Final Report:
Forest Restoration in Mbalmayo, Cameroon

Client:
Roger Bruno Tabue Mbobda, National Forestry School of Cameroon

Advisor:
Dr. Kevin Njabo

Team Members:
Jordan Corral, Katryn Heine, Anna Novoselov, Laine Nowak,
Alexandra Preston, Davina Truong, Kimberlee Wong

University of California, Los Angeles
Institute of the Environment and Sustainability
Environment 180C: Practicum in Environmental Science
Professor Noah Garrison
June, 2024

Table of Contents

Abstract

The urban landscape of Mbalmayo, Cameroon is under immense strain from urban sprawl and the conversion of open spaces, as well as environmental pressures like climate change and pollution. This can harm natural habitats and put the health and well-being of humans, biodiversity, and the provisioning of ecosystem services at risk. Applying nature-based solutions to restore degraded, damaged, or destroyed urban ecosystems can help to address such challenges. Our practicum team collaborated with the staff and students of the National Forestry School of Cameroon to research forest degradation and rehabilitation. Each UCLA student was matched with a NFS student to work together, share research, and create a lasting international connection. Before our trip, we researched different types of restoration methods, such as applied nucleation and plantation. In addition to this, we shared our findings about the common downfalls and importances of forest restoration with our collaborators to establish a common ground from which we built upon. While in Cameroon, we gained field experience and partook in the start of what we hope will be a generations-long restoration project for 100 hectares of degraded land. We also visited two schools to speak about the importance of forests and provide the students with insight into college life. After leaving Cameroon, we continued to support the NFS in the monitoring of the planted saplings and found funding to provide a solution to the poor soil quality. Because the NFS is a two-year college, we anticipate that this project will be continually passed down to new students and improved every year. Our report will discuss the methods we took in preparing for and implementing forest restoration and the results that were found after the local surveys and animal observations were made.

Introduction

National Forestry School of Cameroon

The National Forestry School in Mbalmayo, Cameroon supports the ambitions to restore, rehabilitate and reconnect ecosystems along the urban-rural interface. They work to advance the state of knowledge, build capacities for coherent urban planning, and foster exchange and collaboration on restorative nature-based solutions. A partnership with the Environmental Science undergraduate students from the University of California, Los Angeles will help provide technical assistance to community groups and restoration enterprises in these degraded landscapes. This project focuses on restoration techniques, nursery management, marketing, and financial management. Nature-based solutions can foster ecosystem recovery as a means to increase resilience and conserve biodiversity, while also benefiting society, the environment, and the economy.

Applied Nucleation

Applied nucleation is a specific forest restoration technique that integrates tree planting and natural succession as a way to restore degraded and deforested land. Trees are planted in clusters, or nuclei, and are then allowed to expand naturally over time by the process of ecological succession and the help of animal dispersers. In comparison to alternative forest restoration methods, namely passive restoration and plantation, applied nucleation has shown to be a favorable middle ground between the two. Plantation is the strategy where trees are actively

and densely planted over the whole area of restoration. It is typically the most effective method, but also the most time, money, and energy intensive. Passive restoration is the technique where an area of restoration is essentially left with minimal human intervention, and trees are allowed to grow back on their own. The case studies from this are not very effective, but it does not require much money or resources. Applied nucleation has success rates that are about as high as plantation, but it is cheaper and less labor intensive.

Plant Nursery

The National Forestry School of Cameroon had prepared a plant nursery for this project. There were ten species of saplings: Andok (Irvingia gabonensis), Assamela (Pericopsis elata), Ayous (Triplochiton scleroxylon), Bubinga (Guibourtia tessmannii), Dibetou (Lovoa trichilioides), Ebony (Diospyros crassiflora), Djansang (Ricinodendron heudelotii), Frake (Terminalia superba), Teak (Tectonia grandis), and Wengue (Millettia laurentii).

Soil Testing

Areas of forest land that have been degraded often also experience poor and degraded soil quality. To ensure our restoration efforts are effective, we must ensure that soil quality can support the trees we plant. Knowledge of soil indicators during forest restoration is essential for understanding the recovery of ecosystem functions. Soil monitoring through suitable soil indicators should be implemented before, during, and after restoration projects. To understand soil health, the soil's physical, biological, and chemical components must be measured (Gatica-Saavedra et al., 2022).

Soil Treatment

After our soil analysis results showed that the soil was quite acidic, the National Forestry School recommended a treatment of dolomite. Dolomite is often used in restoration projects because of its reaction with acid that makes it a soil conditioner. Studies have determined that there are beneficial results on soil after a dolomite treatment was added, such as reduced acidification, improved enzyme activity, and increased magnesium content (Lasota, Jarosław et al., 2021). Because the funding for this treatment came from The Green Initiative Fund at UCLA, we ensured that its production was sustainable, so it was purchased from a local Cameroonian supplier.

Wildlife Presence

Seed dispersers and predators are crucial to the health of tropical forest ecosystems. While planting trees was the focus of our project, the long-term restoration success depends on those trees' abilities to thrive and reproduce. Animal pollination is typically species specific, but plants may use a myriad of allochory distribution methods for seeds. There is some debate about whether the majority of rainforest trees use autochory, distributing seeds themselves by ballistic ejection and gravity, or allochory, relying on water, wind and animals. Clark et al. (2001) posit that abiotic means of seed dispersal dominate in tropical lowland forests, while Beaune et al. (2013) found that 88% of species and 95.1% of individuals at a site in the DRC to be zoochorous – reliant on animal seed dispersers. Regardless, it’s been a tenant of biodiversity sciences since

the 1970s that seed dispersers and predators are crucial to the high plant species diversity in rainforests (Janzen, 1970). In fact, so many rare plant species thrive in rainforests due to low densities of more common species, which is a result of animal seed dispersal and parent trees' seed shadows (Howe and Miriti, 2000). Over large distances, elephants and primates are more effective seed dispersers, but much local dispersal relies on birds. Examining 100 hectares of land in Mbalmayo, we recognize there is likely a dearth of large animals, so we narrowed our focus to birds. In identifying birds present on the site, we aimed to understand the state of the surrounding forest and predict potential outcomes for our restoration project.

Research Questions

1. What are the main reasons for forest degradation and how can we reduce that demand?
2. Why do forest restoration projects normally fail and what are some factors of success?
3. What are local perspectives on the importance of forests and how will forest restoration benefit the locals in Mbalmayo?
4. What is the current soil quality of the degraded site and how can we ensure high soil health/quality?
5. What specific plant species will be used and how/why will they be planted?
6. How does applied nucleation work as a forest restoration technique?
7. How does wildlife recolonization aid in forest restoration and serve as a measure of success?

Deliverables

The primary objective of this project is to restore 100 hectares of degraded land, with the initial phase concentrating on 2 hectares. Soil samples from this area were analyzed to provide detailed information about soil content and health, which were crucial for the success of our restoration efforts. Based on the analysis results, we recommend using dolomite to increase the pH of the degraded soils and a compost system to improve organic carbon content.

Survey and interview responses were meticulously analyzed and summarized, with the original responses available as supplementary material. Data from yes/no questions were presented using graphs. These responses informed our restoration and maintenance strategies and raised awareness about the complex causes and consequences of deforestation in low-income countries. This approach helped us understand local perspectives and needs, ensuring that we considered the local context in our restoration efforts. Additionally, it prompted cross-culture collaboration on complex environmental issues.

We created an informational poster about the benefits of forest restoration in Cameroon, the causes of forest degradation, and the ways locals can help protect the forest. These posters, printed in both English and French, were displayed in educational and community buildings to serve as engaging and accessible learning resources.

To further support our mission of fostering cross-cultural dialogues on environmental issues, equity, and international development, we created social media posts and articles for the public. These were shared by our practicum team's Instagram (@mbalmayoforestryteam) and UCLA's Institute of the Environmental and Sustainability (@uclaioes). An article was published on the UCLA IoES website that detailed our restoration efforts. This article incorporated local perspectives from surveys and interviews that highlighted forest degradation. We attempted to reach out to nonprofits and organizations involved in Cameroon, Congo Basin reforestation, and sustainable forestry to publish blog posts on their websites and social media channels. This would've amplified our message and encouraged broader engagement with our restoration efforts if it was successful.

Methods

Fundraising

Our team collaborated with UCLA SPARK Campaigns to raise funds for travel and accommodation expenses, successfully securing over $14,000. This campaign enabled us to travel to Cameroon and actively participate in restoration efforts led by the National Forestry School. Additionally, we obtained a $10,000 grant from The Green Initiative Fund (TGIF) by writing a comprehensive proposal and presenting our research to their committee. This grant allowed us to purchase essential items for a successful restoration project.

Soil Analysis

There was no specific number to follow when deciding how many samples per hectare to use for our soil analysis. It can vary based on the nature of the landscape and in our case, largely decided by financial ability. In any case, a higher number of samples would give us more precise data on the health of the soil and its different components. To determine a sampling plan for this project, we needed to identify different components of the site and its heterogeneity. Factors we considered were slope/erosion, land cover type, physical soil surface characteristics (color, texture), and previous land uses. The experts we worked with at the International Institute Of Tropical Agriculture (IITA) of Cameroon, Rose Ndango and Viviane Mandah, suggested collecting ten samples per hectare was the best way to conduct a comprehensive analysis. The site we planned to restore was originally about 15 hectares, so they suggested we collect 150 samples in total. Within each sub-unit (1/10th a hectare), it was suggested that we collect at least 2 kg of soil from 20-30 random sampling points to form one composite sample. At each sampling site, samplers should describe the environmental surroundings during sampling and record the coordinates of each sampling unit. A description of the sampling site will assist in interpreting the results, given the heterogeneity of the land. A description sheet should consist of the following factors: slope/erosion, land cover type (secondary adult forest, secondary young, degraded forest, swamp forest, cassava fallow, other crop fallow), soil surface texture/color/structure, plant growth vigor, irrigated land, or rain-fed land. If the land is afforested, meaning not previously covered in a forest landscape, it is also recommended that the sampling depth is at least 60cm (Shengwei et al., 2013).

For our official soil analysis, National Forestry School students went into the field and gathered 20 samples across the 15 hectares, 2 of which we restored (Figure 1). For reference, 1 hectare is equal to 2.47 acres. We worked with soil expert Rose Ndango at the International Institute of Tropical Agriculture (IITA) of Cameroon to decide which metrics were most important to analyze based on our limited budget. Of the 20 samples gathered, 10 were used to analyze exchangeable cations, organic carbon, soil nitrogen, Malchor bray phosphorus, exchangeable ions (Ca, Mg, K, and Na) by atomic absorption spectroscopy (AAS), and cation exchange capacity (CEC). We only analyzed these for 10 of the samples because it was a more expensive analysis but still deemed important. For all 20 samples, we measured pH water parameters, pH KCl, and electrical conductivity. Results of the analysis showed that soil quality is poor.

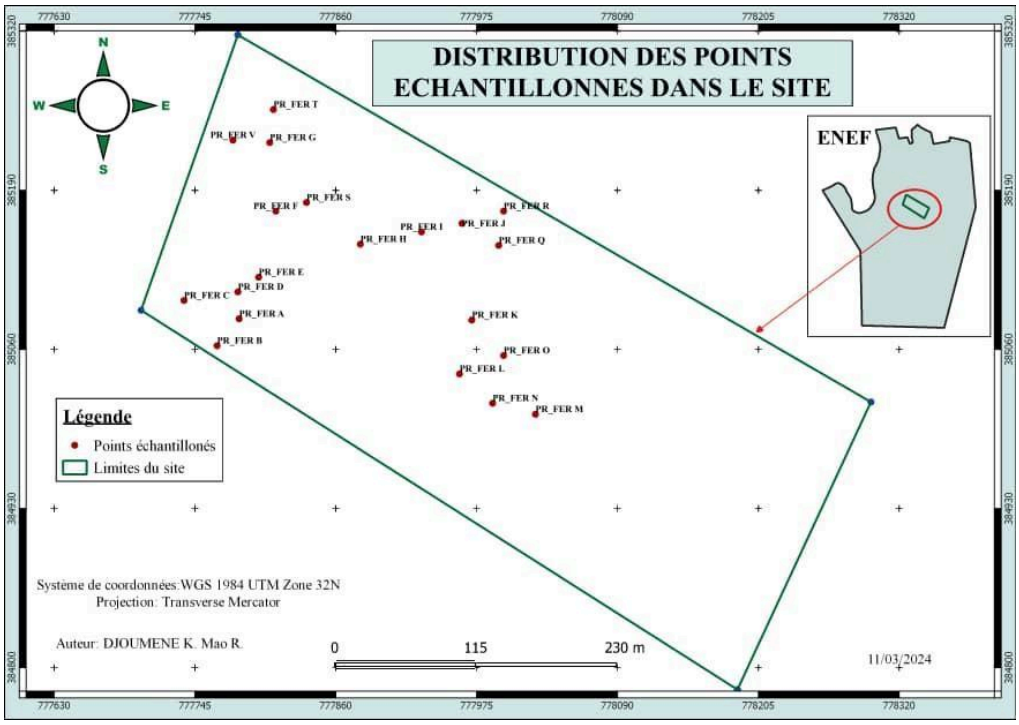

Fig. 1: Map showing 22 samples that were taken from the 15-hectare plot in Mbalmayo, Cameroon. Note that we only analyzed 20 of the 22 samples due to errors with two of the samples. Mao Rodrigues from the National Forestry School assisted in the creation of this figure.

Soil Treatment

Treatment of the soil is still in its preliminary stages. Working with the NFS and IITA we decided to first raise the soil pH using dolomite. Dolomite is a limestone that is known to help neutralize soil acidity, raising the pH while also improving the phosphorus and nitrogen concentrations (Mkhonza et al.). The dolomite was collected in Souza, a part of The Littoral region in Cameroon. Funding for the dolomite was acquired through The Green Initiative Fund (TGIF) and dolomite was acquired in Cameroon through Agri-Business Consulting (ABC), a partner supplier. Once the students at the NFS can add the dolomite to the soil, we can suggest ways to improve the organic carbon content. Cation exchange, nitrogen, and phosphorus will hopefully see improvement from the placement of the dolomite as well. For organic carbon we

suggest the National Forestry School investigate setting up a low-cost compost, using dead leaves and other organic waste.

Restoration Techniques

Applied nucleation is a promising forest restoration technique, but it is not yet well-known, closely studied, or thoroughly documented. For that reason, the National Forestry School of Cameroon decided to implement a grid plantation strategy for the restoration site instead. This is a basic technique that requires more resources, but will ultimately take less time. 31 plots (25m by 25m) were established with 36 saplings planted in each (5m apart). Applied nucleation was still, however, used in smaller supplemental plots. Because this is a pilot program and there are plans to restore more land, the success of each strategy will be compared to decide on appropriate restoration techniques in the future.

Bird Surveys

Identification of animals on site proved to be a challenge. Eventually, we were able to gain an understanding of the bird species present thanks to Dr. Kevin Njabo's knowledge of local bird species. We also noted local passersby carrying small rodents out of the forest. For bird surveying, while at the restoration site and when walking to and from the area, we listened for recognizable and species-specific bird songs. Using binoculars, we were able to look more closely at a few individuals, but most small forest birds were too camouflaged and fast to be seen clearly. We referenced each species seen or heard in *Birds of Western Africa* by Borrow and Demey. Once back in the US, we researched each species to understand its habits and diet and consequential impact on the ecosystem.

Local Surveys

To gauge local perspectives on the importance of forests and avenues for restoration, we distributed a survey to the students at the National Forestry School via Google Forms. The survey included broad questions to sample their understanding of forest functions and co-benefits, the factors they find most important in restoration efforts, and the perspectives they have about the best practices for forest restoration. The complete responses are included as supplemental information. Here is the full set of questions:

1. What do you think are the 3 most important reasons to protect forests?
2. Do you think protecting forests is important to most people in Cameroon? Why or why not?
3. Does forest destruction affect local communities in Cameroon? Does it affect you personally?
4. Do you think someone should be responsible for protecting and restoring forests? If so, then who?
5. What do you think is causing forest degradation?
6. Why do you think restoration efforts sometimes fail?
7. What do you think would make restoration efforts successful?
8. Do you know what applied nucleation is? If yes, what do you know?

9. What traditional practices and knowledge are important for sustainably managing forests in Cameroon?
10. Do you think deforestation plays a role in climate change? If yes, how?

Results

Soil Analysis

For the analysis, we wanted to investigate 8 components of the soil samples. These components are listed in Table 1 below. Unfortunately, due to budgeting constraints, we revised the number of samples we planned to collect to 20 on the entire plot. We hoped these analyses will provide adequate information about the quality and content of the soil in the area we plan to restore. With this information, we were able to suggest proper treatments to the National Forestry School that'll help ensure soil health for the restoration.

The results of the analysis showed extremely poor soil quality across all metrics studied. The results of the laboratory analysis can be seen in Table 1. All nutrients are much lower than the healthy threshold. pH of water ranges from 3.85-4.58, pH of KCl is 3.46-3.81, electrical conductivity ranges from 19.83-51.08 uS/cm, organic carbon 0.723-0.859%, total nitrogen ranges from 0.054-0.095%, carbon/nitrogen ratio ranges from 8.88-14.60 and bray phosphorus 0.037-0.561 ug/g. CEC was 4.95-7.99 ccmol(+)/kg and nutrients measured by AAS were measured in units of ccmol (+)/kg which is centimoles of positive charge per kilogram of soil. The soil had a calcium (Ca) concentration of 0.272-2.082 ccmol(+)/kg, magnesium (Mg) of 0.197-0.638 ccmol(+)/kg, potassium (K) of 0.043-0.079, and sodium (Na) of 0.081-0.093 cmol(+)/kg. CEC is a measure of the soil's ability to hold these positively charged ions (Ca, Mg, K, and Na) and exchange them. A higher CEC value means the soil has a greater ability to supply nutrients to plants (*Cations and Cation Exchange Capacity - Qld | Fact Sheets | Soilquality.Org.Au*). Higher CEC in soils are generally more fertile because they can store and release nutrients for the plants better. 10-15 cmol(+)/kg would be an ideal range for CEC in our soil, which is currently underperforming. Organic carbon, nitrogen, and phosphorous are also all underperforming in concentration and are essential for soil health management and performance. Phosphorus and nitrogen play important roles in limiting and regulating plant growth and development, while soil organic carbon (SOC) impacts overall productivity (Zhong et al.). These metrics are also below healthy levels, for example, the organic carbon percentage is below 1% on all samples but ideally should fall in the 2-4% range (Kome et al.). The first metric to take note of and treat is pH. The healthy pH should fall within or near the range of 6.5-7 (Hatten and Liles). Low pH is a partial indicator of low cation concentration in the soil, and if the pH remains low the soil will be unable to take in nutrients. It was deemed necessary to increase the pH as our first step in the soil treatment.

Analysis data for soil samples submitted by CBI students													
Lab #	Sample ID	pH	pH	EC	Org C	Total N	C/N	Bray P	CEC	Ca	Mg	K	Na
		Water	KCl	uS/cm	%	%		ug/g	----------cmol(+)/kg----------				
hfs022237	PR_FER_A	4.25	3.61	51.08	0.802	0.070	11.50	0.144	6.32	0.448	0.329	0.074	0.093
hfs022238	PR_FER_D	4.24	3.57	24.30	0.842	0.095	8.88	0.037	7.99	0.272	0.197	0.062	0.082
hfs022239	PR_FER_J	4.29	3.72	30.80	0.859	0.084	10.28	0.561	5.48	0.401	0.218	0.072	0.083
hfs022240	PR_FER_M	4.39	3.71	27.50	0.845	0.084	10.12	0.144	5.54	0.768	0.491	0.055	0.081
hfs022241	PR_FER_N	4.58	3.74	29.60	0.849	0.067	12.61	0.422	5.26	2.082	0.436	0.079	0.088
hfs022242	PR_FER_O	4.44	3.72	19.83	0.802	0.071	11.30	0.283	5.66	0.740	0.396	0.048	0.082
hfs022243	PR_FER_Q	4.30	3.81	31.20	0.784	0.054	14.60	0.422	4.95	0.340	0.638	0.043	0.080
hfs022244	PR_FER_S	4.32	3.68	28.80	0.829	0.068	12.15	0.283	5.96	0.698	0.352	0.046	0.081
hfs022245	PR_FER_T	3.94	3.69	33.80	0.765	0.068	11.23	0.283	5.62	0.463	0.385	0.074	0.083
hfs022246	PR_FER_V	4.36	3.71	23.70	0.723	0.059	12.19	0.283	5.40	0.722	0.344	0.050	0.084
hfs022247	PR_FER_B	3.85	3.46	47.30									
hfs022248	PR_FER_C	4.04	3.55	48.20									
hfs022249	PR_FER_E	4.19	3.67	29.50									
hfs022250	PR_FER_F	4.30	3.78	40.20									
hfs022251	PR_FER_G	4.17	3.69	24.60									
hfs022252	PR_FER_H	4.38	3.80	27.60									
hfs022253	PR_FER_I	4.51	3.76	37.50									
hfs022254	PR_FER_K	4.12	3.59	57.40									
hfs022255	PR_FER_L	4.38	3.77	22.80									
hfs022256	PR_FER_R	4.45	3.75	23.50									

Table 1: Table showing the results from the laboratory soil analysis conducted at the International Institute of Tropical Agriculture of Cameroon. Lab analyses were conducted with the assistance of soil expert Rose Ndango.

Nursery and Planting

After our time in the field, we successfully planted 6 of the 10 species from the nursery. Below, in Figure 2, a map was made by Prince Adiang Bassama, the chief cartographer and field coordinator at the National Forestry School of Cameroon, that shows the distribution of the 6 different species. Figure 3 is a more general map of our restoration site that also shows its location within Cameroon.

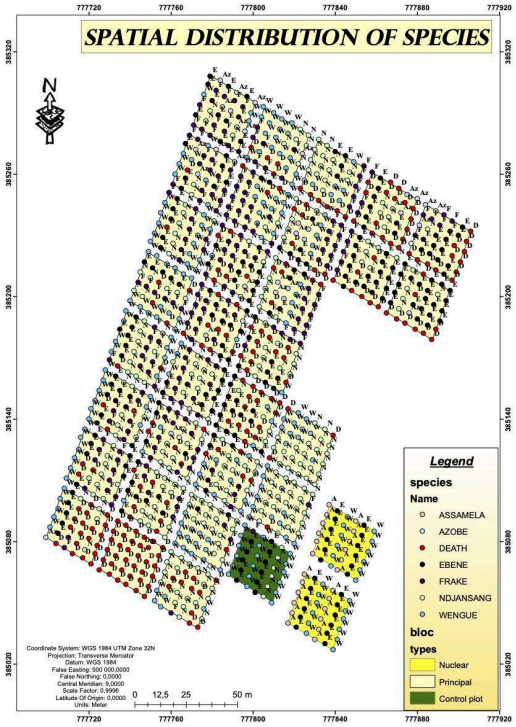

Fig. 2: Restoration Site with Distribution of Plant Species

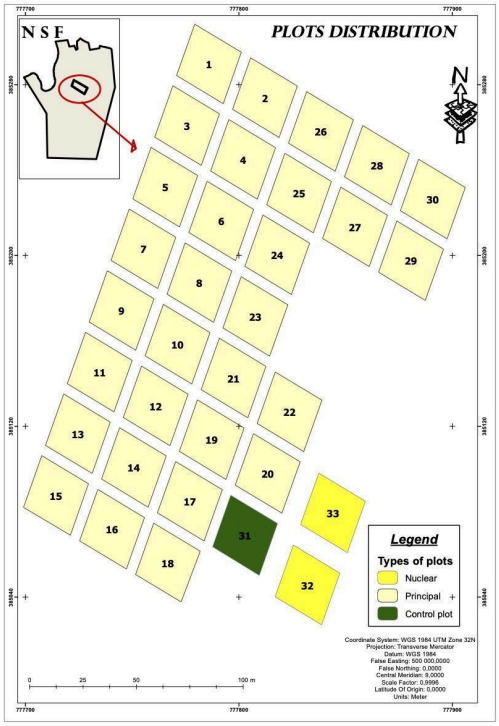

Fig. 3: Restoration Site with Distribution of Plots

Animal Presence

We wanted to understand the presence of small mammals at the site, but an intern of the National Forestry School noted that while rodents are common, they flee human activity, especially in the daytime. While the students had been working, any rodents had vacated the area, but we still witnessed at least three people leaving the forest carrying dead cane rats (*Thryonomys Spp.*). Cane rats are a common source of food for many locals, and it is interesting to note they are abundant enough to be captured daily. Catching them is quite difficult, as the rodents build multiple escape routes of their burrows that people must find and cover. Ultimately, small fires are built to smoke them out, and occasionally these fires are left burning after a hunt. These small fires can be destructive, especially to restoration projects in dry, degraded areas.

With Dr. Njabo's help, we identified 18 bird species. After researching the species, we learned that about two thirds of them are primarily insectivores. Birds relying on insects for their diet are not typically as involved in seed distribution as frugivores, so our findings corroborate that idea that this area is degraded and lacks larger frugivorous birds.

Common Name	***Scientific Name***	**Diet (listed in order of species' preference)**
African jacana	*Actophilornis africana*	Insects
African black duck	*Anas sparsa*	Aquatic plants, insects, crustaceans, fruit
Little greenbul	*Andropadus Virens, Andropadus gracilis*	Fruit, occasional insects
Little green sunbird	*Anthreptes seimundi*	Nectar, insects, ficus seeds
Yellow-spotted barbet	*Buccanodon duchaillui*	Fruits
Klaas's cuckoo	*Chrysococcyx blaas*	Insects
African emerald cuckoo	*Chrysococcyx cupreus*	Insects (caterpillars)
Yellow-throated cuckoo	*Chrysococcyx cupreus*	Insects, occasional fruits
African marsh harrier	*Circus ranivorous*	Small mammals, other vertebrates
Speckled mousebird	*Colius striatus*	Fruits, leaves, nectar
Pied crow	*Corvus albus*	Omnivore: insects, small vertebrates, fruits, carrion, human garbage
Cardinal woodpecker	*Dendropicos fuscescens*	Insects

Common Name	***Scientific Name***	**Diet (listed in order of species' preference)**
Grey woodpecker	*Dendropicos goertae*	Ants, termites, insects, oil palm
Common waxbill	*Estrilda astrild*	Grass seeds, insects
Yellow breasted boubou	*Laniarius atroflavus*	Insects
Yellow longbill	*Macrosphenus flavicans*	Insects, arachnids
Red kite	*Milvus milvus*	Small mammals, carrion, earthworms
Western bluebill	*Spermophagia pustulata* *Spermophagia haematina*	Fruits (berries), grass seeds, oil palm husk

Table 2: Birds identified near the restoration area at the NFS in Mbalmayo.

The bird species identified on the site are majority insectivore species that are small and do not possess the long range seed dispersal capabilities of larger rainforest birds. The short time frame of our study presented limitations; we were only able to survey birds for three days in late March, which may have overlapped with nesting seasons and led us to observe fewer birds. We also noted birds that were identifiable by songs and familiar to Dr. Njabo, so we may have missed some birds' songs and erroneously omitted them from this study. Our results do not claim to be representative of the entire bird community in Mbalmayo's forests; these were merely the birds identified at and around our 2 hectare restoration site. Still, there was a strikingly low number of species for a tropical forest. Most of the bird song was likely greenbulls, which are small and insectivorous.

A 2012 study in the Congo noted most of the trees were zoochorous, but in identifying each tree's seed dispersers, they found them to be mostly mammals, hornbills, and turacos (Beaune et al. 2013). Neither of these avian species were observed at the plantation site. Fragmented landscapes and anthropogenic pressures are likely decreasing hornbill and turaco populations. Moreover, the seed distribution patterns in new growth and restored forests have not been rigorously studied, so it is unclear if the same patterns as old growth forest persist (Babweteera & Brown, 2007). Additionally, much of the surrounding area is designated as community forest and may be used for growing crops and agroforestry; these landscapes cannot support bird communities like mature forests. It is clear to researchers that zoochorous tree species are in danger of declining by up to 80% if seed dispersers continue to disappear from the landscape, whether from hunting or habitat loss (Beaune et al. 2013). With climate change affecting heat, wind patterns, and rainfall, all types of seed dispersing trees are at risk. Animals may be able to ensure the continuation of zoochorous species, but increasing limitations to movements and declining population are reducing the access that animals and plants have to each other. It is imperative that animal presence is prioritized in restoration sites, as their presence correlates with plant diversity and adaptability (Hernandez et al. 2023). Of the species we planted, Assamela and Ebony are zoochorous, while Djansang, Azobe, Frake, are wind or water dispersed. Encouraging mammals to the site would especially benefit these Assamela and Ebony

trees, but it is unlikely to see mammals where there is high human activity. Limiting consistent human presence on the site may encourage more animal recolonization, but that would mean forgoing data collection on the growth of the saplings. Restoration projects must balance these challenges, and we suggest continuing to check up on the trees until they are well established to ensure the forest begins to grow and *then* minimizing people at the site as much as possible.

Local Surveys

Surveys allowed our team to understand the value students at the National Forestry School place on forests. Most mentioned the importance of conserving forests to protect the resources that support the livelihoods of Cameroonians. In the Congo Basin, 80% of people depend on agriculture, fisheries, and livestock for their survival, so forests are of crucial economic importance (Akinwande, 2012). While planting, we saw several locals walking by with wood strapped to their backs. Responses also mentioned forests' role in the preservation of biodiversity, mitigating of climate change, and provisioning of ecosystem services like regulating the climate.

One responder mentioned the political actions which Cameroon has taken, writing that Cameroon has drafted laws and ratified the United Nations Convention to Combat Desertification, the United Nations Framework Convention on Climate Change, and the Convention on Biological Diversity, representing its commitment to mitigating forest destruction. The responder also mentioned that illegal exploitation and poverty counteract these efforts. In Cameroon, one significant contributor to deforestation is the exportation of high-value timber products, which are in high demand in the Global North, especially China and Western Europe. In 2017, Cameroon produced 3.6 million meters of logs with an export value from primary timber processing totaling $933.7 million ("Overview of Timber Sector of Cameroon n.d.).

All of the survey respondents agreed that forest destruction affects local communities in Mbalmayo due to the effects of global warming, increasing scarcity of forest products, and loss of native species. One survey responder mentioned that forests provide essential natural resources such as timber, fruits, medicinal plants, and water resources which local populations depend on. Forest destruction is making such products more rare and expensive, threatening the economic well-being of Cameroonians.

One of the questions also gauged locals' perspectives on who should be responsible for protecting forests. Responders indicated that they believed restoration efforts should be managed by multiple entities, including governments, conservation organizations, local communities, and businesses (including forestry, mining and agricultural industries). Several responders emphasized the need for a collaborative approach that integrates responsibilities of numerous stakeholders. Another question asked what factors the students believe contribute most to forest restoration. Responses included the population boom, bush fires, expansion of agriculture, and unsustainable logging.

To devise strategies for effective long-term monitoring of our restoration project, we also wanted to gauge what factors the NFS students believe lead to failures. Responders mentioned a lack of resources, inadequate planning, and a failure to consider the needs of local populations as some of the main contributors. These responses were supported by conservations we had with the students while planting, as well as direct observations. One of the biggest challenges the NFS faces in regard to restoration is pushback from the local community, who do not understand their efforts or are unaware of how restoration could also benefit them. Near the tree planting sites, we

saw farmed crops like red peppers, as well as fires started by the locals who want to use land set aside for restoration for personal farming. While walking to and from the site, our collaborators sometimes stopped to talk to passing locals to explain our efforts and urge them to not destroy the newly planted saplings.

We also asked students what factors lead to successful restoration efforts. Students explained that successful restoration efforts depend on clearly defining the objectives of the restoration project, involving all stakeholders, and performing effective evaluation and monitoring programs. Many students also mentioned understanding the needs of local communities and sensitizing the local population to the benefits of forest restoration. Additionally, one student mentioned conducting a soil analysis to determine that ecological conditions for promoting plant growth are met. Based on a request from the NFS project managers, our team coordinated an analysis of the plant site soil composition and communicated recommendations to supplement the nutrient levels and decrease the acidity.

Because our team proposed applied nucleation as the most efficient restoration technique, we aimed to understand if the NFS students had familiarity with it. The majority of students said they were familiar with it and mentioned that it involves planting tree patches to accelerate forest habitat restoration, mimics natural succession, and relies on animal species to disperse native tree seeds. However, some students did not have an accurate understanding of the technique. One mentioned that it poses a risk of killing the natural microorganisms of the soil and another said they did not know the term. As a result, we worked to disseminate our research on applied nucleation to the NFS to encourage the adoption of this technique in order to improve the success of future restoration efforts. We also gauged the students' understanding of deforestation's role in climate change. Students explained how trees act as carbon sinks which store carbon dioxide, a greenhouse gas, and prevent it from accumulating in the atmosphere.

Our last question asked about what traditional practices and knowledge are important for sustainably managing forests in Cameroon. We aimed to understand the values of local Cameroonians to ensure cross-cultural understanding and foster respectful collaboration. Students mentioned that natural restoration is the most commonly practiced restoration technique and that traditional practices that are important include rotation of agricultural land, fallowing of fields, agroforestry, creation of fruit tree plantations, and use of compost. One student explained how in the west of the country, indigenous people use sacred forests for sacred rites, such as the enthronement of Kings, and in the east, people use the forest for hunting and gathering as well as to enthrone their leader known as "Kaggen."

Additionally, we created a poster featuring information about why forests are important, the causes of forest destruction, and how local people in Cameroon can help protect forests. More specifically, it explained that forests are important as they provide ecosystem services like oxygen, supply resources like timber and food products, and serve as a habitat for wildlife. It also listed logging and unsustainable agriculture as key causes of deforestation and gave suggestions for how Cameroonians can mitigate deforestation. This includes practices like talking about deforestation with their friends and family, choosing sustainably sourced materials, and farming responsibly. The poster was hung up at the NFS.

References

African Black Duck Facts and Information | United Parks & Resorts. https://seaworld.org/animals/facts/birds/african-black-duck. Accessed 13 June 2024.

"African Marsh-Harrier." *Wildlife of Kenya by Nicolas Urlacher*, http://www.wildlifeofkenya.com/categories/birds-of-prey/harrier-african-marsh/. Accessed 13 June 2024.

"Animals in Cameroon." *A-Z Animals*, https://a-z-animals.com/animals/location/africa/cameroon/. Accessed 30 Apr. 2024.

Babweteera, Fred, and Nick Brown. "Can Remnant Frugivore Species Effectively Disperse Tree Seeds in Secondary Tropical Rain Forests?" *Biodiversity and Conservation*, vol. 18, no. 6, June 2009, pp. 1611–27. *Springer Link*, https://doi.org/10.1007/s10531-008-9546-6.

Beaune, David, et al. "Seed Dispersal Strategies and the Threat of Defaunation in a Congo Forest." *Biodiversity and Conservation*, vol. 22, no. 1, Jan. 2013, pp. 225–38. *Springer Link*, https://doi.org/10.1007/s10531-012-0416-x.

Cations and Cation Exchange Capacity - Qld | Fact Sheets | Soilquality.Org.Au. https://www.soilquality.org.au/factsheets/h1-cations-and-cation-exchange-capacity-queensland. Accessed 13 June 2024.

Cheke, Robert, and Clive Mann. "Little Green Sunbird (Anthreptes Seimundi), Version 1.0." *Birds of the World*, 2020. *birdsoftheworld.org*, https://doi.org/10.2173/bow.ligsun2.01species_shared.bow.project_name.

Chrysococcyx Klaas (Klaas's Cuckoo). https://www.biodiversityexplorer.info/birds/cuculidae/chrysococcyx_klaas.htm. Accessed 13 June 2024.

Clark, C. J., et al. "The Role of Arboreal Seed Dispersal Groups on the Seed Rain of a Lowland Tropical Forest1." *Biotropica*, vol. 33, no. 4, 2001, pp. 606–20. *Wiley Online Library*, https://doi.org/10.1111/j.1744-7429.2001.tb00219.x.

Dirzo, Rodolfo, et al. "Size-Related Differential Seed Predation in a Heavily Defaunated Neotropical Rain Forest." *Biotropica*, vol. 39, no. 3, 2007, pp. 355–62. *JSTOR*, https://www.jstor.org/stable/30044948.

Ecology of Seed Dispersal. https://www.annualreviews.org/docserver/fulltext/ecolsys/13/1/annurev.es.13.110182.001221.pdf?expires=1718348150&id=id&accname=ar-229710&checksum=18A411806476A655B7DC1583635B02F8. Accessed 14 June 2024.

Effiom, Edu O., et al. "Bushmeat Hunting Changes Regeneration of African Rainforests."

Proceedings: Biological Sciences, vol. 280, no. 1759, 2013, pp. 1–8. *JSTOR*, https://www.jstor.org/stable/23478571.

Fishpool, Lincoln, and Joseph A. Tobias. "Little Greenbul (Eurillas Virens), Version 1.0." *Birds of the World*, 2020. *birdsoftheworld.org*, https://doi.org/10.2173/bow.litgre2.01species_shared.bow.project_name.

Gatica-Saavedra, P., Aburto, F., Rojas, P. and Echeverría, C. (2023), Soil health indicators for monitoring forest ecological restoration: a critical review. Restor Ecol, 31: e13836. https://doi.org/10.1111/rec.13836.

Giuggioli, Luca, et al. "Stigmergy, Collective Actions, and Animal Social Spacing." *Proceedings of the National Academy of Sciences*, vol. 110, no. 42, Oct. 2013, pp. 16904–09. *pnas.org (Atypon)*, https://doi.org/10.1073/pnas.1307071110.

Hatten, Jeff, and Garrett Liles. "Chapter 15 - A 'Healthy' Balance – The Role of Physical and Chemical Properties in Maintaining Forest Soil Function in a Changing World." *Developments in Soil Science*, edited by Matt Busse et al., vol. 36, Elsevier, 2019, pp. 373–96. *ScienceDirect*, https://doi.org/10.1016/B978-0-444-63998-1.00015-X.

Henry F. Howe and Judith Smallwood. *Ecology of Seed Dispersal | Annual Reviews*. 1982, https://www.annualreviews.org/content/journals/10.1146/annurev.es.13.110182.001221.

Herbivores and the Number of Tree Species in Tropical Forests - University of California Los Angeles. https://search.library.ucla.edu. Accessed 14 June 2024.

Hernandez, Jonathan O., et al. "How Does Changing Environment Influence Plant Seed Movements as Populations of Dispersal Vectors Decline?" *Plants*, vol. 12, no. 7, Mar. 2023, p. 1462. *PubMed Central*, https://doi.org/10.3390/plants12071462.

Howe, Henry F., and Maria N. Miriti. "No Question: Seed Dispersal Matters." *Trends in Ecology & Evolution*, vol. 15, no. 11, Nov. 2000, pp. 434–36. *ScienceDirect*, https://doi.org/10.1016/S0169-5347(00)01965-0.

Janzen, Daniel H. "Herbivores and the Number of Tree Species in Tropical Forests." *The American Naturalist*, vol. 104, no. 940, 1970, pp. 501–28. *JSTOR*, https://www.jstor.org/stable/2459010.

"Jill J. Tan." *Tumblr*, https://jilljtan.com/post/181156848549/allochory-allochory-refers-to-seed-dispersal. Accessed 14 June 2024.

Kome, Georges Kogge, et al. "Soil Organic Carbon Distribution in a Humid Tropical Plain of Cameroon: Interrelationships with Soil Properties." *Applied and Environmental Soil Science*, vol. 2021, no. 1, 2021, p. 6052513. *Wiley Online Library*, https://doi.org/10.1155/2021/6052513.

Lasota, Jarosław et al. "Effect of dolomite fertilization on nutritional status of seedlings and soil properties in forest nursery." Soil Science Annual, vol. 72, no. 1, 2021, 132236. doi:10.37501/soilsa/132236.

Ministère Des Forêts Et De La Faune| Accueil. https://www.minfof.cm/. Accessed 30 Apr. 2024.

Mkhonza, N. P., et al. "Effects of Lime Application on Nitrogen and Phosphorus Availability in Humic Soils." *Scientific Reports*, vol. 10, no. 1, May 2020, p. 8634. *www.nature.com*, https://doi.org/10.1038/s41598-020-65501-3.

Oakland Zoo | Pied Crow. https://www.oaklandzoo.org/animals/pied-crow. Accessed 13 June 2024.

Parc de La Méfou Cameroun. Directed by jaimelevoyage aventure, 2013. *YouTube*, https://www.youtube.com/watch?v=kX9K-RNmHdU.

Payne, Robert B. "Yellow-Throated Cuckoo (Chrysococcyx Flavigularis), Version 1.0." *Birds of the World*, 2020. *birdsoftheworld.org*, https://doi.org/10.2173/bow.yetcuc1.01species_shared.bow.project_name.

Payne, Robert B., and Peter F. D. Boesman. "African Emerald Cuckoo (Chrysococcyx Cupreus), Version 1.1." *Birds of the World*, 2021. *birdsoftheworld.org*, https://doi.org/10.2173/bow.afecuc1.01.1species_shared.bow.project_name.

"*Pericopsis Elata*." *Wikipedia*, 31 Mar. 2023. *Wikipedia*, https://en.wikipedia.org/w/index.php?title=Pericopsis_elata&oldid=1147534352.

"Red Kite." *British Bird Of Prey Centre Wales*, https://www.britishbirdofpreycentre.co.uk/our-birds/red-kite/. Accessed 13 June 2024.

Shengwei Shi, Wen Zhang, Ping Zhang, Yongqiang Yu, Fan Ding, A synthesis of change in deep soil organic carbon stores with afforestation of agricultural soils, Forest Ecology and Management, Volume 296, 2013, Pages 53-63, ISSN 0378-1127, https://doi.org/10.1016/j.foreco.2013.01.026.

Short, Lester L., et al. "Yellow-Spotted Barbet (Buccanodon Duchaillui), Version 1.1." *Birds of the World*, 2023. *birdsoftheworld.org*, https://doi.org/10.2173/bow.yesbar1.01.1species_shared.bow.project_name.

Winkler, Hans, and David Christie. "African Gray Woodpecker (Dendropicos Goertae), Version 1.1." *Birds of the World*, 2023. *birdsoftheworld.org*, https://doi.org/10.2173/bow.grywoo1.01.1species_shared.bow.project_name.

Zhong, Yangquanwei, et al. "Soil Organic Carbon, Nitrogen, and Phosphorus Levels and Stocks After Long-Term Nitrogen Fertilization." *CLEAN – Soil, Air, Water*, vol. 43, no. 11, 2015, pp. 1538–46. *Wiley Online Library*, https://doi.org/10.1002/clen.201400872.