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Full Length Research

Assessment of Site Index and Site Quality for *Azadirachta indica* A. JUSS Plantation in Warwade, Dutse, Jigawa State, Nigeria

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Documentation of site index and soil characteristics for harvesting of neem must be known due to the improvement of the database for the study site. Therefore, the study was carried out in the Warwade plantation to investigate the growth attributes, site quality and index of neem plantation. Double line transects 200m apart were laid with two plots of equal size (30m × 30m) for the collection of floristic information and a 1 x 1m sample plot was established in each of the main plots for soil assessment. Diameter at breast height and height were accessed with the aid of diameter tape and spigeal relascope while the volume and basal area were calculated. The soil samples were analyzed in a laboratory for physiochemical properties while the derived site index equation used in the study area was SI = exp[ln(Hd)- b_1 (A^{-1}) 141.26.60m^3]. The result showed that the site had a total volume and Basal area of 141.26.60m^3 and 339998.19m^2 respectively. The study area is sandy loamy with 83% of sand, 4% of silt and 14% of silt respectively. The area is acidic but with a low amount of nitrogen which results from farming. The site index showed that the site is dominated by trees, 10m in height with a harvesting age of 30 years was found appropriate for the plantation. The study showed that soil texture is one of the most important factors influencing the physical and chemical properties of the soil and nutrients of the plantation. Therefore, selective harvesting, proper farming activities, and further re-establishment of plantations in reserve should be encouraged.

Keywords: Assessment, Site index, Site quality, Neem plantation and Warwade dam

INTRODUCTION

The increase in demand for wood and its products in Nigeria has put much pressure on natural forest resources, depleting and resulting in a situation in which resources can no longer meet current and future needs. Consequently, there has been a shift from tropical natural forest management to management of plantation of only exotic species like *Azadirachta indica* (neem) (Forestry Monitoring and

Evaluation Unit, 1991). There is a shift in emphasis from the management of natural forests to plantation forests by the forestry service (Onyekwelu and Akindele, 1995). Forest plantations were only established to make sure the desired size and volume were achieved in the shortest possible time to ensure the continuous supply of wood raw materials to wood base industry (Ogunwusi, 2013).

The features of forest plantation (trees), intensity of production, high density, fast growth rate, high productivity, etc. have raised concerns that many of the sites on which the plantations are established may be incapable of sustaining their productivity (Onyekwelu et al., 2006). Site assessment is an intensive measure of site (soil) quality, and it generally reflects on the potential productivity of a stand of trees on the plantation (Hanson et al., 2002). Soil is a complex and dynamic ecosystem where substantial physical, chemical, and biological processes take place (Jelena et al., 2018). According to Nannipieri et al. (2003), the most important biological processes in soil (80-90%) occur due to microbial enzyme systems reactions. Rousk et al. (2008), stated that soil chemical and physical characteristics are major factors of soil microbial community structure. The physico-chemical properties of soil are ultimately related to soil fertility which intends to affect the floristic composition of the forest. There is a mutual connection between the soil microflora and the vegetation of an ecosystem. Microorganisms help in the mineralization and decomposition of plant materials to a form that can be absorbable by plants (Pietikainen, 1999). Sigstad et al. (2002), also pin-pointed that bacterium as the most occurrences and it is through their metabolic activity that minerals and soil organic matter are transformed in a way that important nutrients such as N, P, and S are simultaneously converted into assimilable forms for plant and other micro-organisms.

Soil fertility is the capability of the soil to provide plant nutrients and water in adequate amounts and when required, for good growth and development of the crops. Soil fertility decline is a deterioration of chemical, physical and biological soil properties and subsequent reduction in providing the crops with adequate nutrients and water (Gbenga, 2020). The major ecological role of soils in forests and the natural environment cannot be overemphasized. Soils are significantly affected by geologic and geomorphologic factors (water, wind, temperature change, gravity chemical interaction. topography, vegetation, living organisms and pressure differences) (Boul, 1990). Different characteristics of soil such as depth, consistency, temperature, nutrient contents, moisture content, permeability, porosity, etc. can greatly influence the nature of vegetation that grows on them (Boyle and Powers, 2013, Salami and Akinyele, 2023). The physical, chemical and biological processes sustained by soil make it a dynamic zone, consisting of inorganic (rocks) and organic particles (plants and animals remains), liquid (water and chemicals in solution) and gaseous substances (Isah et al., 2014). Nutrients and water needed by trees to grow are provided by soil; while trees and other plants are important factors in the formation and enrichment of soil (Food Agriculture Organization [FAO], 2015). The biological nitrogen fixation, phosphorus solubilization and decomposition of organic matter in rhizosphere and non-rhizosphere zones of plants increases soil organic matter, improving soil structure and nutrient cycling of soils (Schoenholtz et al., 2000). Likewise, the gathering of nutrients by different tree species as well as their potential to return these nutrients to the soil can cause variations in soil properties (Rawat, 2005). The relationship between trees and soil is important since they are dependent on each other and on the environment as a whole (Food Agriculture Organization, 2015). Therefore, this study aims to develop the site index equation for *Azadiractha indica* of different ages in Warwade plantation in view of enabling the management of the plantation to predict the productivity of the plantation.

MATERIALS AND METHOD

Study Area

This study was carried out at Warwade Forest Reserve which was about 6km away from the capital city of Jigawa State. It was established during the administration of former military governor Audu Bako in the 1970s (Ringim and Shafiu, 2019; Ilu et al., 2021; Salami et al., 2021). The reserve is located between latitude 11^0.43' 30"N - $11^0$46'30"N and longitude $9^0$11'30"E - 9^0 16'30"E. The relief is flat with little undulation (Tasiu, 2018). The geology of the area is a sedimentary formation of the Chad basin (Olofin, 1987). The soil type is sandy-loam, loamy and clay-loam soil respectively (Jigawa Agricultural

Rural Development Agency, 2016; Jibo et al., 2021). The area is characterized by low surface water and high groundwater. The water table of the area is from 25m to 50m (Tasiu, 2018). It covers a surface area of 526.0 ha, a height and Reservoir of 10m and 12.3m^3 (Salami et. al., 2021). The optimum day temperature at day time is 29-33^{0}C and declines to 19-23^{0}C at night, annual rainfall per year is 1200 to 1500mm. Fishing activities take place regularly day and night by local fishermen. Also, some agricultural activities are carried out by local farmers both in the rainy and dry seasons (Salami et al., 2019; Salami et al., 2020; Salami et al., 2021).

Warwade Plantation

Warwade plantation was established to reduce water evaporation from the dam. It serves as a habitat for many bird species and reptiles within the dam. They also act as a giant filter clearing the air we breathe. Warwade Dam plantation was established in the 1970s to support diverse vegetation of plant species including shrubs, herbs and trees. Some important plant species are Neem (*Azadirachta indica)*, which are dominant species and some shrub species include: Kharroub (*Piliostigma reticulum*), Kapok tree (*Calotropis procera*) and grass species: Coco grass (*Cyperus rotundus*), Sickle pod (*Cassia tora*) and Cane grass *(Eragrostis tremula*). The reserve is also used for propagating arable crops (rice, sorghum) during the rainy season. The area is comfortable and attractive. Different plant species and shrubs dominated are: *Acacia species*, *Adansonia digitata*, *Azadirachta indica* and *Mangifera indica* are found within.

DATA COLLECTION

Tree Enumeration and Measurement

The floras of the study area were surveyed to document the composition and abundance of the species. All Woody plants with diameter at breast height (Dbh) of 10 cm and above were enumerated. Tree growth variable such as the diameter at the base (Db) and diameter at the breast height (Dbh) were measured using measuring tape in centimetre (cm) while the diameter at the top and the height were assessed using Spiegel Relaskop in centimetres(cm). Basal area and volume were determined using equations 1 and 2.

Soil Sample Collection

Soil samples were collected for each of the sample plots with the aid of a soil auger. The soil samples were collected at a depth of 0 -15 cm. All soil collected within the sample plot at a particular depth was bulked and mixed. The bulked samples were air dried and sieved with a 2 mm sieve and taken to the laboratory for a fertility test.

Sampling Technique for Floristic Composition and Soil

The laying of the plot was carried out using the systematic line transects (Figure 1). Two parallel transects of 200 m apart were laid. Thereafter, two sample plots of equal size (30m × 30m) were alternately laid on each transect for the collection of floristic information and a 1 x 1m sample plot was laid in each of the measured plots for floristic purposes for soil assessment.

DATA ANALYSIS

Basal Area Calculation

The basal area of all the trees in the sample plots was calculated using the formula:

$$BA = \frac{\pi D^2}{4} \quad \text{(eqn 1)}$$

Where BA = Basal Area (m^2), **D** = diameter at breast height (cm) and **π** = (3.142).

Volume Calculation

Using smailian's formular:

V = h(Db+Dt)/2……..(eqn 2)

Site Index Estimation

Site index is simply a measure of the height of dominant and co-dominant trees in a stand at a given base age. Dominant and co-dominant trees are used to describe site index because they are assumed to have grown free throughout their life; thus, the growth of the tree is somewhat independent of other vegetation.

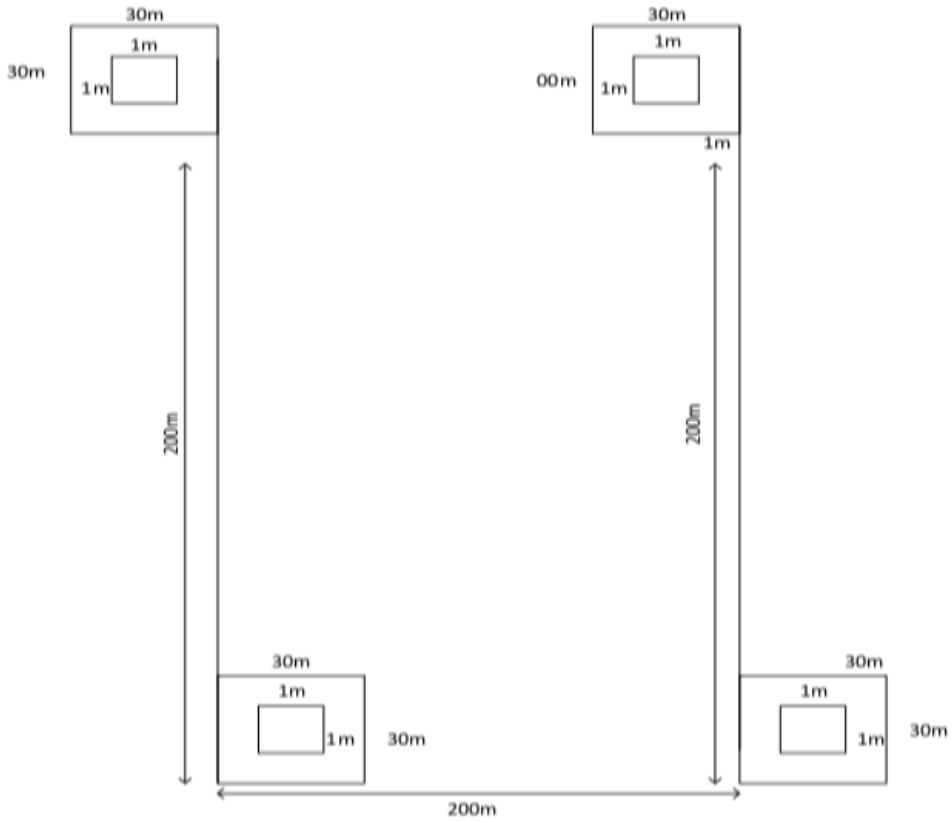

Figure 1: Systematic Line Transects

Development of the Site Index Equations

$SI = \exp[\ln(Hd) - b_1 (A^{-1})]$.
$SI = \exp[\ln(Hd) - b_1 (A^{-1})]$
where SI =site index
ln =natural logarithm
Hd = height of dominant trees
A^{-1} = tree age, b_1 = regression constant.

Soil Fertility Determination

Soil samples were collected from each layer separately, air-dry and sieved through a 2 mm sieve. The selected soil physicochemical properties that were investigated are: Sand, silt, clay, soil pH, potassium, nitrogen and phosphorus.

RESULTS

Site index is the measure of the average height dominate and co-dominate tree species on the site. Site index of *A. indica* reveals the site quality is good and trees are responding well to the silvicultural practices which site is subjected to. On the average, the site index can be used to predict for the trees of the same species with similar site conditions.

DISCUSSION

Community structure index

Consequently, the descriptive statistics of the tree growth variable obtained as shown in Table 1 indicated that total basal area and volume per hectare are 339998.19m^2 and 141.26m^3 ha^{-1} respectively. The mean Dbh and volume per hectare were found to be 22.2cm and 174.40m^3 ha^{-1} respectively. The value obtained for the basal area is an indication of a well-stocked forest (Alder and Abayomi, 1994) and (Nurudeen et al., 2014). The

Table 1: showing the tree growth variables

Parameter	Minimum	Maximum	Total	Mean	Std. Deviation
Dbh (cm)	9.87	34.70	1802.91	22.26	5.55
Dm (cm)	7.64	35.33	1761.53	21.75	5.81
BA (m^2)	754.87	9332.53	339998.19	4197.50	1972.43
Height (m)	4.00	12.30	632.51	7.81	2.25
Volume (m^3)	34.38	408.71	141.27	174.40	78.87

Source: Field survey, (2022).

Table 2: showing the height distribution for Neem in Warwade Forest Reserve.

Height (m)	Number of plants	Percentage (%)
0-5	7	8.64
6-10	64	79.00
11-15	10	12.35
Total	**81**	**100.00**

Source: Field survey, (2022).

Table 3: showing the diameter distribution.

Diameter classes (cm)	Freq/ha	Percentage (%)
10-20	0	0
21-30	1	1.24
31-40	4	4.93
41-50	3	3.70
51-60	6	7.40
61-70	27	33.33
71-80	18	22.22
81-90	15	18.52
91-100	2	2.47
>100	5	6.17
Total	**81**	**100**

Source: Field survey, (2022).

mean Dbh and height encountered (22.26cm and 7.80m) is an indication that most of the trees encountered in the study area are above the minimum merchantable size of 48cm stipulated by the logging policy of northwestern Nigeria.

Height distribution

The result from Table 2 showed that the height of all trees sampled in the plantation ranged between 0 to 15m. The range of height of the tree between 6-10m had the highest percentage (79%) followed by 11-15m with the value of 12.35%. The least performance range was 0-5m with the value of 8.64%. This is in line with the work of Salami et al., 2021 who got similar results from Warwade plantation. This implied that the little differences in the height distribution are attributed to improper management practices and competition with farmers within the reserve.

Diameter distribution at breast height

There was a higher number of stems per hectare in the diameter classes of 61-70cm with population sizes of 27 trees (33.33%) in Warwade Forest Reserve. Diameter ranges of 71-80 cm had 18 trees/ha (22.22%), while the diameter class of 81-90cm had 15 trees/ha (18.52%) in Reserve. A smaller number of stems per hectare was recorded in diameter classes of 91-100 cm in the

Table 4: showing the Mean Values of Soil Physical Properties.

Study site	Sand %	Silt %	Clay%	Textural classes
Neem	83.00±5.89	4.00±2.80	13.00±5.39	Sandy loam

Source: Field survey, (2022).

study area and the range of 0 to 20cm as shown in Table 3 had population value. It implies that a higher number of the trees were mature and they were merchantable. Salami and Akinyele (2017); Salami and Akinyele, (2018) discovered the highest number of trees for diameter class 10-19.9 cm (27.93%) at Gambari Forest. Also, Oduwaiye and Ajibode (2005); Salami et al., (2016) reported the highest number of trees for a diameter class of 11-30 cm followed by those of between 0-10 cm at Gambari Forest Reserve. Conversely, Oduwaiye et al*.,* (2002) revealed that all the plots accessed had the largest class of diameter below 10 cm at the Okomu Permanent Sample Plot.

Physical Properties

The percentage mean of sandy content in the neem plantation was found to be 83.00±5.89, the percentage mean of silt content in the plantation is 4.00±2.80 while the percentage of clay was 13.00±5.39. Texturally, the studied soil is sandy loam since it has a higher mean percentage. Tete-Mensah (1993) reported that soils with loose particles such as sand result in a single-grain structure while those that are clayey and rich with fine-grained particles usually become firm (hardpan), impermeable to water and impede penetration of plant roots. Izwaida et. al., (2015); Salami et. al., (2022); reported the importance of clay in the 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 a great influence on the development of soil aggregates. Soil structure is another important factor for plant growth, is developed through the 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, there are appreciable amounts of silt and clay in the studied site.

Chemical Properties

Table 4 shows the result of the chemical properties of the topsoil in the plantation site. The result showed the percentage of nitrogen in the locations as it ranges from 0.07% to 0.09%. The mean percentage of nitrogen from the plantation site is 0.08%. 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 microflora 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. The percentage proportion of phosphorus found in the study site ranges from 2.96 g/kg to 7.33g/kg with the mean percentage being 6.15g/kg ±3.89. Also result of the percentage proportion of potassium content in the topsoil of the plantation is 0.13cmol/kg to 0.2cmol/kg with the mean percentage being 0.14cmol/kg ±0.26. 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 5.4 to 6.67 in the plantation (Table 5) signifying a slightly acidic pH. As a result, slightly acidic soil from the site may likely be due to the presence of acid parent materials.

Site Index

The site index curves generated for the study site (Figure 2) revealed the height development patterns of trees in the stands. Since it a plantation, the study area is expected to have the same height and age. The index curve showed that the plantation is

Table 5: showing the mean values of Soil Chemical properties.

Parameter	Min	Max	Mean	Total	S.E
Nitrogen (g/kg)	0.07	0.09	0.08	0.315	±4.12
Phosphorus (Mg/kg)	2.96	7.33	6.15	24.62	±3.89
Potassium (Cmol/kg)	0.13	0.20	0.14	0.57	±0.26
pH	5.46	6.67	5.83	23.3	±1.34

Source: Field survey, (2022).

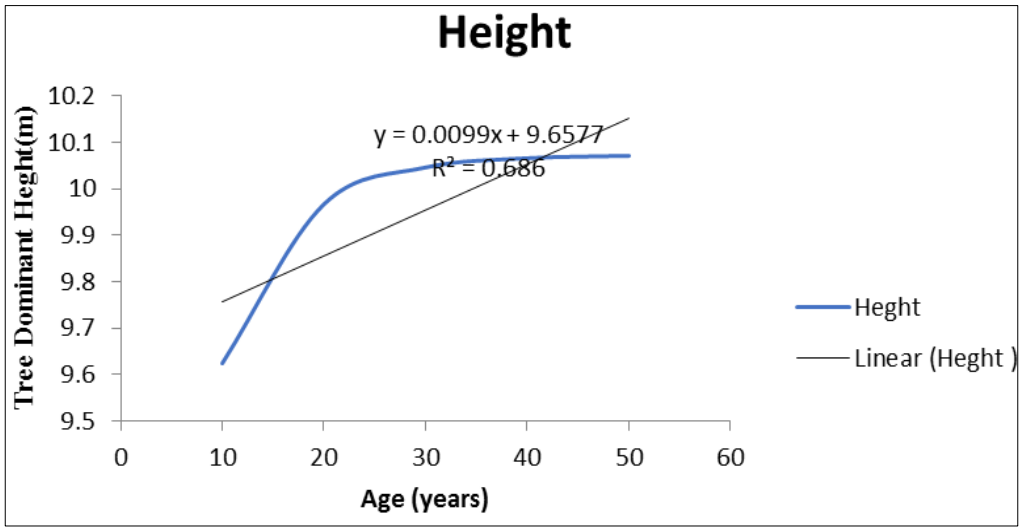

Figure 2: Showing Site Index Curve.

dominated by neem trees with 10m in height. Based on the site index, a harvesting age of 30 years was found appropriate for the site. Thus, 40 years old Neem stand attained an average dominant height of 10-15m on site since good site quality is responsible for the height growth (Nurudeen et al., 2018; Adekunle, 2006). Thus, the average age of a neem tree is 150-200 years with an average height of 15-30m and occasionally 40m (Tewari, 1992). The suitability of this form of model was also confirmed by Akindele (1990). Forestry Monitoring and Evaluation Unit, (1991) and Onyekwelu (2003) this equation is useful for predicting the current and future value of site index for *A. indica* in the study area within the age range studied. Consequently, the site index equation and index curve generated in this study will be a useful tool for yield studies in Neem plantations in Warwade plantation.

CONCLUSION

Assessment for the stem volume of neem trees was investigated on the plantation. The study showed that trees with the highest number of stands are mature and merchantable height tree shows that the plantation is adequately managed despite the agricultural activities. The physical properties of the soil in the study site showed that the plantation is texturally sandy-loamy since the soil is found to have the highest proportion of sandy soil. The chemical properties of the soil in the study area showed that the plantation is acid in nature with low richness in nitrogen which results from the farming activities carried out by the community with the plantation and also washing away of the top layer of the soil by erosion as a result of the topographic nature of the plantation. The forest reserve serves as protection for

the soil as well as promotes the fertility and productivity of the soil to support flourishing vegetation types in the area. The result of this study reveals that the suitable index age of 30 years was found to be more accurate for the study site. Therefore, harvesting could be done at a height of 10m.

RECOMMENDATIONS

Based on the study carried out, the appropriate site index equation generated for site quality is therefore recommended for use but should, however, be applied within the age range of 30 years in the study area. Initial timber harvesting and further reestablishment of Neem plantation in Warwade plantation should be concentrated upon. The models developed are useful aids for making sound silvicultural management decisions. This study should help promote the development of tree volume predictions for multispecies stands. It is believed that this study will provide a basis for further data collection management of the study site.

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APPENDIX

Appendix 1: Summary Output					
Regression Statistics					
Multiple R	0.828237				
R Square	0.685977				
Adjusted R Square	0.581303				
Standard Error	0.121969				
Observations	5				
Appendix 2: ANOVA					
	Df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.097492	0.097492	6.553448	0.083216
Residual	3	0.044629	0.014876		
Total	4	0.142121			

Appendix 3: Residual Output.

Observation	Predicted Heght	Residuals
1	9.756424	-0.13142
2	9.855162	0.110838
3	9.9539	0.09071
4	10.05264	0.011762
5	10.15138	-0.08189

Appendix 4: Analysis between intercept and age.

	Coefficients	**Standard Error**	**t Stat**	**P-value**	**Lower 95%**	**Upper 95%**	**Lower 95.0%**	**Upper 95.0%**
Intercept	9.657686	0.127922	75.49659	5.12E-06	9.250581	10.06479	9.250581	10.06479
Age	0.009874	0.003857	2.55997	0.083216	-0.0024	0.022148	-0.0024	0.022148