



**TREE SPECIES DIVERSITY, SOIL PHYSICOCHEMICAL, BIOMASS, CARBON STOCK
AND CARBON DIOXIDE ASSESSMENT IN MUNGULVU GRAZING RESERVES
MUBI-NORTH LGA, ADAMAWA STATE, NIGERIA**

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ABSTRACT

This study evaluated the diversity of tree species, soil physicochemical properties, biomass, carbon stock, and carbon dioxide (CO₂) sequestration in the Mungulvu grazing reserve. A systematic line transect approach was adopted, consisting of two parallel transects, each 1500 m long and spaced 500 m apart. Along each transect, four sample plots of 50 × 50 m were established at 100 m intervals, given a total of eight plots. Within each plot, all living trees with a diameter at breast height (DBH) ≥ 10 cm were identified and measured for diameter at breast height, diameter at the base, middle, and top, as well as total height. Soil samples were collected at four depth intervals (0–15, 16–30, 31–45, and 46–60 cm) from three points per plot. Data were analysed using one-way analysis of variance (ANOVA) and Student's t-test. A total of 11 tree species belonging to six families were recorded, with a density of 62 trees ha⁻¹ and dominance of the Phyllanthaceae and Fabaceae families. Diameter and height class distributions indicated a concentration of individuals in lower size classes. Total aboveground biomass, carbon stock, and CO₂ were estimated at 7.94 t ha⁻¹, 3.97 t ha⁻¹, and 14.56 kg, respectively. Soils were predominantly sandy, with moderate bulk density, porosity, and water-holding capacity. Chemical properties indicated a slightly acidic to near-neutral pH, low electrical conductivity, moderate organic matter content, and a moderate effective cation exchange capacity. The findings highlighted the importance of sustainable grazing and soil management practices to conserve biodiversity, enhance biomass and carbon storage, and maintain ecosystem stability in the Mungulvu grazing reserve.

Keywords: Tree-species, Soil, Physicochemical, Biomass, Carbon-stock, Carbon-dioxide

INTRODUCTION

Biodiversity research has therefore developed to become an important part of conservation biology and functional ecology (Ma, 2013, 2016). Species diversity is a crucial concept of biodiversity and is intuitively simple yet conceptually complex. A quantitative assessment of species diversity is thus essential for effective biodiversity conservation and management (Magurran, 2004). Measures of species diversity usually include two components: richness and evenness. Richness represents the total number of species within a given area, while evenness measures how similar species are in their abundances (Magurran, 2004). Species richness and evenness are two independent criteria that may differ in their responses to local habitat factors (Ma, 2005). The higher amount of biodiversity lost in Nigeria savannah zones account through human activities e.g poverty, illiteracy, dependent on fuel wood, traditional shrines/medicine, agriculture, population increase, and industrialization. Natural account through erosion (water and wind) of soil nutrients deplete regrowth of tree species (Umar *et al.*, 2026a). According to Umar and Adekunle, (2026) dominant trees thrive in finer-textured, water-retaining soils in grazing reserve and exchange capacity is a key fertility driver for girth and stand volume expansion also a sustainable management of forest and grazing reserves to minimise biodiversity loss, which directly affects biomass, carbon stock, and ecosystem stability through control erosion control, organic matter management, and soil fertility enhancement.

Physical properties of forest soils develop under natural conditions by the influence of permanent vegetation over a long period of time. Physical properties of forest soils may be almost permanent properties unless modified by harvesting operations, shifting cultivation, and forest fires. Important physical properties of forest soils include texture, structure, porosity, density, aeration, temperature, water retention, and movement (Speir, 2010).



Biomass as “organic material both above and below-ground, living and dead e.g trees, crops, grasses, tree litter, roots etc”. Above-ground biomass consists of all living biomass above the soil including stem, stump, branches, bark, seeds and foliage (Zheng *et al.* 2004). Below-ground biomass consists of all living roots excluding fine roots (less than 2mm in diameter). In forest biomass studies, two biomass units are used fresh weight (Araujo *et al.*, 1999) and dry weight (Aboal *et al.*, 2005; Montagu *et al.*, 2005). Many biomass estimation studies conducted focused on above-ground forest biomass (Kraenzel *et al.*, 2003; Laclau, 2003; Losi *et al.*, 2003) because it accounts for the majority of the total accumulated biomass in the forest ecosystem. Biomass Assessment is important for many purposes (Zheng *et al.*, 2004). It is aimed at two major objectives: for resources use and for environmental management. The amount of carbon sequestration can be inferred from the biomass change since 50% of the forest dry biomass can be inferred as carbon (Montagu *et al.*, 2005). The selective removal of large trees and grazing pressure appear to limit biomass and CO₂ sequestration potential in the reserve. System dynamics and regional forest carbon models further emphasise that forest structure, fertility, and moisture regulation strongly determine biomass density and carbon outcomes across Africa’s savanna belts (Kindermann *et al.*, 2008; Martinez-Moyano and Richardson, 2013, Umar *et al.*, 2026a).

Carbon exists in the earth’s atmosphere primarily as carbon dioxide. It constitutes a very small percentage of the atmosphere, about 0.04%. However, it plays an important role in supporting life on earth, as plants make themselves from it. During photosynthesis, plants take up carbon dioxide from the atmosphere, converting it into carbohydrates and releasing oxygen into the atmosphere. When these plants or trees die or are burnt, the carbon stored in them are released back into the atmosphere. This natural cycling of the carbon is maintained and controlled by a dynamic balance between biological and inorganic processes since the geological history of earth. The carbon dioxide concentration in the atmosphere has increased from about 280 ppm, during the pre-industrial period, to approximately 390 ppm in the present-day (Patino *et al.*, 2004).

MATERIALS AND METHODS

The Study Area

Adamawa State is located at the North Eastern part of Nigeria. It lies between latitude 7° and 11° N of the equator and between longitude 12° and 13° E of the Greenwich meridian E in the Upper Benue catchment (Figure 7). Mubi-North LGA lies between latitude 10.3498° N and longitude 13.4065° E. The population of 151,515 (2006 population census), recent estimates 244,800 (projection 2025). Mungulvu grazing reserve is located in (Mubi-North LGA), established and has an area of 1,976.8 hectares. The State covers a land area of about 38,741 km². It is divided into 21 Local Government Areas. It has a population of 3,168,101 (National Bureau for Statistics, 2007 and National Population Commission, 2006).

Sampling Procedure and Plot Demarcation

The study covered the savannah ecosystem types in the Adamawa State (Southern Guinean Savannah). One grazing reserve was randomly selected from the ecological zones. Systematic line transect was employed in the laying of the plots. Two parallel transects of 1500m in length with a distance of 500m between the two parallel transects was used. Sample plots of 50m x 50m in size was laid in alternate along each transect at 100m interval and thus summing up to 4 sample plots per 1500m transect and a total of 8 sample plots in Mungulvu grazing reserve.

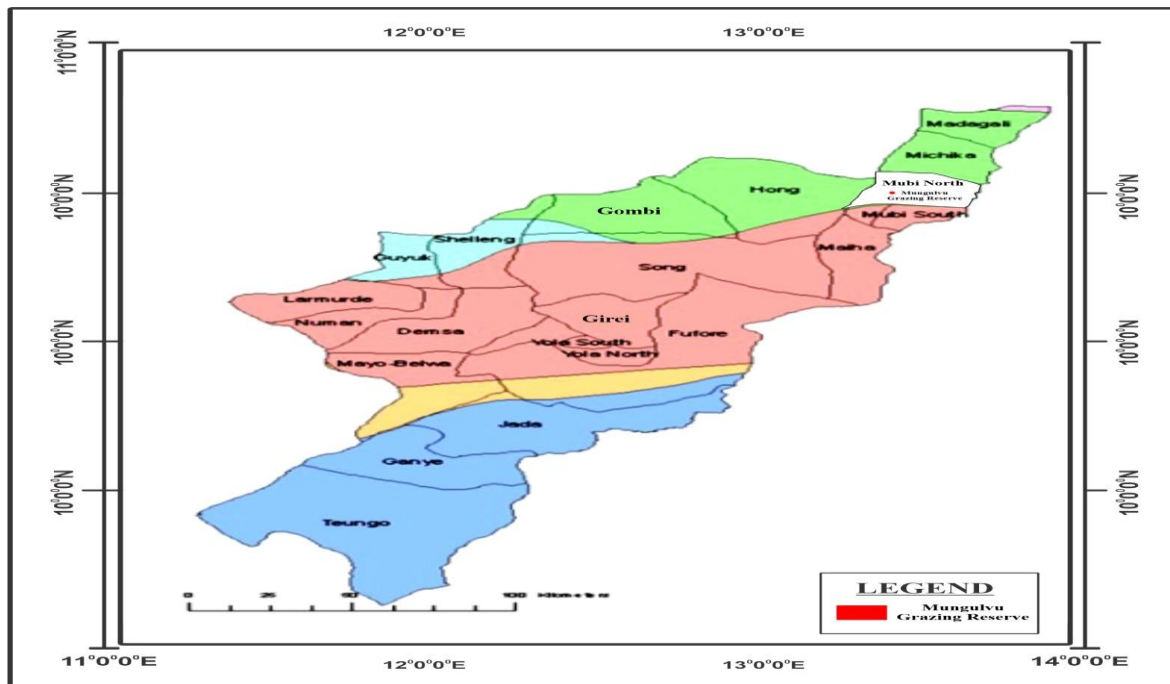


Figure 1: Map of Adamawa State Showing Mungulvu Grazing Reserve in Mubi-North LGA
Source: Umar, *et al.*, (2026) in Adebayo and Nwagboso, (1999)

Method of Data Collection

Tree species identification

The botanical name of every living tree encountered in each sample plot were recorded for each of the study site. When a tree’s botanical name is not known immediately, it was identified by its commercial or local name. Such commercial or local name were translated to correct botanical name using Key (1989).

Tree Growth Variable Measurement

In each sample plot, all living trees with dbh ≥ 10 cm were identified and measured for dbh, diameter at the base, middle and top and total height. Diameter tape and Spiegel relaskop were used for tree height and diameter at the base, middle and top, while diameter/girth tape was used for dbh measurement.

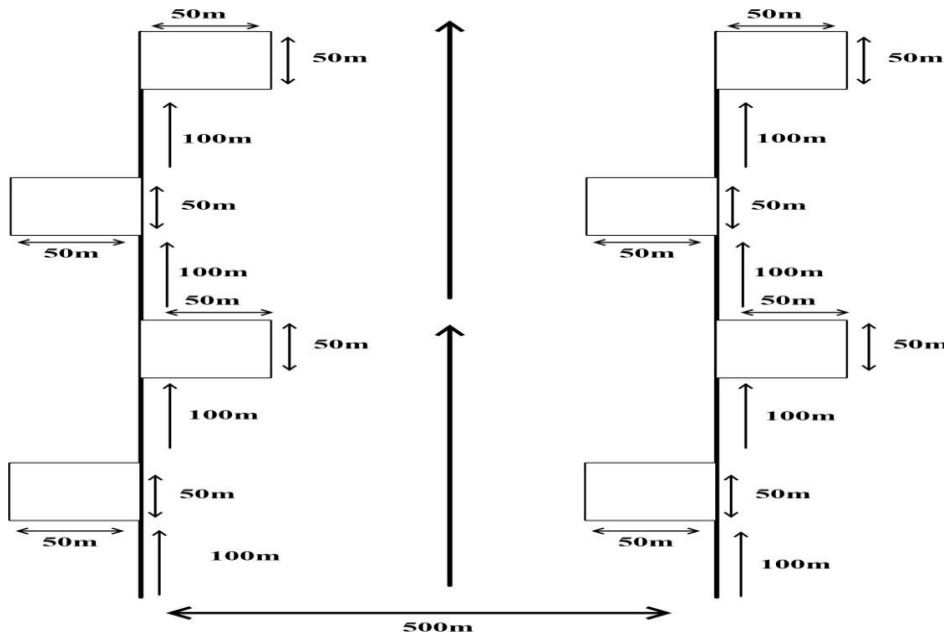


Figure 2. Plot Layout with Systematic Line Transect Sampling Technique
Source: Umar, *et al.*, 2026ab

Soil sample collection

A diagonal line was laid within the sample plot for soil sample collection. Soil samples were taken from four soil depths of 0 – 15cm, 16 – 30cm, 31 – 45cm and 46 – 60cm at three points (i.e. at the two edges and middle of the line). Soil samples from the same depths and from the same plot were thoroughly mixed to form a composite soil sample, from which samples were taken for laboratory analysis.

Method of Data Analysis

Basal Area Estimation

The Basal areas of all trees in the sample plots in the selected study area were calculated using the formula:

$$BA = \frac{\pi D^2}{4} \dots \dots \dots (1)$$

Where BA – Basal area (m²), D – Diameter at breast height (cm) and π – Pie (3.142). The total basal area for each of the sample plots were obtained by summing of the BA of all trees in the plot. While mean basal area per hectare was obtained by multiplying mean basal area per plot with the number of 50 x 50m plots in the six grazing reserves.

$$BA_{ha} = \frac{BA_p}{n} = \frac{\sum BA}{n} \dots \dots \dots (2)$$

Where BA_{ha}= Basal area per hectare.

- BA_p= Mean basal area per plot
- n= number of all possible sample plot

Stem Volume Estimation

The volume of individual trees was estimated using the formula of Newton’s formula of (Husch *et. al.*, 2003). The equation is expressed as follows:

$$V = \frac{\pi h}{24} (D_b^2 + 4D_m^2 + D_t^2) \dots \dots \dots (3)$$

Where

V = Volume of tree (m³)



- D_b = Diameter at the base (m³)
- D_m = Diameter at the middle (m³)
- D_t = Diameter at the top (m³)
- h = height (m)

Total plot volume was obtained by adding the volume of individual trees encountered in the plots. Mean volume for sample plots was calculated by dividing the total plot volume by the number of sample plots (8 plots) in the grazing reserve (Umar *et al.*, 2026ab).

Volume per hectare was obtained by multiplying mean volume per plot V_p with the number of 50 x 50m plots in a hectare (8 plot) (Adekunle, 2007; Adekunle *et al.*, 2013; Umar *et al.*, 2026ab).

$$V_{ha} = V_p \times 8 \dots\dots\dots(4)$$

Where V_{ha}= Volume per hectare

V_p = Mean Volume per plot

Tree Species Classification and Biodiversity Indices

- (i) The relative density of the species was computed as:

$$RD = \frac{n_i \times 100}{N} \dots\dots\dots(5)$$

Where:

- RD = species relative density
- n_i = number of individual of species i
- N = total number of all tree species in the community.

- (ii) Species relative dominance (RD_o (%)) was computed using the equation:

$$RD_o = \frac{\sum Ba_i \times 100}{\sum Ba_n} \dots\dots\dots(6)$$

Where:

- Ba_i = Basal area of individual tree belonging to species i
- Ba_n = Stand basal area

- (iii) Species diversity index was calculated using the Shannon – Weiner diversity index (Kent and Coker, 1992)

$$H' = - \sum_{i=1}^s P_i \ln (P_i) \dots\dots\dots(7)$$

Where:

- H' = Shannon – Weiner Diversity index
- S = Total number of species in the community
- P_i = Proportion of S made up of the ith species
- ln = natural logarithm

- (iv) Shannon’s maximum diversity index was calculated using the relationship:

$$H_{max} = \ln(S) \dots\dots\dots(8)$$

Where

- H_{max} = Shannon’s maximum diversity
- S = Total number of species in the community

- (v) Species evenness in each community was determined using Shannon’s equitability (E_h).

$$E_H = H' = \frac{\sum_{i=1}^s P_i \ln (P_i)}{\ln (S)} \dots\dots\dots(9)$$

- (vi) Family Importance Value (FIV)



The family importance Value (FIV) was used to understand a family's share in the tree community. FIV is defined as the sum of its relative dominance (RD_m), its relative density (RD) and its relative frequency (RF), which is Calculated as follows:

$$RD_m = \frac{\text{Total basal area for a family}}{\text{Total basal area for all families}} \times 100 \dots\dots\dots(12)$$

$$RD = \frac{\text{Number of individuals of a family}}{\text{Total number of all individual}} \times 100 \dots\dots\dots(13)$$

$$RF = \frac{\text{Frequency of a family}}{\text{Sum of frequencies of all families}} \times 100 \dots\dots\dots(14)$$

$$\text{Thus, Family importance Value} = RD_m + RD + RF \dots\dots\dots(15)$$

Biomass equation

To estimate the above – ground live biomass, the equation of Brown (1997) for tropical wet climate zone was adopted. The equation is given as

$$Y = 21.297 - 6.953 (D) + 0.740 (D^2) \dots\dots\dots(16)$$

Where

- Y is biomass per tree in kg
- D is diameter at breast height (dbh) in cm.

Estimation of Above and Below-ground Biomass

Estimation of the above–ground live biomass was carried out by multiplying the volume of each tree by its respective wood density or using biomass equation ($Y = 21.297 - 6.953 (D) + 0.740 (D^2)/1000$). Below-ground biomass was estimated as 15% of the above-ground biomass (Mac Dicken, 1997).

Carbon Stock estimation

Carbon stock of trees was calculated by dividing the total biomass value or by converted to carbon stocks using 0.5 carbon fractions as default values (Mac Dicken, 1997, Penman, 2003 and IPCC, 2006) and expressed in t/ha.

$$\text{Carbon Stock (ton)} = \text{Total biomass} / 2 \text{ or } \text{Total biomass} \times 0.5 \text{ (Sharma } et al., 2014) \dots\dots\dots(17)$$

Estimation of CO₂ Sequestration

The estimation of CO₂ sequestration in the trees was calculated by multiplying the carbon stock in the trees by 3.66673 or 44/12 as adopted by (Pascua *et al.*, 2021)

$$\text{CO}_2 \text{ sequestration in trees} = \text{Atomic weight of CO}_2 \times \text{Carbon stock} \dots\dots\dots(21)$$

Where CO₂ = Carbon dioxide (tons/ha)

Laboratory Analysis

Soil physical and chemical properties were determined using standard laboratory analysis.

Statistical Analysis Methods.

One-way ANOVA was employed to assess differences in soil nutrients, tree density, species diversity and richness, basal area, and bio-volume across the grazing reserves.

RESULTS

Tree Species Diversity and Abundance

The results obtained from Mungulvu grazing reserve is represented in Table 1 and 2. A total of 11 species, 6 families and 123 species/plots were encountered in 8 plots of 50x50m along a transect in the grazing reserve. Phyllanthaceae and Fabaceae families has 65 and 33 sample/plots highest while lowest Juglandaceae and Rubiaceae have 1 and 3 samples/plot. Total nha-1 is 62 of all species. MDBH, MVOL, Ba/ha, and Vol/ha (321.59cm, 8.28m³, 0.48cm, and 4.37m³) respectively. Most tree species encountered belong to Phyllanthaceae, Fabaceae and Sapotaceae families, having frequency of occurrence (65, 33 and 15) respectively.



Table 1: Tree Species Abundance/ha, Diversity Indices and Tree Growth Variables in Mungulvu Grazing Reserve

Location	S/no	Species	Families	Sample		RD	MDBH	MVOL	MBA	MHT	PI	LN PI	PI LN PI
				Plots	nha-1								
Mungulvu G.R	1	<i>Acacia muricata</i>	Fabaceae	1	0.5	0.81	23.4	0.20	0.04	5.20	0.01	-4.81	-0.04
	2	<i>Acacia senegalensis</i>	Fabaceae	11	5.5	8.94	24.67	0.31	0.05	7.90	0.09	-2.41	-0.22
	3	<i>Azadirachta indica</i>	Meliaceae	6	3	4.88	53.33	1.44	0.22	8.10	0.05	-3.02	-0.15
	4	<i>Bridelia mollis</i>	Phyllanthaceae	65	32.5	52.85	14.04	0.15	0.02	8.50	0.53	-0.64	-0.34
	5	<i>Carya glabra</i>	Juglandaceae	1	0.5	0.81	3.5	0.01	0.01	5.80	0.01	-4.81	-0.04
	6	<i>Daniellia oliveri</i>	Fabaceae	2	1	1.63	36.45	1.24	0.11	13.20	0.02	-4.12	-0.07
	7	<i>Nuclear latifolia</i>	Rubiaceae	3	1.5	2.44	54.3	2.27	0.23	11.90	0.02	-3.71	-0.09
	8	<i>Phileoptera violacea</i>	Fabaceae	1	0.5	0.81	32.2	0.76	0.09	12.10	0.01	-4.81	-0.04
	9	<i>Piliostigma thonningii</i>	Fabaceae	14	7	11.38	17.78	0.18	0.03	8.60	0.11	-2.17	-0.25
	10	<i>Prosopis Africana</i>	Fabaceae	4	2	3.25	19.35	0.25	0.03	9.70	0.03	-3.43	-0.11
	11	<i>Vitellaria paradoxa</i>	Sapotaceae	15	7.5	12.20	42.57	1.48	0.16	11.00	0.12	-2.10	-0.26
Total				123	62		321.59	8.28			1	-36.04	-1.59

nha⁻¹ – number of species per hectare, RD- Species Relative density, MDbh- Mean Diameter at breast height (cm), MVol- Mean Volume per hectare(cm³), MBa- Mean Basal area (m²), MHt- Mean Height (m).

Table 2: Families Important Index (FIV) for Mungulvu Grazing Reserve

S/No	Family	Frequency	Ba/ha	Vol/ha	RF	RD	RDo	FIV
1	Fabaceae	33	0.17	1.48	27.05	27.05	35.12	65.81
2	Meliaceae	6	0.11	0.72	4.92	4.92	22.37	17.29
3	Phyllanthaceae	65	0.01	0.08	52.46	52.46	2.13	105.63
4	Juglandaceae	1	0.00	0.00	0.82	0.82	0.10	1.67
5	Rubiaceae	3	0.12	1.35	2.46	2.46	23.92	12.89
6	Sapotaceae	15	0.08	0.74	12.30	12.30	16.35	30.04
	Total	123	0.48	4.37				

Biomass, Carbon Stock and Carbon dioxide (CO₂)

Results from Table 3 below show biomass, carbon stock, and CO₂ for all tree species encountered in the Mungulvu grazing reserve. A total mean height of 102.00m. The total biomass, carbon stock and carbon dioxide observed (7.94ton/ha, 3.97tons/ha and 14.56kg) respectively. *Nuclear latifolia* highest in biomass, carbon stock and CO₂ (2.10tons/ha, 1.05tons/ha and 3.85kg) respectively followed by *Azadirachta indica* (2.02tons/ha, 1.01tons/ha and 3.70kg) biomass, carbon stock and CO₂ respectively. Lowest biomass, carbon stock and CO₂ were obtained in *Carya glabra* (0.02ton/ha, 0.01ton/ha and 0.03kg) respectively followed by *Bridelia mollis* (0.08ton/ha, 0.04tons/ha and 0.15kg) respectively.

Table 3: Biomass, Carbon Stock and Carbon dioxide (CO₂) of Species in the Grazing Reserve

Mungulvu G.R	Species	MDBH (cm)	MHT (m)	Above Ground Biomass ton/ha	Below Ground Biomass ton/ha	Total Biomass ton/ha	Carbon Stock ton/ha	CO ₂ kg
1	<i>Acacia muricata</i>	23.4	5.2	0.26	0.04	0.30	0.15	0.56
2	<i>Acacia senegalensis</i>	24.67	7.9	0.30	0.05	0.35	0.17	0.63
3	<i>Azadirachta indica</i>	53.33	8.1	1.76	0.26	2.02	1.01	3.70
4	<i>Bridelia mollis</i>	14.04	8.5	0.07	0.01	0.08	0.04	0.15
5	<i>Carya glabra</i>	3.5	5.8	0.01	0.01	0.02	0.01	0.03
6	<i>Daniellia oliveri</i>	36.45	13.2	0.75	0.11	0.86	0.43	1.58
7	<i>Nuclear latifolia</i>	54.3	11.9	1.83	0.27	2.10	1.05	3.85
8	<i>Phileoptera violacea</i>	32.2	12.1	0.56	0.08	0.65	0.32	1.19
9	<i>Piliostigma thonningii</i>	17.78	8.6	0.13	0.02	0.15	0.08	0.28
10	<i>Prosopis Africana</i>	19.35	9.7	0.16	0.02	0.19	0.09	0.35
11	<i>Vitellaria paradoxa</i>	42.57	11	1.07	0.16	1.23	0.61	2.25
	Total		102			7.94	3.97	14.56

Soil Physical Properties in Mungulvu Grazing Reserve

The soils of the Mungulvu grazing reserve are predominantly sandy across all depths (73–83%), with low silt (10.87–20.07%) and clay (6.13–8.67%) contents, indicating a coarse-textured profile. Bulk density values are moderate and consistent (1.61–1.66gcm⁻³), suggesting minimal compaction, while particle density (2.10–2.33gcm⁻³) falls within the normal range for mineral soils. Total porosity is generally low to moderate (23.52–29.21%), with slightly higher values in surface and subsurface layers. Water holding capacity remains low to moderate (14.63–16.79%), reflecting the dominance of sand and limited clay content. The soils are well-drained but moisture-limited, which may constrain forage productivity during dry periods.



Table 4: The Descriptive Statistic for Soil Physical Properties in Mungulvu Grazing Reserve

Grazing Reserve	Soil Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Bulk Density(g/cm ³)	Particle Density (g/cm ³)	Total Porosity (%)	Water Holding Capacity (%)
Mungulvu	0-15	83.00±2.00	10.87±0.95	6.13±1.14	1.66±0.03	2.33±0.17	28.53±3.93	14.63±0.62
	16-30	76.67±8.74	15.00±4.70	8.33±4.39	1.62±0.08	2.28±0.09	29.21±0.89	16.33±2.60
	31-45	79.67±9.29	11.67±9.35	8.67±0.23	1.61±0.02	2.10±0.09	23.52±4.02	15.80±1.85
	46-60	73.00±6.93	20.07±6.22	6.93±1.03	1.63±0.04	2.21±0.11	26.31±3.41	16.79±1.54
	Total	78.08±7.34	14.40±6.44	7.52±2.26	1.63±0.05	2.23±0.14	26.90±3.66	15.89±1.75

Table 4.1: Soil Textural Class in the Grazing Reserve

GRAZING RESERVE	TEXTURE CLASSES
Mungulvu	Sandy loam Loamy clay Sandy



Chemical Properties of Soil in Mungulvu Grazing Reserve

The soils of the Mungulvu grazing reserve are slightly acidic to near neutral (pH 6.40–6.77) across all depths, a range favourable for nutrient availability. Electrical conductivity values are very low (0.05–0.09 dS m⁻¹), indicating non-saline conditions. Organic carbon (1.13–1.32%) and organic matter (1.94–2.27%) are moderate and decline slightly with depth, reflecting surface organic inputs. Total nitrogen is uniformly low to moderate (0.11–0.12%), suggesting limited N reserves. Available phosphorus is moderate (8.10–9.14 mg kg⁻¹), with minor depth-related variation.

Exchangeable bases are dominated by Ca (2.93–3.74 cmolkg⁻¹) and Mg (1.26–1.74 cmol kg⁻¹), while K remains moderate (0.53–0.58 cmolkg⁻¹) and Na is relatively low (0.52–0.67 cmol kg⁻¹). Total exchangeable bases (5.47–6.68 cmolkg⁻¹) and effective cation exchange capacity (7.31–8.52 cmolkg⁻¹) indicate moderate nutrient-holding capacity. Per cent base saturation is relatively high (67.55–78.50%), whereas exchangeable sodium percentage remains below critical limits (6.50–8.04%), confirming non-sodic soils. The soils are moderately fertile but constrained by low organic matter and nitrogen, which may limit productivity without fertility enhancement.



Table 5: The Chemical Properties of Soil in Mungulvu Grazing Reserve

Grazing Reserve	Soil Depth	PH (1:2)	EC (dS/m)	Organic	Organic	TN (%)	Av-P (mg/kg)	Ca (cmol/kg)	Mg (cmol/kg)	Na (cmol/kg)
	(cm)			carbon (%)	Matter (%)					
Mungulvu	0-15	6.67±0.24	0.05±0.01	1.32±0.22	2.27±0.37	0.12±0.02	8.26±0.24	3.74±1.84	1.74±0.57	0.67±0.11
	16-30	6.43±0.38	0.06±0.01	1.13±0.13	1.94±0.23	0.11±0.01	9.14±0.73	2.93±0.24	1.48±0.32	0.52±0.15
	31-45	6.40±0.10	0.05±0.01	1.17±0.15	2.02±0.26	0.11±0.02	8.66±0.77	3.31±1.01	1.26±0.79	0.59±0.14
	46-60	6.77±0.47	0.09±0.06	1.16±0.18	2.00±0.31	0.11±0.02	8.10±0.36	3.11±0.94	1.45±1.11	0.53±0.21
	Total	6.57±0.33	0.06±0.03	1.20±0.17	2.06±0.28	0.11±0.02	8.54±0.64	3.27±1.04	1.48±0.67	0.58±0.15
	Soil Depth (cm)	K (cmol/kg)	H (cmol/kg)	AI (cmol/kg)	TEB (cmol/kg)	TEA (cmol/kg)	ECEC (cmol/kg)	PBS (%)	ESP (%)	
	0-15	0.53±0.17	0.72±0.13	1.12±0.12	6.68±1.47	1.84±0.16	8.52±1.34	77.87±4.99	8.00±1.96	
	16-30	0.54±0.07	0.82±0.14	1.19±0.12	5.47±0.06	2.01±0.06	7.48±0.08	73.12±0.63	6.94±1.98	
	31-45	0.58±0.15	0.52±0.36	1.06±0.20	5.73±0.55	1.57±0.21	7.31±0.76	78.50±0.65	8.04±1.38	
	46-60	0.54±0.18	0.71±0.14	1.96±0.23	5.63±2.23	2.67±1.37	8.30±3.19	67.55±10.47	6.50±1.01	
	Total	0.55±0.13	0.69±0.22	1.33±0.66	5.88±1.26	2.02±0.73	7.90±1.60	74.26±6.76	7.37±1.56	

Values are means±SD



DISCUSSION

The results from the Mungulvu grazing reserve indicated that soil physical and chemical properties strongly regulate tree growth, species composition, and ecosystem functioning under grazing influence. The relatively low tree species richness (11 species from 6 families) and moderate tree density (62 trees ha⁻¹) suggest a simplified woody structure, typical of semi-arid grazing systems where anthropogenic pressure and moisture limitation constrain regeneration. Dominance of Phyllanthaceae and Fabaceae reflects the adaptive advantage of these families to nutrient-poor, sandy soils and recurrent disturbance, as widely reported for savanna and grazing landscapes (Tellen and Yerima, 2018, Umar *et al.*, 2026ab).

Biomass and carbon stock estimates (7.94 t ha⁻¹ biomass; 3.97 t ha⁻¹ carbon) are relatively low, reflecting the sparse woody structure and small stem sizes. Species such as *Nauclea latifolia* and *Azadirachta indica* contributed disproportionately to biomass and carbon storage, consistent with findings that few dominant species often account for most carbon stocks in savanna woodlands (Feyisa *et al.*, 2022). The low contribution of species such as *Carya glabra* and *Bridelia mollis* further highlights structural inequality within the stand.

Soil physical properties reveal a predominantly sandy texture (73–83%), with low clay content and moderate bulk density, resulting in low water-holding capacity. Such soils are well-drained but highly prone to moisture loss, which strongly constrains tree growth and biomass accumulation during dry seasons.

Soil chemical properties indicate slightly acidic to near-neutral soils, low salinity, moderate base saturation, and moderate ECEC, suggesting generally favorable chemical conditions. However, low organic carbon and total nitrogen point to nutrient limitations, particularly for sustained growth.

CONCLUSION AND RECOMMENDATION

The study demonstrates that tree diversity, structure, and productivity in the Mungulvu grazing reserve are primarily controlled by soil physical constraints and grazing pressure rather than by soil chemical fertility. The dominance of a few well-adapted species and the moderate but uneven diversity reflect adaptation to sandy, moisture-limited soils. Strong relationships between tree size variables and soil texture, particularly the positive influence of clay content and water-holding capacity, indicate that moisture availability is a key driver of tree growth and biomass accumulation. Although soil chemical properties are generally favourable, low organic matter and nitrogen, together with coarse soil texture, limit overall productivity. Therefore, improving soil moisture retention and reducing grazing pressure are essential for enhancing woody vegetation diversity, growth, and carbon storage in the Mungulvu grazing reserve.

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