FEASIBILITY STUDY FOR THE EXPANSION OF THE TAYLOR GUITARS EBONY PROJECT

As called for in the Public-Private Partnership Agreement signed by The Government of Cameroon and Taylor Guitars on November 14, 2017 in Bonn, Germany

Report submitted by

The Congo Basin Institute and the International Institute of Tropical Agriculture (IITA)

to

The World Bank

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Version 1 – Preliminary Report

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SUMMARY

For decades, people and institutions attempting to conserve tropical forests have confronted a paradox: the most environmentally valuable use for land–pristine, mature forests–is also considered the least economically valuable. Despite this paradox, evidence shows that approaches that offer stable solutions, and effectively fulfill twin goals of human development and conservation, will be critical to maintaining tropical biodiversity and preventing increased carbon emissions. This Feasibility Study assesses whether one small intervention, The Ebony Project: (1) shows efficacy at meeting human development and conservation goals, and (2) can be scaled to larger impact. Broadly, this study suggests the project shows promise to do both. It recommends additional monitoring to better understand the long-term impact of the project, and makes recommendations for how to successfully scale it up.

The Ebony Project is funded by Bob Taylor of Taylor Guitars, and is a partnership where business, local communities, and researchers work together to conduct basic ecological research, protect a commercially valuable timber species, reforest degraded land, and improve rural livelihoods. In its first two years, the project has planted over 2,000 ebony trees, with plans to exceed 15,000 by the spring of 2020. The Ebony Project also supports national and regional efforts to conserve biodiversity, rehabilitate degraded forest, and sequester carbon.

On 14 November 2017 Taylor Guitars and the Cameroonian Ministry of Environment signed a Public-Private-Partnership (PPP) at the UN Climate Change Conference in Bonn, Germany. The agreement had three basic steps. First, Taylor Guitars would continue to fund the Ebony Project; second, the government of Cameroon would commission a feasibility study to better understand the opportunities and challenges to expanding the project into Cameroon's subnational REDD+ program area; and third, if the feasibility study concluded that project expansion was possible, then the government would seek to expand it. Taylor continues to fund the project and this document represents the second step, a feasibility study to analyze project expansion scenarios across Cameroon's REDD+ Emission Reduction Program (ER-P) area.

Signing of the PPP by respresentatives from the Cameroon Ministry of the Environment and Taylor Guitars.

Following a service agreement signed by the International Institute of Tropical Agriculture (IITA) and the World Bank, our team conducted a feasibility study from September to December 2018 to assess the opportunities for expanding The Ebony Project to other locations, species, and value chains. The study consisted of a desk analysis that covered six objectives: (1) develop a framework for expanding project locations; (2) develop guidance for selecting and propagating plant species; (3) identify logistics and infrastructure needs for expansion; (4) summarize high-priority gaps in ecological research expansion to other locations; (5) assess financial needs for potential scale; and (6) develop an impact monitoring plan. This feasibility study examined how the project has operated to date, and how it might be expanded to advance national and regional priorities like rural development, conservation, and reduced carbon emissions. Based on data collected and strategies developed during the two-year running

of the Ebony Project, we applied various modeling approaches to assess and develop a framework for expanding project locations as well as guidelines and infrastructure for propagating plant species in southern Cameroon. Key findings include:

- *High potential for expansion*: The ebony distribution model shows a high potential in the humid forest zone of Cameroon for ebony growth in both mono-modal and bimodal rainfall zones. It also shows that ebony can be paired with site-specific fruit and medicinal plant species.
- *Potential for carbon sequestration*: The agroforestry model promoted by The Ebony Project shows promise for long-term carbon sequestration, and may provide sequestration at twice the rate of natural growth humid tropical forest. Located in the core of the ecological niche model of ebony, the Emission Reduction Program (ER-P) area, in development by the Cameroon government and the National REDD+ Technical Secretariat, will strongly benefit from the expansion of the Ebony Project, especially in association with new cacao farms created on fallow lands or on the forest-savanna interface to serve the national REDD+ goals and rural development objectives of the Ministry of Economy, Planning and Regional Development.
- *Durable solution*: The Ebony Project is designed so re-forested land provides both medium and long term value to communities. If the standing forest is able to deliver value to forest adjacent communities as planned, this approach would likely be more durable than other approaches—i.e. the land is less likely to be deforested again. This suggests that while The Ebony Project approach requires more community engagement (and thus more resources), it is more effective in medium and long term than “lower touch” approaches. Even with this additional engagement, financial analysis and modeling showed that about US$1,000,000 would support the planting of approximately 36,000 trees (and up to 54,000 trees) comprising 50% ebony species and 50% of locally valuable fruit trees in seven years, and would result in approximately 360 ha (up to 540 ha) of reforested land.
- *Importance of scientific research*: Original ecological research has provided critical new information important to the sustainable management of the species, including an enhanced understanding of the species natural range and new insight into the threat played by the poaching of key mammalian seed dispersers. Additional scientific research could help quantify the level of biodiversity supported by the project and better assess the durability of the Ebony Project approach verses other reforestation projects.
- *Community selection*: The strong community engagement being undertaken as part of the ongoing Ebony Project at Ekombite (South Region) and Somalomo (East Region) has led to the formulation of the general style of collaboration with farmers and procedures for skill transfer and plant management/care. Expansion would require a formalized approach to community selection, and an initial survey instrument may be a useful tool to select new communities and set expectations for the project.
- *Assessing outcomes*: The Ebony Project should use any future expansion scenario as an opportunity to move towards a more sophisticated monitoring and evaluation approach. The current nature of existing funding and project scale makes it difficult to accurately assess the project’s medium- and long-term impact.

The Ebony Project has shown promise as an effective way to improve rural livelihoods, protect a vulnerable species, and collaborate successfully with the private sector. The expansion of the Project would clearly support national and regional efforts to conserve biodiversity, rehabilitate degraded forest, and sequester more carbon. Monitoring and evaluation plans developed in the present document will be used to evaluate the impact of the project on the target communities, the timber industry, and the environment.

Background

In November 2011, Taylor Guitars and Madinter International purchased the Crelicam ebony mill based in Yaoundé, Cameroon. Through Crelicam's operations, they seek to emphasize in-country value-added processing, and the export of legal and socially responsible parts for musical instruments. The parts are made from West African ebony (*Diospyros crassiflora* Hiern), a tropical hardwood species which in Cameroon can only be sourced from the Non-permanent Forest Estate and for which the government determines annual quotas based on requests.

In 2016, Taylor Guitars partnered with the Congo Basin Institute (CBI) in Yaoundé to develop a community-based livelihoods program focused largely on West African ebony (*D. crassiflora*).

The Project objectives were to:

- Work with communities to create a scalable program for the sustainable production and stewardship of ebony seedlings in rural areas.
- Model West African ebony distribution to better understand sustainable harvesting rates and appropriate planting areas.
- Understand the basic ecology of ebony necessary to enhance natural reproduction and dispersal, and test restoration approaches to determine the most successful methods.
- Test alternative propagation approaches, including tissue culture, to identify optimal conditions for cultivating ebony.

The long-term goal of The Ebony Project is to create sustainable populations of West African ebony, provide a source of meaningful income for local communities, and serve as a test bed for scalable community-based rainforest restoration efforts involving other hardwood species across Central Africa. The ongoing Taylor-funded Ebony Project has an initial target to plant 15,000 ebony trees and is currently on pace to surpass this goal by 2020.

The Ebony Project model has garnered interest from several important governmental and inter-governmental institutions, raising questions about the possibilities for expanding the project into other geographies and land-use settings. The PPP signed in Bonn, Germany was, in part, facilitated by the World Bank's Forest Carbon Partnership Facility, German Development Bank (KfW), and the REDD+ Technical Secretariat in Cameroon. Additional actors such as the United Nations Food and Agriculture Organization (FAO) and U.S. Forest Service International Programs have also visited project areas and remain peripherally engaged. Additionally, the government of Benin is in discussions with the Congo Basin Institute about implementing the project model in Benin, although likely substituting ebony for another commercially valuable tropical hardwood species, as ebony does not grow in Benin.

Study Objectives

This feasibility study examines the challenges and opportunities of scaling up the existing project and includes:

- *Objective 1: Develop a Framework for Expanding Project Locations:* Under the existing program, current and planned project sites are all in southern Cameroon, all operating at a community level, and all in areas where West African ebony naturally occurs. However, the basic model has the potential to operate throughout Cameroon's REDD+ project area, and throughout Central and West Africa. Further, the project can be adapted to different land use categories such as larger scale cacao and coffee production areas, with different locations possibly focusing on the restoration of different site-appropriate hardwood species and mix of locally known fruit and medicinal plants. As such, this feasibility study identifies and examines associated pertinent issues.

- *Objective 2: Develop Guidance for Selecting and Propagating Plant Species:* West African ebony (*D. crassiflora* Hiern) is just one of many valuable African hardwood species that could be incorporated into community-based agroforestry. It was selected because Taylor Guitars and its partner, Madinter International, own an ebony mill. However, other species that grow within Cameroon's subnational REDD+ program area such as bubinga (*Guibourtia arnoldiana*) and sapelli (*Entandrophragma cylindricum*) are of considerable commercial interest, and incidentally also used for musical instruments. Accordingly, this study will assess not only the expanded planting of West African ebony but also that of other appropriate hardwood species to better understand which are most appropriate in different geographies, and which provide enhanced intercropping values in different applications.

  Furthermore, Cameroon's subnational REDD+ area is also home to significant cacao, coffee, and oil palm industries which may themselves benefit in the long run from being co-cropped or grown in a less monocultural, more diverse shade environment. Accordingly, the feasibility study will examine key aspects of the Ebony Project to explore their applicability to other smallholder farmers and, in some cases, a more industrial setting.

- *Objective 3: Identify Logistics and Infrastructure Needs for Expansion*: Expanding the Ebony Project will require increased capacity in plant propagation and the identification of additional planting areas. This objective will examine the opportunities and obstacles of expanded plant propagation in increasingly remote rural settings, the establishment of hub-and-spoke regional nurseries and the maintenance of plants over variable periods, and ultimately the transport of individual plants into the field. The state of knowledge of plant propagation via in vitro propagation will also be examined which holds the promise of mass produced, healthy plantlet production from selected plant material.

- *Objective 4: Summarize High-priority Gaps in Ecological Research*: While much is known about the ecology and propagation of high value native fruit and medicinal trees the same cannot be said for most hardwoods in the Congo Basin. As is the case with most African timber species, very little was known about the ecology and propagation of *D. crassiflora* when the Ebony Project began in 2016. There are no sustainable agroforestry or plantation-based production models of *D. crassiflora* in Central and West Africa. Although much is still unknown, in only a few short years basic research conducted under the auspices of the Ebony Project has begun to unlock essential basic ecological secrets related to phenology, pollinators, seed dispersers, and environmental requirements that influence growth and reproduction of the species. Such simple and basic research is essential for the successful reintroduction of ebony and other valuable hardwood species, for developing future value chains and ultimately allowing for larger integrative rainforest restoration and sustainable forest management. This objective will examine existing research efforts and describe high-priority gaps in existing knowledge.

- *Objective 5: Assess Financial Needs for Potential Scale*: To date, The Ebony Project has received support from one philanthropic source, an annual personal gift from Bob and Cindy Taylor. This source of funding is not designed to support a large scale up of the project as envisioned in the PPP. To expand, project will require additional institutional support based on its potential for biodiversity conservation, community development, reforestation, and ecosystem services such as carbon sequestration. This section will focus on determining the costs of scaling the project.
- *Objective 6: Develop an Impact Monitoring Plan*: If the Ebony Project expands, monitoring, evaluation, and learning approaches will need to become more robust. Currently, the project measures mostly *output* metrics—i.e. the products and services delivered by the project like the number of nurseries created or trees planted—and incorporating lessons learned through an informal mechanism. This section will create a plan for more robust monitoring, evaluation, and learning that better tracks the *impact* of the project, like how long the land stays forested, and its impact on biodiversity and carbon sequestration.

The resulting feasibility study will act as a roadmap for potential expansion of the project to additional communities, hardwoods, and value chains.

OBJECTIVE 1: DEVELOP A FRAMEWORK FOR EXPANDING PROJECT LOCATIONS

The Ebony Project currently operates in two communities in central Cameroon, and will expand to three to five more in the coming 12 to 18 months. As currently funded, the project is capable of supporting no more than 10 project sites at any given time. The team selected existing and future sites based on several informal criteria including their distance from Yaoundé where Crelicam and CBI are located, locations where ebony was likely to thrive, and because of prior or existing successful working relationship with CBI. In each circumstance, and in close cooperation with Crelicam, CBI worked directly with each community to reach an agreement on the scope and scale of each site-specific project. CBI also provided training and materials to help participants build a plant nursery, and provided capacity building on agroforestry techniques as needed.

The Ebony Project model has the potential to operate throughout Central and West Africa, with different locations focusing on restoration of different hardwood species and a diverse mix of local fruit and medicinal plants. However, significantly scaling up the project will obviously require working with a large number of communities inevitably raising questions about selection criteria. The current approach for selecting both project sites and local partners is based first and foremost on the region's suitability for growth of the target species (i.e., *D. crassiflora*) and existing positive working relationships between Ebony Project team members and specific communities. This has proved an effective approach given the size of the existing project, but would be unworkable at scale. As such, this feasibility study identifies and examines, based on the project experience and a literature review, key community traits that have led to project success to date. To develop a suitable framework for expanding the Ebony Project model to other locations, this study analyzes these traits to develop a community selection approach that will allow efficient selection of an expanded number of communities.

The emerging focus on the jurisdictional approach within REDD+ increases the attractiveness of The Ebony Project's agro-forestry centric design and provides a pathway to further expand it via the carbon credit market. For example, recent studies (Alemagi et al. 2015; Vaast and Somarriba 2014) have shown that intensification of a cacao farm diversified ecologically with fruit trees, food crops, non-timber forest products and/or timber species such as ebony can enhance carbon stocks to the level similar to that of an older secondary forest (Silatsa et al. 2016). It could also contribute to a reduction in carbon dioxide emissions, and increase cacao productivity combining to create multiple income streams for the farmers while reducing the need to clear additional land.

1.1: Assessment of Existing Community-based Operations

Carbon sequestration

Ebony's potential for carbon storage was assessed using data from 306 trees that were planted 30 years ago in cacao farms in the locality of Ekombite (Mbalmayo). Diameter at breast height (DBH) and tree height (H) were measured in the field and the carbon stock per tree was estimated using Chave et al. (2014) allometric equation for tree biomass estimation (with ebony specific density of 0.86). This data was then used to build a project carbon scenario based on the introduction of 45 ebony trees in an improved and diversified cacao-based agroforestry comprising a maximum of 1,110 useful tree species per hectare. The statistical summaries are shown in Table 1. All the variables were positively skewed with coefficients varying between 0.06 and 2.09. This means that the mean of each variable was greater than the median.

Table 1*: Summary statistics of DBH, H, and C stock from 30-year-old ebony plantation in Ekombite.*

	DBH (cm)	H (m)	C stock (tons/tree)
N	306	306	306
Minimum	1.3	1.6	0.16
Maximum	24.2	17.4	251.5
Interquartile range	7.4	4.7	45.97
Median	8.32	8.4	17.79
Sum	2,762	2,482	10,217
Arithmetic mean	9.03	8.12	33.39
Geometric mean	7.54	7.39	12.52
Standard deviation	5.08	3.16	42.56
Variance	25.8	9.97	1,811.4
Coefficient of variation (%)	56	39	127.5
Skewness (G1)	0.64	0.06	2.09
Kurtosis (G2)	-0.3	-0.5	4.97

The coefficients of variation of the three variables are high, varying from 40% to about 130%. This implies that the low growth rate of ebony trees is also strongly impacted by other local factors such as soil fertility and farm management. During the 30-year period, the biggest ebony tree had a DBH of 24.2 cm as compared to an average of 9 cm; and the tallest tree had a height of 17.4 m as compared to an average of 8.12 m. The carbon stocked in these trees as estimated using Chave et al (2014) allometric equation for tree biomass estimation (with a dry wood density of 0.86 for ebony), showed a total carbon stock of 10,217 tons for the 306 trees measured, given an average of 33.4 tons/tree. This implies that a one-hectare land planted with 40 to 100 ebony trees would be able to store thousands of tons of carbon stock after 30 years while continuing to grow.

While ebony's slow growth makes it difficult to develop a functional agroforestry model, its dense wood and slow growth rate means that it sequesters large amounts of carbon for longer periods of time than most other trees species. As a result, the Ebony Project has the potential to sequester significantly more carbon than a standard cacao-based agroforestry approach. Figure 1 demonstrates this effect. Using Chave et al (2014) allometric equation for tree biomass estimation (with ebony specific density of 0.86), an introduction of 45 ebony trees in an improved and diversified cacao-based agroforestry comprising a maximum of 1,110 useful tree species per hectare would be able, at maturity, to sequester more than 450 metric tons of carbon/hectare (tC/ha) in tree biomass. Meanwhile, in this central African region the mode of carbon of a mature undisturbed forest is around 250 t/ha.

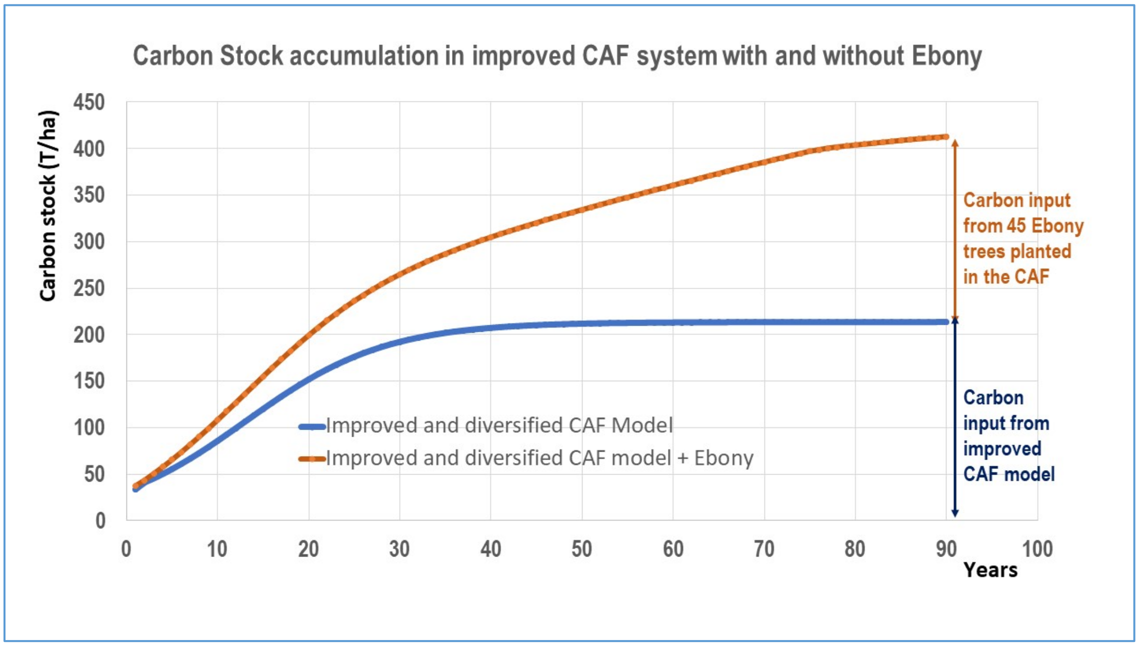


Figure 1: Estimated carbon stock accumulation in the CAF model (C) with 45 ebony trees/ha in figure 10. The model can stock up to 450 TC/ha.

1.2 Expansion Plan to Additional Community-based Operations

The Ebony Project collected both qualitative and quantitative data to assess what makes the project successful at the community level. This information is used to assess what makes a successful participant community and to develop guidelines for future selection. This information will prove useful to any such project expansion as it will help identify and select appropriate participants after exhausting previously existing relationships.

Ultimately, expanding the existing project to a larger scale effort will require a range of approaches when vetting prospective new communities. Experience in the existing villages, as well as existing literature provides considerable guidance identifying traits to look for in potential participant communities. This section summarizes those factors, suggests how we may effectively and efficiently screen for those factors, and notes where there are likely to be early indicators that can be used in monitoring the success of new communities.

1.2.a. Understanding from existing programs and literature

The Ebony Project employs a participatory agroforestry approach based on efforts by the World Agroforestry Center (ICRAF). ICRAF's work has demonstrated that agroforestry can be an effective approach to diversify farm incomes and in some cases increase crop yields. (Tchoundjeu et al 2010, Asaah et al 2014). ICRAF promotes their agroforestry approaches through Rural Resources Centers (RRCs) (Degrande et al 2015). The RRCs were established over the course of years, and provided a range of services including agricultural inputs, connections to microfinance, and training on topics ranging from tree propagation to bookkeeping (Degrande et al 2015).

While ICRAF's work with the RRCs provides important background knowledge and improved varietals and techniques that inform The Ebony Project, the project itself is not a recreation of the RRCs. Indeed, each serves different goals, and the RRCs require a longer-term and more intensive investment than is appropriate for The Ebony Project. There is also some evidence that RRCs are most successful in the savannah zone, and in areas with a history of tree domestication (Tchoundjeu et al 2010). We recommend The Ebony Project continue to benefit from the rich history of the RRC program in regard to:

- improved fruit and medicinal tree varietals
- plant propagation techniques and training
- methods for low-cost nursery construction

Based on the RRC program and The Ebony Project's different goals and approach, we do not recommend that The Ebony Project plan to transition participating communities to permanent nurseries. If individual communities show strong interest and aptitude in transitioning to private operations as they phase out of the project, there is a possibility for some transitional support. However, long term operational nurseries should not be added as a goal for The Ebony Project.

1.2.b. Ecological factors

Does ebony grow well?

A significant expansion of the Ebony Project model focused on *D. crassiflora* would require research beyond what has been accomplished to date to further understand where reintroduction or restocking would be most likely to succeed. The same would hold true for any possible substitute species such as bubinga (*G. arnoldiana*) or sapelli (*E. cylindricum*). Fortunately, thanks to work conducted by the existing Ebony Project, the historical geographical distribution of these species is already somewhat understood. Geographical coordinates of known populations including: (i) data from Crelicam and other private timber companies; (ii) herbarium specimens collected during the project; (iii) data shared by Kew Gardens and Botanic Garden Meise; (iv) the RAINBIO dataset, a comprehensive database of geo-referenced records of vascular plants in Africa (Dauby et al. 2016); (v) tree inventory data from old-growth forest without signs of recent human disturbance (Slik et al. 2015); and (vi) the ebony inventories made for the project in the Dja Biosphere Reserve have provided the first such range map for *D. crassiflora*.

The team used this type of information, and more, to produce an ebony distribution model across its native range (Figure 2). This work was extensively reported in a technical submission to the IUCN committee re-evaluating the species' conservation classification. With newly gathered ecology data, the distribution model will be updated and estimated inventories of the species improved. The ebony distribution model shows a high potential of the humid forest zone of Cameroon for ebony growing including both monomodal and bimodal rainfall zones.

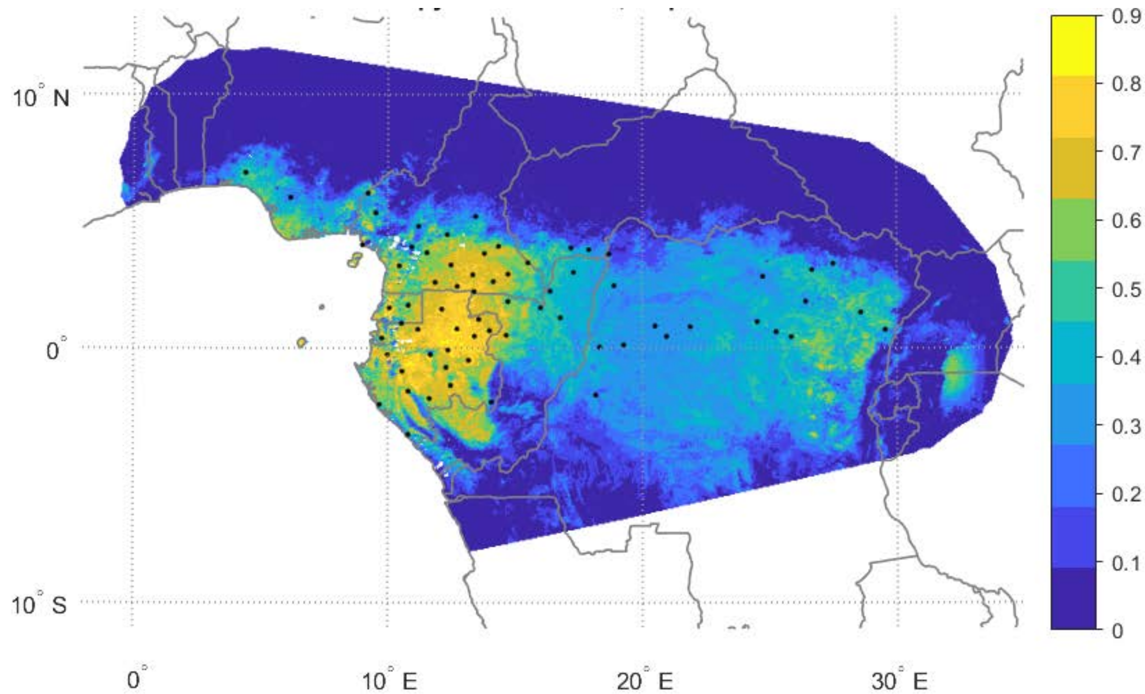


Figure 2: D. crassiflora *suitability map built using MaxEnt algorithm*. Black dots represent 68 known localities used for model training.

Accordingly, we recommend that any project expansion focused on ebony should take place within the areas in yellow and green on the map (Figure 2). In similar fashion to the process that produced the first ebony range map, collating data from a diversity of sources such as private timber companies, international collections such as Kew Gardens, herbarium collections that in some cases date back to the 19th century, RAINBIO dataset, and of course ongoing basic field work could easily create a similar such analysis for other commercially valuable hardwoods. Such range maps largely do not exist but should be considered baseline information for any rainforest restoration or carbon sequestration project.

Do other potentially valuable hardwood species grow well?

West African ebony is just one of many valuable African hardwood species that could be incorporated into community-based agroforestry. In fact, it was selected for the simple reason that Taylor Guitars and their partner Madinter International own an ebony mill and Taylor underwrites The Ebony Project. However, other species that grow within Cameroon's subnational REDD+ program area such as bubinga (*Guibourtia arnoldiana*) and sapelli (*Entandrophragma cylindricum*) have large scale commercial interests. Accordingly, this objective assesses other appropriate hardwood species that could augment or even substitute for ebony intercropping within the ER-P project area.

Bubinga is the common name given to three *Guibourtia* species of Central African evergreen rainforests that are popular for their beautiful hardwood (*G. demeusei*, *G. pellegriniana*, and *G. tessmannii*). None of the three species have been evaluated with regard to the IUCN red list. However, *G. tessmannii* and *G. pellegriniana*, are found at very low densities in terra firma forests. Both are light-demanding, non-gregarious species with typically low regeneration rates. *G. tessmannii* is found in the Lower Guinean region of West Africa (Gabon, Cameroon, Equatorial Guinea), and *G. pellegriniana* is restricted to the littoral forests of the same area (Figure 3). Both species are remarkably similar except for the flower pedicel, the structure of their bark, and wood anatomy. These subtle differences make it difficult even for experts to distinguish the trees and the wood from each species. *G. demeusei* is more widespread and is locally abundant along large rivers and swampy valleys. Its range extends well into the Congo Basin. Its wood, while of poorer quality, is still confused with the wood of the other two bubinga species on international markets.

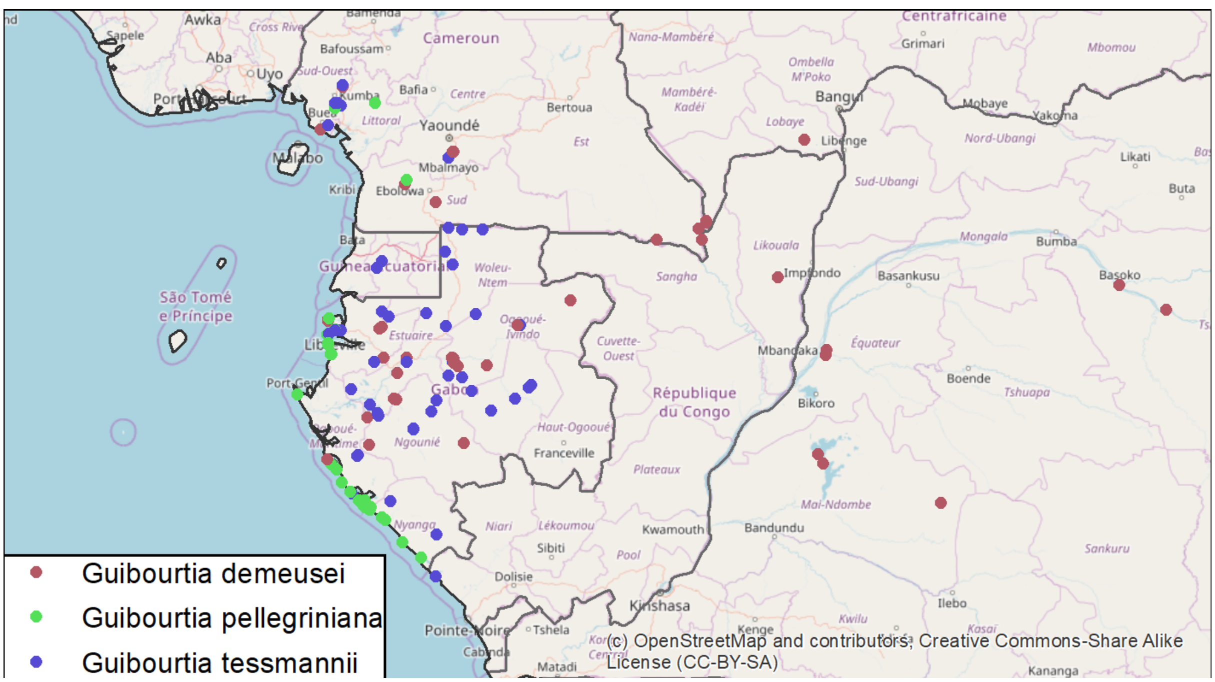


Figure 3: Known occurrences of the three Guibourtia *species.*

There is serious concern about the increasing exploitation of bubinga in part due to the fact that it has gradually become an alternative for Asian rosewood *(Dalbergia* spp.) which is highly prized for hongmu furniture in China and Vietnam. The word "hongmu" means "red wood" in Chinese, and the term refers to a range of red-colored tropical hardwoods, used to produce a certain style of furniture. In fact, the skyrocketing demand for hongmu species was the driving force behind the October 2016 decision at the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) to list the entire *Dalbergia* genus (except for Brazilian rosewood, which was already listed in Appendix I), as Appendix II. Growing interest in bubinga in the

Chinese markets has led to increased exploitation of the species across its native range, particularly Gabon and Cameroon. Today, it is the most expensive wood from the tropical rainforests of Central Africa, by a considerable margin.

On 9 November 2012, Ministerial decision n°2401/Minfof/Cab suspended the legal exploitation of bubinga until its inclusion in the CITES appendix. In January 2017, the species was placed on Appendix II of CITES at the request of Gabon and France. Although not proven to be currently threatened with extinction, *G. pellegriniana* and *G. tessmannii* were included in this appendix because of the risk of their being threatened if their trade is not subject to strict regulation (Article II (2)(a) & Resolution Conf. 9.24, Rev.Cop16). *G. demeusei* is similar in appearance to the other two, but it more widespread and abundant. It was included because enforcement officers who encounter specimens of the two former species are unlikely to be able to distinguish between them (Article II (2)(b) & Resolution Conf. 9.24, Rev.Cop16). Regardless, any effort to responsibly manage the species and it someday removed from its current CITES listing will benefit from an increased ecological understanding of the species as well as the existence of an active restoration initiative, such as the ebony project.

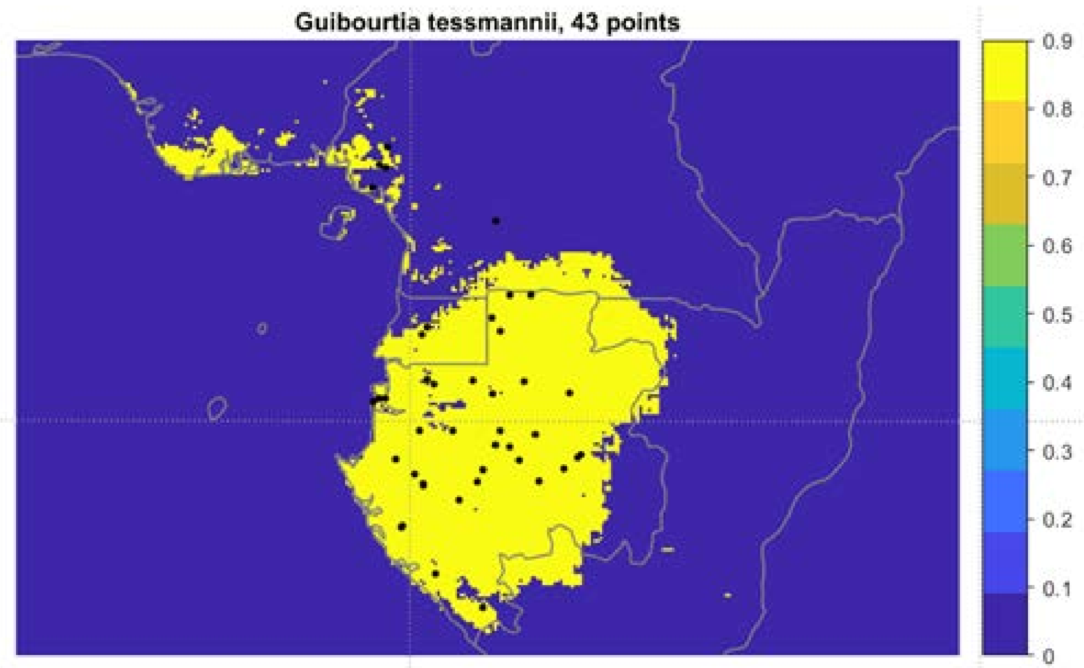


Figure 4: G. tessmannii *suitability map built using MaxEnt algorithm*. Black dots represent 43 known localities used for model training.

Sapelli, *Entandrophragma cylindricum*, is a widespread species over West and Central Africa (Figure 5). It is a major source of African hardwood, and has growth rates among the slowest in its genus. Although last evaluated over 20 years ago, IUCN considers the population to be "vulnerable," and it is increasingly being exploited heavily throughout its range. Genetic erosion caused by the large-scale depletion of mature individuals from populations has also taken place in some countries (Hawthorne 1998).

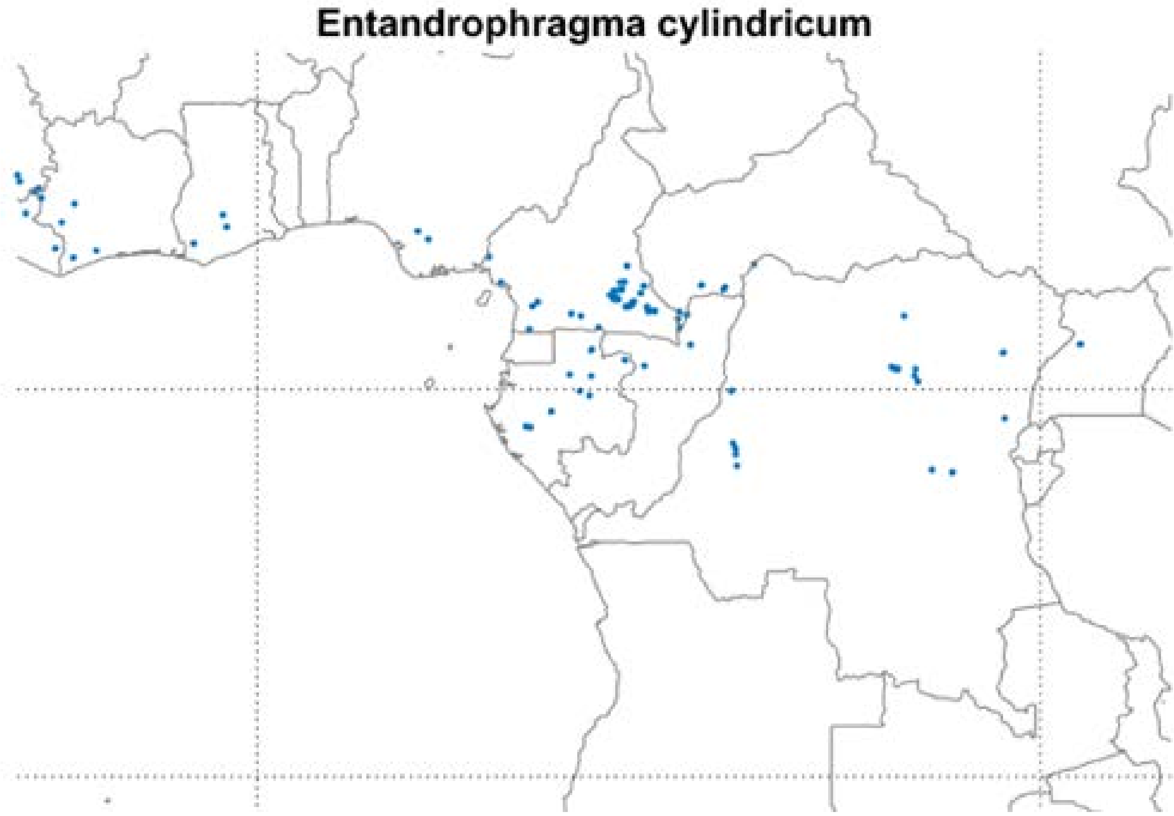


Figure 5: Known localities for E. cylindricum.

1.2.c. Geographic factors

Distribution models for a species native range are instructive in establishing broad boundaries for a potential scale up, but additional metrics are needed to narrow the scope to a more manageable level. For example, key overlays would be national-level planning for the Reducing Emissions from Deforestation and forest Degredation (REDD+) and the role of conservation, sustainable management of forests, and enhancement of these existing carbon stocks. Cameroon's Emissions Reducation-Program Implementation Note (ER-PIN) was approved in July 2016, and covers much of the southern area of Cameroon (Figure 6). The ER-PIN program area overlaps extensively with the ecological niche model of ebony, as a result almost anywhere in Cameroon in which the Ebony Project operates will also serve the goals of the national REDD+ effort.

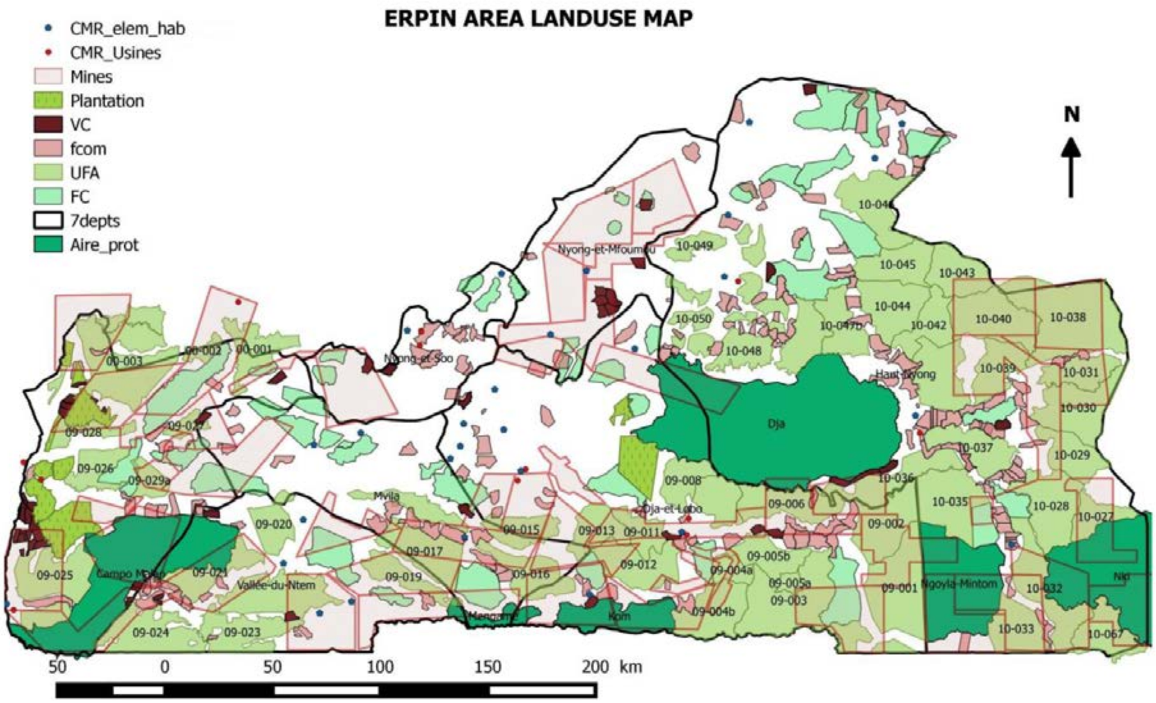


Figure 6: Land use map of ERPIN (Emission Reduction Project Idea Note).

Aside from the extensive overlap between the REDD+ program area and ebony's natural range, the Congo Basin Institute has identified four geographic attributes that will be important in the selection of future participating communities:

1) *Land availability*: The project focuses on rehabilitating degraded land; to date mainly secondary forest, fallowed farm land, and monocultural agroforestry sites. Selecting areas that have high proportions of these land types will make project expansion more efficient and effective. To assess the distribution of degraded land in Cameroon, we calculated the area considered (i) cropland and (ii) cropland-vegetation mosaic, from the ESA CCI Land cover 2015. ESA CCI Land Cover is a 300 meters resolution global land cover data derived from satellite products. We summarized the surfaces of cropland, forest and urban area by department and region. The map in Figure 7 shows the actual distributions within Cameroon. Habitat that is ideal for ebony growth (see Figure 2), is largely further east than areas with the highest proportion of cropland. However, the current project site of Ekombite in the Dja et Lobo division is in an area of relatively high cropland density, and the map to the left in Figure 7 demonstrates that there are pockets of cropland density throughout the natural range of ebony. The second site, Somalomo in Haut Nyong division, is located in such an area. Project expansion that focused on the areas of these two divisions that show high levels of cropland would likely have sufficient degraded land to justify project intervention.

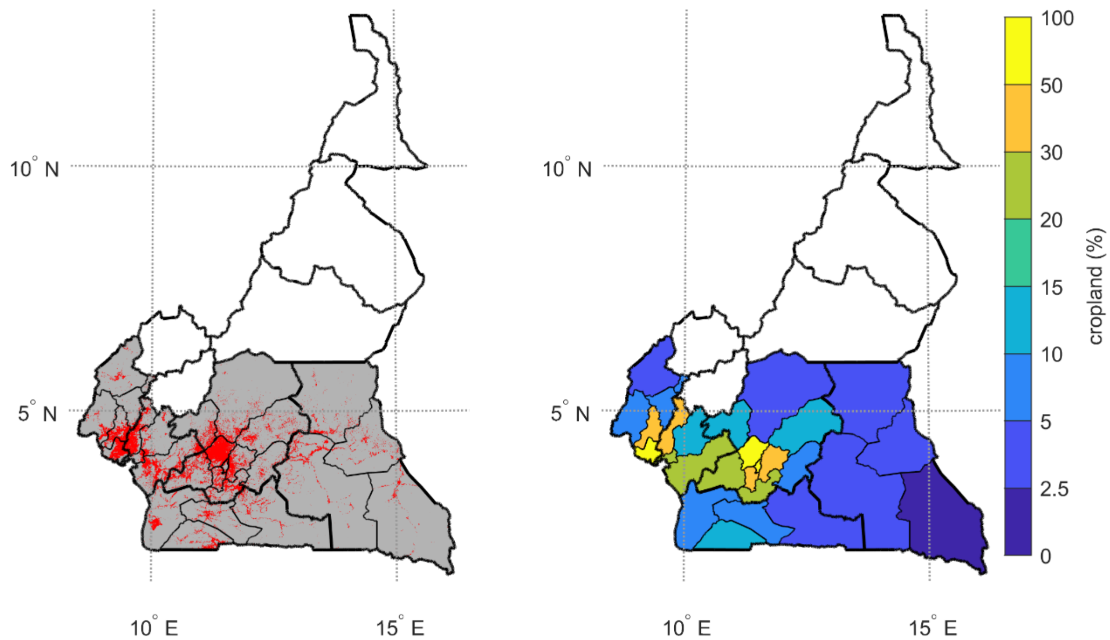
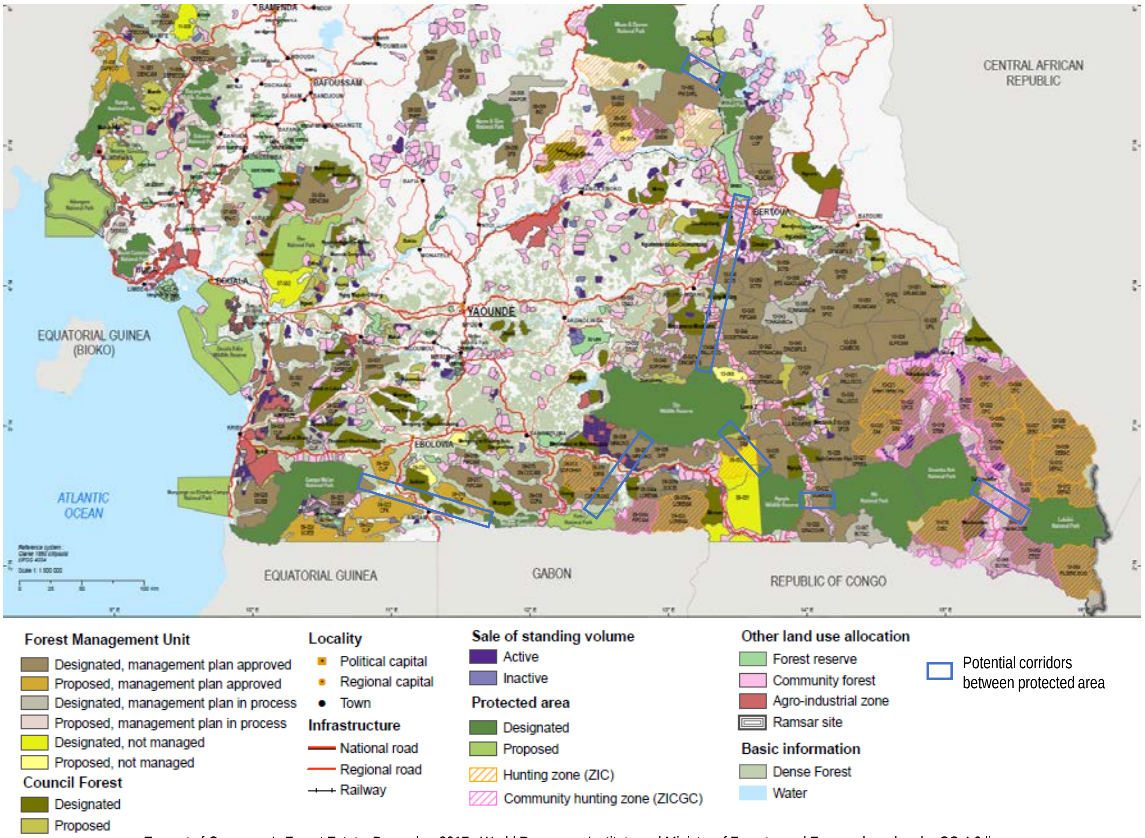


Figure 7: Distribution of croplands in the forest area of Cameroon. Actual distribution of cropland (red) and other land covers (gray) is shown on the left panel. The proportion each department covered by cropland is shown on the right. The five regions shown in white are not suitable for the growth of Diospyros crassiflora and therefore not included in the analysis. Administrative boundaries of regions and departments are shown as black lines.

2) *Conservation value of land*: While not a prerequisite to participation, strategic selection of communities or project sites in areas of particularly high conservation value would increase the ability of the project to contribute to sub-national, national, and even regional conservation priorities and also meet the objective of a number of international conventions such as the Convention on Biological Diversity (CBD) and the United Nations Framework Convention on Climate Change (UNFCCC). It will also limit the likelihood that important commercially traded timber species are downgraded on the IUCN Red List or listed on the Convention for International Trade in Endangered Species (CITES). This could be achieved, for example, by focusing on buffer zones or potential conservation corridors between protected areas. There are numerous maps of priority areas based on conservation of specific species, various measures of biodiversity, and socioeconomic restrictions. The Congo Basin Institute recently participated in a project that mapped the vulnerability of a range of species under climate change, and compared those results to endemism, species richness, and land use in Cameroon. Local participants from government agencies, NGOs, and research institutes then debated priority conservation areas. Participants focused on connectivity between protected areas, and particularly creating east-west and north-south corridors that allow populations to move in response to climate change. For example, a corridor between Campo Maan in the west, Mengame and Kom in the south, and the Dja, Ngoyla, Nki, Boumba Bek, and Lobéké parks in the east would create an east-west corridor through the heart of ebony's range. Connecting the eastern parks to Deng Deng and Mbam et Djerem further north

would create a critical north-south corridor (Figure 8). By focusing on these prioritized corridors, the Ebony Project could assist in improving the ability of habitat in these areas to support biodiversity.



Excerpt of Cameroon's Forest Estate, December 2017. World Resources Institute and Ministry of Forestry and Fauna, shared under CC 4.0 license

Figure 8: Map of forest estate in ERPIN area from December 2017 with potential corridors.

3) *Proximity to other participating communities or project sites*: Clustering participating communities and project sites together provides efficiencies across many aspects of the project. Such grouping cuts the logistical and personnel costs for each community, making the project more cost effective while facilitating more community-to-community support networks that may ease implementation and facilitate local market development. Project site proximity may also enhance conservation benefits by providing more high-quality habitat close together. Clustering may also assist with community uptake, with nearby villages more likely to hear about the project, witness results, and express interest in participating. Based on our current experience, we suggest cluster villages within 20 km of each other, possibly with a center node or anchor.

4) *Connection to markets*: Proximity to markets will facilitate economic benefits in participating communities through sale of the locally valuable fruit and medicine products, the planting of which is an integral aspect of the project. Conversely, the project seeks to impact disadvantaged communities, which often have poor market access. Thus, while proximity to market should not be a requirement for participation, we recommend that selected communities have the potential to access or expand regional markets to take advantage of anticipated surplus. For example, across the river from one

existing project site is a series of villages that have been isolated since a small vehicle ferry broke years ago. By expanding the project to incorporate one or more of these villages the project would help reestablish connectivity between communities through the supply and demand of high value fruit. Likewise, the exiting Taylor funded project is planning to incorporate a Baka village nearby to other project sites and the town of Somalomo. The inhabitants of this community are a marginalized social group and their settlement is not formally recognized as a village. Currently they do not enjoy significant connections to markets and services. The existing Ebony Project team hopes the planting of a considerable number of valuable fruit trees will improve connectivity and enhance living standards.

The project expansion will be limited by the availability of suitable land. However, the forest estate map of Cameroon (see Figure 8), provides important insight into several possible opportunities to work with communities, such as within commercial logging concessions (brown) and with Community Forests (light pink).

1.2.d. Sociocultural factors

Two sociocultural issues of importance for project expansion:

1) *Community engagement*: At each project site, at least one advocate and leader is required who both understands and believes in the project's short- and long-term value. There are no restrictions on the gender or social standing of the person or people, only that they are motivated and serve as a dedicated local focal point to keep the project going. To assess this, it is recommend that potential new villages and site locations be visited by project staff to assess whether there are individuals who meet these requirements. It is further recommend that a simple survey be developed to assess any perspective site's preparedness. Such a survey would document, for example, assess the number of individuals who appear highly motivated, the amount of accessible degraded land available for reforestation, and space and water supply for a plant nursery. This upfront investment of resources will increase the likelihood that a selected village will succeed in the project, and provide a baseline for improved monitoring and evaluation of project impact. The current project has demonstrated that the success of participating villages is a very effective tool for recruiting neighboring villages. Two of the three new villages being added to the existing project asked to be included in the project after seeing it implemented in a neighboring community.

2) *Existing sensitization to conservation*: Experience shows that the attitude of the local population towards conservation are important and should be considered in any future site selection. This said, while communities that display some conservation ethos might be more enthusiastic participants, the project might have more impact in areas that lack such experience. Rather than making demonstrated conservation experience a requirement for the project, we recommend exploring this concept during the initial survey phase mentioned earlier, and then modify project activities accordingly, possibly dedicating specific training to communities with less conservation experience. For instance, communities in the humid savanna region have a history and stronger experience with tree-planting, and therefore would require less training on plant propagation, planting and maintenance.

1.3 Assessment of Potential for Expansion to Other Value Chains

1.3.a. Cacao and coffee farms

The ideal habitat for growing cocoa trees is the lower understory of an evergreen rainforest with appropriate temperature and rainfall. Cocoa plants respond well to temperature between 20-30°C and rainfall between 1500-2000mm, with less than one month dry spells. Research shows that variations in the yield are affected more by rainfall than another climatic factors. Cocoa is grown in a wide variety of soil types and are sensitive to soil water deficiency.

A climatic suitability map for cocoa production has been developed for Cameroon illustrating the characteristics that determine which areas have the highest potential for crop success. Bioclimatic variables were used, calculating suitability ranges from MaxEnt, which provide suitability estimates 0–1 for each variable (Läderach et al., 2013). Figure 9A shows the climatic suitability of cocoa in Cameroon as adapted from Schroth et al. (2016). The western and central portions of the Cameroonian REDD+ Emission Reduction Program (ER-P) area is considered highly suitable for cocoa growth. There is also overlap between cacao, coffee, and ebony suitability in the Central region, diminishing as you move east.

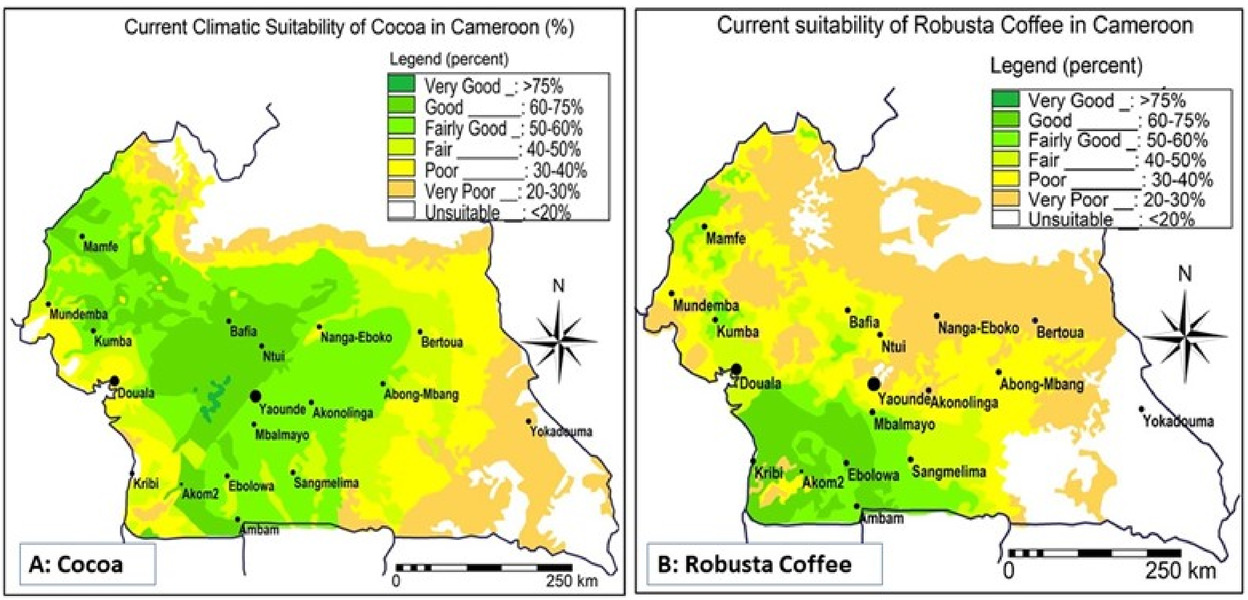


Figure 9: Theobroma cacao *and* Coffea canephora *(Robustas).climatic suitability map in Cameroon.* A*dapted from the Relative climatic suitability for Cocoa and Coffee of the West Africa cocoa belt by Schroth et al. (2016) of CIAT.*

Within the ER-P project area intercropping ebony and high value fruit trees with shade-grown cacao has the potential to enhance rural smallholders livelihoods, enhance biodiversity and meet the commitments of multiple international conventions such as the Convention on Biological Diversity (CBD) and the United Nations Framework Convention on Climate Change (UNFCCC).Shade-grown cacao is considered significantly better for conservation than many other land uses such as monoculture or livestock rearing (Clough et al. 2009) or some forms of timber extraction (Chaudhary et al. 2016). When cultivated with the right species of native shade trees and allowing some understory, shade-grown cacao can reach species diversities nearly rivaling mature rainforests.

Cacao agroforests also have the potential to serve as reservoirs for rainforests hardwoods, contributing to overall seed rain and eventual germination and reestablishment of native rainforest. Despite findings from West Africa in the 1960s, shade grown cacao delivers long-term yield rates that are competitive or even better than full sun cacao. (Sonwa and Weise 2008).

Several authors (Sanchez, et al. 1997; Leakey 1999; González-Estrada et al. 2008; Albrecht and Kandji 2003) have presented Cacao Agroforestry (CAF) systems as an option to simultaneously improve (i) biodiversity, (ii) medium- to long-term carbon sequestration, (iii) socioecological resilience, (iv) livelihood enhancement, and (v) a means to significantly contribute to climate change mitigation. Such intensified and diversified models of CAFs are feasible under the following assumptions or conditions: (i) timber and fruit trees which are preferred by cacao farmers are integrated into the system. These species include *Dacryodes edulis* (safou or bush plum), *Persea Americana* (avocado), *Elaeis guineensis* (oil palm), *Citrus sinensis* (orange), *Mangifera indica* (mango), *Milicia excels* (African teak), *Cola nitida* (cola nut), *Ricinodendron heudelotii* (njangsa), and *Terminalia superba* (timber); (ii) the best possible planting distance between the cacao and non-cacao trees is respected; (iii) required shade is properly managed; (iv) diseases and pests which could attack cacao plants and trees are well managed; (v) incentives are put in place to encourage farmers to establish such farms. See Objective 2 for one example of how to incorporate cacao agroforestry into the existing Ebony Project model that meets these conditions.

Opportunities to expand the Ebony Project onto cacao lands

There are two categories of cacao plantations in Cameroon that offer the opportunity to expand The Ebony Project. The first is *older plantations*. Many cacao plantations in the cacao production basin are more than 35 years old and have very low yields. Many of these less productive plantations face soil fertility and phytosanitary problems. Incorporating these lands into an expanded Ebony Project would facilitate improved agroforestry practices and transition these lands to a shade grown, more diversified crop of higher-value and improved yields. While providing additional short term prosperity via the intercropping of fruit trees, the project also improves greater long-term economic options by planting ebony, a commercially valuable hardwood that will not reach maturity for decades. Further, under an expanded Ebony Project model older cacao farms could be rejuvenated through the grafting of high-producing varieties to old cacao plants. The technique under application in the southwest of Cote d’Ivoire is very promising, increasing the yield from 350 kg/ha to 1.7 tons/ha in two-three years after the grafting. Such approaches could be applied in the cacao production basin in Cameroon.

The second is *new cacao plantations*. Cacao production is expanding in Cameroon as the government seeks to reach new targets and fill gaps in lost production from the Southwest region due to social conflict. New cacao plantations would benefit from improved inputs, diversified shade species, and enhanced training but the value proposition for new and old, however, is the same: improved yield, diversity of product and enhanced biodiversity. Other important intercropped plant that can be incorporated include *Irvingia* spp.(bush mango), *Ricinodendron* sp. (njangsa), *Garcinia* sp. (bitter cola), *Dacryodes* sp. (safou or bush plum). And both categories would also benefit by incorporating findings from IITA’s CocoaSoils project, which looks to increase soil fertility in West and Central African cacao.

Coffee

The coffee tree is a tropical evergreen shrub of the genus *Coffea*, with two most commercially important species being *Coffea arabica* (Arabicas) and *Coffea canephora* (Robustas). Whereas Robusta coffee can be grown up to about 800 meters above sea-level, Arabica does best at higher elevations. Ideal average temperatures for Arabica coffee range between 15 to 24ºC and 24 to 30ºC for Robusta, and annual rainfalls of 1500 to 3000 mm, with Arabica needing less than Robusta. Figure 9B shows the climatic suitability map of Robusta coffee in Cameroon as adapted from Schroth et al. (2016).

As coffee and cacao grow in different ecoregions (Figure 9), high value fruit intercropping options will differ. For coffee, *Dacryodes* (safou), *Persea* (avocado), *Cola*, *Citrus* would all make suitable options. Under the auspices of an expanded Ebony Project approach the production of coffee plants could further be improved by using vegetative propagation techniques such as rooting, grafting, and marcotting of high-producing plants yielding four to five years after initial planting.

1.3.b Large-scale palm oil

The establishment of large-scale monocultural palm oil plantations has proved detrimental in maintaining regional biodiversity and has become a leading cause of tropical forest destruction worldwide. In fact, large-scale commercial agriculture, such as that of oil palm and soy, drives 71 percent of all tropical deforestation (CLUA 2014). Creating the optimal mono-cultural, full sun growing conditions for oil palm precludes most agroforestry approaches. This said, oil palm plantations can be made more hospitable to biodiversity by planting indigenous trees such as ebony at least 10 m from the edges of the plantations and not restricting sunlight.

1.3.c Timber

Under the 1994 Forestry Law, a management plan is required for logging inside Forest Management Units and the completion of an Environmental Impact Assessment is a pre-requisite for approval. Companies with approved management plans will often include reforestation commitments. The 2006 Cameroon National Reforestation Program included recommends that in order to attain long term productivity of production forests that natural regeneration in Forest Management Units should be supplemented by plantations sylviculture and enrichment. The Program recommended to undertake this work in degraded sectors of FMUs such as wood lots and young secondary forest. The Sectoral Program for Forest and Environment proposed 5000 ha of reforestation per year in the forest zone, i.e. ca 50 ha per FMU per ear; this equates to around 10.000 plants/FMU/year. Land restoration in Cameroon has been limited by the lack of seeds and know-how for plant production particularly for commercial forest species. Thanks to vegetative propagation techniques it is now possible to produce important planting materials of forest species. Research clearly indicates that *Triplochyton scleroxylon* (ayous), *Khaya ivorensis*, *Lovoa trichiloides*, and other important forest species could easily be multiplied by juvenile rooting stem cutting. By carefully selecting cuttings, with desired traits such as “straight stem” can be captured. Moreover, a predictive test for ayous has been developed for the selection at the early stage in the nursery. This test is based on the strong apical dominance developed by this species. So it is possible to produce plants of given forest species through vegetative propagation techniques.

Developing these techniques and promoting their implementation in rural villages adjacent to commercial forestry operations presents a viable business opportunity for production and sale of plants to locally operating companies. Some timber companies in Cameroon have already begun producing their own plants as part of their obligation to reforest within their concessions.

Objective 1 Conclusions and Recommendations

Based on results described earlier, three key recommendations can be formulated from Objective 1:

(a) Agroforestry approaches incorporating ebony have the potential for significant carbon sequestration, beyond standard levels for tropical humid forest. Thus, though the Ebony Project has not been coined or operated as a carbon sequestration project to date, it has the potential to be one.

(b) An expansion of the project will require changes in how participating communities are selected. We recommend developing a simple survey instrument to assist in the selection of participating communities, and to facilitate group agreement on objectives and outcomes.

(c) The Ebony Project has great potential to expand into cacao and coffee value chains, where it could enhance biodiversity and carbon sequestration.

OBJECTIVE 2: DEVELOP GUIDANCE FOR SELECTING AND PROPAGATING PLANT SPECIES

2.1 Co-cropping Species

In order for standing forest to provide significant value to local communities, it must include species that can fulfill economic or food security needs of the surrounding communities. That means the selection of co-cropping species is paramount to the success of The Ebony Project. Table 2 summarizes species that can be used for co-cropping.

Table 2: Co-cropping species.

Common name	**Scientific name**	**Image**	**Growing season**	**Sun & water requirements**	**Uses**
Food and medicinal species					
Nsangomo	*Allanblackia floribunda*		Fruits all year	Shade loving	Edible fruits, stearic acid, hypertension
African bush plum ("safou")	*Dacryodes edulis*			Shade loving; 1400-4000 mm of rain/year	Edible fruits high in triglycerides, used as anti-microbial
Bush mango	*Irvingia gabonesis*		April–October	1500-3000 mm of rain/year	Edible fruits, used to treat diarrhea in traditional medicine.
Tonic root or African ginger	*Mondia whitei*			Shade tolerant	Root used for flavoring and medicine (anti-depressant, aphrodisiac)

Common name	Scientific name	Image	Growing season	Sun & water requirements	Uses
Mango	*Magnifera indica*			Semi- to full sun; drought tolerant	Edible fruit
Rambutan	*Nephelium lappaceum*		July-August and November-December	Partial shade when young followed by full shade as an adult	Edible fruit
Avocado	*Persea americana*			Semi- or full sun	Edible fruit

Common name	Scientific name	Image	Growing season	Sun & water requirements	Uses
West African pepper	*Piper guineese*				Spice
Njangsa	*Ricinodendron heudelotii*		November - April	Prefers full sun; 800-4000 mm rain/year	Kernels are used as flavoring and thickener in cooking; bark used for many ailments in traditional medicine
Bitter kola	*Garcinia kola*				Consumed socially as a digestive and used medicinally
Moabi	*Baillonella toxisperma*		N/A	Full sun or semi-shade; 1500-3000 mm of rain/year	Timber production

2.2: Suggested Intercropping Approaches

There are myriad possible intercropping approaches. We focus on three approaches: (1) an agroforestry approach using only local trees; (2) an approach that incorporates annual food crops; and (3) A cocoa agroforestry approach.

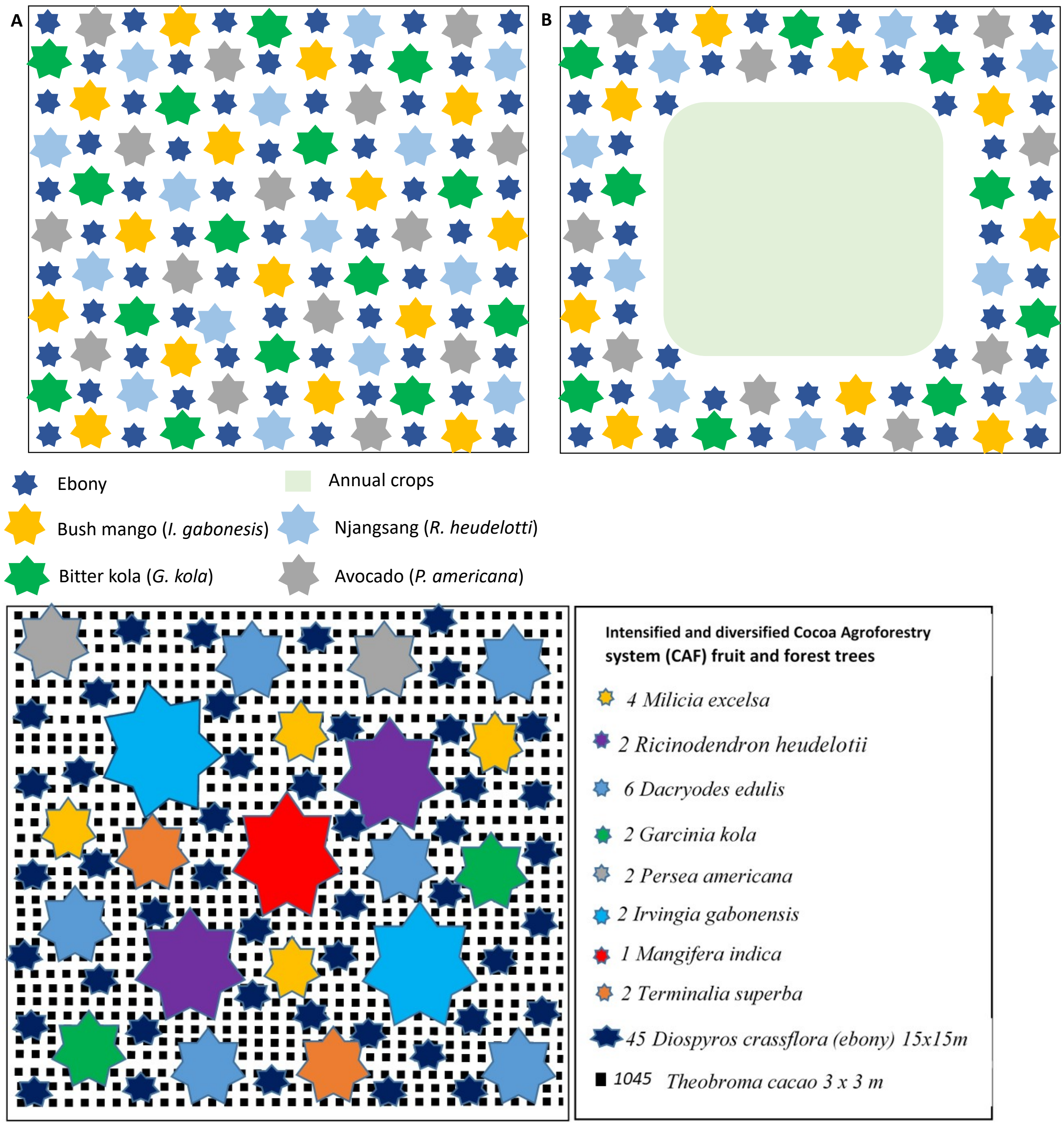


Figure 10: Intercropping agroforestry models with ebony. A is an agroforestry approach using only local species; B incorporates annual food crops with agroforestry; C represents a modified cocoa agroforestry system that includes ebony.

Synergies	Potential challenges	Maturity and productivity
The diversity is still the same even if there are some ebony plants inside the spot. The competition is minimized between the different species as the plant spacing is still maintained at 10 × 10 m. The advantage is in the building up of biodiversity as the number of species increase the diversity	We need to paid attention to multi-strata system by choosing the appropriate propagules. For example, *Ricinodendron* should be mainly from seedlings and would occupy the first strata. *Irvingia* will be the second strata (cutting or marcots) while cacao and cola nut will be on the first layer. With this multi-strata system, the competition will be minimized.	**Time to maturity** *R. heudelotii*: 3 - 5 years after planting *G. kola*: 4 - 5 years after planting *I. gabonesis*: 3 - 5 years after planting *P. Americana*: 3 - 4 years after planting

2.3: Potential Sourcing for the Species

There are the two viable approaches for medium to large scale production of saplings for use in the Ebony Project: seeds and cuttings. Generating plants from seeds requires finding high quality seeds; for locally valuable fruit trees this must usually be done *in situ* in the forest. These must usually be purchased from villagers at a relatively high cost. The seeds are then germinated and tended in a nursery until they are ready for transplantation. Production from cutting starts with a cut piece of a live plant, usually a leaf or a shoot from a stump. When grown in a non-mist propagator in appropriate media, the cutting can root and ultimately grow a new stem. The resulting plant, once of sufficient size, can be transplanted like a plant produced from seed. Approximately 300 cuttings can be grown at a time in a 2x1m non-mist propagator. Cuttings is the most feasible approach to reach the large scale production that would be necessary under an expanded version of the ebony project, but seed production should be continued as an alternative form of production to make the supply chain more robust.

An ebony cutting in substrate. The small brown growth between the substrate and the base of the leaf will become the main stem of the new plant.

Table 3: Benefits and Challenges of Plant Production Approaches.

	Benefits	**Challenges**
Seeds	Germinates and grows quickly. High germination and survival rate under appropriate conditions. Relatively easy to grow.	Erratic production, usually alternating between high and low production years. Number of seeds limited by natural production; for ebony this ranges from 3,000 seeds in lean years to 20,000 in productive years. Relatively high cost as each fruit must be gathered before rotting. Difficult to impossible to select for beneficial traits.

Cuttings	Production not limited by natural inputs, allowing for large scale up. Allows for selection of "plus" or "best" varieties. Lower cost than production from seed.	Best case survival rate of 60-90%. Grows more slowly than plants germinated from seed. Requires more training and inputs than seedlings.

Specifics for both approaches vary by species. Seed availability is more regular in some species, although most experience fluctuation. The availability of "best" source material for cuttings varies by species, as does the techniques needed for cuttings and their survival rate.

OBJECTIVE 3: IDENTIFY LOGISTICS AND INFRASTRUCTURE NEEDS FOR EXPANSION

An expansion of The Ebony Project would require increased propagation capacity, the development of propagation techniques for new species, and the identification of additional planting areas. This objective examines the opportunities and obstacles of propagating plants in remote rural settings, the establishment of "hub-and-spoke" remote regional nurseries, the maintenance of plants over variable periods of time, and ultimately the transport of individual plants into the field. The state of knowledge of plant propagation via in vitro propagation is also examined as a potential source of mass produced, healthy plantlet production from selected plant material.

3.1: Increased demand by species

Determining levels of demand in plant propagation will depend on the scale of any expansion to the project, but it is recommended to maintain a production ratio of roughly one local fruit tree for every ebony/hardwood tree. Other key guidance for plant production based on previous experience includes:

- Cuttings and marcotting will be important production techniques as:
    - They overcome annual inconsistencies in the availability of seed.
    - They avoid the cost and difficulty of seed collection.
    - They allow the regeneration of productive individuals (although this requires some care to ensure the nurseries maintain some levels of genetic diversity within species).
- Plant nurseries can produce large numbers in relatively small spaces. A nursery of 1000 m^2 (roughly 30 m × 30 m) can house 20,000 plants at a time.
- Nurseries, including those established at the community level, should have access to small levels of pesticides and fertilizer. The high concentration of young plants attracts pest of multiple varieties that can be controlled with limited pesticide use.

3.2: Securing Appropriate Plant Source Material

See Section 2.3

3.3 Comparison of Production Models

Expanding the project will require an expansion of the plant nursery infrastructure. Currently, a central nursery in Yaoundé supports the two existing and four planned community nurseries. Designing an approach for an expanded project requires tradeoffs between logistical and financial efficiency and concerns about pests and disease that are driven by high concentrations of young trees from the same species grouped together. Table 4 summarizes the potential approaches, and their benefits and challenges.

Table 4: Comparison of proposed production models.

	Highly decentralized	Moderately centralized	Highly centralized
Approach	Community nurseries are largely standalone, possibly networked with other nurseries in same area	Community nurseries grouped into nodes, with one or more major nursery facility	One or more major nursery facility providing all plants for project
Benefits	High level of community autonomy; possible cost savings from central nursery	Professional sourcing for the nurseries if needed; main repository for improved varietals; communities can learn from others in their node	All plants are professionally managed; less community engagement needed
Challenges	With no centralized professional nursery, sourcing can be very challenging	Increased costs for centralized nursery and coordination of nodes	Highly susceptible to pests; very little opportunity for capacity building at community level.

If the Ebony Project is expanded, it is recommended to move forward with a moderately centralized approach. Relevant experience shows that it is helpful to have supply nurseries within about 40 km of community nurseries. Under this system, there would be a handful of central nurseries that support “node nurseries.” Node nurseries are community-based nurseries that are fairly central to a small group of other participating communities and show higher than average skill and motivation at nursery maintenance. They would then support 5-10 other community nurseries in their area (Figure 11).

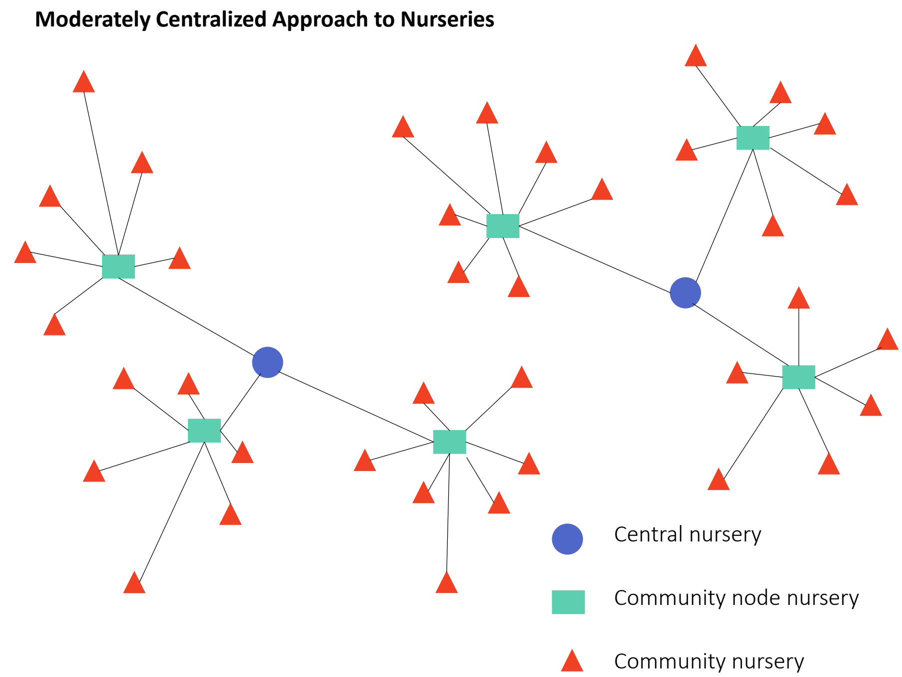


Figure 11: Schematic of nursery approaches.

For a central nursery to be functional, a secured land of about 1,000 m^2 is needed. This area needs to be protected from grazing animals wild or domestic. It will require a clean permanent source of water, particularly needed during the dry season. Access to electricity is also an advantage. A nursery should be easily accessible and have a small storage area for keeping materials such as substrate, plastic bags for saplings, and fertilizer and pesticide. Specific nursery size and capacity will depend upon the predetermined landmass designated for ultimate restoration. Propagated fruit tree species will be determined based on the priorities of the farmers involved in the project and what is deeded site appropriate. To facilitate the adaptation of planted species is highly recommended the project should mainly focus on the species existing in the project site.

As designed, the central nursery could easily accommodate 20,000 plants distributed as follows:

1. Seedlings: 10,000 for 4-5 different species
2. Cuttings: 8,000 from 4-5 different species
3. Marcots: 1,000 from 4-5 different species
4. Grafted : 1,000 plants from 4-5 different species
5. Non-mist propagators: 10
6. Giant Non-mist propagators: 5
7. A shade house covering at least 10 non-mist propagators and five weaning giant propagators. To avoid pests and diseases, the soil of the shade house should be cemented.

Community nurseries will be significantly smaller, requiring an area of around 250m^2 and having the capacity to grow around 5,000 plants.

Objective 3 Conclusions and Recommendations
If the project expands, it is recommend adding mid-level hub nurseries to bridge the gap between central, professionally managed, production nurseries and community nurseries. These "node" nurseries would be a cost-effective way to expand capacity to grow plants, and would provide an opportunity to train a select number of community members to be skilled nursery managers.

OBJECTIVE 4: IDENTIFYING KEY THREATS ON THE LIFE CYCLE OF THE SPECIES: ECOLOGICAL RESEARCH

Effective conservation and stewardship of any species requires an understanding its basic ecology in order to understand treats and opportunities, and to inform conservation and management decisions. When the existing Taylor funded Ebony Project began in 2016 such information about ebony was sorely lacking. The project's commitment to research has led to several important scientific discoveries in a few short years. Research conducted as part of The Ebony Project has provided important insights into such issues as pollination, seed dispersal, native range and growth rates. The existing project proves that a small amount of dedicated research can yield valuable information. The research focuses on finding the answers to four key questions:

1. *Where does ebony grow?* The project has already provided an improved range map of ebony (see section 1.2), which is helping to guide potential expansion.
2. *How much ebony is there, and what are the threats to its continued survival?* The project developed the best known estimate of *D. crassiflora* stock and identified climate change as a significant threat to its continued survival. This work has already informed the recent IUCN classification process for ebony and an official reclassification issued in March 2019.
3. *How does ebony reproduce?* New research is elucidating the reproductive cycle of ebony and identifying its pollinators. It has also identified the poaching of the species' seed dispersers as a key threat to its continued survival.
4. How fast does ebony grow, and what conditions are most conducive to its growth? This research helps increase the likelihood of focusing harvesting efforts on high quality trees, and provides vital information to model species survival.

Having the time and resources to answer these questions has been important to the success of the project. We strongly suggest that any expansion or extension of The Ebony Project support ecology research on ebony or other key species. Following is a summary of the existing knowledge and key questions that remain.

4.1: Summary of the State of Knowledge about Ebony
Demography

Diospyros crassiflora is a shade-tolerant species; found under shade conditions both as young and older plants (Bongjoh & Nsangou 2001; Sepulchre et al. 2008). The distribution of stem diameter from inventory data in both semi-evergreen and evergreen forests show a decreasing frequency with increasing diameter as is characteristic of trees with good regeneration rates (Sepulchre et al. 2008).

The species is reported to be more abundant in semi-evergreen than in evergreen forests (White, 1978; Sepulchre et al., 2008). In Southeastern Cameroon, Sonke and Couvreur (2014) using established 5 km long transects and covering 22.5 ha, found 0.58 ebony trees/ha and a basal area of 0.066 m^2/ha (for trees above 10 cm in diameter). At the Mbaïki experimental station in Central African Republic, in 40 ha of semi-evergreen forest measured in 1982, density was 4.4 trees ha^{-1} and basal area was 0.3 m^2 ha^{-1} (Bedel *et al.*, 1998). The relatively low abundance of the species makes it difficult to estimate the spatial variability in abundance using standard vegetation plots of 1 ha or less. Future studies should consider using kilometer-long transects or larger plots to accurately estimate the spatial variability of abundance of *D. crassiflora*.

Maximum annual diameter growth rate of trees above 10 cm in diameter was estimated to be 0.64 cm yr^{-1} (95th percentile in 10 permanent 4-ha plots followed annually since 1982) at Mbaïki, Central African Republic (Gourlet-Fleury *et al.*, 2011; Fayolle *et al.*, 2012). Estimated average growth rates were 0.17 and 0.33 cm yr^{-1} in unexploited forest and exploited-thinned forests respectively (Bedel *et al.*, 1998). An average growth rate of 0.8 cm/yr was reported for the three largest trees in a 50-year old ebony tree plantation of the Mbalmayo arboretum in Cameroon (Owona Ndongo 2009). These rates make it one of the slowest growing species found in the Congo Basin rainforests, comparable with *E. cylindricum, E.oblonga, G. thompsonii, L. alata, M. africana,* and *S. kamerunensis* (Owona Ndongo 2009; Fayolle et al. 2012).

The oven dry wood density measured in five different studies ranged from 0.80 to 0.99 g/cm^3 and 0.858 g/cm^3 on average (Zanne et al. 2009) which is higher than obtained for most other species from the same habitat. For instance, in the Dja Biosphere Reserve, Cameroon, average oven dry density of standing wood was 0.60 g/cm^3 (Djuikouo et al. 2010).

High wood density together with slow diameter growth and evergreen leaves are typical characteristic of shade tolerant species. Both low nutrient and low water availability may favor species with high wood density (Fayolle et al. 2012). However, it is not known whether *D. crassiflora* tends to be associated with relatively poorer soils or more xeric conditions within its habitat.

Phenology

By compiling the geographic coordinates of herbarium samples along with phenology state: flower or fruits, we can see that the phenology of both is annual. The initiation of flowers happens at the onset of the rainy season and fruit mature within four to six months (Fig. 12).

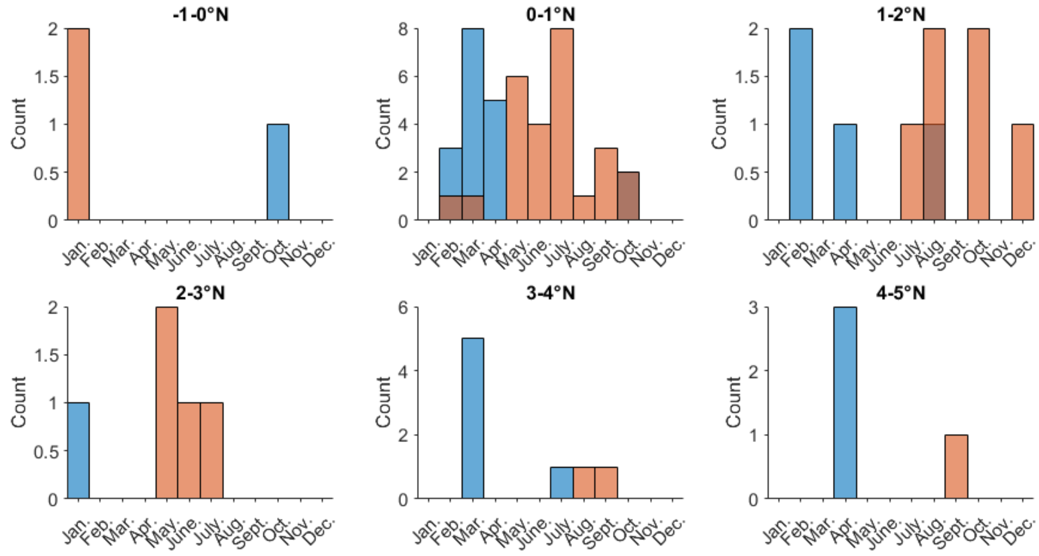


Figure 12: Phenology of fruit (red) and flower (blue) production on the latitudinal gradient.

A nine-year phenological study conducted in the Lopé Reserve, Gabon, suggests that the flowering of *Diospyros* species is triggered by minimum temperatures (19 °C or lower) in the dry season. Inter-annual differences in minimum temperatures are small in lowland forests, and a small shift upwards in minimum temperatures resulting from global warming could therefore have dramatic consequences—not only would these species cease to reproduce, the quantity of food available to frugivores that depend on ebony, would also be drastically reduced (Tutin & Fernandez 1993; Tutin & White 1998).

Seed and pollen dispersal

Being a dioecious species with relatively low abundance of mature individuals, the effective dispersal of pollen from staminate to pistilate individual trees can be a limiting factor of the fruit set. Limited pollen dispersal is likely to be more severe in in the part of its range where it has been overcut (see above). Similarly, because only the pistilate trees, i.e. half of the population, can produce fruits, the dispersal of seed at distance from the mother tree may as well be critical. As of to date, no information is available on the identity of pollinators and the possible dispersal limitation. CBI staff Vincent Deblauwe and Eric Onguene are currently investigating these aspects in the Dja Biosphere Reserve. CBI have developed with IRD partners a portable camera set-up that was mounted in the canopy of ebony trees to monitor flower pollination. The cameras emit infrared light at night for continuous filming. Thanks to this observational setup we discovered that ebony flowers attract a limited number of species, mostly Hymenoptera and Diptera. Pollen limitation is also being investigated by monitoring fruit and seed sets.

Given the large size of fruits and seeds (up to 5 cm) one would expect that only the largest mammals would disperse *D. crassiflora*. The efficient dispersion and subsequent germination of the species is a rare event as the annual rate of recruitment of trees (crossing of the 10cm diameter threshold) do not exceed two percent of this class of diameter annually (Bedel *et al.*, 1998).

Forest elephants (*Loxodonta africana cyclotis*, vulnerable according to IUCN) are known to swallow the seeds of *D. crassiflora* (Blake 2002).

Egestion of intact seeds in the feces of several ungulates in open tropical habitats has been observed for small seeds of various species. The largest duiker species, the yellow backed (*Cephalophus sylvicultor*, near threatened according to IUCN), has been observed ingesting seeds up to 4.7 cm long, and could disperse ebony seeds by ingesting them and spitting out viable seeds after some time in the rumen, a process referred to as spit dispersal (Feer 1995). Unidentified ruminants (Gautier-Hion et al. 1985) have been reported to eat ebony fruits.

Critically endangered Western lowland gorillas (*Gorilla gorilla gorilla*) have been reported to consume *D. crassiflora* fruits in Central African Republic and the Republic of Congo (Nishihara 1995; Doran et al. 2002; Fuh 2013; Masi et al. 2015; Luef et al. 2016). More than half of gorilla scat remains, and therefore half of the seeds they disperse are found at their nesting sites. As they prefer to make their nests in forest areas with an open canopy (Haurez et al. 2015), gorillas disperse seeds preferentially to sites with optimal light conditions for seedling recruitment and growth of non-pioneer light-demanding species (Haurez et al. 2015; Petre et al. 2015), which may be favorable to *D. crassiflora*. The pulp and seeds of ripe fruits of *D. mannii*, a species with fruits (9.3 × 7.2 cm) and seeds (5.2 × 3.3 cm) of comparable size and overlapping distribution with *D. crassiflora*, are eaten by gorillas. Intact seeds have been found both at the feeding sides and inside their feces, which proves that they can disperse large *Diospyros* seeds (Tutin et al. 1996).

Chimpanzees (*Pan troglodytes*) consumption of *D. crassiflora* fruits has been reported in Gabon and the Republic of Congo (Hladik 1973; Morgan & Sanz 2006). They however have a smaller swallowing threshold than gorillas; ingestion of seeds up to 2.7 cm long has been reported in Uganda (Wrangham et al. 1994). Chimpanzees have been observed eating *D. manni* fruit flesh but only crunched fragments of seeds have been found in their feces (Tutin et al. 1996).

Mandrills (*Mandrillus sphinx*) in Makokou region, Gabon, eat the flesh of the fruits but do not swallow the seeds (Lahm 1986). *Diospyros crassiflora* does not have repellant hairs on its fruits like *D. mannii*; primates are therefore possible predators of immature seeds as reported for other *Diospyros* species (Williamson et al. 1990). Immature seeds of all *Diospyros* fruit are vulnerable to predation as the testa is initially soft, and only hardens progressively during seed development. Within the genus, the potential vulnerability to predation increases with seed size (Tutin et al. 1996).

Large rodents, such as Emin's pouched rat (*Cricetomys emini*) and the African brush-tailed porcupine (*Atherurus africanus*) have been shown to cache and eat large seeds of other trees and may act as both seed predators and dispersers (Rosin & Poulsen 2017).

These large-bodied species, which are probably the main seed dispersers of *D. crassiflora*, are also the most exposed to commercial hunting (Laurance et al. 2006; Haurez et al. 2013) and are all included in the IUCN Red List of Threatened Species. Elephant populations are already in sharp decline in the region (Poulsen et al. 2017). With no dispersers, it is possible that *D. crassiflora* will only regenerate below mother trees, thus becoming a gregarious species. This was shown to be the case in Mauritius for *D. egrettarum* following the extermination of their main disperser, the native giant tortoise (Griffiths et al. 2011).

The removal of effective dispersers is known to lead to important plant population declines due to recruitment limitation (Terborgh et al. 2008). T he long-term impact of bushmeat hunting on D. crassiflora was therefore investigated by establishing permanent 400 ha comprehensive ebony surveys in hunted and non-hunted sites. We discovered that the removal of large mammalian fauna is not only limiting the dispersion of the species, which distribution becomes clustered, but it also decreases the regeneration rate. An experiment was set-up in which the dispersal distance achieved by rodents was observed by following seeds attached to radio-waves emitting transmitter. The rodents that remain in the hunted forest are not able to replace the larger mammals as they disperse seeds to several tens of meters at the most.

The identity of seed dispersers was investigated during The Ebony Project by camera trapping of frugivore species below mother trees. We confirmed that the main fruit eaters are elephant and yellow-backed duikers. In 2018, a systematic survey of ebony seedlings over 30 ha after fruit set showed that all the seedlings of that year were sprouting in elephant dungs.

Conversely, the large fruits of *D. crassiflora* might constitute an important seasonal diet for the mammalian fauna who also disperse the seeds. Dedicated studies during ebony fruit set season are warranted to clarify how and to what extent the removal of mature ebony tress is impacting the food web.

Pathogens and Predation

In the tropical rainforest, during fructification of higher plants, the seeds of some species are attacked by various fungi as the fruits mature, before the fruit growth is completed. These seminicolous fungi species can be host-specific. In the Mbalmayo forest reserve Cameroon, *Penicilliopsis clavariiformis* Solms was found exclusively on seeds of *D. crassiflora* (Douanla-Meli 2007). In addition, a more generalist plant pathogenic fungus, *Pestalotiopsis theae*, and an unspecified *Penicillium* were found in seed tissues of *D. crassiflora* (Douanla-Meli & Langer 2009). *Colletotrichum gloeosporioides*, reported to cause the anthracnose of *D. kaki* was a common foliar endophyte found on *D. crassiflora* (Douanla-Meli & Langer 2012). The African Ebony may also suffers from leaf-eating insects, with defoliation exceeding 50% in some individual cases in a disturbed forest of Cameroon (Foahom 2004).

Ebony wood

Ebony is a generic name referring to a homogeneous black or veined black heartwood that is hard, dense, fine-grained (Normand et al. 1960; Gérard et al. 2011), which was among the exotic materials that have been valued since classical times.

The heartwood of *D. crassiflora* is relatively resistant to insect and fungi (Gérard et al. 2011), and has a high volume swelling and good abrasion resistance (Sproßmann et al. 2017). It comes in a wide variety of patterns and colors, from whitish to jet black. T here is currently no information regarding the biotic or abiotic factors which may explain this variability.

4.2: Summary of the State of Knowledge of Locally Valuable Fruit and Medicine Trees

For the last 20 years the World Agroforestry Center (ICRAF) and partners have been working on the domestication of high-value fruit trees and medicinal plants from West and Central Africa. The following steps were conducted to select and manage the key indigenous fruit trees and medicinal plants:

(i). Priority setting:

This was a crucial phase in determining which tree species could be recruited into the domestication process. Taking into account the important diversity of humid forests of West and Central Africa (at least 300 different tree species) it was decided to carry out a survey in at least four countries of the region to determine the key species which could fulfill famers needs while helping them to conserve the fragile forest of the Congo Basin. A multidisciplinary team of scientists comprising agronomists, foresters, economists, anthropologists, biometricians, agroeconomists, geneticists, and foresters developed a questionnaire that was administered to at least 6,000 farmers from Nigeria, Cameroon, Ghana, and Gabon. The aim of this priority setting was to:

- Help the farmers identify the indigenous trees and medicinal plants used in their daily life.
- Identify actions to be taken by scientists to facilitate the cultivation of lesser-known but useful tree species.
- Bring the scientists to develop the value chain of lesser-known but high-value indigenous trees able to improve farmers' livelihood.

(ii). Analysis of data

The analysis of data collected from four countries indicated clearly that the choice of priority species was consistent within and between countries. In general, no farmers chose the timber species such as mahogany, bibolo, or sapelli. They all preferred the indigenous fruit trees and medicinal plants. They opted for what could nourish and cure them. Farmers confirmed this choice when the restitution exercises were conducted in different villages where surveys took place. Moreover, during the restitution phases farmers indicated clearly the type of improvements they expected from the scientists working on the high-value indigenous fruit trees: early fruiting materials, capture of desired traits in fruit trees when doing multiplication, production of big and sweet fruits, among others.

It was realized that the desired traits enumerated by farmers could be captured through vegetative propagation techniques if these traits are genetically controlled. This is how participative tree domestication was developed in West and Central Africa. Simply put, participative tree domestication is the process that scientists, farmers, and other stakeholders use to select, propagate, and manage the lesser known but high-value fruit trees and medicinal plants which the poor-resource farmers used in their cropping systems. Contrary to conventional cash crops (cacao, coffee, rubber, etc.), species selection for tree domestication should be a farmer-driven and market-led process. So, farmers should primarily consume the products of the species before selling the surplus.

The domestication program had generated positive and encouraging results since its conception in 1998. More than 136 different tree species in the world are being propagated in the world using this approach. ICRAF scientists based in West and Central Africa, Indonesia, East Africa, Southern Africa, and China are using this approach to select, manage, and propagate the indigenous fruits trees and medicinal plants used by farmers in different regions. The tangible results are the early fruiting materials, the capture of desired traits achieved through domestication processes, namely the vegetative propagation techniques (rooting juvenile cuttings, grafting, and marcotting of mature trees). Moreover, tree domestication helps to mass-produce any plus tree selected in the natural stands. By so doing one only plants a well-known material as it is not acceptable nowadays to do any planting and realize 15 or 20 years later that a wrong or non-adapted material was used.

The early fruiting has been a big incentive for farmers engaged in tree planting. For example, *I. gabonensis* takes 15-20 years to fruit when planting in the natural stands. Farmers were enthusiastic to see that marcots of the same species will fruit 4-5 years after planting in the field. Similarly, marcots or grafted *Dacryodes edulis* will fruit 2-4 years after planting while plants from seeds may take 8-10 years after planting before bearing fruits. The early fruiting materials are dwarf plants producing less shade in food crop fields, therefore women easily accepted to integrate the dwarf plants in their food crops farms; achieving the diversification which also diversifies the source of their income.

It is important to point out that the domestication is not only focused on indigenous fruit trees and medicinal plants. It was initially successfully tested on timber tree species such as *Lovoa trichiloides* and *Kaya ivoirensis*. The domestication approach could be considered as a powerful tool for land regeneration widely undertaken in the world today. Tree planting is usually seen as a very long-term investment. By using tree domestication techniques (rooting of juvenile cutting, grafting and marcotting from mature materials), farmers and other stakeholders involved in land restoration could now accept tree planting as they could have a quick return from fruit trees and medicinal plants. Such quick returns are not possible from forest tree species such as ebony, which could easily take more than 100 years prior to any exploitation. It is really urgent and important to expand this technology in Cameroon and other countries such as Democratic Republic of Congo, Congo, Gabon, and Central African Republic if we want to reduce the deforestation of Congo Basin forests, which is the second continuous forest in the world after the Amazon.

Objective 4 Conclusions and Recommendations

The ecological research aspect of The Ebony Project has resulted in a number of scientific discoveries that will be detailed in peer-reviewed papers to be published in the coming months. In addition to these scientific discoveries, the feasibility study identified three conclusions from the ecology work:

(a) It identified poaching of seed dispersers as a key threat to the survival of ebony. This suggests that planting by humans as The Ebony Project does is likely to be an effective approach to addressing this key threat, and suggests that natural reforestation approaches that support the role of seed dispersers are also promising.
(b) It demonstrates the value of basic scientific research even in applied projects. The ecology research on ebony has informed planting and growth decisions, and supports the impact of tree planting overall. Any expansion that includes additional hardwood species should include resources to conduct similar research on the growth, life cycle, and threats for focal species.
(c) Previous survey work on locally valuable tree species has been a valuable guide in the existing project and should continue to be included in any expansion.

OBJECTIVE 5: ASSESS VALUE PROPOSITION OF POTENTIAL SCALE UP

The implementation of the Ebony Expansion Project will need to seek financial and institutional support based on its potential for biodiversity conservation, community development, reforestation, and ecosystem services such as carbon sequestration. That requires a clear statement of its value proposition: what does The Ebony Project provide, and at what cost? The value of the project is summarized in its Theory of Change (figure X), that it provides durable gains in three key metrics: community livelihoods, biodiversity, and carbon sequestration.

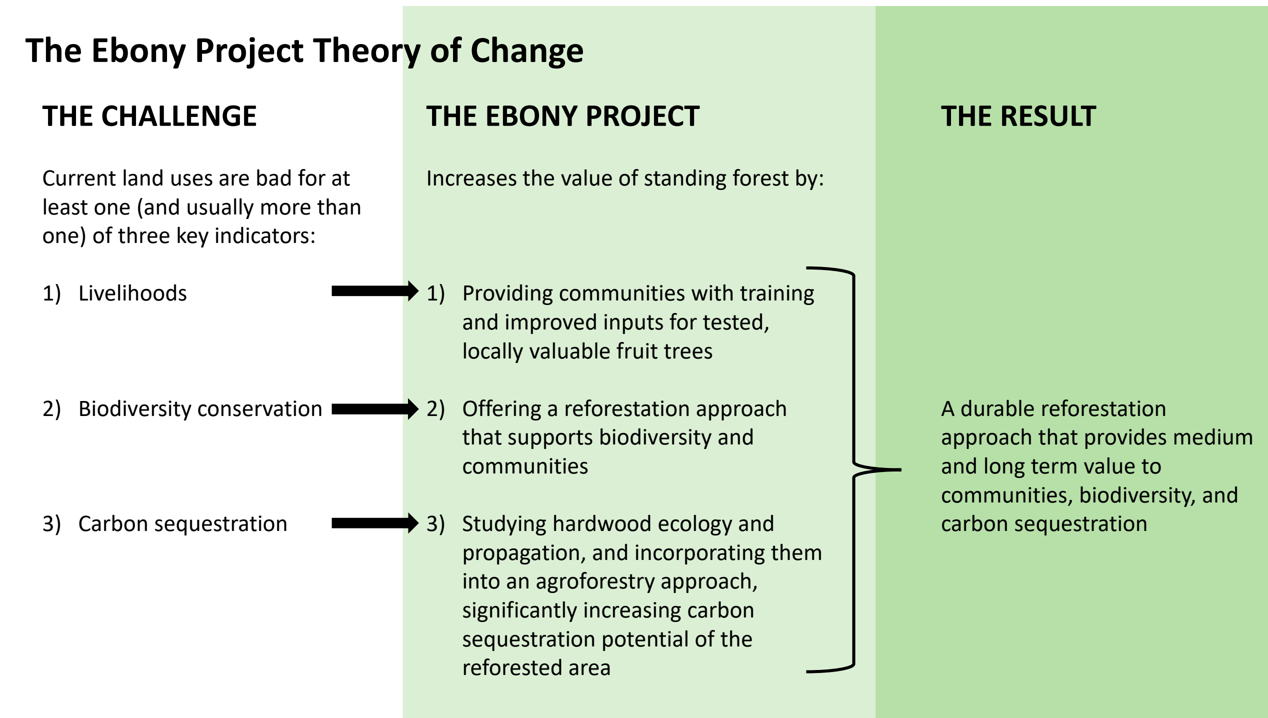


Figure 13: Theory of Change of Ebony Project.

This section assessed the costs associated with achieving those results, focusing on determining the costs of scaling the project.

5.1. Budget for Discrete Scale up Scenario

In the previous four objectives, we have identified the following six potential variables in designing an expansion of the project (Table 5).

Table 5: Potential variables in designing an expansion of the project.

Variable name	Description	Variable values
Average trees planted/community/year	The average number of ebony trees we can expect each community to plant per year. The number of non-ebony trees will be dependent on the inter-cropping approach chosen	600, 1,000, 1,500

Intercropping approach	What ebony and agroforestry species are intercropped with, and at what ration	A, B, and C[1] scenarios from Objective 2
Ratio of nursery types	Central nurseries: node nurseries: community nurseries	1:10:20, 1:10:10, 1:5:5
Years of planting	Number of years a community plants for once it has joined.	3, 5
Annual community payments	What incentives the communities received for participating, both amount and justification	CFA300,000/year; CFA300,000/year + per tree maintenance of CFA180
Years of payment	The number of years the communities receive incentive payments	3, 5

If we modeled every possible iteration of these variables, it would provide 216 possibilities for expanding the Ebony Project. It is not feasible to create that many discrete models, or for funders or other decision makers to use that many models to select a pathway forward. Instead, we have focused on the following five models (Table 6):

Table 6: Five potential models for expansion.

Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Average trees planted/community/year	600	1,000	600	1,000	1,500
Intercropping approach	A	A	B	C	C
Ratio of nursery types	1:10:20	1:10:10	1:10:20	1:10:10	1:5:5
Years of planting	3	5	3	3	5
Annual community payments	300,000	300,000+	300,000	300,000	300,000+
Years of payment	3	5	3	3	5

Likely to be a blend of these models, some communities will follow one, while other communities will follow others.

5.2. Model

Using the budget and expenses for the existing project, and the planting numbers and projections, we modeled out the cost of an expansion of the community agroforestry portion of the project. The model is designed to scale in units of 10 communities, with a central nursery supporting 10 community nurseries. The expected costs for three years of planting and five years of support for tree tending are:

[1] A: ebony and locally valuable tree intercropping; B: perimeter and corner agroforestry around annual crops like manioc and maize; C: cacao-based agroforestry that incorporates 45 ebony trees and eight co-cropping species. A and B use 10 m × 10 m spacing for ebony, while C uses 15 m × 15 m spacing.

Table 7: Modeled costs for 10 community project (in US$).

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Total
Nursery start-up	45,000	0	0	0	0	0	0	45,000
Nursery ongoing	11,000	11,330	11,670	12,020	0	0	0	46,020
Vehicle	40,000	0	0	0	0	0	0	40,000
Staff	36,000	37,080	38,192	39,338	21,385	22,026	22,687	216,708
Supplies	5,000	5,150	5,305	5,464	5,628	5,796	5,970	38,312
Management	52,500	54,075	55,697	57,368	44,317	45,646	47,016	356,620
Travel	10,000	10,300	10,609	10,927	5,628	5,796	5,970	59,230
Community payments	0	5,618	5,787	5,960	6,139	6,323	6,513	36,340
Overhead (20%)	39,900	24,711	25,452	26,216	16,619	17,118	17,631	167,646
Total	239,400	148,264	152,712	157,293	99,716	102,705	105,787	1,005,877

A basic investment in this approach would result in the planting of approximately 36,000 trees—18,000 ebony trees and 18,000 locally valuable fruit and medicine trees. This would result in the reforestation of approximately 360 hectares of forest. The estimated cost is approximately US$1,000,000, or US$28/tree and US$2,800/ha reforested, and the total project would last for seven years.

This model assumed a conservative number of trees planted annually per community (600 ebony and 600 fruit trees). We think it is feasible that communities could plant at least 50% more trees, which would bring the number of trees planted to 54,000—27,000 ebony trees and 27,000 locally valuable fruit trees, and result in the reforestation of approximately 520 hectares. This would put the cost per tree at US$19 and the per hectare cost at US$1,900. These operations are scalable by groups of 10 villages.

Note these estimations do not include continued ebony research or monitoring and evaluation, which are recommended in other sections of this feasibility study.

OBJECTIVE 6: DEVELOP AN IMPACT MONITORING PLAN

Currently, the Ebony Project is measuring output and outcome metrics associated with the activities, and incorporating lessons learned through an informal mechanism. As the Ebony Project expands, monitoring, evaluation, and learning approaches will need to be quite robust to coordinate several sites dispatched throughout a larger area. Additionally, the first three years of operations have raised questions and efficacy and causation that cannot be answered during the current project period. This section attempts to develop a plan for more robust monitoring, evaluation, and learning within the constraints of what is possible, based on what we have learned so far.

6.1. A Roadmap for Improvement: Recommendations for Enhanced Monitoring and Evaluation

This Feasibility Study has given the team an opportunity to step back and explore the purpose of the project and how it is assessed. Based on this experience, we have five recommendations for any potential expansion of The Ebony Project:

1) *Transition from activity-based goals to outcome-based goals*: At inception, there was so little known about ebony that the project goals largely stated the activities that would be undertaken during the project, rather than the results that would flow from those activities. The two-year progress report has demonstrated that the project has been very successful in implementing the activities. The next stage for The Ebony Project is to move from activity-based goals to outcome and impact goals. Thus, rather than set as goals the activities it will implement, the project should set outcome and if implemented at a larger scale consider impact goals. This would capture aspects that have always been at the heart of the project like supporting biodiversity, improving community livelihoods, rehabilitating degraded forest, increasing canopy cover and increasing carbon stocks and make them explicit. This Feasibility Study is the first step in that process, as it models the outputs we think are possible based on our learnings from the current project. As the current project progresses, it should adapt to begin assessing outcomes, and use those findings to both refine the project design (see adaptive management below) and to develop outcome and impact indicators for a larger scale project.

2) *Dedicate resources to project monitoring*: Thus far, the project has monitored and evaluated its progress organically, an approach that has been effective and appropriate given the scale of the project. A scale-up of the project should include dedicated resources for project monitoring and evaluation. This would support assessment of the larger project, and allow the project to assess more complex outcomes and impacts.

3) *Expand the use of the adaptive management approach*: We recommend that the project continue its use of the adaptive management approach that includes stakeholders from CBI, IITA, Taylor/Crelicam, and HIES. A scale up is an opportunity to thoughtfully grow the management approach in line with the growing project, and we recommend being explicit and purposeful about its adoption. Given the widespread use of adaptive management in conservation programs and increasingly in international development work, we think this is an appropriate choice.

4) *Consider implementation research as a mechanism for better understanding outcomes:* recent developments in implementation research have allowed a better understanding of the intrinsic impact of development projects especially where comparison sites are difficult to find and measure. As a scaled-up version of the Ebony Project will be phased in across multiple and varied sites a Stepped-wedge Trial (Brown and Lilford 2006) design would be well suited to this approach and would allow for site and seasonal effects to be controlled while also allowing for the project to be implemented in all sites. Measurements would need to be carried on beyond the normal follow up period of the project and this may be possible under a scaled up version of this project.

5) *Seek to conduct research on project attributes outside the scope of normal M&E work*: The Ebony Project has shown positive signs of effecting change in ways that other projects have struggled to do, and has pointed to opportunities that should be explored.

In some cases, novel research will be needed to assess the potential impacts of the program, or to model to assess opportunities it has raised. Because the funding for "implementation" of projects like this rarely comes with opportunities for research funding, we recommend the project continue to find resources for research, and recommend some potential areas of study.

6.1. Goals and Objectives

A potential expansion of The Ebony Project offers an important opportunity to better track the impact of the project and further revise the project design based on lessons learned. This necessarily starts with defining the vision and the goals of the project. The original project has stated goals, though they are written largely in terms of activities to be undertaken rather than outcomes to be achieved:

1) Work with rural communities to create a scalable program for the sustainable production and stewardship of ebony. We set an initial goal of planting 15,000 ebony trees.
2) Model West African ebony distribution and assess harvesting rates and appropriate planting areas.
3) Understand the basic ecology of ebony to enhance natural reproduction and dispersal, and test restoration approaches.
4) Test alternative propagation approaches, including tissue culture, to identify optimal conditions for cultivating ebony.

The project has been very successful at meeting these goals, specifically:

1) Creating a program for sustainable production: The project has developed two community nurseries and one central nursery. We have planted over 2,000 ebony trees, and with over 20,000 more in the nurseries, we plan to exceed the initial 15,000 tree goal by March 2020.
2) Modeling distribution: The project completed a model of ebony distribution and projected density, and an estimate of the total number of trees within the range. Collection of new growth data and collation of old data has also provided a much more accurate assessment of ebony's growth rate under different growing conditions. Aside from providing much needed demographic information, the assessment also suggested that a lack of seed dispersers caused by bushmeat hunting poses a larger threat to the species than over-harvesting or habitat destruction.
3) Basic ecology: In just two years, the project has better defined ebony's life cycle, identified its main pollinators and seed dispersers, and clarified its phenology. This work has given clues about how to conserve the species in the face of threats from bushmeat hunting and other anthropogenic activity.
4) Testing alternative approaches to ebony tree propagation: The project enhanced our ability to produce ebony trees from fruit by improving the germination and survival rate of saplings grown from seeds. It has pioneered production through cuttings by refining the use of fertilizers and hormones to incite growth, and it has made significant advances in generating plants from tissue culture.

As part of the Feasibility Study process, the team reviewed the goals for the project, and discussed also developing a vision. Below are the draft vision and goals. These are still under discussion within the larger project team.

Draft vision: To protect and restore Central African forests and support forest-dwelling communities

Draft goals:

1) Sustainably reforest degraded land to support Central African biodiversity and sequester carbon. [The exact metrics for this need to be driven by funding, e.g. reforest at least 300 ht, with 90% remaining reforested 5 years after planting, and supporting at least a 50% increase in biodiversity].
2) Provide communities with a viable livelihoods opportunity that enhances food security and/or household income.
3) Expand our model for partnership between business, academia, and communities by expanding to at least one additional value chain
4) Develop sufficient understanding of ebony cultivation to support production and transplanting with a [80%] survival rate
5) Use approach and platform created by the Ebony project as a model of larger scale rainforest restoration, in which other species of native hardwood a can be grown and planted.
6) Further studies and pilot projects to explore how natural seed rain can be increased in areas where forests regeneration is being undertaken. Data from natural studies of rainforest restoration are available from the Congo Basin Institute

These goals would them be tracked in revised and potentially expanded metrics.

6.2 Outcomes and Metrics

While the only formally set metric for the project was the goal to plant 15,000 ebony trees, we have also used the following metrics to assess project success:

- Number of plants produced, by species, method, location, and origin
- Number of saplings transplanted (ebony and locally valuable fruit trees)
- Locations of the planted trees and approximate dates of planting
- Papers and reports published increasing the understanding of ebony
- Number of communities involved
- Number of farmers who plant trees

These metrics are tracked in internal project documents, and shared through mechanisms like the progress report. The existing data allows us to track project outputs quite effectively, and this data should continue to be collected for any project expansions.

During this pilot phase, the project has focused on output indicators, rather than outcome or impact indicators. Any expansion offers the opportunity to add metrics, particularly ones aimed at assessing outcomes or impacts. However, added metrics must be reasonable given the resource and time constraints that all projects operate under. Time constraints can be particularly challenging for projects involving African hardwood species, given their time to maturity is often multiple lifetimes.

Opportunities for enhanced monitoring and evaluation include:

Using initial community surveys as a baseline for community impact: Objective 1 suggests the use of a basic survey instrument to assess whether a community is a good candidate to participate in the project. This survey could also collect very basic data about community livelihoods and environmental practices, which would serve as a baseline for communities that ultimately participate in the project. Subsequent surveys with standardized questions throughout the length of the project could provide more information about the impact the project is having on community livelihoods and well-being. However, most of the benefits to the communities will come from fruit production that will happen after the project ends. For a more thorough investigation of the impacts of the project on the community, we recommend it be considered as a topic for implementation research or as a separate research project (see Section 6.4 below).

Expand database of trees planted: The project currently maintains a database of the numbers of trees of different species in all of the project locations, and takes more detailed growth and reproductive data about a subset of these trees. The project also tracks mortality rates of saplings grown from different propagation techniques, and viability rates for a subset of transplanted ebony trees. This data collection should continue in any expansion of the project, and is an important part of tracking the numbers of trees planted. Additional data collection will allow for revised plant survival numbers, and may provide insight on the most productive conditions for transplantation success and growth rates under different conditions.

Estimate carbon sequestration potential of project sites: Initial results from Objective 1 suggest that incorporating ebony into agroforestry approaches may lead to a significant increase in carbon sequestration over time compared to the baseline (see Figure 1). Refining the estimated carbon sequestration values calculated in Objective 1 would be of value to potentially qualify the project as a mechanism of reducing net emissions in the region.

Table 8: Existing and proposed indicators for The Ebony Project.

INDICATOR	**TYPE**	**NOTES**
In progress indicators		
Number of trees grown, by method, location, and stock	Output Outcome	Allows the calculation of success rate for different propagation approaches
Number of trees planted (ebony and locally valuable fruit trees)	Output	Allows for estimates of land reforested
Locations of the planted trees and approximate dates of planting	Output	Allows for growth rate estimates
Number of farmers who plant trees	Output	Asking for the number of people in their families would allow us to better estimate the total number of beneficiaries
Number of communities involved	Output	
Papers and reports published increasing the understanding of ebony	Output	

INDICATOR	TYPE	NOTES
Proposed Indicators		
Current deforestation rate	Baseline	Remote sensing
Deforestation rate during project implementation	Impact	To determine whether the project deferred deforestation, was neutral, or spurred deforestation
Annual household income sources	Baseline	Taken in community survey
Income and food security impact of locally valuable fruit trees	Impact	Cannot be completed during the life of the project (see research section)
Surviving transplanted trees	Outcome	Already being collected in a limited fashion; would not need to be collected for all trees. Allows for calculation of success rate
Estimated carbon sequestered over baseline	Impact	Requires additional research on carbon sequestration potential, but can otherwise be estimated from data the project already collects

6.3. Resourcing and Managing Monitoring and Evaluation

To date, The Ebony Project team has engaged in regular assessment and course corrections, whereby the original project design has evolved based on monitoring of project activities. This is based on both assessment of our informal metrics and regular project management discussions. Some examples of this include:

- Uneven seed production led the team to focus on diversifying the sources of ebony saplings and creating a centralized nursery to support production in years where ebony fruit production was high.
- The number of ebony trees planted has varied by community and by year. We are using this new information to revise our understanding of the rate of planting for communities.

We consider that this approach has been fairly effective, particularly as the project includes stakeholders from the private sector, research, and local communities. It resembles an adaptive management approach (see text box), and we recommend that if the project expands that it more purposefully and effectively incorporate an adaptive management approach. This process has already begun with the drafting of the vision and revised goals for the project, as well as integrating findings from the project so far into the recommendations of this study.

6.4. Suggested Research

In the process of developing this Feasibility Study, the team identified a number of questions raised by The Ebony Project that are too complex to be determined as part of the project. These are topics that would require independent research, but would do much to answer outstanding questions about effective reforestation approaches in the Congo Basin. High priority research questions include:

> **Adaptive Management** exploring alternative ways to meet management objectives, predicting the outcomes of alternatives based on the current state of knowledge, implementing one or more of these alternatives, monitoring to learn about the impacts of management actions, and then using the results to update knowledge and adjust management actions. At its core, it relies on a partnership of stakeholders, in this case communities, scientists, business, and policymakers to learn together how the project best operates.

- *Carbon sequestration potential of ebony-based agroforestry*. Initial results from the Feasibility Study suggest that the project's ebony agroforestry approach has the potential to sequester more carbon and for longer than standard agroforestry approaches. To improve this estimation and minimize uncertainty, we recommend gathering a more accurate measurement of the density of Cameroonian ebony, comparing the results of different calculation methods, comparing the results to those for other hardwood species, and modeling out different scenarios. We believe we have found a group of students who can do the initial work on this research project.
- *Natural reforestation approaches*. Community-based approaches to reforestation like those currently used in The Ebony Project have the benefit of community support, but are unlikely to be as efficient as leveraging natural processes to reforest degraded land (e.g. animal seed dispersal). There is promise for a modified version of The Ebony Project to help play this role, but research is required to determine the appropriate methodology. We recommend at least a three year project to conduct novel tests of different reforestation methodologies in Cameroon using timber species with economic value. The project would first characterize key ecological parameters of pristine forest and document ecological patterns and processes critical to natural regeneration. It would also work directly with members of the local community by involving them in the selection of target tree species with economic value for future timber harvest and non-timber forest products as well as ecological value for restoration. The project would then use this knowledge to design scientifically rigorous tests of alternative restoration methodologies. This project will result in a scientifically sound and socio-economically sustainable blueprint for future restoration efforts, with broad applications throughout the Congo Basin.
- *Longevity of The Ebony Project's impact on reforestation*. Swidden agriculture—rotating agricultural production among forest plots as soil fertility wanes—is a common practice in the Congo Basin. Research elsewhere in the tropics suggests that even land that is purposefully reforested following agricultural use is often again degraded within a few decades (Reid et al 2018). We hypothesize that the inclusion of locally valuable fruit trees which are compatible with local agricultural practices will help protect the project areas from being deforested in at least the medium term, but a multi-decade research project would be required to determine if this is the case, and to compare the results to

control areas in the region. It is possible that with improved remote sensing abilities this project could be accomplished with minimal field work, but it would require a long time scale.

- *Value of biodiversity support compared to other land uses*. The Ebony Project has the ability to succeed on at least three levels: community development, reforestation, and carbon sequestration. One key aspect of its potential to promote reforesting degraded land stems from its promise to support some of the Congo Basin's rich biodiversity. Prior studies have shown variation in biodiversity support by land use, including different types of agroforestry (Chaudhary et al 2016). The intercropping system proposed here is relatively diverse, and so has good potential to support biodiversity. Testing the system's ability to support biodiversity would potentially demonstrate another benefit of the project. It would require measuring a subset of the biodiversity over time and comparing it to a control (mature rain forest) and potentially other land use types.
- *Economic value of the project to participating communities*. The willingness of communities to participate in The Ebony Project is a good indication that they see it as valuable to them and their members. However, the project would benefit from a more rigorous assessment of the impact of the project on community livelihoods, food security, and household income. The gold standard for such research would be a randomized control trial that would need to cover multiple years, including once the fruit trees begin producing. These are usually undertakings costing upwards of $500,000 USD, and required researchers with expertise outside that of The Ebony Project team. However, we recommend that the project ask for basic livelihoods information in initial community surveys in an effort to set a baseline for economic impact on the community.

The team would welcome the inclusion of resources for these projects into future expansions of the project, but also believes we should seek separate funding to move forward with some of these research projects.

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