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Woody species composition, diversity and vegetation structure of two rangelands areas along a climatic gradient in Burkina Faso (West Africa)

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Abstract

Climate variability added to anthropogenic pressures leads to habitat fragmentation, degradation and loss of rangelands resources in Burkina Faso. Studying vegetation structure and woody species composition is important in monitoring vegetation dynamics for efficient rangeland management. This study was carried out to characterize woody vegetation along a climatic gradient. Sixty-four quadrats of varying size were laid in each of the rangeland (Sidéradougou and Mankarga). Thus, the inventory unit was 1000 m² (50 m x 20 m) in savannas and 500 m² (50 m x 10 m) in gallery forests. In each plot, all woody species with a diameter at breast height (DBH) ≥ 5 cm were systematically identified and measured. The data were analyzed by using Shannon-Wiener diversity and equitability indices, and the structural analysis was carried out based on frequency, density, DBH, height and basal area/ha-1. A total of 89 forage plant species belonging to 64 genera and 25 families from Sidéradougou and 80 plant species belonging to 57 genera and 23 families from Mankarga was identified. Fabaceae and Combretacea was the dominant family in the two rangelands with diverse population structures. The small trees and shrubs dominated the rangeland suggesting its status under a secondary stage of development. Some woody species require urgent conservation measures. Therefore, local and regional stakeholders should integrate and work together to develop and implement sound conservation and management strategies that encourage the sustainable utilization of rangeland resources.

Introduction

Pastoral ecosystems play a major role in the global climate balance and provide numerous ecosystem goods and services (FAO 2020). They also contribute to socio-economic well-being through the woody and non-woody forest products that they provide. The use of these woody and non-woody forest products makes an invaluable contribution to food production in rural areas (Nacoulma et al. 2011). Woody plants forages provide proteins essential to the dietary balance in livestock feeding strategy on natural pasture during the dry season (Du et al. 2023). Moreover, in Sahelian rangelands, fodder supply from annual fodder species during the dry season or in years of low rainfall remain problematic. In this circumstance woody species

become an important source of forage in the livestock feeding strategy (FAO 2020). Anthropogenic activities are exerting high pressures on natural resources inducing a rapid biodiversity erosion that affects the capacity of ecosystems to provide the goods and services for human uses (Cardinale et al. 2012).

Thus, the current study in the Sidéradougou and Mankarga rangelands in Burkina Faso is critical due to a lack of documentation on the diversity and structure of the woody forage plants. Specifically, it seeks to answer the following research questions: (i) What is the species richness and diversity of woody vegetation in the Sidéradougou and Mankarga rangelands? (ii) How are rangelands structured in terms of tree density, basal area, and diameter class distribution?

Materials and methods

Study area

The research was carried out in the Mankarga and Sidéradougou sylvopastoral zones, located respectively in the Sudanian and Soudano-Sahelian zones of Burkina Faso. Mankarga's rangelands cover an area of 6,270 hectares and lie between latitudes 11°59' and 12°06' North, and longitudes 00°53' and 00° 59' West. The Sidéradougou area covers 51,500 ha and lies between latitudes 10°30' and 11°104' North and meridians 3°55' West and 4°50' East (Fig.1).

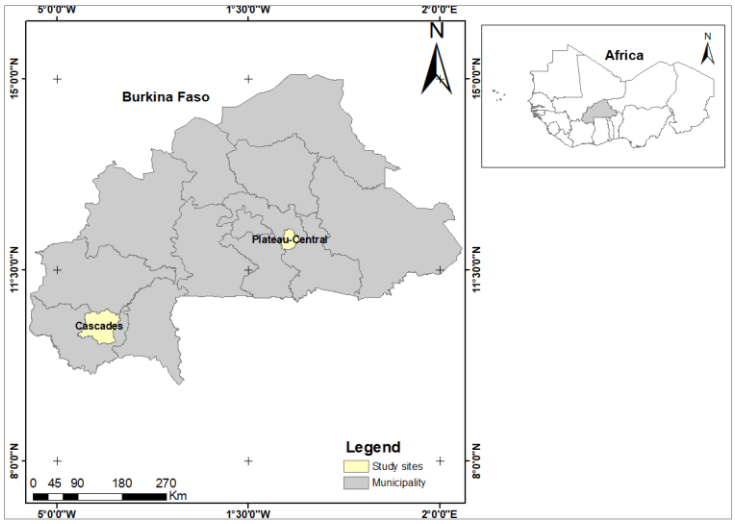

Figure 1: Map showing the study sites.

Data collection

Floristic inventories were conducted at two study sites at the onset of the dry season (November to December 2023) when the plots were readily accessible. A total of 128 plots were established, comprising 64 plots per site within homogeneous stands of plant formations. The inventory unit was 1000 m² (50 m × 20 m) in Savannas and 500 m² plots (50 m × 10 m) in gallery forests. Within (Thiombiano et al. 2016) each sampling plot, phytosociological methods were employed to assess woody plant.

Vegetation data analysis

Diversity indices

The Shannon diversity (H') and evenness (J) indices are used to measure both species richness and species evenness (Kent, 2012). The Shannon Wiener diversity index (H') was computed for each plant community

types using the equation:

$$H' = -\sum_{i=1}^{s} pilnpi \quad (1)$$

where S = total number of species in the community (richness) and pi is relative abundance of the i^{th} species in a sample plot. The Shannon evenness (J) was calculated from the ratio of observed diversity to maximum diversity using the equation:

$$J=H'/Hmax=H'/lns \quad (2)$$

Where Hmax is the maximum level of diversity possible within a given population, which equals ln (number of species). J (species evenness) is normally ranges between 0 and 1, and with 1 representing a situation in which all species are equally abundant (Magurran, 2003).

Structural data analysis

To analyze the population structure of woody plant species, tree diameters were categorized into 5 cm intervals. The diameter class distribution of each vegetation type was fitted to a theoretical value of the Weibull distribution, whose probability density function is defined as follows (Johnson and Kotz, 1970) :

$$f\ (x) = \frac{c}{b}\left(\frac{x-a}{b}\right)^{c-1} exp\ \left\{\left(\frac{x-a}{b}\right)^{c}\right\} \quad (3)$$

In this equation, x represents the tree diameter; a (threshold parameter) equals 5 cm; b is the scale parameter linked to the central value of diameters; and c is the shape parameter of the structure, also known as the Weibull slope.

Results

Floristic composition and species diversity

A total of 169 woody species, spanning 121 genera and 48 families, were identified across the two rangelands. In the Mankarga rangelands specifically, 80 species from 57 genera and 23 families were recorded, while the Sidéradougou rangelands harbored 89 species across 64 genera and 25 families. In Sidéradougou, Fabaceae emerged as the most represented family (7.86% of species), followed by Combretaceae and Malvaceae (both at 5.61%). In contrast, Combretaceae was the dominant family in Mankarga (10% of species), followed by Fabaceae (7.5%) and Rubiaceae (5%).

The species richness of inventoried individuals varied across pastoral zones, averaging 10.28 ± 2.51 in the Sidéradougou rangelands and 9.61 ± 2.70 in the Mankarga rangelands (Table 1). Considering the species richness, statistical analyses revealed that there was no significant difference between gallery forest and wooded savannas within the same rangeland or between the two rangelands. The diversity indices (Shannon's index, Shannon evenness) exhibited significant variations along the two rangelands ($P < 0.001$) and among different vegetation types (Table 1). The Shannon evenness (J) values for the rangelands of Sidéradougou and Mankarga were 0.87 ± 0.13 and 0.83 ± 0.18, respectively, indicating a relatively equal distribution of species within the communities of both rangelands.

Table 1: Diversity indices by plant formation type in each Rangeland

Rangelands	Index	Gallery forest	Woodland savanna	Overall	Chi-square	p
Sidéradougou	J	0.95±0.02[a]	0.93±0.02[b]	0.87±0.13	70.67	<0.001

	H	2.32±0.18[a]	2.26±0.21[a]	1.95±0.57	83.33	<0.001
	S	11.47±1.76[a]	11.40±2.03[a]	10.28±2.51	78.01	<0.001
Mankarga	J	0.84±0.17[a]	0.85±0.19[a]	0.83±0.18	21.46	<0.001
	H	2.18±1.41[a]	2.01±0.56[a]	1.91±1.04	45.45	<0.001
	S	10.73±2.13[a]	10.46±2.38[a]	9.61±2.70	70.32	<0.001

Values along columns with different letter differ significantly.

Woody forage plant population structure

The diameter class distribution of woody forage species in the two rangelands exhibited reversed J-shape (L-shape) pattern (Fig. 2). The majority of individuals fell within the 5-20 cm diameter class. This indicates that the species frequency distribution peaked in the lower diameter classes and gradually decreased towards the higher classes. The 'c' parameter of the Weibull distribution ranged between 0.72 and 0.82, confirming this trend.

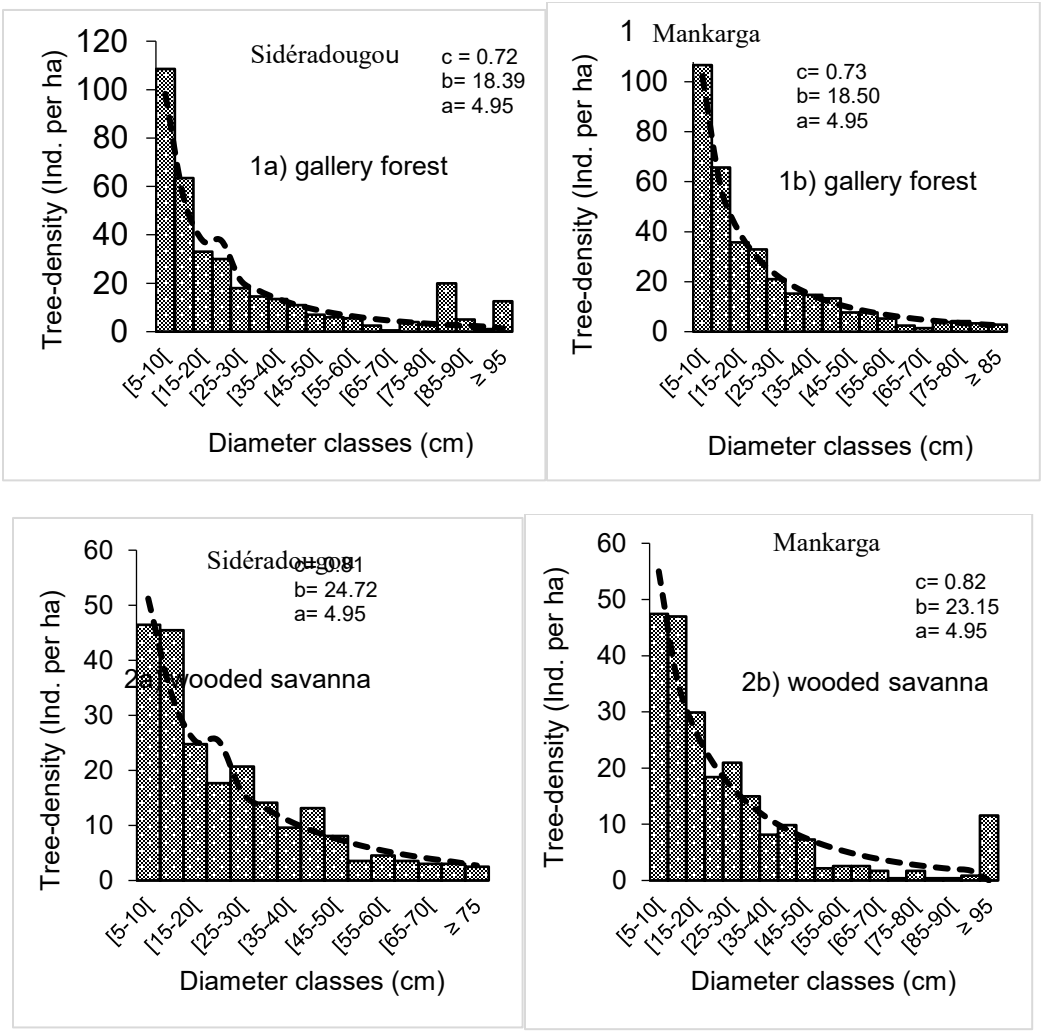

Figure 2: Diameter class size distribution of the two vegetation types in the two rangelands: gallery forest 1a and 1b; wooded savanna 2a and 2b

Discussion

Floristic composition and species diversity

Across the studied rangelands, the Sidéradougou rangeland recorded an average Shannon-Weiner diversity index (H) of 1.95 and an evenness (J) value of 0.87. Similarly, the Mankarga rangeland showed an average Shannon-Weiner diversity index (H) of 1.91, accompanied by an identical evenness (J) value of 0.87. These values are lower than those reported for forest corridor from Burkina Faso (H'= 2.85) (Sanou et al., 2021), but higher than Sahelian woodland formations from Burkina Faso (H'= 1.76; J= 0.55) (Savadogo et al., 2016). Cavalcanti et al. (2004) classify forest diversity into four categories based on the Shannon-Weiner diversity index: high diversity is indicated by a value above 3.0, medium diversity falls between 2.0 and 3.0, low diversity ranges from 1.0 to 2.0, and very low diversity is below 1.0. Therefore, the woody species diversity of the two rangelands falls within the low category, as the estimated value is between 1 and 2. The low value of the Shannon diversity index suggests that there are various factors contributing to these results, including illegal harvesting, agricultural expansion, overpopulation, and livestock intervention (Atsbha et al., 2019). Fekadu et al. (2019) have highlighted that human intervention, overgrazing, and illegal activities pose threats to the diversity and distribution of woody species in rangelands.

The species richness observed in this study is lower than that reported by Sambaré et al. (2011) in similar gallery forests in Burkina Faso. This discrepancy may be attributed to the intensity of disturbance factors and climatic variations that hinder the establishment of certain species in both study sites.

Population structure of fodder trees

The inverse J-shape of the diameter class distribution characterizes tree populations dominated by small diameter individuals. This size class distribution pattern serves as evidence that woody species have young populations with genuine capacities for rejuvenation in these rangelands. However, the absence of trees with large stem diameter in the stands could lead to the regression of the individuals stands because large trees are the best seed producers and thus support the natural regeneration (Tesfaye et al., 2004). The density of plant species decreased with increasing diameter at breast height (DBH) classes, and the lower DBH classes exhibited a greater diversity of species compared to the medium and higher DBH classes. Similar studies have shown that species with a diameter at breast height greater than 30 cm were exploited by local populations for construction and charcoal production (Badji et al., 2014). According to Atsbha et al. (2019), this bell-shaped pattern indicates a low reproductive rate and poor species recruitment.

Conclusions and implications

Assessment of diversity and regeneration status of tree species is crucial for their sustainable utilization, management, and conservation. This study examined the overall population structures of tree species in the Sidéradougou and Mankarga rangelands, revealing significant insights into their contribution to ecosystem health. This study makes a significant contribution to our understanding of tree species diversity and regeneration patterns in African savannas, providing valuable insights for policymakers and conservation practitioners working in similar ecosystems.

Acknowledgements

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