Completion Report

Testing biochar-pigeon pea agroforestry businesses in Zambia (ClimChar Zambia), Zambia, NCF7, NCF-C7-091

Grantee: Menon Economics

Local Partner(s): Conservation Farming Unit (CFU)

Other Partner(s): Norwegian Geotechnical Institute (NGI), Norwegian University of Life Sciences (NMBU)

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1. EXECUTIVE SUMMARY

This completion report presents the purpose, expected and achieved outcomes and outputs, as well as other relevant climate and development outcomes and impacts, for the project "Testing biochar-pigeon pea agroforestry businesses in Zambia" (the ClimChar project).

The purpose of the project has been to test a new, green business concept for Zambian farmers in four districts; Kaoma, Choma, Chipata and Mkushi.

The expected outcomes for the project were:

- At least 500 farmers take up pigeon pea production.
- Increased farm incomes from pigeon pea production and potentially improved nutrition due to pigeon pea consumption.
- Improved maize yields and reduced vulnerability of maize yields to climate variability Increased soil carbon storage.
- Robust knowledge on the profitability and potential for scaling up biochar-pigeon pea businesses.

In the first milestone period, farmers received training in pigeon pea production for consumption and sale. In the second milestone period, farmers received training in biochar production using biomass from pigeon pea residuals. The farmers also applied biochar as a soil amendment for maize production, combined with conservation farming techniques.

In the third and final milestone period, we measured and analysed the effects of biochar on maize yield, plant-available water and soil carbon contents, through soil samples and household surveys, including an experiment on risk and ambiguity aversion among farmers. We have also explored the potential for voluntary carbon credits as an incentive for biochar application.

The project has confirmed that biochar, when produced and applied correctly, has the potential for enhancing soil moisture retention by up to 3 volume percent in our conditions, improving the drought-tolerance of the farmers' maize crops and thus contributing to climate change adaptation. In addition, average maize yield increases in the 2020-2021 season of 12-37 percent were observed in all four districts upon the addition of 4 ton/ha biochar.

The previous year, with severe droughts in parts of Zambia, has underlined the importance of increasing farm households' resilience to droughts. Given that climate change is expected to result in increased dry spells during the Zambian growth season, the need for more drought-tolerant methods and technologies will likely increase in the coming years.

Furthermore, biochar helps to store carbon in the soil, mitigating climate change. There is potential to finance carbon storage through the international voluntary carbon market. Such mechanisms can make biochar more profitable for more farmers, with benefits to farmers as well as for climate mitigation. We find that it is only financially viable to develop such a carbon storage programme, i.e. that farmers receive payments for carbon storage, if the

combined benefits of improved maize yields and carbon revenues are accounted for. That is, carbon storage by use of biochar on its own was not financially viable.

2. ACHIEVEMENT OF RESULTS

2.1 Achievement of outcomes and outputs

Expected outcomes and outputs	Indicator(s):	Achievement of outcomes and outputs:
Outcome 1.1: At least 500 farmers take up pigeon pea production	Number of beneficiaries from pigeon pea trainings	The number of beneficiaries is estimated at 3 915, superceeding the target of 2 600 persons. 452 households took up pigeon pea production, almost 10 percent lower than the target of 500 households. 883 planted pigeon peas. The attrition from planting to harvest (49 percent) could indicate the difficulty of introducing a new technology among farmers with limited capacity to make (uncertain) investments.
	Number of farm households with pigeon pea production	
Output 1.1.1: At least 1000 CF MT[1] farmers receive training for pigeon pea production	Number of farm households that receive training	1266 households received training, superseding the target of 1 000 households.
Outcome 1.2: Increased farm incomes from pigeon pea production and potentially improved nutrition due to pigeon pea consumption	Consumption of pigeon pea	Average household consumption of pigeon pea is higher in the treatment groups (27.2 kg) than in control group (2.6 kg), exceeding the target of 10 kg increase in consumption.
	Farm household income	We find no clear effect on farm household income. When testing for effect of biochar we see a clear and positive correlation between applying biochar and household income. The "remaining" treatment (training, conservation agriculture) is then significantly negatively correlated with farm household income. The target of 5 percent increase is thus not clearly achieved. This may reflect the practical challenges of introducing new technologies in small-scale farming. The effects depend not only on the biophysical processes, but also on the implementation by

[1] CF-MT stands for conservation farming minimum tillage.

		the farmers themselves, *which inter alia* is a result of their capabilities and the trainings. The positive effect of biochar on income in itself seems to be robust.
Output 1.2.1: At least 500 farmers produce approx. 125 tons of high-quality pigeon peas for sale and/or own consumption	Pigeon pea harvest	The observed average harvest of the 452 farmers is 23 kg per farmer. Average produce per farmer is much lower than targeted (250 kg per farmer), *inter alia* due to pests (bollworm), drought and sub-optimal trainings and follow-up due to Covid restrictions.
	Pigeon pea sales	On average 34 kg per farmer who sold pigeon peas (173 farmers). This is less than the targeted 200 kg and is due to less harvest than targeted (see above) and unexpected challenges in establishing the market.
Outcome 2.1: Improved maize yields and reduced vulnerability of maize yields to climate variability Increased soil carbon storage	Expected direct emissions reductions	43,5 tonnes of CO2 in the course of the project. Achievement is below target of 1 033 tonnes of CO2. Fewer farmers than expected applied biochar (168; target: 500). Also, the amount of biochar applied per farmer was lower than expected, mostly because of small amounts of biomass obtained with the annual variety of pigeon peas. An important lesson learnt is that several pigeon pea varieties need to be tested to find a variety that combines good pea yields with high amounts of biomass.
	Maize yields	Estimated mean maize yield increase of about 12-37 percent in 2021 due to biochar. Smaller increase in maize yield than the targetd 50 percent, mainly because the 2020-2021 growing season was relatively wet. Consequently, the effect of biochar on plant-available water was small and did not result in a large increase in maize yield. Larger increases in plant-available water and thus maize yields are to be expected in relatively dry years.

	Soil Organic carbon (SOC) content	Biochar caused increase in SOC in planting basins in all 4 districts from about 0.5 weight-% to 1.9 weight-% (increase 1.4 weight-%), thus exceeding the target of 0.5 weight-%.
	Soil water retention	Increase in plant- available soil water in the growth season from 0 to 50 percent (average 25 percent) at 4 t/ha biochar. Biochar addition to the soil results in more significant increases in *in-situ* plant-available water in relatively dry seasons. In relatively wet seasons biochar addition had less significant effects on plant available water. This is lower than the targeted 50 percent increase.
Output 2.1.1: At least 1000 CF MT farmers receive training for biochar production and application. At least 500 farmers produce biochar to be used as a soil amendment and/or briquettes Integrated CF MT biochar practices across 500 maize hectares	Amount of biochar applied as soil amendment	103 kg per household (17.3 tonnes total). This is lower than the targeted 4 tonnes per hectare.
	Number of beneficiaries reached	3 915 beneficiaries. This is more than the targeted 2 600 beneficiaries, mainly due to a higher adoption rate than expected (target: 500 of 1000 trained households, and 753 households participated in trainings, see below).
	Number of farm households that receive training	753 households. This is less than the targeted 1 000 households. Not all participating farmers attended the biochar training. This was partly due to Farmers Input Support Program (FISP) in which most farmers across the villages were receiving farming inputs from the government. In addition, the trainings some places coincided with meetings organized by chiefs as well as funerals. Other farmers were simply not interested.
	Number of farm households that sell biochar briquettes	Briquette selling was not prioritized, as the farmers expressed more interest in using biochar as soil amendment (which also ensures its climate change mitigation effect), and as the team could not travel to Zambia due to Covid to implement the more complicated briquette training and

		equipment. Target was 100 households.
	Number of green business concepts tested	The target was to test 1 green business concept - the biochar pigeon pea agroforestry business concept. This has been done.
	Number of households that apply biochar as soil amendment	168 households. This is less than the targeted 500 households, due to less pigeon pea harvest available for biochar production.
Outcome 3.1: Robust knowledge on the profitability and potential for scaling up biochar-pigeon pea businesses	Papers (for academic and policy audience) on potential of pigeon pea biochar businesses	No papers published yet. This is less than the targed 3 papers. The results are less clear cut and more complicated to analyse and present. Analysis is still ongoing.
Output 3.1.1: High quality data on farm incomes, yields, input use and take-up of business concept under various conditions	Baseline and endline survey data collected from trained farm households and control group	Two rounds of survey data collected and analysed, as targeted.

2.2 Deviations from the planned outputs and activities

Most activities were performed, and outputs were achieved. There has, however, been some challenges.

Covid-19 caused some challenges for milestone 2 and 3, particularly in following up Zambian partners in biochar-making **trainings** and in training enumerators for the endline survey. The main activities were conducted as planned, but with less control and thus possibly affecting data quality. One part of the biochar trainings was not conducted: training in making biochar briquettes. This is more complicated and required that the team travelled to Zambia to lead the trainings. Since farmers expressed more interest in using biochar as soil amendment and biochar production was lower than targeted, we consider the lack of briquette production and sales as of minor importance. The pandemic also impacted the farmers and their families, including their financial vulnerability. This could again have affected their willingness to participate in trainings and try out the production and application of biochar.

Several other challenges also arose during the project period, affecting other activities as well:

- **Baseline and endline survey:** The project initially targeted farmers in four districts: Chipata, Choma, Kaoma and Mkushi. By the time the project started, CFU had pulled out of Mkushi and therefore no longer had a fully functioning CFU network of lead farmers and farmers there. The trainings were still implemented in Mkushi, in close collaboration with a local partner, but the baseline survey was not implemented in Mkushi.

- **Buyer and price offered:** Initially we had an MoU with a large commodity buyer company in Zambia, stating that they would purchase the pigeon pea crop. This MoU did not result

in a price offer to the farmers, in part because the company had shifted from crop output to farming inputs, and because the amount of sellable pigeon peas was less than initially expected. Instead, local buyers were found, resulting in different prices to the farmers.

- **Bollworm infestation**: Pigeon pea crops in all four districts were infested by the African bollworm, and the chemicals that had been provided to the farmers were not effective in tackling this pest, which is not ubiquitous in Zambia. After testing out wood vinegar (WV), a by-product of biochar manufacturing, on one farmer's crop in Mkushi we discovered that this seemed to kill off the bollworms. Inferior WV qualities may contain carcinogenic polycyclic aromatic hydrocarbons (PAH), so we tested our WV batch for this contaminant class and observed their concentrations to be negligibly small. Saving the pigeon pea crop was essential for the success of the ClimChar project and required immediate action. The project could not afford to lose the crop as this would leave the farmers without enough feedstock for biochar and demotivate the farmers. Bollworm infestations at this scale are uncommon in Zambia. The farmers were provided with enough WV for two sprayings on their pigeon pea plots (in total slightly about 100 L required–spraying at 1:200 dilution). Wood vinegar was locally produced in Mkushi from available pigeon pea biomass and was rapidly distributed to the participating farmers in the region. Due to transportation challenges, the participating farmers in the other districts had to wait an additional 1-2 weeks before WV was available. Despite the effectiveness of WV, the bollworm infestation did have a negative effect on pigeon pea production, in particular in Chipata, Choma and Kaoma. This heavy pest infestation contributed significantly to the low yields. It is not clear whether the mixed results in the three other districts is due to later application or other characteristics specific to those districts, such as different soil types, or limited ability to follow up on the application of WV. Notably some farmers in among other Chipata found WV to be effective. The spraying of wood vinegar happened when there were restrictions on movement due to Covid-19. This made it difficult to follow up on the application of WV, which may also have affected the effectiveness in saving the farmers produce.

2.3 Achievement of NCF indicators

NCF core indicator	Results (quantitative)		Clarifications/Means of verification
Number of beneficiaries reached	women	3234	The cumulative number of beneficiaries refers to all individual farmers that participated in pigeon pea training and/or biochar training. This number is higher than the expected beneficiaries from pigeon pea trainngs, because it also includes those who participated in biochar training, but did not attend the pigeon pea trainings. Each farmer is assumed part of a household with on average 5.2 persons, with on average an equal share of men and women in the households.
	men	3234	
	total	6469	
Number of people with increased resilience to climate change	women	3234	See above
	men	3234	
	total	6469	
	women	3234	See above
	men	3234	

Number of people	total		6469	
New decent jobs created	full-time	women	N/A	These indicators are not relevant for this project, as jobs are not created as part of the project.
		men	N/A	
		total	N/A	
	part-time	women	N/A	
		men	N/A	
		total	N/A	
	seaso-nal	women	N/A	
		men	N/A	
		total	N/A	

3. CLIMATE CHANGE

The project had a stated goal of reducing expected direct emissions by 1 033 tonnes of CO2e. Actual reductions are estimated to 43,5 tonnes of CO2e. The discrepancy is due to several reasons. Fewer farmers than expected applied biochar (168; target: 500). Also, the amount of biochar applied per farmer was lower than expected, mostly because of small amounts of biomass obtained with the annual variety of pigeon peas. An important lesson learnt is that several pigeon pea varieties need to be tested to find a variety that combines good pea yields with high amounts of biomass.

Overall, the project contributes to both climate mitigation and adaptation, albeit at a lower scale than initially expected. Carbon is stored both via biochar amendment, extra soil organic carbon build-up ("priming") and pigeon pea trees. Also, the need for new farmland establishment decreases, due to increased harvests from the generally little fertile and often degraded soils (10-25 percent increase), water conservation is improved by less erosion (agroforestry) and in particular due to biochar amendments; nutrient cycling is improved both by the biochar and by nitrogen binding of the leguminous pigeon pea trees, which are introduced as part of crop rotation. Furthermore, biochar has been found to reduce the emission of nitrous oxide, a potent greenhouse gas, as was found in two of our parallel projects.

Another indirect effect of biochar is reduced emissions from mineral fertilizer use, because a higher crop yield per unit fertilizer applied is obtained. This reduces the CO2 footprint per unit crop yield, as shown in life-cycle (LCA) analyses carried out by this team in a parallel project.

In future developments, household members can utilize the renewable energy (heat) generated by the kilns for cooking, grilling, drying, bread baking and distillation, avoiding deforestation due to the firewood usually used for these purposes. Also, the energy from the biochar making can be used to melt high-quality plastic to novel products. In spinoff projects in Uganda and Tanzania, we are trying out the concept of full sustainable waste treatment, where dry organic waste is turned into biochar and the energy is used for melting plastic into new products.

4. DEVELOPMENT IMPACTS AND CROSS-CUTTING ISSUES

The business concept's development impact occurs through several channels:

1. Improved food security through reduced crop vulnerability to climate variability and increased farm incomes.

2. Poverty reduction through increased farm incomes and reduced income volatility through reduced reliance on drought sensitive maize.

3. Providing access to a business concept that generates cash income may strengthen the female position in the household, also since female farmers where targeted for trainings.

4. Economic development through increased and more stable incomes for rural households and expansion of production of an export cash crop, with potential employment - and indirect effects on other sectors.

5. Reduced vulnerability to climate change is achieved directly through the CF-MT practices combined with biochar, and the reduced reliance on a single, drought sensitive crop.

These channels of impact are aligned with Zambia's seventh national development plan for 2017-2021. The goal of the plan is to create a diversified and resilient economy for sustained growth and socioeconomic transformation driven, among others, by agriculture. Development outcome number one in the plan is "A diversified and export-oriented agriculture sector." The plan also described the channels through which increased farm incomes are expected to create economic growth: First, through supporting rural demand, which results in the development of new activities and the diversification of the local economy. Second, through leading to the development of both upstream and downstream activities, the consolidation of value chains and the expansion of agro-industries, which are significant sources of employment and present real opportunities for economic diversification. Other priorities in the plan include reducing gender equality, enhancing food security and nutrition, and increasing employment opportunities in rural areas.

The impact of the project on maize yields was assessed using different sources and methods. A comparison of maize yields from plots with and without biochar for farmers that applied biochar shows a significant increase in yields. The observed increases in yield for the 2020/2021 season were 10 percent, 12 percent, 19 percent and 37 percent for Chipata, Mkushi, Choma and Kaoma, respectively. Thus, yields on plots with biochar were on average 270 kg per hectare greater than yields on plots without biochar, representing a significant ($p<0.05$) increase in yields upon biochar addition. Applying biochar thus has the potential of increasing the yield of a key staple crop in Zambia. The results comparing maize yield between farmers in the control and treatment groups (randomized control trial) are less conclusive. This is in part because not all farmers that received training took up the technology. Further differences in drought exposure, access to fertilizer, and actual take-up of the technology (planting maize on plots previously planted with pigeon peas, and biochar application) affect the results. The mixed results with regards to the impact on maize yield based on the randomized control trial, also results in inconclusive results on the impact on farm household income.

Pigeon pea is a new crop to many farmers introduced by the project. The farmers that participated in the training and harvested the crop have thus increased their knowledge of a drought-tolerant, nutritious crop. The crop was found to be popular for own consumption. Households in the treatment group consumed on average around 25 kg more pigeon peas than the control group, exceeding the target of 10 kg per household.

Continuous observation of soil moisture for the whole growth season revealed that biochar indeed increased soil moisture by up to 3 percent in absolute terms, and up to 40 percent in relative terms. In addition, biochar delays drying out of the soil during dry spells. As the climate in Sub-Saharan Africa is expected to be more capricious with longer dry spells within the growth season, this can contribute to climate change adaptation.

5. ASSESSMENT OF THE RESULTS AND IMPACTS OF THE PROJECT

5.1 Relevance

About 64 percent of the Zambian population lives in poverty, and the poverty rate in rural areas is close to 80 percent. Many of the poorest households are headed by women. Farm productivity is low due to a number of factors, such as lack of access to inputs, transport and markets. In addition, the soils may be poor for agricultural purposes due to acidity, nutrient leaching and poor water retention capacity. This makes yields sensitive to droughts. Under such conditions, conventional farming involving full tillage, is generally found to be unsustainable, causing declines in soil organic matter and water retention capacity, further increasing the rural population's vulnerability to climate variability.

The ClimChar project tackles several of the above challenges, albeit at a small scale: 1) Mitigating climate change: carbon is stored in soils when biochar is applied as a soil amendment. 2) Adaptation to climate change: conservation farming combined with the application of biochar provides improved nutrient and water retention of soils. 3) Improved nutrition and health may be achieved through the supply of protein rich pigeon peas, provided they are accepted as part of the Zambian diet.

5.2 Effectiveness

The project was ambitious in its outset, both aiming to test out new technologies (pigeon pea varieties) while assessing the take up of this technology simultaneously – and within a short project period. In addition, the new technology or business concept involved farmers investment over two seasons, requiring long-term commitment for a group that is vulnerable to income fluctuations due to weather events such as droughts, and that may be risk-averse in testing out new crops and technologies. Successful implementation of the technology required several steps, making room for many adjustments and deviations along the way that in total has resulted in lower-than-expected impact. The farmers' need for multiple trainings and close follow up requires a well-functioning local collaborative organization. While still functional, the local partner CFU was flexible and dealt with numerous challenges, including bollworm infestation. Existing collaborative structures can also be key to tackle sudden challenges.

5.3 Efficiency

The project involved collaboration between three Norwegian partners and a local, Zambian partner. The project had at the outset a cost-efficient organization building on the existing, extensive structure of the Zambian partner to organize trainings of a large number of Zambian farmers. The Norwegian partners ensured key trainings prior to this, where the "trainers of the trainers" were trained in biochar making, after which the knowledge was transferred down to lead farmers and their smallholder groups. Due to Covid-19 travelling restrictions planned travel activities were not implemented. This had negative impacts on the quality of the trainings, both in biochar production and the experimental component of the endline survey. In addition, the team faced several challenges during the project period, including the bollworm infestation and disruptions in the local partner organization. These challenges were largely met in a cost-efficient manner, e.g. the bollworm infestation was combatted by locally made wood vinegar instead of more deleterious and costly regular insecticides.

5.4 Impact

The tested technology resulted in increased soil water retention, increased carbon uptake, increased maize yields and increase consumption of a nutritious crop, pigeon peas. These elements contribute positively to the local and global environment and potentially also farm households' income and health, although at a lower scale than targeted. Further assessments would be needed to assess the robustness and longevity of these impacts.

5.5 Sustainability

The project involved distribution of free pigeon pea seeds to small-scale farmers, in addition to training in pigeon pea production and biochar application. Farmers that planted pigeon peas expressed interest in access to seeds for a new planting season, indicating that the crop is of interest. Whether or not farmers will plant again depends on liquidity/credit access and access to seeds. The latter is likely to differ by district. There is already an existing market for pigeon peas in Chipata, making the likelihood of replanting higher in this area. The project revealed a market for selling pigeon peas to commercial farmers in Mkushi, yet limited seed access may inhibit future market developments. Some farmers used part of their harvest for replanting and in this way increased their area where pigeon pea was cropped, increasing the likelihood of continued practice.

Farmers also showed a keen interest in the production of biochar. Women in Chipata often went together to make a shared kiln, as this was more cost-effective, showing signs of local innovation and ownership that may increase the likelihood of continued practice.

Large fixed costs of setting up carbon financing is a challenge for the sustainability of the project. Payments to farmers for carbon sequestration would make biochar application more profitable, but our calculations indicate that as an isolated carbon project it is not financially viable, in particular due to the costs of monitoring, reporting and verification. In combination with increased maize harvests, the project may be viable and thus economically sustainable. The project has led to an identification of possible financing mechanisms applicable for smallholder farmers and it turns out that carbon certificates could in principle cover the whole cost of biochar making in Zambia. In spinoff projects in Tanzania and Uganda the

smallholder farmers will probably be paid carbon credits for their biochar making and soil application, through the CarbonLife/Warm Heart/CarbonFuture[2] financing mechanism.

5.6 Coherence

During the project period, we have had positive but limited cooperation with government agencies and other actors in Zambia. Also, to our knowledge, there is no similar efforts elsewhere in Zambia. Our Zambian partner, The Conservation Farming Unit (CFU) was a major actor within conservation farming and conservation agriculture practices in Zambia, but has during the project period suffered from lack of funding, to the point that most activities were cancelled and most employees left. The potential for synergies or duplication of efforts in Zambia has thus been limited. During the project contacts with Export Trading Group has been established, and this has led to spin off proposals in Uganda, on biochar implementation for 20 000 coffee farmers, with this important private actor. Also, synergies between the ClimChar project and our other projects in Tanzania and Uganda have been acquired, especially with regards to emissions during biochar making, and with regard to carbon credit payment (see also section 7).

6. INNOVATION

The innovation of the business concept lies particularly in the combination of four elements: 1) Production of biochar from pigeon pea biomass, 2) "climate smart" conservation agricultural practices, 3) production of pigeon peas for sales, and 4) the application of biochar as a soil enhancer. While each element has existed to some extent individually, the project explored a potentially commercially viable value chain to harvesting the benefits of biochar as a soil amendment. This may provide a business system where the farmer generates cash income from multiple sources, while improving yields of maize, reducing the vulnerability of income to climate variability, and mitigating climate change through carbon sequestration. As is described elsewhere in the completion report, these elements have to some extent been shown to be realized in the projects, and others have been shown to be challenging to realize.

7. POTENTIAL FOR SCALING UP AND FOLLOW-UP INVESTMENTS

We have assessed the impact of a pilot project on different outcomes. To assess the potential for scaling up, it is necessary to both discuss factors that would have to be altered in a scaled-up version and identify necessary conditions for a successful scale-up. We think the most important requirements for a successful scale-up are i) number of farmers; ii) longer project duration in combination with a more suitable pigeon pea variety to demonstrate robust results over time, and iii) successful payment of carbon credits to incentivise investment in the public benefits of carbon storge.

[2] How it Works (carbonfuture.earth), Biochar, a natural solution to reducing global warming (warmheartworldwide.org)

The pilot project covered a limited period, thus placing certain limitations on the project and the final outcomes. For example, small amounts of biomass were obtained with the annual variety of pigeon peas. This variety has been selected for two reasons; 1) due to the short duration of the project we were bound to an annual variety, and 2) this annual variety was the only one available in sufficient quantities in Zambia at the onset of the project. In an earlier project in Zambia the team used a variety that gave a lot of biomass (up to 37 tonnes per ha in year 2) but with little pea yield. A proper pea yield of around 1 tonne/ha is needed in year 1 to provide farmers with a direct incentive to embark on pigeon pea/biochar agroforestry. Thus, an important lesson learnt is that several pigeon pea varieties need to be tested to find a variety that combines good pea yields with high amounts of biomass.

A large functioning organization with a good extension network among farmers is a crucial precondition for successful implementation of a large-scale version of the project. Even with a well-functioning organization to ensure proper training, a remaining question is whether there is potential for scaling up the project while still targeting small-scale farmers. To answer this, we must separate between what has been tested, e.g., the impact of training in pigeon pea and biochar production on farmer-related outcomes, versus the impact of the business concept, e.g., training in pigeon pea and biochar production and carbon credit offsets. A possible advantage leading to lower cost and effort per tonne biochar made is collaborative biochar preparation. This is exemplified by a large farm in Mkushi, Zambia, where 100 tonnes of biochar were made in only two weeks with flame curtain kilns, under the auspices of this project team, and at a cost of only 15 dollars per tonne biochar. In a spinoff Norad-funded Tanzania biochar project, we will also test the biochar/pigeon pea value chain in farmer collectives, where “commercial villages” have been formed and prepare biochar as a collective effort. This can potentially create economies of scale and reduce costs substantially and share knowledge and motivation among farmers. Socio-economic analyses will reveal how viable the concept and value chain are in such a context.

When scaling up, also biochar-compost formulations should be implemented. These have a much higher value as their agronomic effect is much stronger than that of the raw biochar. The team found this concept to be incompatible with current Zambian farming practice, as the concept of composting is almost unknown. In the spinoff Tanzania project, biochar/compost formulations will be an important part of the value chain. Work by this team and Ithaka institute in Nepal has shown that biochar/urine, biochar/compost and biochar/bokashi systems can render extremely strong agronomic effects, even in relatively rich soils. Raw biochar is only effective in dry, weathered nutrient-depleted soils.

As said, we think the direct incentive of carbon certificate payment is mandatory for a large-scale biochar initiative to succeed in the smallholder context where there is a short-term perspective of days/weeks (in which credits should be paid) instead of months/years (when increased harvests can be expected). As a carbon project, a larger project size would clearly benefit from economies of scale. We performed a simple cash flow analysis considering the carbon sequestration and storage and improved maize yield benefits, and compared these with the costs of producing the biochar and implementing the carbon project. We found that – due to the costs associated with carbon projects (monitoring, reporting and verification, fees to the government, implementation/developer costs) - it only made sense (positive net present value) to develop the carbon project if the combined benefits of improved maize yields and carbon revenues were accounted for. That is, the carbon project on its own was not financially viable.

We consider that scaling-up of the present activities are not likely to materialize without further funding and facilitation, as well as carbon credit payment, at least in the short term. The good news is though that the ClimChar project has led to direct spinoff projects in Tanzania (Norad-funded) and Uganda (Norwegian Research Council funded), where all these requirements will be met – i) up to 10 000 farmers will be trained, leading to a larger scale; ii) the projects will last 4-5 years, allowing more thorough implementation; iii) more pigeon pea varieties exist in Uganda and Tanzania, allowing the selection of a more suitable variety combining pea harvest and ample biomass; iv) there will be enough time to develop carbon credit payment app solutions and financing mechanisms. We have continued collaboration with private sector actor ETG (Export Trade Group) in the project in Uganda.

8. Risks

Project risk description	Impact on project	Mitigating measures and responsibility
Covid-19 affects farmers' financial situation and willingness to await harvest measurement.	Data quality is reduced, affecting the results.	N/A
CFU suddenly lost funding from their main funder.	There were no available staff in the field to monitor field activities, no funds to cover co-financing part thus affecting timely activity implementation	Funds advanced to CFU to re-engage staff to conduct harvesting and data collection.
Thermometers and masks were needed in order to implement the endline survey	Covid-19 could threaten health of enumerators and respondents.	Masks and disinfection were approved as budget items and procured as part of survey.
Covid-19 made it impossible for team members in Norway to travel to Zambia for the trainings, soil sampling and endline survey, including the experiment.	Less control of data collection	Provided the CFU team on the ground with clear instructions for trainings, soil sampling and the end-line survey. In addition, transferred funds (originally put up as co-funding for Zambia field work by NMBU and NGI) to CFU to re-hire field staff as soon as possible in order not to lose time.
The pigeon pea crop was infected by African bollworm	Reduced yields, as the bollworm entered the pigeon pea pods and damaged the seeds.	Wood vinegar was procured, and the crops were treated. This abated the bollworm infestation and saved part of the crop.
Severe drought in Zambia	The drought in the 2019/2020 growth season had impacts on the crop of farmers.	Pigeon pea is a drought-resistant crop and in itself a mitigation measure towards severe dry spells. However, there were still quite a few farmers who were affected by the 2019/2020 drought, and experienced that their yields suffered.
ETG (the pigeon pea trader) was late on offering a price for PPs	Farmers in danger of not being able to sell their PPs	Farmers could sell their pigeon peas through one of three options: 1) Farmers in Chipata could sell to a local dealer, Sheni.

		2) Farmers in other districts could sell to commercial farmers in Mkushi 3) Farmers could go out to sell in their local markets. All in all, our impression is that the farmers are actually better off by not selling to ETG but to alternative buyers.

9. MONITORING AND EVALUATION

This specific project has not been monitored and evaluated on site, as NCF had no opportunity to visit due to the Covid pandemic. However, the overarching activities of local partner CFU have been subject to extensive M&E by donor FCDO (former DFID) and have been found satisfactory for the payment of ongoing and executed activities. The decision of FCDO to discontinue the funding of CFU has not been a consequence of M&E results, but rather of a shift in focus countries and areas of interest. Menon has also continiously monitored and evaluated activities in Zambia and Norway through close dialogue with all project partners, and in particular in preparations for and during field activities.

10. LESSONS LEARNT

The most important lessons learnt have been stated above in section 6 and taken into account when setting up the spinoff projects in Tanzania and Uganda; i) sufficient size; ii) sufficient project duration; iii) suitable pigeon pea variety, and iv) carbon credit payment.

It is always challenging to introduce a new agricultural technology, and even more so to farmers with limited resources and who face a range of external risk factors. The introduction of the technology was further challenged by Covid-19 restrictions on travel and gatherings, affecting information flow. To minimize the impact of materialized risks, it is important to be able to act swiftly on new information. This requires flexibility with respect to the use of contingency to take immediate action if needed. We made adjustments to better consider these aspects (see 8. Risk).

The co-financing became a challenge to the local partner (CFU), because of limited funds after FCDO discontinued their funding. This crippled and slowed down field activities that required to be delivered within a certain period of time, resulting in delayed delivery and distortion. We advanced internal independent NGI and NMBU funds to CFU staff to re-engage these to facilitate harvesting and collect data in the endline survey.

The most important lessons learnt have been stated above in section 6 and taken into account when setting up the spinoff projects in Tanzania and Uganda; i) sufficient size; ii) sufficient project duration; iii) suitable pigeon pea variety, and iv) carbon credit payment.

11. OUTREACH

The project was presented for a large part of the Nordic biochar community at the 2nd Nordic biochar conference at Stockholm, 15 October 2019, in a presentation with the title "Large-Scale Implementation of Biochar for Sustainable Soils in Seven Countries: Technology and Agronomic Effects". Two projects were presented: the "ClimChar" project, and the Biochar for Sustainable Soils (B4SS) project, a GEF-funded project (2016-2019). The main objective of both projects was to demonstrate and promote the adoption of Sustainable Land Management practices involving biochar in tropical countries.

About the ClimChar project the following message was received with a lot of interest in the workshop discussion groups: "In Zambia, the main reason for the agronomic effect of biochar is its water retention capacity. The primary objective of the ClimChar project is to reduce vulnerability to climate change and improve livelihoods of farming communities in Zambia through increased on-farm profitability, food security and entrepreneurship via adoption of climate-smart agriculture (CSA), including pigeon pea production and the use of biochar. Recently, we found pigeon pea to provide ample biomass for biochar (37 tons per ha per year), while the peas improve diet and soil, and are a marketable commodity. Local pigeon pea businesses and voluntary carbon credits will be explored. With regard to technology, we will implement a novel, clean and sustainable manner to prepare biochar from many types of feedstock: flame curtain "Kon Tiki" kilns. With benefits such as high-quality biochar, low emissions of smoke and toxic gases, no need for start-up fuel, fast pyrolysis time and, importantly, easy and cheap construction and operation the flame curtain technology represent a promising possibility for sustainable rural biochar production."

Webinar for Norad – Norad has expressed its interest in a webinar about biochar and its potential as a soil enhancer. The webinar is scheduled for December 2022.

Presentation of the potential of biochar made from cocoa pod husks at the CocoaSoils project meeting in Cameroun (IITA, January 2020). Cocoa plantations produce large amounts of cocoa pods, particularly rich in potassium. Charring the husk produces large amounts of biochar, which was shown to be effective in enhancing water retention in cocoa soils. In addition, returning cocoa pod waste to cocoa plantations in the form of biochar returned significant amounts of potassium, which is known to improve the resistance of cocoa crops to drought.

The project has been presented during a summer school (Climate smart agriculture), in Zambia organized by NMBU and the School of Agriculture, University of Zambia (UNZA). The summer school involved 15 graduate students from Zambia and Norway and about 8 staff from both universities. It was organized from 27 January – 9 February 2020 (just before lockdown) and included a visit to several of the pigeon pea growing smallholders in Mkushi. A biochar training was part of the summer school.

Last but not least, the project has been presented during biochar training to 12 field officers and 56 lead farmers in four districts in Zambia. These field officers and lead farmers have again presented the project to 1266 participating farmers.

12. FINANCIAL SUMMARY

Table 1. Project financing per partner

	Financing, EUR						
Expenditures, EUR	NCF	Menon	CFU	NGI	NMBU	Revenues from the project	Total
Menon	181 800	33 390	-	-	-	-	215 190
CFU	98 022	-	111 242	-	-	-	209 264
NGI	84 630	-	-	23 709	-	-	108 339
NMBU	91 839	-	-	-	80 472	-	172 311
Total	456 291	33 390	111 242	23 709	80 472	-	**705 104**

13. CONCLUSIONS AND RECOMMENDATIONS

Biochar has the potential of enhancing soil moisture retention in relatively dry years. This improves the drought-tolerance of the farmers' maize crops and contributes to climate change adaptation. In relatively wet years (e.g., the 2020-2021 season) the effect of biochar on soil moisture retention was significantly smaller. Yet, even in the relatively wet 2020-2021 season, average maize yield increases of 12-37 percent were observed in all four districts upon the addition of 4 ton/ha biochar. This may lead to increases in farm household income (controlling for costs and efforts in producing and applying the biochar). The results from the baseline and endline surveys of the randomized control trial indicates that treatment effects observed in controlled settings may be hampered by the uptake of the technology. Farmers' willingness and capacity and their access to seeds and other inputs are important factors determining effects of training farmers in conservation agriculture and biochar application. This is a challenge for scaling up.

The previous years, with severe droughts in parts of Zambia, has underlined the importance of increasing farm households' resilience to droughts. Given that climate change is expected to result in increased dry spells during the Zambia growth season, the need for more drought-tolerant practices and technologies will increase in the coming years. Furthermore, biochar helps to store carbon in the soil, causing an increase in soil organic carbon by 20 – 30 percent, mitigating climate change. In this project, 168 households applied an average amount of 103 kg biochar, giving a total of 43,5 tonnes of CO_2-eq. of direct emission reductions during the project period. There is potential to finance carbon storage through the international voluntary carbon market. Such mechanisms can make biochar more directly profitable for more farmers, with immediate benefits to farmers as well as for climate mitigation. These immediate benefits can often cover the complete cost of biochar making in the low-wage contexts of sub-Saharan Africa. However, we also found that – due to the costs associated with carbon projects (monitoring, reporting and verification, fees to the government, implementation/ developer costs) - it only made sense (positive net present value) to develop the carbon project if the combined benefits of improved maize yields and carbon revenues were accounted for. That is, the carbon project on its own is not fully financially viable without yield improvements and/or larger-scale implementation.

The project has shown the potential positive impacts of applying biochar in subsistence farming in Zambia, both for the farmers and to mitigate climate change. The challenges for creating these impacts are, however, linked to the ability and willingness of small-scale farmers to adopt the technology, and the fixed costs for carbon financing, e.g., costs for monitoring, reporting and verification. Further research is needed to better understand how such barriers better can be overcome and thus if and how such projects may be successfully realized at larger scales.

Apart from the climate change adaptation and mitigation through biochar making, the project also contributed to the introduction of protein-rich pigeon peas, where the consumption of self-produced pigeon peas far exceeded the initial project target. Even without considering biochar, the introduction of pigeon peas has brought a useful incentive to the farmers, and many have expressed the will to continue growing this drought-tolerant crop.

Annex 1 Project completion fact sheet

Project Name:	**Testing biochar-pigeon pea agroforestry businesses in Zambia**		
Project no.	NCF-C7-091		
Country:	Zambia	**Financing:**	
		EUR	**%**
Nordic Partner:	Menon Economics, NGI, NMBU	137 570	19 %
Local Partner:	CFU	111 242	16 %
Other Partner:			
	NCF grant disbursed	456 291	65 %
	Total	**705 103**	**100.00**
Classification:	Mitigation/ Adaptation/ Combination		
Project cycle:	Project start date: 15/02/2019 Original closing date: 15/08/21 Actual closing date: 15/12/2021		
Short project description:	This project tested a new, green business concept in four locations in rural Zambia. Selected farmers received training in pigeon pea production, a relatively new crop in the Zambian context. The biomass from the pigeon pea trees were used to produce biochar that can be used as a soil amendment for maize production. Storing stable and carbon-rich biochar in the soil is a technique that enables farmers to store significant amounts of carbon for long periods of time, thus contributing to climate change mitigation. Biochar also improves soil quality as it increases water- and nutrient retention, and can lead to significant yield increases and reduced crop vulnerability to droughts. The farmers received training to produce and apply the biochar to their maize fields, combined with conservation farming minimum tillage (CF-MT) agricultural practices. Production of biochar is low cost, using a simple and recently developed, low-emission and safe, open flame kiln. Biochar can be used on the farmer's own maize fields to improve yields, but can also be made into and sold as fuel briquettes. The business concept was tested through a randomized control trial approach, to obtain robust knowledge on developmental and environmental impacts. We also explored the potential for voluntary carbon credits as a payment for the carbon storage provided by the farmers. The project was led by Menon Economics in cooperation with the Norwegian Geotechnical Institute, the Norwegian University of Life Sciences and Conservation Farming Unit (Zambia). It commenced in 2019 and finished in 2021.		
Project performance:	**Expected Outcomes and Outputs**	**Achieved**	**End-of-project status**
	Outcome 1.1: At least 500 farmers take up pigeon pea production	Partly	90 percent of target.
	Output 1.1.1: At least 1000 CF MT farmers receive training for pigeon pea production	Yes	127 percent of target.
	Outcome 1.2: Increased farm incomes from pigeon pea production and potentially improved nutrition due to pigeon pea consumption	Partly	No clear total effect on income. Increase in pigeon pea consumption.
	Output 1.2.1: At least 500 farmers produce approx. 125 tons of high-quality pigeon peas for sale and/or own consumption	No	34 percent of target number of farmers, 9 percent of target amount of peas.
	Outcome 2.1: Improved maize yields and reduced vulnerability of maize yields to climate variability Increased soil carbon storage	Partly	Exceeding targets of SOC content and soil water retention, reasonable maize yield increase (15 percent) and 5 percent of targeted carbon storage.
	Output 2.1.1: At least 1000 CF MT farmers receive training for biochar production and application At least 500 farmers produce biochar to be used as a soil amendment and/or briquettes Integrated CF MT biochar practices across 500 maize hectares	Partly	75 percent of targeted no. of trained farmers, 34 percent of targeted no. of farmers producing biochar.
Climate change outcomes and impacts:	Mitigation: 43,5 tonnes of CO2-eq. of direct emission reductions during the project period Adaptation: Increase in soil organic carbon content in planting basins in all 4 districts from about 0.5 weight-% to 1.9 weight-% (increase 1.4 weight-%). Increase in plant-available soil water in the growth season from 0 to 50 percent (relative) at 4 t/ha biochar.		

Development outcomes and impacts:	- Average maize yield increases of 12-37 percent upon the addition of 4 ton/ha biochar. - Increased household consumption of pigeon pea potentially improving nutrition. - About 50 percent of the beneficiaries are women.

NCF core indicators

NCF core indicator	Results (quantitative)			Clarifications/Means of verification
Number of beneficiaries reached	women		3234	The cumulative number of beneficiaries refers to all individual farmers that participated in pigeon pea training and/or biochar training. Each farmer is assumed part of a household with on average 5,2 persons, with on average an equal share of men and women in the households.
	men		3234	
	total		6469	
Number of people with increased resilience to climate change	women		3234	
	men		3234	
	total		6469	
Number of people with improved livelihoods	women		3234	
	men		3234	
	total		6469	
New decent jobs created	full-time	women	N/A	These indicators are not relevant for this project, as jobs are not created as part of the project.
		men	N/A	
		total	N/A	
	part-time	women	N/A	
		men	N/A	
		total	N/A	
	seaso-nal	women	N/A	
		men	N/A	
		total	N/A	

Annex 2 Results Framework

Impact 1

Description	Milestone	Assumptions	Risks
Improved food security and reduced vulnerability to climate change due to increased incomes and multiple income sources, leading to reduced poverty and improved position for women.		Successful adoption of pigeon pea agroforestry for at least some farmers. Does not rely on assumption of positive yield impacts from biochar application.	Lack of farmer participation Lack of acceptance of new crops Low export price of pigeon pea Crop failure

Indicators

OUTCOME 1.1

Description	Milestone	Assumptions	Risks
At least 500 farmers take up pigeon pea production	Milestone 1	At least 50 percent adoption rate among farmers that receive training	Low adoption

Indicators

Number of beneficiaries from pigeon pea trainings

Description	Sources of Verification	Targets		
Number of beneficiaries based on assumption of 50% adoption rate and average 5.2 persons per household Sub indicators include: District - Number of beneficiaries by district. Share children - Number of beneficiaries by age, where children are defined as beneficiaries younger than 18 Share female - Number of beneficiaries by gender	Monitoring adoption, endline survey	**Baseline**		**0**
		Target	Milestone 1	**2 600** Persons
		Results	Complete	**3 915** persons

Number of farm households with pigeon pea production

Description	Sources of Verification	Targets		
The number of farm households that have taken up pigeon pea production amongst those trained. Sub indicators include: Age of household head, District, Education of household head, Gender of household head, Number of household members, Size of land holdings	Field visits to households trained, monitoring of pigeon pea production. Disaggregated results based on household background data in baseline household survey, for instance on gender of household head.	**Baseline**		**0**
		Target	Milestone 1	**500** Households
		Results	Complete	**452** households

Output 1.1.1

Description	Milestone	Assumptions	Risks
At least 1000 CF MT farmers receive training for pigeon pea production	Milestone 1	CFU is able to identify at least 1000 eligible farmers in the four locations for training.	Lack of farmer participation

Indicators

Number of farm households that receive training

Description	Sources of Verification	Targets		
Number of farm households that receive training for pigeon pea production and presentation of business concept. Sub indicators include: Age of household head District Education of household head Gender of household head Number of household members Size of land holdings	Counting the number of participants at trainings, and verifying which households they belong to based on the baseline household survey. Can be disaggregated by gender of participants and gender of household head.	**Baseline**		**0**
		Target		**1 000** households
		Results	Complete	**1 266** households

Activity

Description	Milestone
Activity 1.1.5: Monitoring pigeon pea production: CFU will, with assisance from NMBU, closely monitor the pigeon pea production, and provide assistance if needed. The monitoring will take place through the CFU network.	Milestone 1

Activity

Description	Milestone
Activity 1.1.1: Identification of eligible farmers through CFU network and baseline survey, including soil samples: 350 eligible farmers in CFUs existing network will be selected in four locations: Kaoma, Choma, Mkushi and Chipata. These four locations are chosen because of the variation of agro-climatic factors, in order to test the business concept under varying conditions. We will conduct a detailed baseline household- and agricultural survey of a representative sample of the eligible farmers. The survey allows us to track impacts of the business concept on household income, both cash income and crop production, food consumption, input use, etc., to assess profitability and poverty impacts of the business concept. Baseline soil samples will be collected to monitor impacts of the conservation farming-biochar on soil quality and carbon sequestration.	Milestone 1

Activity

Description	Milestone
Activity 1.1.3: Inception workshop Including detailed plans and materials for first training. Workshop to prepare materials for the pigeon pea/business concept training.	Milestone 1

Activity

Description	Milestone
Activity 1.1.2: Selection of farmers for training: Farmers that are offered trainings (1000 farmers) will be randomly selected among the eligible farmers (1400 farmers). This allows us to follow both trained farmers and a control group of untrained farmers, in a so-called Randomized Control Trial. This is the gold standard of assessing impacts of development interventions, and allows us to identify the causal impact of the business concept on the outcomes of interest (environmental and poverty impacts).	Milestone 1

Activity

Description	Milestone
Activity 1.1.4: Training for pigeon pea production and introduction of business concept: Training will be funneled through the local partners' cost effective, professional and existing farmer-to-farmer extension services. NMBU is responsible for the pigeon pea training, and will provide training to partner field staff as well as to project Lead Farmers and farmers. The CFU field staff will look after correct implementation afterwards. Both biochar and pigeon pea training will be bundled with existing CF MT training organized by CFU so that maximal synergy and participation is obtained. Pigeon pea seeds will be distributed, the sowing protocol will be explained (planting distance, magnitude of the plantations), as well as the harvesting procedures for farmers to obtain their own seed for next seasons. One NMBU staff member and 1-2 CFU staff members will be present at these trainings. Both the pigeon pea production and the business concept, including the role of the pigeon pea exporter, ETG, and the use of the feedstock for biochar, will be explained using simple cartoons. For both biochar and pigeon pea procedures, detailed "cartoon" instructions will be made and handed out to the farmers, to increase interest and to facilitate proper adherence to the guidelines. Also, CFU staff will monitor the farmers closely and ensure the implementation is done properly also after the demonstration. The pigeon pea training and presentation of the business concept will take place before the first pigeon pea planting in November 2018.	Milestone 1

OUTCOME 1.2

Description	Milestone	Assumptions	Risks
Increased farm incomes from pigeon pea production and potentially improved nutrition due to pigeon pea consumption	Milestone 3	Successful implementation of pigeon pea agroforestry	Sufficiently high farm-gate price of pigeon pea Acceptance of pigeon pea as food crop

Indicators

Consumption of pigeon pea

Description	Sources of Verification	Targets		
Total household consumption of pigeon pea. Since this is not a common food crop in Zambia, we expect baseline consumption to be zero kg, and we expect the project to result in an increase in consumption to minimum 10 kg per household. Sub indicators include: Age of household head District Education of household head Gender of household head Number of household members Size of land holdings	Comparing change in consumption of pigeon pea consumption among control households (those that have not received training) with change in pigeon pea consumption among those that have received training (a difference in differences approach). Based on baseline and endline household surveys, with detailed questionnaires, including data on household income (cash and in kind), crop production, food consumption, etc. Disaggregated results based on household background data in baseline household survey	**Baseline**		**0** kg
		Target	Milestone 3	**10** kg
		Results	Complete	**24,6** kg

Farm household income

Description	Sources of Verification	Targets		
Farm household incomes (cash and value of farm production produced on farm). A conservative target is a five percent increase in household income. Sub indicators include: Age of household head District Education of household head Gender of household head Number of household members Size of land holdings	Comparing change in farm incomes among control households (those that have not received training) with change in farm incomes among those that have received training. Based on baseline and endline household surveys, with detailed questionnaires, including data on household income (cash and in kind), crop production, food consumption, etc. Disaggregated results based on household background data in baseline household survey	**Baseline**		**0** %
		Target	Milestone 3	**5** %
		Results	Complete	**0**%

Output 1.2.1

Description	Milestone	Assumptions	Risks
At least 500 farmers produce approximately 125 tons of high quality pigeon peas for sale and/or own consumption	Milestone 2	At least 50 percent adoption among farmers that receive training. Average 0,25 ha of pigeon pea planted per farmer, and average yield 1000 kg per ha.	Low adoption, low yields

Indicators

Pigeon pea harvest

Description	Sources of Verification	Targets		
Pigeon pea harvest, measured in kg Sub indicators include: Age of household head District Education of household head Gender of household head Number of household members Size of land holdings	Measurement of harvest in collaboration with farmers. The CFU wioll assist farmers in measuring their harvest. Will be measured after the first and the second growing season. We expect a total of 125 tonnes across 500 farmers, or on average 250 kg per farmer. Disaggregated results based on household background data in baseline household survey	**Baseline**		**0** kg
		Target	Milestone 2	**250** kg
		Results	Complete	**23** kg

Pigeon pea sales

Description	Sources of Verification	Targets		
Kg of pigeon peas sold to the ETG for export, or in the local market. We expect each farmer to on average harvest 250 kg pigeon pea, and 200 kg of these sold, while the remaining harvest is consumed on farm and kept for seeds for the coming season. Sub indicators include: Age of household head District Education of household head Gender of household head Number of household members Size of land holdings	Monitoring harvest and sales, assistance from CFU in contact with ETG. Will be monitored after first and second growing season. Disaggregated results based on household background data in baseline household survey	**Baseline**		**0** kg
		Target	Milestone 2	**200** kg
		Results	Complete	**34** kg

Activity

Description	Milestone
Activity 2.1.1: Monitoring pigeon pea harvest and contact with sales: CFU will, in collaboration with NMBU closely monitor the pigeon pea harvest to measure the yield, and facilitate the pigeon pea sales to the pigeon pea trader (ETG). This involves ensuring that each farmer is given the possibility to sell their pigeon pea produce.	Milestone 2 ETG for

Impact 2

Description

Improved food security and reduced vulnerability to climate change due to higher and less volatile maize yields, leading to reduced poverty and improved position for women. Mitigation of climate chage

Milestone

Assumptions

Biochar application as soil amendment with favorable impacts. Women have the main responsibility for maize farming. Stable soil carbon storage

Risks

Low impacts of biochar as soil amendment for yields and carbon storage

Indicators

OUTCOME 2.1

Description	Milestone	Assumptions	Risks
Improved maize yields and reduced vulnerability of maize yields to climate variability Increased soil carbon storage	Milestone 3	Biochar application as soil amendment with favorable impacts. Stable soil carbon storage	Low impacts of biochar as soil amendment for yields and carbon storage

Indicators

Expected direct emissions reductions

Description	Sources of Verification	Targets		
Expected sequestration through storing biochar in soil. See calculations in GHG emissions reductions sheet for assumptions.	Calculations based on measurement of carbon content, information on number of ha with CF-MT biochar maize and parameters from previous plot trials	**Baseline**		**0** tonnes of CO2
		Target	Milestone 3	**1 033** tonnes of CO2
		Results	Complete	**43,5** tonnes of CO2

Maize yields

Description	Sources of Verification	Targets		
Maize yield in biochar enhanced soil under minimum tillage relative to the yield in soils without biochar addition, under conservative management (full tillage). Sub indicators include: Age of household head District Education of household head Gender of household head Number of household members	Change in maize yield among farm households that have applied biochar, compared to change in maize yields among control farm households (difference in differences approach). Based on yield measurements (harvest divided by land area) and recall data from baseline and endline surveys of farmers. We have conservatively assumed an average yield impact of 50%.	**Baseline**		**0**
		Target	Milestone 3	**50** %
		Results	Complete	**12-37** %

Organic carbon content

Description	Sources of Verification	Targets		
We will measure soil organic carbon content in soil samples at baseline and endline to monitor both the carbon content as an indicator of carbon sequestration, and soil health in general. Soil carbon is an important indicator of soil structure, with more structure giving less erosion and improved water infiltration. Will measure percent change in soil organic carbon, as share of total soil weight.	Soil samples taken at baseline and endline. We expect an increase of about 0,1 percentage points per year, from an average 0,4% carbon content, to 0,5% carbon content. (By comparison, increasing the soil carbon by 0.4% worldwide would solve the whole climate change problem, www.4p1000.org)	**Baseline**		**0.4%**
		Target	Milestone 3	**0.5** %
		Results	Complete	**1.9** %

Soil water retention

Description	Sources of Verification	Targets		
We will measure soil water retention from selected soil samples, comparing water retention in soil from conventional agriculture with water retention in soil with conservation farming with biochar.	Soil samples at baseline and endline. Note that our indicator is measured as percentage change in soil moisture, measured as percent humidity in the soil. We expect 10-25 percent increase in soil humidity.	**Baseline**		**0**
		Target	Milestone 3	**25** %
		Results	Complete	**50** %

utput 2.1.1

Description	Milestone	Assumptions	Risks
At least 1000 CF MT farmers receive training for biochar production and application At least 500 farmers produce biochar to be used as a soil amendment and/or briquettes Integrated CF MT biochar practices across 500 maize	Milestone 2	At least 50 percent adoption of biochar production and CF MT practices among trained farmers. The majority of biochar is used as soil amendment. On average 1	Farmers focus on briquette production rather than using biochar as soil amendments

hectares ha maize per farmer.

Indicators

Amount of biochar applied as soil amendment

Description	Sources of Verification	Targets		
Kg of biochar applied to maize fields to enhance yields. The optimal application rate is 4 tonnes per ha. Note that the target value below refers to kg per hectare, not per farm household. Disaggregated results based on household background data in baseline household survey. Sub indicators include: Age of household head District Education of household head Gender of household head Number of household members Size of land holdings	Monitoring biochar application	**Baseline**		**0**
		Target	Milestone 2	**4 000** kg
		Results	Complete	**103** kg

Number of beneficiaries reached

Description	Sources of Verification	Targets		
Number of business concepts tested multiplied by household size from each household. Disaggregated by gender, persons age and geographic location of household Sub indicators include: District Share of children Share of female Sub indicators include: District Share of children Share of female	Baseline survey combined with data on households that implement the business concept. Target based on national average household size of 5.2, and take-up of 50 %	**Baseline**		**0**
		Target	Milestone 2	**2 600** persons
		Results	Complete	**3 915** persons

Number of farm households that receive training

Description	Sources of Verification	Targets		
Number of farm households that receive biochar production and application training Sub indicators include: Age of household head District Education of household head Gender of household Number of household members Size of land holdings	List of participants at training, combined with information from baseline survey to verify which household the farmer head belongs to	**Baseline**		**0**
		Target	Milestone 2	**1 000** households
		Results	Complete	**753** households

Number of farm households that sell biochar briquettes

Description	Sources of Verification	Targets		
Number of households that proceed to produce biochar briquettes and selling these for cash income following the training. We expect this to be an attractive, alternative source of cash income from households that have access to a lot of feedstock for biochar production, and/or have limited yield gains from using biochar as soil enhancer. We estimate that 100 farmers out of the 1000 trained may produce biochar briquettes. This will also be monitored in the endline survey. Sub indicators include: Age of household head District Education of household head Gender of household head Number of household members Size of land holdings	Monitoring biochar application. Disaggregated results based on household background data in baseline household survey	**Baseline**		**0**
		Target	Milestone 2	**100** households
		Results	Incomplete	**0** households

Number of green business concepts tested

Description	Sources of Verification	Targets		
We will test one business concept through this project - the biochar pigeon pea agroforestry business concept.	Monitoring project implementation	**Baseline**		**0**
		Target	Milestone 2	**1** business concept
		Results	Complete	**1** business concept

Number of households that apply biochar as soil amendment

Description	Sources of Verification	Targets		
Number of farm households that proceed to produce and apply biochar to their maizefields following the training Sub-indicators include: Female-headed households, household size, region, number of children, land ownership, education of household head	Monitoring application. Disaggregated results based on household background data in baseline household survey	**Baseline**		**0**
		Target	Milestone 2	**500** households
		Results	Complete	**168** households

Activity

Description	Milestone
Activity 3.1.2.: Training for biochar production, application as soil amendment and as briquettes: Training will be funneled through the local partners' cost effective, professional and existing farmer-to-farmer extension services. NGI will provide the necessary biochar related technical training to partner field staff as well as to project Lead Farmers and farmers. The CFU field staff will look after correct implementation afterwards. Both biochar and pigeon pea training will be bundled with existing CF MT training organized by CFU so that maximal synergy and participation is obtained. A typical training will take one day, with 2 to 4 instructors (2 from NGI, 2 from CFU) and 30 to 50 actively participating farmers. The technology will be demonstrated, with emphasis on correct shape of the kiln, dryness of the feedstock, correct timing of feedstock placement to avoid unnecessary gas emissions, proper finalization of the biochar making process, and crushing of the biochar (alternatively, preparation of the simple briquettes). Training will take place in the extended dry season (April-October), after the pigeon pea has been harvested and the feedstock is ready for biochar production. Farmers will be invited to actively participate in the biochar making. Several feedstocks will be shown. For both biochar and pigeon pea procedures, detailed "cartoon" instructions will be made and handed out to the farmers, to increase interest and to facilitate proper adherence to the guidelines. Also, CFU staff will monitor the farmers closely and ensure the implementation is done properly also after the demonstration.	Milestone 2

Activity

Description	Milestone
Activity 3.1.1. Implementation workshop with detailed plans and materials for second training: Workshop between all project partners to discuss progress and prepare the necessary materials for the biochar training.	Milestone 2

Impact 3

Description	Milestone	Assumptions	Risks
Economic development, mitigation of adaptation to climate change		Business concept is profitable and sustainable	All risks described above and apply

OUTCOME 3.1

Indicators

Description	Milestone	Assumptions	Risks
Robust knowledge on the profitability potential for scaling up biochar-pigeon pea businesses	Milestone 3	Successful implementation of randomized control trial and successful data collection on socioeconomic and environmental variables	Poor communication and between partners leading to poor implementation and data collection

Indicators

Papers (for academic and policy audience) on potential of pigeon pea biochar businesses

Description	Sources of Verification	Targets		
Results will be disseminated through papers for both academic and policy audience. The production of these papers requires robust knowledge, and they thus act as indicators of this outvcome.	Presence of papers	**Baseline**		**0**
		Target	Milestone 3	**3** units
		Results	Incomplete	**0** units

Output 3.1.1

Description	Milestone	Assumptions	Risks
High quality data on farm incomes, yields, input use and take-up of business concept under various conditions	Milestone 3	Successful implementation of randomized control trial and successful data collection on socioeconomic and environmental variable	Poor communication between partners leading to poor implementation and data collection

Indicators

Baseline and endline survey data collected from trained farm households and control group

Description	Sources of Verification	Targets		
High quality household survey data, including farm production data and soil samples. Baseline data collected prior to first training, endline data collected after second harvest.	Presence of two rounds of survey data	**Baseline**		**0**
		Target	Milestone 3	**2** units
		Results	Complete	**2** units

Activity

Description	Milestone
Activity 4.1.2 Monitoring maize harvest and endline survey, including soil samples: The maize harvest will be closely monitored and measured, and endline household survey data will be collected from the same households as those surveyed at baseline. Soil samples will be collected from selected plots, both with and without Conservation farming – biochar technology.	Milestone 3

Activity	Description	Milestone
	Activity 4.1.3 Analysis of profitability, environmental impact and potential for scaling up: Synthesising the results from the business concept test based on the household survey data, the soil sample analysis and the carbon credit experiment and exploration of voluntary carbon credits. Dissemination of results to policy makers and academic audience. Knowledge of the impact of the business concept will be spread through the farmer to farmer CFU network.	Milestone 3

Activity	Description	Milestone
	Activity 4.1.1: Carbon credit experiment and exploring potential for voluntary carbon credits: Our project will explore the need and potential for including a carbon finance component. To investigate the need for a carbon payment, we will conduct a small field experiment to elicit the necessary carbon price among households that do not take up the technology. An economic experiment is a controlled and incentivised choice situation, where respondents make choices among defined options that result in different levels of private payoffs. The method is particularly relevant to elicit shadow prices and to explore why new, beneficial technologies are not adopted. There are several individual level hindrances to adoption. Risk or uncertainty averse farmers tend to be less willing to adopt new technologies, in which case insurance or assurances from trustworthy members of the community may improve uptake. Farming community with strong traditions or norms attached to older techniques may need to coordinate and adopt new techniques collectively, meaning that an external push is needed. Economic experiments is a tool to explore which factors are most relevant in hampering adoption and to identify solutions to facilitate adoption. Field economic experiments are conducted with relevant respondents, on their premises and in a relevant context. To investigate the potential for voluntary carbon credits, we will consult with national and international sellers and buyers of credits, developing a methodology for verifying results (MRV) and assessing the feasibility and attractiveness of including this revenue stream in the financial model to be applied in the next stage (at scale). At least two CDM methodologies and one VCS methodology exist that can be drawn on. We will liaise with the American Carbon Registry, the International Biochar Association, the British Biochar Foundation and others to develop this work stream as efficiently as possible. Concrete outputs will include financial scenario analyses of the impact of different carbon/offset prices on the financial viability of the business case, the establishment of relationships with international and Zambian carbon market players, the development of a draft MRV methodology, and a short report summarising findings and recommended next steps.	Milestone 3

Annex 3 Pictures

Grain from field. Selling per cup in photo at ZMK 6. Photo by Gibson Simosokwe

Pigeon pea crops of one of the farmers. Photo by Gibson Simosokwe

Biochar instruction in Chipata. Photo by Gibson Simosokwe

Biochar produced at trainings in Chipata. Whole and crushed biochar. Photo by Gibson Simosokwe

Biochar production flame curtain kiln after finishing the biochar making and covering with wet sand. Photo by Gibson Simosokwe

Annex 4 Other supplementary deliverables/documentation/links

Annex 5 Impact story

Zambia has one of the highest levels of poverty and inequality in the world. More than half of the population earns less than the poverty line of $1.90 per day. Three quarters of them living in rural areas, where smallholder farming is a main livelihood strategy. Farm productivity is low due to several factors, such as lack of access to inputs, transport and markets, as well as soil conditions. The natural conditions, the dependency on them and the low capacity to respond to shocks make the group vulnerable towards climate change.

The project has confirmed that biochar, when produced and applied correctly, has the potential for enhancing soil moisture retention, which improves drought-tolerance of farmers' maize crops, contributing to climate change adaptation and increases maize yields, potentially leading to increases in farm household income. The results indicate average maize yield increases of 12-37 percent upon the addition of 4 ton/ha biochar. Recent severe droughts in parts of Zambia, has underlined the importance of increasing farm households' resilience to droughts. Given that climate change is expected to result in increased dry spells during the Zambian growth season, the need for more drought-tolerant methods and technologies will increase in the coming years.

Biochar furthermore helps to store carbon in the soil, causing an increase in soil organic carbon by 20-30 percent, thus contributing to mitigating climate change. In this project, 168 households applied an average amount of 103 kg biochar, giving a total of 43,5 tonnes of CO2-eq. of direct emission reductions during the project period. There is potential to finance carbon storage through the international 'voluntary carbon market'. Such mechanisms can make biochar more profitable for more farmers, with benefits to farmers as well as for climate mitigation. We found that – due to the costs associated with administrating, monitoring, reporting and verification of carbon projects, the financial viability of biochar as a carbon project in this context relies on improved maize yields as well as carbon revenues. That is, the carbon project on its own was not financially viable.

The observed increases in maize yields, farmer incomes and carbon sequestration are lower than targeted. Reasons include a wet growing season in 2020-2021, meaning that the effect of biochar on plant-available water was smaller than to be expected in drier years; the amounts of applied biochar was lower than targeted, mostly because less than expected production of residual biomass; and that fewer farm households than expected adopted the new techniques.

An important lesson learned is that technology adoption takes time, stressing the need for strong training and close follow-ups, in addition to patience in evaluating results of new agricultural techniques. This project has covered two agricultural seasons. After the second season the farmer may see benefits on their staple crop (maize), which could in turn increase adoption also for neighbouring farmers. Another learned lesson is to test several different varieties of the new crop (pigeon pea) to

find a variety that combines good yields with high amounts of biomass, to be used for biochar.