Final Evaluation Report

Your Details	
Full Name	OPITO EMMANUEL ABWA
Project Title	A Community Partnership to Promote Endangered Species Recovery, Reforest a National Park, and Battle Invasive Plants
Application ID	37305-1
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1. Indicate the level of achievement of the project's original objectives and include any relevant comments on factors affecting this.

Objective	Not achieved	Partially achieved	Fully achieved	Comments
Establish 60 removal and control plots to assess how our procedures promote tree recovery			Fully achieved	Experimental plots have been established in Kibale National Park by February 2023 (Appendix 1).
Remove Lantana and Acanthus from large areas of the park where they are suppressing forest		Partially achieved		There is need for adequate equipment and funds for extensive removal and processing of biomass to briquettes. Luckily, preliminary findings from this study contributed to winning an Ecosia grant for large scale removal of *Acanthus* and planting of the cleared area with native tree species.
Continue long-term wildlife population monitoring		Partially achieved		Monitoring wildlife using the area is in progress. Data collection will progress for a minimum of 2 years. This will run until January 2025.
Conduct before and after assessments of community attitudes to the park and quantify the flow of benefits we generate throughout the community	Not achieved			Large scale removal of invasive species and processing of briquettes adequate to meet the community demands is yet to commence. With, support of the Ecosia grant larger impacts will be realised in the community which will be assessed.

Build a sustainable business model for the continuation of the project		Partially achieved		Cashflows for all activities, at all stages are recorded. These will guide in developing a sustainable business model for the management of invasive species within protected areas.

2. Describe the three most important outcomes of your project.

a). *Acanthus* removal enhances forest regeneration in Kibale.

Thirty-three plots of 15 x 15m have been established, from which *Acanthus* has been removed. Likewise, 33 corresponding control plots have been established, within which *Acanthus* thickets have been maintained. Three of the plots were planted with indigenous tree species to make observations on success of regeneration through planting after removal of *Acanthus*. Removal of *Acanthus* was physical, involving the use of simple tools, machetes and hand hoes. Also, removal was carefully done to minimise damage on pre-existing trees of all sizes within the plots. All trees above 1.3 m present were recorded to species, their height and diameter at breast height measured and the trees were also given tags.

Monitoring has been done for 30 naturally regenerating plots (6,750 m^2) that have made 12 months since plot establishment. Preliminary findings give hope that removal of *Acanthus* can help enhance forest regeneration in Kibale. Diversity of tree species above1.3 m has risen from 35 to 39 species. As expected, the new tree species recruited are early succession, high light demanding tree species like *Trema orientalis.* Other tree species recruited include *Rothmania* spp, *Dombeya kirkir* and *Dovyalis macrocarpa.*

Stem density of these trees above 1.3 m has doubled (from 107 to 262 trees), one year after removal of *Acanthus.* The highest increment by species is observed in *Croton macrotstachyus*, another early succession tree species, with a rise from three to 88 stems in 1 year (Appendix 2). Majority of the other species didn't change in density over the year. Survival of trees has been very high (96%) after removal of *Acanthus*.

Alternatively, increase in tree species abundance after removal of *Acanthus* was lower in areas with *Acanthus* thickets. Tree species abundance increased by half in areas left with *Acanthus* thickets. This increment was by 29 trees, from 57 to 86 stems. Likewise, increase tree species composition was lower in areas with *Acanthus,* increasing by only two species in 12 months (26 to 28 tree species). The new species registered are *Funtumia spp* and *Prunus africana.* Also as hypothesised, average height (-0.5 m) and diameter (-0.49 cm) gains are much lower in areas with

Acanthus than areas cleared off *Acanthus*. However, mortality of trees in areas with *Acanthus* (3%) compared well with areas from which *Acanthus* was removed (4%). Monitoring of the plots for tree growth, recruitment and mortality after removal of *Acanthus* will continue until February 2025.

b). *Acanthus* removal enhances use of the areas by large park animals.

Monitoring of use of the area by wild animals has been done using camera traps installed in cleared plots (n=4) and plots with *Acanthus* thickets (n=4). Several days (2,378 days) have of monitoring been accumulated over one year for all the cameras. Several days have been lost due to loss/theft of a camera, malfunction of cameras, disturbance by animals, card errors or low battery on some cameras.

Observations over the one year indicates a higher daily percentage use of areas from which *Acanthus* was removed (72%) by animals compared to areas with the thickets (59%). More specifically, larger animals (bush barks, elephants, baboons and giant forest hogs) are using areas without *Acanthus* more than areas in which the thickets are present. Smaller animals like squirrels, rats, birds and duikers are using *Acanthus* thickets more than areas without *Acanthus* (Figure 1).

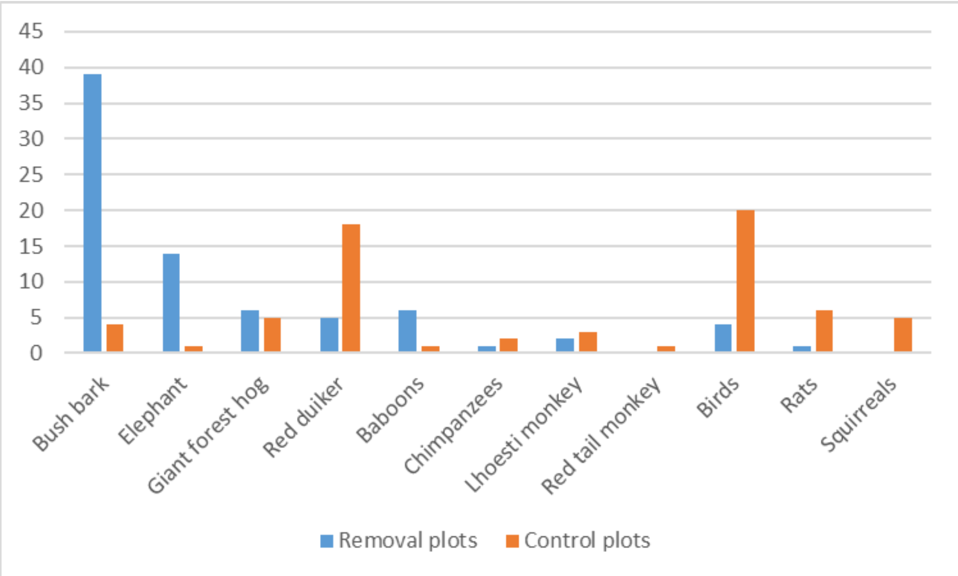

Figure 1: *Percentage daily chance of animals using the area 12 months after removal of Acanthus*

This trend could be associated with ease of movement of large animals in open areas compared to challenges in moving through thickets of *Acanthus*. This could possibly explain the high use of *Acanthus* thickets by smaller animals like rodents, birds and duikers. Smaller animals could also be using *Acanthus* thickets as shelter from predators. These predators could be less of a threat to the larger animals that are left to freely use open areas from which *Acanthus* has been cleared. This trend could change in the long run as trees grow bigger and create shade over the cleared areas.

However, on the contrary, chimpanzees have used areas with *Acanthus* thickets higher than areas without the thickets. This is likely due to high levels of foraging on Acanthus by the chimpanzees in seasons where fruit availability if low.

Also, more species of animals have used areas with *Acanthus* thickets (20) compared to areas without *Acanthus* (18) over the 1st year after removal of *Acanthus* from Kibale. Some of the species that were yet to visit areas without *Acanthus* include red tail monkeys, golden cats, and the blue duikers. However, the Sitatunga has used areas without *Acanthus* and are yet to be sighted in areas with *Acanthus* thickets.

***c). Acanthus pubescens* produces quality cooking briquettes.**

Test results reveal briquettes from *Acanthus* possess desirable fuel properties. With support from Uganda Wildlife Authority, efforts by New Nature Foundation, The Rufford Foundation and equipment donated by IDEA wild, assessment of fuel properties and heating dynamics of briquettes made from *Acanthus* and other native weeds that pause conservation challenges in Uganda's national parks has been achieved.

A proximate analysis was conducted to assess moisture, volatile organic matter, ash and fixed carbon content has been done for briquettes made from *Acanthus, Dichrostachys cinera, Harrisonia abyssinica* and *Lantana camara* (an alien invasive species). Additionally, mechanical properties like density and shatter index of these briquettes have also been established. Finally, calorific value, heating rate, specific fuel consumption as well as indoor air quality after cooking with *Acanthus* briquettes has been assessed.

These have been chipped, dried and moisture content after drying determined. The samples now await carbonisation and the subsequent stages to make cooking briquettes.

Preliminary findings reveal high calorific value for *Acanthus, Dichrostachys, Harrisonia* and *Lantana* briquettes. Briquettes made from the invasive species have a low moisture content (ranging from 6.64% to 7.85%), desirable volatile organic matter content (ranging between 32.84% and 62.71%), and a low ash content (10.76% to 12.91%). Moisture content less than 4 or 5% tends to reduce stability in briquettes, resulting in burning at a higher rate (Fadele et al., 2021). However, high moisture content reduces the combustion temperature and has an adverse effect on combustion (Dinesha et al., 2018). A mean moisture content of 5%–10% is recommended for high standard charred briquettes (Adu-Poku et al., 2022; Akolgo et al., 2021; Aransiola, Oyewusi, Osunbitan, & Ogunjimi, 2019). Briquettes easily ignite within this range of moisture content (Akolgo et al., 2021). Therefore, all the briquettes made using the four invasive species have desirable moisture content.

In line with ash content, the European standard (EN 14775) recommends an ash content < 3% while the ISO 18122 standard requires an ash content < 5% (Chungcharoen & Srisang, 2020). For barbequing, maximum ash content of 8% is recommended (Jelonek, Drobniak, Mastalerz, & Jelonek, 2020). Although higher than 3%, the ash content in the briquettes produced from *Acanthus, Dichrostachys, Harrisonia* and *Lantana* all fall below 8%. This implies minimal negative effects of ash like corrosion and limited burning of the briquettes. Therefore, the briquettes are suitable for cooking and barbequing.

The briquettes produced from all the species also have good mechanical strength; with a high shatter index (93.7% to 99.9%) and high density (2.02 to 2.74 g/cc). These shatter indices compares well with other quality briquettes made from palm kernel shell, sawdust, rice husk and corn cob with average shatter indices of 95.52%, 95.02%, 93.75% and 94.34% respectively (Adu-Poku et al., 2022). High shatter index implies minimal loss of briquettes to crushing during transportation.

The briquettes made from *Acanthus, Dichrostachys, Harrisonia* and *Lantana* also have high average energy levels with calorific values ranging between 6.04 and 8.68 Kcal/g. The DIN51731 standard recommends calorific value of at least 17.5 MJ/kg (4.18 Kcal/g) for fuel briquettes (Chungcharoen & Srisang, 2020). Also, the benchmark value for the Wood Pellet Association of Canada is 16 MJ/kg (3.82 Kcal/g) while the Austrian NORM M7135 is 18 MJ/kg (4.3Kcal/g) (Adu-Poku et al., 2022; Akolgo et al., 2021). Therefore, briquettes made from these invasive species have high energy levels sufficient for cooking.

Additionally, to produce a safer cooking alternative, preliminary findings from cooking with briquettes made from *Acanthus* reveal safe indoor air quality while cooking with the briquettes. Emission of volatile organic compounds (0.15) and formaldehyde (0.0325) are rated excellent, while emission of particulate matter is rated good (50 µg/m3) and carbon dioxide levels are mild (1,327.5). Particulate matter is the most destructive pollutant to humans and low levels in the indoor air after cooking with the briquettes could help curb the increase in infections associated with the pollutants. However, additional tests are still being conducted to obtain sufficient sample size on which to conclude on indoor air quality from cooking with *Acanthus* briquettes.

In conclusion, *Acanthus* biomass is good for briquettes production. In fact, *Acanthus* briquettes produced with lower (5%) of binder show better fuel properties. These have 7.85% moisture content, 53.75% volatile matter content, 12.25% ash content and 8.68 Kcal/g. The briquettes also have good strength with 2.02 g/cc density and 97.2% shatter index. Increase in the proportion of binder had inverse effects on calorific values of all the briquettes made. Increase in proportion of binder from 5% to 10% led to reduction of calorific values in the briquettes produced from *Acanthus, Dichrostachys, Harrisonia* and *Lantana*. This is a positive observation which lowers cost of producing quality briquettes, as cassava flour binders are costly in briquettes production.

However, a high loss in biomass is incurred the production of *Acanthus* briquettes. A higher loss of *Acanthus* biomass (88.9%) is incurred during the carbonisation of dried biomass into char, compared to the loss incurred with the other species (*Lantana*-63.3%, *Dichrostachys* 63.8% and *Harrisonia* 65.6%). Although this loss could be associated with the difference in wood density of the different species; the high loss could also be associated with duration of carbonisation, maturity of the stems used, size of the wood chips carbonised among others. Investigation is therefore vital to identify a proper mechanism to maximize *Acanthus* char production.

3. Explain any unforeseen difficulties that arose during the project and how these were tackled.

During the budgeting, much attention was accorded to labour of the manual cutters ignoring the vital need for expert tree identifiers. These were vital after cutting *Acanthus* and during the monitoring of seedling recruitment. Seedlings tend to differ in appearance from mature trees thus there was need for expert identifies to help identify them. This implied an unforeseen additional cost of labor for the project.

The planned time frame was also overlapped due to field disturbances that were unavoidable. Disturbance by elephants meant delayed activities in some areas causing overall delays in our schedule. Elephants often cut out certain areas within which our team intended to work, causing dead days or delay in completion of certain tasks. Labor was therefore paid with less work done implying the need to hire additional hands for cutting and tree identification to compensate for lost time. These additions imply cost increase as well. The impact of the dry spell on mortality of seedlings also delayed cutting activities until onset of the next season's rains. These factors implied additional time in the field.

Weeds have colonised the areas from which the *Acanthus* has been removed in a much shorter duration than anticipated. Herbaceous plants, *Acanthus* and lianas are still colonising the areas in periods less than 4 months. These then suppress any upcoming seedlings within the plots. Labor has also been split for weeding plots that were established earlier on. This has brought about delays in establishment of new plots. Additional labour is needed for the future to help match the growth of weeds/*Acanthus* in the early months/years after removal of *Acanthus*. About three rounds of weeding may be adequate to allow tree seedlings survive on their own.

4. Describe the involvement of local communities and how they have benefitted from the project.

Besides the few currently employed manual cutters, there is little community involvement at this stage. Community participation is however expected to increase soon. With the winning of other grants like Ecosia, production of briquettes is expected to increase with availability of more processing equipment. This will mean a need for additional labour for harvesting of the invasive and hyper abundant species biomass. Increased removal of *Acanthus* and *Lantana* also implies increased labour demands for weeding the area after removal. Currently, three rounds of weeding at 6 month intervals proves adequate to allow the trees compete favourably with the shrubs. Women, who can perform relatively lighter physical activity will be more employed at this stage to carry out the large scale weeding. This has been proven viable as women have successfully implemented weeding and slashing activities in the south of the park.

There is also intention to plant the large areas from which *Acanthus* will be removed with indigenous tree species. Planting and management of the planted areas requires adequate hands, thus more employment to the community. The housewives and children who highly engage in fuel wood collection will also benefit when affordable briquettes are available for them.

5. Are there any plans to continue this work?

Yes, there are concrete plans to continue with our efforts to restore degraded Kibale.

In the short run, I and my team intend to continue monitoring the effect of removal of *Acanthus pubescens* and *L. camara* on passive forest regeneration and wildlife use of the area.

I also intend to test how active restoration can contribute to restoration of the areas after removal of *Acanthus.* This will be by planting native tree species after removal of *Acanthus* to assess how tree planting enhances regeneration after removal of *Acanthus.* Seeds of native tree seedlings will be corrected from dung of primates along roads and trails within the park and raised in community seedling nurseries. Other sources of seeds/seedlings will be compounds of facilities within the parks where seedlings often grow in large numbers under the parents but are regularly mooed.

I also plan to seek avenues of maximising char produced from *Acanthus* biomass as well as the cost of its production. This could be by engaging local charcoal burners to pyrolyse *Acanthus* stems locally to maximise returns while cutting costs. Also, large and more efficient kilns can be set up in the community to not only maximise char returns from *Acanthus* stems but also overall returns from pyrolysis of any other biomass material carbonised.

6. How do you plan to share the results of your work with others?

Initially, I intend to share raw data with partners doing related studies. At present, data captured while monitoring wildlife use of the area has proven useful for another parallel PhD study. Naomi Mathews, a PhD candidate at hopes to use data from our camera traps towards his study chapter entitled 'Conservation Ecology of Giant Pangolins in Uganda.' The data shared specifically from pangolins will be used to build a database on pangolin occurrence and to perform a countrywide occupancy analysis for each species as well as species distribution modelling.

Additionally, results from our different study objectives will be published in peer-reviewed journals for access by other people.

Methods and findings have been presented at conferences/symposia. In June 2023, my study methods and preliminary observations were presented during the Uganda Wildlife Authority's researchers' symposium in Fort Portal. The symposium was highly attended by the academia, community groups, research organizations among others.

7. Looking ahead, what do you feel are the important next steps?

In the next few months (~2 month), I hope to have concluded the final experiments to determine cooking efficiency of briquettes made using *A. pubescens, L. camara, D. cinerea* and *H. abyssinica* using cassava flour as the binder. A two factorial study will be done based on the different material and different mix proportions of the cassava flour binder. Proximate analysis, analysis of mechanical properties, combustion properties as well as calorific value test will be done.

Also, monitoring of areas from which *L. camara* was removed will commence in the southern parts of the park.

Finally, I and my team also intend to raise native tree seedlings from 'dead seeds/seedlings', plant native tree seedlings in area from which *Acanthus* will be removed to test how planting would enhance forest regeneration after removal of the forest weed. Although Ecosia is doing large scale removal and planting in the area, there is need to study how planting enhances regeneration of the forest. Also, raising of seedlings for planting has not been deeply implemented with high quantities of viable seeds being discarded on roads and active trails where they are destroyed after germination. These seedlings could be saved from mortality by raising in nurseries and planting.

Regarding my studies, I submitted all the necessary requirements for full admission to my PhD Program at Makerere University, a step which comes upon successfully defending the PhD proposal. I intend to start writing a journal article in the next few weeks upon obtaining full results of on the different variables on briquettes quality.

8. Did you use The Rufford Foundation logo in any materials produced in relation to this project? Did the Foundation receive any publicity during the course of your work?

During my presentation of methods and preliminary findings at the Uganda Wildlife Authority Researchers' Symposium 2023, I used the Rufford logo as I appreciated their support to the project.

Through this, I got to link up with one of the former beneficiaries like Bruce currently working with KARED, Bigodi.

9. Provide a full list of all the members of your team and their role in the project.

Name	**Role played**	**Comments**
1. Kaseregenyu Richard	Cutting acanthus	Started the project
2. Mwesige Robert	Cutting Acanthus	Started the project
3. Ahabyona Joseph	Cutting acanthus	Started the project
4. Tusiime Laurence	Tree identification specialist	Joined the team during monitoring stage
5. Aliganyira Emmanuel	Tree identification specialist	Joined the team at the monitoring stage
6. Basaija Robert	Tree identification specialist	Joined the team at the monitoring stage
7. Margret Kemigisa	Processing Acanthus to briquettes	Manager at New Nature Foundation
8. Bahati Nicholas	Transportation of Acanthus	

10. Any other comments?

I would like to thank The Rufford Foundation for considering this project worth financing. Support from the funds has not only helped us establish the intended study plots, but also aided us in collection valuable field data during monitoring, acquisition of necessary field supplies, field accommodation and change of life of the community that has directly and indirectly benefited from the grant funds. I look forward to applying for the subsequent phases of the seed grant.

Appendix 1: Test plot (15m by 15m) after removal of *Acanthus*

Appendix 2: *Croton macrostachys* that naturally regenerated in Plot 9