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Full Length Research

Evaluation of Stem Volume, Litterfall, and Soil Fertility of *Azadirachta indica* A. Juss and *Eucalyptus camaldulensis* Dehnh at Shelterbelts in Kiyawa, Jigawa State Nigeria

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Abstract

This study was carried out in the year 2021 at Kiyawa community which aimed to investigate stem volume, litterfall and soil status in two different shelterbelts. 1-kilometer line transect was laid with four sample plots established (30 × 30m) which were used for collecting data on the tree with an interval of 100m from each plot. Also, 1×1m mini-plots were used for measuring quantity of litters. Diameter at breast height and height were accessed with the aid of meter rule and Haga altimeter while volume and Basal area were calculated. Litterfall was collected, weighted with the aid of sensitive weight and oven-dried for 48hrs under 70°C constant temperature. Inferential statistic such as ANOVA and t-test were used for analysis. The results showed that *Azadirachta indica* sampling plots had the highest volume of 1941.55m^3 followed by the *Eucalyptus camaldulensis* hotspot which had the least value of 695.7m^3. The physical property of soil in the sites showed that the Neem shelterbelt had the highest percentage of sand (83.00%) and lower percentage of silt (4.00%) and clay (13.00%) compare to Eucalyptus plots which are sand (81.00%), silt (5.5%) and clay (13.50%.) respectively. Neem hotspot had the highest mean nitrogen and phosphorus content of 1.05 g/kg and 10.24 mg/kg followed by Eucalyptus hotspot with 0.19 g/kg and 9.25 mg/kg respectively. Eucalyptus sample plot had the highest mean value of potassium, pH and litterfall which was 0.44cmol/kg, 6.32 and 717.8g±3.96 compare to Neem sample plots which are 0.20cmol/kg,6.24 and 694.6g±1.43. Analysis of variance showed that there were significant differences (p<0.05) among parameters for both chemical and physical properties. Litterfall proved to be significant. The Shelterbelt serves as a protection for the soil as well as promoting the fertility and productivity of the soils to support a flourishing vegetation types in the area. Therefore, it is recommended that Neem Shelterbelt supported the performances of stem volume, chemical and physical soil properties in Kiyawa, Dutse Jigawa State.

Keywords: *Azadirachta indica*, *Eucalyptus camaldulensis,* Kiyawa shelterbelts, litterfall, Physico-chemical parameters, soil fertility and stem volume.

INTRODUCTION

Plant species can influence the composition of underlying soil microbial communities (Garbeva et al., 2006). These influences can be due to differences in canopy cover, rooting depth, and litter quality and quantity (Gregory, 2006). It could also be due to secondary effect on soil pH, moisture, and nutrient levels (Gregory, 2006). Forest trees substantially affects soil physical, chemical and biological properties by species-specific stem flow, root architecture, leaf and root litter input, root exudates, nutrients uptake, shade, and micro climate (Cesarz et al., 2013). Understanding these processes and how they are influenced by environmental conditions helps optimizing nutrient availability and plant productivity. Nutrient supply to plant roots is a very dynamic process (Salami et al., 2020). Invasive woody plant trait from native plants has the potential to alter soil microbial communities, which may turn affect biogeochemical cycling and ecosystem functioning (Carney and Matson, 2006). Because of direct or indirect tree effects, change in the spatial distribution of microbes, vertically through the soil profile as well as horizontally with increasing distance from tree trunks, can occur (Cesarz et al., 2013).

Any loss in microbial diversity has consequences of environmental changes such as land use, nitrogen enrichment and climate change would alter the capacity of microbes to sustain multiple above and below ground ecosystem functions (Florentino et al., 2012). According to Van Der et al. (2008), soil microbes, especially those that live in symbiosis with plants, also contribute to plants diversity.

Soil fertility, geographic position, climate, herbivores and disturbance are major factors to influence plants species richness. All these constitute major factors that determine the composition and diversity in plant community (Mercel et al., 2008). According to Hartman *et al.* (2008), the volume of soil and living roots which are influenced by root metabolism is known as the rhizosphere. As plant roots grow, they release water- soluble compound such as amino acids, sugar and organic acids that supply food for the microorganisms. The food supply as a result of microbiological activities in the rhizosphere is much greater, than in soil away from plant roots. The climate in Jigawa is one of the moderate weathers in Nigeria which makes woody species like *Azadirachta indica* and *Eucalyptus camaldulensis* with hard cambium thrive well compared with other regions. The Neem and Eucalyptus trees have the ability can adapt to the semi-arid condition which makes it well known among the woody tree species in the area. The shelterbelt is managed with little or no consideration for the improvement under soil ecosystem. These shelterbelts were established in late 1980's at the same time. The main aim of the study is to assess the Stem volume, Litterfall, the Soil fertility at the two different Shelterbelts in Kiyawa, Jigawa State with the view of making proper management plans and policy making.

MATERIALS AND METHODS

Description of the Study area

The Shelterbelt was established in 1989 by the Department of Forestry, Ministry of Environment, Kano State. Jigawa and Kano were ruled under the same government. Kiyawa Local Government Area later fall under Dutse Emirate. It covers an area up to 3ha which is equivalent to 0.03 square kilometers. The Shelter belt comprises both Neem and Eucalyptus planted in rows (Plate 1 and 2) (JARDA, 2016).

Kiyawa is located at latitude 11°47′05″N 09°36′30″E and longitude 11.78472°N 9.60833°E and has an estimated population of 17,704 (NPC, 2016). Kiyawa is among the food producers not only in Jigawa State but in Nigeria (Figure 2). During raining season people of Kiyawa are seeding farm crops like millet, guinea cone, rice, groundnut, beans, and maize Likewise in dry season farmers in Kiyawa make their way to the pond for irrigation, seeding watermelon, sweat melon, tomato, pepper and wheat. The rain season lasts for 2months, from March 17 to May 22, with an average daily high temperature above 100°F. The wet season lasted for 3 months with mean daily temperature above 37.78°C. Annually, April 13 appears to be the hottest day with least and high temperature of 22.78°C and 39.44°C respectively. Furthermore, dry season lasts for 2 months which ranges from December to January, with an average daily high temperature below 32.78°C. The coldest day of the year is January 2, with an average low of 12.22°C and high of 30.5°C. A wet day is one with at least 0.04 inches of liquid or liquid-equivalent precipitation. The

Plate 1: Shelterbelt of *Azadirachta indica* (Neem).
Source: Field source (2021).

chance of wet days in Kiyawa varies very significantly throughout the year. The rainy season lasts 4months, from May 17 to September 30, with a greater than 38% chance of a given day being a wet day. The chances of a wet day peak at 75% on August 16. The dry season lasts for seven and half months, starting from September, 30 to May, 17. The smallest chance of wet day is 0% on January 1, Jigawa Agricultural Rural Development Agency (2016).

Sample Plot Demarcation and Design

Systematic sampling design (Systematic line plot) was employed for the laying of the plot in the shelter belt. A line transected was laid at the center of the Shelterbelts (Figure 1). Four (4) Sample plots of equal sizes (30 by 30m) was laid along a line transect at 100m intervals. A total area of 7,200m^2 was sampled out of 3ha (Onyekwelu et al., 2007; Salami and Akinyele, 2017; Salami and Akinyele, 2018). The sampling intensity was 2.4%.

Data collection

Floristic survey

The vegetation of the study sites was surveyed in order to document composition and abundance of the species. In the study sites, systematic sampling methods were adopted to generate data on the floristic composition of the study sites.

Measurements of Tree Growth Variables in the Plantation

Identified and measured trees were woody plants with diameter height between ten (10cm) Diameter at breast height, and above. The tree growth variable

Plate 2: Shelter belt of *Eucalyptus camaldulensis*,
Source: Field source (2021).

measured included: Diameter at breast height measured with girth tape while basal area and volume were evaluated.

Soil Sample Collection

Soil samples were collected with the use of soil auger in study areas. The samples were collected at depths (1-15cm depth) each. Soil samples were determined in the study areas by establishing a sub plot (1 x 1m) in each plot during inventory period. The collected samples were put in to small sterilized polythene bags. The Petri plates were then incubated at 28°C to 30°C in dark. The plates were observed for seven to nine days.

Litter collection

The weight of Litterfall was determined from the established two (2) sub-transects (1mx 1m) in each plot during the inventory period. Sample of Litters was collected from four (4) sample plots. Initial weight was assessed and later oven dried for 48hours at 70^{0}C (Salami et al., 2020; Chanh et al., 1991).

Data Analyses

Stem Volume Estimation

The volume of individual trees encountered in the plots. Mean volume for sample plots was calculated by dividing the total plot by the number of sample plots. Volume per hectare was obtained by multiplying the mean volume per plot (VP) with the number of 50×50m plots (Salami, 2017)
The volume of all trees in the sample plots was calculated using this formula:
V = B.A× H ……………….. (Eqn. 1).
The data collected was analyzed using descriptive statistics such as: tables and bar chart

Basal Area Calculation

The basal area of all trees in the sample plots was calculated using the formula:
$BA = \frac{\pi D^2}{4}$ ....(Eqn. 2)
Where **BA** = Basal area (m^2), **D** = Diameter at breast height (cm) and Pie (3.142).
The total basal area for each of the sample plot was

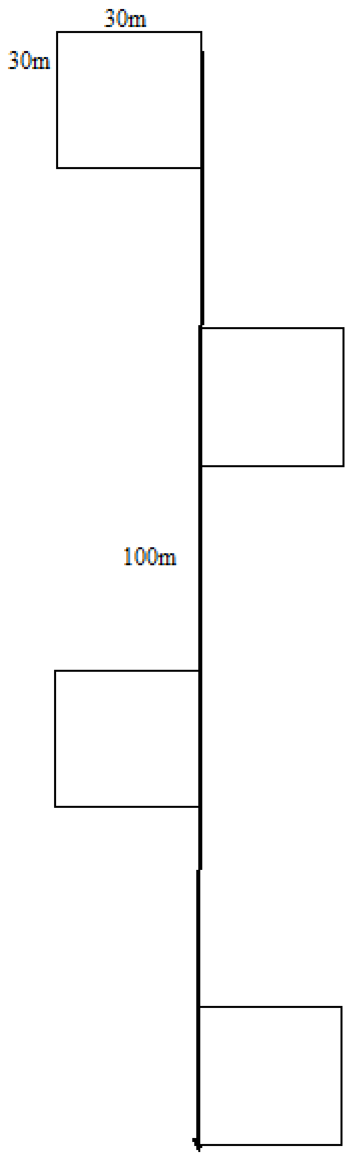

Figure 1. Plot Layout with Systematic Line Transects Sampling Technique.

obtained by adding the BA of all trees in the plot while mean BA for the plot (*BAp*) was obtained by dividing the total BA by the number of sample plots. Basal area per hectare was obtained by multiplying mean basal per plot with the number of 50 × 50m plots in a hectare (4).
Where *ha BA* = Basal area per hectare
Where BA = Basal area (m^2), D = Diameter at breast height (cm) and Pie (3.142).
The soil pH was determined with the aid of glass electrode pH meter in soil solution of 0.01 mol L^{-1} calcium chloride (Ogunwale et al., 2021).

Data analysis

The results from the soil laboratory experiment were subjected to an ANOVA test for a significant difference in their nutrient contents. Analyses were carried out using SPSS software. Data collected on litterfall, percentage of litterfall mass remaining during the study was analyzed using T- test to determine the level of significance.

RESULTS AND DISCUSSION

A designed assessment for exploratory checklist inventory of biodiversity and community structure in two different shelterbelts of Neem and Eucalyptus are presented in the Tables 1-5. A total of one hundred and three (103) and one hundred and five (105) stands were identified in the Neem and *Eucalyptus camaldulensis* shelterbelt respectively. Inventory showed that Eucalyptus plots had more stands than Neem plots.

Physical Properties of Soil

The mean physical attributes of soil samples of the Neem and Eucalyptus Shelterbelts in Kiyawa were assessed. The results are revealed in Tables 1-5. Soil texture refers to the degree of fineness or coarseness of the diverse soil particles; it represents particle sizes constituting the soil. Soil texture classes describe the amount of sand, silt and clay percentages. In this study, for Neem, the soil samples were sandy-loam in nature while Eucalyptus was sandy-loam in nature too (Table 1). Physical properties of forest soils may be 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. The physical properties of forest soils affect every aspect of soil fertility and productivity (Osman, 2013). The interaction of numerous physical, chemical and biological properties in soil controls plant nutrient availability. Understanding these processes and how they are influenced by environmental conditions assist in optimizing nutrient availability and plant productivity**.** The percentage mean of clay content in the Neem shelterbelt was found to be 13.00%±5.39 (Table 1) while Eucalyptus plots found to be 13.5±6.89%. The percentage mean of silt content in the shelterbelt was higher than Neem plots with 5.5%±4.24 and

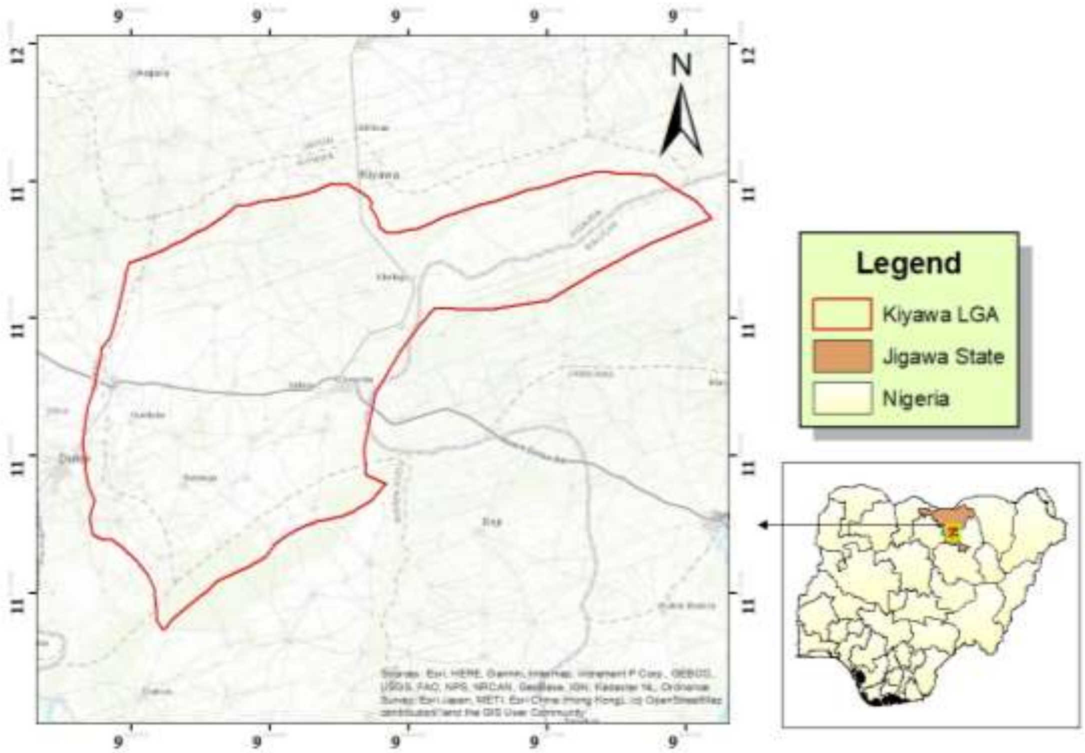

Figure 2. Showing map of Kiyawa.

Table 1. Mean of Physical Properties of Soil in the Two Study Sites.

Study site	%Sand	%Silt	%Clay	Textural classes
Neem	83.00±5.89	4.00±2.80	13.00±5.39	Sandy loam
Eucalyptus	81.00±3.43	5.5±4.24	13.5±6.89	Sandy loam

Source: Field survey (2021)

4.00%±2.80 (Table 1) respectively. The percentage mean of sandy content in the shelterbelt was higher Neem plots than Eucalyptus plots with 5.5%±4.24 and 4.00%±2.80 (Table 3) respectively. The ANOVA indicated that there were significant differences among the means of the clay, sand and silt contents respectively. Texturally, the studied soils were sandy loam (Table 1). Tete-Mensah (1993) reported that soils with loose particles such as sand results into a single grain structure while those that are clayey rich with fine grained particles usually become firm (hard pan), impermeable for water and impede penetration of plant roots. Izwaida et al. (2015), reported significant importance of clay in formation of organic matter and its capacity to retain the nutrients in the soil as well as influencing the nutrient level of the soil. According to Fisher and Binkley (2000) the main difference in the soil texture is the surface areas of different particle sizes which affect water potential, organic matter binding cation exchange and overall biotic activity. Therefore, the texture of the soil has great influence on the development of soil aggregates. Soil structure another important factor for plant growth according to is developed through help of soil biota such as earthworms and microbes which in turn creates openings for water, entrance for air, secretes sugars and glues which can bewilderment silt and clay particles together to form aggregates (Chinevu et al., 2013). Thus, the appreciable amounts of silt and clay in the studied

Table 2. Mean of Chemical Properties of Soil in the Two Study Sites.

Parameter	Study site	Min	Max	Mean	Total	S.E
%Nitrogen	Neem	0.63	1.64	1.05	4.18	±4.12
	Eucalyptus	0.17	0.70	0.19	0.75	±2.89
Phosphorus mg/kg	Neem	7.98	12.04	10.24	40.97	±3.89
	Eucalyptus	6.25	11.36	9.25	36.99	±3.23
Potassium Cmol/kg	Neem	0.18	0.21	0.20	0.78	±0.26
	Eucalyptus	0.28	0.63	0.44	1.74	±2.23
pH	Neem	6.20	6.30	6.24	24.97	±0.23
	Eucalyptu	6.07	6.72	6.32	25.29	±1.34

Source: Field survey (2021)

Table 3. Showing Growth Assessment of *Azadirachtai ndica* and *Eucalyptus camadulensis* Shelterbelt

Parameters	Study site	Min	Max	Total	Mean	Standard error
DBH(cm)	Neem	19.5	145	8441.75	82.25	±1.23
	Eucalyptus	18.0	107	6562.25	62.50	±0.93
Basal area (cm)	Neem	0.15	1.65	92.70	0.90	±0.15
	Eucalyptus	0.025	0.90	48.56	0.463	±3.43
Height (m)	Neem	2.90	13.00	818.85	15.90	±0.24
	Eucalyptus	1.20	6.30	393.75	3.75	±0.03
Volume (m^3)	Neem	56.55	1885	99,989.8	970.78	±4.27
	Eucalyptus	21.60	674.1	36,524.25	347.85	±2.43

Source: Field survey (2021)

soils suggest that the soil from Shelterbelt in the studied areas had a good structure. Generally, all soil samples from Kiyawa Shelterbelts were dominated by high % sand fractions followed by % clay and lastly % silt. The variation in particle size pattern signified that these soils were not formed from the natural agent of basic parent material but quite from deposited particles from erosion similar agent (Ogunwale et al., 2019).

Chemical Properties

Table 2 show the result of chemical properties of the topsoil in both sites. The result showed percentage of nitrogen in the two locations as it ranges from 0.17% to 1.64%. The highest mean percentage of nitrogen from Neem followed by Eucalyptus with 1.05±4.12% and 0.19±2.89% respectively. Ogunwale et al. (2021), reported that nitrogen content is an indicator of biomass and they are a contributor to the general renewal of microbial plants. Naturally, if it is below 0.20%, it will be good enough to satisfy the N requirements of micro flora that decay the remains (Ogunwale et al., 2021). In line with Ogunwale et al. (2021) the low levels of nitrogen values showed high disintegration and effective mineralization activity of the soil site. In this work, percentage nitrogen in soil was higher in the Neem due to the oxidation of dead plant organic-litter which was more on the top soil stratums. The organic carbon as a decomposed matter of litter from shelter belts which plays a major role in soil structure and texture.

About phosphorus, the values varied from 7.98 to 12.04 mg/kg and 6.25 to 11.35 mg/kg, yielding an overall mean of 10.24 mg/kg and 9.25 mg/kg for Neem and Eucalyptus, respectively (Table 2). The power of poultry soil to keep or emit P is one of the significant occurrences which govern the content of inorganic/organic P in the overlying soils. In this work, higher values of inorganic P were recorded Neem

Table 4. Showing the Quantity of Litterfall in the Study Areas.

S/N	Initial Weight for parts of Neem (g)	Initial Weight for parts of Eucalyptus (g)	Percentage weight for parts of Neem	Percentage weight for parts of Eucalyptus
1	95.8	75.9	13.792	10.574
2	134.4	67.8	19.349	9.445
3	38.3	84.7	5.514	11.799
4	108.2	100.3	15.577	13.973
5	25.9	79.5	3.729	11.075
6	46.1	76.0	6.636	10.587
7	98.3	79.5	14.152	11.075
8	85.5	65.5	12.309	9.125
Total	**694.6±1.43**	**717.8±3.96**	**100**	**100**

Parts of plants- Dry leaf, seeds, barks and twigs.

Table 5. Model Fitting Results.

Parameters	Probability level	Model	Significant
Physical property	0.05	ANOVA	**
Chemical property	0.05	ANOVA	**
Litterfall (g)	0.05	t-test	**

Keys: ns Not significant; **: Significant

sample and low values in Eucalyptus. The higher values available may stem from decomposing dead organic matter from the top soil layer and possibly, dissolution of phosphorus containing underlying rock soils or applied phosphate fertilizers. All the soil samples had elevated K^+ values over 0.15 Cmol/kg soil which is regarded as lower value for fertile soils (Ogunwale et al., 2021). Exchangeable K^+ ranged from 0.18 Cmol/kg soil to 0.63 Cmol/kg soil in Shelterbelt soils for the two woody species; these values were beyond 0.15 Cmol/k soil, which is given as the guideline limit of exchangeable K^+ in soils (Ogunwale et al., 2021). Interpreting is that the soil was abundant in nutrients; an evidence of healthy produce ability outside of any input of inorganic fertilizers.

pH is defined as a measure of the degree of acidity or alkalinity of the soil. Soil pH below 7 is said to be acidic and above 7 is alkaline while 7 is neutral. Soil pH varied from 6.20 to 6.30 in Neem and 6.07 to 6.72 in Eucalyptus (Table 2) signifying a slightly acidic pH. As a result, slightly acidic soil from both Neem and Eucalyptus site may likely due to the presence of acid parent materials and nutrient uptake by Neem and Eucalyptus during the period of sample collection (Ogunwale et al., 2021). The soil pH was higher in Neem (6.24) than Eucalyptus (6.32) probably as a result of redox variations in the soils and water column aside from the impact of weather (Ogunwale et al., 2021). Soil in Savannah shelterbelt is likely to possess slightly acidic pH as notified by several authors (Ogunwale et al., 2021; Salami et al., 2020).

Stem Volume and Basal Area

The result of the stem volume showed (Table 3) that *Azadirachta indica* had the highest mean volume of 970.78 ±4.27m^3 followed by *Eucalyptus camaldulensis* which had the lowest volume of 347.85±2.43m^3. However, the results were obtained from two different studies sites. It showed that *Azadirachta indica* had the greatest volume not only even volume even in terms of richness, height and growth compared to *Eucalyptus camaldulensis.* Mean basal area obtained was 0.90±0.15m^2 from Neem shelterbelt which implied that the study area had a high values of trees density and values that can be useful when properly managed and harvested for human purposes such as the construction of furniture's, electric poles, foal fuel, charcoal production followed by 0.463±3.43m^2. The inventory count of different species in the study area was fifty (50) in number. This disagrees with Salami et al., (2021) whose reported lower mean volume and Basal area at the two different shelterbelts.

Quantity of Litterfall

Litterfall production in two shelterbelts was determined by climatic condition, species composition and succession stage in its development (Haase, 1999). In this study, the total observed litterfall in Neem shelterbelt was higher than Eucalyptus with value of 694.6g±43, and 717.8g±96, respectively (Table 4). There is a significant difference between the study sites. Xu and Hirata (2002) observed that significant differences among *Castanopsis kawakami* (NF) and adjacent monoculture plantations of *C. kawakami* (CK) and Chinese fir (*Cunninghamia lanceolate*, CF) could be attributed to tree behavior. Weng *et al.* (1993) also reported that the litter production in the CK and CF was lower than NF likewise (Zheng et al., 1995).

CONCLUSION

Assessment for stem volume of Neem stands and Eucalyptus in Kiyawa Shelterbelt was investigated. The result showed that the *Azadirachta indica* had the highest volume compare to *Eucalyptus camaldulensis hotspot* which has the lowest volume. However, the results were obtained from two different study sites which showed that, the *Azadirachta indica* has the highest volume and better quality in terms of richness, height and growth compared to *Eucalyptus camaldulensis.*

The physical properties of soil in the two study sites showed that Neem shelterbelt had the highest percentage of sand but was lower in terms of silt and clay. The study showed that Neem plots had the highest mean of nitrogen and total phosphorus. The potassium content (Cmol/kg) of Eucalyptus plots was higher than Neem plots in terms of mean and total. The study showed that soil texture is one of the most important factors influencing the physical and chemical properties of the soil. Soil physical and chemical properties were the dominant factors influencing the extent of decomposition process. Thus, the forest reserve serves as protection for the soil as well as promoting the fertility and productivity of the soils to support a flourishing vegetation types in the area. Neem biological hotspot is a good signal for farming activities, agroforestry practices should be encouraged, community involvement, motivation and punishment of offenders, it is recommended that Neem Shelterbelt supported the performances of stem volume, chemical and physical soil properties in in Kiyawa, and Dutse Emirate, Jigawa State. It is hoped that this study will be of value to forest managers, policy makers and growth modelers. It is believed that this study will provide a basis for further data collection management at Kiyawa Shelter belt.

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