated with biochar and sheep manure, collectively had an average height that was 4.5cm higher than the average height of plants in the control sample.

These results indicate that the addition of the donated biochar as well as the biochar and sheep manure mixture produced plants that were on average slightly taller than those growing in the untreated soils of the Kuyasa gardens in this study.

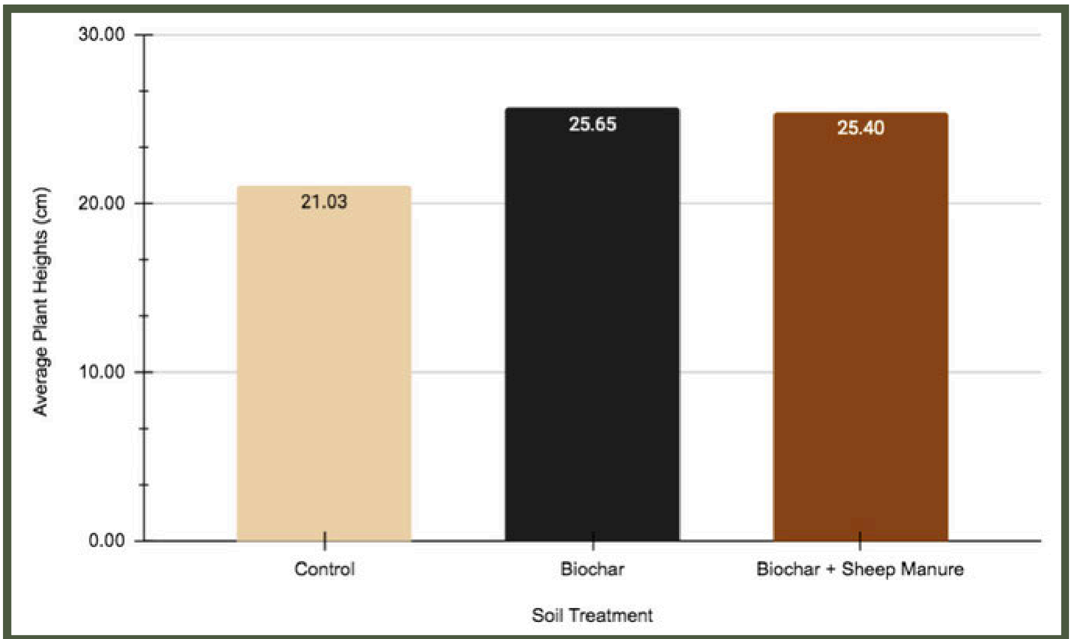


Figure 3: Shows the average heights of plants grown in different soil treatments.

Buds and Flowers

What do the number of buds and flowers on a plant tell us?

The buds on plants develop into flowers which will eventually develop into fruit, in this case peppers or tomatoes. As such the number of buds and flowers indicates how many harvestable peppers or tomatoes the plants might yield.

The results reflected in **Figure 4** indicate that on average the plants growing in the control soil produced 8 flowers/buds per plant. While the plants growing in biochar-treated soil comparatively produced 45.3% more buds/flowers with an average bud/flower count of 11.63. Plants growing in the biochar and sheep manure treated soil produced the greatest number of average buds/flowers with 13.18 buds/flowers per plant.

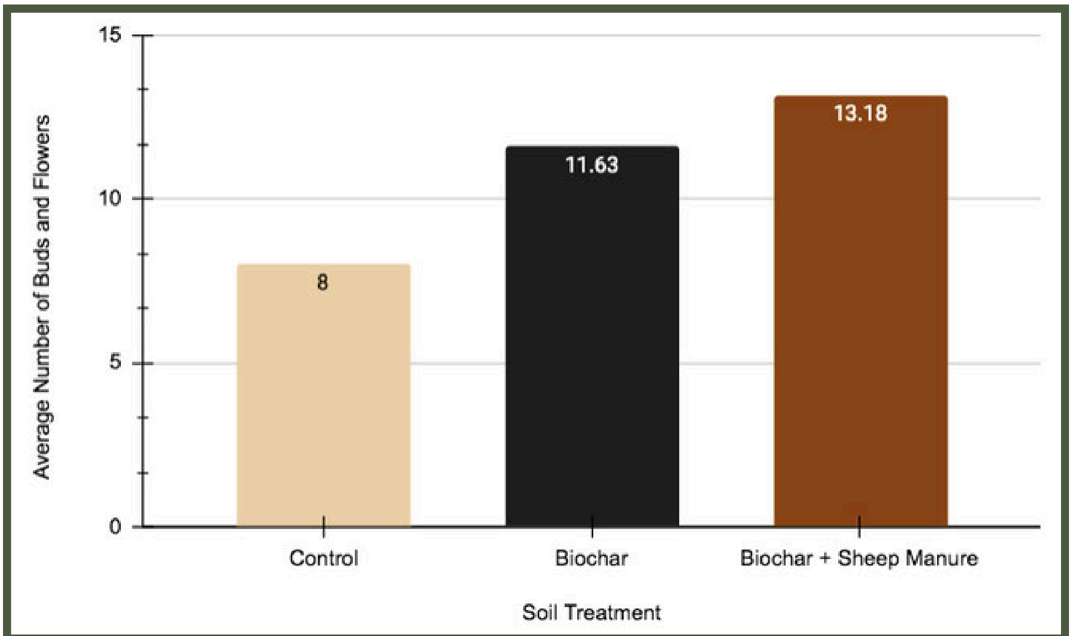


Figure 4: Shows the average number of buds/flowers on plants grown in different soil treatments.

As such the average bud/flower count of the plants growing in biochar and sheep manure treated soil was 72.5% higher than the control group and 13.5% greater than the average count for the biochar-only plants.

This means that the addition of biochar on its own increased the potential yields of gardeners in the study by 45.3% while the biochar and sheep manure mixture increased their potential yields by 72.5%.

Given the time frame set out for the study the data collection period ended before actual yields of the gardeners could be counted.

The takeaway from this is that treating the soil in Kuyasa with the donated biochar showed the potential to notably increase the food crop yields of gardeners. While the mixture of the biochar and composted sheep manure showed the potential to increase their yields by an even greater margin. increase the food crop yields of gardeners. While the mixture of the biochar and composted sheep manure showed the potential to increase their yields by an even greater margin.

Result Limitations

Boundaries of these research findings.

It must be noted that this study was carried out in the style of preliminary research. As such, there are some suggestions to improve the robustness of future research.

As an example, adding a fourth soil treatment patch of composted sheep manure-only would have produced results that more clearly show what changes to the soil and plant production could be owed to the addition of biochar versus what changes might have been brought about by the addition of the manure.

In future experiments of this nature, setting up studies with larger sample sizes and conducting a greater number of experimental repeats would also offer more insightful findings.

Additionally, evaluating the statistical significance of such findings would be critical for making reliable conclusions about the efficacy of biochar as a sustainable soil amendment in the context of the Cape Flats.

Building on the Experimental Results

After drawing up conclusions from these initial experimental findings the project was extended in order to:

- Gather feedback from the study participants about what effects they observed the biochar-based soil treatments had on the bell pepper plants growing in their gardens.
- To share the initial findings and the scope of the research with all of the gardeners who participated
- To produce research outputs, other than this report, that were targeted at engaging Kuyasa and Abalimi Bezekhaya’s gardening communities. Namely: a participatory biochar research workshop, a poster and a reel.

The workshop and the corresponding qualitative outcomes of this research project are described in the upcoming sections of this report.

Biochar Research Workshop

A knowledge sharing session.

Workshop Overview

Five months after the experiment sites had been planted, a workshop centred around the biochar research project was organised in Kuyasa. Its aims were to:

- Share the research findings with Kuyasa's gardening community.
- Hear the participants' feedback on how the biochar-based compost treatments affected their gardens.
- Facilitate a space for knowledge sharing on how to create more climate resilient gardens
- Thank everyone from Kuyasa for their hospitality and involvement in the project.

Invite that was sent out to the gardeners.

Workshop Outcomes

The workshop turned out a collaborative, knowledge-building success thanks to: the facilitation and interpretation done by the hosts, contributions made by the study participants and the active involvement of all the attendees in a safe, shady and peaceful venue.

Conversations about biochar and soil fertility were woven together with singing and humour. Unplanned discussions about the following topics also came up and were unpacked:

- How to make biochar
- Alternative ways to improve the drought tolerance of gardens in the Cape Flats, other than using biochar or compost.
- The health and environmental hazards associated with using synthetic soil inputs (e.g. biochar made out of synthetic waste).
- What climate change is and how it might affect food farming and future generations.

At the end of the workshop some of the gardeners who were not a part of the study requested materials to be able to test out the biochar treatments in their own yards, signalling the gardeners' eagerness to carry on testing the efficacy of biochar themselves.

The photos below show what happened at the workshop:

About 30 gardeners attended: most of the study participants along with other home and community farmers from the neighbourhood.

The scope of the research and its findings were presented in isiXhosa and English.

Some of the study participants shared how they found the biochar compost treatments affected the size and yields of their bell pepper plants.

Questions and conversations emerged!

Refreshments, fruits and freshly baked goods from a Khayelitsha-based bakery were enjoyed by everyone.

Qualitative Outcomes

The products of this research project, other than its measured findings.

Revisiting the gardens

In addition to the workshop, all ten gardens that had been a part of the study were revisited five months after the experiment sites had been planted. The visits and the workshop were opportunities to gather information about the project's qualitative outcomes and to share the quantitive findings of the study with those who participated in it.

The garden visits revealed that almost all of the participating gardeners had yielded bell peppers from the seedlings that were planted for the experiments. They reported incorporating the harvested bell peppers in meals prepared at their schools and homes, or selling them!

Main qualitative outcomes

Through the garden visits and biochar research workshop, this project produced many non-numerical outcomes beyond the findings of the initial quantitative study. At the same time, because no research methodology for collecting qualitative data and making sense of it was formally set out, no conclusive qualitative findings can be reported. However, for the purpose of this report, the qualitative outcomes of that most apparently, albeit incrementally, improved food security and community resilience in Kuyasa will be considered the main qualitative outcomes of this research project, these were that:

- The participating gardeners yielded vegetables to eat and sell from the experiments that were set up.
- Knowledge was produced and shared about how to improve soil fertility and create more sustainable food gardens on the Cape Flats.

At the visits, Spekbooms were gifted to the gardens to thank the participants for their involvement and for being custodians of the experiment sites.

Conclusions

The findings, outcomes and future applications of this project.

This research project set out to establish whether biochar could improve the productivity of food gardens in Kuyasa. While testing this, the project itself stimulated the production of food and knowledge about establishing climate resilient food gardens in the Cape Flats.

Most of the public interest surrounding biochar is centred around its potential to increase food security and tackle climate change. Yet, existing research communicates that whether or not biochar is able to effectively carry out these functions is highly variable. For the most part, however, biochar has been1. shown to positively impact plant production in sandy soils.

It appears that the Cape Flats region of Cape Town could stand to benefit from the use of biochar. It is an area characterised by its sandy soils and need for improved food security as well as sustainable livelihood opportunities. If biochar can make it easier to grow vegetables in Kuyasa it could be a resource for bringing about sustainable transformation on the Cape Flats.

Quantitative Findings

Drawing from data collected at ten biochar-testing experiment sites in Kuyasa, Khayelitsha, the following findings were made. On average:

1. Biochar applied on its own marginally decreased the detectable water content in the gardens' soils. However, the application of a pre-mixture of biochar and sheep manure slightly increased the detectable soil water content.
2. Neither, the addition of only biochar or a pre-mixture of biochar and sheep manure had a measurable impact on soil pH.
3. The bell pepper plants in this study grew taller in biochar-only and biochar-sheep manure pre-mixture treated soil compared to those growing in control soil patches.
4. Compared to the control group, the bell pepper plants grown in biochar-only treated soil showed a notably higher potential to yield bell peppers while those grown in soil that was treated with a pre-mixture of biochar and sheep manure had the highest potential yield.

These results indicate that biochar might be a promising resource for increasing plant productivity in the Cape Flats because the biochar based treatments which were tested increased the heights and potential yields of the plants studied. As for how the biochar treatments alter the pH and water content of soil in the Cape Flats, this study drew no meaningful conclusions.

Qualitative Outcomes

Five months after the experiment sites had been planted, all of the gardens in the study were revisited and a participatory research workshop was hosted in Kuyasa. The visits and the workshop were opportunities to gather information about the project's qualitative outcomes and share the quantitive findings of the study.

At the workshop:

- The aims of the biochar-testing research and the quantitative findings of the study were presented to all of the attendees in English and Xhosa.
- Some of the study participants' shared their feedback on how the biochar treatments affected their gardens.
- Further questions and conversations about biochar, creating climate resilient gardens and organic food growing practices emerged.
- Gardeners who attended the workshop and had not been apart of the study requested access to the leftover supply of donated biochar-based soil treatments so that they could test these soil inputs in parts of their gardens too.

While the garden visits revealed that the participating gardeners had been able to harvest bell peppers from the plants in the experiment sites to use in meals or sell.

It was concluded that the most valuable qualitative outcomes of the project were the ways in which it contributed to improving food security and community resilience to climate change in Kuyasa. This could be summarised into two main qualitative outcomes:

1. The fact that the project brought gardening resources into Kuyasa that allowed residents to grow and harvest vegetables to eat or sell.
2. That knowledge was produced and shared about how to improve soil fertility and create more sustainable food gardens on the Cape Flats, largely thanks to the participatory research workshop.

Whilst not an exhaustive, all of qualitative outcomes of this research that were noted in the report serve to elucidate the value of the project beyond its limited quantitative findings.

Future Applications

The Kuyasa-based biochar-testing project that has been described in this report has laid ground for future collaborative research projects that explore how biochar inputs affect the sandy soils of the Cape Flats and whether such biochar inputs will be valuable resources for food growers in the area. Further experiments which track how biochar alters the growth of plants and properties of soil on the Cape Flats over time will have to be conducted to build on this research.

Project Reflections

What did this project teach us?

Lessons on things that worked:

A guiding principle of this project was to try to produce non-extractive research. That meant trying to identify and prioritise the needs and perspectives of the community members involved in the research, as opposed to conducting extractive research which favours the goals of external researchers and can involve taking information from the community without giving back.

Looking at this project in retrospect, it seems like many successes arose from this focus. Here are some learnings that can be taken from it:

Key Learning	Project Specific Success
Research processes can be designed to bring resources into the communities.	Seedlings and biochar-based compost were distributed to set up the experiments for this project.
Research centred around knowledge sharing and not the extraction of results/information will improve the odds of developing local community resilience.	Hosting a participatory research workshop instead of just publishing a report about this project meant the knowledge produced was circulated amongst and co-created by the community who the research intended to benefit.
People who can interpret information between different languages and frameworks of understanding are required to produce collaborative research between non-homogenous groups.	Translation between isiXhosa and English and code-switching between scientific language and colloquial language, was the glue that allowed meaningful collaboration to take place throughout this project.

Lessons learnt from obstacles that were encountered:

As a pilot study this project succeeded in identifying ways in which future iterations of this research project could be improved. Here are two of these learnings:

Key Learning	Project Specific Obstacle
Repeats and refinements of scientific experiments would be necessary to more definitively determine how biochar impacts plant production and soil chemistry in the Cape Flats.	The biochar-testing sites lacked a sheep manure-only patch with which to compare results derived from the biochar-only and biochar-sheep manure pre-mixture treated soil patches. Once the results had been analysed, it also became clear that the instrument used to test soil moisture content and pH, the ZD-03, had not been sensitive enough to derive meaningful results.

Acknowledgements

This report is the culmination of a collective effort and I would like to acknowledge some of the people and groups who contributed to the project described in it.

Firstly, I would like to thank **Asiphe Mntuyedwa**, from Abalimi Bezekhaya, who hosted me in Khayelitsha and accompanied me for all of the fieldwork. Asiphe helped me set up all of the experiment sites and collect data from them, she was also my translator and co-host at the workshop. None of the real life work of this project was done without Asiphe and I cannot imagine how the project would have succeeded in her absence. Thank you also to **Babalwa Mpayipi** who oversaw the work Asiphe and I were doing in Kuyasa. Babalwa was the person who initially helped identify and bring onboard the ten gardens that hosted the experiment sites. She did this in her capacity as a field manager at Abalimi. My thanks also goes out to **the whole Abalimi team at the Khayelitsha Garden Centre** for their warm support and hospitality.

Of course, I would also like to thank **Aimée Tredoux**, at SouthSouthNorth, for her guidance and contributions to co-creating the outputs of this research project. Aimeé kindly nurtured me and the work I was producing from the very start until the very end of this project. I am also grateful to **Carl Wesselink** and **SouthSouthNorth** for taking me onboard and trusting me with this pilot project.

A special thanks also goes out to **Zuko Ndamane**, the project manager of the Kuyasa CDM. Zuko was amazing at translating scientific research findings into conversational isiXhosa at the workshop. An invaluable asset!

Thanks is also due to **David Phillips** who supplied the biochar used in this project. He can be reached at +27 82 558 8998 for further inquiries about procuring or producing biochar.

My final acknowledgement is to **all of the gardeners I met in Kuyasa**. I am grateful to have spent time in some of your beautiful, little oases and in your company. Thank you for all of the knowledge you shared with me. I hope that this research project has sewed a few seeds of prosperity in Kuyasa and that you get to enjoy its fruits.

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