

CONSULTANCY TECHNICAL REPORT

On-Farm Organic Resources Conversion and Soil Fertility Improvement

*Farmer-participatory evaluation of coffee husk biochar and cattle manure for maize production
in Central Uganda*

**Client**

World Vision Uganda

Consultant

Dr Samuel Obeng Apori, MEnvSc

Assignment location

Kakonge, Butambala District, Central Uganda

Field implementation period

2019-2020

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Executive Summary

World Vision Uganda engaged Dr Samuel Obeng Apori to support an on-farm organic resources conversion and soil fertility improvement assignment in Kakonge, Butambala District. The consultancy combined farmer training, practical conversion of coffee husks into biochar, establishment of farmer-managed field trials, agronomic monitoring, soil fertility assessment, profitability analysis, and farmer feedback. The work responded to declining soil fertility, limited access to inorganic fertiliser, and the need to convert locally available organic residues into practical soil amendments.

A total of 56 smallholder maize farmers (30 women and 26 men) participated. Farmers were trained to convert coffee husks into biochar using a modified barrel kiln and to apply coffee husk biochar, cattle manure, raw coffee husks, and a biochar-manure mixture in replicated on-farm plots. Five treatments were evaluated over two cropping seasons on two farmer fields. The combined biochar + cattle manure treatment consistently produced the strongest agronomic and economic response.

56	2	5	40
participating farmers	farmer-managed sites	soil amendment options	plots per season

Headline finding: combining coffee husk biochar with cattle manure delivered the most consistent gains in soil fertility, maize yield, profitability and farmer preference, while also showing clear potential for locally led organic resource conversion.

Key results

- The combined treatment increased soil pH by 1.11-1.26 units relative to the control and substantially improved organic carbon, cation exchange capacity, available phosphorus and exchangeable potassium.
- Maize grain yield increased from 4.43 to 6.95 t/ha in the wet season (+56.9%) and from 4.28 to 6.95 t/ha in the dry season (+62.4%).
- The combined treatment produced the highest net profit: US\$1,023/ha in the wet season and US\$923/ha in the dry season.
- 69.6% of participating farmers selected biochar + cattle manure as their preferred treatment.
- The main barriers to wider uptake were labour demand, limited access to kilns or production equipment, and the need for additional training.

1. Assignment Background and Purpose

Smallholder farmers in the project area reported declining maize productivity, acidic and nutrient-poor soils, and limited access to inorganic fertiliser because of cost. At the same time, coffee-producing communities generated coffee husks that were frequently underused or applied directly to soil with variable results. The consultancy therefore focused on practical conversion of locally available organic resources into higher-value soil amendments and on testing those options under farmer-managed conditions.

The assignment was designed as a practical extension-research intervention rather than a laboratory-only study. Farmers participated in biomass collection, biochar production, field preparation, amendment application, crop management, field observation and discussion of treatment performance. This ensured that technical performance was considered alongside labour, access to materials, ease of use, cost and farmer preference.

1.1 Consultancy objectives

- Train participating farmers in the safe and practical conversion of coffee husks into biochar using a low-cost modified barrel kiln.

- Compare locally available organic resource options for improving soil fertility and maize productivity under smallholder field conditions.
- Assess whether combining coffee husk biochar with cattle manure provides complementary agronomic benefits.
- Estimate treatment-level production costs, profitability and efficiency.
- Document farmer perceptions, adoption constraints and practical requirements for scaling.

1.2 Main consultancy outputs

Output	What was delivered
Farmer mobilisation and training	Participatory training on organic resource use, coffee husk conversion, amendment handling and plot management.
On-farm demonstration and trials	Two farmer-managed trial sites with five treatments, four replicates per treatment and 40 plots per season.
Organic resource conversion	Field production of coffee husk biochar using a modified barrel kiln under limited-oxygen conditions.
Technical assessment	Soil fertility, maize yield, profitability and farmer perception assessment across two cropping seasons.
Scaling recommendations	Practical guidance on amendment choice, labour, kiln access, training needs and group-based production.

2. Assignment Area, Participants and Implementation Approach

2.1 Location and farming context

The assignment was implemented in Kakonge, Butambala District, Central Uganda, at approximately 00°17'04.6"N and 32°15'34.0"E. The area has a bimodal rainfall pattern and highly weathered Acric Ferralsols that are generally acidic, low in organic carbon and available phosphorus, and limited in nutrient-retention capacity. These conditions made the area suitable for evaluating organic amendment options that farmers could source locally.

2.2 Farmer participation

Fifty-six smallholder maize farmers participated, comprising 30 women and 26 men. Selection was undertaken with local agricultural stakeholders and World Vision Uganda, prioritising farmers actively involved in maize production, interested in soil fertility improvement, and able to access organic resources such as coffee husks and cattle manure. Farmers were involved throughout the learning cycle rather than being treated only as recipients of a finished technology.

30	26	100%	2
women farmers	men farmers	farmer-participatory	cropping seasons

2.3 Participatory implementation cycle

Stage	Farmer and consultant activities
1. Diagnose	Discuss soil fertility problems, input constraints and locally available residues.
2. Convert	Demonstrate conversion of coffee husks into biochar using a modified barrel kiln.
3. Test	Establish replicated on-farm plots comparing five organic resource treatments.
4. Observe	Monitor crop vigour, soil response, yield formation and practical labour requirements.
5. Evaluate	Compare agronomic performance, costs, returns and farmer preferences.
6. Adapt	Identify feasible options and constraints for broader farmer use.

3. Organic Resource Conversion and On-Farm Trial Design

3.1 Coffee husk conversion to biochar

Coffee husks were converted to biochar using a modified oil-barrel kiln configured as a simple top-lit updraft system. The barrel incorporated lower and upper air vents and a metal chimney to support air movement and smoke release. Coffee husks were loaded and ignited from the top, then pyrolysed under restricted oxygen to favour char formation rather than complete combustion. The biochar was cooled under restricted air exposure and stored dry before field application.

Under field production conditions, one documented production cycle took approximately 44 minutes and produced 7.2 kg of biochar, equivalent to about 9.70 kg/hour. Proximate analysis indicated approximately 43.22% fixed carbon and 34.96% ash. This confirmed successful conversion of the coffee husk feedstock into a carbon-rich amendment with potential liming and nutrient-retention functions.



Participating farmers observing the practical on-farm organic resource conversion demonstration.



Modified barrel kiln used to convert coffee husks into biochar under field conditions.

3.2 Treatment structure

The experiment was conducted across two farmer-managed sites and two maize-growing seasons. Each site used a randomised complete block design with five treatments replicated four times. This produced 20 plots per farm and 40 plots per season. Individual plots measured 4 m × 5 m. No inorganic fertiliser was applied, allowing the organic resource effects to be assessed directly.

Treatment	Coffee husk biochar	Cattle manure	Raw coffee husks
Control	0 t/ha	0 t/ha	0 t/ha
Biochar (B)	15 t/ha	0	0
Cattle manure (CM)	0	15 t/ha	0
Raw coffee husks (CHKS)	0	0	15 t/ha
Biochar + cattle manure (B+CM)	7.5 t/ha	7.5 t/ha	0

3.3 Monitoring and analysis

Soil was sampled before treatment application and after harvest from the 0-20 cm layer. Standard laboratory procedures were used to determine soil pH, total nitrogen, available phosphorus, organic carbon, exchangeable potassium, cation exchange capacity and exchangeable acidity. Maize grain yield and yield components were recorded at maturity and adjusted to standard grain moisture. Treatment costs and grain income were used to

estimate net profit, benefit-cost ratio, production efficiency and monetary efficiency. Farmer perception was assessed through structured interviews and group discussions with all 56 participants.

4. Findings: Soil Fertility Response

The combined coffee husk biochar + cattle manure treatment produced the most consistent improvement in soil fertility across both seasons. Its advantage reflected complementary functions: cattle manure provided readily available nutrients, while the biochar contributed alkalinity, stable carbon and additional nutrient-retention capacity.

Indicator	Wet season: B+CM vs control	Dry season: B+CM vs control
Soil pH	+1.11 pH units	+1.26 pH units
Organic carbon	+78.8%	+335.9%
Total nitrogen	+165.2%	+184.2%
Cation exchange capacity	+91.9%	+110.4%
Available phosphorus	+113.8%	+116.4%
Exchangeable potassium	+59.3%	+81.3%

The strong pH response is particularly relevant for the acidic Ferralsols of the study area because improved pH can reduce acidity-related constraints and create better conditions for nutrient uptake. The large increases in cation exchange capacity and organic carbon indicate improved capacity to retain nutrients, while the increases in available phosphorus and potassium show that the amendment strategy also improved nutrient supply.

5. Findings: Maize Productivity

Maize responded strongly to the combined amendment. The treatment produced the highest grain yield in both seasons and also improved grain weight per plant and 1000-grain weight. Biochar and cattle manure applied alone improved performance, but neither treatment matched the combined application.

Treatment	Wet-season grain yield (t/ha)	Dry-season grain yield (t/ha)
Control	4.43	4.28
Biochar	5.32	5.25
Cattle manure	5.25	5.32
Raw coffee husks	4.28	4.42
Biochar + cattle manure	6.95	6.95
+56.9% wet-season yield gain relative to the control		+62.4% dry-season yield gain relative to the control

The weaker response from direct incorporation of raw coffee husks indicates that simply returning residues to soil was less effective than converting them into biochar. Conversion changed the material from a readily decomposable residue into a more stable and alkaline amendment, while combination with manure provided a stronger nutrient supply.

6. Findings: Economic Performance

The combined treatment also produced the best overall economic performance. Its higher amendment cost was offset by the larger grain yield and revenue. Biochar alone was more profitable than cattle manure alone because the feedstock was locally available and the treatment had a lower cost base.

Season / treatment	Gross income (US\$/ha)	Net profit (US\$/ha)	Benefit-cost ratio
Wet - Control	974	613	2.70
Wet - B+CM	1,529	1,023	3.02
Dry - Control	766	405	2.12
Dry - B+CM	1,429	923	2.82

Compared with the control, the combined treatment increased net profit by 66.9% in the wet season and 127.9% in the dry season. These findings show why organic resource recommendations should consider labour, transport, equipment and local material access alongside crop response.

7. Farmer Perception, Adoption Potential and Constraints

Farmer observations were broadly consistent with the measured agronomic results. The combined treatment was the preferred option for most participating farmers, particularly because farmers observed stronger crop vigour and better cob formation. Cattle manure was often recognised for early greenness, while the combined treatment became more visibly superior later in crop development.

Farmer response	Number of farmers	Share of participants
Preferred B+CM as best treatment	39	69.6%
Preferred cattle manure	10	17.9%
Preferred biochar	5	8.9%
Preferred raw coffee husks	2	3.6%
Coffee husk availability seen as an advantage	48	85.7%
Limited finance for inorganic fertiliser noted	46	82.1%
Biochar production labour identified as a constraint	34	60.7%

Farmer response	Number of farmers	Share of participants
Lack of kiln/equipment identified as a constraint	28	50.0%
Need for further biochar training identified	21	37.5%

7.1 Practical adoption lessons

- Resource availability matters: coffee husks were accessible to many participants, making them a practical feedstock for local conversion.
- Labour is a central adoption variable. Biochar production must be organised efficiently to avoid shifting excessive workload to farm households.
- Kiln access is a bottleneck. Group-owned or community-managed kilns can lower capital barriers and improve utilisation rates.
- Training must combine production quality, safe handling, application rate, timing and integration with other organic resources.
- Where manure is scarce or expensive, biochar alone may remain a viable lower-cost option, although the combined treatment delivered the strongest overall performance.

8. Photographic Evidence of Field Implementation

The photographs below document farmer participation, practical biomass conversion and field-based learning during the assignment. They demonstrate that the intervention was implemented as a hands-on, farmer-participatory activity rather than as a laboratory-only exercise.



Participating farmers and community members at the on-farm demonstration site.



Modified barrel kiln positioned in the field for coffee husk conversion.



Field operation of the modified barrel kiln during biochar production.

9. Conclusions

The consultancy demonstrated that on-farm conversion of coffee husks into biochar can create a useful soil amendment from a locally available agricultural residue. The strongest treatment was the combination of coffee husk biochar and cattle manure, which consistently improved soil chemical properties, maize productivity, profitability and farmer preference. The intervention also showed that farmers can participate effectively in biomass conversion, trial implementation and evaluation when the process is designed around practical demonstration and learning.

The results also highlight that technical effectiveness alone is insufficient for scaling. Labour demand, kiln availability, access to manure, transport costs and training requirements are critical adoption factors. These constraints should therefore be incorporated into future extension programmes and farmer field learning approaches.

10. Recommendations for Scaling

Priority	Recommended action
1. Promote combined organic amendments	Where coffee husks and cattle manure are both available, promote co-application as the preferred option for acidic, low-fertility soils, subject to local validation of rates.
2. Support decentralised biochar production	Establish group-based or community-managed kiln systems to spread equipment cost and reduce household labour burden.

Priority	Recommended action
3. Integrate training with field learning	Use farmer field schools, demonstration plots and lead-farmer approaches so farmers can observe conversion quality, application methods and crop response.
4. Match technologies to resource access	Recommend biochar-alone options where manure is scarce or costly, rather than promoting one package uniformly across all households.
5. Improve production quality and safety	Standardise simple kiln operating procedures, quenching/cooling, safe handling, storage and application guidance.
6. Track labour and economics	Include labour time, feedstock transport, equipment depreciation and local grain prices in future economic assessments.
7. Continue multi-season validation	Expand testing across more farms, soil types and seasons before making broad long-term claims on residual fertility or carbon sequestration.

11. Assignment Limitations and Follow-up Needs

The work covered two farmer fields and two cropping seasons. This was sufficient to demonstrate treatment differences under local conditions but not to establish long-term residual effects across the wider farming system. Soil moisture, nutrient leaching, ammonia volatilisation, greenhouse gas emissions, microbial biomass and enzyme activity were not measured. These processes therefore remain important topics for future validation. Additional work should also compare different kiln designs, labour-saving production arrangements and lower application rates that may be easier for smallholder farmers to implement at scale.

12. Consultant Statement

This report presents the technical work undertaken by Dr Samuel Obeng Apori under the World Vision Uganda on-farm organic resources conversion assignment, using the field records, analytical results and farmer-participatory data generated during implementation. The report has been structured as a consultancy technical report to document the assignment, methods, results, lessons and recommendations.

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