



RESEARCH ARTICLE

STATUS OF THE WOODY VEGETATION IN THE KOYLI-ALPHA COMMUNITY NATURE RESERVE (NORTHERN SENEGAL): FLORISTIC COMPOSITION, STRUCTURE, AND REGENERATION TRAJECTORY

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ABSTRACT

The Koyli-Alpha Community Nature Reserve, located in northern Senegal, is a major site for ecological restoration and biodiversity conservation within the Great Green Wall zone. This study establishes a baseline assessment of the reserve's woody vegetation based on 29 systematic sampling plots covering a cumulative area of 7.25 ha. Floristic composition, diversity, stand structure, and natural regeneration were analyzed. A total of nine species, belonging to three families and five genera, were recorded, including six species in the adult compartment and eight in the regeneration layer. The adult stand exhibited a strong oligodominance of *Vachellia tortilis subsp. raddiana* and *Balanites aegyptiaca*, which accounted for 95.4% of individuals, 97.5% of basal area, and 97.0% of canopy cover. Adult stand density reached 106.9 individuals·ha⁻¹, with a basal area of 3.00 m²·ha⁻¹ and canopy cover of 28.6%. Natural regeneration was relatively abundant (229.4 individuals·ha⁻¹) but remained dominated by the same species, which accounted for 90.1% of young individuals. Floristic richness was comparable to that reported by Kébé *et al.* (2020), despite differences in secondary species composition and stand density. These findings indicate an active but still poorly diversified regeneration dynamic. The conservation of less abundant species, monitoring of seedling survival and recruitment, and assessment of herbivory by reintroduced wildlife are essential for evaluating the reserve's restoration trajectory. Establishing permanent monitoring plots inside and outside the reserve would further strengthen long-term ecological monitoring.

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INTRODUCTION

Sahelian ecosystems are subject to climatic and anthropogenic constraints that strongly influence the structure and dynamics of woody vegetation. The droughts of the 1970s and 1980s left a lasting imprint on Sahelian landscapes, while rainfall variability, grazing, and other disturbances continue to shape vegetation trajectories (Herrmann *et al.*, 2005; Hiernaux *et al.*, 2009). Woody plants nevertheless play a major role in the functioning of Sahelian ecosystems, notably through their contribution to forage resources, the maintenance of soil properties, carbon storage, and biodiversity-related ecosystem services (Sinare & Gordon, 2015; Dendoncker, 2022). In this context, the Great Green Wall represents a major landscape restoration initiative, based in particular on stand protection, natural regeneration, and participatory resource management (Goffner *et al.*, 2019). The Koyli-Alpha Community Nature Reserve, established in 2016 over approximately 635 ha, is an important site for monitoring vegetation restoration and its integration with wildlife conservation. Research conducted at Koyli-Alpha has addressed different aspects of biodiversity and ecosystem functioning, including wildlife (Niang & Ndiaye, 2021; Thiaw *et al.*, 2024), melliferous plants (Diatta *et al.*, 2019), and the ecological characteristics of woody stands in the Ferlo (Kébé *et al.*, 2020). Diatta *et al.* (2019), in particular, recorded 17 melliferous species at Koyli-Alpha, while Kébé *et al.* (2020) described the structural characteristics of woody vegetation in the site's rangelands. However, the woody vegetation within the reserve itself remains insufficiently documented, particularly with regard to its floristic composition, structure, and regeneration. This gap limits the availability of baseline data needed to monitor stand changes and guide reserve management. It is especially important because woody vegetation is a structuring component of wildlife habitats and contributes to ecosystem functioning, notably through the resources and conditions it provides to fauna (Thiaw *et al.*, 2024). A detailed characterization of the reserve's woody vegetation is therefore needed to

establish a baseline of its composition and structure and to provide useful information for its management. The present study tests two hypotheses: (H1) protection from disturbance within the reserve promotes the maintenance of a relatively substantial natural regeneration process, reflected in a high proportion of young individuals within the stand; (H2) the demographic structure of the stand reflects the coexistence of several developmental stages, characterized by the simultaneous presence of an adult stock and a substantial contingent of young individuals. The overall objective of this study is to characterize the floristic composition, structure, and regeneration of the woody vegetation in order to establish a baseline for ecological monitoring of the reserve. The specific objectives are to: (i) inventory woody species; (ii) quantify diversity and the main structural indicators; (iii) characterize the vertical structure and maximum diameter of adults; (iv) assess species' contribution to regeneration and their relative regeneration potential; and (v) compare the floristic, structural, and demographic characteristics of the stand with those reported by Kébé *et al.* (2020), in order to better assess the condition of the reserve.

MATERIALS AND METHODS

Study area: The Koyli-Alpha Community Nature Reserve is located in northern Senegal, in the commune of Mboula, arrondissement of Yang-Yang, Linguère Department, Louga Region (15.730° N; 15.511° W) (Figure 1). The area has a semi-arid Sahelian climate, with a short rainy season (July–September), mean annual rainfall of approximately 347 mm, high interannual variability, and mean temperatures above 28 °C (Kébé *et al.*, 2020).

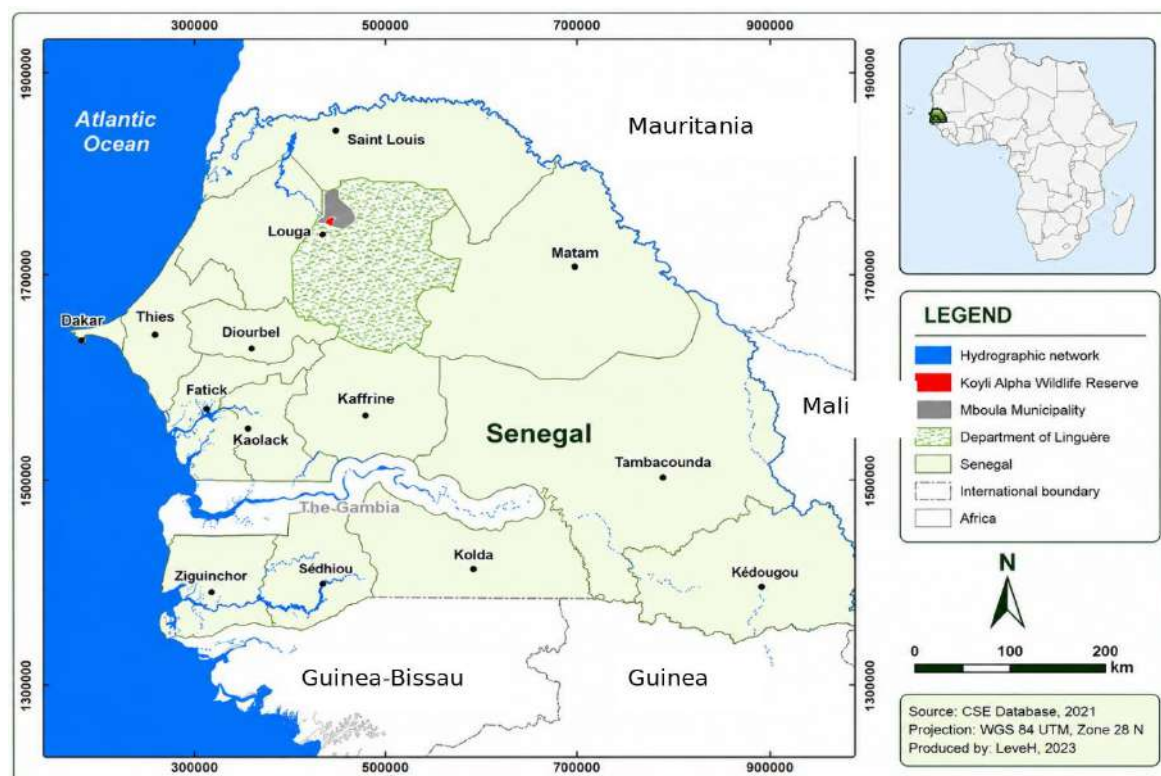


Figure 1. Geographic location of the Koyli-Alpha Community Nature Reserve

The reserve is part of a community-based restoration and conservation dynamic. Its protection from disturbance, progressively established during the 2010s over approximately 635 ha, was subsequently strengthened through interventions by FAO and the Action Against Desertification project (FAO, 2026). This restoration strategy also relies on the reintroduction of emblematic animal species. An initial group of 20 African spurred tortoises (*Centrochelys sulcata*) was reintroduced in 2017 with support from FAO/ACD and the Turtle Conservation Fund (Diagne & Diagne, 2017), and the species' presence has since been documented in studies of the herpetofauna of Koyli-Alpha (Thiaw *et al.*, 2024). The reintroduction of the scimitar-horned oryx (*Oryx dammah*) is another component of this strategy: six individuals, including four females and two males, were introduced in 2020, and the population reached ten individuals in 2021, notably following the birth of four young (Niang & Ndiaye, 2021). The study by Kébé *et al.* (2020) is the main reference study on the woody vegetation of Koyli-Alpha. These authors recorded nine species and reported an adult stand density of 47.8 ± 12.6 individuals $\cdot$ ha⁻¹, canopy cover of 16.5%, regeneration density of 267 ± 103 individuals $\cdot$ ha⁻¹, and a regeneration rate of 85%. They also characterized the soils as highly sandy and relatively poor in organic matter, nitrogen, and available phosphorus.

Sampling design and inventory: The inventory of the reserve's woody vegetation was conducted using systematic sampling. Twenty-nine square plots measuring 50 × 50 m (2,500 m² each) were established on a regular grid with 250 m spacing between sampling units. This configuration was intended to provide homogeneous spatial coverage of the reserve while keeping plots away from the boundaries of the protected area in order to limit edge effects. Each plot was delineated and georeferenced using a GPS to ensure precise location and facilitate possible re-establishment during subsequent monitoring. The total inventoried area was 7.25 ha, representing 1.18% of the reserve.

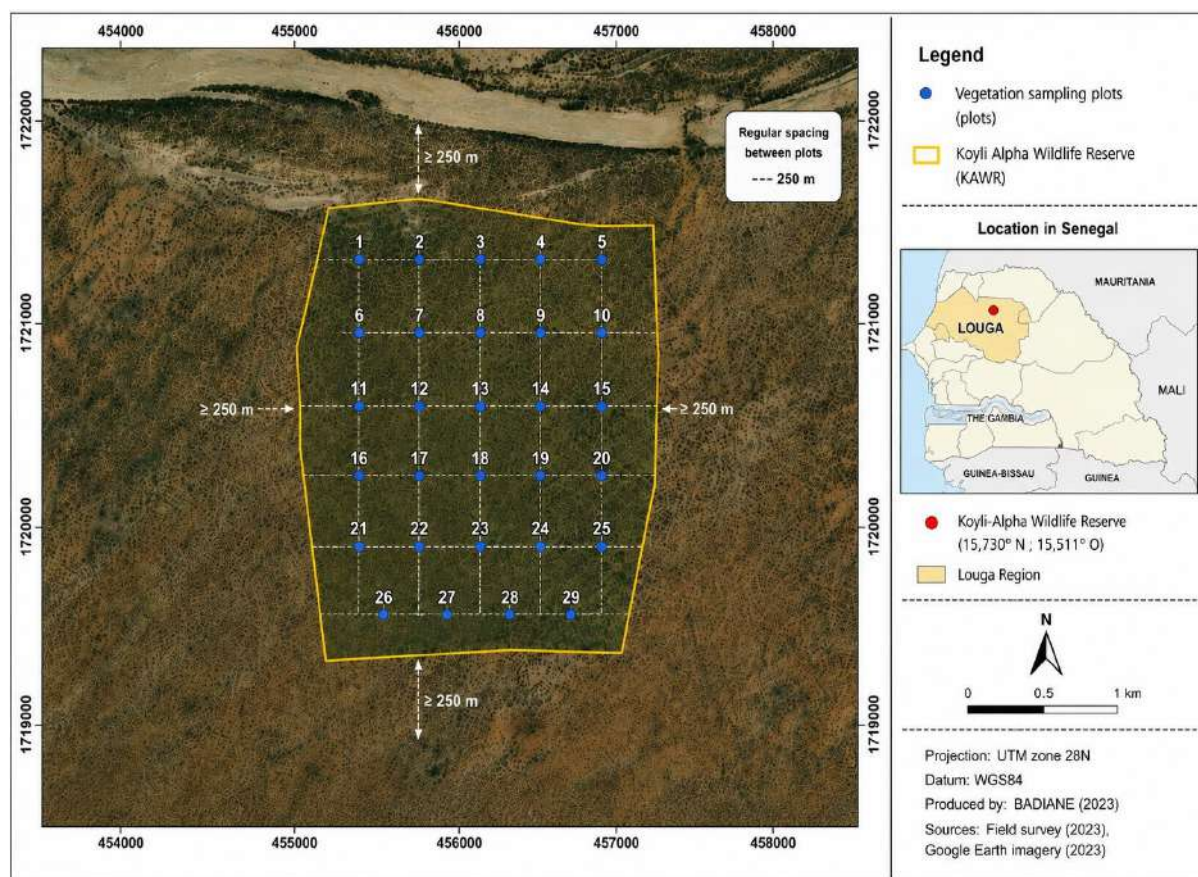


Figure 2. Spatial distribution of the 29 inventory plots in the Koyli-Alpha CNR.

Within each plot, all woody individuals were recorded and identified to species level. Adults were defined as individuals with a diameter measured at 0.30 m above ground ($D_{0.30}$) ≥ 3.5 cm; individuals with a diameter below 3.5 cm were classified as regeneration and counted by species. For each adult, diameter, total height, and canopy dimensions were recorded. Standing dead individuals were also counted. Botanical identification was verified using World Flora Online (WFO, 2026) and Plants of the World Online (POWO, 2026). Nomenclature was harmonized with currently accepted names.

Data analyses

Floristic diversity: Total species richness (S) and mean richness per plot were calculated. Diversity in the adult compartment was assessed using the Shannon–Wiener index, $H' = -\sum p_i \log_2(p_i)$, and Pielou's evenness, $J = H'/\log_2(S)$.

Structural parameters: Stand density, expressed as individuals·ha⁻¹, was calculated by relating counts to the area actually inventoried in each plot. Overall densities were calculated from the total number of individuals and total area, whereas plot-level means and standard deviations were calculated after standardizing each plot to one hectare. Basal area was calculated as $G = \sum \pi D_i^2/4$ after converting diameters to meters. Canopy cover corresponds to the ratio between the cumulative projected canopy area and the total inventoried area.

Importance Value Index: The structural importance of each species was assessed using the Importance Value Index:

$$IVI = DR + FR + DoR$$

where DR, FR, and DoR correspond to relative density, relative frequency, and relative dominance, respectively.

Natural regeneration and relative regeneration potential: The species-specific contribution to regeneration (ISR_i) corresponds to the proportion of young individuals belonging to species i .

$$ISR_i = \frac{N_{i,reg}}{N_{reg}} \times 100$$

where $N_{i,reg}$ represents the number of young individuals of species i and N_{reg} the total number of young individuals recorded.

To compare species representation between the adult and regeneration compartments, a relative regeneration index was calculated as:

$$IRR_i = \frac{P_{i,reg}}{P_{i,adulte}}$$

where p_i, reg represents the proportion of species i in regeneration and $p_i, adult$ its proportion in the adult stand.

An $IRR > 1$ indicates relative overrepresentation of the species in regeneration; an $IRR < 1$ indicates the opposite.

Species–area curve: A species–area curve was constructed from the accumulation of species richness across the 29 plots, using the actual area of each plot (0.25 ha). Five thousand random permutations were used to obtain the mean curve and its 95% confidence interval. A power-function fit, $S = cA^z$, describes the overall accumulation trend.

RESULTS

Floristic composition and frequency of occurrence: The inventory recorded nine species, distributed among three families and five genera (Table 1). Six species were observed in the adult compartment and eight in the regeneration layer. The Fabaceae comprised five species: *Vachellia nilotica*, *Vachellia tortilis subsp. raddiana*, *Senegalia senegal*, *Senegalia mellifera*, and *Vachellia seyal*. The Apocynaceae comprised *Calotropis procera*, *Leptadenia lanceolata*, and *Leptadenia pyrotechnica*, while the Zygophyllaceae were represented by *Balanites aegyptiaca*.

Table 1. Floristic composition and frequency of occurrence of the recorded species.
Frequency of occurrence refers to all compartments (adults + regeneration); relative frequency is calculated for the adult compartment only. Species absent from the adult compartment are marked (*)

Family	Species	Frequency of occurrence (%)	Relative frequency of adults (%)
Apocynaceae	<i>Calotropis procera</i> (Aiton) W.T.Aiton	3,4	*
Apocynaceae	<i>Leptadenia lanceolata</i> (Poir.) Goyder	62,1	1,64
Apocynaceae	<i>Leptadenia pyrotechnica</i> (Forssk.) Decne.	3,4	*
Fabaceae	<i>Vachellia nilotica</i> (L.) P.J.H.Hurter & Mabb.	3,4	1,64
Fabaceae	<i>Vachellia tortilis subsp. raddiana</i> (Savi) Kyal. & Boatwr.	100,0	47,54
Fabaceae	<i>Senegalia senegal</i> (L.) Britton	3,4	1,64
Fabaceae	<i>Senegalia mellifera</i> (Vahl) Seigler & Ebinger	6,9	*
Fabaceae	<i>Vachellia seyal</i> (Delile) P.J.H.Hurter	3,4	1,64
Zygophyllaceae	<i>Balanites aegyptiaca</i> (L.) Delile	100,0	45,90

Frequency of occurrence was highest for *Vachellia tortilis subsp. raddiana* and *Balanites aegyptiaca* (100% of plots), followed by *Leptadenia lanceolata* (62.1%). *Vachellia nilotica*, *Senegalia senegal*, and *Vachellia seyal* occurred in 3.4% of plots. *Calotropis procera*, *Leptadenia pyrotechnica*, and *Senegalia mellifera* were observed only in the regeneration layer. In the adult compartment, relative frequency was 47.54% for *Vachellia tortilis subsp. raddiana*, 45.90% for *Balanites aegyptiaca*, and 1.64% for each of the four other adult species. Species richness, diversity, and sampling completeness: Total richness was nine species. Mean richness was 2.86 ± 0.79 species per plot for all compartments combined and 2.10 ± 0.31 species per plot in the adult compartment. The Shannon index was $H' = 1.22$ bits and Pielou's evenness was $J = 0.47$. *Vachellia tortilis subsp. raddiana* and *Balanites aegyptiaca* accounted for 95.4% of adults. Cumulative richness reached nine species at 2.85 ha in the observed plot-sampling order and then remained stable up to the total area of 7.25 ha. The randomized curve also converged toward nine species.

Density, canopy cover, and spatial heterogeneity: Overall adult density was 106.9 individuals·ha⁻¹. The mean density standardized by plot was 105.3 ± 61.1 individuals·ha⁻¹, ranging from 44 to 272 individuals·ha⁻¹ across the 29 plots (Figure 4). This variability was partly related to differences in plot area (0.09 and 0.25 ha).

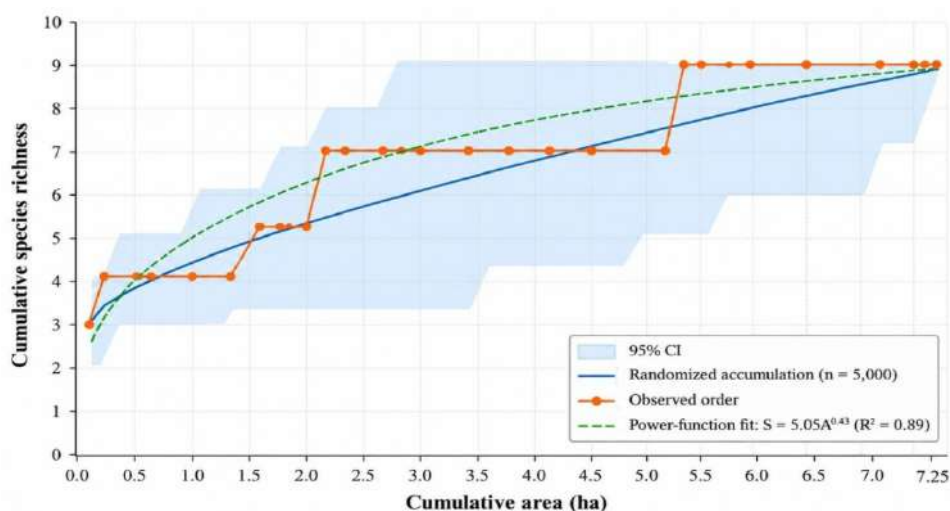


Figure 3. Species–area curve of the Koyli-Alpha CNR. The randomized curve is based on 5,000 permutations; the shaded area represents the 95% confidence interval. The power-function fit is $S = 5.05A^{0.43}$ ($R^2 = 0.89$)

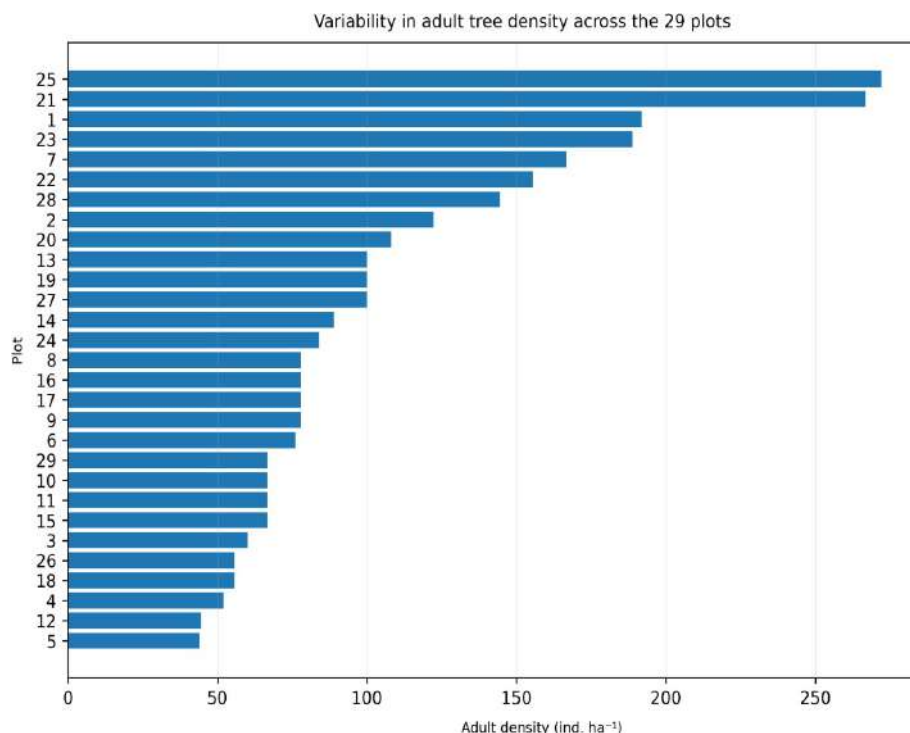


Figure 4. Variability in adult tree density across the 29 inventory plots

Standardized basal area ranged from 1.59 to 5.49 m²·ha⁻¹ among plots, with a mean of 3.13 ± 0.95 m²·ha⁻¹; the overall value, calculated across the entire 7.25 ha, was 3.00 m²·ha⁻¹. Total canopy cover was 28.6%, corresponding to 2,862.3 m²·ha⁻¹. *Vachellia tortilis subsp. raddiana* accounted for 73.0% of canopy cover and 63.7% of dominance; *Balanites aegyptiaca* accounted for 24.0% of canopy cover and 33.7% of dominance. Together, the two species accounted for 97.0% of canopy cover and 97.5% of basal area (Table 2).

Table 2. Contribution of adult species to canopy cover and basal area

Species	Canopy cover (m ² ·ha ⁻¹)	Relative canopy cover (%)	Basal area (m ² ·ha ⁻¹)	Relative dominance (%)
<i>Vachellia tortilis subsp. raddiana</i>	2 088,2	73,0	1,91	63,7
<i>Balanites aegyptiaca</i>	687,7	24,0	1,01	33,7
<i>Vachellia nilotica</i>	61,3	2,14	0,04	1,31
<i>Senegalia senegal</i>	11,5	0,40	0,03	1,11
<i>Vachellia seyal</i>	10,0	0,35	< 0,01	0,10
<i>Leptadenia lanceolata</i>	3,6	0,13	< 0,01	0,02
Total	2 862,3	100,0	3,00	100,0

Structural hierarchy of species: The Importance Value Index (IVI) revealed a clear structural hierarchy (Table 3). *Vachellia tortilis subsp. raddiana* had the highest value (IVI = 172.93), followed by *Balanites aegyptiaca* (113.36). The other species had IVI values below 7.

Table 3. Importance Value Index (IVI) of adult woody species. DR: relative density; FR: relative frequency; DoR: relative dominance

Species	RD (%)	RF (%)	DoR (%)	IVI
<i>Vachellia tortilis subsp. raddiana</i>	61,66	47,54	63,73	172,93
<i>Balanites aegyptiaca</i>	33,72	45,90	33,74	113,36
<i>Vachellia nilotica</i>	3,46	1,64	1,31	6,41
<i>Senegalia senegal</i>	0,23	1,64	1,11	2,98
<i>Vachellia seyal</i>	0,69	1,64	0,10	2,44

Species	RD (%)	RF (%)	RD ₀ (%)	IVI
<i>Leptadenia lanceolata</i>	0,23	1,64	0,02	1,89
Total	100,0	100,0	100,0	300,0

Diameter structure: The distribution of adult individuals across D_{0,30} diameter classes showed a strong concentration in the smallest classes, with a maximum in the 3.5–7 cm class, followed by the 7–10.5 cm class. This structure was mainly driven by the two dominant species, *Vachellia tortilis subsp. raddiana* and *Balanites aegyptiaca*, which were strongly represented in the smaller diameter classes. Abundance then generally decreased with increasing diameter, despite some intermediate fluctuations. Individuals with diameters above 35 cm were scarce, but the largest observed diameter reached 67.8 cm.

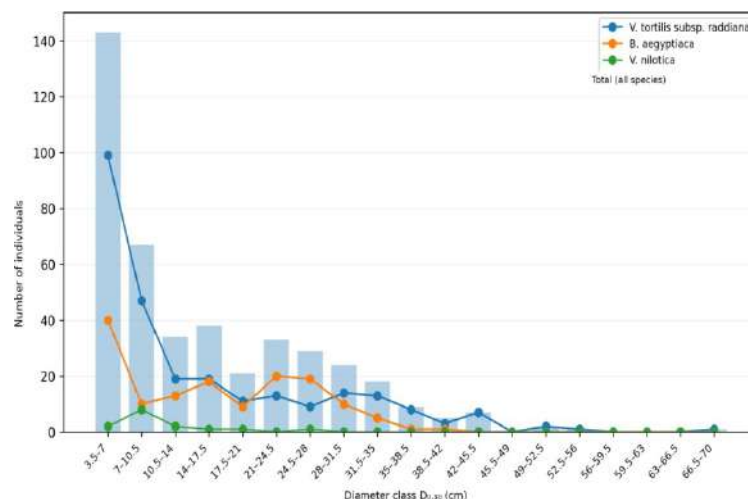


Figure 5. Diameter structure of the adult woody stand and contribution of the main species. Bars represent the total number of individuals in each $D_{0,30}$ class

Vertical structure: The vertical structure of the stand was mainly concentrated in the low and intermediate height classes. The 1.5–4.5 m and 4.5–7.5 m classes accounted for approximately 52% and 36% of individuals, respectively, representing nearly 88% of the total abundance. This distribution was mainly associated with the dominant species, particularly *Vachellia tortilis subsp. raddiana* and *Balanites aegyptiaca*, which largely structure the woody stand. Individuals exceeding 7.5 m remained a minority, with a maximum observed height of 11 m (Figure 6).

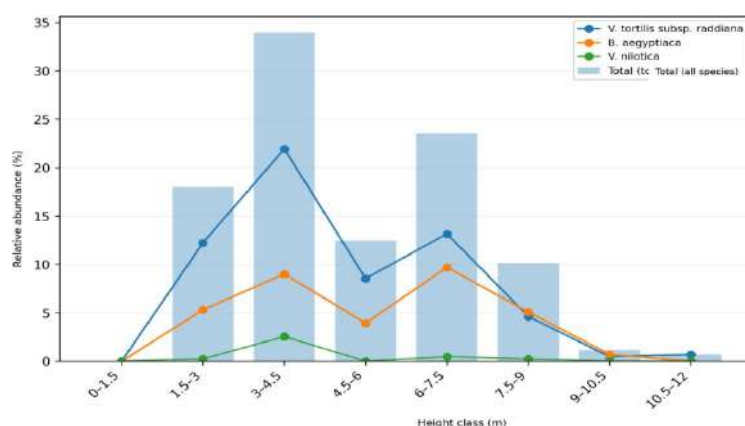


Figure 6. Vertical structure of the adult woody stand and contribution of the main species. Bars represent the relative frequency (%) of individuals in each height class

Natural regeneration, relative regeneration potential, and mortality: Regeneration density was 229.4 individuals·ha⁻¹. Regeneration represented 68.2% of living individuals and corresponded to 2.15 regenerating individuals per adult. However, it was very unevenly distributed among species, being dominated by *Vachellia tortilis subsp. raddiana* (68.5%) and *Balanites aegyptiaca* (21.6%), which together accounted for 90.1% of young individuals. The other species, namely *Leptadenia lanceolata* (5.4%), *Vachellia nilotica* (3.1%), and *Vachellia seyal* (1.0%), made only minor contributions (Table 4).

Table 4. Relative contribution of species in the adult and regeneration compartments and relative regeneration index (IRR)

Species	Adults (%)	Regeneration (%)	IRR	Mortality (%)
<i>Vachellia tortilis subsp. raddiana</i>	61,66	68,46	1,11	88,6
<i>Balanites aegyptiaca</i>	33,72	21,64	0,64	2,3
<i>Vachellia nilotica</i>	3,46	3,12	0,90	0
<i>Vachellia seyal</i>	0,69	0,97	1,40	0
<i>Leptadenia lanceolata</i>	0,23	5,38	23,30	9,1
<i>Senegalia senegal</i>	0,23	0,00	0,00	0
<i>Senegalia mellifera</i>	0,00	0,22	—	0
<i>Leptadenia pyrotechnica</i>	0,00	0,11	—	0
<i>Calotropis procera</i>	0,00	0,11	—	0
Total	100,00	100,00	—	100,00

Assessment of species-specific regeneration revealed substantial differences among species. *Vachellia tortilis subsp. raddiana* had an IRR of 1.11, whereas *Balanites aegyptiaca* had a value of 0.64. *Vachellia seyal* had an IRR of 1.40, while *Vachellia nilotica* reached 0.90. *Leptadenia lanceolata* stood out with a particularly high IRR (23.30), associated with the

presence of a single adult compared with 50 young individuals. *Senegalia mellifera*, *Leptadenia pyrotechnica*, and *Calotropis procera*, absent from the adult compartment but present in regeneration, did not allow calculation of the IRR. Forty-four standing dead trees were recorded in the reserve, distributed among *Vachellia tortilis subsp. raddiana* (88.6%), *Leptadenia lanceolata* (9.1%), and *Balanites aegyptiaca* (2.3%).

Comparison of floristic and structural characteristics between the two inventories: The inventory by Kébé *et al.* (2020) was conducted in the Koyli-Alpha rangelands using three 5-km transects, for a total length of 15 km, converging toward the protected plot. The main floristic and structural parameters obtained in these two contexts are presented in Table 5. Both inventories recorded a total richness of nine species. *Balanites aegyptiaca* and *Vachellia tortilis subsp. raddiana* were among the dominant species in both inventories, although their order of dominance differed. Adult density was 47.8 ± 12.6 individuals·ha⁻¹ in the rangelands studied by Kébé *et al.* (2020), compared with 106.9 individuals·ha⁻¹ in the reserve. Canopy cover was 16.5% and 28.6%, respectively. Regeneration density was 267 ± 103 individuals·ha⁻¹ in the rangelands studied by Kébé *et al.* (2020), compared with 229.4 individuals·ha⁻¹ in the reserve. Diameter structure was described as bell-shaped in the rangelands studied by Kébé *et al.* (2020), whereas it was strongly concentrated in the smallest classes in the reserve. In both contexts, vertical structure was characterized by two main strata (Table 5).

Table 5. Comparison of the main indicators of the Koyli-Alpha woody stand between Kébé *et al.* (2020) and the present study

Indicator	Rangelands (Kébé <i>et al.</i> , 2020)	Reserve (Present study)
Total richness	9 species	9 species
Adult density	47.8 ind.·ha ⁻¹	106.9 ind.·ha ⁻¹
Canopy cover	16.5 %	28.6 %
Regeneration density	267 ind.·ha ⁻¹	229.4 ind.·ha ⁻¹
Dominant species	<i>B. aegyptiaca</i> and <i>V. tortilis subsp. raddiana</i>	<i>V. tortilis subsp. raddiana</i> and <i>B. aegyptiaca</i>
Diameter structure	Bell-shaped	Strong concentration in the smallest classes
Vertical structure	Two main strata	Two main strata

DISCUSSION

The discussion places the main floristic, demographic, and structural findings for the woody stand of the Koyli-Alpha Reserve in context in order to characterize its dynamics and draw implications for ecological management of the site. The woody assemblage at Koyli-Alpha shows broadly stable species richness compared with the results reported by Kébé *et al.* (2020), with nine species recorded in each inventory. The presence of a shared floristic core between the two inventories indicates a degree of continuity in the woody assemblage, while differences in associated species may reflect spatial heterogeneity in habitats and soil conditions across the Ferlo. They may also result from differences in sampling design and the extent of the surveyed areas, which necessarily affect the probability of detecting species with low abundance or aggregated distributions. This distinction is particularly important in Sahelian ecosystems, where woody plant distribution is strongly controlled by resource gradients, topography, and soil properties (Dendoncker & Vincke, 2020; Dendoncker *et al.*, 2023; Sagna *et al.*, 2024). The strong dominance of *Vachellia tortilis subsp. raddiana* and *Balanites aegyptiaca* suggests a stand organization likely shaped by pronounced environmental filtering. Under the arid conditions of the Ferlo, water and edaphic constraints are major factors selecting species capable of maintaining survival, growth, and recruitment, thereby favoring taxa with high drought tolerance (Sankaran *et al.*, 2005, 2008; Dendoncker & Vincke, 2020). In the Sahel, maintenance or recovery of woody cover may therefore be driven primarily by drought-tolerant species without a concomitant increase in species diversity (Hänke *et al.*, 2016; Brandt *et al.*, 2017). Regeneration is a major indicator of stand dynamics at Koyli-Alpha. The substantial contingent of young individuals, together with higher adult density than that reported in the rangelands by Kébé *et al.* (2020), suggests conditions favorable to stand renewal. In the reserve context, protection from disturbance may contribute to improving the survival of young recruits by reducing anthropogenic pressures and herbivory, thereby facilitating their gradual transition into the adult compartment. This interpretation nevertheless needs to be confirmed through longitudinal monitoring, because recruit survival also depends on water availability, soil conditions, proximity to seed trees, and herbivore pressure (Gijsbers *et al.*, 1994; Dendoncker *et al.*, 2024). Renewal nevertheless remains strongly differentiated among species. The dominant species show relatively favorable recruitment dynamics, whereas *Leptadenia lanceolata* stands out for its strong representation among young stages. The presence of *Senegalia mellifera*, *Leptadenia pyrotechnica*, and *Calotropis procera* only in the regeneration layer also represents a potential source of diversification of the adult stand. Continued protection and monitoring of recruit survival will therefore be decisive in determining whether this dynamic actually leads to progressive stand diversification. The diameter structure confirms the renewal signal revealed by regeneration. The strong representation of small diameter classes, together with the presence of individuals in larger classes, indicates a multi-class structure characteristic of active stand renewal. This pattern is consistent with observations by Sagna *et al.* (2024), who associated a strong representation of small diameter classes with active renewal dynamics. It contrasts with the bell-shaped structure reported by Kébé *et al.* (2020), dominated by intermediate classes and interpreted, according to Sagna *et al.* (2024), as indicating insufficient renewal. The vertical structure, dominated by low and intermediate strata, reinforces this interpretation by revealing the coexistence of several developmental stages. The convergence of signals provided by regeneration, diameter structure, and vertical structure therefore indicates active stand renewal, still strongly structured by the dominant species. Spatial heterogeneity of the stand is also an important characteristic of the Koyli-Alpha reserve. The variability observed among plots may reflect, at least in part, local differences in environmental conditions. In the Ferlo, topography controls, among other things, the redistribution of water and soil resources, with lower topographic positions generally associated with greater density, higher canopy cover, and greater stability of woody stands (Dendoncker & Vincke, 2020; Dendoncker *et al.*, 2023; Sagna *et al.*, 2024). Although topographic position was not incorporated as a stratification factor in the present sampling design,

the diversity of topographic contexts encountered among plots should be considered when interpreting this spatial variability. This dimension should be explicitly incorporated into subsequent monitoring to better distinguish variation related to local conditions from changes associated with the restoration trajectory.

For restoration at Koyli-Alpha, the challenge is therefore not limited to increasing woody cover or density, but also includes maintaining species diversity and the survival of recruits capable of progressively renewing and diversifying the stand. Conservation of the less abundant species present in the reserve, together with retention of the species previously reported by Kébé *et al.* (2020), is important for preserving functional diversity and niche complementarity, in line with restoration principles based on native species and local participation (Sacandé & Berrahmouni, 2016; Sacandé & Muir, 2022). The reintroduction of *Centrochelys sulcata* and *Oryx dammah* also gives particular importance to monitoring herbivory, which may influence the survival and recruitment of young woody plants. However, the absence of a pre-protection baseline and of a control site prevents establishing a causal effect of protection on the observed dynamics. The 29 plots therefore constitute a reference network that should be maintained, with long-term monitoring enabling quantification of recruitment, survival, growth, mortality, and stand diversification trajectories, while also assessing interactions between vegetation restoration and wildlife management.

CONCLUSION

The inventory of the Koyli-Alpha Community Nature Reserve reveals a woody stand characterized by strong oligodominance, but with substantial regeneration and a demographic structure compatible with active renewal. Current dynamics are nevertheless strongly driven by *Vachellia tortilis subsp. raddiana* and *Balanites aegyptiaca*, while the contribution of less abundant species remains limited. The presence of several species only in the regeneration compartment nevertheless represents a potential for diversification of the adult stand, the realization of which will depend on the survival and recruitment of young individuals. These results establish an essential baseline for monitoring restoration at Koyli-Alpha. They support the hypothesis of substantial regeneration and highlight the coexistence of several developmental classes, but they do not allow estimation of an annual recruitment rate or direct attribution of this dynamic to protection from disturbance. The restoration trajectory should therefore be assessed over time, distinguishing changes in canopy cover and density from changes in diversity, recruitment, growth, and mortality. Conservation of less abundant species and recruits is therefore a major management issue for the reserve, particularly in the context of wildlife reintroduction. The 29 plots should be maintained as a permanent monitoring network, with repeated measurements of recruitment, survival, growth, mortality, and stand structure, complemented by herbivory monitoring. Such a system will make it possible to determine whether the dynamics currently observed lead, in the medium and long term, to a sustainable, structurally functional, and more diverse restoration of the woody stand and associated habitats.

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