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ARTICLE

Evaluation of Plant Diversity for Sustainable and Inclusive Management in Rural Areas: A Case Study from Daressalam, Niger

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ABSTRACT

Plant biodiversity plays a major role for sustaining livelihood of rural population. However, unsustainable exploitation of woody plants for firewood in Niger is creating ecological challenges. This study aims to evaluate plant species composition, richness and equitability for sustainable and inclusive management in rural areas. Plot vegetation inventory method was employed. Forty-eight plots each measuring 2500 m^2 were laid down systematically on a transect with the village at the centre. On each plot, plant species were identified and the number of each species counted. A total of twenty-five (25) plant species belonging to thirteen (13) families were identified among which *Guiera senegalensis* J. F. Gmel. accounted for 61%. The Shannon index was low (H' = 0.45) as well as species equitability (E = 0.14). Species richness differed significantly ($p < 0.000$) with land use type with agroforestry parklands recording significantly higher species compared to plateaus. For effective plant biodiversity restoration and management, irrigated agroforestry is recommended to restore ecological balance and to assure and improve the quality of plant biodiversity in the study area.

1. Introduction

Loss of biodiversity is a global concern, which needs urgent attention. The biodiversity resource on earth is not evenly distributed with majority around the equator. The loss of biodiversity in this region has increased as a result of climate and environmental change impacts which was reported to have resulted in the mass extinction of over 99.9% of biodiversity on earth [1]. Nonetheless, 86% of the remaining biodiversity on earth has not been documented whereas little is known about the status and trends of bio-

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diversity documented [2].

Indicators of biodiversity decline including resource consumption, invasive alien species proliferation, nitrogen pollution, overexploitation and climate change impacts showed increases especially in the Sahel region. In Niger, 77% of primary energy consumption comes from traditional biomass [3] which may have dire consequences on plant diversity and its services such as food supply and rural livelihood. In urban areas, 62% of people had access to electricity but in rural areas, only about 8% [4]. In rural areas of Niger, poor access to modern energy, resource consumption and overexploitation of forest resources for energy remains a prominent driver of plant biodiversity decline. The situation is even worse in Daressalam rural areas that lack access to electricity and modern energy service. The population relies basically on rainfed agriculture with low yield as a result of water deficits caused by perennial droughts during the growing season [5]. Due to lack of water, no irrigation is practiced in the village, and during the long dry season, the village mostly relies on the sale of firewood to meet their daily livelihood. This practice is further reducing plant biodiversity and its services for sustaining rural livelihoods.

Most rural communities rely on agriculture and plant species for livelihood, hence maintaining plant biodiversity under Sahelian climatic condition continuous to be a challenging task. However, continuous evaluation of plant biodiversity can offer evidence-based management intervention in rural areas; provide directive policy on direct contribution of plant biodiversity to rural livelihoods that will not only address water, energy and food security but also contribute to biodiversity restoration. This study aims to evaluate plant species diversity and its role in sustaining rural livelihood. The study will test the hypothesis that: i) Low plant species diversity exists in a rural area of Daressalam where access to water and clean cooking still remains a challenge and ii) land use systems in the rural area has negative influence on plant species diversity.

2. Material and Methods

2.1 The Study Area

This study was carried out in a rural area of Daressalam, located in the department of Boboye, Dosso region from Republic of Niger. The study area is located on longitude 13.2002283° N, latitude 2.711605° E, 240 m above sea level. Figure 1 illustrates the map of the study area. The area is characterized by Sahelo-Sudanian climate with an average annual rainfall of 495.6 mm. The forest type in the community can be classified as sudan savannah

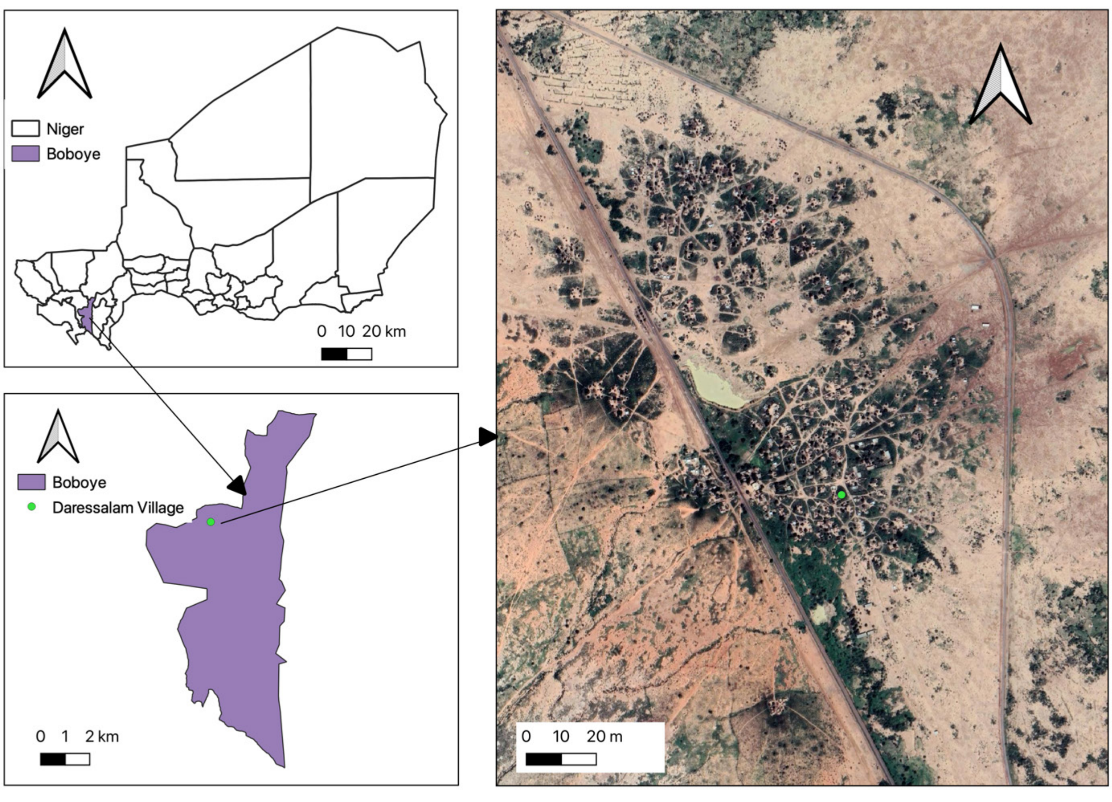

Figure 1. Map of Niger showing the study Area

woodland with relatively short trees with thick bark and tiny leaves which reduces transpiration during the dry season and are resistance to drought as well. The soil types can be classified as sandy soils (leached, unleached soils) and tropical ferruginous soils. The community has a total population of 2211 inhabitants with 435 households. Agriculture and livestock production are the main economic activity in the community. The major crop grown in the community is millet with cowpea, sorghum, groundnut and some vegetables like okra, hibiscus spp., etc grown as minor crops. The main source of energy in the community is firewood, which is collected from the bush or purchased from vendors despite the fact that, plants abundance is scarce in the area. The firewood is used for cooking and other domestic heating services.

2.2 Methodology

2.2.1 Plant Biodiversity Inventory

The plant biodiversity in the community was evaluated using a vegetation inventory. The plot inventory approach was used to collect the woody species data in a plot of 50 m × 50 m [6]. Eight (8) transects were followed perpendicularly to each other using the village as the center. In order, to obtain much information and due to the heterogenous nature of the ecosystem in the area, six plots each with a constant plot size of 50 m × 50 m was laid out systematically at a constant distance of 200 m on each transect 500 m from the village. The plots were fixed using the 3, 4, 5 method to get right angles at each corner of the plot [7]. The 3, 4, 5 method involves creating right angle triangles from each corner of the plots with lengths of 3 m, 4 m and 5 m. In total, 48 plots were studied with varied land use systems. The land use systems are agroforestry areas and plateaus. Agroforestry parklands are areas where there are farming activities with a mixture of trees, shrubs and grasses with off season livestock grazing. Plateaus are land use systems where only certain portion of the land is covered by shrubs leaving rocky bare grounds due to surface runoff. No agriculture production is carried out in this area because the land is unsuitable. These are the main land use systems observed in the study area forming a characteristic tiger bush forest pattern.

2.2.2 Data Treatment and Analysis

Plant species were identified using plant sample collection, photographs, and vernacular (local) names obtained from the field. The data were processed using excel spreadsheet to compute Shannon and equitability indices, as well as species abundance in the study area. Kruskal Wallis test was used to determine the impact of land use system on plant biodiversity using RStudio and the means compared using Bonferroni's post hoc test. The presence absence data of plant species were explained using cluster dendrogram plotted in R software [8].

The diversity indices were measured using diversity indices described by most researchers and it allows for quantitative characterization of diversity, which takes into consideration the number of species, the number of individuals of different species in a sample, habitat or a community.

Alpha diversity

It refers to diversity within a habitat or intra-community diversity. It has two components namely species richness and evenness. Species richness quantifies the number of individual species per locality or habitat. Evenness describes the equality of distribution of the individual species within a habitat. The indices used to study alpha diversity include;

- ***Species richness index***:

This is the total number of species (S) present in a community.

$$\text{Species richness index} = S \tag{1}$$

This is estimated by simply counting the number of different species present in a given habitat. Species richness index also known as variety index, are higher for species rich communities and vice versa [9].

- ***Shannon Index*** (H'):

This index gives an estimation of species diversity within a community (alpha diversity). It is estimated as the proportion of individuals in a species (n_i) to the total number of individuals in a community (N).

It is estimated using the formula:

$$H' = -\sum_{i=1}^{S} \frac{n_i}{N} \log_2 \frac{n_i}{N} \tag{2}$$

The values of Shannon index are generally between 1 and 5 bits in most ecological studies. The Shannon index increases as both the richness and the evenness of the community increase. The higher the value, the greater the diversity.

- ***Equitability index***:

This index gives the relative abundance of different species of a community in terms of their evenness of distribution.

It is estimated using the formula:

$$E = H'/\log_2 S \tag{3}$$

Where H' represents the Shannon index and S represents the species richness index. A community, in which the species have equal number of individuals of different species, will have a higher evenness index as compared to a community dominated by one or few species in terms of the number of individuals, will have a lower evenness index [9]. The evenness (equitability) of a sample implies equality in the number of individuals of species. The number of equally common species in a sample is called effective number of species [9]. This index characterizes the true diversity of a community.

3. Results and Discussion

3.1 Plant Species Richness and Diversity

From the survey, the species richness index is twenty-five (25). The number of plant species recorded from the study was in conformity with the findings of Hiernaux and Gerard [10] where they observed between 22 to 26 plant species which was slightly above Sahelian vegetation average despite low number of species per plot with bare soil excluded. This species richness reflects the diversity in edaphic niches resulting from the redistribution and localized concentration of water resources and shade. Table 1 presents the list of species identified from the study and the family they belong to. It was observed that, *Guiera senegalensis* J. F. Gmel. is the most dominant plant species since it represents 61% of plant individuals in the studied area. *Combretum micranthum* G. Don. and *Cassia sieberiana* DC. accounted for 28% and 7% respectively of the plant individuals studied. The remaining species accounted for less than 4% of the plant individuals of which *Piliostigma reticulatum* Hochst. represents 1.4%. The high abundance of *Guiera senegalensis* J. F. Gmel. is an indication of high degradation of land in the study area, which only favours invasive species proliferation. This means that, other important plant species will be totally outcompeted with time leaving only these species that are invasive. The Shannon index indicated very low plant diversity in the study area. This is due to the low equitability of distribution among species with over 80% of the species being less than 4% of the studied plant population.

Table 1. The list of plant species identified from the study area and their families.

S/N	Vernacular Name (Zarma)	Botanical Name	Family
S10	Baani/Jihi	*Acacia nilotica* (L.) Wild. ex Delile	Fabaceae
S21	Danga	*Acacia senegalensis* (Houtt.) Roberty	Fabaceae
S17	Mufa	*Anona senegalensis* Pers.	Annonaceae
S14	Garbey	*Balanites aegyptiaca* (L.) Delile	Balanitaceae
S15	Namali/Nammary	*Bauhinia rufescens* Lam.	Fabaceae
S24	Forogo	*Bombax costatum* Pellegr. & Vuillet	Bambacaceae
S7	Hasu Kwarey	*Boscia augustifolia* A. Rich.	Capparaceae
S8	Yiyaahi	*Boswellia papyrifera* Hochst.	Burseraceae
S18	Sageye	*Calotropis procera* (Aiton) W. T. Aiton	Apocynaceae
S3	Sinsan	*Cassia sieberriana* DC.	Fabaceae
S16	Buburé	*Combretum aculeatum* Vent.	Combretaceae
S9	Korkorbi	*Combretum glutinosum* Perr. ex DC.	Combretaceae
S1	Koubou	*Combretum micranthum* G. Don.	Combretaceae
S22	Deli	*Combretum nigricans* Lepr.	Combretaceae
S5	Korombé	*Commiphora africana* Endl.	Burseraceae
S13	Gau	*Faidherbia albida* (Delile) A. Chev.	Mimosaceae
S6	Tondi Fara	*Gardenia sokotensis* Hutch.	Rubiaceae
S25	Inkomdi	*Gardenia ternifolia* Schumach. & Thonn.	Rubiaceae
S2	Sabara	*Guiera senegalensis* J. F. Gmel.	Combretaceae
S19	Pfataka	*Pergularia tomentosa* L.	Apocynaceae
S4	Kosey	*Piliostigma reticulatum* Hochst.	Fabaceae
S20	Diney	*Sclerocarya birreae* (A. Rich.) Hochst.	Anacardiaceae
S11	Bari turi	*Stereospermum kunthianum* Cham.	Bignoniaceae
S23	Farka hanga	*Terminalia avicennioides* Guill. & Perr.	Combretaceae
S12	Daréy	*Ziziphus mauritiana* Lam.	Rhamnaceae
Species richness index		**25**	
Shannon index		**0.45**	
Equitability index		**0.14**	

3.2 The Effect of Land Use System on Plant Species Richness

Land use system had a significant effect ($p < 0.000$) on plant species richness (Figure 2). Agroforestry parklands recorded 57% more species as compared to plateaus. This observation could be due to large numbers of few species recorded on plateaus (*Guiera senegalensis* J. F. Gmel., *Combretum micranthum* G. Don. *and Cassia sieberriana* DC.). These are the dominant species found in the rural area of Daressalam and they are better adapted to the Sahelian ecosystem, and are responsible for the characteristic tiger bush vegetation found in the Parc double vé of Niger. According to Zerbo *et al.* [11], land use had a significant effect on herbaceous vegetation composition and herbaceous species diversity changed with environmental conditions. However, the floristic composition of dominant species is driven by both climate and land use. The frequency of distribution demonstrated that herbaceous species occurrences were more influenced by the mixed effect of climate and land use than their separate effects. Similarly, forest cover, presence of streams and nutrient status of soil water and sediment are significant predictors of plant species richness. Growing season precipitation has been shown to have contributed exponentially to plant species richness while maintaining positive diversity indices [12]. In addition, because most farmers in these areas are smallholders, they practice mixed cropping systems with off season grazing, these may have resulted in crop heterogeneity on agroforestry parklands. Crop heterogeneity has been reported by Alignier *et al.* [13] to have caused the occurrence of high plant biodiversity on smallholder farms. Similarly, smaller farms records higher yields, as well as have higher crop and non-crop biodiversity [14]. Moreover, as a climate change adaptation strategy, most farmers prefer to leave some tree plants on their farms which may have contributed to high plant species richness observed on cultivated agroforestry parklands as compared to plateaus.

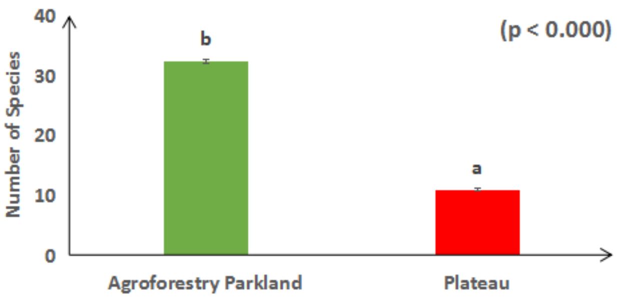

Figure 2. The effect of land use type on plant species richness

3.3 Plant Species Distribution and Interaction

The interaction of plant species in terms of abundance and occurrence with other plant species is represented in Figure 3. The plant community is less uniform which is expressed quantitatively and clustered in a dendrogram using hierarchical agglomerative cluster analysis and Euclidean distance inequality matrix [15]. Six clusters can be classified at 4.5 Euclidean inequality distance matrix. The most dominant plant species represented as (S1, S2, and S3) constitute cluster one (C1) where S2 and S3 converge at 3.6 Euclidean inequality distance matrix which later converge with S1 at 4.5 Euclidean distance inequality matrix. The second cluster (C2) represented with S4 and S12 converge at 2.5 Euclidean distance inequality matrix. Similarly, in cluster three (C3), S9 and S11 initially converge at 1.8 and at 2.0, the two species converge with S14. These three species later converge with S19 at 2.6 Euclidean distance inequality matrix. Moreover, in cluster four (C4), S16 and S17 converged at 0.2 Euclidean distance inequality matrix where the two species later converge with S13 and S22 with 1.7 Euclidean distance inequality matrix at 1.8. S13, S16, S17 and S22 finally converge with S20 at 2.4 Euclidian distance inequality matrix. In cluster five (C5), a total of eight species were observed with four sub cluster of two species each. In this cluster, S5 and S6 initially converge at 1.6 and later converged with S8 and S23 which also initially converged at 1.6 at Euclidean distance inequality matrix of 2.2. These four species finally converged with S18 and S24 at 2.4 Euclidean distance inequality matrix. In cluster six (C6), S7 and S10 converged at 3.8 Euclidean distance inequality matrix.

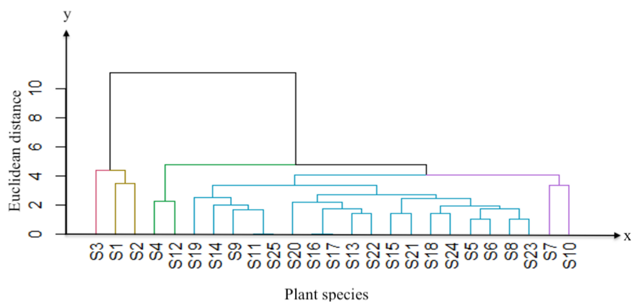

Figure 3. A cluster diagram of plant species distribution in the study area

This shows that, the less frequent plant species in the rural area of Daressalam are represented with cluster four. For example, *Stereospermum kunthianum* and *Gardenia ternifolia* which belongs to Bignoniaceae and Rubiaceae families respectively have about 2% chance of disappearing from the study area and can be described as endangered [16]. Plant species in cluster five occurred

4.25% more frequent than those in cluster four (Figure 4). Similarly, the distribution of individual plant species in C5 is more even as compared to those in C4. For example, *Commiphora africana*, *Gardenia sokotensis*, *Boswellia papyrifera* and *Terminalia avicennioides* all have the same frequency of occurrence in the study area but occurred 14% more than *Stereospermum kunthianum* and *Gardenia ternifolia.* The low frequency of these species may be attributed to grazing during the dry season because the leaves of these plant species serve as the only source of forage, hence low regeneration rate due to animal browsing effect. The dominant plant species represented in C1 occurred 25.3% more frequent than those in C4. *Guiera senegalensis* and *Combretum micranthum*, major plant species in C1 and the study area represent more than 65% of the studied plant population. These plants are indicator plants for highly degraded environmental conditions and can be described as invasive plant species in the study area. According to Seghieri and Simier [17], *Guiera senegalensis* has a high resistance to the increasing cutting pressure for cultivation due to its semi-evergreenness property thereby contributing to its invasive nature in the study area.

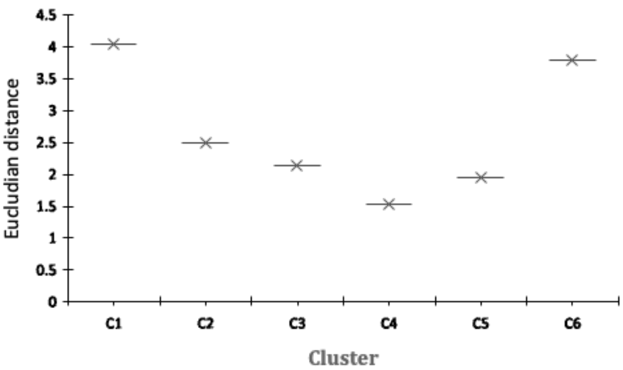

Figure 4. Average Euclidean distance inequality matrix for cluster comparison

4. Conclusions and Management Implication

Plant diversity restoration and management especially in the Sahel is crucial for sustainable development goals to be achieved and for effective management, there is the need for periodic evaluation and monitoring at the local, national and global levels so that management strategies be tailored to current trends and status in plant diversity. The study reveals very low Shannon index (0.45) even though species richness is twenty-five (25). This is due to the abundance (about 80%) of very few numbers of species observed. The quality of diversity is low in the community, so management strategy must be focussed on creating competitive environment to promote native plant species in the community. Attention should be paid to dominant plant species and how resources are distributed to them. Similarly, harvesting of plant species for firewood should be done only on *Guiera senegalensis* J. F. Gmel. and *Combretum micranthum* G. Don. and these two species should be avoided when planning irrigated agroforestry programmes in the community. Energy crops are recommended for the study area to help decrease the pressure over native plants. Local plant diversity committees, bye laws and taboos should be enacted by the traditional rulers on the utilization or harvesting of other plant species for firewood other than *Guiera senegalensis* J. F. Gmel. and *Combretum micranthum* G. Don. to help restore ecological balance in the study area.

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Conflict of Interest

The authors declare that they have no individual relationships that could have performed to affected the work reported in this study and have no known conflict of financial interests.

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