The Ebony Project

Expanding Agroforestry Value Chains and Surveying Technology to Improve Reforestation Efforts in Cameroon

Final Report

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Abstract

The Ebony Project is a partnership between Taylor Guitars, local Cameroonian communities, researchers of the Congo Basin Institute (CBI) and the Higher Institute of Environmental Sciences (HIES), to preserve the iconic hardwood species West African Ebony. Now in its fourth year, our team addresses how The Ebony Project fits into broader efforts to conserve tropical rainforests. Prior Practicum teams have focused on ebony itself, looking at legal classifications, species range, and other high-value timber species. We focused on answering three distinct questions: 1) are there proven successful strategies to avoiding tropical deforestation and how does The Ebony Project's approach compare to successful and unsuccessful techniques, 2) what would a successful value chain for the co-cropped fruits look like, and, 3) would technology improve the process of recording tree planting and obtaining land tenure? Although there are three distinct questions, Figure 1 demonstrates areas of overlap between the three research topics. Over the course of nine months, we have made some considerable progress through literature reviews, expert interviews, and remote field simulations. Our research culminated in deliverables that include an updated literature review of successful and unsuccessful reforestation techniques accompanied with recommendations for the project based on our findings. Research on how to add value to agricultural crops lead to recommendations for a detailed value chain model for the co-crops, djansang and avocado, used in the project. Lastly, a software recommendation to improve land tenure documentation. Our research on both technology and reforestation will allow productive value chains to supplement ebony growth, essential for the longevity of the Ebony Project.

Key Takeaways

1.

Introduction

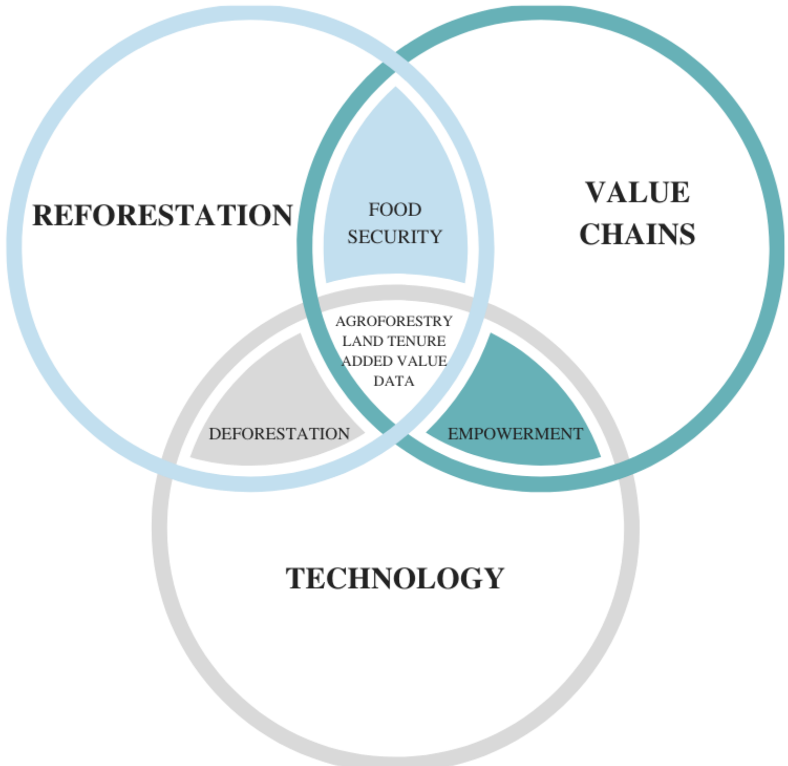

Figure 1: The intersection and overlap of concepts introduced by reforestation efforts, value chains, and survey technology.

The Congo Basin is one of the world's largest tropical forests, yet it has been grossly exploited and is in danger of mass agricultural conversion from palm oil and rubber developers in the upcoming years (Greenpeace, n.d.). Mainly, however, the most constant cause of deforestation, at a rate of about 250,000 to 300,000 hectares per year, is due to small-scale agriculture and fuel wood gathering (EU, 2014). When the Ebony Project began four years ago, there was a dearth of information on the ecology and preservation of West African ebony (*Diospyros crassiflora*) beyond knowing this exotic hardwood species takes 80-200 years to reach maturity. The Ebony Project was developed in partnership with Taylor Guitars, CBI, and UCLA's Institute of Environment and Sustainability to combat this decline. This year's practicum team focused on developing an optimized methodology for reforestation, creating models for the implementation of successful value chains, and updating our technological bandwidth of data collection and storage.

The 2019-2020 practicum addressed the community impact the project had in local villages by focusing on developing value for co-crops that could better support both nutrition and local economies. We assessed environmental needs for future growth and explored opportunities for improvement in land ownership and community relations. Unfortunately, due to COVID-19, we were unable to travel to our field sites to collect data. Because of this, our research and results were based heavily on comprehensive literature reviews, expert interviews, and market analyses. Ultimately, this year's project aimed to work towards securing land tenure and economic value by establishing comprehensive value chains as well as a technological footprint of land planting and care. Our client, Taylor Guitars, decided to balance community engagement with economic viability in hopes of expanding their business model; by maintaining logging and processing operations within the country, this project enables Cameroonians to benefit more from ebony harvesting, thereby bettering the livelihoods of participants and their families. On a larger scale, Taylor Guitars, in conjunction with other major stakeholders, is performing one of the first forward facing and sustainable business models in both the country of Cameroon and the entire music industry (The Ebony Project, 2018).

The Ebony Project Summary

The Ebony Project is a privately run reforestation project that is fully funded by Bob Taylor, the CEO of Taylor Guitars and co-owner of the Yaounde-based ebony mill, Crelicam. The project utilizes an agroforestry approach (explained below) to reforestation. Before the project begins, project coordinators conduct a village meeting that explains the end goals and allows the villagers themselves to choose whether they want to proceed. The community members decide amongst themselves their own roles within the project such as working the nursery or planting trees. The coordinators then provide the building materials for nurseries and train the community members on how to construct and manage the nursery. This approach allows the community to take control of the project, with the outside aid being in forms of education and financial support.

Deforestation

Tropical rainforests endure the constant threat of three human lead activities: forest fragmentation, forest degradation, and deforestation (Laurance, 1999). Forest fragmentation occurs when human activity such as the creation of roads or pasture land breaks up a forest, while forest degradation occurs when a forest can no longer function well and its ecosystem services halt (Snyder, 2014; IUCN, 2017). Unlike forest fragmentation and degradation, deforestation differs by turning once forested land into permanent non-forest land used for human activities such as agriculture, resource extraction, or urban development (van Kooten and Bulte, 2000). Drivers of deforestation and reforestation limitations vary depending on the location, economy, and ways of life. Agents of deforestation can vary from slash and burn farmers, commercial farmers, ranchers, loggers, firewood collectors, infra-structure developers, and others who are cutting down the forests. The actual causes are the forces that motivate the agents to clear the forests (Chakravarty et al., 2012). However, deforestation is typically driven by multiple drivers that can be difficult to pinpoint. In a study done by Kinari Webb, they discovered that 100% of those that were logging illegally wanted to quit but could not because they needed to support their families. This example shows the complexity of deforestation drivers and the need to understand the specific causes of deforestation in each area.

To address the threat of deforestation, the United Nations Framework Convention on Climate Change created the “Reducing Emissions from Deforestation and forest Degradation, and the role of conservation, sustainable forest management, and enhancement of forest carbon stocks,” more commonly known as REDD+ (Mbatu, 2016). REDD+ is designed to provide financial incentives to developing countries that reduce their carbon emissions associated with deforestation and forest degradation while improving their carbon stocks.

Agroforestry and Tree Ownership

Agroforestry can be defined as the integration of trees and crop systems which may lead to agriculture, influencing social, environmental, and monetary gains (USDA, 2020). It creates a basis for pairing reforestation with agricultural crops in order to gain both sociocultural and ecological benefits. The combination of trees and farms can lead to reduced environmental degradation, carbon sequestration, and healthy soil, while also promoting stable incomes and wellness (Brown et al., 2018). It is important to educate communities on the opportunity to produce non-timber forest products (NTFPs) such as fruit that can be grown without clearing the land. Furthermore, the ability to produce productive fruit or other species can provide low income communities with nutritional security that may not be able to be matched by timber plots. The cumulative social, environmental, and economic benefits generated through agroforestry are demonstrated in Appendix B.1 by Brown et al., 2018.

Forest areas in Cameroon are divided into two categories: non-permanent and permanent forest areas, both of which are owned by the state. Non-permanent areas are owned by the state, where people living in forest areas typically do not retain their full, traditional user rights. As a result, disputes over forest ownership and the demarcation of boundaries have been prevalent in the past and remain so today (ETTF, 2018). Recognition of such enjoyment rights and ownership began under the 1994 Forest Law, where community forest areas and decentralized taxation were introduced. This corresponds to the management for forest areas and resources that was put in place for the benefit of the populations (Forest Peoples Programme, 2009).

Food Security

Food security exists in society when all people have proper economic assets and access to nutrient dense foods. When available food supports a healthy, active lifestyle for the members of society, then a region is said to be food secure. The Food and Agricultural Organization of the United Nations (FAO) notes that food security includes food availability, access and utilization, and stability. There are various pathways one could take to be considered food secure; some of which include: focusing on sustainable agriculture growth, addressing root issues of poverty, and opening a dialogue between stakeholders and the community for food security initiatives and goals (FAO, 2006).

The United States Agency for International Development (USAID) approximates 2.6 million people within Cameroon are currently food insecure. This is due, in large part, to heavy violence, limited agriculture, and conditions leading to displacement in certain regions. International aid organizations such as USAID continue to classify food insecurity in these regions in order to understand emergency assistance which may be necessary to meet basic needs (USAID, 2020).

Added Value and Value Chain

Valuation is subjective and is often determined by end consumer preference. To reduce subjectivity, a metric of added value assesses the contribution of actors, costs, and benefits of acquiring final products or services (FAO, 2004). A market system is only as good as the sum of its parts. Therefore, the total value of any given market system is given by the sum of valuations at each step of the value chain.

A value chain refers to the processes, inputs, and transactions between initial production and final consumption in a commodity or consumer market (Attaie, H., & Fourcadet, O., 2003).

Value chains can look at one phase, or consider a full life cycle analysis of a product. The general value chain analysis model consists of a framework that includes four stages: birth, expansion, efficiency, and self renewal. As the value chain progresses through phases, net profit generated by the commodity crop should increase (see Appendix B.3). Primary, foundational actions include production and logistics whereas secondary roles consist of improved infrastructure as well as any other addition to the base value chain (Attaie, H., & Fourcadet, O., 2003). It is important to keep track of limitations to added value. Limitations often exist in the form of low market power, limited infrastructure, and low access secure markets (Neven, FAO, 2014).

Added value takes into account the perception of value from all actors rather than focusing solely on the end-user (Chermatony et al., 2000). To gain the most added value, marginal benefits should increase as the value chain progresses. These benefits may lead to short term costs in production, but yield benefits later on. Differentiating a specific product between producers is vital to have a sustainable value chain (Aaron French, 2020). According to Chermatony et al., added value could also be interpreted as the ability to charge higher prices. The goal of each actor should be to add more value than the cost of acquiring the product. In a market of consumer choice, it is important to differentiate an export; in our case, we had to differentiate Cameroonian avocado from Mexican avocado to persuade the consumer that our product was preferential. Differentiation fuels competition in the international market where consumers have two things in mind: the best quality for the best price.

The Ebony Project Silvicultural Booklet

Silviculture refers to the practice of maintaining forest growth, structure, and composition to control and enhance the utility of a forest area for any purpose (DNR, 2003). Currently, a paper-based draft Silvicultural Booklet is available for farmers and field researchers involved with the Ebony Project, where it provides details on the documentation and management of ebony trees. It is intended to record the planting of trees in an effort to aid the documentation for farmers and thus the possible ownership of land. The planting of ebony and fruit trees are recorded, as is ebony tree growth. The team labels 20 trees per plot each year, and records the GPS coordinates of the plot edge to calculate the surface of the plot. The team does not take coordinates for each tree because they are planted 5 meters apart and the accuracy of the GPS is only around 15 meters (Deblauwe, 2020). All data is collected by the CBI staff during planting and entered into a computer back in Yaoundé, Cameroon.

Data and Mobile Technology

Data gathering is very important for field research. Pen-and-paper approaches are often very time-consuming, and may present challenges with accessing materials at remote locations, facilitating enough survey participants, and transcribing and transferring data correctly (Mourão et al., 2010). A suitable tool could bridge the gap between technology solutions and remote rural fieldwork. This can be an issue when considering software which requires internet access or online functionalities.

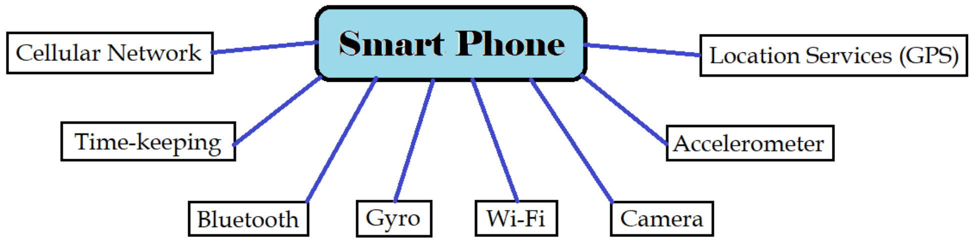

Figure 2: Essential sensors and functions on a smartphone device.

The rapid growth of the cell phone industry is associated with recent economic growth in the agricultural sector in Cameroon (Aker et al., 2010). Mobile phone and wireless technologies have the potential to perform adequately in field research settings, especially when wireless networks allow access to telecommunications in a region with fixed, limited lines (Tomlinson et al., 2009). In Africa, mobile users account for 83 percent of telephone subscribers, a higher proportion than any other region in the world (Tomlinson et al., 2009). The use of mobile phones is widespread even in remote areas of rural Cameroon with increasing numbers of people having access to the cell network. Field data collection with a mobile phone has the potential to drastically enhance any service that relies on accurate and up-to-date information, including geographical location information, emergency response services, as well as time-sensitive spatial data that can only be recorded remotely (Mourão et al., 2010). The use of several in-device functions such as the camera, QWERTY keyboard, and GPS network capabilities significantly improves user experience while accessing and inputting relevant data, as shown in Figure 2 (Mourão et al., 2010). As a result, mobile phones and smart devices can be an effective and cost-effective method to gather such data.

Open Data Kit (ODK): A Mobile Surveying Tool

The Open Data Kit project was created to develop a suite of software tools that helps individuals and organizations record, collect, and manage data remotely (ODK, 2020). The goals of the project are to make open-source and standards-based tools that are easy to try, use, modify, and scale (ODK, 2020). It utilizes a server as its central component in data management, allowing for survey distribution among mobile devices, consolidation of results, and the general administration for data values (Mourão et al., 2010). Open Data Kit began as a Google.org sponsored project, with an initial team that included a selection of dedicated developers as well as University of Washington (UW) graduate students. Two deployments of the tools were piloted and tested in Uganda and Brazil, which proved to be very effective. This led to an increasing number of engineers and programmers for the project as each year brought newer and more advanced technology to the global market. In late 2016, the project began a transition out of UW, and is now supported by a growing community of users, implementers, and developers (ODK, 2020). Over the years, Open Data Kit has been supported by many different organizations, including WHO in Nigeria, the Red Cross, and even the Centers for Disease Control and Prevention. The use of "open data" through open information visibility is highly coveted for all involved stakeholders, especially in resource-constrained environments.

Since the application of ODK relies on further collaborative work, the resulting product development is very much demand-driven. There is an active community forum, where users can report bugs, request new features, and even directly ask the developers and ODK community about certain issues. ODK is also deployed as a collection of GitHub repositories where everyone can access under the OpenSource License. New features, update releases and bug fixes for the product are then announced to the ODK community by the standard interface of the GitHub repository or from the original Open Data Kit website. As a result, Open Data Kit is maintained regularly by an active community, allowing for consistent upkeep and maintenance for field data collection as technology and the environment advances in conjunction day by day. Open Data Kit is not tied to any one organization or business, and this helps to mitigate software discontinuation risks.

Methodology

All interviews were conducted via video calls with industry experts in ecology, economics and technology (see Table 8 in Appendix for more details on experts interviewed). We attempted to reach out to additional contacts from the INVEST software, a geographical positioning system (GPS) aimed at mapping regions and their specified yields; unfortunately, they were unable to help us due to training impacts related to COVID-19. We believe that further research into the use of INVEST may be able to benefit the Ebony Project in the future.

Reforestation and Tropical Fruit Value Chains

We conducted an in depth review of global reforestation projects and evaluated their reforestation strategies. We utilized the search engine, Google Scholar, to review a total of 35 scholarly articles and grey literature pertaining to both successful and unsuccessful reforestation projects and methods to combat deforestation. We employed different criteria to find our specified literature, mainly sourced from “successful (or unsuccessful) reforestation projects” and “successful (or unsuccessful) methods to combat deforestation”. To record and collect our data, we constructed an Excel spreadsheet with columns indicating year, location, method to combat deforestation, noted successes and failures, factors that contribute to deforestation, and recommendations. Additionally, we conducted interviews with several experts in the field of reforestation. Because West African Ebony is a slow growing species, we had to brainstorm how to best make the project valuable for the local communities in the short term.

For the development of value chains of ebony trees and its co-cropped fruits, we searched the literature for information on the formation of agroecology value chains that could serve as a model to the development of our project. Specifically, we focused on case studies involved in the agroecology of developing nations, indigenous regions, and those which centered around the same crop species as our observed fruiting trees: avocado, djangsang, and bush mango. We then documented observed successful structures, actors, and processes into the project’s planted species and community structure. Our sources included literature, industry experts, professors, educational videos, and personal interviews. We qualitatively combined this data to create our value chains. We created a detailed value chain model by analyzing currently planted species within the project to understand how to both assess value and assign modes of importance to our actors. The current species count, shown in Figure 3, will be used to project the future of the value chains for the Ebony Project. Current plant count may be able to allow us to recommend which market is appropriate given the current state of the project. By identifying sources of value and applying it to mock value chains for both avocado and djangsang, we generated a theoretical model for the added value of both fruit trees and medicinal plants. We also designed a nutritional guide for the community and an estimation of economic and ecological gains from successful value chains.

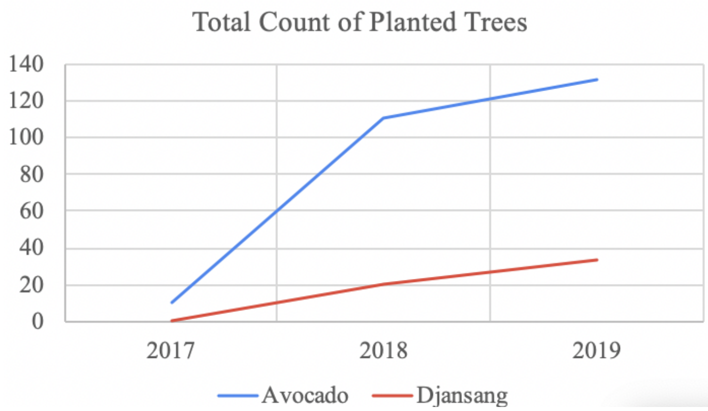

Figure 3: Fruit trees transplanted to the field at the time of writing (Count from: *Deblauwe et al.*, 2019).

Incorporating Technology into the Silvicultural Booklet

This research question involves the use of technology to digitize the Silvicultural Booklet, in an effort to better support local farmers' property right claims and improve the project's data management. Since only the state of Cameroon can grant land rights, the Ebony Project seeks to document the planting of ebony trees in order to track project objectives and to give the local farmers concrete evidence for their planted trees. This will hopefully help farmers obtain ownership rights from the state, but is not guaranteed (Zaunbrecher, 2020). Additionally, as we aim to incentivize the cultivation and maintenance of ebony trees during its long maturity period, providing digital evidence for planted trees is helpful to not only the survival of the trees themselves, but the success of the project in the long run.

In order to do this, we focused on the needs of the Ebony Project field research team in order to make their process of recording, collecting, and analyzing data more simple and efficient. We assessed relevant academic papers and interviewed specific experts and researchers in their field to assess incorporating technology into the Silvicultural Booklet. We also analyzed the viability of using technological surveying tools to address issues surrounding forest ownership and property rights, as well as an online cloud platform to store all relevant data and information securely. We assessed a key surveying tool, Open Data Kit (ODK), that can be easily accessed and allows for manageable data collection on the field in Cameroon, as well as other alternatives such as KoBoToolbox and Google Forms. We evaluated the tools against specific metrics (see Appendix C.3), including free and offline access, user-friendly interfaces, secure and private support, and quality control.

We performed mock field tests with a smart device from our own homes and the surrounding environment. We employed a previously-used Sony Xperia V5 which supported ODK Collect, the main data collecting application for Open Data Kit. We then conducted two full tests on the smart device, once with an internet connection and once without. All the necessary tools were downloaded and tested on our computer systems, including generating and designing surveys, importing all relevant field data from the device into the computer, and exporting such data into a storage platform on Google Drive. Additionally, we opted to run an online emulator that simulates an Android operating system from our computers to confirm our tests. This provided additional feedback close to the originally planned investigations in

Cameroon, allowing us to experience the applications and tools (despite not being in the desired location) more reliably and accurately. All findings and collected data, including raw numbers, edited forms, and unexpected error reports were stored on the Ebony Project Google Drive. They were then compiled and sorted on a document, and analyzed using comparison tables and screenshots captured on the smart device and emulator.

Results

Tropical Deforestation and Reforestation

Through our literature review, we were able to create a list of successful and unsuccessful methods to avoid deforestation and influence reforestation. An outline of these methods, as well as the current Ebony Project approach, can be seen in Table 1 below. Our results below reflect our literature review with further explanation.

Table 1: Documented successful and unsuccessful methods to combat tropical deforestation.

METHODS TO COMBAT DEFORESTATION

SUCCESSFUL METHODS	THE EBONY PROJECT	UNSUCCESSFUL METHODS
Ecological • Landscape heterogeneity and biological diversity • Managed selective logging • Proper land preparation • Address underlying causes of forest loss and degradation • Agroforestry **Social** • Enhance and diversify local livelihoods • Socio-economic incentives • Address underlying causes of forest loss and degradation • Secure land tenure • Long-term management planning • Strong local leadership **Governmental** • Protected Areas • Indigenous Lands	**Ecological** • Agroforestry model • Village nurseries **Social** • Locals are provided with a fruit tree as a form of incentive • Locals are paid for surviving ebony trees • Community led • Locals decide amongst themselves who will participate in the project and what jobs they will have • Silvicultural booklet for land tenure **Funding** • Privately run • Fully funded by Bob Taylor	**Ecological** • Lack of successful seed banks • Unsuitable species selection • Grazing livestock • Unsuitable planting locations • Scarcity of water • Roads **Technical** • Weak program management • Scarcity of leadership • No long term planning • Lack of incentives for locals • Existing cultures and lifestyles of the communities not considered • Limited population or stakeholder participation • Lack of funding **Governmental** • Dated policies • Corruption

Ecological

Research has shown the importance of taking into account the ecological needs of a given area to increase reforestation success. Increasing biological diversity of the landscape improves the ability of the forest and surrounding area to regenerate to a productive ecosystem (Brancalion et al., 2017). A heterogeneous ecosystem provides more ecological niches and space for a variety of flora and fauna (Brancalion and Chazdon, 2017). When reforesting, using seeds from local seed banks increases the chance of sapling survival as the genetics have evolved to handle the specific climate. In many tropical environments, forest recovery is hindered by aspects related to seed viability and seed banks. Because the window of viability for tropical forest seeds tends to be incredibly short, a lack of proper seed dispersal often limits the recovery of a forest during reforestation projects (Holl, 2002). It is critical to take into account seed placement and dispersal when attempting to reforest any given area. In many reforestation programs, the exact time frame in which tree seeds are required to germinate varies from region to region and species to species.

In addition, the type of tree planted plays a large role in the success of programs. Planting native species is crucial to having a successful long-lasting forest because surrounding flora and fauna have evolved to compete and survive around each other. Introducing an invasive species can severely disrupt the ecosystem and, in some cases, lead to further degradation (Piotto et al., 2003). Unsuitable species selection often results in a lack of successful growth in young trees which ultimately hinders the progression of programs (Trac et. al.,2007). This can be due to ecological mismatches or shortcomings within the project such as a lack of capacity or knowledge to successfully manage the trees (Piotto et al., 2003). It is also important to include species that "can fulfill the demands of local people and the ability of the forest to support local livelihoods"' (Le et al., 2013). This can be accomplished by incorporating agroforestry and including outputs such as fuelwood, increased nutrition, and food security (Thatcher et al., 1996). Agroforestry can increase biodiversity and local subsistence while maintaining the ecosystem, especially when compared to a monocrop. It is also important to manage sustainable selective logging in an agroforestry model to stay within the renewable capacity of the forest (Johns, 1985). Using a system to track which trees have been removed has the potential to improve management and keep a record for high-quality seedlings.

Furthermore, taking into account proper land preparation and weed management when managing a reforestation project can increase success. Assessing and managing the soil quality prior to planting, in conjunction with proper spacing and positioning on slopes, increases sapling survival (Zhang et al., 2002). Weed management gives desired saplings an increased chance at survival as they are not outcompeted (Le et al., 2013). Mimicking nature and working on bringing the ecosystem back to a prospering and diverse state allows for long term success and an increase in livelihoods beyond the environment. As reforestation projects tend to occur in rural communities, the presence of livestock can hinder the success of a project. Livestock grazing on reforested land can damage newly planted trees, endangering tree survival rates (Trac et al., 2007). The same study also found that tree survival decreases when the land used had not been previously forested (Trac et. al.,2007). The scarcity and availability of water around reforestation projects was another limitation to success (Epule et al., 2014). In addition to the lack of water, many conservationists have also highlighted the detrimental impact roads have on deforestation. Roads create easy access to rainforests that are otherwise incredibly difficult to navigate. One study recorded that "nearly 95% of all deforestation occurred within 5.5 km of roads or 1 km of rivers" (Barber et al., 2014). These ecological attributes showcase the need for a prior understanding of project sites to ensure a successful program.

Social/Technical

Many studies have found that the most stable and successful projects are those that include local people and take social factors into account. Each region has its own respective drivers of deforestation that typically stem from the economic interests of local populations (Webb, 2016). One way to include local communities in reforestation projects is to enhance and diversify local livelihoods (Le et al., 2013). This can be done by providing other sources of income derived from agroforestry, managing reforestation, value chains, etc. The specific needs of each region will vary, requiring stakeholders to take time to assess, speak to, and include the community. Understanding and addressing the root causes of why deforestation is happening while providing alternatives creates space for long term success (Le et al., 2013). It is also important to provide socio-economic incentives greater than what they were receiving from the forest; otherwise, deforestation will continue. This can be done by increasing local income, job opportunities, compensation, food security, and local empowerment (Le et al., 2012; Le et al., 2013). Local communities are unlikely to take part in reforestation projects if they are not beneficial, rendering the efforts futile. When projects are not designed to provide medium and long term utility, participants often take actions that provide the highest utility, which translates into cutting down the reforested trees for fuelwood or other uses (App, 2004). Hence, projects that do not provide stable incentives for initial and future care of the project will ultimately result in failure (Trac et al., 2007). The existing cultures and lifestyles of participating communities should be incorporated into the project goals to increase the likelihood of long term success (Trac et al., 2007; Coca, 2018).

Additionally, increased land tenure and property rights of the local people strengthen the success of a project because "land users are only likely to participate in reforestation if they or their families will benefit" which is influenced by secure land tenure (Le et al., 2012). The accumulation of land tenure may also lead to less conflict and a sense of pride and responsibility for the land. Furthermore, moving towards providing payments for ecosystem services will better help secure future income (Burivaloca et al., 2019). Ecosystem services can be defined as "the benefits people derive from ecosystems" and can be better monitored with proper land tenure and property rights (IUCN, 2016). This can also provide more incentive to save forests.

The inclusion of the local people in management has proven to be successful in the long term. Spreading leadership throughout the affected region allows for greater participation and thus a higher chance that the project will be long-lasting (Le et al., 2012). Programs with weak and absent management practices often lack the capacity to successfully achieve project goals (Trac et al., 2007). Strong leadership is also a key factor that determines the success of a project. Weak leadership can quickly lead to issues within these complex projects due to confusion on both management and participant levels (Epule et al., 2014). Denis Sonwa highlighted the need to include youth in management and leadership to help increase education, creativity, long term management, and local pride (Sonwa, 2020). Youth participation is important to ensure that the project may be able to sustain itself even when the initial stakeholders are not present. Youth involvement in the project can be improved by providing proper education, holding open meetings, and including the entire community from the start. Upholding rules and consequences by creating a network of accountability within the community rather than from a foreign entity improves management. The local people also provide a plethora of valuable knowledge on ecosystems and the community that enhances reforestation for such projects.

Many studies have highlighted the need for long term planning and management. Long term goals and leadership can allow the projects to continue in perpetuity. Projects that have cultivated long-term protection of reforested sites have been able to maintain the land better than the alternatives (Le et al., 2012; Le et al., 2013; App, 2004). The absence of long term planning for projects, which includes plans for maintenance, protection, and payments for the local communities or peoples implementing the project, can be detrimental for the longevity of reforestation projects (Le et al., 2012). Reforestation projects that are managed fully by the local people can also create a clearer path of funding beyond the beginning stages with stakeholders. Local communities implementing the programs, often termed "participants," join reforestation projects when participating has greater utility than not participating (Thacher et al., 1996). Additionally, projects with limited participation of local populations and stakeholders affect the success of a project (Epule et al., 2014). Due to the often large incurred costs associated with reforestation projects, a lack of adequate funding greatly reduces the likelihood of success (Horstman, 2017).

Lastly, REDD+ programs also experience limitations with regard to project planning and execution. Early REDD criticism heavily focused on the lack of indigenous people participation and local community integration in projects, with many projects lacking transparency and not placing issues of land tenure, customary rights, and benefit-sharing at the forefront (Freudenthal et al., 2011). For REDD+ to be effective at combating deforestation, progress must be made to accelerate the programs while ensuring that the indigenous peoples, local communities, and stakeholders are adequately involved in every step of the process. Proper project planning must address the livelihood of the local community while ensuring a strong management program with a clear path moving forward.

Governmental

Globally, creating clearly-defined boundaries through protected areas (PAs) and indigenous lands has decreased deforestation levels. Protected areas, as defined by the International Union for Conservation of Nature (IUCN), are "clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long term conservation of nature with associated ecosystem services and cultural values" (IUCN Definition, 2008). PAs have been exceptionally successful in the Amazon, with research showing that "97% of protected areas experienced less land clearing than did a surrounding 10 km belt" (Clark et al., 2008). Unfortunately, protected areas do not always see the same level of success as shown in the Amazon. Corruption, lack of funding for proper and long-lasting protection, and a lack of resources to properly monitor the forest often weaken the success of PAs (Nolte et al., 2013; Clark et al., 2008; Chakravarty et al., 2012). In addition, PAs do not take into account the local indigenous land rights or the needs of the local people. Although there are caveats to PAs, they have made major progress in combating deforestation, even being labeled as the gold standard in conservation (IUCN, 2012). There is also an opportunity within the defined boundaries of PAs to increase reforestation and the healing of a forest.

Furthermore, indigenous lands, established to help protect the rights and livelihoods of indigenous people, have also aided in forest protection. Indigenous lands are similar to protected areas in that they have a defined boundary, however, the indigenous population is allowed to live on the land. Previous research has noted that indigenous lands tend to have a positive outcome as the people "have stronger incentives than disinterested or understaffed government agencies to protect their livelihood base against externally driven deforestation pressures" (Nolte et al., 2013). The highest rates of success were seen in areas of high deforestation pressure (Armenteras et al., 2009; Nolte et al., 2013). Unlike PAs, the collaboration between indigenous communities and governmental entities encourages use of the land while setting restrictions to avoid degradation. Overall, PAs and indigenous lands both have more concrete barriers and protection compared to community-based projects, creating more success over broader spaces. These efforts are instrumental in avoiding further deforestation while providing the opportunity for reforestation in degraded lands. Applying similar rules and regulations to severely degraded lands can also vastly improve the success of reforestation projects.

Most forested land belongs to the government, making it highly susceptible to political pressures. Governmental policies pertaining to forests may be out of touch with the current demands of today's society. This is seen in Japan, where a timber production boom in the 1900s led to the mass deforestation of native trees in favor of the mass planting of two economically viable, timber producing trees. The Japanese government enacted a policy that prohibited the removal of said trees, requiring that saplings of the same trees be planted should they be cut down. This policy is currently hindering reforestation projects throughout Japan as they do not consider the biological processes required for a healthy forest but rather prioritize economic factors (Coca, 2018).

Governmental corruption and transparency play a significant role in the likelihood of success for a project. Denis Sonwa stated that transparency is required in the forest sector; if transparency is not achieved, restoration efforts will be negatively affected (Sonwa, 2020). Unfortunately, corruption runs rampant in many of the countries that house tropical reforestation projects. Cameroon ranks low on the Transparency International's Corruption Perception Index, earning a 25/100 and ranking 153 out of 198 countries in the 2019 report (Transparency International, 2019). The lack of transparency contributes to the failure of international reforestation projects like REDD. Progress has been made in countries like Cameroon, that have been actively involved in REDD processes. Cameroon has focused on improving its institutional development which in turn has polished the planning, coordination, and development of REDD programs within the country (Alemagi et al., 2014). However, despite the progress being made to address the earlier stated issues, the pace of REDD+ implementation has slowed. Sonwa stated that the speed of REDD programs in Cameroon has been largely delayed - and even halted - as engagements with the World Bank, the entity that provides funding for REDD+ programs, have proven to be difficult. The absence of a legal framework behind REDD+ implementation as well as inadequate methods to include stakeholders are also hurdles (Alemagi et al., 2014). These examples demonstrate how governmental forces can inhibit processes meant to combat deforestation, jeopardizing the likelihood of success of these programs.

Assessing Tropical Fruit Value Chains

We were able to recommend sources of added value in value chains for Cameroon crops in respect to currently available fruits, including both fleshy fruits and herbs, of interest. After conducting the literature review below, we constructed a detailed value chain model for our selected fruits(shown in Table 5 below). These specified value chains recommendations can be applicable when modified to include details of other co-cropped species projects.

Selection of Species

Avocado

Avocado (*Persea americana*) is a member of the family Lauraceae and is composed of different subspecies determined by planting region. There are three main races of avocado: Mexican, Guatemalan, and West Indian. The type of the avocado determines its size, oil content (%), climate preference, and ability to form hybrids. Hybridized avocados can be grown to reflect the desired market preferences.. For example, the popular and high quality Haas avocado is a hybrid of Mexican and Guatemalan races, predominantly grown in the subtropics. The avocado fruit originated in Mexico and Latin America. To date, Mexico remains the dominant producer of avocados (Bill et al., 2014). In response to high avocado demand, Chile and The United States have increased production. International exports are an outlet for avocado consumption, but domestic consumption remains a predominant end-user placement within Mexico. Export markets should consider geographical proximity and transportation feasibility. From Cameroon, export to the European Union (EU) could minimize cost and maximize market profitability. Furthermore, “The United Kingdom is the third largest importer of avocados in the EU, and it is reported to have imported 11,753 t from South Africa in 2008” (Bill et al., 2014). It is important to note that export markets differ depending on cultivar type. Haas dominates USA growth and export, but other cultivars such as those with green skin, like Pinkerton, dominate different regional markets (Bill et al., 2014).

From Mexico, exports to the USA can model theoretical avocado value chains from Cameroon to the EU. Mexican avocados entered the American market, met conditions for regulation and price premiums, differentiated in product, and met increased demand. The export market from Mexico to the United States developed in the 1990’s once the United States Department of Agriculture(USDA) approved the standards for imported avocados. The system of USDA standards has led to a diversification of producers within the Mexican avocado farmer industry. Appendix B.7 shows how certification determines the level at which the farmer can participate in markets beyond the regional area (Coronado et al., 2015). Certifications and standards may regulate Cameroonian farmers who engage in export markets to the EU or USA.

A case study on the Mexican avocado market notes: “Nowadays, two markets can be identified: a national market for low quality avocado, and an international market for high quality (Coronado et al., 2015).” We can expect the divide to occur in Cameroon during the productive phase. Low quality avocados can be consumed by farmers and their families while high quality avocados can be sold to regional and international markets. Over 15 years, the avocado supply chain within Mexico developed by government interaction and state mandated taxes and wages. Implementing fair wages and benefits for workers by the Mexican government led to visible social change that did not occur before avocado labor force. The combination of higher profits and wages for the region allowed taxes to support the construction of infrastructure such as roads, hospitals, and other improvements to society which were supporting resources for the value chain (FAO, 2004). We expect to see this change within our project communities as well. Even in the absence of international trade, the availability of both social and nutritional capital has the potential to add economic security to the lives of smallholder farmers. The longevity of a value chain relies heavily on maintaining a demand which drives profit for the farmers (FAO 2004).

Djansang

Djansang (*Ricinodendron heudelotii*), popular in both Asian and African cultures, is a member of the family Euphorbiaceae. Commonly used as a spice and native to Tropical Africa, Djansang is a fruit producing tree. This tree reaches fruiting stage 8-10 years after planting (Tchoundjeu et al., 2006). Similar to the avocado, the extracted oil and fruit flesh pods can be a dietary staple (Kapseu, 1995). Its native abundance and health benefits has made the djansang fruit a popular commodity in Africa.

Though its wood is commonly used for timber, Djansang - as a NTFP - can be harvested and sold as primary products or turned into secondary products without harvesting the entire tree. In fact, because the tree is an annual one, its entire life cycle is completed within one growing season. Once harvested, the Djensang tree will cease producing new fruit, therefore the entire tree, with the exception of one root stock, is able to be harvested without damaging future crop yield (French, 2020). Even its bark is harvested and sold for its medicinal benefits (Brown, et al, 2010). For this reason, djansang is considered a priority NTFP, a "product with high economic/trade value [and] important for auto consumption" (Caspa, 2018). As a result, the fruit has been "promoted by the World Agroforestry Centre (ICRAF) in project villages in Cameroon with the aim to alleviate poverty of small-scale farmers" (Cosyns et al., 2011). As depicted in Appendix B.6, a multi year pilot study conducted by ICRAF found that the commercialization of djansang within the studied localities led to significant increase in capital for participating households (Cosyns et al., 2011).

The djangsang market is well established in Cameroon. The country has a place for commodity exchange "near the border of Cameroon or located within walking distance of it (less than 20km)," that serve as locations of consumption and pathways of goods to broader localities (Nkendah, 2010). Border markets bring together aspects of "real" or "spontaneous" markets in terms of supply, demand, and economic fluctuation (Fafchamps, 2006; 2007). The commercialization of djansang has led to increased economic viability and social capital, according to a study conducted by ICRAF (Cosyns et al., 2013). By managing fruit crops, local households were able to forge new relationships with both their regional and community counterparts (Cosyns et al., 2013).

Unlike avocados, djangsang can be harvested, dried, and sold for year-round consumption. Various uses creates a unique opportunity for a consistent flow of goods. Nearly 96% of the sale of djangsang is directed to primary wholesalers, so the expansion of our value chain to include larger stakeholders should be relatively simple (Caspa, 2018).

Analysis of Pre-Production Phase in Successful Value Chains

The pre-production phase lays the foundation for the project, including: educating participants on how to care for planted species, growing and maintaining healthy sapling trees for transplanting, and providing farmers with the necessary resources. During the pre-production phase, value can be added by investing in sustainable practices (Poofoun, 2020). Farmer participation at the pre-production level allows for farmers to accumulate knowledge on the best practices for tending to each particular species. The cost of building and maintaining a nursery is approximately 200-300USD, but can be outweighed by the integration of community involvement and autonomous planting with high success (Tchoundjeu, 2020).

Understanding the ecology of the species can maximize production, promoting higher levels of food security as well as greater margins of profit. Because numerous species are intercropped with one another, it is critical that we understand the ecological needs of each tree species planted. One way we may be able to accomplish this is by monitoring soil health to ensure that each species has access to appropriate nutrient levels. Maintaining soil health is a foundational source of added value as it promotes crop health and can directly affect production yield. One major caveat of the Ebony Project is its current lack of soil assessments. Access to soil assays may be able to give insight to crop shortcomings and elevate local discourse. Understanding, obtaining, and monitoring soil composition of a crop plot would be especially beneficial for the project's highly sensitive trees, such as the avocado.

Avocado

When growing avocado in an agricultural setting, yield varies based on variant type, cultivation, and zone. An adult orchard typically stabilizes at 80 to 100 kg of fruit per tree per year, but can vary depending on the age and orchard tree density. Young trees have a lower yield than adults, producing from 10 to 20 kg per tree, and stabilize their production at 10-15 years of age. (FAO 2004, SAGAR, 1999, Rodríguez-Suppo, 1992). The variants planted by The Ebony Project are usually one year old at the time of planting which shortens time between planting and harvest(Zaunbrecher, 2020). Using superior nursery techniques seeds should fruit within 3-5 years after planting (Deblauwe et al., 2019).

Girdling the trunk of the tree during preliminary growth has been shown to shorten the juvenile period of the trees lifespan (Schaffer, 2013). If girdling of our nursery specimen is conducted on a routine basis, we may reduce the time between initial planting and first harvest. Reduced production time would lead to a great extraction of value from the crops. In fact, girdling has "increased the proportion of seedlings that flowered from 47% to 100%, nearly tripling flower intensity (from rate 1.0 to 2.7) and significantly increasing the proportion of seedling setting fruit (14.9% versus 65.4%). Most importantly, this resulted in a sevenfold increase in number of fruit per tree (1.3 versus 9.3)" (Schaffer, 2013). Increased spacing between planted trees leads to higher productivity as space between trees allows greater nutrient uptake(Biazin, 2018).

Historically, avocados have been a tricky crop to grow. Plagued by a variety of issues, including pests and disease, this fruit is incredibly temperamental; but the difficulties in growth are rewarded by the sale price (Schaffer, 2013). The Ebony Project plants mixed variants, making the soil composition difficult to account for. Avocado trees are severely affected by root rot, a disease which causes roots to turn black, brittle and, in most cases, leads to the death of the tree (Yang, 2001). Inter-dispersing the trees between other productive flora and maximizing the space between them allows for the trees' natural defenses to more adequately fight off the pathogen (Biazin, 2018). Likewise, planting the avocado tree in the absence of pollen producing flora inhibits the notorious persea mite from laying eggs on the tree's leaves (Gonzalez, 2009).

Djansang

Djansang is an annual root herb that ceases growth once harvested (French, 2020). Similar to ginger, the root stock can be harvested continuously if a portion of the original plant continues to grow. Due to this, it is critical that farmers are properly educated on harvesting time to ensure continual growth of existing stock. By maintaining the same place of planting over the years, nutrient cycling can occur. We believe nutrient cycling can aid healthy co-cropping of fruits and herbs. Additionally, vegetative propagation, cloning, of a tree containing optimal traits would allow for a reduced fruiting age; thereby adding a considerable amount of value to the project(Tchoundjeu, 2020). These desired traits include growth rate, fruiting size, yield, and overall fruit health.

Analysis of Post-Production Phase in Successful Value Chains

Currently, the value chain of all co-crops are still in the production phase. Moving forward, farmer labor will provide value while simultaneously becoming a production cost. Table 2 shows various species-specific ways to add or reduce value during the production of co-crops. A(−)indicates a loss of value during production, and(+)indicates a way to add value. In order to minimize fruiting times, the Ebony Project is attempting to implement a number of techniques to the current modes of production, particularly marcotting (Tchoundjeu, 2020). Djansang trees begin fruiting at about 8-10 years of age. Djansang is typically only able to secure one harvest per tree and may not bear fruit each year, but rather every 2-3 years (Tchoundjue, 2006). This pattern should be accounted for even after the tree reaches productive maturity. Appendix B.3 demonstrates general sources of value during early phases of production and future expansion. Productive avocado takes 15 years to reach harvest without improved practices to accelerate fruiting or marcotting. It is important to identify current ways to add value since co-cropping is only in year 3-4 of planting. We can assume that for avocado, as a species, a normal value chain will be in the production phase for 10 years (FAO, 2004). However, the Ebony Project has started to implement marcotting which allows for growth of trees that reach productivity within 3-5 years. The main form of propagation is from seed, but the goal is for all saplings to be produced using marcotting techniques. Currently, the Project notes that 2020 planting may rely on commercial fruit trees to supplement nursery supply of produced saplings (Deblauwe et al., 2019).

Currently in its third year of planting co-crops species, avocado and djansang have not yet reached their productive phase.

Table 2: Actions during production for each species.

Species	Action During Production	Value Added	Source
Avocado	Addition of nutrients in deficient soil (nitrogen and potassium)	(+)	*Biazin (2018)*
	Cross pollination	(+)	*Biazin (2018)*
	Relying on self-pollination	(−)	*Biazin (2018)*

	Insufficient spacing between trees	(−)	*Biazin (2018)*
	Taller trees (damaged avocados from falling)	(−)	*Buazub (2018)*
	Use of biological pest control	(+)	*Gonzalez - Fernandez (2009)*
	Continual maintenance, girdling the tree	(+)	*Schaffer (2013)*
Djangsang	Seed set, manipulation of variant of djansang	(+)	*Nehemie et al. (2007)*
	Growth of *Balamba and Santchou* (two variants) ❖ Liberation of almonds ❖ Thickness of shell for cracking	(+)	*Nehemie et al. (2007)*
	Preservation of root stock for continued growth	(+)	*Aaron French (2020)*
	Fast growing	(+)	*Kinge (2019)*

Harvest and Post-Harvest Cycles

At the point of harvest or prior, the destination market (self consumption, domestic, or international) will be determined. Benefits of consumption can drive the demand for each fruit. For example, nutritional benefits including high fat content of avocados can be incorporated into the diet of local Cameroonians. Having a resource to promote food security may create unique demand for avocado.

At the time of harvest, it is important to account for labor requirements. The harvesting of the fruit at this phase may provide monetary value. Preventing ailments such as malaria that decrease farmer productivity will increase value (Powell, 2020). The farmer may perform grading techniques to identify diseased, misshapen, rotted, or malformed products after harvest. Proper post-harvest storage, transport, and shipment techniques must be used to retain value. Once produce reaches the final destination, the return and unacceptable produce can be accounted for (ISCEA CSCA, 2020). Tracking both acceptable fruit and unaccepted fruit can lead to beneficial changes in the value chain for the following year. Post-Harvest practices drive development of farming and transport processes in the future growing seasons.

The market determines the final price of the product. Strategies to add value into the marketing phase of the value chain include, but are not limited to: the creation of additional demand in order to created by dietary changes or consumer preference, minimal processing to reduce production costs, reduction of the intermediate transactions to reduce transitory fees, increasing the orchard size with adequate labor for harvest, production of secondary products when demanded, documentation of contracts between farmers and intermediates, certifications of

farmer and product such as organic or fair trade, and lastly deciding which market will be most valuable given economy, yield, and experience of the farmer.
At the time of harvest, there are certain actions that can be taken to add value to the overall co-crop process.

Table 3: Mechanisms to add value during harvest and the initial market.

Species	Action	Value Added	Source
Avocado	Cold shock treatment technology	(+)	*Chen et al. (2017)*
	Grafting of successful plots for future season	(+)	*Schaffer (2013)*
	Proper time between harvest and consumption for ripening	(+)	*Schaffer (2013)*
Djangsang	Boiling (antioxidant properties)	(−)	*Kinge (2019)*
	Roasting (antioxidant properties)	(+)	*Kinge (2019)*
	Sun drying	(+)	*Kinge (2019)*
	Use as functional food	(+)	*Ene Obong et al. (2018)*
	Macro and micro nutrients within the seed	(+)	*Ene Obong et al. (2018)*

Nutritional Gains from Each Species

Nutritional benefits are one of the most favorable outcomes of The Ebony Project co-crop approach. Access to stable food sources and adequate nutrition can be scarce in local villages of Cameroon (FAO, 2020). The Ebony Project hopes to support the local community by supplying a source of nutrition. Therefore, the nutritional benefits from each co-cropped species should be accounted for and the produce should be incorporated into Cameroonian diet.

Table 4: Nutritional and medicinal content of avocado and djansang (see Appendix B.2 for nutrition per variant).

Avocado *(Persea americana)*	**Djansang (*Ricinodendron heudelotii)***
Energy From Consumption of Flesh	Medicinal Herb
Protein Rich and Fat Soluble Vitamins ❖ Vitamin (A,B) ❖ Median levels of (D,E)	Protein, Fat, and Vitamin Rich ➢ Composed of 30.6% protein ➢ 20.6% fat

	➢ High potassium content ○ Aids in bone and heart health
Unsaturated Fats ❖ Mono-unsaturated fat ❖ Control LDL cholesterol	Phytochemicals to Promote Human Health ➢ Therapeutic but also curative ➢ Coughs ➢ Reproductive conditions: ○ Fertility ○ Menstruation
High Potassium Content ❖ Prevention of metabolic syndrome ❖ Aids in heart and bone health	Bark ➢ Reproductive Ailment ○ Fertility ○ Menstruation ○ Childbirth pain
Cancer Prevention / Cholesterol Control (β-sitosterol) ❖ Phytosterol with antioxidant properties	Roots ➢ Stomach ailments ➢ Laxative
(β-sitosterol) ❖ Immunity promoting ❖ Fight viruses, HIV	Djansang Extract ➢ Phytochemicals: inhibit the growth of human leukemia cells by up to 50% ➢ Reduction of free radicals ➢ rich in polyunsaturated fatty acids (~79%)
Consumption Benefits of Meaty Flesh ❖ Reduced heart disease ❖ Glucose intake in Diabetic people	High Amounts of Phenolic Compounds ➢ Use against antibiotic resistant bacteria ➢ Use in EU for antibiotic/antibacterial properties ➢ Access to unique market ➢ Can fight against multidrug-resistant & Gram-negative bacteria
Sources: (*Fulgoni et al.*, 2013) (*Duarte et al.*, 2016) (*Hasan*, 2016)	Sources: (*Yakubu et al.*, 2019) (*Kuete*, 2013) *(Fankam et al.*, 2017) (*Ene Obong et al.*, 2018)

Current Ways to Add Value

In order to assess value added, the steps within each value chain cycle can be indicated as an action that either adds immediate value or subtracts immediate value. A value chain can look at value from the perspective of each actor's contribution or by looking at the value of each phase in the various phases. Appendix B.4 provides a web showing the interconnected nature of the actors at each phase. The next step is to identify the actions of each actor. It is important to note that although an action, i.e. planting the tree, may be accounted as an initial financial loss, this process is necessary for future added value. Therefore, the overall goal is for the sum of all added values to be positive (Poofoun, 2020).

We were able to design a theoretical model of added value applicable to both fruits and medicinal herbs, a nutritional guide for the community, and an estimation of economic and ecological gains from successful value chains.

Table 5: Important ways to add value at current stage of value chains (3 years post-planting).

Source of Added Value (Specific to Value Chains of The Ebony Project)	**Corresponding Stage and Actor**	**Sources**
❖ Providing of Healthy Sapling ❖ Access to tools for planting / maintenance / harvest ❖ Communication between Nursery & Farmer ❖ Adequate disease prevention in farmers ❖ Farmer education of species / certification of the farmer ❖ Community Interest ❖ Access to Pest Control ❖ Farmer Empowerment ❖ Plantation Ownership (Silvicultural Booklet) ❖ Sufficient Labor ❖ Access to Transport ❖ Promote Sustainability / Recovery Analysis from Previous Harvest: including but not limited to climate conditions, waste reduction	Pre-Production	Jonas Poofoun, Personal Communication Aaron French, Personal Communication Zac Tchoundjeu, Personal Communication ISCEA CSCA, 2020
❖ Education of harvesting technique ❖ Proper Storage once Harvested ❖ Connection of Farmer to Market ❖ Health of Farmer ❖ Grading, Acquiring Technology for Post-Harvest Management	Production	Biazin et al., 2018 Aaron French, Personal Communication Luke Powell, Personal Communication Alam, Dr. Md. M, 2020

Theoretical Yields Based on Current Count of Planted Fruits

We created a theoretical model to estimate the value, in USD, a planted tree of each species will produce based on the current world price, which can fluctuate greatly. We assumed survivorship of 70% based on expert opinion (Tchoundjeu, 2020).

Monetary value of avocado production calculations:

Case studies of avocado agriculture in Tanzania reveal that, "Analysis of farmers' earnings based on type of avocado grown revealed that the farmers growing only local varieties earned higher (US$ 46.47 per tree) than those growing only commercial cultivars (US$ 25.63 per tree) (Juma et al., 2019). These numbers were used to create a theoretical value for the equation utilized below. Although trees will be owned by different people with varying access to markets, an estimation of profit for the project per tree can be used as a rough guideline of expected earnings based on project survivorship. The project has planted 131 avocado trees to date.

Equation 1:

Expected Monetary Yield Per Tree = (Expected Price per Tree)*(Expected Survival of Trees(as a decimal))

Theoretical USD earnings from currently growing avocado trees if all are sold as raw fruit:
(25.63)(.7) = 17.941 USD (~ 10,350.37 XAF)

To calculate the theoretical monetary yield from djansang production:

The price of Cameroonian djansang did not change significantly between 2015-2018 (Ndumbe et al., 2018). This suggests the commodity is relatively price-stable. According to Ndumbe et al., price depends on the stage of sale. Processing the kernel allows for a higher market price. Small volumes of production, less than 300kg, lead to less vulnerability to bribery during transporting processes. Insufficient enforcement of taxes payable on NTFP, such as djansang, lead to corruption that can disrupt the value chain (Ndumbe et al., 2018). The average profit margin/kg of initial djansang (raw sale) without processing profit can be estimated as .34 average profit € / kg (Ndumbe et al., 2018). The Ebony Project currently has 34 djansang trees planted (Deblauwe et al., 2019). The average weight of fruit ranges from .165- .275 kg, and an individual tree can produce around 900 fruits per fruiting year (Tchoundjeu et al., 2006). For calculation purposes, the average fruit weight used was the mean of the weight ranges: .220kg.

Expected Monetary Yield Per Tree = (Expected Profit per kg Fruit)*(Expected Survival of Trees(as a decimal))*(Estimation of Fruit per tree)(Average kg per fruit)

Equation 2:

(.34 average profit € / kg)(.7)(900 fruits/tree)(.220kg/fruit) = 47.124 € average profit per fruiting tree =53.18 USD (30,680.16 XAF) profit

Current Currency Equivalence: 1.09 USD = 1 €
1.00 USD = 606.72 XAF
(Source: Markets Insider, 2020)

Therefore, a tree currently planted without export to the international or processing market would yield 17.941USD profit from avocado and 53.18 USD profit from djansang based on information available at this time. These theoretical profits prove that the value chain is still profitable at the harvest stage which increases future promise from expansion to processing and export markets.

Non-Species Specific Model of Added Value Per Phase Per Market

We recommend the following steps and methods to add value. Adding value to fruit is contingent on the fruit's end goal, whether it be self-consumption or exportation to an international market. Phase specific and market specific added value is summarized in Figure 4 below:

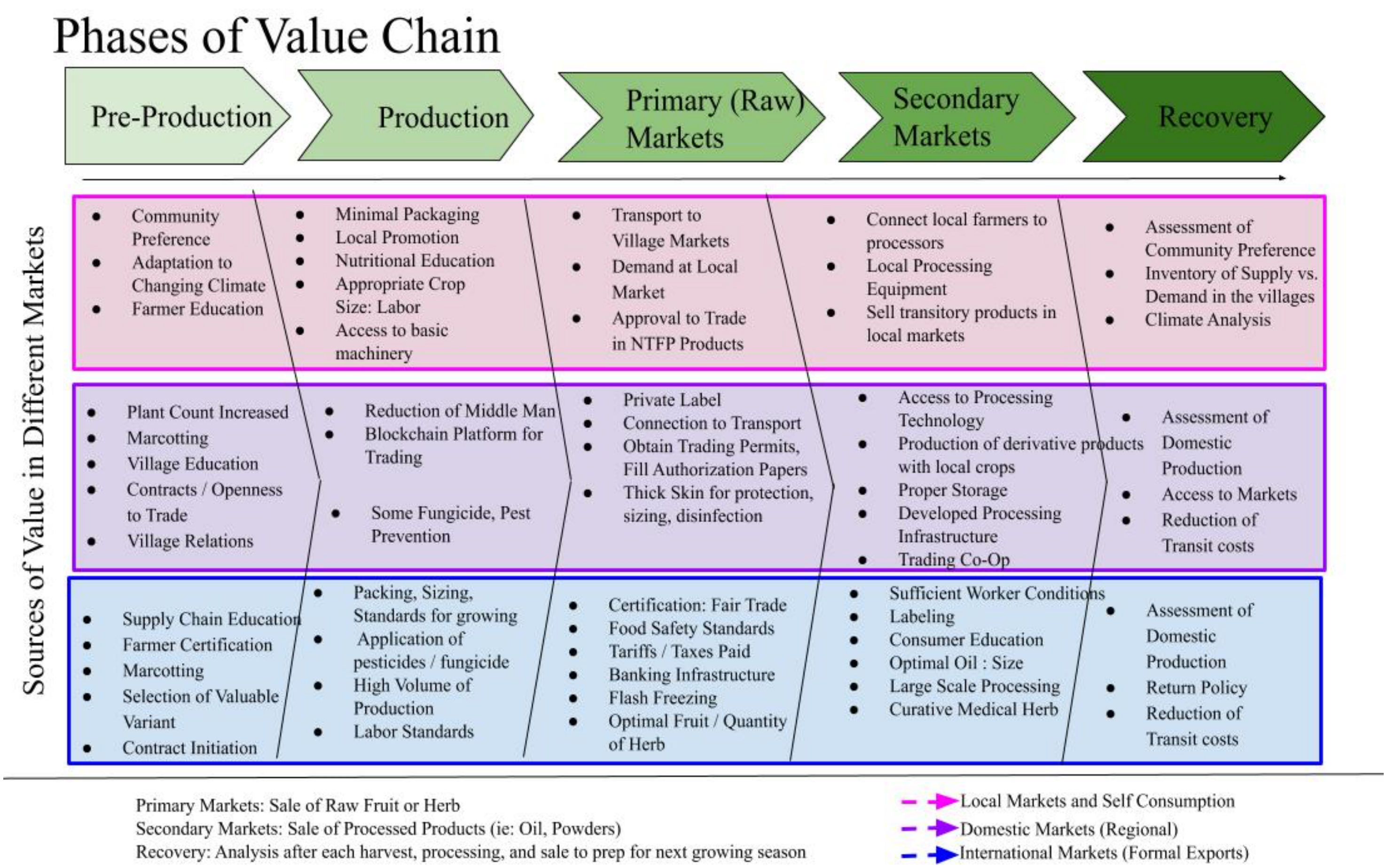

Figure 4: Summary of value chain results per market outcome of NTFP.

Incorporating Technology into the Silvicultural Booklet

Selecting a Suitable Mobile Surveying Tool

One of the many advantages of using the Open Data Kit tools is its ability to support offline use. The benefit of utilizing the open-source function allows for the production of free and downloadable software for collecting, managing and using data in environments that are resource-constrained. This is especially true for ODK Collect, the main mobile application component for on-site data collection, which enables cost-effective, scalable, and user-friendly implementation of mobile surveying activities. Since many of the end-users are mostly CBI field researchers who may not be able to afford software that requires purchasing a license or subscription, Open Data Kit is a simple and robust mobile data collection solution. Paid software is not universally affordable; therefore, by using and sharing this free and open-source application within the Ebony Project, the costs of implementing technology for the Silvicultural Booklet are much lower. Investing in commonly-used open-source software such as Open Data Kit that has a large, active community allows all parties to gain the benefits equally as well.

In addition to a suite of tools that are open-source and free to use, Open Data Kit allows for offline capabilities in mobile settings, which is beneficial for data collection in remote and rural locations such as Cameroon. Individuals can fill out surveys on mobile devices and ensure privacy without a network connection (ODK, 2020). This is especially important when privacy concerns of the communities must be respected and they may want to submit data with their own devices. It also allows compatibility between multiple storage and server platforms, including Google Drive. This is beneficial for the team as all of our current research data is stored in a team-shared folder on Google Drive. Open Data Kit mainly follows the following five steps in data collection, show in Figure 5:

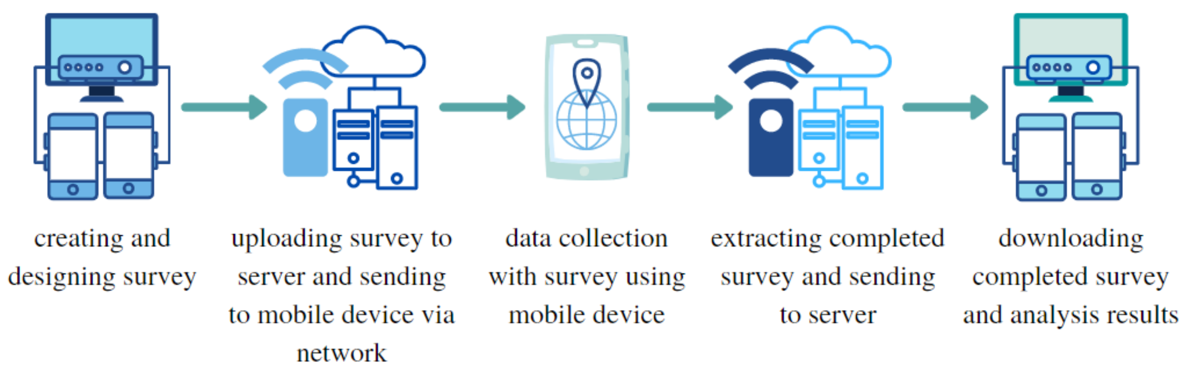

Figure 5: Consolidated workflow for the ODK data collection process.

Currently, the mobile data collecting application for Open Data Kit is only supported on Android smartphones, while its companion tools are supported on any operating computer system. Key components within its suite of tools include:

- **ODK Collect:** a free-to-download, open-source surveying application on all Android devices, available on the Google Play Store
- **ODK Build:** a major component used for the personalized design of a survey or questionnaire for ODK (supports both online and offline functionality)
- **ODK XLSForm:** a tool that allows for simplifying the creation and the conversion of forms from Excel-based documents to ODK-supported files (supports both online and offline functionality)
- **ODK Briefcase:** a downloadable Java-script application for importing and exporting forms and their contents, used in conjunction with a mobile device

- **ODK Aggregate:** the main open-source, multi-platform Java server for the ODK infrastructure, able to store, analyze, and present survey data as well as receiving the data from a mobile device (optional server choice)

Previously, the team compiled a list of all suitable candidates for mobile applications as well as cloud-based platforms for data storage and management. These include (GoFar)mer, Open Data Kit (ODK), KoboToolbox, ONASurveys, TaroWorks, Google Forms, and Ground. We scrutinized each one in detail based on their performance level and practicality, where our specific measurables included: whether it will work when not connected to the internet, whether it is relatively user-friendly or not, whether data can be transferable between the application and the cloud platform, and whether the financial implications of both the application and the platform will be an issue in the long term or not. We based our comparisons on a detailed assessment rubric which can be found in Appendix C.3. Since KoboToolbox relies on the same data collection server as ODK, we selected to focus our findings on ODK solely. Table 6 below shows our results:

Table 6: Preliminary assessment rubric for a mobile surveying tool.

Application Comparison	**ODK**	**KoBoToolbox**	**ONASurveys**	**TaroWorks**	**Google Forms**	**Ground**
Free to Use	X	X			X	X
Offline Usage	X	X	X	X		X
User-friendly	X	X			X	
Custom Builds	X	X	X	X	X	X
Open Source	X	X	X			X
Mobile (Android)	X	X	X	X	X	X
Desktop	X	X	X	X	X	X
Server	X	X	X	X	X	X
Primary Data Collection Server	ODK	ODK	ODK, Enketo	TaroWorks	Google	Google

Cost-Benefit Analysis

Following the selection of a data collection application, we performed a cost-benefit analysis on Open Data Kit, as shown in Table 7. We found that mobile phones are becoming more affordable and common in Cameroonian society. Second-hand phones can be found for 3000 CFA, or $5.40, from table sellers in Cameroon. For comparison, a large can of imported jam is sold at 3,700 CFA at the local supermarkets. Otherwise, a new Android can be purchased for 15,000 CFA, or $27 (Smith, 2018). Furthermore, a GSMA prediction in 2019 estimated that nearly two-thirds of Africa will be smartphone owners.

Table 7: Cost-benefit analysis of implementing mobile surveying technology for the Silvicultural Booklet (Deblauwe, 2020).

	Category	Details	Potential Value
Costs	Devices	Requires the use of mobile device and GPS device	(−)
	Technology Supportive Infrastructure	Requires access to power and possibly internet	(−)
Neutral	Workforce	Existing functional team shifts from current process to technology based process	(=)
Benefits	Ownership	Provides detailed and supportive documentation Longevity of records	(+)
	Reduced Labor in Monitoring	Eliminates need to digitize and compile Adds ability to transfer data to centralized location	(+)
	Quality Control	Ensures all data is recorded and reduces incorrect inputs/inconsistencies Standardizes process for surveyors	(+)
	Better Suited for Future	Smartphone adoption expected to grow to 67% in Africa by 2025 (GSMA, 2019)	(+)

Storing Data on Multi-platform Servers

This file storage and synchronization service developed by Google allows users to access files on their servers, synchronize data across supported devices, and even share the said file with multiple parties. It also offers applications with offline capabilities, usable on iOS and Android-based mobile devices as well as computer systems running on Windows and MacOS. Most importantly, the Drive is account-specific, meaning each unique account preserves and provides the same access to previously stored data. Google Drive also allows for the importing of different file types, which is beneficial for the CBI research team as data is collected each day in different formats, such as spreadsheets, coordinates, images as well as written notes. Conversion of files can also be done via Google Drive using their desktop-supported extensions, providing a simple and accessible way of handling data that only certain software can read. Since Open Data Kit can opt for the synchronization with a Google account, using Google Drive is very beneficial to the project.

Additionally, Google Drive is relatively safe and secure, as it is constantly monitored by the internal Google servers. They are secured by firewalls to prevent unauthorized access and denial of potential service attacks, in addition to the pre-installed anti-virus technology from computer systems. Any unauthorized login attempts will be recorded and notified by any linked devices to the account, preventing major theft of important data. Access to the Google Drive interface from the web and smart device is protected by passwords as well. Users can even change the privacy settings for each individual file stored and share stored data to different people easily.

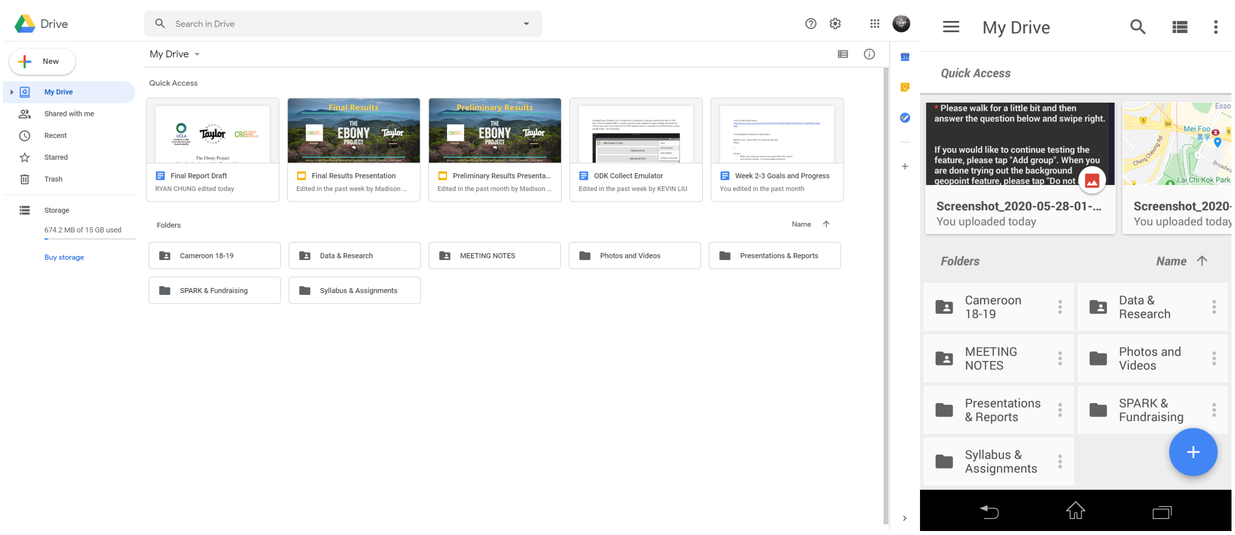

Figure 6: The interface for Google Drive, fully compatible with smart devices as well as desktops.

Designing, Importing and Exporting Surveys

In order to tailor survey implementation and subsequent data collection for the Ebony Project, it is essential to create and design custom surveys or forms in a manner that allows for the retrieval of all relevant data efficiently. ODK Build acts as the first step in the overall collection process and is a key component for the integration of surveys. Its main function is to create new surveys making them available to a host server. Any existing surveys can be accessed through the file system, and separate new surveys can be created at the same time. All forms created will be saved in the ODK Aggregate server according to the user's account. A sign-in feature is required for this function, which is recommended as it enables surveys to be saved after designing and retrieving forms. ODK Build is an online HTML5 web application that provides great accessibility, which works on all internet browsers and computer systems. However, this requires an online connection to the internet; users who do not have reliable internet connection or need to design forms offline may opt for a downloadable version of ODK Build instead. This would require pre-installation of the program onto the user's computer system and would provide unlimited offline usage.

Using a simple drag-and-drop interface, ODK Build provides a selection of prompts that aid in the design of simple forms, as seen in Figure 7. This includes questions pertaining to text, numeric values, date and time, location coordinates, and even barcodes. Such prompts can be moved around easily, allowing questions to be switched accordingly and customized to the user's content. Each prompt has its own selection of criteria that can be specified under certain circumstances as well as a set of advanced options that can be turned on or off according to the collection process of the survey. This is beneficial if the data collection requires logic gates that permit certain actions or values from being inputted. Additionally, ODK Build allows for a real-time preview of all prompts while editing, and even providing search capabilities on the survey tree.

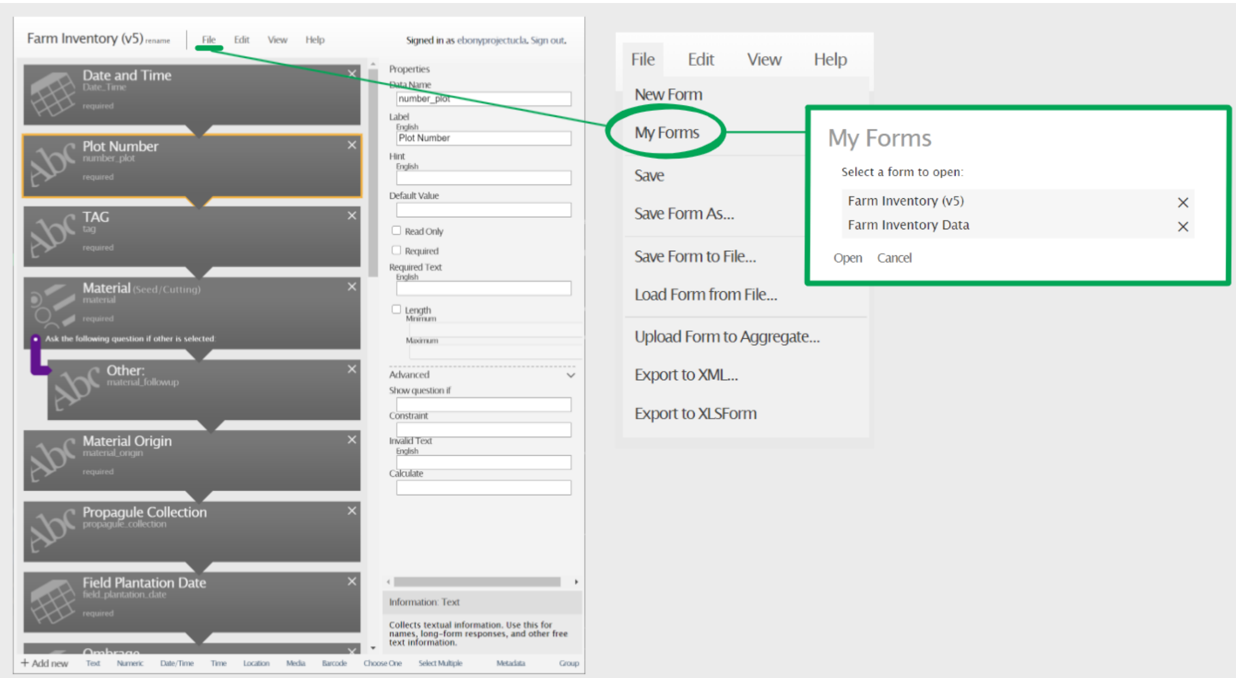

Figure 7: The interface for ODK Build, showing several importing, exporting and saving options under the option "Forms".

ODK Build's exporting formats and its compatibility with selected servers are key advantages. Traditionally, all forms created will be saved onto ODK Aggregate and use the associated *.odkbuild* file formats. This can be an issue since the storage space for the ODK platform can be limited and privacy of data may be compromised. Incidentally, ODK Build allows for the exporting of created surveys into XML and XLS data formats. XML is a text-based file format that can be opened in different text editors and is a type of markup language that many current applications utilize to read. However, XLS has a binary file format and is integral to Microsoft Excel, thus being affected by the change from XLS files to XML and vice versa. Since Excel is one of the largest data management softwares and is used by many organizations and individuals, including the Ebony Project team and CBI researchers, having the option to convert a web-based survey into an Excel-supported spreadsheet within the form designer itself is extremely beneficial and efficient. Furthermore, the exported surveys can be uploaded onto Google Drive, which can be directly read by the mobile data collecting application, ODK Collect.

Using ODK Collect for Data Collection

One of the many great features that ODK Collect provides is its free open-source usage. The application itself is only supported on Android systems and can be downloaded directly from the Google Play Store (the corresponding application store for Android) with internet connection. This works very well with the current setup for the Ebony Project, as the majority of the local Cameroonian villagers as well as the CBI researchers use Android-based mobile phones (The Ebony Project, 2017).

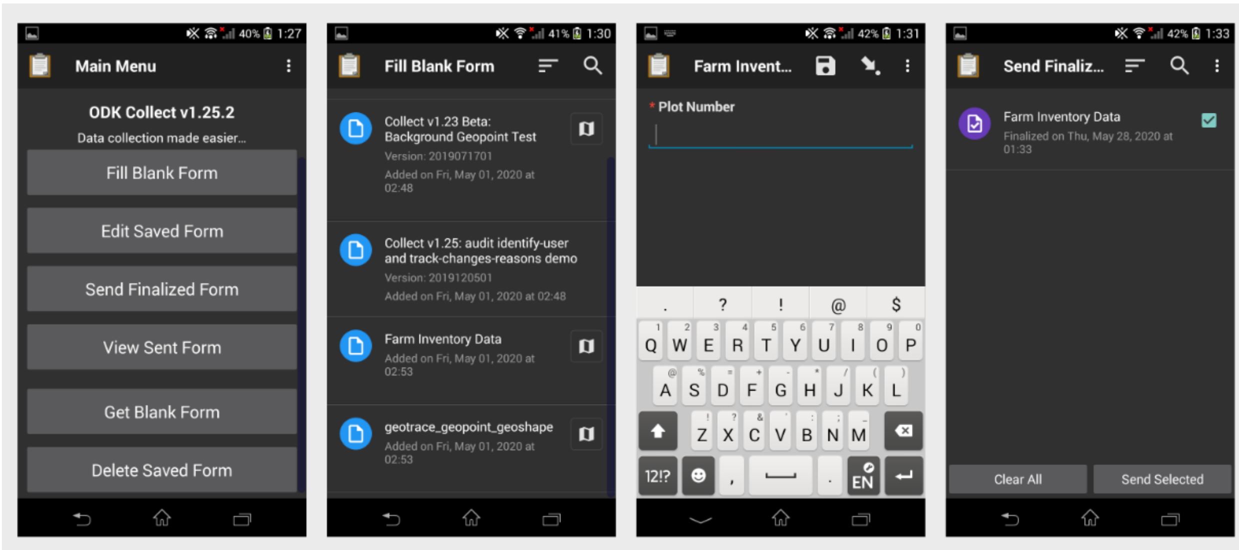

Figure 8: The interface for (from left to right): the main menu of ODK Collect; the list of downloaded surveys in the device; the input screen while a survey is opened; the final screen for sending finalized forms.

Once all forms and surveys are uploaded onto the Drive and the settings for ODK Collect are managed correctly, the forms and surveys can be easily accessed through the main interface. Selections include: "Fill Blank Form", for inputting data into a newly downloaded survey; "Edit Saved Form", for editing and changing values in surveys that have been filled already; "Send Finalized Form", for sending a finalizes survey to a chosen server through internet access; "View Sent Form", for reviewing finalized surveys that have been submitted to said server; "Get Blank Form", for downloading and retrieving desired surveys from a chosen server; "Delete Saved Form", for deleting surveys that have been filled already. As seen from the figures above, ODK Collect can incorporate free text, multiple choice options, as well as different question types such as numeric, date, time and location values. It can accommodate skip logic as well as enforced validation during operation, which follows all instructions applied to the designed surveys through ODK Build. If responses do not match the required value data, ODK Collect has the ability to deny such inputs and request another value again.

Additionally, all completed surveys must be finalized before they can be sent to a specific chosen server. This allows for multiple individual responses being generated from one selected survey. Finalized surveys are automatically uploaded to the host server once "Send Finalized Form" is selected. If there is no internet access or mobile network coverage, the finalized surveys are stored securely in ODK Collect until a signal is found, at which time the finalized surveys will then be uploaded and sent. If Google Drive is selected, one can immediately access the survey results from the server and manage all other data simultaneously. Alternatively, one can manually extract said surveys from the internal storage of the smart device backed up by ODK Collect and retrieve the finalized forms in this way (see Designing, Importing and Exporting Surveys). All survey data are also encrypted, maintaining the privacy and confidentiality of the responses in this way. The total number of surveys stored seem to be limited to the internal storage size of the smart device, although this has not been confirmed.

While attempting to run mock field investigations with ODK Collect, a multitude of these functionalities have been replicated and confirmed. The overall usage experience has been fulfilling, producing results that were up to expectations. All data inputs have been exported in an accurate manner, with the exception of GPS coordinates. The application itself does not seem to take up too much battery life of the smart device, with the battery percentage decreasing by about 1% every 5 minutes. However, this is entirely dependent on the age of the device and the workings of the internal circuitry, and therefore may be different when ODK Collect is run on other, more updated devices.

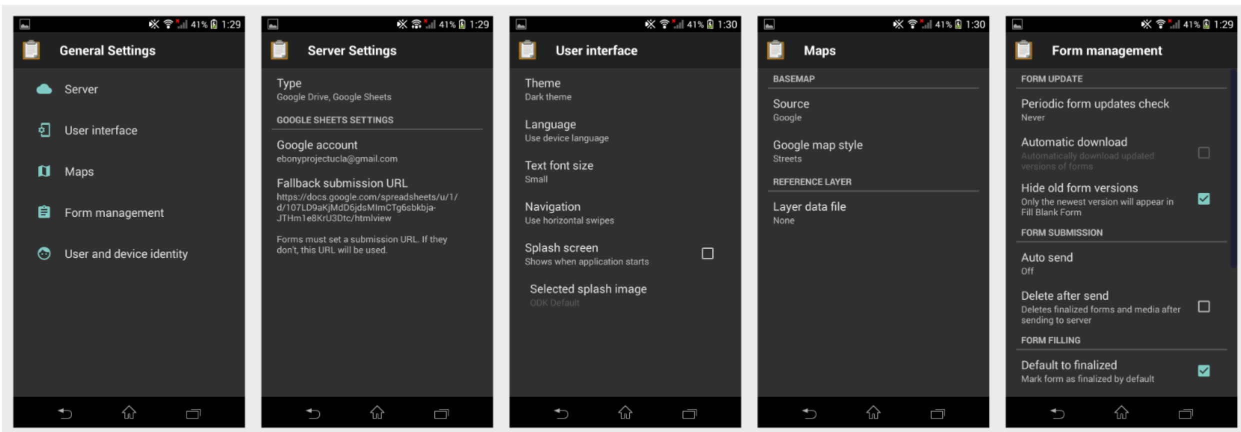

Figure 9: The interface for (from left to right): general settings in ODK Collect; server settings; user interface; maps; form management.

The application itself provides a large variety of different settings that can be customized and changed according to the preference of the user. This includes options for servers, general user interface, maps, form management, and user and device identity. ODK Collect allows an online connection between the device and the choice of a particular server, which consists of ODK Aggregate, Google Drive, and private servers. Furthermore, the user interface for ODK Collect is very friendly and easy to read. Titles are simple and each selection made provides an understandable description based on its function. This makes the learning curve for this application very linear and straight-forward. Subjectively, the appearance of ODK Collect is clean and appealing, making the experience of using this application in long periods of time rather smooth and pleasant.

In order to further assess the viability of using mobile data collection methods, amid the restrictions of COVID-19, our team utilized an Android Phone emulator. *NoxAppPlayer* is a desktop application that emulates a mobile phone experience. The application allowed for the team to disable location services without disconnecting network functions — this best simulates the connectivity conditions that would have been experienced while conducting work on site, in Cameroon. *NoxAppPlayer* (v3.0.2) emulator was used on a Macbook to simulate an android field test of our ODK form “Farm Inventory Data”. The emulator represented the mobile device that a field surveyor would use and a personal iPhone was only used to manually input GPS coordinates, similar to the current use of *Garmin* GPS’s by Deblauwe and his team.

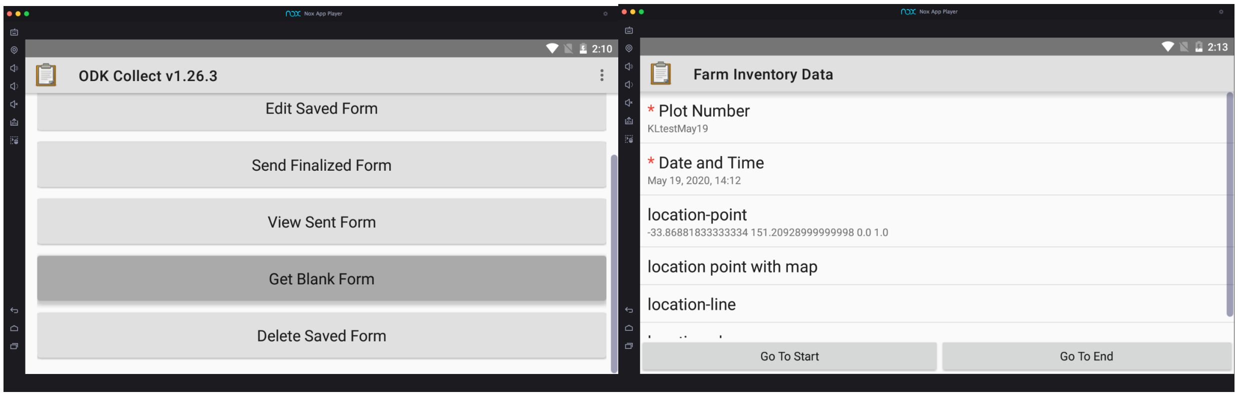

Figure 10: Using *NoxAppPlayer* to simulate and perform tests on ODK Collect.

Considerations and Limitations

To expedite this process of designing and exporting surveys, Open Data Kit has another tool known as ODK XLSForm. As a standard for forms created to help simplify the management of surveys in Excel, ODK XLSForms allows for the simple authoring of complex forms and the conversion between XLS file formats and associated formats with ODK Build, which is ideal for transcribing necessary information into Excel spreadsheets. Conversely, forms designed with Excel can also be converted to XLSForm-based file formats that can be used with other ODK tools. It is worth noting that this allows for the specific design of forms with Excel instead of using ODK Build, provided that the user is technically knowledgeable with such tools. ODK XLSForm is available in an online web-based setting as well as a downloadable software for offline use, much like ODK Build.

There may be certain situations when the manual insertion or extraction of files from the mobile device is required. ODK Briefcase offers a simple solution for this and bridges the technological gap between the device and the survey builder. As a downloadable desktop application that can run on multiple operating systems on a computer, ODK Briefcase is used for pulling, phishing, and exporting forms on ODK servers such as ODK Aggregate and from local storage files. More specifically, it can be used to pull and upload forms directly from ODK Collect. Several other functions of this application include exporting data from forms to Excel-supported files, decrypting encrypted surveys, backing up and transferring forms in between servers, as well as working from a command line in an offline setting (as opposed to the traditional graphical user interface). ODK Briefcase is a useful tool since its functionality makes it easier to use the data in GIS or other downstream tools, providing a data export option in a geographic file format (e.g. GeoJSON file) instead of the standard Excel spreadsheet. This process was vital as we attempted to record background GPS data in our mock field tests with ODK Collect and needed to find a method to extract the data without using the original ODK Aggregate server.

Despite being able to input GPS coordinates into the generated forms, there may be cases when it may be troublesome to input every value while switching between GPS coordinates and the specific data being recorded at that time. Other problems include ensuring that the user has gone to the designated location for data collection and that no junk data has been filled up from some other location (ODK, 2020). An automatic GPS-recording system can act as a possible solution for these issues and give confidence to researchers that the data collected is reliable and in good quality. As such, the ODK community has developed an optional feature to occasionally collect GPS coordinates in the background to provide evidence that data was collected in a particular place, known as the Background Geopoint Test. This form automatically fills up GPS coordinates in a separate file in the background once downloaded onto ODK Collect, creating a hidden question with a binding "auto_gps" value without the user's knowledge (ODK, 2020). Furthermore, this particular function records location once whenever a form is opened and once more every time a question about a particular location coordinate is asked.

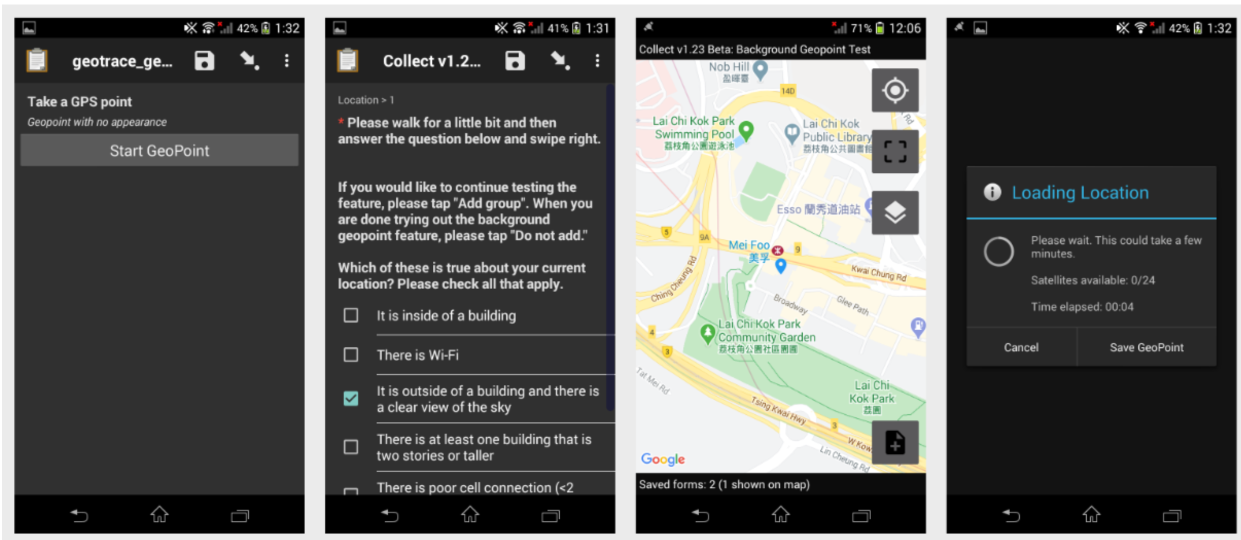

Figure 11: The interface for (from left to right): inputting a geopoint in an opened survey; selecting for different options in the Background Geopoint Test form; a geographical visual of the GPS coordinates; the device obtaining current GPS coordinates.

As of right now, there are two main ways of collecting GPS coordinates: **Satellite GPS** and **Network GPS**. Both methods are utilized through the smart device, and this option can be selected from the General Settings interface in ODK Collect. Satellite GPS gives a highly accurate reading of the current GPS coordinates of the smart device, but will consume a large amount of battery. There is a timeout function defined (about 30 seconds) in the system, which will show how much time the application will attempt to retrieve a GPS reading. Coordinate data will be recorded if the Satellite GPS is able to get a reading. Otherwise, the Network GPS will act as a backup and will be filled up within the hidden question. Network GPS tends to give the approximate location of the smart device from nearby cell towers which can be fairly unreliable, but is very fast and consumes negligible battery. The freedom of choosing between these two methods of recording GPS data is highly beneficial when considering locating specific trees, plots or even boundaries.

The Background Geopoint Test was implemented to ODK Collect v1.23.0-beta.1 and all later versions and is currently under future development and updates. However, this function only works in conjunction with ODK Aggregate, where the form originates, and lacks compatibility with ODK XLSForm. Therefore, GPS data cannot be transferred onto Google Drive, as tested after the mock field experiments. This feature will also not work without a SIM card inserted into the mobile device, meaning it requires at least a basic level of GPS locating service within the device in the first place. Additionally, there is a potential for breach of privacy and security of the user while using this function; the ODK community provides a thorough discussion around this feature which includes a good debate about privacy control.

One major drawback of using Google Drive is the limited storage space. This year, we have established a new account for storing research data under the Ebony Project credentials and are currently using the first free 15 gigabytes of storage. This harshly limits the amount and size of files stored on the Drive, considering that this account may be used in the future by the next Practicum teams as well as the current Ebony Project team.

ODK will be most effective as a tool for mobile data collection, if the following are addressed. First, ensure all project states have Android smartphones. Second, offer informational sessions to educate staff about the use of our forms and the program. Additionally, since our ODK Collect forms were built in English and that the current language option available is English only, a fluent French speaker would need to assist in creating French forms. Possible additions of other languages may be included with future features and updates from the ODK community and developers. Once individuals understand how to use the program, they need a source of an internet connection to upload the forms, but the internet is not always readily accessible. Lastly, the trials conducted by our team used Google Drive as the data storage hub (where one can access forms to fill out and submit completed forms). For larger scales, another data solution can increase capacity at a cost to the project.

Discussion

The founder of the Ebony Project, Bob Taylor, stated early in our project that his goal was “for the Ebony Project not to be special”. He believes that if the Ebony Project wasn’t special, that would mean the world was making advancements towards sustainability and stewardship of our planet. At this time, the Ebony Project is special and requires passion and hardwork to close the gap. To achieve Taylor’s ultimate vision, this installment of the Practicum explored three interwoven facets: successful reforestation practices, value chains, and a digitized land tenure system. It is important to note that The Ebony Project is larger than this practicum. Our research is an addition to the pool of hardworking research that came before us and will continue after us.

The three research questions equally support each other in advancing the Ebony Project. The topics, shown in Figure 12, demonstrate that added value can stem from the culmination of improved reforestation, technology, and value chains. Proper reforestation techniques promote successful regrowth and agroforestry which can create the opportunity for successful value chains. Creating a successful value chain will provide empowerment to the local communities along with improved food and income security. These factors largely improve the likelihood of success for a reforestation project, as the livelihood of the local community is placed at the forefront of the project. Through an improved, digitized silvicultural booklet, the local communities are provided with a simpler pathway to document trees and thus aid in the process of obtaining property rights (though not guaranteed). The booklet also holds and monitors data of co-crops which is essential for a successful value chain. Through secure data collection, the local communities are able to own the trees they are caring for while being able to profit off the goods they produce. These ideals are critical for the success of a reforestation project, reducing issues of land tenure, promoting income and food security, and increasing local community empowerment.

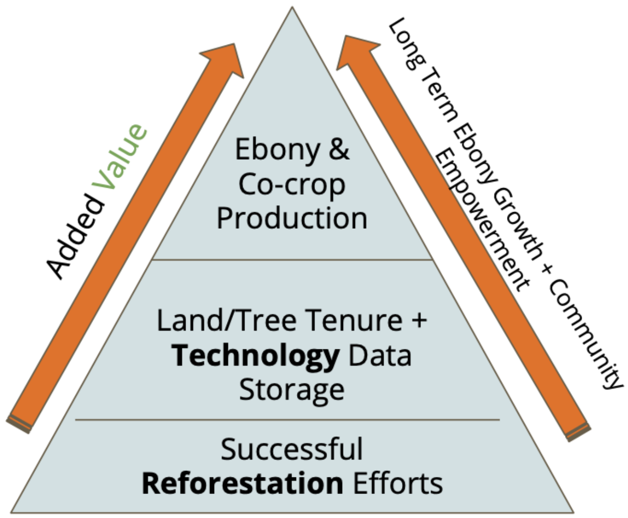

Figure 12: The interconnection between all three research questions in this installment of the Ebony Project.

The most dramatic weakness of the project was the onset of COVID-19 during our practicum. The pandemic led to the cancellation of our field research in Cameroon. Furthermore, we have shifted our deliverables from the initial start of the project. Although we were able to produce valuable results, valuable time was spent fundraising, applying for grants, and receiving medical preparation, time that could have otherwise been used for our research. The greatest weakness was pivoting our research and suggestions off of what we have heard about Cameroon, without having our own first person experience. Additionally, COVID-19 shut down other workshops for programs such as INVEST, which may have been applicable to value chains. Inability to test software on the ground, and not being able to reach some experts through Zoom calls continued to accelerate weakness driven by COVID-19.

Future Recommendations

Tropical Deforestation and Reforestation

The Ebony Project is a community-based project with active stakeholders which has created a strong foundation for the project. The agroforestry model is likely to increase both the success of the ebony and fruit trees, as well as the biological diversity and health of the ecosystem. The addition of fruit trees as well as Crelicam, a responsible international supplier of ebony located in Yaoundé, has enhanced and diversified local livelihoods and added socio-economic incentives to the project.

With the project still in the early stages, there are some factors that need to be taken into account and solidified in order to better secure the future of the Ebony Project and reforestation in Cameroon. As ebony trees take around 80 years to reach maturity, the long scale project needs to be properly managed. Creating a reliable and certain long term management plan will be necessary for the upcoming years as the project shifts to waiting for the ebony trees to grow and focusing more on the fruit trees and protection of the forest. In addition to the quarterly field meetings with participating villages, the project can look into implementing a suggestion drop off box which would allow villagers to address specific questions, perceived barriers, concerns, or recommendations throughout the year. The drop box should be located in an area easily accessible to all members of the community and checked regularly. Implementing surveys for the farmers throughout the year can also act as checkpoints for the project and increase communication. Ensuring and deepening connection and communication between Taylor Guitars, the Ebony Project staff, and Cameroonians is integral in improving the project and creating longevity.

In addition, Cameroon lacks secure land tenure and property rights which decreases involvement and security. Making initial steps towards finding a way to provide access to land tenure is especially vital as the ebony and fruit trees begin to grow and fruit. Improved methods of documentation pertaining to land tenure would benefit the project and is explained at length below in the “Incorporating Technology” section. Additionally, a proper outline for selective logging and removal of forest products will need to be created as the project shifts in the upcoming years from growth to outputs. A guideline of the removal of ebony trees will help the long term success of the species as a whole as well as the ecosystem. This is another area the silvicultural booklet would enhance the project.

Community education is a vital component of the Ebony Project, however the current educational portion focuses heavily on methods to care for the trees. Further educating the local people will provide avenues for them to diversify and deepen their involvement and knowledge. The project can look to implement additional workshops that focus on a variety of other factors pertaining to climate change such as the drivers of deforestation and the ability of ebony to sequester carbon. Providing said workshops would stress the long-term benefit of the project and allow the participants to understand that their work plays into the larger goal of combating deforestation. The Ebony Project can look into adopting a Community Based Social Marketing (CBSM) approach that has been successfully utilized by the L.A. based urban reforestation group, TreePeople. Edith Guzman explained that CBSM encourages community behavioral change through community lead initiatives (Guzman, 2020). The Ebony Project could implement initiatives that would help promote the goals of the project such as poster boards located in an area frequented by locals or information pamphlets that can be placed in participant homes. These informational outlets can work as a constant reminder for the participants to properly care for the trees by stressing the generational importance of the land tenure, food security, and the other stated goals of the project. This form of information-based campaigning can encourage participants to continue their active role in the project long after the initial five year payment, as they would have a constant reminder of the long-term goals of the project.

Due to the nearly century-long maturation of the ebony tree, future funding of the project must be questioned. A review of the current scope of the project should be completed to evaluate the source of future funding should the project choose to exceed its initial goal of 15,000 planted ebony trees. Questions pertaining to how long project funding will be provided, will the project exceed its initial planting goal, what would happen to the project should funding end, and how the project will proceed should funding be halted, should be clarified. There are also opportunities in Cameroon to add value by monitoring carbon offsets and increasing carbon credits. Finding an avenue into the green economy to sell carbon offsets by monitoring the offsets created by the Ebony Project can add financial stability to the project to possibly expand or increase the current tree planting goals. One avenue to receive financial aid is to strengthen ties and continue working with The World Bank, which has already begun. The project can also look towards calculating the total emissions produced from the Ebony Project to find ways to minimize the project's carbon footprint. This work can possibly be conducted and expanded by future practicum teams.

Finally, it is vital that the community continues to be supported by the project in order for continued active participation. This can be done through the added success of the value chains of the fruit trees which is outlined in the section below. The project can provide an avenue for the local people to expand the value chain of the co-crop should they choose too. The value chain can be expanded to local, regional, and national levels to increase the income security of the local communities. As the fruit co-crops are expected to fruit within the coming year, educational classes pertaining to the options participants can in regards to the value chains would be beneficial. Additional incentives for participants ought to be considered should the fruit trees fail to produce successful yields and as a method to maintain village support of the program. Incentives such as yearly village-wide festival-like events can be utilized to boost the morale of the participants and reward them for their commitment to the project. Cultural, or community-based incentives can provide the participants with a meaningful way to continue forth with the project in the event that the fruit trees do not successfully produce a short-term benefit or to simply encourage community involvement.

Assessing Tropical Fruit Value Chains

A successful agroforestry value chain has components of positive outcomes in the following divisions: social, environmental, and economic impacts, but also takes into account agroecology and market dynamics. It is critical to account for the indigeneity of the region as well as local ecology by incorporating ecosystem services and cultural sensitivities into market valuation. We recommend adopting existing successful value chains models and modifying them to reflect the values of Taylor Guitars, the Congo Basin Institute, and the communities the project serves.

Cameroonian farmers historically grow cash crops, such as cocoa, which are not used for local consumption. Since these products are mostly for export, the farmer does not yield nutritional benefit. As Dr. Zacharie Tchoundjeu points out, farmers who consume the product keep the value chain short. The farmer could consume a portion of the crop, and sell the surplus which would benefit the farmer nutritionally and economically. Having the choice to pursue the market or consume may promote farmer empowerment by controlling the outcome of their own crop. In the future, the goal is that farmers have the power to set their own prices (Tchoundjeu, Personal Communication, 2020). A successful fruit value chain in terms of The Ebony Project sees the most value in providing nutritional security for the farmer while allowing for an opportunity to receive proper compensation at market.

Once the trees of the project reach their fruiting stage, the project should be able to gain a better idea of whether market expansion is possible or whether challenges in production inhibit value chain growth. The productivity of planted fruit trees is currently unknown. We believe that further research into the use of INVEST by future practicum teams may be able to benefit the Ebony Project.

To assess the current and future states of the value chain, a questionnaire supplied to the farmers can be filled out post-harvest to indicate the given challenges and successes of the season. The questionnaire should identify common limitations of added value in smallholder farms. The value chain could adjust each year in response to the answers provided in order to fill any gaps and prevent losses from recurring where possible. Optimization of the value promotes both economic and food security of local communities and helps ensure farmer autonomy.

No matter how many interviews we conducted, literature we read, or videos we watched, being unable to travel to Cameroon limited our ability to fully understand the region and culture we spent so much time studying. After researching avocado and djansang, we realized that creating a value chain for bush mango, in place of avocado, may have been more valuable to the project's participating villages. The bush mango, unlike the avocado, is unique to Cameroon and does not have established supply chains elsewhere in the world; therefore, the product could peak interest for international demand without competition from established stakeholders. After conversing with experts, we came to the realization that avocado holds very little cultural relevance within Cameroon and is therefore marginally consumed by native peoples. The african bush mango, on the other hand, is an indigenous fruit with high rates of local consumption. Moving forward, we recommend forming a value chain for bush mango due to economic and nutritional relevance within the region.

Though we performed extensive research throughout the year, we understand that there may be some elements of local dynamics we may have missed. We hope that our value chain models are able to be further developed and adjusted according to further project development and local demand. Despite being unable to experience the workings of village markets firsthand, we feel that we have developed meaningful contributions that may be utilized to promote both community health and wealth.

Incorporating Technology into the Silvicultural Booklet

Looking ahead, the Silvicultural Booklet will hopefully be digitized and be updated regularly in subsequent years (for instance to say which trees are still alive and growing) based on our prior knowledge of the survivability and maturity of the ebony trees (Deblauwe, 2020). It would also have even more specific growth data in the booklet for the farmers and field researchers, so that the best estimate of the number of ebony trees will be available for each plot or said farmer, thus avoiding guesses about how many trees can belong to one family. This further strengthens the case that a said tree is the same one that they have previously planted (Deblauwe, 2020). Additionally, it will be worthwhile to map out each farmer's plot showing where the trees are and digitizing it afterwards, as it is useful to locate trees that have been planted in the past but may sprout in the coming future (Deblauwe, 2020). These findings suggest that the integration of mobile surveying tools is most applicable in these situations and will aid in the enhancement of ebony conservation as well as the co-cropping program for all parties involved.

We highly recommend using Google Drive as the current temporary server for all data and files related to the Ebony Project, as well as choosing Google Drive as the main host server on ODK Collect (see Storing Data on Multi-platform Servers). In this way, all data previously stored on the Ebony Project account can be accessed easily and utilised via ODK Collect. Online versions of ODK Build and ODK XLSForms are recommended since they offer better accessibility, are always up-to-date and allow users to preview what generated forms will look like in real time. To ensure great longevity to the Drive and subsequently the project itself, we recommend potentially purchasing a paid plan through Google One and thus increasing the permanent storage space (up to 30 terabytes) for the Ebony Project account. Files uploaded can be up to 5 terabytes in size, with much more space for possible backup storage as well, in case the worry of losing digital data comes up. Alternatively, Google also offers G Suite, a monthly subscription-based offering that caters specifically towards businesses and organizations. Google Drive is included in this suite, and as part of certain plans, the Drive may offer unlimited storage, enhanced administration and privacy controls, advanced file audit reporting, and collaboration tools for multiple teams.

Another option the Ebony Project may consider is using servers hosted by Open Data Kit, which is accessible by utilizing ODK Aggregate. As an open-source Java application that stores, analyzes, and presents survey data collected from ODK Collect, it supports a wide range of data types and is designed to work well in any hosting environment, much like Google Drive (ODK, 2020). ODK Aggregate can also allow the server to be hosted on other cloud providers such as Amazon Web Service, DigitalOcean, or a custom cloud server. If the Ebony Project is well-established in its technological storage in the future, this option would prove to be very useful in the long run, as all data stored on ODK Aggregate may be organized and accessed according to the goals of the project. A personal server also increases the privacy and security of data stored; however, this requires a large number of expenses to generate and maintain. An I.T. personnel may also be required in case errors or bug fixes come up.

Lastly, a physical data storage device such as external computer hard drives may be used in the place for data storage. However, this is not recommended, as all online functionality and accessibility will be lost, resulting in the abandonment of the Open Data Kit tools.

Alternative Solutions

While we were conversing with experts and conducting our research for Open Data Kits, we came across several other applications and programs that provide similar functionalities. In terms of downloadable applications that support mobile data collection, Kobo Toolbox and Google Forms are ideal programs. Currently, KoBoToolbox is a set of mobile surveying tools much like Open Data Kit and is based entirely on the Open Data Kit system (despite having its own application and server), so all recording methods, editing processes, and software compatibility are the same. This can be very beneficial for mobile phones that run on earlier Android operating systems and cannot support the most updated version of ODK Collect. Google Forms is also a great alternative, as it is very easy to run. It offers utilities and functionalities that almost all survey and form-generating applications have, and is currently free to use and download, acting as a complementary companion to the Google Drive within the Ebony Project team. All data can be easily accessed and retrieved from the Google servers, making this storage option an efficient one.

There are other software that are worth considering as well. i-Tree offers a set of desktop and web-based applications as well, much like Open Data Kit. Based on the research and development of the US Forest Service, i-Tree consists of innovative applications which provide tools for advocates and managers that can quantify ecosystem services and benefit values of community trees and forests at multiple scales (i-Tree, 2020). Similar to Open Data Kit, it has a host of “Core Tools” such as i-Tree, MyTree, i-Tree Landscape, and i-Tree Design that can collect surveying data, upload and extract editable forms and perform necessary administrative tasks on computer systems. However, i-Tree specifically caters its programs solely for trees and forests, but not other factors such as plot size or GPS coordinates. It also has a support team that does not update i-Tree as frequently and cooperatively as the Open Data Kit community does, and usually requires additional help and external maintenance. Another application known as OpenTreeMap also provides very similar functions and applications much like i-Tree. However, this surveying software requires a yearly subscription estimated at USD $2,937 annually (OpenTreeMap, 2020). This may be too expensive when considering the funding from the Ebony Project and the UCLA Practicum teams. It is also a software that caters specifically for urban trees and their data, so the conversion of its functions towards the project might be complicated.

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Appendix

Table 8: List of stakeholders interviewed.

Stakeholder	Affiliation / Relevant Subject	Communication Method
Dr. Vincent Deblauwe	The Ebony Project coordinator and head ecologist	Video Call
Denis Sonwa	Researcher for the Center of International Forestry Research with sound knowledge in REDD+ operations in Cameroon	Video Call
Dr. Luke Powell	Conservation ecologist at the University of Glasgow	Video Call
Edith Guzman	Director of research for the Los Angeles-based nonprofit, TreePeople	Video Call
Dr. Zacharie Tchoundjeu	Agroforestry expert who created the Ebony Project's agroforestry model, ICRAF Regional Director for West and Central Africa	Video Call
Dr. Jonas Poofoun	Environmental Natural Resource and Development Economist from University of Lorraine; working with the Congo Basin Institute	Video Call
Suzanne Mogue	Assistant Project Manager GCRF TRADE Project; working with the Congo Basin Institute	Video Call
Aaron French	Ecologist with vast experience in the supply chain management of exotic fruits and international outlets; Sustainable Supply Chain & Operations	Video Call
Alexa Sheldon	2017-2018 Practicum Team and the current Program Associate for the global organization, IREX	Video Call and Email Correspondence
Dr. Kevin Njabo	Practicum Advisor, Assistant Adjunct Professor, Center for Tropical Research	Video Calls (Weekly Meetings) and Email Correspondence

Virginia Zaunbrecher	Practicum Advisor, Associate Director Center for Tropical Research, CBI	Video Calls (Weekly Meetings) and Email Correspondence

A) Tropical Deforestation and Reforestation

Appendix A.1: Successful Practices

Table 9: Successful strategies to combat deforestation.

Categories	Successful Practices	References
Governmental	❖ Protected Areas ❖ Indigenous Lands	❖ Armenteras et al. (2009); Clark et al. (2008); Clark et al. (2008); Burivaloca et al. (2019); Chakravarty et al. (2012). ❖ Armenteras et al. (2009); Nolte et al. (2013); Clark et al. (2008)
Ecological	❖ Promote landscape heterogeneity and biological diversity ❖ Weed control ❖ Muvuca, a strategy that demands that seeds from more than 200 native forest species are spread over every square meter of burnt and mismanaged land. ❖ Manage Selective logging, encourage less used species ❖ Proper land preparation ❖ Address underlying causes of forest loss and degradation (social too) ❖ Agroforestry	❖ Brancalion and Chazdon (2017) ❖ Le et al. (2013) ❖ Townsend (2017) ❖ Johns (1985) ❖ Zhang et al. (2002) ❖ Le et al. (2012); App (2004) ❖ Bishaw (2001); Le et al. (2013); Horstman (2017); Thacher et al. (1996)
Social	❖ Enhance and diversify local livelihoods	❖ Brancalion and Chazdon (2017); Le et al. (2012); Le et al. (2013); Epule et al. (2014)

	❖ Socio-economic incentives ❖ Socio-economic status and gender-based inequality, reduce CFG conflict and increase CFG cohesion ❖ Address underlying causes of forest loss and degradation ❖ Secure land tenure and equitable land tenure systems ❖ Secure property (tree and land) rights ❖ Long-term management planning ❖ Strong local leadership to enforce collective rules and risk involved ❖ Agroforestry ❖ Payment for environmental services provided by forests ❖ Long-term maintenance and protection of reforested sites ❖ Increase food security	❖ Le et al. (2012); Le et al. (2013); Thacher et al. (1996); Piotto (2003) ❖ Baynes et al. (2015) ❖ Le et al. (2012) ❖ Lopez-Carr and Burgdorfer (2013); Le et al. (2012); Thacher et al. (1996) ❖ Baynes et al. (2015) ❖ Le et al. (2012); Le et al. (2013) ❖ Le et al. (2012) ❖ Bishaw (2001); Le et al. (2013); Horstman (2017); Thacher et al. (1996) ❖ Burivaloca et al. (2019); Le et al. (2012); Le et al. (2013); Awono et al. (2014) ❖ Le et al. (2012); Le et al. (2013); App (2004) ❖ Le et al. (2013)

Appendix A.2: Unsuccessful Practices

Table 10: Unsuccessful strategies to combat deforestation.

Limitations	Unsuccessful Practices	References
Ecological	❖ Lack of successful seed banks ❖ Struggling growth due to unsuitable species selection ❖ Herds of grazing livestock on reforested land	❖ Holl (2002) ❖ Trac et. al. (2007; Piotto et al. (2003) ❖ Trac et. al. (2007); Zhang et al. (2002) ❖ Trac et. al. (2007)

	❖ Many of the planting locations were barren slopes and wastelands, not previously forested. ❖ Scarcity of water	❖ Epule et al. (2014)
Project	❖ Weak/absent program management ❖ Scarcity of leadership ❖ No long term planning ❖ Lack of incentives for locals, paid for initial planting, but not future care. ❖ Policy measures did not take into account the existing cultures and lifestyles of the communities inhabiting the areas ❖ Limited population or stakeholder participation ❖ Lack of funding	❖ Trac et. al. (2007) ❖ Epule et al. (2014) ❖ Thacher et al. (1996) ❖ Trac et. al. (2007) ❖ Trac et. al. (2007); ❖ Coca (2018) ❖ Epule et al. (2014) ❖ Horstman (2017)
Political	❖ Dated policies ❖ Corruption	❖ (Coca, 2018) ❖ (Sonwa, 2020)

B) Assessing Tropical Fruit Value Chains

Appendix B.1: Outcomes

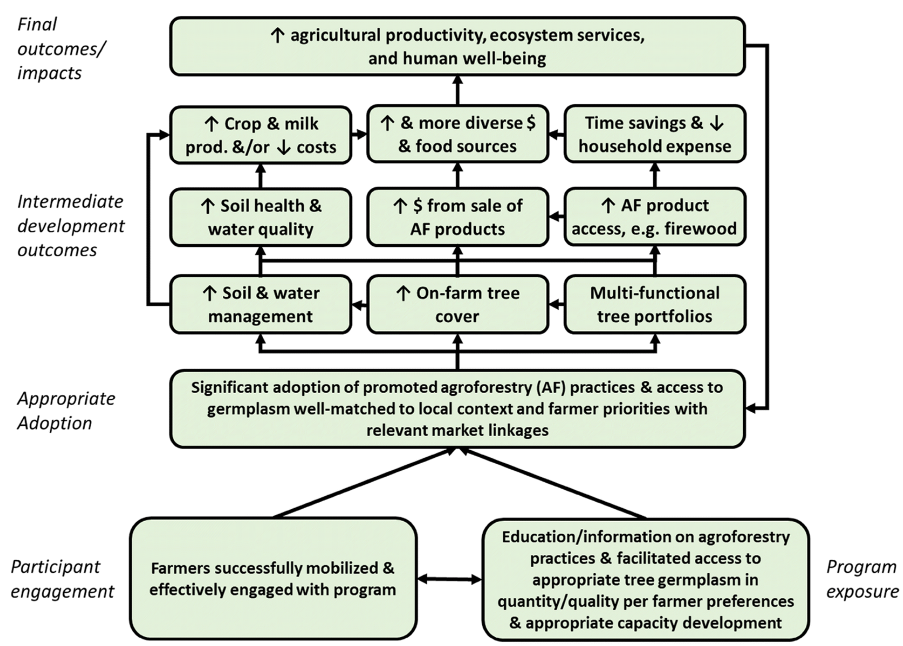

Figure 13: Outcomes from the implementation of agroforestry (Brown et al., 2018).

Appendix B.2: Nutrition

Variety	Energy	kJ/kcal	Moisture (g)	Ash (g)	Fat (g)	Protein (g)	Carbohy-drates (g)	Total fiber (g)
Pellejo[a]	519/124	77.40	1.10	1.37	1.37	1.37	3.70	3.73
Grande[a]	176/42	88.60	0.50	1.37	1.37	1.37	4.82	2.25
Verde[a]	757/181	72.40	1.10	1.81	1.81	1.81	5.89	0.40
Hass[b]	715/171[c]	77.30	1.30	1.60	1.60	1.60	5.60	----

[a] INNSZ, 1996
[b] Ortiz, A., 2003
[c] this value was estimated from the nutrient contents.

Figure 14: Nutrition of avocado variants (FAO, 2004).

Appendix B.3: Value Chain Stages

CHARACTERISTIC	BIRTH	EXPANSION	EFFICIENCY
Objective	Initial establishment phase of chain	Chain existing - expansion of sales targeted	Efficiency of activities targeted
Links between chain actors	No/low links between the chain actors	Growing integration of chain actors	Relatively tight network between chain actors
Sales	Low sales related to market potential	Relatively rapid rise in sales	Peak sales
Number of Customers	Low number of customers related to market potential	Rising number of customers	Peak number of customers
Profits	Profits relatively low – might be negative	Rising Profits	Peak Profits
Investments	Investment in market entrance	Investment in market expansion	Investment in process to improve efficiency

Figure 15: Stages of value chain and corresponding goals (Attaie, H., Fourcadet, O., 2003).

Appendix B.4: Value Chain Actors

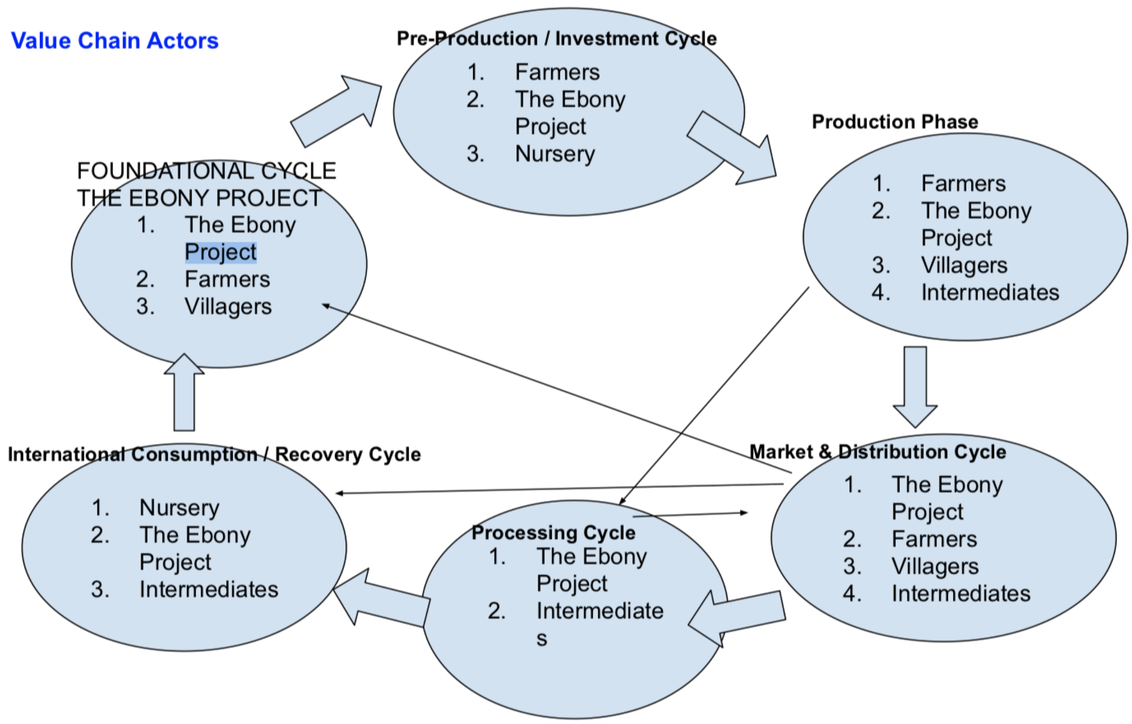

Figure 16: Actors of each step of the value chain of co-crop fruit/medicinal herbs.

Appendix B.5: Foundational Value Chain

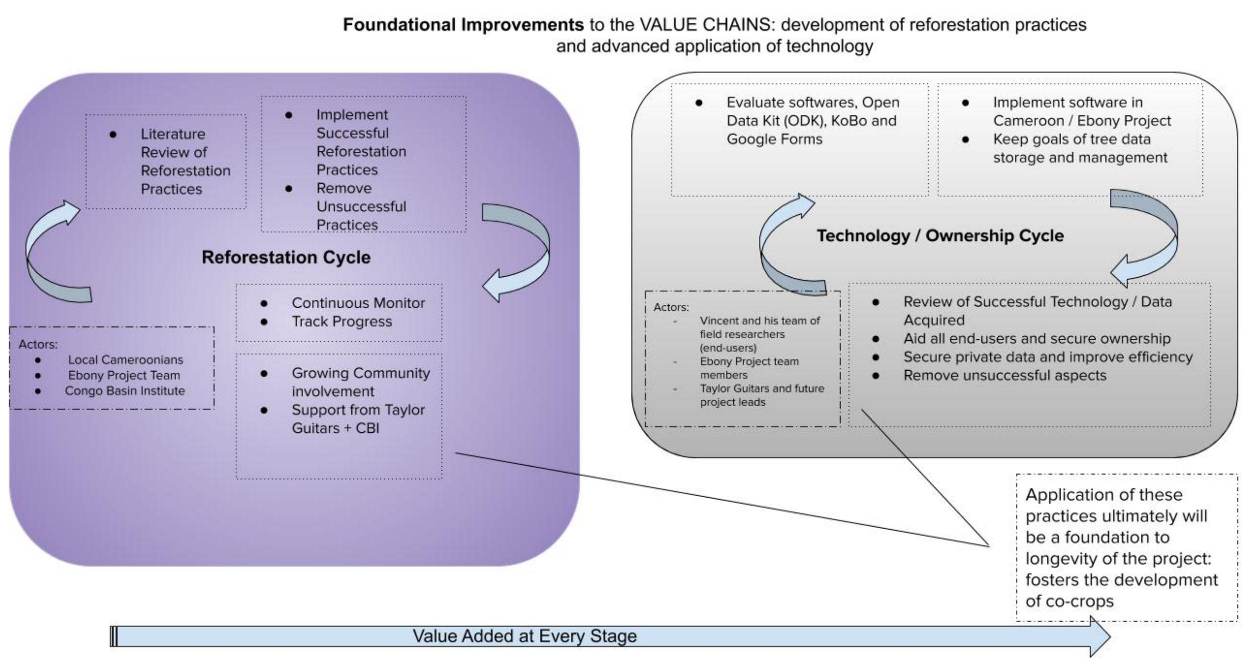

Figure 17: Foundational value chain (incorporation of reforestation efforts and surveying technology).

Appendix B.6: Absolute Income

	*Median 2005 (USD)**	*Middle 50 % (between quantiles 1/3) (USD)*	*Median 2010 (USD)**	*Middle 50 % (between quantiles 1/3) (USD)*	*Median Change 2005-2010 (USD)**
Project households	36.7[a]	14.7–117.3	73.3[a]	40.5–123.9	21.9[a]
Control households	41.6[a]	19.6–97.8	61.0[a]	31.3–93.8	18.6[b]

* Different superscripts indicate significant differences

Figure 18: Absolute income from djangsang commercialization (Cosyns et al, 2011).

Appendix B.7: Producer Characteristics

Type of producer	Number of producers	Share of total production	Type of quality standard adopted	Compliance and investment	Market destination
Certified producers for the US market	2290 (20%)	28%	Complex quality standards such as US-GAP, Eurep- GAP, Organic	Compliance with phytosanitary conditions and investment in fertilizers and irrigation systems	US and other foreign markets such as Japan, Canada and Europe
Certified producers for non-US markets	3545 (30%)	28%	One of each three producers adopts complex quality standard	One of each three producers compliance with phytosanitary conditions and investment in fertilizers and irrigation systems	Mainly supplying domestic supermarkets; limited export to Central America
Non-certified producers	5892 (50%)	44%	No quality standards	No compliance with phytosanitary conditions and no investment in fertilizers and irrigation systems	Small and medium-sized retailers in the domestic market
Total	11727 (100%)	100%			

Figure 19: Avocado producer characteristics in each marketing channel (Ramos, Sanchez, as cited in Coronado et al., 2015).

C) Incorporating Technology into the Silvicultural Booklet

Appendix C.1: Instruction Manual

For a comprehensive guide on downloading, operating and understanding the Open Data Kit software, we advise following the user documentation provided by the ODK community and developers.

A simple step-by-step manual for using the Open Data Kit tools for the purpose of the Ebony Project can be found here.

Appendix C.2: Additional Figures/Form Preview

The following appendix shows the build of a form, then the usage of the form on a mobile device and simulator. ODK Collect form "Farm Inventory Data" shown from the initial build in ODK, then on a mobile android device (Sony Xperia), and NoxAppPlayer (v3.0.2) android emulator.

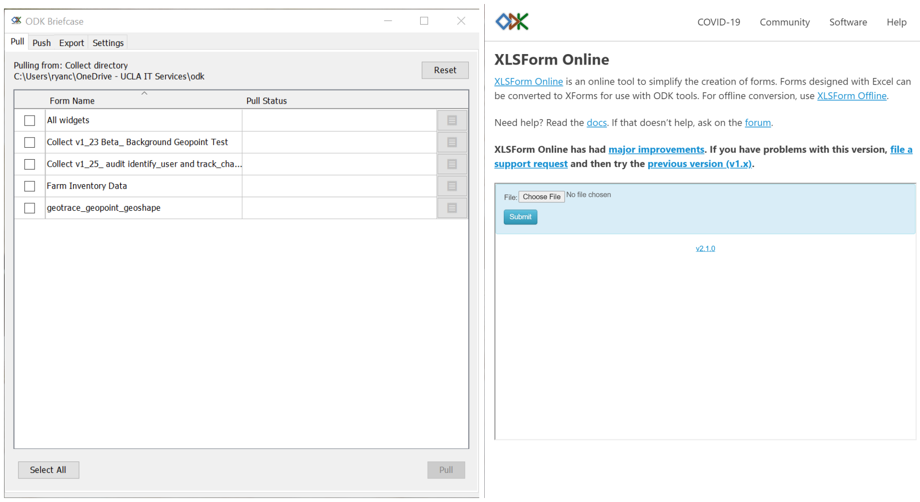

Figure 20: Interfaces for ODK Briefcase and ODK XLSForm used to design and build “Farm Inventory Data”.

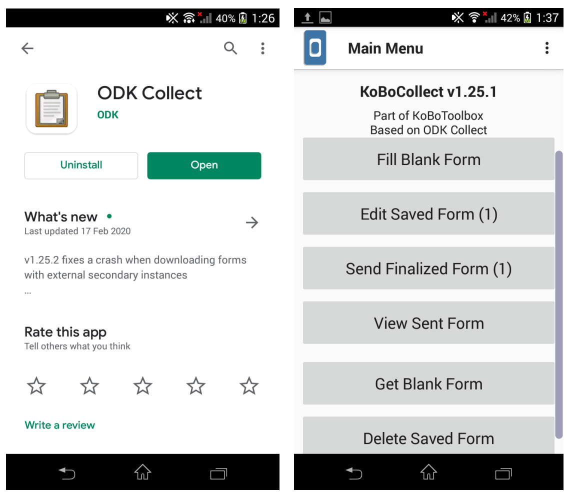

Figure 21: ODK Collect and KoBoToolbox launched on Sony Xperia V5 demonstrates similar functionalities on a mobile device.

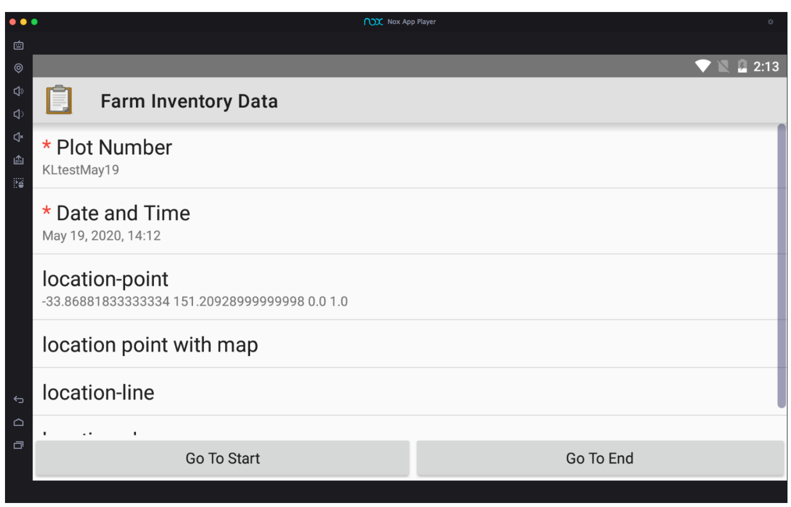

Figure 22: ODK Collect launched on *NoxAppPlayer* demonstrates functionality on an Android emulator.

Appendix C.3: Assessment Rubric for a Mobile Data Collection Platform

PLATFORM ASSESSMENT PROTOCOL			
Form Features	Question Type	Simple Fields: integer, double, free text	
		Data Fields (not a string)	
		Picture/Photo/Image/Signature	
		GPS Coordinates (points)	
		Select: Multiple/Single	
		Hints & Notes	
		Calculations based on previous answers (i.e. age based on today's date and date of birth)	
		Simple Constraints: (i.e. answer must lie between 1-10)	
		Custom Constraints: (i.e. Given sapling availability in Crelicam, only xyz species)	
		Skip Logic: (skip questions if they don't apply)	
		Require Question: (can't submit form without surveyor name)	
		External Lists: (use csv to fill in multiple choice)	
		Recurring Group, "child" questionnaire, sub-form: (for each sapling in plot PA1)	
	Metadata	Unique ID for submission	
		User or Device Indentifier	
		Submission Date and Time	
		Start/End Time of a Survey	
		User or Device Indentifier: Username or Device ID	
	Language & Charset	Supports UTF-8 encoding, (incl. right-to-left and non-Latin)	Advanced
		Allows only left-to-right languages or Latin characters	Basic
	Switch Language	Switch Language in Form: Switch from EN to FR if question not understood by surveyor	Advanced
		Switch Language on phone: EN to FR before survey and all languages sored and analyzed together on server	Basic
		One Language - one form	No
	Monitoring	Monitoring or Editing on the phone keeping track of edits or link different submissions to the same parent	Advanced
		Neither Monitoring nor editing on phone	Basic
Server Features	Filters	Filter by any field, allow several filters at a time	Advanced
		Filter by some fields, only one at a time	Basic
		No filters	No
	Charts/Graphs	Takes Filters into account when creating charts	Advanced
		Only very simple pie/car charts, no filtering	Basic
		No charts	No
	Map	Customize map using filters/categories	Advanced
		Only display GPS points	Basic
		No map	No
	View Images	Images accessible on server	Yes
		Images not accessible on server	No
	Edit	Edit any answer on server	Advanced
		Editing possible with exceptiion of certain fields	Basic
		No editing	No
	Delete	Deleting possible	Yes

Figure 23: Assessment rubric used to determine data collection platform, edited for the Ebony Project and adapted from *Benchmarking of Mobile Data Collection Solutions* (CartONG, 2017).

Appendix C.4: Application Feedback Form

1. Please indicate device and operating system used for the NURSERY data collection form:

2. Please indicate beginning battery level and end battery level:

3. Please indicate beginning usage time and end usage time, while filling out forms:

4. Please indicate number of form entries completed:

5. Were you able to fill out the form?

6. Were you able to upload your entries?

7. Did you experience bugs while filling out the form? If so, please describe the events leading up to the bug.

8. Did you experience bugs while uploading entries? If so, please describe the events leading up to the bug.

9. Was the form confusing? If so, how?

10. Did the form crash? If so, please describe the events leading up to the crash.

11. Was the form missing any features/questions?

12. Was the NURSERY FORM GUIDE helpful? Were any of the steps unclear? What clarification would you like made?