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ARTICLE

Former Botanical Garden of ORSTOM (Côte d'Ivoire): What Remain after Thirty Years of Abandonment and Forest Restoration

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ABSTRACT

Botanical gardens represent important places for *ex situ* conservation. One of these botanical gardens has been abandoned in Côte d'Ivoire for 30 years. This is the former botanical garden of ORSTOM. This study was conducted to determine the level of diversity of this former garden in order to assess the opportunity for its rehabilitation. The authors carried out inventories in 18 quadrats of 500 m^2 through the vegetation to collect woody species. Dendrometric measurements (height, diameter) were also recorded to assess the structure of the site. A total of 190 species have been identified. They belong to 141 genera and 47 families. This former botanical garden contains important species because of their origin, status or particularity (threatened, endemic, rarity, etc.). A total of 19 threatened species including 2 endangered and west African endemic (*Chrysophyllum azaguieanum* J. Miège*, Placodiscus pseudostipularis*) were found at the site. Also, *Chrysophyllum azaguieanum* is declared extinct from Côte d'Ivoire. Four species are rare in the flora of Côte d'Ivoire: *Balanites wilsoniana, Chrysophyllum azaguieanum, Gilletiodendron kisantuense* and *Loesenera kalantha*. The most abundant species is *Hopea odorata*. Although this introduced species is considered globally vulnerable, it presents a risk of invasion in the forest of Côte d'Ivoire. The diameter and height structures show that all the stages of development are presented indicating a good regeneration on the site. Ultimately, this botanical garden deserves to be rehabilitated and especially urgent management of *Hopea odorata* is needed to prevent an invasion of this species.

Keywords: Botanical garden; ORSTOM; Côte d'Ivoire; Forest restoration; *ex situ* conservation

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1. Introduction

A botanical garden is an area in which plants are cultivated, maintained and reproduced for several purposes such as education, science, tourism and above all conservation [1,2]. With their living collections of plants, or seed banks, botanical gardens are important places holding genetic diversity and threatened species. The mission of conservation is increasingly crucial due to the massive loss of biodiversity. Today, more than 40% of endangered plant species are protected out of their habitats, in botanical gardens [3]. This type of protection called *ex situ* conservation has become one of the main missions and activities within modern botanical gardens worldwide. There are more than 2500 botanical gardens in the world with the majority of them located out of the (sub) tropical regions where there is nevertheless a higher concentration of biodiversity [4]. Africa is one of the poorest regions in botanical gardens, like the other tropical zones, compared to Europe or North America. Moreover, the existing botanical gardens on the African continent rarely have seed banks [5]. The advent of botanical gardens in this continent began with colonization during the 19th and 20th centuries. Thus, in West Africa, the botanical gardens of Bingerville (Côte d'Ivoire) and Abury (Ghana) were created in 1904 and 1890, respectively. After these historical botanical gardens and by far the biggest ones, some other botanical gardens were installed even after the independence. Thus, in Côte d'Ivoire, the French research agency called ORSTOM (Office de la Recherche Scientifique et Technique Outre-Mer), now IRD (Institut de Recherche pour le Développement), settled a botanical garden in the village of Adiopodoumé in 1946 near Abidjan. At the end of the 1980s, ORSTOM left Côte d'Ivoire and its facilities, including the botanical garden, were given to the national center of Agronomy, the CNRA. Despite the increasingly important role of botanical gardens, in *ex situ* conservation of plants, particularly the threatened ones, the ORSTOM botanical garden was not maintained after the departure of this institution. Fortunately, the site was not destroyed. After more than thirty years of abandonment, the garden has turned into a secondary forest. At the current state of the site is difficult to find the limits of this garden from the surrounding forests based on the physiognomy of the vegetation. Moreover, very little information is available on this garden either in the CNRA archives or in the literature. Thus, little is known about its floristic composition at the moment of the departure of ORSTOM. In the absence of this historical data, are there any chances of finding species that are certain to have been planted there? For example, species from other phytogeographical regions or from other regions of Côte d'Ivoire? Can the role attributed to this botanical garden at its creation be detected from its current species composition? The abandonment of the garden and its recolonization by the local flora certainly led to more or less important changes in its specific composition. The current state of the site is the result of an ongoing ecological succession. This process can lead to the disappearance of certain species. Indeed, ecological succession occurs in different stages including invasion, competition, Co-action and Stabilization (climax) [6]. The competition stage can conduct in a change in the species and diversity [7]. Amani, B. H. K. et al. [8] showed that in Côte d'Ivoire, a secondary forest in reconstitution, after 20 years, recovers 90% of the diversity contained in an old forest. It is established that most of the plants introduced in the garden are not naturalized [9]. But in climate change conditions, it is difficult to predict the trajectories of the recovery. Studies conducted by Haeuser, E. et al. [9] under controlled conditions, have concluded that native species could be less competitive with climate warming. Such a scenario would mean that in an old botanical garden, exotic species would be more represented after years of abandonment. But it is clear that the contrary could also be obtained. Indeed, the trajectories of the succession can be under the influence of several factors including the nature of species (native and introduced) [10,11]. This paper aims at investigating the floristic richness and diversity of the former botanical garden of ORSTOM.

2. Materials and methods

2.1 Site location and description

The site of the botanical garden is located in the surroundings of the village of Adiopodoumé in the north of Abidjan (South-East of Côte d'Ivoire). The place is located between 05'19''16.32 N-05'19''25.68 N and 04'07''53.76 W-04'07''58.80 W (**Figure 1**). The region was initially covered by wet evergreen forests characterized by a high frequency of *Turraeanthus africanus* (Welw. ex DC) Pellegr. (Meliaceae) and *Heisteria parvifolia* Sm. (Olacaceae). Today the Banco National Park is one of the remnants of this type of forest. The region experiences high rainfall that can reach almost 2000 mm per year. The temperatures vary very little and oscillate between 24.51 °C (August) and 27.67 °C (March) [12]. In the absence of documentation on the limits of the garden, we carried out the inventory work with the help of a former technician from ORSTOM. Mr. Henri Teré worked in the botanical garden of ORSTOM for more than 25 years and had an accurate knowledge of the limits. He has published a paper on ethnobotany [13]. A reconnaissance visit was thus carried out with him so that he indicated the places supposed to be the limit of the garden. These boundaries have been georeferenced.

2.2 Methods of inventory and identification of the species

For the inventory of the species, we have settled 18 plots of 500 m^2 (25 m × 20 m) according to the physiognomy of the vegetation. In each plot, all the species were recorded. This method of inventory is usually used in the studies of African vegetation [14-16]. In addition, all individuals with a DBH (Diameter at Breast Height) greater than or equal to 3 cm were counted and the DBHs mentioned for each individual. The heights of these individuals were also recorded. The DBH was measured at 30 cm from the ground. Herbaria samples were collected for the unknown plants for their identification. These identifications were done at the herbarium of the "Centre Suisse de Recherches Scientifiques en Côte d'Ivoire" (CSRS). All the specimens collected are deposited in this herbarium registered in Index Herbariorum. (https://sweetgum.nybg.org/science/ih/herbarium-list/?NamOrganisationAcronym=CSRS).

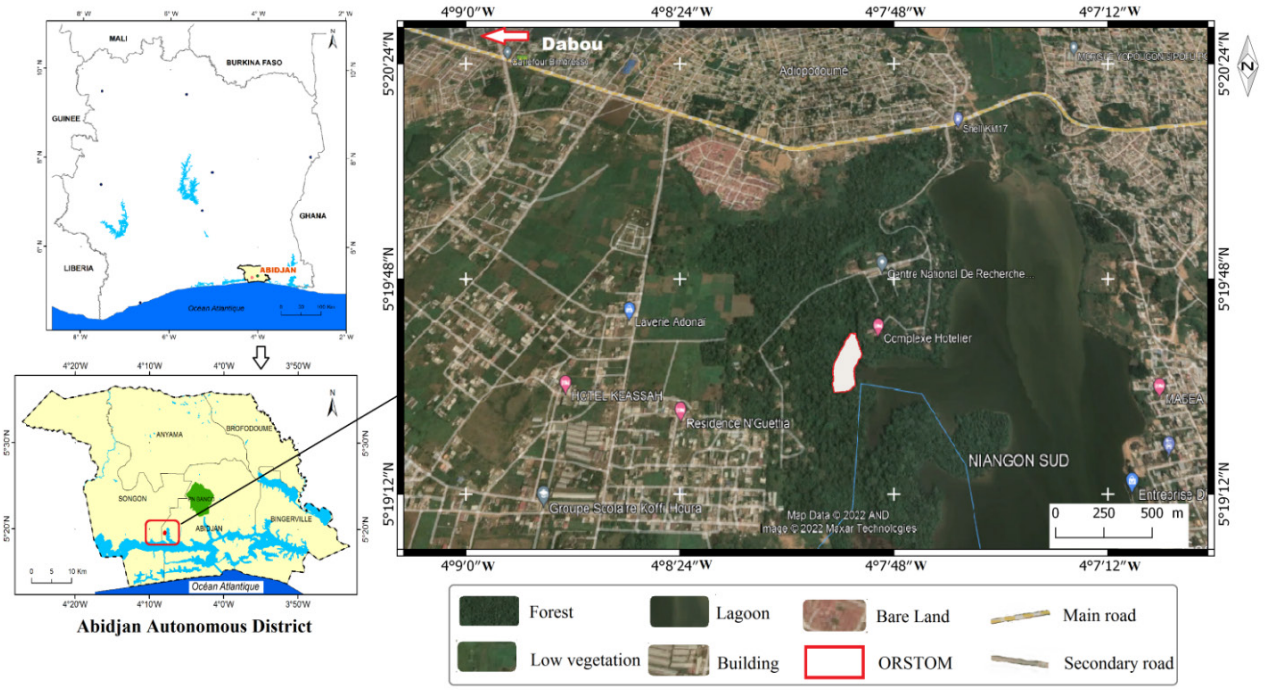

Figure 1. Location of the former botanical garden of ORSTOM.

2.3 Analysis of the diversity

A qualitative analysis of the diversity was carried out in this study. First, the taxonomic diversity was assessed through the number of species, genera and families after the identification of each plant including those that were brought into the herbarium. The nomenclature of the families adopted is that of the phylogenetic classification [17]. Then the conservation status, of each species was checked on the IUCN website (https://www.iucnredlist.org/). Also their rarity, endemism and chorology were checked [18-22]. The level of endemism considered was that of Côte d'Ivoire or West Africa. We used the chorology proposed by Aké-Assi, L. [20] as follows:

-GC: Guinean-Congolese species;

-SZ: Sudano-Zambesian species;

-GC-SZ: Common species for the Guinean-Congolese and Sudano-Zambesian phytogeographical regions;

-GCW: Endemic species of the forest area situated at the west of Togo, including Ghana, Côte d'Ivoire, Liberia, Sierra Leone, Guinea, Guinea Bissau, Gambia and Senegal.

2.4 Analysis of the structure

The vertical and horizontal structure of the vegetation can be assessed through several parameters [23-25]. The diameter classes for the analysis of the horizontal structure and the height classes for the analysis of the vertical structure were used. The diameter classes thus constituted have an amplitude of 10 cm and the height classes have an amplitude of 5 m.

3. Results

3.1 Taxonomic diversity

A total of 190 species have been inventoried on the site. These species belong to 141 genera and 47 families. The most species-rich families are those of the Fabaceae (39 spp), Malvaceae (16 spp), Euphorbiaceae (15 spp), Meliaceae (13 spp), Annonaceae (9 spp), Sapotaceae (9 spp). These families include more than 50% of all the species recorded (**Figure 2**).

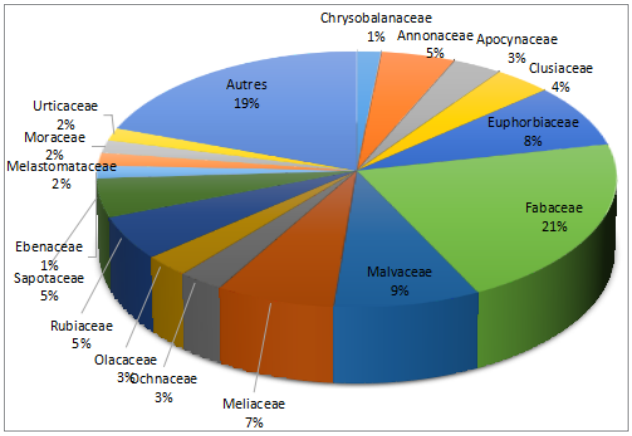

Figure 2. Proportions of species in the families listed in the former botanical garden of ORTOM.

3.2 Chorologie and endemism

We found 134 Guinean-Congolese (GC) species which represent 70.52% of the species. There are a total of 12 GC-SZ species and only 1 SZ species. Twenty-two (22) endemic species of the Upper Guinean forest were recorded at the site (**Table 1**). Some of these species have been inventoried, until now, in only two or three countries in West Africa. Indeed, *Chrysophyllum azaguieanum* J. Miège (**Figure 3**) is known in Côte d'Ivoire and Ghana. *Loesenera kalantha* Harms has been observed in Liberia and the west of Côte d'Ivoire.

3.3 Introduced species

Among the species, 6 do not belong to the natural flora of Côte d'Ivoire. They have been introduced in the garden definitely from other countries. These are: *Hopea odorata* Roxb, *Laurus nobilis* L., *Fatsia sp*, *Xylopia sp*, *Olea europaea* L.and *Aucoumea klaineana* Pierre (**Figure 3**). *Aucoumea klaineana* is also a threatened (vulnerable) species from central Africa. Twenty individuals, the majority of which were in the young or subadult stages, were counted. This shows that the first individual introduced reproduces and its seeds germinate. Moreover, this individual has been observed with inflorescences (**Figure 3**).

Table 1. West African endemic species in the former botanical garden of ORSTOM in Côte d'Ivoire.

Species	Family
Berlinia occidentalis Keay	Fabaceae
Calpocalyx aubrevillei Pellegr.	Fabaceae
Chrysophyllum azaguieanum J.Miège	Sapotaceae
Coelocaryon oxycarpum Stapf	Myristicaceae
Cola caricifolia (G. Don) K. Schum	Malvaceae
Copaifera salikounda Heckel	Fabaceae
Daniellia thurifera Benn.	Fabaceae
Dialium aubrevillei Pellegr.	Fabaceae
Diospyros liberiensis A.Chev. ex Hutch. & Dalziel	Ebenaceae
Drypetes aylmeri Hutch. & Dalziel	Euphorbiaceae
Drypetes ivorensis Huche. & Dalziel	Euphorbiaceae
Eugenia leonensis Ingl. & Brehmer	Myrtaceae
Loesenera kalantha Harms	Fabaceae
Octoknema borealis Hutch. & Dalziel	Octoknemaceae
Placodiscus pseudostipularis Radlk.	Sapindaceae
Schumanniophyton problematicum (A. Chev.) Aubrév	Rubiaceae
Strephonema pseudocola A. Chev	Combretaceae
Tarrietia utilis (Sprague) Sprague	Malvaceae
Tetrapleura chevalieri (Harms) Baker f.	Fabaceae
Tricalysia reticulata (Benth.) Hiern	Rubiaceae
Desmostachys vogelii (Miers) Stapf	Icacinaceae
Xylia evansii Huche.	Fabaceae

Figure 3. Leaves and inflorescences of *Aucoumea klaineana,* an introduced species in the former botanical garden of ORSTOM.

3.4 Abundance of the species

The most abundant species of this site are: *Hopea odorata* (76 ind.), *Pycnanthus angolensis* (60 ind.), *Tarrietia utilis* (Sprague) Sprague (52 ind.), *Quassia gabonensis* Pierre (37 ind.), *Carapa procera* (34 ind.), *Strombosia pustulata* Oliv. (23 ind.), *Berlinia confusa* (22 ind.) and *Aucoumea klaineana* (20 individuals). Apart from these species with 20 or more individuals, we noted 14 species with the number of individuals varying from 10 to 19. Among these species *Lophira alata* Banks ex CF Gaertn. and *Mitragyna ledermannii* (K. Krause) Ridsdale with 19 individuals each. We have counted 95 species with 2 to 9 individuals. A total of 73 species (38.42%) were represented by only one individual. It is important to highlight the fact that among the 8 most abundant species 3 are introduced species including *Hopea odorata* which have the highest number of individuals (76 individuals).

3.5 Threatened and rare species

A total of 19 threatened species were found at the site (**Table 2**). Among them, 2 species are en-

dangered and 17 are vulnerable. Also, the two endangered species are endemic to the west African Guinean Forest. These are *Chrysophyllum azaguieanum* J. Miège and *Placodiscus pseudostipularis* Radlk (**Figure 4**). Four species are rare in the flora of Côte d'Ivoire: *Balanites wilsoniana, Chrysophyllum azaguieanum, Gilletiodendron kisantuense* and *Loesenera kalantha*.

3.6 Horizontal structure

The diameter structure of the species in the botanical garden has an "inverted J" shape (**Figure 5**). The number of individuals decreases from small diameter classes to large diameter classes. Thus, individuals with a diameter between 0 cm and 10 cm are the most represented. These individuals represent more than 70% of the plants inventoried. Less than 1% of individuals have a diameter greater than 100 cm. This shows that young individuals are more numerous than adult individuals.

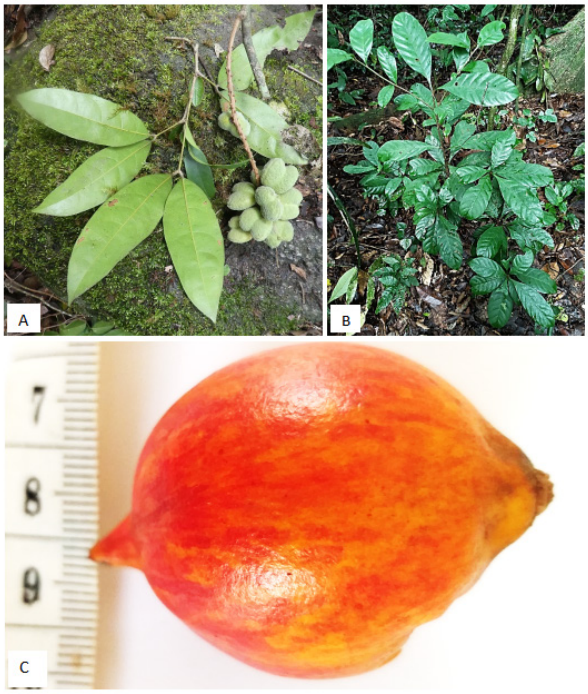

Figure 4. Two west african endemic and endangered plants: A. Leaves and fruits of *Placodiscus pseudostipularis* Radlk.; B, C. Young individual and fruit of *Chrysophyllum azaguieanum* J. Miège.

Table 2. Threatened and or rare plant species inventoried in the former botanical garden of ORSTOM in Côte d'Ivoire.

Category of threat	Species	Family
Endangered	Chrysophyllum azaguieanum J.Miège	Sapotaceae
	Placodiscus pseudostipularis Radlk.	Sapindaceae
Vulnerable	Aucoumea klaineana Pierre	Burseraceae
	Bombax brevicuspe Sprague	Malvaceae
	Copaifera salikounda Heckel	Fabaceae
	Entandrophragma angolense (Welw.) C.DC.	Meliaceae
	Entandrophragma cylindricum (Sprague) Sprague	Meliaceae
	Entandrophragma utile (Dawe & Sprague) Sprague	Meliaceae
	Garcinia kola Heckel	Clusiaceae
	Guarea africana Welw. ex C. DC.	Meliaceae
	Guarea cedrata (A. Chev.) Pellegr.	Meliaceae
	Hopea odorata Roxb.	Dipterocarpaceae
	Hymenostegia neoaubrevillei J.Leonard	Fabaceae
	Lophira alata Banks ex CF Gaertn.	Ochnaceae
	Nesogordonia papaverifera (A. Chev.) Capuron ex N. Hallé	Malvaceae
	Pterygota bequaertii De Wild.	Malvaceae
	Schumanniophyton problematicum (A. Chev.) Aubrév	Rubiaceae
	Synsepalum aubrevivillei (Pellegr.) Aubrév. & Pellegr	Sapotaceae
	Turraeanthus africanus (Welw. ex C. DC.) Pellegr.	Meliaceae

3.7 Vertical structure

The height distribution of species in the botanical garden gives a negative exponential form (**Figure 6**). Indeed, the smallest class of high (0-10 cm) concentrates the highest number of individuals. There is a predominance of individuals of low height. More than 70% of individuals have a height less than 20 m. There are very few individuals with a height greater than 40 m. This structure indicates the good regeneration of the species.

Figure 5. Distribution of the individuals of the former botanical garden of ORSTOM in the diameter classes.

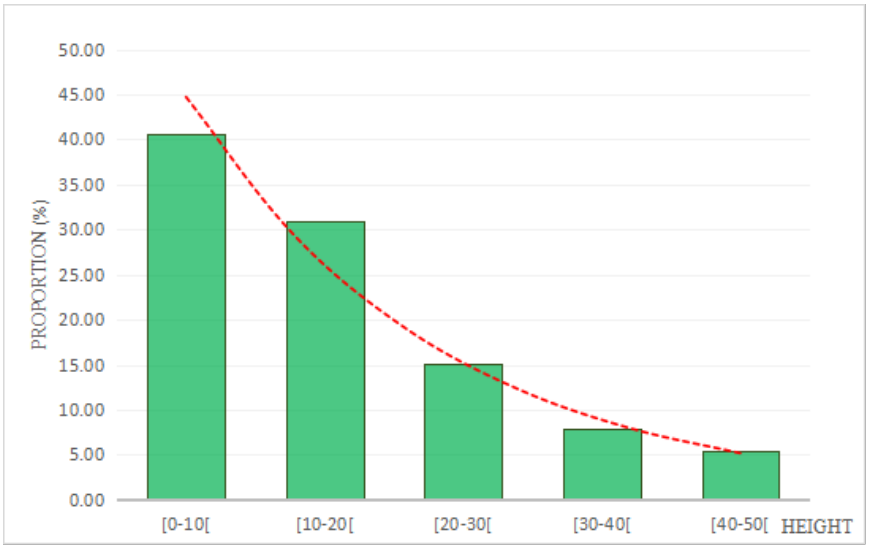

Figure 6. Distribution of the individuals of the former botanical garden of ORSTOM in the height classes.

4. Discussion

4.1 Richness and conservation value of the former botanical garden of ORSTOM

This study leads to the inventory of 190 species belonging to 141 genera and 47 families in the site of the former botanical garden of ORSTOM in Côte d'Ivoire. If the species observed are the result of the influence of the neighboring forest, there is evidence of introduced species in the garden. For instance, *Aucoumea klaineana* Pierre, *Hopea odorata* Roxb, *Laurus nobilis* L., and *Olea europaea* L. are not native of the flora of Côte d'Ivoire. The absence of

historical documents on the garden makes it impossible to know whether certain species have disappeared. After more than 30 years of abandonment, the former botanical garden of ORSTOM contains species of extreme importance for conservation. The West African Guinean forest is one of the hotspots of biodiversity [26] meaning that it has a rich biodiversity, a high rate of endemism but also a high rate of deforestation. In this context, threatened, rare and endemic species need more attention in terms of *ex situ* conservation. The former botanical garden of ORSTOM seemed to play this role regarding the number of threatened (18), rare (4) and endemic (22) species inventoried and it is clear that some species have disappeared. Indeed, we found in this garden, evidence of native cultivated species of the ivorian flora. This concerns species that are restricted to the western area of the country such as *Balanites wilsonia, Loesenera kalantha* and also *Chrysophyllum azaguieanum* J.Miège, which is considered extinct from Côte d'Ivoire [22]. Indeed, the presence of these species on this site shows that they were cultivated there as part of the enrichment of the garden. That is why we choose to call them "native cultivated species" rather than introduced species.

4.2 Breeding capacity of native cultivated species

The native cultivated species such as *Balanites wilsonia and Loesenera kalantha* are rare in their area of distribution [27]. Only two individuals of each were recorded indicating that they do not have easy reproduction which could explain their rarity in nature. However, 9 individuals of *Chrysophyllum azaguieanum* were observed, with two individuals in a reproductive state. Yet according to Aké-Assi, L. [21] only one individual of this species had been introduced into the garden and as the specimen Aké Assi 12019 has been collected from this individual in 1973, it is clear that this individual has been introduced before this date. In other words, in 2022, one can say that the individual is at least 50 years old. In any case the number of individuals of this species is low. During the inventory we found only one fruit on the first individual. A year later, monitoring revealed the presence of numerous flowers on the two adult individuals, but when the fruits matured, only 7 fruits were observed. It seems that in the current environment of this botanical garden, *Chrysophyllum azaguieanum*is facing a reproductive problem. We suspect the absence of its pollinator which is not formally known for the moment.

4.3 Abundance of the species and risk of invasion

Among the 8 most abundant species, 3 are introduced species, not part of the original flora of Côte d'Ivoire: *Hopea odorata* (76 individuals), *Quassia gabonensis* Pierre (37 ind.), *Aucoumea klaineana* (20 ind.). Therefore, *Hopea odorata* is the most abundant species on the site. The second and third most abundant native species are *Pycnanthus angolensis* (60 ind.), *Tarrietia utilis* (Sprague) Sprague (52 ind.), respectively. *Hopea odorata* is a vulnerable species according to the IUCN categories and is orinated from the South-East Asia [28]. The species is also a fast-growing species and is appreciated for its wood. These are certainly the reasons that led to its introduction in Côte d'Ivoire in the 70s. However, it should be noted that this species could be invasive in the forest ecosystems in Côte d'Ivoire. We have also observed many young individuals of this species. The invasive potential of *Hopea odorata* was observed by Tiébré, M.S. et al. [28] in the Banco National Park. These authors found in their study site, that 97% of the individuals identified belonged to *Hopea odorata*. The invasive potential of the species could be explained by its high capacity of dispersion even if the germination rates observed in Côte d'Ivoire are around 30% [29]. The abundance of *Pycnanthus angolensis* and *Heritiera utilis* can be explained by the edaphic conditions and the ecological strategy of these species. Indeed, they are both species that prefer humid zones and are light demanders [30]. These conditions were well met on the site of the former botanical garden of ORSTOM. This type of environment is also suitable for *Carapa procera*. This is why there are 34 individuals of this species on the

site, which is therefore the fifth most abundant species and the third among native species. *Aucoumea klaineana* is a pioneer and light-demander species, which often colonizes places after deforestation by forming pure stands. In their distribution area (Gabon and Congo basin) *Aucoumea klaineana* and *Quassia gabonensis* often grow in the same places and conditions, especially sandy soils [31] so that they can characterize a type of forest.

5. Conclusions

This study has shown that 30 years of forest restoration have not led to the disappearance of all the species preserved in the ORSTOM botanical garden. The current rate of loss of biodiversity makes botanical gardens more essential than ever in the tropics. Given the conservation status of many species, this garden had a clear mission: to preserve endangered plant biodiversity. It remains a site of high conservation value. This is why its rehabilitation and strengthening are desirable.

Conflicts of Interest

The authors declare no conflict of interests.

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ARTICLE

Restoration Planning of Mining Wastelands : A Case Study

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ABSTRACT

Mining plays an important role in the economic development of a country. But the consequences of the mining can be seen in the form of degradation of soil, water, and native vegetation, which ultimately results in the disturbance of the local ecosystem. The ecological restoration of such disturbed ecosystems involves the reclamation of soil, conservation of water, erosion control, and re-vegetation of native vegetation. This can be achieved by improving the physical properties of soil, enhancing the nutrient status of soil, selecting appropriate plant species for re-vegetation, providing provision of irrigation facilities for re-vegetated mining wasteland, and so on. The present study was conducted in the Kota district of Rajasthan, where stone mining is one of the major industrial activities. The paper provides a scientific assessment of the existing vegetation of limestone mining wastelands through field surveys and physicochemical analysis of soil and water. Loss of natural vegetation and excessive stoniness of the substratum were major hurdles that restrict the easy recovery of vegetation on mining wastelands but there is almost no negative impact on the water quality. The study summarizes the holistic technology including the vegetational approach to the restoration of mining wastelands and puts forward some existing problems and their solutions.

Keywords: Mining; Wasteland; Reclamation; Vegetation

1. Introduction

SER defines restoration as "The process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed." [1]. Restoration aims to guide a degraded ecosystem to a pre-disturbance state; and is generally based on the successional establishment of a stable climax community [2]. In most cases of restoration, ecological outcomes such as vegetation structure, species diversity and abundance, and ecological processes are used as ma-

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jor attributes as these are the most commonly used indicators of the ecological condition of any system [3,4]. The ultimate and often exclusive goal of any restoration project is to create an ecosystem that can support itself and is resilient i.e., does not need further assistance [1,5].

1.1 Study rational and objectives

Ecological restoration in areas of environmental degradation can help reverse global biodiversity losses, as well as promote the recovery of ecosystem services [6]. Thus knowledge of ecosystem diversity and distribution is important in the conservation of biodiversity [7-10].

Usually natural restoration process can take hundreds of years. The main objective behind the present research work is to find out the most suitable plans to mitigate and manage the negative impact of mining in the study area and to suggest ways to intervene in such a way that helps to accelerate the restoration process.

1.2 Study area

The study was conducted in the Ramganjmandi area of the Kota district of Rajasthan which is famous worldwide for building limestones. Kota district lies in the southeastern part of Rajasthan. The limestone deposits are found between 24°32' and 24°48' N latitudes and 75°50' and 76°05' E longitudes. Geographically, Kota stone is part of semi series of the lower Vindhyan group and has a vast reserve of limestone deposits spread over 150 sqkm area with a total probable reserve up to mineral limits of about 100 million tonnes. In the study area the average yield of Kota stone per hectare of the land area is 1 Lakh MT and with the current trend of yearly production level, 55 to 60-hectare land is brought under mining each year. It is estimated that to date 900 hectares of prime agricultural land has been lost to limestone mining in Kota and Jhalawar district. Kota, with 22.13 sqkm of mining wasteland ranks third in land area under mining waste after Rajsamand (46.20 sqkm), Jodhpur (33.56 sqkm), and Bikaner (28.50 sqkm) in Rajasthan (**Figure 1**).

2. Material and method

Characterization of the mining waste dump was also done to identify the fertility status and identify the factor that may cause hindrance to the establishment of the plant species. Physico-chemical characterization of the soil of mining wastelands, the water of mined-out and abandoned mining pits and existing flora in the study area were analyzed as a starting point in a strategy aimed at selecting suitable restoration planning of abandoned mine spoils and degraded land along with post-mining alternative land use objectives.

2.1 Analysis of soil

Soil texture was determined by mechanical analysis, a method commonly known as the hydrometer method [11]. The electrical conductivity (EC) was measured with the help of a conductivity meter in soil water extract in a ratio of 1:2. The pH was determined in the soil-water suspension of a ratio of 1:2 using a pH meter. For the measurement of soil organic carbon (SOC), the titration method was followed [12]. The extraction method [13] was adopted to determine available phosphorus. The Ammonium acetate method [14] was used to determine available potassium. For a rapid and accurate analysis of available Zn, Cu, Fe, and Mn, the DTPA method [15] is used.

2.2 Analysis of water

Water samples were collected twice during the study period from ten locations each of unmined and mined areas. Alkalinity was estimated by titration method. Total hardness and Calcium hardness were determined by the EDTA method. Sulphate was estimated by the Turbidimetric method and Chloride by titration method using $AgNO_3$. Nitrate and Flourides were also estimated by the titration method.

2.3 Analysis of vegetation

Vegetation sampling was done by five 10000 m^2

(1 hectare) areas selected for sampling trees. Each 10000 m^2 plot was divided into 100 equal nested quadrats of 10 × 10 m^2 and 10 such quadrats were selected for shrubs, woody climbers + saplings based on randomized block design. Further two 100 m^2 quadrat was divided into 100 nested quadrats of 1 × 1 m^2 and herbs + seedling were sampled from 10 such quadrats based on randomized block design. The vegetation data were quantitatively analyzed for frequency, density, basal area, and IVI (Importance Value Index) following the studies [16,17]. Basal areas of the trees and shrubs were expressed as m^2/hectare and herbs were expressed as cm^2/m^2.

3. Observation and results

3.1 Survey of mining wastelands

Open cast mining creates huge mining wastes which are dumped in nearby cultivable land. Many mines are abandoned after exhaustive excavations and the pits remain unfilled. Other mining-related activities such as cutting and polishing also create wastes in the form of slurry which is disposed of directly into the water courses or in nearby agricultural fields. Every year about 2.5 to 3 lakh MT of stone polish is discharged which affects about 5-10 Ha of land every year. In the study area, most of the mine leases are large (4 Ha to 25 Ha), so side by side pit filling is not possible. Large quantity of blasted wastes is dumped over prime agricultural fields. The present trend of production level is likely to generate about 138 lakh m^3 of waste material every year. Presently only 35% of waste material is filled back in the mined-out pits, leaving behind 90 lakh m^3 of waste dumped over prime agricultural land, requiring 40-50 Ha of fresh land for waste dumping per year. Presently it is estimated that about 1800 lakh m^3 of waste material is dumped in adjacent agricultural land covering about 900-1000 Ha area. Overburden accounts for 80% of total solid waste generated in "*Kota stone*" mining. Excavation and disposal of large quantities of waste cost about 25-30% of the total cost of production. In "*Kota stone*" mining the mineral recovery has never been more than 25%. The mineral-to-waste ratio has varied between 1:10 to 1:8.

Figure 1. View of the study site (mining wastelands in Ramganjmandi, Kota).

3.2 Physical features of mining wastelands

Mining wastelands in the study area feature huge waste dumps with a very large amount of pieces of limestone. The physiography of the surface is a slope with a very low content of clay and silt. Mining causes a loss of valuable topsoil at the rate of 8-8.5 m^3 per year. The texture of the soil is dependent on the parent rock material by weathering, of which the soil is formed. But disturbances in soil may change the physical properties of soil including texture. There exists a change in the ratio of components of soil defining a textural class of soil around mining wastelands and of waste dumps. Excessive stoniness of the substratum and lack of clay is the major problem in the study area (**Figure 2**).

3.3 Characteristic of soil

Chemical analysis of soil in mining wasteland areas shows reduced organic content and low nutrient level. Change in physico-chemical properties

includes increased pH, texture, reduced organic carbon, and reduced macro as well as micronutrients (Iron, Copper and Manganese) [18]. Among micronutrients Iron and Manganese show more than 70% decrease from control. There is no remarkable change in Available potassium, the level of which is above the reference value in both the non-mining and mining areas (**Figure 3**).

3.4 Vegetation characteristic of mining waste dumps

A preliminary survey of the study area shows the dominance of shrubby flora in the mining waste dumps. Floristic inventory of the reference vegetation is represented by a total of 171 plant species belonging to 50 families comprising 45 dicotyledonous and 5 monocotyledonous families. Whereas in areas around mines and on waste dumps only 42 plant species belonging to 20 families comprising 19 dicotyledonous families and 1 monocotyledonous family got representation. Dicotyledons contribute mainly to the characteristic flora of protected vegetation in terms of families **(Table 1**). 65 plant species belonging to 29 families form the tree and shrub layer of the vegetation in control sites whereas 111 plant species including seedlings of a few trees and shrub species belonging to 33 families form the ground cover (**Table 2**). Trees and shrubs are represented by 11 families with 14 species and herbaceous plant cover is represented by 28 plant species belonging to 13 families in mining wastelands (**Table 2**).

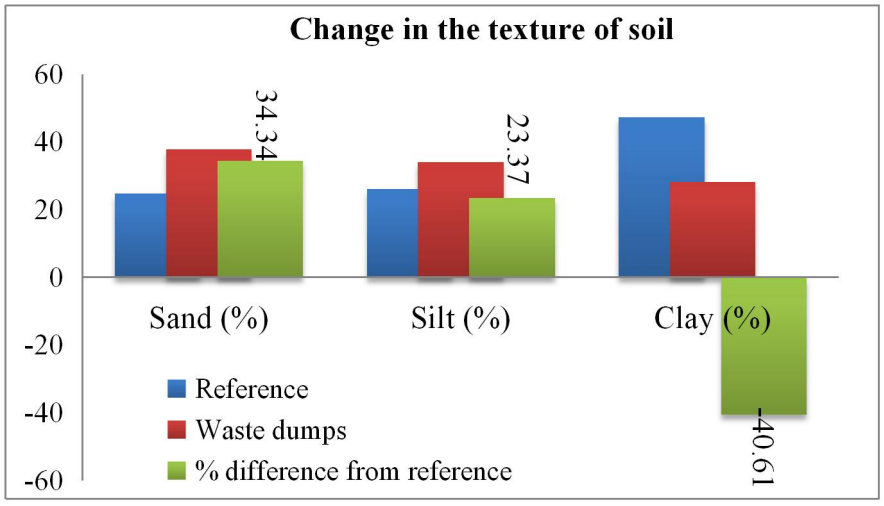

Figure 2. A graphical presentation of the change in components of soil determining texture.

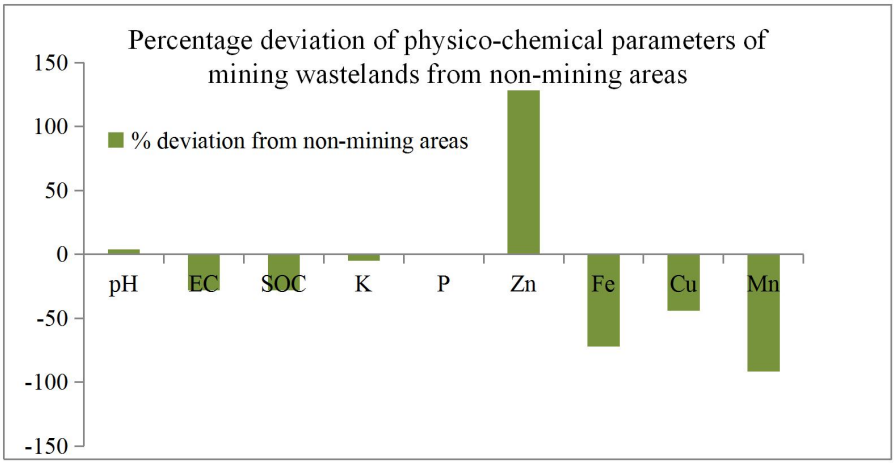

Figure 3. Physico-chemical analysis of the soil from control and experimental areas.

Table 1. Statistical synopsis of the flora of two different sites (non-mining area and 5-10 years old abandoned waste dump) in the study area.

Taxonomic group	Protected vegetation (Control)			Abandoned waste dump (5-20 years old)		
Angiosperms	Families	Genera	Species	Families	Genera	Species
Dicotyledons	45	120	140	19	34	35
Monocotyledons	05	23	31	01	06	07
Total	50	143	171	20	40	42

Table 2. General floristic and diversity characteristic of vegetation in non-mining area and mining waste dumps in RamganjMandi.

Parameters	Values	
	Protected vegetation stands	Mining waste dumps
Plant species forming tree+shrub layer	65	14
Plant species forming ground layer	111	28
Families forming tree+shrub layer	29	11
Families forming ground layer	33	13
Total density of trees/hectare	5.22	3.2
Total density of shrub/hectare	793.7	328
Total density of herbs/m^2	72.184	9.04
Total basal area of trees (m^2/hectare)	0.244	0.060
Total basal area of shrubs (m^2/hectare)	2.495	1.08
Total basal area of herbs (cm^2/m^2)	69.201	17.182

Shrubs form the characteristic vegetation in the protected as well as exploited habitats (**Figure 4**) because they are represented by higher density per hectare and basal area (m^2/hectare) in both the sites as compared to trees among individuals having cbh > 10.5 cm. There is a decrease in density and basal area of all the growth forms (trees, shrubs and herbs) in the exploited areas as compared to control sites. There exists a considerable decrease in species/family ratio and species/genus ratio in exploited areas as compared to protected vegetation sites.

3.5 Hydrological characteristics of mining wastelands

Physico-chemical analysis of water shows no major impact on water quality when compared with the water quality from non-mining areas (**Table 3**). All the parameters remain within the limits of the reference values. Whereas pH, Alkalinity, Total hardness, Calcium hardness, Chloride, Sulphate, Total dissolved solids, and even Fluoride are decreased as compared to non-mining areas [18]. The study area

Figure 4. General floristic and diversity characteristics of natural vegetation and mining waste dumps in RamganjMandi.

faces water scarcity during summer and opens abandoned pits are reservoirs of water that are used as drinking water at places (**Figure 5**).

All these have resulted in a negative impact on the natural environment with total disruption and modification of landscape, changed hydrology, drainage patterns and altered vegetation. The impacts of mining can be seen in the form of deforestation, water, and air pollution, changing patterns of rainfall and the local climate, depleting water balance, and many others [19,20]. Based on an extensive survey and study of mining wastelands in the study area, a restoration plan of the same is presented.

4. Discussion

The results show lower diversity in both the growth forms i.e. trees + shrubs and ground flora in areas of mining wastelands. Results indicate increased competition between species which in turn has narrowed down the number of species able to make a living in exploited areas. The abundance of very dissimilar species in exploited areas whereas the somewhat similar proportion of constituent species in the protected sites. The condition is reversed in the case of herbaceous species. Majumdar [21] has reported 700 species occurring in the Hadoti region**.** Sharma and Tyagi [22] reported 619 species from the same region whereas Sharma [23] reported 1098 species. Losing biodiversity not only affects the environment in very close vicinity but affects the ecosystem as a whole [24]. State of Environment Report India [25], states that extensive mining is causing severe fragmentation (landscape discontinuities) of habitats and forest areas. The natural successional process is usually slow, taking 50-100 years, at least a human lifetime [26]. A minimum period of 50 years to a century is required to establish advanced specific plant species in denuded, mining overburden-filled land [27]. In areas of degraded ecosystems due to mining appropriate intervention may be required to initiate and enhance the succession process.

Table 3. Characteristic of water from the non-mining areas and abandoned mines.

Sr. No.	Parameters (all results in mg/L except pH)	Reference values	Control (non-mining areas)	Experimental (mining pits)
1.	pH	6.5-8.5	7.8	7.33
2.	Alkalinity (methyl orange)	200	326.5	112
3.	Total hardness ($CaCO_3$)	300	257.5	146.5
4.	Calcium hardness ($CaCO_3$)	187	114	91.5
5.	Chloride (Cl^-)	250	160.5	66
6.	Sulphate (SO_4^{-2})	200	84	2.7
7.	Nitrate (NO_3^-)	45	30.7	4.8
8.	Total dissolved solids	500	1119.6	419.2
9.	Fluoride	1.0	0.79	0.313

Figure 5. Abandoned mining pits in the study area.

4.1 Restoration of mining wastelands in the study area

Restoration of the mined-out wastelands includes approaches; management of mining wastes, reclamation of abandoned waste dumps, and re-vegetation of the waste dump.

Management of the mining waste dumps

Reuse and Recycle the mining waste for producing commercial products: Recycling and reusing waste to produce a commercial product may be the best option to sustain the future economy not only by generating additional employment in the region but also by releasing lands locked in the storage of mining waste. In a study conducted by CBRI, Roorkee in the early 90s Sand Lime Brick can be manufactured by blending Polish Waste (Slurry) and Calcined Kota Stone quarry waste which has a strength of 150-180 kg/cm^2 as compared to normal clay brick of 20-30 kg/cm^2 strength. The manufacturing process involves calcination and hydration of Kota stone waste to yield low-grade lime powder, mixing this Lime powder with polish waste and river sand in different proportions, hydraulic pressing, and passing saturated steam at about 14-15 kg/cm^2 pressure in autoclave then curing for 4-6 hrs.

Studies carried out by Civil Engineering Department, Engineering College, Kota prove that Kota Stone waste aggregate can be used to make cement concrete and the loss in compressive strength when compared with cement concrete (Sandstone) is only 15.7% and cement can be replaced up to 30% by Kota Stone Slurry in cement concrete with loss in compressive strength only up to 6%.

Lately, an Italian Company has come up with technology to produce Compound Stone involving compaction by vibro-compression under vacuum of a mixture formed by stone aggregate and binding paste to produce high-density Compound Stone wherein 84%-91%, by overall weight, will be the stone aggregate from Kota Stone quarries. The Compound Stone so produced will have outstanding geo-mechanical properties such as high compressive strength, low water absorption, mechanical resistance, resistance to chemical agents, heavy density, etc., which are compatible with natural stone.

Identification of post-closure land-use objectives: Sustainable land-use options and restoration/rehabilitation of these degraded ecosystems will control erosion, halt further degradation and preserve environmental quality [28]. The "commercial forest land" or "managed forest" plantation option provides an opportunity to achieve wood production, fuelwood, fodder, and other commercial forestry objectives. Establishing biofuel plantations (e.g., *Jatropha, Pongamia*) on degraded soils can be a win-win strategy provided that these soils are adequately restored and specific problems (e.g., nutrient and water imbalance, loss of topsoil, shallow rooting depth, drought stress, salinization, compaction, crusting) are alleviated [29]. In the post-mining landscapes, short-rotation tree plantations as a special form of energy forests have recently come into focus [30]. A large number of laticiferous plants like species of *Euphorbia* and *Calotropis procera* growing naturally on the mine spoils can be utilized for the production of biofuel [31] or as petro crops [32]. *Jatropha gossypifolia, Lantana camera,* and *Prospopis juliflora* which occur naturally in the study area produce a higher amount of biogas and are identified as biofuel crops [33].

Alternative use of abandoned mining pits: Shallow mining pits may be used for algal biomass cultivation to provide biofertilizers which may further be used for reclamation of the nearby mining wastelands and animal feed for the livestock reared by local inhabitants. Limestone mining operations are generally confined to 4-50 meters in depth and this is because there is a general scarcity of water in limestone areas [34]. Thus these pits can be best used for rainwater harvesting [35].

Reclamation of mining-affected soil

Physico-chemical analysis of overburdened material along with a sampling of the vegetation on mine spoils will help characterize mine waste materials as growth media and find out factors that could be limiting plant growth which will in turn help to evaluate the relationship between material properties and plant responses.

Physical amendment: Landscape designing (Re-sloping, Bunding, Terracing, etc.) will help erosion control. Mulching and the addition of organic matter to the soil will help to amend soil compaction. Grading and sloping the post-mine landscape to a 3% slope were the most effective and cost-effective reclamation approaches. Leveling or terracing to give the shape of a saucer may be adopted for soil and water conservation. Mulching and bundling along the contour of the waste dump can help in erosion control. Segregation and utilization of the waste stone pieces will lower the size and slope of waste dumps, and reduce excessive stoniness of substratum, and native soil trapped in the waste dumps will be made available for further amendment.

Amendment of mine-spoils (Identifying and, if necessary treating, any soil factors that are limiting): Finding out the most suitable soil working technique, remediation of soil fertility, amendment of mine-spoils with organic materials and bio-fertilizers.

4.2 Recovery of natural vegetation on mining wastelands

Phyto-sociological survey of the study area will help to find out suitable trees, shrubs, and grass species for site improvement through afforestation. Floristic analysis conducted to study the local flora and their interaction with the local climate has helped in the identification of pioneer species during the early stages of rehabilitation. Natural ecological processes such as colonization and population expansion in bare areas can be enhanced by planting native legumes [36]. Species to be used in restoration projects should be chosen from among the local vegetation [37]. Broadcasting the seeds of herbs and shrubs instead of going through the plantation of tree species is the best option [38]. Direct seeding of native species is a useful and cost-effective restoration method globally [39-42]. To increase the survival success of key shrubs and small tree species (thicket) planting of saplings is required [43].

Revegetation strategy, planning, and technique

Selection of appropriate species, Establishment of ground cover, shrub, and tree cover, planting techniques for establishing selected species for revegetation over mine spoils and overburdens will improve vegetation cover, type, vigour, and vitality of the species planted, and planting at the appropriate time and density will increase the survival of the plant. Finding out suitable planting techniques, time, and density of planting will increase the success rate of recovery of native vegetation.

Maintenance, evaluation of success criterion, and monitoring

Invasion by animals, weeds, and human activities can thwart rehabilitation efforts thus maintenance of the area being reclaimed is necessary to check the failure of the re-vegetation attempts. Maintenance might include replanting failed areas, repairing erosion problems, implementing fire management systems, controlling pests, weeds, and animal populations, using fertilizer, and applying amendments to the physico-chemical properties of the substratum.

5. Conclusions

The success of restoration planning of wastelands depends on a holistic approach integrating all aspects of restoration viz. evaluation of extent and type of degradation, management of waste, reclamation and physico-chemical amendment of wastelands substratum, selection of appropriate technique, time and plant species for re-vegetation.

Conflict of Interest

The author declares that there is no conflict of interest.

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ARTICLE

Evaluation of Women's Contribution in Agroforestry Demonstration through Moringa Species Introduction in Western Oromia, Ethiopia

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ABSTRACT

Agroforestry technologies are very keen practices in most small-scale farming systems where gender issues are not well considered in most developing countries. Moringa is a tropical plant that consists of 13 species, while five of them are found in Ethiopia. This study aimed to evaluate the potential and contribution of women in agroforestry demonstrations where *Moringa oleifera* and *Moringa stenopetala* are introduced in farmers' fields. Selection of the best performing moringa species and preferred by farmers for further scaling up was also another objective. The activity was conducted in five districts of west and east Wallagga zones. A total of 10 FREG comprising 150 farmers were established. The two moringa species were planted on 100 farmers' fields where 50 women and 50 men were purposively selected and given responsibilities of moringa demonstration. Leaflets and practical training on moringa production, importance and utilization were prepared and given to all concerned bodies. 84% of women and only 32% of men effectively demonstrated the moringa species. A total of 200 farmers were interviewed to evaluate and select the best from the two species depending on their growth performance, fresh leaf taste and odor, and survival rate. Based on the above criteria, 143 (71.5%) farmers preferred *Moringa oleifera*. In general, the two moringa species were performed well in most places, and its utilization started at household level. Finally, the authors recommend that women are the potential for demonstrating agroforestry technologies, and *Moringa oleifera* is a more preferred species in western Oromia.

Keywords: Agroforestry; Demonstration; Feedback; Growth performance; Moringa; Women

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1. Introduction

Agroforestry practices are gender sensitive where the roles and responsibilities of women and men are critical. For instance, women and men have different understandings of and knowledge about the natural resources in their environment while linking knowledge with action for sustainable development should consider gender issues [1]. Due to cultural belief, ploughing is specifically categorized as a male chore while women's rights to tree products are usually limited to products that are considered to have little or no commercial value; men reserve higher value products for themselves. Many studies reveal that the products that women control are mainly homestead trees, fuel wood sources, fruits and vegetables, fodder and mulch. However, medicinal and commercial plants and trees are mostly preferred and managed by men [2-4].

Within the gender issues, the adaptation of two moringa species namely *Moringa stenopetala* and *Moringa oleifera* was conducted at Bako some years back and well adopted in the environment [1-3,5]. *Moringa oleifera* and *Moringa stenopetala* are the two most common species among the 13 species of the Moringa family, Moringaceae. *Moringa oleifera* originates from the Himalaya (northwestern India), while *Moringa stenopetala* is endemic to East Africa, where it occurs in northern Kenya and in Ethiopia. Both species have many characteristics in common. For both species the uses as a vegetable and water purifier are similar. They share several medicinal uses and both have high contents of oil in the seeds between 32%-42%. *Moringa oleifera* has a faster development and yields bearing fruits and seeds quickly [5]. *Moringa stenopetala* is better suited to a drier climate; yields of seeds are higher and they have a higher coagulant content [6]. The two most common English vernacular names for the tree are 'drumstick' (describing the shape of its pods) and 'horseradish' (describing the taste of its roots [7]. Additional names have been given to them such as "Never Die Tree", "The Magic Tree", "The Tree of Paradise" or "Best Friend" based on the multipurpose behavior of the trees. In Ethiopia it is widely cultivated [8].

People have different nutritional requirements at different stages in their lives. The leaves from moringa are exceptionally nutritious for people of all ages and the use of the plant as side dishes or sauces provides daily allowances of important nutrients. The leaves have a high content of Vitamin A and Vitamin C when they are raw. Vitamin A is required for good eyesight and Vitamin C strengthens the gums. The content of minerals like Calcium is very high, which is rare among plants. Calcium is used for strengthening bones. 100 grams of moringa leaf powder contains: four times the calcium of milk, four times the vitamin A in carrots, two times the protein in milk, three times and the potassium in bananas and seven times the vitamin C in oranges [9].

Since moringa is very important in the food context and medicinal values and we want to identify its performance among gender management, we need to demonstrate and scale up/out it in its agroecological ranges. Accordingly, we addressed a total of 5 districts in west Shawa and east Wallagga zones, west Oromia, Ethiopia, and equally distributed its management for men and women.

2. Materials and methods

2.1 Description of the study area

Traditional agroforestry practices are well known in western parts of Ethiopia, but not well studied in the cases of gender roles and dominant niches while moringa species which are highly valuable agroforestry trees are not well known in the areas. Therefore, in this study we incorporated the gender issues and moringa species introduction and demonstration in the western parts of Oromia, Ethiopia. Five (5) districts were randomly selected based on their agroecology and accessibility for this activity. These districts were Bako Tibe, Guto Gida, Diga, Wayu Tuqa and Boneya Boshe (**Figure 1**).

2.2 Methodologies

Phase 1 of the implementation

Areas (districts and/or zones) that have the same

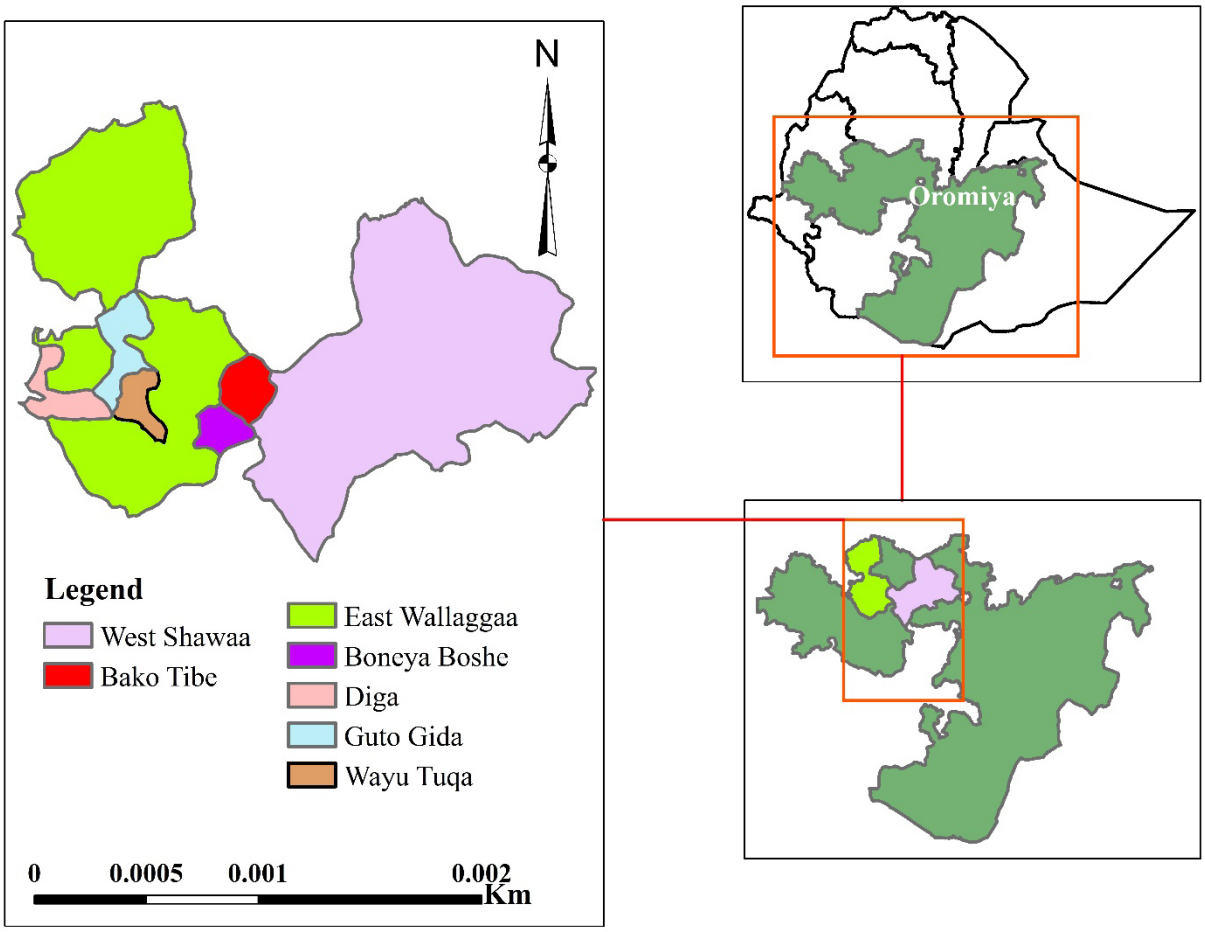

Figure 1. Site descriptions of Moringa species demonstration sites.

agro-ecological zone with Bako agricultural research center (BARC), from west Shawa Zone Bako Tibe district and from east Wallagga Zone Guto Gida, Diga, Wayu Tuqa and Boneya Boshe districts were selected for the pre-demonstration activity of the two moringa species. After the selection of the districts, we decided to pick purposively based on accessibility and potential, one or two kebeles from each district. After all, we form the Farmers' Research Extension Group (FREG) which comprises ten to fifteen members per kebele. A total of 10 FREG comprising 150 farmers (75 males and 75 females) were established. The two moringa species were planted on 100 farmers' fields on an area of 10 m × 10 m = 100 m^2 each and 2 m spacing between plants.

Theoretical and practical training was organized; manuals and leaflets were prepared on Moringa's importance and conservation methods for farmers of FREG members and Development Agents (DAs) of respective kebeles and also for experts of each district.

Five to ten farmers of FREG members were selected to plant those moringa species (the known *Moringa stenopetala* and the exotic *Moringa oleifera*), and they planted them. Survival count, growth performance, disease occurrence and farmers' perception of the two moringa species were recorded.

Phase 2 of the implementation

Training leaflets and manuals on moringa utilization and importance were produced and FREG member farmers were awarded about all. Farmers were organized and asked to visit, use, evaluate and put their feedback on the survival count, growth performance, leaf color, odor and seed bearing duration of the two moringa species. A hint of all important components of growth and uses were provided to

the FREG member and non-members. Additionally, practical training on moringa planting, management, silvicultural operations, seed collection, seed storage, leaf utilization and other moringa benefits were given to the FRG members including neighbor farmers, DA's and other experts. In the practical training, farmers and other participants have also given chance to evaluate both moringa species and select a better one based on the above criteria. The FREG member farmers have been also sharing their experiences with others on moringa planting and management methods.

Data management and statistical analysis

All the necessary data were collected and analyzed. Farmers' assessment/feedback on the technology (growth performance, affordability, complexity, applicability) were collected through regular interaction with farmers and rapid feedback surveys. Simple descriptive statistics by SPSS and Excel tools and matrix while ranking and qualitative analysis of farmers' assessment/feedback were also subjected to SPSS.

3. Results and discussion

3.1 Survival count and growth performance

From the total of 10,000 seedlings of *Moringa oleifera* and *Moringa stenopetala* species which were planted on 100 farmers' fields and the last survival rate of *Moringa oleifera* shows 84% and this survival rate is greater by 4% from the 1st survival count for the same species on average of over all locations. This may be due to regenerating potential of dormant seedlings of moringa during the winter (drier) seasons. This survival rate shows for *Moringa stenopetala* 72.6% on average. *Moringa oleifera* has also evaluated by bearing seeds within less than 8 months after planting. We have observed that the survival rate, fast growth and good stand performances of both moringa species show better at all sites under farmers whose management activities are controlled by women and children (**Figure 2**). This result is inline with Orwa et al.'s study [10], which defines it as *Moringa oleifera* requires mean annual temperature of 12.6 °C to 40 °C and a mean annual rainfall of at least 500 mm. Adapted to a wide range of soil types but does well in well drained clay or clay loam without prolonged waterlogging which prefers a neutral to slightly acidic soil reaction. It is quite a drought tolerant but yields much less foliage where it is continuously under water stress. It is not harmed by frost, but can be killed back to ground level by a freeze. It quickly sends out new growth from the trunk when cut, or from the ground when frozen. On the other hand, *Moringa stenopetala* is also mentioned by its intolerance of cold temperatures for the cultivation of the species in Ethiopia because it does not tolerate frost [10,11].

From the above picture, we can evaluate the growth performances of the two moringa species, and we observed that *Moringa oleifera* bears seed and can be seen by its biomass advantage.

3.2 Gender performance for the implementation

Moringa demonstration under women management

From the total of 50 women selected for the moringa demonstration, about 42 (84%) of them have recorded high performance, and there is no significant difference across the locations (**Figure 3**). However moringa is newly introduced and is demonstrated in the current study areas, women are very happy and actively participated in the activity. This finding is in line with the results [2], which say women's participation is very high in enterprises that are considered to be women's domain, such as indigenous fruit and vegetable products and processing. We assured that women are very keen on their responsibility in agroforestry practices, and they are more careful and tolerant than men in tree management, especially during the tedious silvicultural operations.

Figure 2. Growth and stand performances of *Moringa oleifera* and *Moringa stenopetala.*

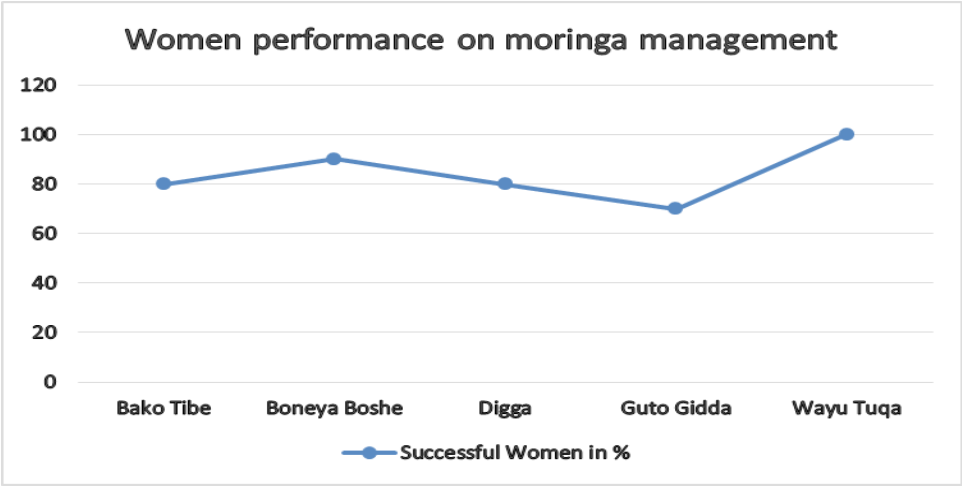

Figure 3. Performance of women on moringa demonstration.

Moringa demonstration under men management

Of the total of 50 men selected for the moringa demonstration, about 16 (32%) of them have recorded high performance, and there is no significant difference across the locations (**Figure 4**). This result agrees with the study that reveals. Men ranked trees that grow straight so that timber is their number one priority, and straightness is followed by trees that grow fast among men [2].

3.3 Farmers perception and species selection

A total of 200 farmers were interviewed to evaluate and select the best from the two species depending on their growth performance, fresh leaf taste and odor, and survival rate. Of the total 100 (50%) farmers were women. Based on the above criteria, 143 (71.5%) farmers preferred the *Moringa oleifera*. The most attractive result here is that from the total women interviewed, about 92% preferred the *Moringa oleifera*, due to its leaf biomass and good odor

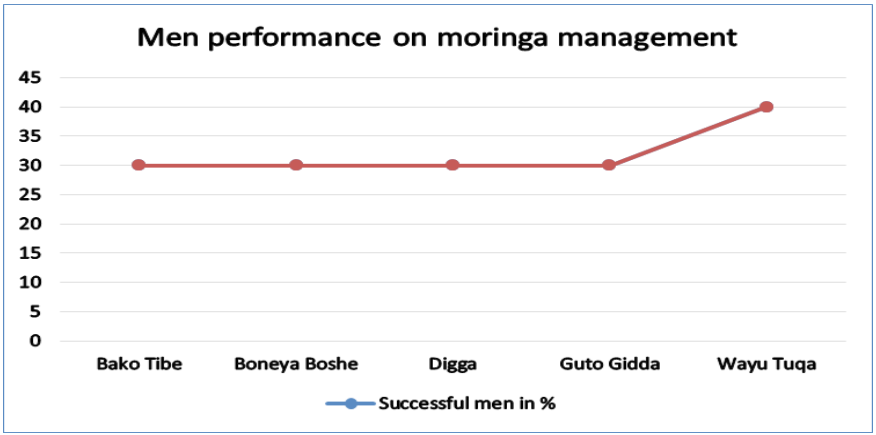

Figure 4. Performance of men on moringa demonstration.

over *Moringa stenopetala* (**Table 1**; **Table 2**). The farmers refer *Moringa oleifera* species, which taste like local cabbage and are simple to grow in a short period of time. They also utilized it and witnessed that they are being cured of headaches, gastric, pressure, diabetes and wounds of different causes. This preference for the *Moringa oleifera* also agrees with the study [10], which will state its contents and uses. Its leaves are a good source of protein, vitamins A, B and C and minerals such as calcium and iron, which are used as a spinach equivalent. They are an excellent source of the sulfur-containing amino acids methionine and cystine, which are often in short supply. Young plants are eaten as a tender vegetable and the taproots as an alternative for horseradish. Young pods are edible and reportedly have a taste reminiscent of asparagus [11].

Table 1. Household information and feedback responses.

Households	Frequency (%) (N=200)
Sex	Male 100 (50%)
	Female 100 (50%)
District	Bako Tibe 40 (20%)
	Boneya Boshe 40 (20 %)
	Diga 40 (20%)
	Guto Gida 40 (20%)
	Wayu Tuqa 40 (20%)

From the above table, we can discuss that most of the assessed farmers were preferred *Moringa oleifera* to *Moring stenopetala*, which may because of its odor, color, fast-growing, taste and overall growing performance.

Table 2. ANOVA table of feedback responses.

Assessment	Variation	Sum of Squares	df	Mean square	F	Sig.
Did you plant moringa species? 1. Yes 2. No	Between Groups	5.581	31	0.180	1.101	0.342
	Within Groups	22.884	169	0.163		
	Total	28.465	200			
Among moringa species, which one is best for you? 1. *M. stenopetala* 2. *M. oleifera*	Between Groups	9.174	25	0.296	1.400	0.097
	Within Groups	29.588	175	0.211		
	Total	38.762	200			
What is/are your selection criteria? 1. Their growth performance 2. Their fresh leaf taste and odor 3. Survival rate 4. Others (specify)	Between Groups	12.568	29	0.405	0.872	0.663
	Within Groups	65.124	171	0.465		
	Total	77.692	200			

4. Conclusions and recommendations

We have observed from the research that women and men have specific forms of knowledge and different productive strategies, but these tend to be complementary and even synergistic in agroforestry practices. In this specific objective of moringa species demonstration among the men and women management, we have assessed the varying performances of gender across the different locations and household types.

Additionally, we have identified that moringa species are extremely fast-growing and highly valued agroforestry trees where trees reach 2.5 m within 1-3 months. In addition to its medicinal value, moringa will help as a supplementary food, and therefore, it is one of the food security tree/shrub species, especially preferred by women over men. From the two moringa species demonstrated and evaluated here, *Moringa oleifera* was mostly preferred by farmers considering its growth performance, survival rate, odor, color and taste. The duration for seed bearing was also another criterion for the farmers to prefer the *M. oleifera* species. Moringa species were well performed under practices where hot pepper, bean and vegetables were incorporated in. We have also observed it was better survived and performed where women and children control its overall management than men from the household members. As far as it is well known that of the three countries in eastern Africa, Ethiopia is the only country that has widely domesticated in its southern landscape as a garden and tree on a farm, we need to demonstrate and scale up/out it further into different parts of the country.

Since women are very close to homestead, and are very responsible in home garden agroforestry management, it is necessarily important to empower them by providing educational and practical extension services to expand agroforestry knowledge and skills, as well as guidance on marketing and selling agroforestry products. Therefore, we highly recommend that women are very potential in agroforestry demonstration, specifically; in moringa-based agroforestry management, and hence they should be invited to participate in projects and training activities. Finally, we call for forestry extension systems to ensure women's stronger performance in decision-making and enjoy the full benefits of agroforestry.

Author Contributions

The first author has participated from the beginning to the end of this article preparation. He did all about the modification of the project from the beginning, training, the implementation, data collection, and processing, analysing, interpretation and report preparation. The second author has put his active participation from the data processing to the article preparation, and the third author has initiated the project's idea and the project was modified to the current description by the first author.

Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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