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Contribution to the Ecological Management of the Arboretum of Jean Lorougnon Guédé University, Côte d'Ivoire

Kouame Jean-Marc KOUMAN [1,*], Kadio Attey Noël KOUA [1], Adjo Annie Yvette ASSALE [1], Claude Bernard AKE[1], Golou Gizèle ZANH [1], Lisette Zeh TOKPA [2] and Yao Sadaiou Sabas BARIMA [1]

[1] *Interdisciplinary Research Group in Landscape Ecology and Environment, UFR Environment / Jean Lorougnon Guédé University, BP 150 Daloa, Côte d'Ivoire.*
[2] *UFR Agroforestry, Jean Lorougnon Guédé University, BP 150 Daloa, Côte d'Ivoire.*

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Abstract

In Côte d'Ivoire, it is difficult to find forest relics in large cities that can serve as oxygenation pockets and provide researchers and students with botanical material. Therefore, the creation of a protected natural area where collections of trees and plants are developed within a landscape framework for educational and ecological purposes is necessary. The overall objective of this study is to contribute to the enhancement of the arboretum of Jean Lorougnon Guédé University through the development of an ecological management plan. To achieve this, Sentinel-2 satellite images were processed to determine land use. Then, floristic inventories were conducted to assess the residual diversity of the environment. Finally, a pedological study was carried out to determine the physical characteristics of the soil. Results showed that the arboretum is dominated by cassava cultivation (28.9 ha), followed by wooded fallow (9.1 ha). A total of 93 species distributed among 61 genera and 32 botanical families were recorded. Among these, nine (09) species have a particular conservation status. The soil study revealed three soil types: reworked ferrallitic soils, typical ferrallitic soils, and indurated ferrallitic soils. An ecological management plan subdivided into 37 thematic plots of diverse plant species was designed. This plan is expected to help preserve and restore the native vegetation of the region.

Keywords: Forest Management; Land Use and Land Cover; Reforestation; Thematic Plots; Cartography; West Africa

1. Introduction

Tropical forests play a fundamental role in climate regulation, soil protection, water resource conservation, and host exceptional floral and faunal diversity (Hanson et al., 2008). However, these forest ecosystems are now severely threatened by increasing anthropogenic pressures, including deforestation, land conversion for agriculture, urbanization, mining exploitation, and climate change. In Côte d'Ivoire, agriculture is the main cause of forest cover loss (Barima et al., 2016). Forest cover, which accounted for about 24% of the national territory in 1990, dropped to 16% in 2000 and only 11% in 2015. Located in the Centre-West of Côte d'Ivoire, the Haut-Sassandra region has also experienced significant deforestation. The forest cover is now fragmented (Kouakou et al., 2018), and many endemic species of this zone are highly threatened with extinction.

In response to this situation, the establishment of a protected natural space in which tree and plant collections can be developed for educational and ecological purposes in the Haut-Sassandra region—specifically on the campus of Jean Lorougnon Guédé University (UJLoG)—is indispensable. Such a site could serve both as a refuge for local biodiversity and as a tool to combat the negative effects of climate change through carbon sequestration. At its creation, UJLoG

* Corresponding author: Kouame Jean-Marc KOUMAN

dedicated a space for an arboretum to preserve and restore native vegetation. This area is expected, on one hand, to ensure ex-situ conservation of original flora and to mitigate climate change impacts, and on the other, to serve as an educational and ecotourism site.

However, before initiating vegetation restoration activities, it is necessary to assess land use, the diversity of residual flora, and the physical and chemical characteristics of the soil. These data will allow for the elaboration of an ecological management plan to guide managers on restoration zones, the selection of plant species to be introduced, and biodiversity conservation strategies in the university setting.

The overall objective of this study is to contribute to the enhancement of the arboretum of Jean Lorougnon Guédé University by developing an ecological management plan. Specifically, the study aims to: (1) map land use, (2) analyze residual floristic diversity, (3) determine the physical characteristics of the soil, and (4) design an ecological management plan for the arboretum.

2. Materials and Methods

2.1. Study Area

This study was conducted within the arboretum of Jean Lorougnon Guédé University (UJLoG), located in Daloa, Côte d'Ivoire (Figure 1). UJLoG covers an area of 402 hectares, of which only 45 hectares are built. The arboretum occupies 60 hectares, divided into two parts, South and North, separated by a water body. The southern and northern parts cover 14 and 40 hectares respectively, while the water body extends over 6 hectares.

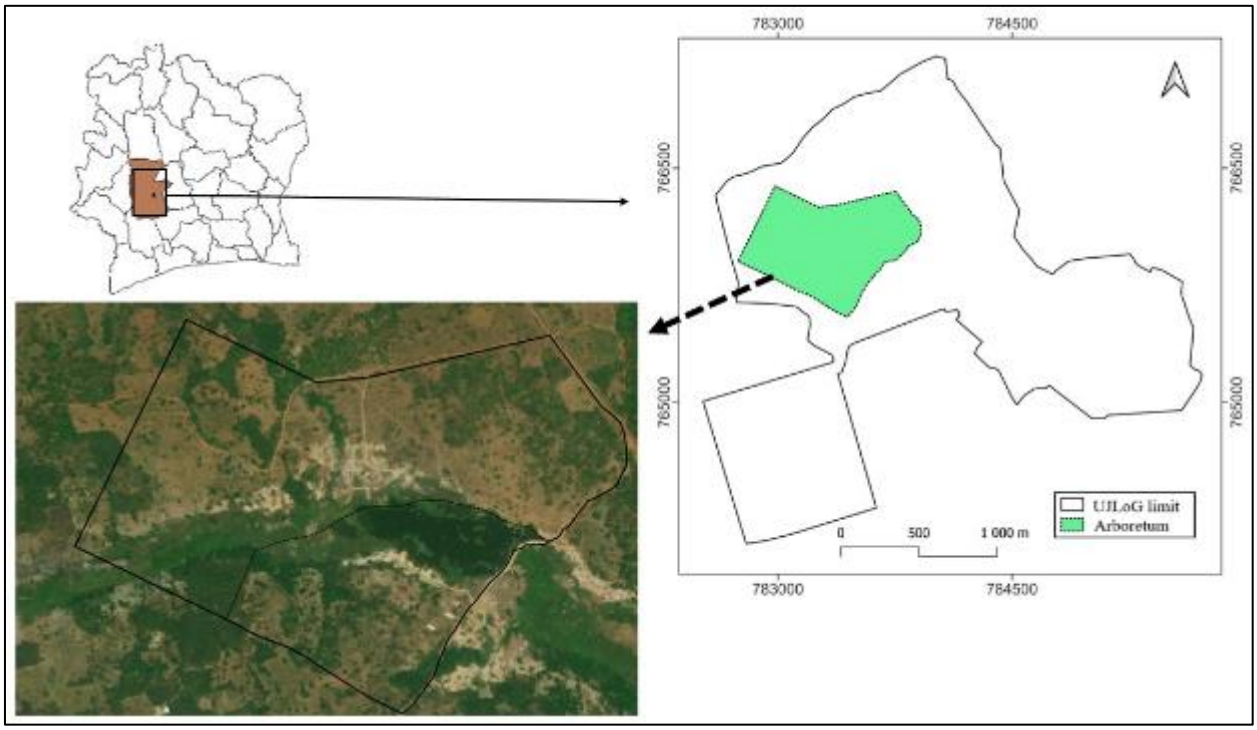

Figure 1 Location of the study area

2.2. Data Collection

2.2.1. Satellite Images

Using a vector file of the study area, a Sentinel-2 satellite image from 2023 was downloaded from the Scihub website (https://scihub.copernicus.eu/) using Google Earth Engine (GEE). Spectral bands with a spatial resolution of 10 m (Blue, Green, Red, and Near Infrared) were used. From a false-color composition of the image, zones with distinct coloration, texture, and shapes were identified and visited during a ground-truthing mission conducted from January 25 to 30, 2023. This mission allowed for the definition of land-use types for mapping purposes. During the mission, GPS points and parcel boundaries were recorded.

2.2.2. Floristic Inventory

To determine the plant diversity of the UJLoG arboretum, floristic inventories were carried out by itinerant surveys within the dedicated area. All species present were recorded to determine floristic richness and composition. The geographic coordinates of woody species were collected using a GPS.

2.2.3. Soil Physical Characterization

Site characterization was conducted along eight transects spaced 100 m apart, traced from the upper slope to the lower slope. On each transect, a soil pit was dug at each slope break (summit, upper slope, mid-slope, lower slope). In total, 21 soil pits were described.

2.3. Data Analysis

2.3.1. Land Use Mapping

The Random Forest classification algorithm was used to map land-use types. It was calibrated based on training data of the seven land-use types observed during the field mission. Input variables for classification consisted of Sentinel-2 spectral bands (randomly sampled pixels from training data). After model calibration, the algorithm was applied to produce a raw land-use map. Ten iterations of land-use maps were generated. Processing was conducted using R software and the randomForest package (Liaw & Wiener, 2002). Map accuracy was evaluated by cross-validation, with overall accuracy, Kappa coefficient, and confusion matrix calculated from a random test sample corresponding to 30% of the field data (Bylander, 2002).

2.3.2. Floristic Richness

Floristic richness refers to the number of species recorded within the study area (Aké-Assi, 1998). Its measurement involved counting all species recorded in each plot regardless of abundance, in order to compile a comprehensive species list. The same approach was applied for families and genera of inventoried species. A spatial distribution map of trees was produced.

2.3.3. Soil Physical Analysis

The description of soil physical characteristics focused mainly on texture, structure, bulk density, porosity, permeability, and water-holding capacity, in addition to color and depth.

2.3.4. Design of the Ecological Management Plan

Based on these analyses, a preliminary design of the ecological management plan was developed using QGIS software. This design included a parking lot, access roads, reforestation areas, conservation areas, and recreational zones. Depending on soil type, tree density, and land use, specific plant species were assigned to reforestation and conservation areas. Two participatory workshops were organized to identify thematic classes and validate the management plan with stakeholders, including forestry agents, representatives from the Ministries of Environment, Agriculture, and Tourism, local authorities, the university community, and local residents. Their input was incorporated into the final ecological management plan.

3. Results

3.1. Land Use Mapping

The overall map accuracy was 95.4% with a Kappa index of 0.89. The classification identified seven land-use types: wooded fallow, grassy fallow, cassava, lowland, rubber plantation, water, and quarry (Figure 2). Cassava was the dominant class with 28.9 ha, followed by wooded fallow with 9.1 ha (Figure 3).

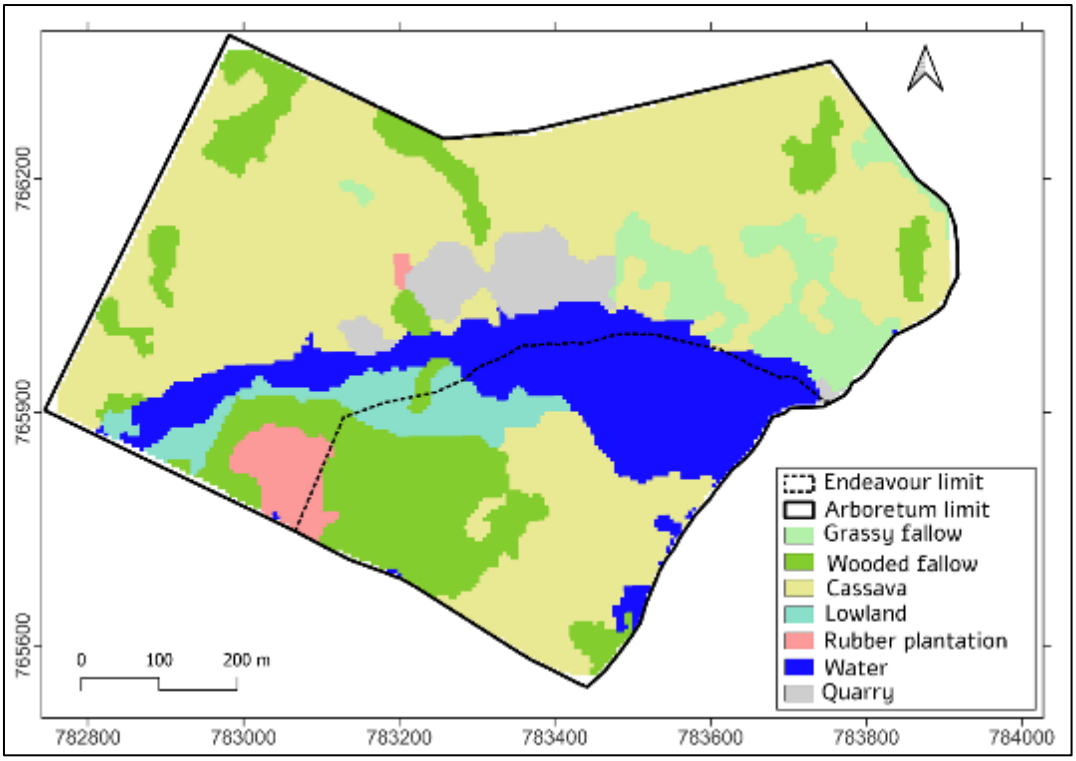

Figure 2 Arboretum Utilization Map

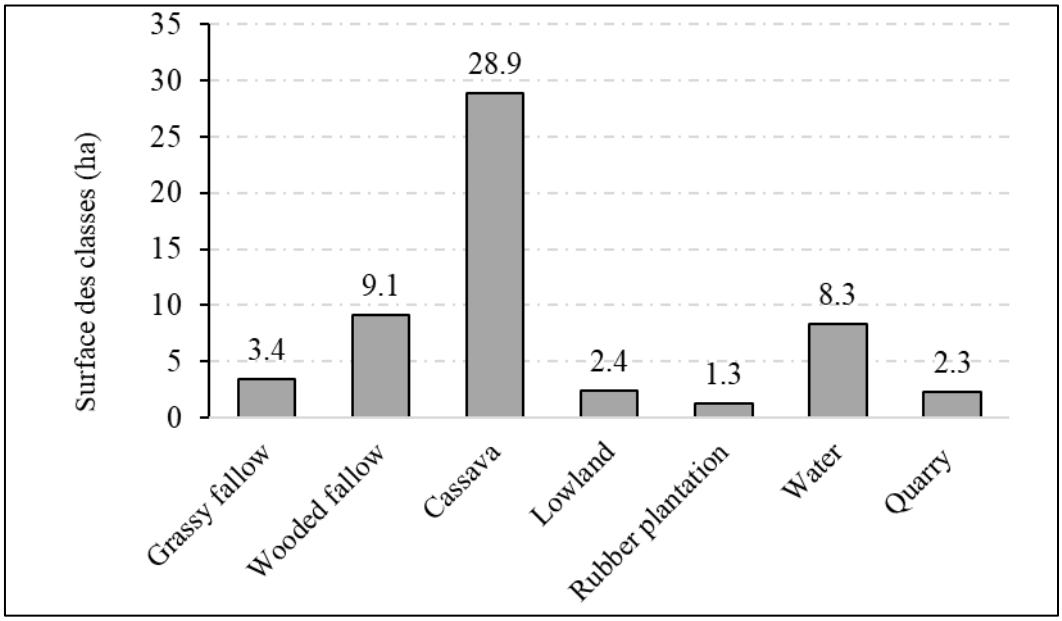

Figure 3 Distribution of Land Use Classes in the Arboretum

3.2. Floristic Diversity

The inventories recorded 1,870 individuals distributed among 93 species, 61 genera, and 32 botanical families (Figure 4). The most represented families were Fabaceae (15.87%), Moraceae (9.52%), Sterculiaceae (9.52%), and Euphorbiaceae (6.35%). The most abundant species were *Harrisonia abyssinica* Oliv.(15.78%), *Albizia adianthifolia* (Schumach.) W.Wight (10.75%), and *Holarrhena floribunda* (G.Don) T.Durand & Schinz (10.59%). Nine species had a particular conservation status, including *Albizia adianthifolia* (Schumach.) W.Wight, *Sterculia oblonga* Mast., *Millettia zechiana* Harms, *Baphia nitida* G.Lodd., *Triplochiton scleroxylon* K. Schum, *Millettia sp*., *Nesogordonia papaverifera* (A.Chev.) Capuron, *Milicia excelsa* (Welw.) C.C., and *Sterculia sp*.

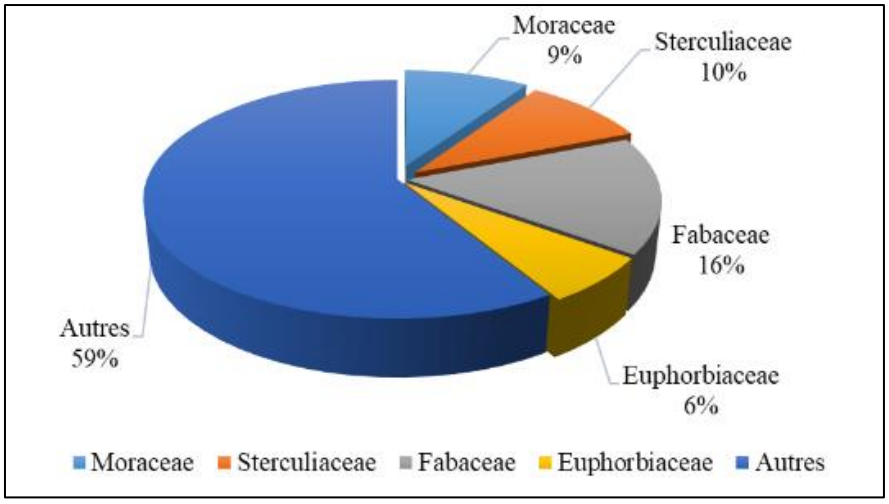

Figure 4 Botanical families with the highest representation in the arboretum

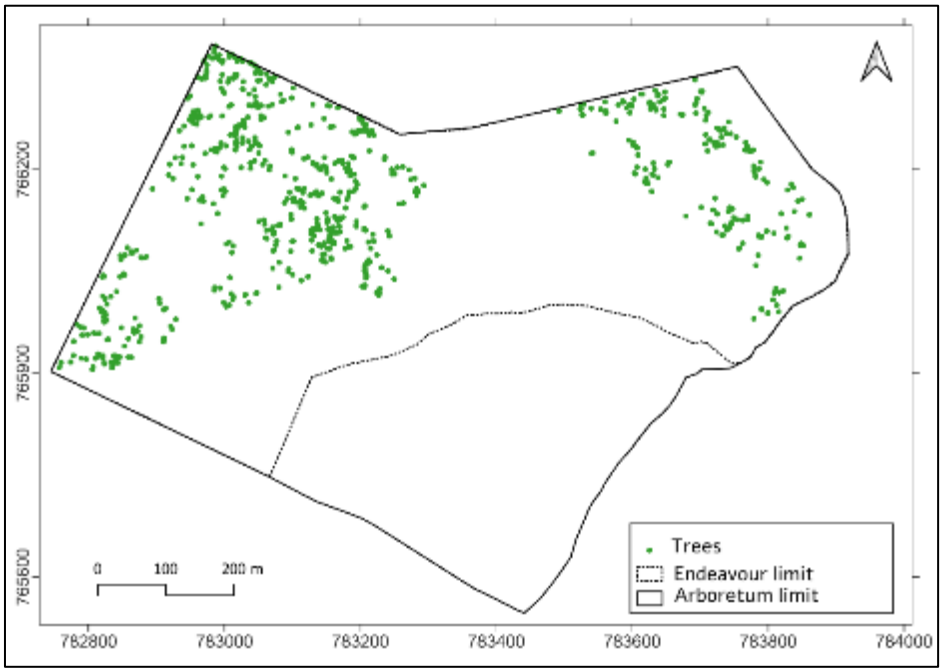

Figure 5 Spatial distribution of trees in the arboretum

3.3. Soil Morphological Characterization

The pedological study revealed that the arboretum is characterized by ferralitic soils of three types: reworked, typical, and indurated (Figure 6). Reworked and typical ferralitic soils are the most dominant. Reworked ferralitic soils account for 71% of the site's soils (Figure 6). They are mainly found on upper and middle slopes. These soils are generally deep (over 120 cm). Their humiferous horizon, with a color ranging from reddish-brown, sometimes dark (5YR3/4), to dark grayish-brown (10YR4/2), has a low thickness (3–13 cm), a crumbly structure, and a sandy-clay texture that allows efficient water drainage (drainage class ranging from 1.2 to 1.5). Below this horizon lies an A12 horizon, poor in organic matter, with colors varying from red to brown (2.5YR4/6 to 10YR5/3), a similar texture, and a structure that is often gravelly or polyhedral crumbly in places. The coarse fragment content varies from low to high (5–40%, up to 50% locally). This horizon is porous, ensures good water drainage (drainage class 1.4–1.7), and allows easy root penetration. Typical ferralitic soils represent 24% of the soils in the northern part of the arboretum (Figure 7). They are also generally deep (over 120 cm). They are mostly found at the footslope, and more rarely on midslopes and hilltops. Their humiferous horizon, with colors ranging from yellowish-brown (10YR5/6) to dark reddish-brown (2.5YR3/6), and from

very dark gray to reddish-gray (10YR3/1 to 2.5YR6/1), has a variable thickness between 21 and 32 cm. It has a sandy-clay texture and a crumbly structure. The soil is porous, with good water drainage (drainage class 1.2–1.7). Indurated ferralitic soils represent only 5% of the arboretum soils. They are shallow, with induration appearing at only 20 cm depth due to the presence of laterite (clay hardening). In the surrounding environment of this soil pit, iron crust (cuirasse) is also encountered.

Overall, the soils are generally deep, with a thick humiferous horizon, favoring the establishment and development of large trees. However, indurated soils present an iron crust at 20 cm depth. The physical characteristics of the site's soils indicate that it is possible to plant all types of tree species adapted to the local climate on 95% of the soils.

In the indurated zone, the planting of herbaceous species is recommended.

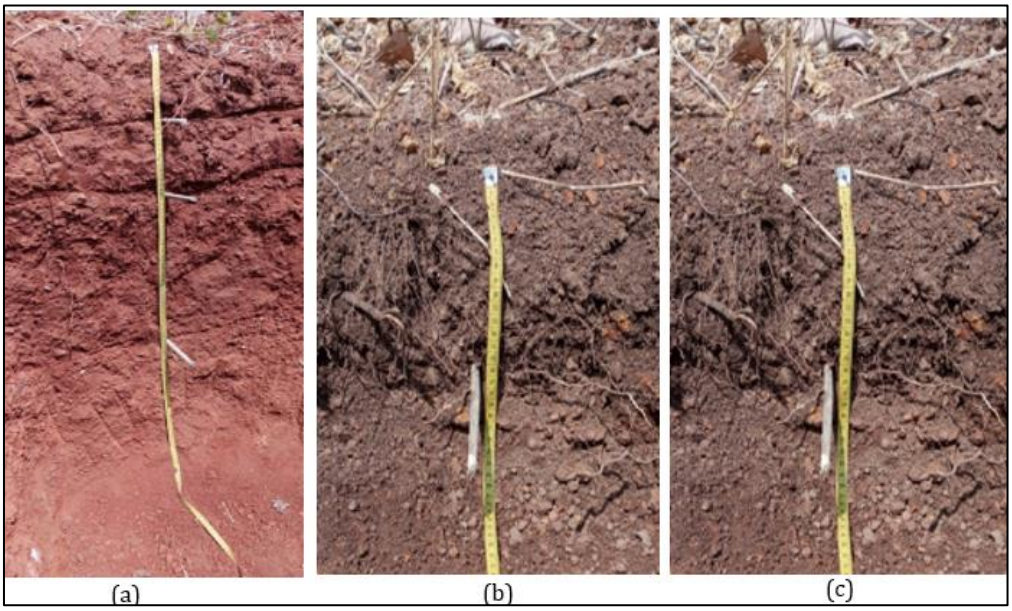

Figure 1 Reworked ferralitic soils: (a) typical, (b) and (c) indurated

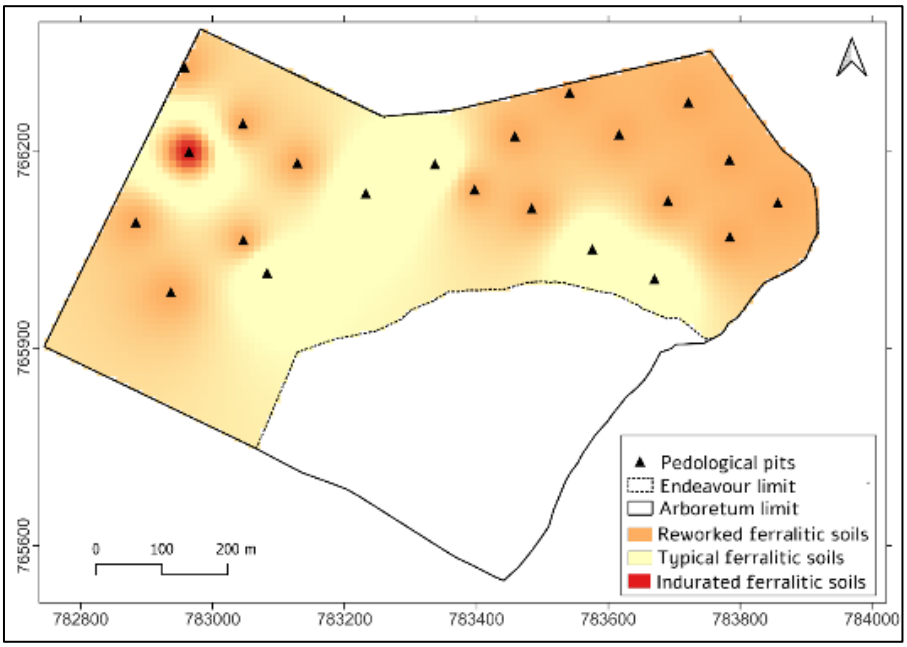

Figure 7 Soil map of the arboretum

3.4. Ecological Management Plan of the Arboretum

The development plan of the UJLoG arboretum provides, in its northern section, thirty-seven (37) thematic plots, along with a parking area, access roads, cycling paths, reforestation areas, conservation zones for natural regeneration, a live hedge, and a base camp (Figure 8). The plots in the northeastern section are arranged in the form of a rising sun, with uniform plots. A one-hectare base camp is also planned in this northern section. In the southern part, the plan includes dedicated plots and an existing mature rubber plantation. The latter will serve as a practical training site for both lecturers and students. The most represented plots are the full reforestation plots (06) and fallows (04), covering 4.41 ha and 3.61 ha respectively (Table 1).

Table 1 Parcel characteristics of the land-use development plan

Code	Plots	Area (ha)	Number
Agr	Citrus	0,42	1
Bam	Bamboo	1,13	2
Base vie	Basic Life	1	1
C.p.a	Perennial Crop and Tree	1,12	2
coco	Coconut Palm	1,1	2
E.aro	Aromatic Species	0,44	1
E.cat.1	Category 1 Species	2,87	3
E.cat.2	Category 2 Species	1,61	2
E.cat.3	Category 3 Species	2,5	2
E.end	Endemic Species	1,67	2
E.ex.fr	Exotic Fruit Species	0,61	1
E.f.fr	Forest Fruit Species	0,41	1
E.med	Medicinal Species	1,46	2
E.orn	Ornamental Species	0,45	1
E.sav	Savannah Species	0,88	1
Haie.v	Live Hedge	5,58	1
Hevea+arbre	Rubber Plantation	1,3	1
Jach	Fallow Land	3,61	4
Par.dedi	Sponsored plot	12,8	1
Parking	Parking	2,39	1
Zn.ino	Flood zone	7	1
R.p	Full reforestation	4,41	6
Roads	Roads	1,21	1
T.palm	Palm tree	3,21	3

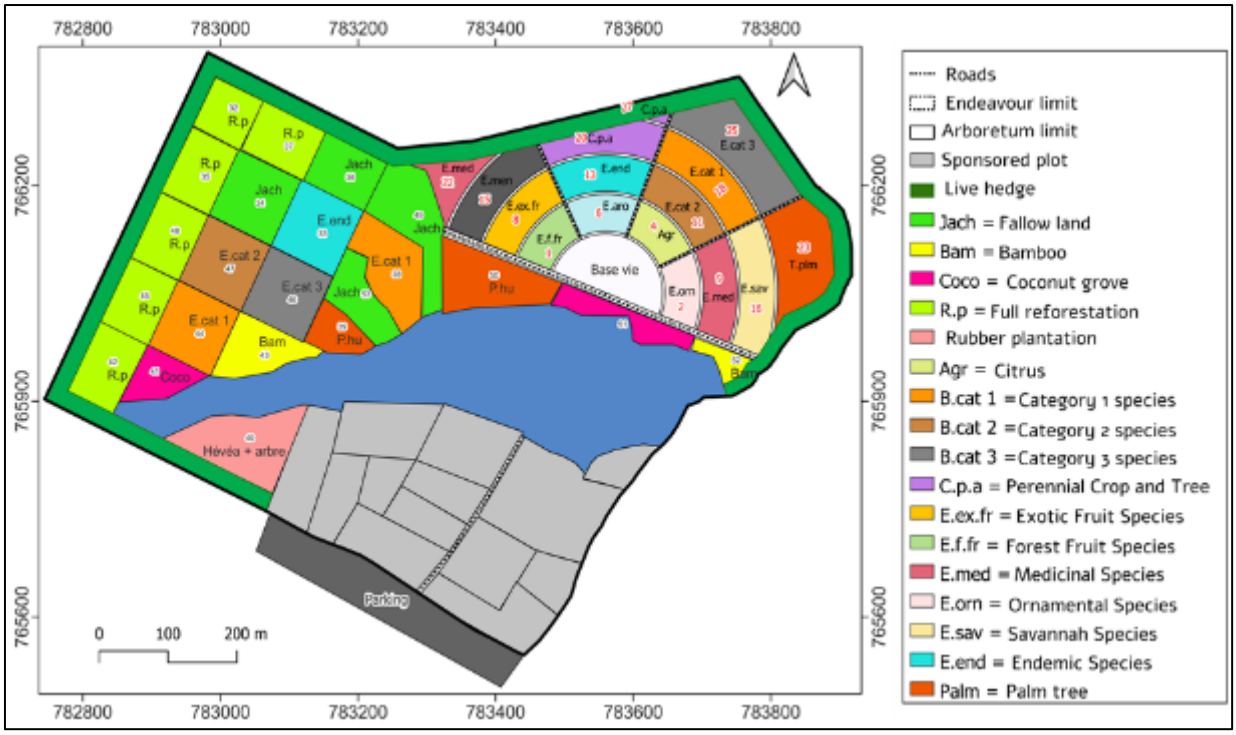

Figure 8 Ecological Development Plan of the Arboretum

4. Discussion

4.1. Land Use Mapping

Validation of the classified image indicated an overall accuracy of 95.4% with a Kappa coefficient of 0.89, confirming the reliability of the map (Pontius, 2000). The low confusion between land-use categories may be attributed to detailed category descriptions and high-quality field data. The dominance of cassava cultivation shows that the space is primarily used for food crop production, the main agricultural income source for populations around Daloa. The absence of dense forest reflects intensive agricultural activity within the university's perimeter.

4.2. Floristic Diversity of the Arboretum

The recorded diversity exceeds that of many secondary formations in Côte d'Ivoire. Kouamé et al. (2018) identified 74 species in a forest fallow in central-west Côte d'Ivoire. This underlines the arboretum's role as a biodiversity bank capable of ensuring natural regeneration. However, the dominance of pioneer species such as Harrisonia abyssinica, Albizia adianthifolia, and Holarrhena floribunda indicates strong human disturbance (Kouman et al., 2022). The floristic composition is dominated by Fabaceae, Moraceae, Sterculiaceae, and Euphorbiaceae, consistent with humid forests of the Guineo-Congolian region Adou et al., 2005 ; Vroh et al., 2013). In particular, Fabaceae are known for nitrogen fixation through symbiosis with bacteria, contributing to soil enrichment and vegetation recovery in degraded ecosystems (Sinsin & Kampmann, 2010).

4.3. Soil Characteristics

The physical characteristics of the site's soils indicate suitability for planting a wide variety of trees on 95% of the area. For indurated soils, herbaceous species are recommended. Soil fertility management should begin with organic amendments and calcium sources to raise pH and improve cation exchange capacity. Nitrogen-fixing legumes could also enhance soil fertility, stimulating microbial activity and organic matter decomposition.

4.4. A Multifunctional Space

The UJLoG arboretum offers multiple scientific, educational, ecological, socio-economic, and ecotourism benefits. Scientifically, it serves as a living laboratory for researchers and students. Ecologically, it conserves species with special status, improves air quality, and reduces greenhouse gas emissions via carbon sequestration. Socio-economically, arboretum trees will provide edible products (fruits, leaves, nuts, seeds, fodder), supporting local markets and creating

jobs. Long-term, fruit sales could provide additional income for the university and surrounding communities. As a tourist site, the arboretum could host cultural activities and eco-friendly recreation, such as cycling and nature walks.

5. Conclusion

The results of land-use mapping, floristic diversity analysis, and soil characterization enabled the design of the ecological management plan for the arboretum of Jean Lorougnon Guédé University in Daloa. The arboretum is dominated by seven land-use classes: wooded fallow, grassy fallow, cassava, lowland, rubber plantation, water, and sand borrow pits. The area contains 93 species distributed among 61 genera and 32 families. The soil analysis revealed three soil types: reworked, typical, and indurated ferrallitic soils. The management plan subdivides the arboretum into 37 thematic plots and provides for parking, access roads, reforestation areas, conservation zones for natural regeneration, and a living base. The arboretum will contribute to ex-situ conservation of regional flora, climate change mitigation through carbon storage, and ecotourism development.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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