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Think globally and act locally: Assessing the environmental impacts of the Nigerian threatened native trees project

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ABSTRACT

The environmental and socio-economic impacts of the Nigerian Threatened Native Trees Project are presented. This project conducted propagation trials and developed a freely downloadable online Manual of Tree Propagation (MTP) for 55 native tree species, training 146 local experts (32 women and 114 men) during the period (November 2015—December 2022). We used Google Analytics and interviews to assess the impacts of this project from January 2018—July 2023 (iEcology). Results show that the MTP has been downloaded 1013 times, with the star apple *Gambeya albida* (76), gum tree *Tetrapleura tetraptera* (65) and bitter kola *Garcinia kola* (50) topping the list. These downloads were from 15 countries spread across the world. Interestingly, the seven African countries that downloaded the MTP are concentrated in the tropical belt with similar floristic composition. The native range of almost all the propagated species overlaps with these African countries, suggesting the adoption of our MTP, and practically demonstrating the conservation mantra of "think globally, act locally". In addition, the MTP has been deployed for academic work (i.e., grey literature) and reforestation (e.g., covering c. 1200 ha in Nigeria). By revealing suitable propagation techniques and training local foresters, our approach could boost the utilization of native tree species for reforestation in Africa.

Specification table.

Subject area	Transportation
Category/categories of societal impact:	Education and Environment
Sustainable Development Goals (SDGs) the research contributes to:	Goal 13: Climate Action; Goal 15: Life on Land
Resource availability:	https://forestcenter.iita.org/index.php/manual-tree-propagation/
Related research article:	None available
Stage of research:	In Progress (since November 2015)

Social impact: what triggers the choice of tree species used for reforestation in Africa?

Reforestation is a practical conservation activity in Africa that aims to restore the lost environmental and socio-economic benefits associated with trees [1]. It is commonly conducted across diverse anthropogenically disturbed areas, such as degraded forests, farmlands (e.g., through farmer-managed natural regeneration or agroforestry) and urban centers [1,5]. Thus, the choice of tree species is crucial to the success of any reforestation program that aims to maximize specific benefits. This leads to the ongoing debate regarding the use and impacts of native *vs* invasive non-native tree species (NNTs) [10]. There are diverse accounts of the negative impacts of NNTs, ranging from landscape and biotic homogenization to the alteration of ecosystem services and functions [2]. Although NNTs still provide some benefits [11], it is worth asking why concerned stakeholders would prefer to grow NNTs if native trees could provide similar or even better services and functions. Answering this question is key toward reconciling some mismatches in the African reforestation agenda.

The lack of information, availability of seeds, and suitable propagation techniques are major impediments to the use of native trees for reforestation in Africa [3,6]. For instance, there is a positive correlation between fruit production and the diameter of some African tree species (e.g., false iroko *Antiaris toxicaria*, ijebu *Entandrophragma angolense*, and star apple *Gambeya albida*) [8], suggesting that the indiscriminate or selective logging of the largest trees reduces seed availability [4]. In contrast, the fast-growing, stress-tolerant, ornamental appeal and income-generating characteristics of NNTs are some of the main reasons people grow them [2]. Of these reasons, the fast-growing attribute

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appears to be highly ranked among many African reforestation stakeholders. For example, conducting reforestation with native trees is less attractive to Ghanaian farmers, who prefer the fast-growing NNTs that could yield quick income necessary to support their families [7]. Breaking the propagation barrier could therefore improve the use of native trees for reforestation in tropical Africa. The Nigerian Threatened Native Trees Project has significantly contributed in this respect, and its impacts are presented here.

Methodology: developing a manual of propagation for West African native trees

The project focused on native tree species and the 55 native tree species were selected on the basis of their conservation status, availability of propagules, and budgets for travel and collecting. It commenced in southern Nigeria in November 2015, and is still ongoing with funding from different donors (see acknowledgement section). It focused on two implementation strategies, namely tree propagation and capacity building, and used the associated experience to develop the English language online Manual of Tree Propagation (MTP). The propagation trials were performed in the project nursery while resulting seedlings were planted out in the Tree Heritage Park (THP: 7°30.213' N, 3°54.576' E; c. 12 ha; 240 m. a.s.l.) and other locations within and outside the campus of the International Institute of Tropical Agriculture in Ibadan, Nigeria. The tree propagation protocol is simplified (Fig. 1) to ease adoption by intending reforestation stakeholders and break the myth around the difficulties of propagating West African native trees. Details specific to each of the 55 species are freely downloadable on the project website (https://forestcenter.iita.org/index.php/manual-tree-propagation/).

The seed collection component of tree propagation involved three key activities: site and tree assessment; time and duration of fruiting; and seed collection. Initially, we relied on the literature and indigenous knowledge through our partners to identify the geographic distribution, availability and fruiting periods of specific tree species in southern Nigeria. Having accessed the site at fruiting time, we performed a population assessment within a 50 m x 50 m of each parent tree (centered) by taking the following data: estimated numbers of seeds and self-sown seedlings of each species, and the height, diameter at breast height (> 10 cm) and geographic coordinates. With respect to promoting natural regeneration, we collected only c. 20 % of the seeds (enough for our propagation trials) from under any parent tree in seven forest patches in southern Nigeria (Omo and Olokemeji Forest Reserves, Ogun State; Queens Forest, Ondo State; Okomu National Park, Edo State; Ekiti Forest Reserve; Emerald Forest Reserve, Osun State and IITA Forest Reserve, Oyo State).

The seed propagation component comprised five main activities, including methods for seed extraction and viability test, dormancy breaking, sowing, pricking out and hardening off (Fig. 1; see MTP for details). The aim of these activities was to optimize seed germination and seedling performance by following existing protocols (e.g., [9]).

During the tending operations, we watered regularly (at least every third day through irrigation when there was no rain), removed competing weeds weekly, and graded the seedlings monthly to enhance growth and development.

We assessed the measurable impacts of this project using three main approaches. Firstly, we used Google Analytics (18 March 2024) to track the number of downloads of each tree species and location by country of each download from 1 January 2018–31 July 2023. Secondly, we estimated the extent of local capacity in tree propagation which was initiated or enhanced during the course of project implementation. To achieve this, we counted the total number of people trained during seed collecting trips to the seven forest patches (10 women and 54 men), two project workshops in 2016 and 2022 (11 women and 42 men), training of four members of staff (1 women and 3 men) for Crescendo Africa (a conservation organization in central Nigeria), and graduate internships (10 women and 15 men trained for at least 3 months between 2016 and 2023). Thirdly, we interviewed eight project beneficiaries (i.e., a male and a female trainee from each of the above groups) through phone calls in May 2024. The aim was to determine the skills gained through use of the MTP and their level of application. We then performed descriptive statistics using Microsoft Excel.

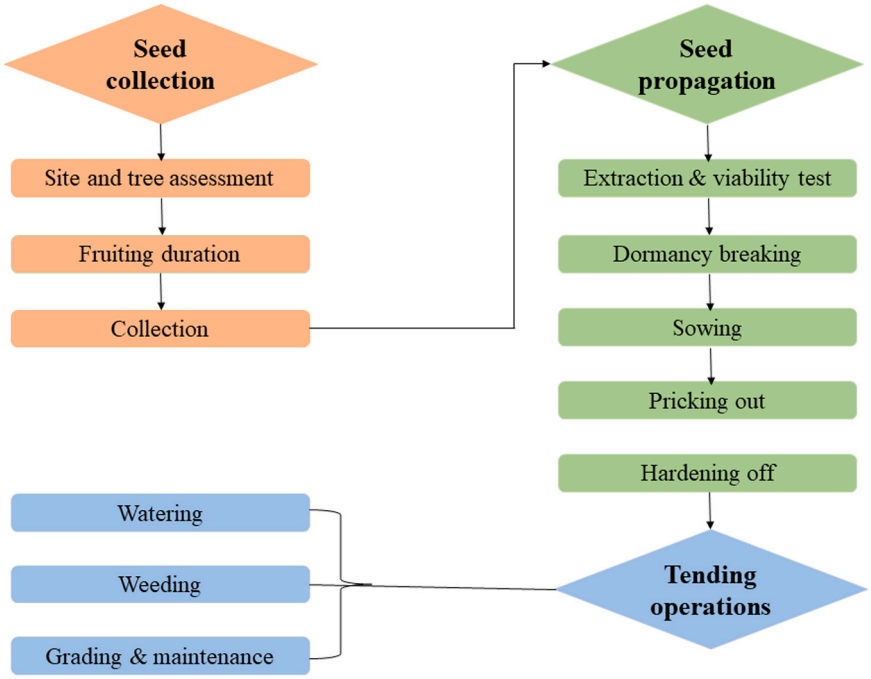

Fig. 1. Basic steps of how to grow West African native tree species from seeds. Specific details about each species are free available on the project webpage (https://forestcenter.iita.org/index.php/manual-tree-propagation/).

Results, discussion and implications

We developed the MTP for a total of 55 native tree species between November 2015 and December 2022 (Table 1). Among these are 24 species (44 %) of serious conservation concern (3 Endangered, 13 Vulnerable and 8 Near Threatened), based on the classification of the International Union for Conservation of Nature. Google Analytics revealed that the MTP for each of the 55 species had been downloaded at least once (e.g., white African cedar *Entandrophragma candollei*) and up to 76 times (i.e., star apple *Gambeya albida*), totaling 1013 downloads across all species between 1 January 2018—31 July 2023 (Table 1). The MTP has been downloaded from a total of 15 countries spread across the world (Table 2), which included seven African countries (Benin Republic, Cameroon, Côte d'Ivoire, Democratic Republic of the Congo, Ghana, Nigeria and Uganda). One hundred and forty-six locally based foresters, including 32 women (22 %) and 114 men (78 %), were trained in tree propagation during the project. In addition, the interviews identified three broad areas of knowledge application: (1) forest rangers in the aforementioned reserves recommended the MTP and the species propagated to other projects and foresters who aimed to collect propagules; (2) graduate trainees used the MTP for academic work (i.e., grey literature); (3) project staff and trainees used the MTP to propagate seedlings to restore c. 1200 ha of degraded forest patches in Nigeria, for example in Olokemeji, Emerald, and Crescendo forest reserves.

Our results showed the wider relevance of this local conservation project, demonstrating the conservation mantra "think globally, act locally". The total number of downloads of the MTP may be considered absolute as it shows a more meaningful/intentional engagement with the project webpage than mere viewing. All seven African countries that downloaded the MTP are concentrated in the tropical belt that shares similar floristic composition [4]. Thus, we could speculate an instantaneous adoption of the MTP for boosting the use of native tree species for reforestation in West Africa. With the exception of okwen *Brachystegia nigerica,* which is endemic to Cameroon and Nigeria, the native range of almost all the other species (https://www.gbif.org/) extends through the other African countries that downloaded information (Table 2). It is therefore not surprising that okwen received fewer downloads (7) than other species, such as the star apple *Gambeya albida* (76), which has a wide distribution across the Afrotropical belt in, for example, Nigeria, Cameroon, Ghana, Benin Republic, and Uganda. The highest number of downloads was from Nigeria, which might be expected given the location of the project. The frequency of downloads might also be associated with the official language of the majority of downloading countries. Translation into French might increase its impact in countries such as neighboring Benin Republic and Cameroon.

The tree species with the most downloads, namely star apple *Gambeya albida* (76), gum tree *Tetrapleura tetraptera* (65), bitter kola *Garcinia kola* (50) and black camwood *Pterocarpus osun* (50), reveal the interests of reforestation stakeholders in the tropical African belt, and should serve as a practical recommendation to governmental and donor agencies that fund African reforestation programs. Furthermore, the most downloaded species are valued more for their non-timber products, such as fruits and medicinal uses, which are in demand both locally and

Table 1
Number of downloads of the Manual of Tree Propagation for 55 native tree species extracted from the project website (https://forestcenter.iita.org/index.php/manual-tree-propagation/) using Google Analytics, 1 January 2018—31 July 2023.

S/N	Species	Number of downloads	Conservation Status
1	*Gambeya albida*	76	Near Threatened
2	*Tetrapleura tetraptera*	65	Least Concern
3	*Garcinia kola*	50	Vulnerable
4	*Pterocarpus osun*	50	Least Concern
5	*Triplochiton scleroxylon*	44	Least Concern
6	*Newbouldia laevis*	43	Least Concern
7	*Terminalia ivorensis*	40	Vulnerable
8	*Pterocarpus erinaceus*	37	Endangered
9	*Irvingia gabonensis*	35	Near Threatened
10	*Hildegardia barteri*	29	Least Concern
11	*Rauvolfia vomitoria*	29	Least Concern
12	*Nauclea diderrichii*	28	Near Threatened
13	*Nauclea latifolia*	28	Least Concern
14	*Kigelia africana*	27	Least Concern
15	*Treculia africana*	26	Least Concern
16	*Buchholzia coriacea*	25	Least Concern
17	*Mansonia altissima*	25	Endangered
18	*Dialium guineense*	24	Least Concern
19	*Pentaclethra macrophylla*	21	Least Concern
20	*Milicia excelsa*	20	Near Threatened
21	*Cola millenii*	18	Least Concern
22	*Daniellia ogea*	18	Near Threatened
23	*Millettia macrophylla*	18	Near Threatened
24	*Baphia nitida*	17	Least Concern
25	*Markhamia tomentosa*	17	Least Concern
26	*Albizia ferruginea*	16	Near Threatened
27	*Allanblackia floribunda*	16	Least Concern
28	*Erythrophleum suaveolens*	15	Least Concern
29	*Lophira alata*	13	Vulnerable
30	*Entandrophragma utile*	12	Vulnerable
31	*Pericopsis elata*	12	Endangered
32	*Synsepalum dulcificum*	12	Least Concern
33	*Antiaris toxicaria*	11	Least Concern
34	*Entandrophragma angolense*	11	Near Threatened
35	*Lonchocarpus sericeus*	10	Least Concern
36	*Khaya senegalensis*	9	Vulnerable
37	*Bauhinia thonningii*	7	Least Concern
38	*Brachystegia nigerica*	7	Vulnerable
39	*Dactyladenia barteri*	7	Least Concern
40	*Pterygota bequaertii*	6	Vulnerable
41	*Caloncoba gilgiana*	5	Least Concern
42	*Carapa procera*	5	Least Concern
43	*Monodora tenuifolia*	5	Least Concern
44	*Afzelia bipindensis*	4	Vulnerable
45	*Irvingia tenuinucleata*	4	Least Concern
46	*Afzelia africana*	2	Vulnerable
47	*Blighia sapida*	2	Least Concern
48	*Holarrhena floribunda*	2	Least Concern
49	*Khaya grandifoliola*	2	Vulnerable
50	*Newtonia griffoniana*	2	Least Concern
51	*Strombosia pustulata*	2	Least Concern
52	*Entandrophragma candollei*	1	Vulnerable
53	*Khaya ivorensis*	1	Vulnerable
54	*Millettia drastica*	1	Least Concern
55	*Sterculia oblonga*	1	Vulnerable
	Total	**1013**	

Table 2
Number of downloads of the Manual of Tree Propagation across countries. The data were extracted from the project website (https://forestcenter.iita.org/index.php/manual-tree-propagation/) using Google Analytics, 1 January 2018—31 July 2023.

S/N	Country	Number of downloads
1	Nigeria	693
2	Finland	58
3	Ghana	44
4	United Kingdom	26
5	Benin Republic	26
6	Cameroon	25
7	Côte d'Ivoire	24
8	Democratic Republic of the Congo	23
9	Uganda	21
10	India	15
11	Germany	14
12	Guyana	14
13	New Zealand	14
14	United States	13
15	Indonesia	3
	Total	**1013**

more widely in the cosmetic and pharmacological industries [4]. With the exception of bitter kola, these species exhibit earlier maturation than timber tree species such as African teak *Milicia excelsa*. Bitter kola *Garcinia kola* was also one of the most difficult species to propagate during this project, a challenge that other African reforestation projects might have encountered, which might further explain the higher number of downloads. As deforestation is widespread across natural and plantation forests in Africa [4], our study suggests that the integration of native trees valued for non-timber economic products could ameliorate this trend. People are more likely to protect trees that yield quick economic returns, whether in forests or via agroforestry.

Regarding the high number of downloads from non-African countries (Finland, Germany, Guyana, India, Indonesia, New Zealand, United Kingdom and United States), we could speculate the use of the MTP as grey literature for academic purposes. For instance, students studying related topics abroad, whether African or non-African, could gain insights from the MTP. Unlike in traditional publishing and indexing of scientific articles in databases (e.g., with doi), we were unable to track the academic use of our MTP in this respect. However, our interviews with graduate trainees identified academic use as an area of knowledge application. It is possible that African reforestation stakeholders could download the MTP while living in or visiting countries outside Africa. Moreover, the MTP could be adopted for developing similar protocols for the propagation of native tree species in non-African countries.

The results of our study showed the transfer of tree propagation skills to almost 150 foresters during the 8-year MTP project implementation period. These skilled individuals constitute an agent of change, both carrying out and promoting the propagation of native trees in their areas, and thus passing on their skills and enthusiasm. The outcome also revealed the need to improve the engagement of women in forestry, which could be achieved through training programs such as this.

In January 2022, the Tree Heritage Park, where the saplings resulting from this project are planted, was recognized internationally through a Level II Accreditation awarded by the ArbNet Arboretum Accreditation Program and The Morton Arboretum, for meeting identified standards of professional practices important for arboreta and botanic gardens (https://forestcenter.iita.org/index.php/projects/tree-heritage-park/). At the time, the THP was the 500th accredited arboretum in the world, but the first in Nigeria and one of only 11 arboreta to achieve such feat in Africa. It is a repository - a "Noah's Ark" - of genetic resources for tropical West African native trees, and is regularly visited for research and educational purposes. The impacts of this project are an indication of its significance, and we recommend its adoption in areas where practical information about the propagation and planting of native tree species is needed to benefit local communities and their environment, and to reduce the invasion of non-native tree species.

Ethics statements

The Nigerian National Park Services, Forestry Research Institute of Nigeria and Forest Management granted us access for seed collecting at the National Parks, State-owned Forest Reserves and Private Forest Reserves, respectively.

CRediT authorship contribution statement

Adewale G. Awoyemi: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Olukunle E. Olasupo:** Validation, Methodology, Investigation, Data curation. **Ademola D. Ajayi:** Investigation, Data curation. **Deni Bown:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Funding acquisition, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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