







Floristic Diversity and Regeneration of Agroforestry Parklands in the Sudano-Sahelian Zone of Cameroon

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ABSTRACT: Agroforestry parklands play a crucial role in biodiversity conservation, soil fertility improvement, and climate resilience in arid and semi-arid regions. This study aimed to assess woody species diversity, regeneration capacity, and agroforestry anthropisation and vulnerability indices and to propose a sustainable management strategy across four sites: Benoue, Mayo-Louti, Mayo-Kani and Diamare in the Sudano-Sahelian zone of Cameroon. Floristic inventories were conducted in 50 m × 50 m plots, where all woody individuals were identified and measured. Species diversity was analysed using Shannon-Wiener, Simpson, and Pielou's equitability indices, with principal component analysis supporting the analysis. Tree density, regeneration rates and anthropogenic pressures were also evaluated. A total of 40 woody species belonging to 36 genera and 22 families were recorded. Dominant species included *Khaya senegalensis*, *Adansonia digitata*, *Balanites aegyptiaca* and *Faidherbia albida*. Tree density ranged from 59 to 179 stems per hectare. Regeneration varied markedly among species, with *B. aegyptiaca* showing a high rate (97.5%) and *A. digitata* a very low rate (0.5%). Deforestation, overgrazing and land clearing were major threats. In conclusion, although agroforestry parklands provide significant ecological and socio-economic benefits, targeted sustainable management measures are essential to ensure their long-term resilience and biodiversity conservation.

Keywords: Agroforestry, Diversity, Regeneration, Vulnerability, Management.

1. INTRODUCTION

Agroforestry parklands are traditional agricultural systems in which trees are intentionally preserved or integrated within croplands. These systems play a crucial role in sustaining rural livelihoods and maintaining

ecosystem services, particularly in arid and semi-arid regions. Agroforestry contributes to biodiversity conservation, soil fertility enhancement, carbon sequestration, and the provision of food, fuelwood, timber, and medicinal products, thereby supporting sustainable rural development (Awazi et al., 2025; Mlambo et al., 2025; Yabi

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et al., 2024). Recent studies published have highlighted the multifunctional role of agroforestry systems across diverse ecological and socio-economic contexts (Sharma et al., 2025). Ulman and Yadav (2024) demonstrated that higher plant diversity in agroforestry systems significantly enhances household income, while Santosh et al. (2024) emphasised the importance of gender roles in the management and sustainability of agroforestry systems. Similarly, Sharma et al. (2025) identified agroforestry as a scientific tool for promoting sustainable livelihoods in rural communities. Studies from different agroecological regions further indicate that agroforestry systems contribute simultaneously to biodiversity conservation, ecosystem service provision and livelihood enhancement (Maurya et al., 2025; Tariyal et al., 2025).

Species-specific and system-based studies also underline the economic and ecological relevance of agroforestry. For example, *Senegalia catechu*-based systems have been shown to generate significant economic returns while maintaining ecological functions (Sharma et al., 2025), whereas sandalwood (*Santalum album*)-based agroforestry systems contribute to income diversification and long-term sustainability (Venkatesh et al., 2023). These findings collectively confirm that agroforestry systems represent resilient land-use strategies capable of balancing production, conservation and socio-economic objectives.

In the Sudano-Sahelian zone of Cameroon, agroforestry parklands play a similarly vital role under conditions of high climate variability, prolonged dry seasons, and increasing land degradation, and are largely owned by individuals and local communities, who also ensure their management. However, despite their importance, comprehensive information on floristic diversity, regeneration potential, anthropisation level and vulnerability of agroforestry parklands in this region remains limited. This knowledge gap constrains effective conservation planning and sustainable management, particularly in landscapes facing increasing anthropogenic pressures. Therefore, the present study aimed to assess the floristic diversity and regeneration potential of agroforestry parklands in the Sudano-Sahelian zone of Cameroon, evaluate anthropogenic impacts and species vulnerability and propose sustainable management strategies to enhance ecosystem resilience and support rural livelihoods.

2. MATERIALS AND METHODS

2.1. Study Area

The research was conducted in the Sudano-Sahelian zone of Cameroon, located at latitude 9°20'43.95"N and longitude

13°34'36.38"E. This agroecological region includes the North and Far North Regions, covering approximately 10.2 million hectares, of which around 0.56 million hectares are currently cultivated (Haiwang, 2001; Seignobos, 2000). Fieldwork was conducted from March to September 2024 across four departments, i.e. (In Cameroon specifically, what used to be called "provinces" are now officially called regions, and departments are the next level below regions), Benoue, Mayo-Louti, Mayo-Kani and Diamare selected for their contrasting agroforestry systems and ecological characteristics (Figure 1).

In the present study, agroforestry parklands were grouped according to the dominant tree species maintained and managed by farmers within cultivated fields. This classification is primarily based on the ecological and structural dominance of tree species, as well as their frequency of occurrence in agroforestry systems. The main types of parklands identified are as follows: *Balanites aegyptiaca*-dominated parklands (PBa), *Adansonia digitata*-dominated parklands (PAd), *Khaya senegalensis*-dominated parklands (PKs) and *Faidherbia albida*-dominated parklands (PFa).

The typology of agroforestry parklands was established based on the following criteria: The presence and dominance of a main tree species, considered as the key structural component of the system; The relative frequency and abundance of this species within agricultural plots; The associated agroecological functions (soil fertility enhancement, shading, ecosystem services, and socio-economic uses); The floristic composition and associated species diversity.

This approach makes it possible to distinguish functionally contrasting agroforestry systems, each reflecting both farmers' management choices and local ecological conditions.

2.2. General Methodological Approach

A mixed-methods approach was employed, integrating both quantitative and qualitative data collection techniques. The methodology included: floristic and structural inventories of woody vegetation; ecological indices (diversity, mortality, regeneration, and anthropogenic pressure); and socioeconomic surveys of local farmers using semi-structured questionnaires. This approach aimed to provide a comprehensive understanding of the structure, composition and management of agroforestry parklands in the study area.

2.3. Sampling Design and Experimental Setup

This diagram illustrates a stratified sampling design in which the study area is first divided into departments (blocks) and then into agroforestry parkland types (treatments). Within each stratum, plots of 50 m × 50 m (Figure 2) are randomly selected and replicated to ensure representativeness and statistical reliability. Data are then collected at the plot level on floristic composition, dendrometric parameters, regeneration and anthropogenic pressures.

The study was conducted using a Randomized Complete Block Design (RCBD), with departments considered as blocks and 50 m × 50 m plots as experimental units. Each type of agroforestry parkland was treated as a separate treatment. Four plots were established per parkland type in each department, resulting in 16 replicates per site (Figure 3). The location of each plot was determined randomly using GPS to avoid selection bias. Individual plots serving as the experimental units. Each treatment was replicated five times per department, yielding a robust dataset for statistical analysis.

2.4. Floristic Inventory

Floristic inventory was conducted following the Lejoly (1993) protocol. Taxonomic identification of species was carried out using Arbonnier (2002), and classification followed the APG IV system (Angiosperm Phylogeny Group, 2016). Sampling was performed in rectangular plots

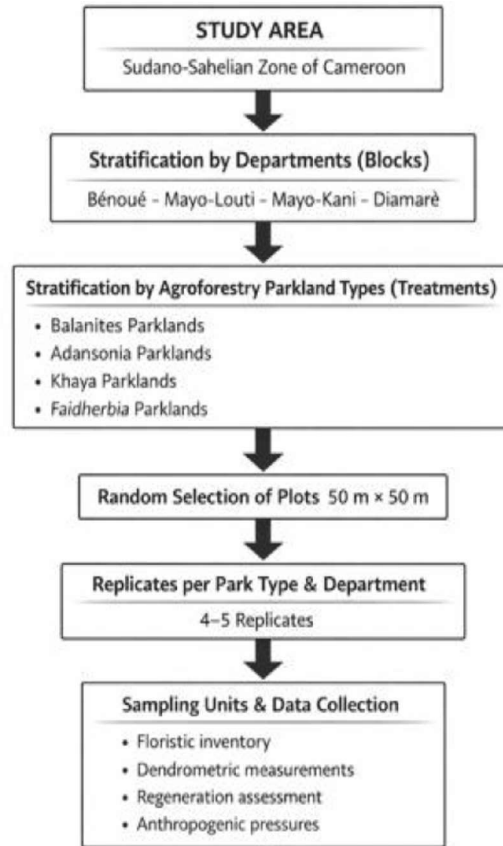


Figure 2. Stratified sampling design of agroforestry parklands in the Sudano-Sahelian zone of Cameroon

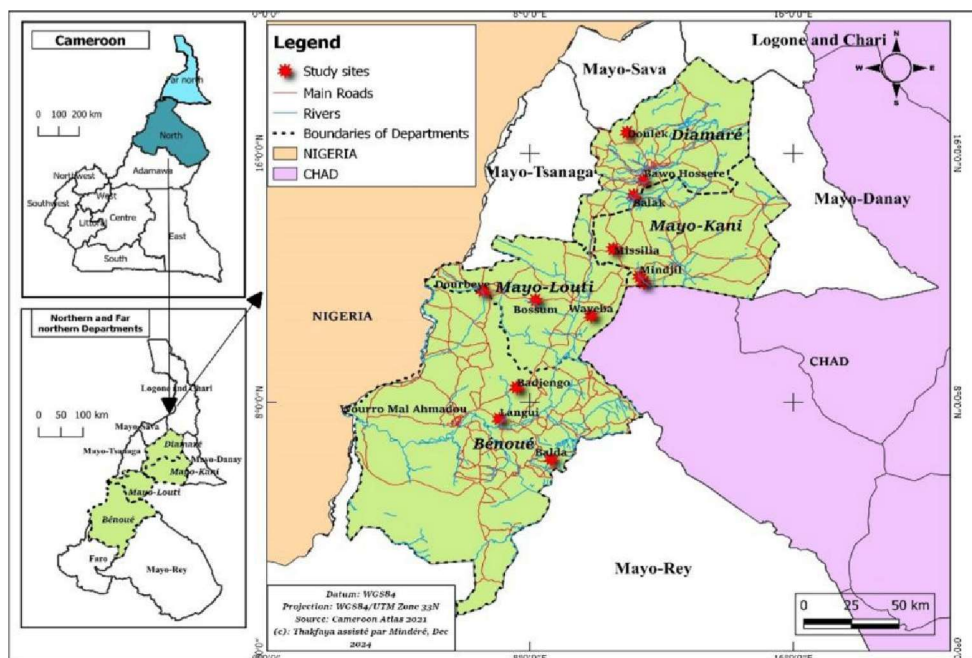


Figure 1. Location of the study area

(Figure 3) measuring 50 m × 50 m (2,500 m²), randomly established in agroforestry parklands. Each plot was considered as a replicate within a stratified sampling design. All woody plant species with a diameter at breast height (DBH) ≥ 10 cm were recorded. The following field equipment was used: a GPS (Garmin Terex 10) to record geospatial coordinates (latitude, longitude, altitude); a decameter and measuring tape for measuring plot boundaries and tree dimensions; a graduated pole for estimating tree height; a machete and string for demarcating plots; a camera (Canon EOS 4000D) for photographic documentation; and a laptop (HP Pavilion) for data entry and processing.

2.5. Structural Characterisation of Agroforestry Parklands

In this study, the structural characterisation of these parklands focused on the analysis of floristic diversity, species composition, and key dendrometric parameters such as tree density, basal area and natural regeneration dynamics. Woody species diversity was quantified using Shannon's diversity index (H'), Pielou's evenness index (EQ) and Simpson's dominance index (S), in order to assess both species richness and distribution patterns within the stands. Particular attention was given to dominant agroforestry species known for their functional roles in parklands systems *K. senegalensis*, *A. digitata*, *B. aegyptiaca* and *Faidherbia albida*. These species, commonly preserved in cultivated plots, interact closely with crops and significantly influence the structural integrity, ecological resilience and productivity of the agroforestry system.

2.6. Dendrometric Measurements

Structural parameters and floristic composition, as well as dendrometric characteristics including tree height (measured using a graduated pole), diameter at breast height (DBH) were assessed to analyse the parkland's structure.

Tree height was measured for both adult and young individuals using a graduated pole, while DBH was calculated from circumference measurements taken at 1.30 m above ground level (Song et al., 2021). Crown diameter was determined using perpendicular measurements in the North–South and East–West directions, providing information on tree canopy cover and spatial distribution.

2.7. Diversity and Floristic Composition

Floristic diversity was quantified by calculating species richness, relative frequency, and relative density. Diversity was further assessed using standard ecological indices, including the Shannon–Wiener diversity index ($H' = -\sum p_i \log_2 p_i$) (Shannon, 1948), Simpson's diversity index ($D = \sum N_i(N_i - 1) / N(N - 1)$) (Simpson, 1949), and Pielou's evenness index ($J' = H' / \log_2 N$) (Pielou, 1966). These indices provide complementary information on species dominance, distribution patterns and overall floristic balance across the studied sites.

2.8. Mortality rate (M)

Dead individuals were identified during the field inventory through direct observation, based on visible signs such as dryness, uprooting, absence of leaves, or lack of regrowth. Each dead individual was recorded within the corresponding plot and compared to the total number of

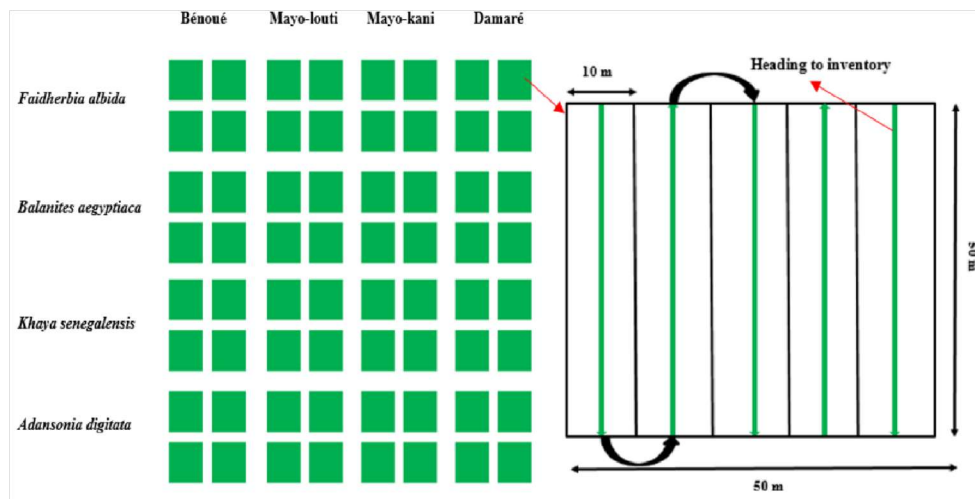


Figure 3. Inventory design (a) and Experimental setup (b)

living individuals. The mortality rate (M) was then calculated as the ratio of dead individuals (n) to the total number of living individuals (N), using the formula: $M = (n / N) \times 100$

2.9. Anthropisation Indices

Anthropogenic factors were recorded through direct field observations. These included the presence of fire traces, tree cutting, bark stripping, pruning and agricultural activities. Such observations provided insights into the frequency of human actions across the different study sites. The frequency of each anthropogenic activity was determined using the following formula (Eq. 1):

Frequency of activity = Number of a given anthropogenic trace / Total number of traces $\times 100$ (1)

2.10. Regeneration

The regeneration potential was assessed by identifying and counting young individuals of tree species (*K. senegalensis*, *A. digitata*, *B. aegyptiaca*, and *F. albida*) in agroforestry parklands. An individual was considered to be regenerating if it had: a stem diameter of less than 10 cm, and a height of less than 4 meters. Their counting allows for estimating the natural renewal capacity of tree populations in these agroforestry systems.

2.11. Assessment of Anthropogenic Pressures and Species Vulnerability

Anthropogenic Pressures and Species Vulnerability such as logging, pruning, fire traces and bark stripping were recorded to assess anthropisation indices. The vulnerability index, adapted from Betti (2001) and Traoré et al. (2011), was used to classify species into low, moderate, or high-risk categories, based on their extraction method, usage frequency and regeneration capacity (Table 1). These

analyses highlight the critical role of conservation strategies in maintaining agroforestry parklands sustainability.

2.12. Farmers' Surveys and Management Perceptions

The management plan was developed based on systematic surveys conducted among farmers in four departments: Benoue, Mayo Louti, Mayo Kani and Diamare. A total of 400 farmers were interviewed, 100 from each site, using semi-structured questionnaires to ensure equitable representation of local contexts. The surveys gathered farmers' perceptions, expectations and suggestions regarding the sustainable management of agroforestry parklands. Key themes included current management practices, priorities such as conservation, reforestation and resource rationalization and ideas for improving the management and productivity of the parklands.

Participants were selected using simple random sampling from lists of cultivators provided by local agricultural services, ensuring equitable representation of local contexts. The surveys focused on farmers' management practices, perceptions and expectations regarding agroforestry parklands. Key themes included current strategies, priorities such as conservation, reforestation and sustainable resource use, as well as farmers' suggestions for improving the management and productivity of the parklands.

Quantitative responses were analysed using descriptive statistics, while qualitative data were examined through content analysis. The insights gained from these surveys served as the basis for developing a context-specific management plan tailored to the needs and realities of each department.

2.13. Data Analysis

All quantitative data were analysed using XLSTAT 2022 and Statgraphic Plus 5.1. Descriptive statistics (mean,

Table 1. Important parameters considered for calculating the vulnerability index

Code	Evaluated parameter	Vulnerability to uncontrolled exposure		
		Low (scale=1)	Medium (scale=2)	High (scale=3)
Q1	Frequency of use (FU)	FU < 20%	Medium 20% ≤ FU <60 %	High FU ≥60%
Q2	Number of uses (NU)	NU < 2	2 ≤ NU ≤ 4	NU ≥ 5
Q3	Plant organ used	Leaf	branch Wood	seed, bark, root, flower
Q4	Collection method	Collection		Picking, cutting
Q5	Stage of development	Old or senescent	Adult	Young
Q6	Relative frequency (RF)	RF ≥ 2/3 Fm	1/3 Fm ≤ RF <2/3 Fm	RF <2/3 Fm

Adapted from (Betti, 2001; Traoré et al., 2011)

standard deviation, percentages) were computed. Analysis of variance (ANOVA) was used to test for differences in floristic parameters across sites, followed by Duncan's Multiple Range Test to separate significant means at $p \leq 0.05$. Graphs were generated in Microsoft Excel (histograms, curves, pie charts). Multivariate analyses were used to examine patterns of diversity and structure among agroforestry parklands. Diversity indices were standardised prior to analysis. Principal component analysis (PCA) and hierarchical clustering were applied to identify overall similarity patterns among parklands. Non-metric Multidimensional Scaling (NMDS) was used to explore compositional dissimilarities, and model fit was assessed using stress values. Multiple factor analysis (MFA) integrated diversity, structural and regeneration variables to identify the main ecological gradients structuring the parklands. Laboratory support for species identification and data validation was provided by the Botany and Ecology Laboratory of the University of Ngaoundéré, in collaboration with the Regional Delegations of Environment and Forestry in the North and Far North Regions.

3. RESULTS AND DISCUSSION

3.1. Floristic Composition per Parkland Types and Department

The floristic composition of agroforestry parklands showed marked variation according to the dominant tree species, whereas no significant differences were observed among departments. However, species richness, as well as genus and family diversity, were significantly influenced by the Department ($p < 0.05$).

Parklands dominated by *Khaya senegalensis* and *Adansonia digitata* exhibited the highest floristic diversity, with up to 18 species, 17 genera, and 13 families. In contrast, parklands dominated by *Faidherbia albida* showed the lowest diversity levels, with only 4 species, 4 genera, and 4 families. The absence of significant differences between Department means suggests that floristic variability in these agroforestry systems is primarily driven by the ecological influence of dominant tree species rather than by geographical location.

Overall, inventory revealed the presence of 40 woody species distributed among 36 genera and 22 families, highlighting the substantial ecological and socio-economic

Table 2. Floristic composition of agroforestry parklands according to department and dominant species

Department	Parameter	Type of parkland				Mean ±SD
		<i>B. aegyptiaca</i>	<i>A. digitata</i>	<i>K. senegalensis</i>	<i>F. albida</i>	
Benoue	Nber of individuals	134 ^b	87 ^b	179 ^a	108 ^b	127.00 ± 40.62
	Nber of species	9 ^c	15 ^b	18 ^a	4 ^d	11.50 ± 6.08
	Nber of genera	9 ^c	15 ^a	17 ^a	4 ^d	11.25 ± 5.68
	Nber of family	6 ^b	11 ^a	11 ^a	4 ^c	8.00 ± 3.16
Mayo Louti	Nber of individuals	84 ^{ab}	106 ^a	59 ^c	78 ^b	81.75 ± 19.42
	Nber of species	11 ^c	18 ^a	15 ^b	10 ^c	13.50 ± 3.70
	Nber of genera	10 ^b	17 ^a	15 ^a	9 ^b	12.75 ± 3.86
	Nber of family	8 ^b	13 ^a	10 ^b	9 ^b	10.00 ± 2.16
Mayo Kani	Nber of individuals	133 ^a	76 ^b	107 ^{ab}	103 ^{ab}	104.75 ± 23.63
	Nber of species	9 ^b	10 ^b	15 ^a	6 ^c	10.00 ± 3.74
	Nber of genera	8 ^b	10 ^b	14 ^a	6 ^c	9.50 ± 3.42
	Nber of family	7 ^b	8 ^{ab}	10 ^a	5 ^c	7.50 ± 2.08
Diamare	Nber of individuals	149 ^a	86 ^c	88 ^c	132 ^b	113.75 ± 31.42
	Nber of species	8 ^c	9 ^c	14 ^a	11 ^b	10.50 ± 2.65
	Nber of genera	6 ^c	14 ^a	13 ^a	9 ^b	10.50 ± 3.87
	Nber of family	6 ^b	10 ^a	10 ^a	7 ^b	8.25 ± 2.06

B. egyptiaca: *Balanites aegyptiaca*, *A. digitata*: *Adansonia digitata*, *F. albida*: *Faidherbia albida*, *K. Senegalensis* : *Khaya senegalensis*, Nber = Number , SD= Standard deviation, Different superscript lowercase letters (a, b, c, ab, d) indicate significant differences between dominant species ($p < 0.05$)

value of agroforestry parklands in the Sudano-Sahelian zone of Cameroon. This level of species richness exceeds that reported in similar systems in Niger and Chad, and is comparable to values documented in Burkina Faso and Mali, indicating that these parklands remain relatively well conserved.

Comparable patterns of high floristic diversity have also been reported in traditional agroforestry systems in India, where long-standing land-use practices and farmer-led tree conservation play a key role in maintaining species richness and ecosystem stability (Ulman and Yadav, 2024; Sharma et al., 2025). These similarities suggest that the observed diversity in northern Cameroon may likewise result from local management practices that favor the conservation of multipurpose woody species.

3.2. Floristic Diversity by Parkland Types and Department

Analysis of diversity indices (Table 3) revealed that Shannon diversity (H'), Pielou's equitability (EQ) and Simpson's dominance (S) were primarily influenced by dominant tree species rather than by the geographical location of Department. Across all Departments, parklands dominated by *Khaya senegalensis* consistently showed the highest Shannon diversity values, indicating a greater complexity of associated woody species. In contrast, *Faidherbia albida* -dominated parklands exhibited the lowest values for all diversity indices, highlighting their

limited contribution to overall floristic diversity and a simpler community structure.

Adansonia digitata -dominated parklands showed the highest equitability values, reflecting a more balanced distribution of associated species and reduced dominance effects. This pattern suggests that *A. digitata* creates ecological conditions favourable to the coexistence of multiple species with relatively similar abundances. Conversely, the lower equitability and diversity values associated with *F. albida* indicate stronger dominance by a few species and reduced structural heterogeneity.

Spatial variation in diversity indices among Department further reflects differences in land-use intensity, management practices and local ecological conditions. Higher Shannon diversity and evenness values observed in Benoue Department suggest more stable and structurally complex agroforestry systems, likely linked to lower anthropogenic pressure and better conservation of woody species. In contrast, lower diversity values recorded in Mayo-Kani indicate a tendency toward dominance by a limited number of species, reflecting higher land-use pressure and reduced ecosystem resilience.

These findings are consistent with observations from dryland agroforestry systems in India, where increasing anthropogenic disturbance has been shown to simplify species composition and reduce functional diversity (Maurya et al., 2025). Additionally, variations in tree density across dominant species and the Department emphasise the

Table 3. Diversity index values of agroforestry parklands according to department and dominant species

Department	Parameter	Type of parkland				Mean ±SD
		<i>B. aegyptiaca</i>	<i>A. digitata</i>	<i>K. senegalensis</i>	<i>F. albida</i>	
Benoue	H' (Shannon)	1.38 ± 0.11 ^b	1.94 ± 0.09 ^a	2.09 ± 0.11 ^a	1.49 ± 0.09 ^b	1.73 ± 0.31
	EQ (Equitability)	0.72 ± 0.03 ^{ab}	0.79 ± 0.04 ^a	0.73 ± 0.03 ^{ab}	0.65 ± 0.09 ^b	0.72 ± 0.06
	S (Simpson)	0.05 ± 0.03 ^b	0.02 ± 0.04 ^a	0.05 ± 0.03 ^b	0.01 ± 0.01 ^a	0.03 ± 0.02
Mayo Louti	H' (Shannon)	1.65 ± 0.11 ^b	1.96 ± 0.09 ^{ab}	2.12 ± 0.08 ^a	1.27 ± 0.08 ^c	1.75 ± 0.37
	EQ (Equitability)	0.74 ± 0.02 ^b	0.83 ± 0.03 ^a	0.71 ± 0.03 ^b	0.46 ± 0.02 ^a	0.69 ± 0.16
	S (Simpson)	0.03 ± 0.01 ^b	0.05 ± 0.03 ^b	0.06 ± 0.05 ^b	0.01 ± 0.01 ^a	0.04 ± 0.02
Mayo Kani	H' (Shannon)	1.85 ± 0.11 ^{ab}	1.51 ± 0.09 ^b	2.04 ± 0.08 ^a	1.92 ± 0.16 ^a	1.83 ± 0.22
	EQ (Equitability)	0.74 ± 0.16 ^a	0.78 ± 0.05 ^a	0.71 ± 0.02 ^{ab}	0.58 ± 0.02 ^b	0.70 ± 0.09
	S (Simpson)	0.05 ± 0.02 ^a	0.04 ± 0.03 ^a	0.05 ± 0.03 ^a	0.03 ± 0.03 ^a	0.04 ± 0.01
Diamare	H' (Shannon)	0.92 ± 0.27 ^c	1.59 ± 0.09 ^{ab}	1.79 ± 0.08 ^a	1.21 ± 0.10 ^b	1.38 ± 0.33
	EQ (Equitability)	0.74 ± 0.03 ^{ab}	0.79 ± 0.03 ^a	0.74 ± 0.03 ^{ab}	0.59 ± 0.02 ^b	0.72 ± 0.08
	S (Simpson)	0.05 ± 0.03 ^a	0.03 ± 0.02 ^a	0.06 ± 0.03 ^a	0.05 ± 0.03 ^a	0.05 ± 0.01

B. egyptica: *Balanites aegyptiaca*, *A. digitata*: *Adansonia digitata*, *F. albida*: *Faidherbia albida*, *K. Senegalensis*: *Khaya senegalensis*, Different superscript lowercase letters (a, b, c, ab) indicate significant differences between dominant species (p<0.05), SD= Standard deviation

combined influence of farmer preferences and site-specific ecological conditions in shaping the structure and diversity of agroforestry parklands.

3.3. Tree Density by Parkland Type and Department

Tree density in agroforestry parklands did not show significant variation between Departments, with mean values ranging from 81.75 ± 19.36 trees ha^{-1} in Mayo-Louti to 127.0 ± 39.64 trees ha^{-1} in Benoue, all belonging to the same statistical group ($p > 0.05$). However, tree density differed significantly according to the dominant species ($p < 0.05$), with *Balanites aegyptiaca* dominated parklands recording the highest mean density (125.0 ± 24.51 trees ha^{-1}), significantly greater than that of *Adansonia digitata* (88.75 ± 10.85 trees ha^{-1}), while densities of *Khaya senegalensis* (108.25 ± 42.38) and *Faidherbia albida* (106.0 ± 13.53) were intermediate and not significantly different from those of *B. aegyptiaca*. These results indicate that tree density is primarily determined by the dominant species rather than the Department location. High densities of *B. aegyptiaca* reflect strong selection and deliberate maintenance farmers due to its multifunctionality and drought tolerance, whereas low densities of *A. digitata* likely result from its large crown size and shading effect, which limit the number of individuals tolerated in cultivated plots. Intermediate densities of *K. senegalensis* and *F. albida* reflect management compromises aimed at balancing agricultural productivity and ecosystem services. The lack of significant differences between Department confirm that geographic or administrative factors play a secondary role in structuring parkland stands, as observed in Sahelian parklands where tree density remains relatively homogeneous at large scales due to comparable agricultural practices and climatic conditions (FAO, 2001). The marked effect of dominant species highlights the importance of farmer decisions in parkland management; high densities of

B. aegyptiaca are consistent with findings by Takimoto et al. (2007), showing that farmers preferentially maintain multifunctional, drought-resistant species, while low densities of *A. digitata* illustrate strategies to reduce competition with crops (Foli et al., 2022). Intermediate densities of *K. senegalensis* and *F. albida* indicate balanced management between agricultural production and ecological functions, with *F. albida* often retained at moderate densities for its positive effect on soil fertility despite its limited contribution to overall stand density (FAO, 2001).

3.4. Regeneration Rate of Species by Agroforestry Parklands

The regeneration rates of woody species varied markedly across different types of agroforestry parklands (Table 5). Several species, including *Agave sisalana*, *Borassus aethiopicum*, *B. dalzielii*, *Daniellia oliveri*, and *Parkia biglobosa*, showed no evidence of natural regeneration in any park type, indicating weak recruitment. In contrast, certain species exhibited relatively high regeneration: *Ziziphus mauritiana* reached up to 67.5% in Adansonia-dominated parklands, *Piliostigma reticulatum* achieved 97.5% in Faidherbia-based parklands, and *Combretum molle* attained 77.5% in Balanites-dominated parklands. Regeneration patterns were clearly influenced by parkland type: Balanites-based parklands favoured the regeneration of *B. aegyptiaca* and *C. molle*, Adansonia-based parklands supported species such as *Acacia seyal* and *Hyphaene thebaica*, Faidherbia-dominated parklands showed strong regeneration of *F. albida* and *P. reticulatum*, whereas Khaya-based parklands generally exhibited low regeneration.

These results reveal pronounced interspecific contrasts in regeneration dynamics. High regeneration rates of *B. aegyptiaca* and *P. reticulatum* stand in sharp contrast to the very low regeneration observed for *Adansonia digitata*,

Table 4. Tree densities of agroforestry parklands according to department and dominant species

Department / Species	<i>B. aegyptiaca</i>	<i>A. digitata</i>	<i>K. senegalensis</i>	<i>F. albida</i>	Mean \pm SD
Benoue	134.0 ± 26.18^{ab}	87.0 ± 9.63^b	179.0 ± 14.86^a	108.0 ± 28.40^{ab}	127.0 ± 39.64^a
Mayo Louti	84.0 ± 13.80^b	106.0 ± 9.06^a	59.0 ± 6.95^c	78.0 ± 18.02^b	81.8 ± 19.36^c
Mayo Kani	133.0 ± 27.72^{ab}	76.0 ± 11.73^b	107.0 ± 14.78^b	103.0 ± 36.22^{ab}	104.8 ± 23.32^b
Diamare	149.0 ± 35.28^a	86.0 ± 13.63^b	88.0 ± 11.68^b	132.0 ± 25.34^a	115.0 ± 23.32^{ab}
Species means \pm SD	125.0 ± 24.51^a	88.8 ± 10.85^b	108.3 ± 4.28^{ab}	106.0 ± 13.53^{ab}	

B. aegyptiaca: *Balanites aegyptiaca*, *A. digitata*: *Adansonia digitata*, *F. albida*: *Faidherbia albida*, *K. Senegalensis*: *Khaya senegalensis*, Letters (a, b, c, ab) indicate significant differences between department and dominant species ($p < 0.05$), SD= Standard deviation

Table 5. Natural regeneration rates of dominant species across different agroforestry parklands types

Species	B. <i>aegyptiaca</i>	A. <i>digitata</i>	F. <i>albida</i>	K. <i>senegalensis</i>
<i>A. ataxacantha</i>	0.0	0.0	0.0	5.0
<i>A. nilotica</i>	17.5	27.5	0.0	2.5
<i>A. seyal</i>	0.0	32.5	5.0	5.0
<i>A. digitata</i>	0.0	0.5	0.5	0.5
<i>A. sisalana</i>	0.0	0.0	0.0	0.0
<i>A. senegalensis</i>	10.0	10.0	17.5	1.5
<i>A. leiocarpus</i>	30.0	0.0	0.0	10.0
<i>A. indica</i>	47.5	47.5	8.5	17.5
<i>B. aegyptiaca</i>	97.5	0.0	0.0	12.5
<i>B. aethiopicum</i>	0.0	0.0	0.0	0.0
<i>B. dalzielii</i>	0.0	0.0	0.0	0.0
<i>C. procera</i>	0.0	0.0	0.0	0.0
<i>C. molle</i>	77.5	0.0	2.5	2.5
<i>D. oliveri</i>	0.0	0.0	0.0	0.0
<i>D. glomerata</i>	0.0	0.0	0.0	0.0
<i>D. mespiliformis</i>	0.0	17.5	0.0	0.0
<i>E. camaldulensis</i>	0.0	0.0	0.0	0.0
<i>F. albida</i>	0.0	10.0	45.0	17.5
<i>F. sycomorus</i>	0.0	7.5	0.0	0.0
<i>F. thonningii</i>	0.0	0.0	0.0	0.0
<i>G. aqualla</i>	0.0	0.0	0.0	0.0
<i>H. monopetalus</i>	2.5	0.0	0.0	0.0
<i>H. thebaica</i>	10.0	50.0	0.0	0.0
<i>I. carnea</i>	0.0	25.0	5.0	0.0
<i>K. senegalensis</i>	0.0	0.0	0.0	0.0
<i>L. schimperii</i>	0.0	0.0	0.0	0.0
<i>M. indica</i>	0.0	0.0	0.0	0.0
<i>M. oleifera</i>	0.0	2.5	0.0	0.0
<i>P. biglobosa</i>	0.0	0.0	0.0	0.0
<i>P. reticulatum</i>	35.0	55.0	97.5	37.5
<i>P. guajava</i>	0.0	0.0	0.0	0.0
<i>S. birrea</i>	20.0	10.0	0.0	0.0
<i>S. singueana</i>	0.0	0.0	0.0	0.0
<i>S. stigeria</i>	0.0	0.0	0.0	0.0
<i>T. indica</i>	20.0	0.0	0.0	0.0
<i>T. glaucescens</i>	20.0	45.0	0.0	0.0
<i>V. paradoxa</i>	0.0	0.0	0.0	0.0
<i>X. americana</i>	0.0	0.0	0.0	0.0
<i>Z. mauritiana</i>	50.0	67.5	60.0	27.5
<i>Z. spina-christi</i>	0.0	2.5	0.0	5.0

highlighting the vulnerability of economically important species to overexploitation, grazing pressure, and poor seedling survival. This pattern of regeneration bottlenecks has been widely reported in both African and Indian agroforestry systems (Bayala et al., 2020; Ulman & Yadav, 2024), and it poses a significant threat to the long-term sustainability and resilience of these parklands. Overall, regeneration dynamics are heterogeneous and largely shaped by the interplay between species traits, parklands types, and ecological conditions.

3.5. Regeneration Rate of Species per Department

The regeneration rates of agroforestry parklands varied among Department; however, these differences were not statistically significant ($p > 0.05$) due to high within-Department variability (Table 6), with the highest mean recorded in Benoue (1.61 ± 1.75), exceeding values in Mayo Kani (0.30 ± 0.28) and Diamare (0.32 ± 0.29), while Mayo-Louti presented an intermediate level (0.67 ± 0.28). In contrast, regeneration differed significantly among dominant tree species ($p < 0.05$), with *Balanites aegyptiaca* showing the highest regeneration (1.82 ± 1.76), largely driven by exceptionally high values in Benoue (4.09). *Khaya senegalensis* exhibited intermediate regeneration (0.82 ± 0.39), whereas *Adansonia digitata* (0.31 ± 0.29) and *Faidherbia albida* (0.45 ± 0.24) displayed significantly lower values. These results indicate that regeneration dynamics are primarily determined by the dominant species rather than by Department location, highlighting the greater regeneration capacity and resilience of *B. aegyptiaca* compared to other species. The observed patterns are consistent with findings in other Sahelian agroforestry systems, where species with multiple economic uses and drought tolerance, such as *B. aegyptiaca*, are preferentially maintained by farmers, resulting in higher natural regeneration rates (Bayala et al., 2020 ; Takimoto et al., 2007). In contrast, species like *A. digitata* often experience regeneration bottlenecks due to overexploitation, grazing, and low seedling survival, which threatens the long-term sustainability of parklands (Ulman & Yadav, 2024). The heterogeneity of regeneration among species underscores the need for targeted management strategies to enhance the recruitment of vulnerable but economically and ecologically important trees, ensuring the resilience and continuity of agroforestry parklands in the Sudano-Sahelian zone.

3.6. Mortality Rate

Table 7 presents the mortality rates of four woody species

(*Balanites aegyptiaca*, *Adansonia digitata*, *Khaya senegalensis* and *Faidherbia albida*) across different Divisions in Northern Cameroon. In the Benoue Department, mortality was 0% for *B. aegyptiaca*, *A. digitata*, and *F. albida*, whereas *K. senegalensis* exhibited a slight mortality rate of 1.67%, indicating a minor sensitivity of this species to local conditions. In the Mayo-Louti, Mayo-Kani and Diamare Department, all four species recorded zero mortality. Overall, plant survival was excellent, with mortality almost negligible, highlighting the strong establishment potential of these species under the studied ecological conditions. The results confirm the hardiness of *B. aegyptiaca*, *A. digitata*, and *F. albida*, while the marginal mortality of *K. senegalensis* suggests that this species may require closer monitoring during early establishment. These findings align with previous studies in Sahelian agroforestry systems, which report high survival rates for drought-tolerant and well-adapted species under appropriate silvicultural management (Bayala et al., 2020; Takimoto et al., 2007). The excellent survival observed also emphasises the feasibility of integrating these species into restoration and agroforestry programs, ensuring sustainable parkland management and long-term ecosystem resilience.

3.7. Anthropisation Index of Agroforestry Parklands by Department

The analysis of anthropogenic pressure in different types

of agroforestry parklands revealed marked variations among practices and Department (Table 8). Cultivation was the most widespread activity, with consistently high values across all Department, peaking in Benoue (35.98) and reaching a minimum in Diamare (22.73). Partial cutting ranked second, particularly high in Benoue (17.05) and Mayo-Louti (14.39), but considerably lower in Diamare (2.27). Peeling and pruning showed generally low intensities, although pruning was relatively more significant in Benoue (4.92) and Mayo-Kani (3.41). Fire trails were almost absent, with minor occurrences only in Mayo-Louti (0.75) and Mayo-Kani (1.14). Among the Departments, Benoue exhibited the highest anthropogenic values across all practices, followed by Mayo Louti, whereas it was lowest in Diamare. Despite these trends, differences among

Table 7. Mortality rate of agroforestry parklands according to department and dominant species

Dominant species	Benoue	Mayo louti	Mayo kani	Diamare
<i>B. aegyptica</i>	0	0	0	0
<i>A. digitata</i>	0	0	0	0
<i>F. albida</i>	0	0	0	0
<i>K. senegalensis</i>	3	0	0	0
Mortality	1.67	0	0	0

B.eagyptica: *Balanites aegyptiaca*, *A. digitata*: *Adansonia digitata*, *F. albida*: *Faidherbia albida*, *K. Senegalensis*: *Khaya senegalensis*

Table 6. Regeneration rate of agroforestry parklands according to department and dominant species

Department / Species	<i>B. aegyptiaca</i>	<i>A. digitata</i>	<i>K. senegalensis</i>	<i>F. albida</i>	Mean ± SD
Benoue	4.09 ± 2.00 ^a	0.18 ± 0.02 ^a	1.4 ± 0.00 ^a	0.78 ± 0.01 ^a	1.61 ± 1.75 ^a
Mayo louti	0.89 ± 0.01 ^b	0.33 ± 0.00 ^b	0.91 ± 0.00 ^b	0.53 ± 0.01 ^b	0.66 ± 0.24 ^b
Mayo kani	0.15 ± 0.01 ^c	0.00 ± 0.00 ^c	0.65 ± 0.00 ^c	0.39 ± 0.00 ^c	0.30 ± 0.28 ^b
Diamare	0.15 ± 0.02 ^c	0.71 ± 0.01 ^d	0.30 ± 0.00 ^d	0.11 ± 0.01 ^d	0.32 ± 0.29 ^b
Mean±SD	1.32 ± 1.85 ^a	0.31 ± 0.29 ^c	0.82 ± 0.42 ^b	0.45 ± 0.29 ^c	

B. eagyptica: *Balanites aegyptiaca*, *A. digitata*: *Adansonia digitata*, *F. albida*: *Faidherbia albida*, *K. Senegalensis*: *Khaya senegalensis*, Letters (a, b, c, ab) indicate significant differences between department and dominant species (p < 0.05), SD= Standard deviation

Table 8. Anthropisation index of agroforestry parklands by department

Department/ Practices	Peeling	Pruning	Fire trail	Partial cutting	Cultivation	Mean ± SD
Benoue	5.30 ± 2.01 ^a	4.92 ± 1.87 ^a	0.38 ± 0.14 ^b	17.05 ± 6.46 ^a	35.98 ± 13.63 ^a	12.73 ± 14.39 ^a
Mayo louti	1.51 ± 0.57 ^b	0.75 ± 0.28 ^b	0.75 ± 0.28 ^{ab}	14.39 ± 5.46 ^{ab}	30.30 ± 11.47 ^{ab}	9.55 ± 12.97 ^{ab}
Mayo kani	0.76 ± 0.29 ^b	3.41 ± 1.29 ^{ab}	1.14 ± 0.43 ^a	11.36 ± 4.30 ^b	26.52 ± 10.04 ^b	8.64 ± 10.87 ^{ab}
Diamare	0.65 ± 0.25 ^b	1.62 ± 0.61 ^b	0.00 ± 0.00 ^b	2.27 ± 0.86 ^c	22.73 ± 8.61 ^b	5.45 ± 9.70 ^b
Practice mean	2.06 ± 2.20 ^c	2.68 ± 1.86 ^c	0.57 ± 0.49 ^d	11.27 ± 6.43 ^b	28.88 ± 5.66 ^a	

Different superscript letters (a,b,c,ab) indicate significant differences (p < 0.05); SD= Standard deviation

Departments were not statistically significant ($p > 0.05$). These results indicate that, although the types of anthropogenic activities are relatively homogeneous across regions, their intensity varies considerably, with Benoue experiencing the highest anthropogenic pressure. Anthropisation emerged as a principal driver of ecosystem degradation, as agricultural expansion, partial cutting, and bark harvesting significantly affect floristic composition and natural regeneration. The vulnerability index further identified *Adansonia digitata*, *Khaya senegalensis*, *Balanites aegyptiaca*, and *Sclerocarya birrea* as highly threatened species, corroborating global conservation assessments. These findings align with studies in Sahelian agroforestry and Indian agroecosystems, which report that anthropogenic pressures such as cultivation and selective tree harvesting significantly alter species diversity, regeneration, and ecosystem resilience (Maurya et al., 2025; Sharma et al., 2025).

3.8. Anthropisation Index of Agroforestry Parklands

The analysis of anthropogenic practices across different types of agroforestry parklands revealed notable contrasts. Cultivation (30.59 ± 2.45) and partial cutting (14.11 ± 2.17) were the most prevalent human pressures, while fire trails were the least frequent (0.57 ± 0.49). Among parkland types, *Balanites*-based parklands (PBa) had the highest mean anthropisation index (11.14 ± 14.40), whereas *Faidherbia*-based parklands (PFa) showed the lowest values (9.39 ± 12.06). Large standard deviations indicate substantial variability in the intensity of human activities across parklands types. These results suggest that, although cultivation and partial cutting are consistently practiced across all parklands, their local intensity varies, resulting in heterogeneous levels of anthropogenic pressure. Differences among parkland types were not statistically

significant ($p > 0.05$), implying that parkland type alone does not strongly determine overall anthropisation. This pattern aligns with observations from Sahelian and Indian agroforestry systems, where human activities such as selective tree harvesting and agricultural expansion vary locally but consistently influence species composition, regeneration and ecosystem resilience (Maurya et al., 2025; Sharma et al., 2025).

3.9. Vulnerability Index of Agroforestry Species and Classification According to IUCN

The vulnerability assessment of agroforestry species revealed that most recorded species were classified as Moderately Vulnerable (MV) or Least Concern (LC) according to the IUCN Red List (Table 10). However, certain species were under higher local threat. For example, *Khaya senegalensis*, *Vitellaria paradoxa*, and *Ipomoea carnea* were rated as Very Vulnerable (VU) or Vulnerable (VU), reflecting high anthropogenic pressure and limited natural regeneration. Other species, such as *Boswellia dalzielii* and *Eucalyptus camaldulensis*, were categorized as Near Threatened (NT), while *Agave sisalana* was classified as Endangered (EN). These findings indicate that, although most agroforestry species remain relatively stable, several ecologically and socio-economically important taxa face critical risks. This highlights the need for targeted conservation and management strategies, including controlled harvesting, assisted regeneration, and species-specific protection measures, to maintain biodiversity and ecosystem services. Similar patterns of localized vulnerability due to human pressure and regeneration constraints have been documented in Sahelian and Indian agroforestry systems (Bayala et al., 2020; Ulman & Yadav, 2024), underscoring the importance of integrating vulnerability assessments into sustainable parkland management plans.

Table 9. Anthropisation index of agroforestry Parklands

Anthropisation practice	Peeling	Pruning	Fire trail	Partial cutting	Cultivation	Practice mean \pm SD
PB. <i>aegyptiaca</i>	1.52 ± 0.57^b	2.65 ± 1.00^{ab}	0.76 ± 0.28^a	16.67 ± 6.31^a	34.09 ± 12.91^a	11.14 ± 14.40^a
PA. <i>digitata</i>	3.79 ± 1.43^a	1.89 ± 0.71^b	0.38 ± 0.14^{ab}	14.02 ± 5.30^a	29.55 ± 11.19^{ab}	9.92 ± 12.20^a
PF. <i>albida</i>	2.27 ± 0.86^{ab}	3.79 ± 1.43^a	0.00 ± 0.00^b	11.36 ± 4.30^a	29.55 ± 11.19^{ab}	9.39 ± 12.05^a
PK. <i>senegalensis</i>	0.76 ± 0.28^b	2.65 ± 1.00^{ab}	1.14 ± 0.43^b	14.39 ± 5.45^b	28.79 ± 10.90^b	9.55 ± 12.14^a
Mean \pm SD	2.08 ± 1.29^c	2.75 ± 0.78^c	0.57 ± 0.49^d	14.11 ± 2.17^b	30.49 ± 2.43^a	

P B. *aegyptiaca*: Parkland with *Balanites aegyptiaca*, P A. *digitata*: Parkland with *Adansonia digitata*, P F. *albida* : Parkland with *Faidherbia albida*, P K. *Senegalensis*: Parkland with *Khaya senegalensis*, Different superscript letters (a,b,c,ab,d) indicate significant differences ($p < 0.05$), SD= Standard deviation

Table 10. Vulnerability status of agroforestry species based on IUCN categories

Species	VI	Local status	Status according to IUCN
<i>A. ataxacanta</i>	2.2	MV	LC
<i>A. nilotica</i>	2.2	MV	LC
<i>A. seyal</i>	2.2	MV	LC
<i>A. digitata</i>	2.8	TV	LC
<i>A. sisalana</i>	2.2	MV	EN
<i>A. senegalensis</i>	2.2	MV	LC
<i>A. leiocarpus</i>	2.8	TV	LC
<i>A. indica</i>	2	FV	LC
<i>B. aegyptiaca</i>	2.8	TV	LC
<i>B. aethiopum</i>	2	FV	LC
<i>B. dalzielii</i>	2.2	MV	NT
<i>C. procera</i>	2.2	MV	LC
<i>C. molle</i>	2.2	MV	LC
<i>D. oliveri</i>	2.2	MV	LC
<i>D. glomerata</i>	2.2	MV	LC
<i>D. mespiliformis</i>	2.8	TV	LC
<i>E. camaldulensis</i>	2.2	MV	NT
<i>F. albida</i>	2.2	MV	LC
<i>F. sychomorus</i>	2.2	MV	LC
<i>F. thonningii</i>	2.2	MV	LC
<i>G. aqualla</i>	2.2	MV	LC
<i>H. monopetalus</i>	2.2	MV	LC
<i>H. thebaica</i>	2.2	MV	LC
<i>I. carnea</i>	2.2	MV	VU
<i>K. senegalensis</i>	2.8	TV	VU
<i>L. schimperi</i>	2.2	MV	NT
<i>M. indica</i>	2.2	MV	DD
<i>M. oleifera</i>	2.2	MV	LC
<i>P. biglobosa</i>	2.8	TV	LC
<i>P. reticulatum</i>	2.2	MV	LC
<i>P. guajava</i>	2	MV	LC
<i>S. birrea</i>	2.8	TV	LC
<i>S. singueana</i>	2.2	MV	LC
<i>S. setigera</i>	2	FV	LC
<i>T. indica</i>	2	FV	LC
<i>T. glaucescens</i>	2	FV	LC
<i>V. paradoxa</i>	2.2	MV	VU
<i>X. Americana</i>	2.2	MV	LC
<i>Z. mauritiana</i>	2.2	MV	LC
<i>Z. spina-christi</i>	2.2	MV	LC

MV: Moderately Vulnerable, LC: Least Concern, DD: Data Deficient, TV: Very Vulnerable, FV: Slightly Vulnerable, VU: Vulnerable, NT: Near Threatened, EN: Endangered

3.10. Strategy for an Agroforestry Parklands

Management Plan

The analysis of proposed management strategies for agroforestry parklands revealed notable variations across Departments (Table 11). Overall, the most emphasised strategies were conservation and restoration in agreement with government policies (22.50 ± 2.08) and the rational use of natural resources (16.50 ± 1.29), highlighting the importance of institutional collaboration and sustainable practices. Moderate attention was given to initiatives such as supporting the Green Sahel project (10.75 ± 1.70), raising

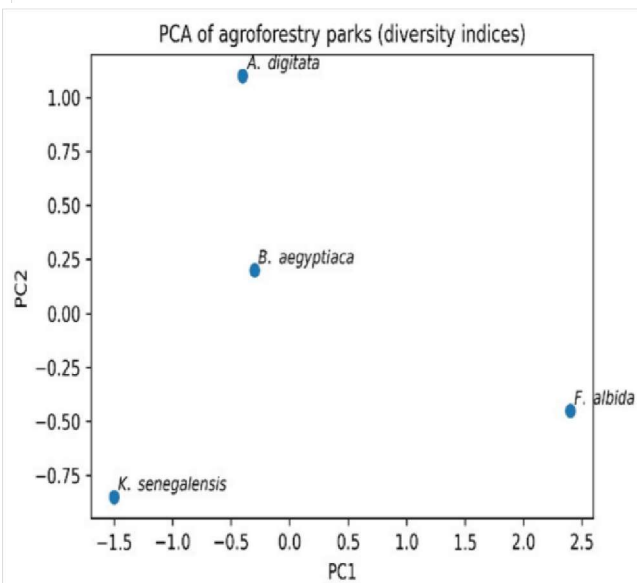
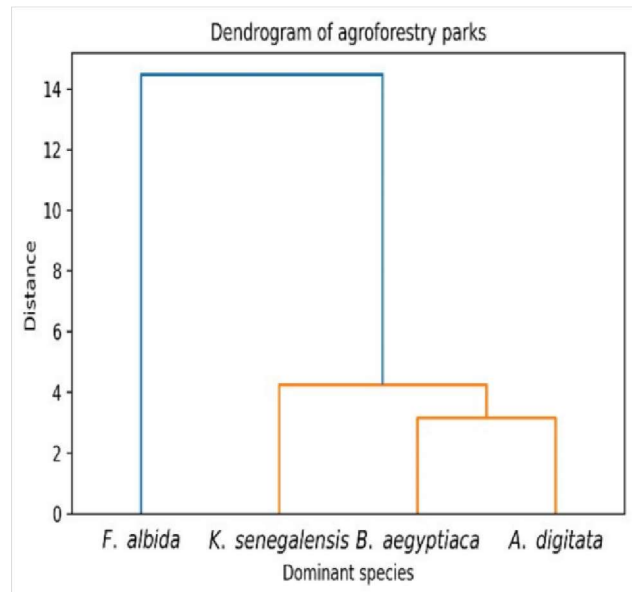


Figure 4. Multivariate structuring of agroforestry parklands based on diversity indices

awareness on the importance of trees (10.00 ± 1.63), and tree planting (10.00 ± 0.82), collectively reflecting a balance between ecological restoration and community engagement. Conversely, less priority was given to protection of young plants (4.50 ± 1.29) and waste protection (4.75 ± 1.26), suggesting that practical, on-the-ground measures for regeneration receive limited emphasis compared to broader policy and awareness-based interventions. Comparisons across Departments showed similar average numbers of strategies implemented (Benoue: 10.00; Mayo-Louti: 10.18; Mayo-Kani: 10.00; Diamare: 9.91), indicating a shared perception of management priorities throughout the study area. These results underscore the predominance of institutional and awareness-driven approaches over strictly technical measures in the management of agroforestry parklands. Similar findings have been reported in Sahelian agroforestry systems, where policy-driven and community

engagement strategies often take precedence over field level technical interventions, emphasising the role of governance and local participation in sustainable management (Foli et al., 2022; Takimoto et al., 2007).

3.11. Multivariate Analysis of Agroforestry Parklands Structure and Diversity

Multivariate analyses consistently revealed a clear structuring of the studied agroforestry parklands according to their dominant tree species and associated ecological characteristics (Figure 4). Hierarchical clustering based on diversity indices highlighted distinct groupings, with *Faidherbia albida*-dominated parklands clearly separated from other parkland types, indicating pronounced differences in species composition and diversity patterns. This separation was further confirmed by principal component analysis (PCA), where *F. albida* parkland was strongly segregated along the first principal axis, reflecting substantial divergence in diversity structure relative to parks dominated by *Khaya senegalensis*, *Balanites aegyptiaca*, and *Adansonia digitata*, which clustered more closely together. These findings suggest that dominant tree species play a key role in shaping community composition and ecological interactions in agroforestry parklands. Similar patterns have been reported in Sahelian and Indian agroforestry systems, where species-specific traits drive species differentiation.

Complementary ordination analyses using Non-metric Multidimensional Scaling (NMDS) and multiple factor analysis (MFA) provided further insights into the ecological gradients shaping agroforestry parklands. The NMDS ordination revealed partial but discernible clustering of

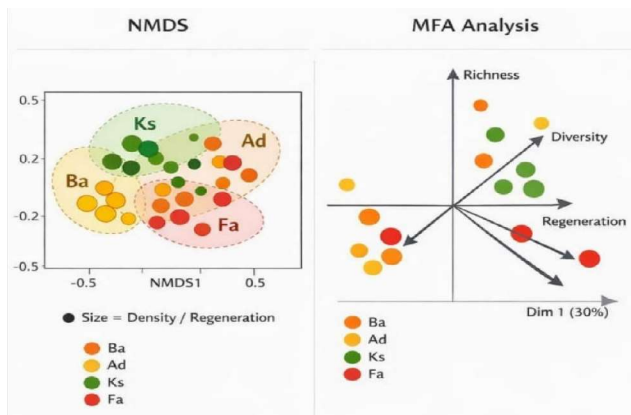


Figure 5. Multivariate analyses of the studied agroforestry parklands using Non-metric multidimensional scaling (NMDS) and multiple factor analysis (MFA)

Table 11. Proposed agroforestry Parklands Management Plan

Strategies	Benoue	Mayo louti	Mayo kani	Diamare	Mean ±SD
Conservation, restoration in agreement with the government	20±3,64 ^a	25±3,86 ^a	23±4,09 ^a	22±4,06 ^a	22.5±2.08 ^c
Tree planting	10±1,82 ^a	08±1,23 ^a	09±1,60 ^a	10±1,85 ^a	9.25±0.95 ^c
Raising awareness of the importance of trees	12±2,18 ^a	09±1,39 ^b	11±1,96 ^{ab}	10±1,85 ^{ab}	10.5±1.29 ^c
Rational use of natural resources	18±3,27 ^a	16±2,47 ^{ab}	15±2,67 ^b	17±3,14 ^a	16.5±1.29 ^b
reducing the pressure to harvest firewood	08±1,46 ^a	07±1,08 ^b	09±1,60 ^a	05±0,92 ^c	7.25±1.70 ^d
Reorganise the green sahel project	10±1,82 ^{ab}	13±2,01 ^a	11±1,96 ^{ab}	09±1,66 ^b	10.75±1.70 ^c
Protecting waste	05±0,91 ^b	03±0,46 ^c	06±1,07 ^{ab}	07±1,29 ^a	5.25±1.70 ^d
Recruitment of forest wardens	09±1,64 ^a	08±1,23 ^a	07±1,25 ^{ab}	06±1,11 ^b	7.5±1.29 ^d
Creation of forest reserves	05±0,91 ^b	06±0,93 ^{ab}	05±0,89 ^b	08±1,48 ^b	6±1.41 ^d
Protection of young plants	03±0,55 ^a	05±0,77 ^{ab}	04±0,71 ^b	06±1,11 ^a	4.5±1.29 ^c
Mean±SD	10±5.49 ^a	10±6.48 ^a	10±5.61 ^a	10±5.41 ^a	10±5.45 ^c

Different superscript letters (a,b,c,ab e,d) indicate significant differences ($p < 0.05$), SD= Standard deviation

parks according to their dominant species, with some overlap among groups, indicating gradual ecological transitions rather than strictly discrete assemblages. MFA further identified clear relationships between parklands types and key ecological variables: the first dimension was primarily structured by gradients of regeneration versus species richness and diversity. *Faidherbia albida*-dominated parklands were closely associated with higher regeneration levels, whereas *Khaya senegalensis* and *Adansonia digitata* parks were more strongly related to richness and diversity variables. *Balanites aegyptiaca* occupied an intermediate position, reflecting mixed ecological characteristics.

These analyses confirm that dominant tree species strongly influence parkland structure and dynamics. The distinct position of *F. albida* parklands reflects its well-documented ecological role in enhancing soil fertility and promoting understory regeneration, as reported in both African and Indian agroforestry systems (Bayala et al., 2020; Ulman & Yadav, 2024). Overall, the results underscore the importance of assisted natural regeneration, protection of juvenile plants, and community-based management strategies to maintain the long-term resilience, productivity and ecological functionality of agroforestry parklands.

4. CONCLUSION

The present study confirms the ecological and socio-economic importance of agroforestry parklands in the Sudano-Sahelian zone of Cameroon. The recorded woody diversity (40 species belonging to 36 genera and 22 families) and the wide variation in tree density (59–179 stems ha⁻¹) reflect the heterogeneity of parkland structures and management practices. Species-specific differences in regeneration highlight a major sustainability concern, with *Balanites aegyptiaca* showing strong regenerative capacity, whereas *Adansonia digitata*, despite its high basal area and ecological value, exhibits critically low regeneration. Anthropogenic pressures, particularly agricultural expansion, partial cutting and bark harvesting, strongly influence floristic composition and regeneration dynamics, increasing the vulnerability of key multipurpose species. These findings indicate that, although agroforestry parklands continue to provide important ecological functions and livelihood benefits, their long-term resilience is increasingly threatened. Sustainable management should therefore prioritize assisted natural regeneration, protection of juvenile plants and community-based restoration strategies, supported by appropriate policy frameworks.

Such integrated approaches are essential for conserving biodiversity, maintaining ecosystem services, and enhancing the sustainability of agroforestry systems in the Sudano-Sahelian region.

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CRediT authorship contribution statement

Tchakfaya Fanehela Felix: Data curation, Funding acquisition, Investigation, Resources, Supervision, Visualization and Writing – original draft. **Ali Ahmed Davy**: Conceptualization, Data collection, Formal analysis, Funding acquisition, Investigation, Methodology, project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft and Writing-review & editing. **Massai Tchima Jacob**: Visualization. **Tchobsala**: Conceptualization, Data curation, Methodology, project administration, Software, Supervision, Validation and Visualization.

Conflict of interest

The author has no conflicts with any step of the article preparation.

Declaration of generative AI and AI-assisted technologies in the writing process

The authors declare that no artificial intelligence tools were used to write this manuscript.

Data availability statement

All data supporting the findings of this study are fully available with the authors.

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