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Secondary Forest Conservation using *Terminalia superba*, *Entandrophragma cylindricum*, and *Terminalia ivoriensis* for Enrichment as Indigenous Species; In the Relic Forest of Mouau Abia State Nigeria

Idiege DA[1], Nzegbule EC[2], Nwajiobi B[2], Imadojemu PE[3]

[1]Department of Hospitality and Tourism Management, Faculty of Agriculture, Federal University Wukari Taraba State Nigeria.
[2]Department of Forestry and Environmental Management, College of Natural Resources and Environmental Management (CNREM), Michael Okpara University of Agriculture Umudike Abia State Nigeria.
[3]Department of Soil Science and Land Resources Management, Faculty of Agriculture, Federal University Wukari Taraba State Nigeria.

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****Corresponding Author***

Idiege, DA

E-mail: *idiege@fuwukari.edu.ng*

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ABSTRACT

Secondary forests constitute 74% of the world's natural forests and, while the conservation value of primary forests is irreplaceable, secondary forests can provide important biological conservation services and secure the future of many species. This study contributed to the sustained growth of the Relic Forest in Micheal Okpara University of Agriculture Umudike (MOUAU) Abia State Nigeria through the use of indigenous tree species whose nursery where raised in Forestry Research Institute of Nigeria (FRIN) Abia State for enrichment planting and fashioning appropriate management strategy. Evaluation of the growth of three (3) indigenous timber species were performed after four (4) years of planting. The selected species were *Terminalia superba, Entandrophragma cylindricum,* and *Terminalia ivoriensis*. They were planted within the forest space on the natural soil of the forest. The objective of this study was to evaluate the role of secondary forest in the conservation of indigenous trees. For this, the survival and growth of 30 seedlings, belonging to three (3) indigenous tree species and planted inside the secondary forest, were analyzed for one year. The soils was sample at the depth of 0-5cm and 15-30 cm, by the use of soil auger to collect the soil sample, texturally the soils belonged to sandy clay loam. The result shows that the survival rate of the species was positively correlated with height and the diameter. In this context, height accounted for a higher variation of the survival rate than the diameter. It was recommended that the secondary forest should be environmentally conducive to the survival of indigenous species of most tree seedlings, it will also imposes growth limitations typical of environments with forest physiognomy.

INTRODUCTION

While there is clear evidence of the irreplaceable conservation value of primary forests (Gibson *et al.* 2011), secondary forests and exotic tree plantations can also provide important biological conservation services (Barlow *et al*. 2007). In certain contexts, forest plantations can make a major contribution to the recovery of native species (Yirdaw and Luukkanen, 2003, Bremer and Farley, 2010). In a well manage secondary forest avoiding exploitation of the forest, secondary forests may be very similar to primary forests in terms of richness and abundance of indigenous species (Sodhi *et al*. 2005). However, spontaneous recovery of indigenous trees has been reported in mono-specific exotic plantations, being able to increase with the realization of clearings, as it has seen in conversion of plantation of exotic coniferous species into natural woodlands in The Netherlands (Jonášová *et al.* 2006).

Forests provide multiple ecosystem services spanning from local livelihoods and socio-economic development related goods and services such as food, wood, and water to the global ecological and economic services, such as ecosystem functioning, biological diversity, carbon dynamics, and climate. However, deforestation and forest degradation are causing a significant reduction in the provisioning of valuable ecosystem goods and services from forests in developing countries (Lundgren and Raintree, 2004). Studies have shown that past and present rates of tropical land conversion clearly indicates that most mature tropical forest will eventually disappear leaving behind a complex landscape consisting of a matrix of agricultural fields and forests patches under different levels of succession (Sanchez- Azofeita *et al.*, 2005 and Miles *et al.*, 2006). The wide spread destruction of tropical forests, is widely thought to be precipitating a global extinction crisis. Despite the biological richness of the tropical forest of Nigeria, the genetic resources are responsible for these threats and pressure on biological diversity in Nigeria, they include agricultural activities, bush burning, fuel wood collection and logging, grazing and gathering (FGN, 2016).

Reforestation is indispensable to prevent further loss of biodiversity under tropical rainforest ecosystem and restore soil fertility while increasing productivity of poor vegetation stock. As an option, reforestation through plantation forestry by planting high quality indigenous trees species is considered as one of the effective way to accelerate recovery of the original ecosystem (Adjers *et al.*, 2015; Appanah and Weiland, 2016). Rehabilitation projects have recognized the importance of using indigenous species not only for environmental reasons, but also to meet the livelihood and cultural needs of local communities who may depend on forest products and services (Sarrailh and Ayrault, 2001). Although the idea of using indigenous species in vegetation is now widely accepted, there is need for continued investigation into the establishment of indigenous species, which perform comparably to exotic species.

Conservation and utilization of indigenous tree species for food security and income generation have become increasingly important issues. Akinnifesi *et al.*,

(2007), pointed out that research on indigenous tree has accumulated considerably in sub-sahara African, and their role is being recognized in the domain of poverty alleviation. The number of species that have become endangered simply implies that there is a poor natural regeneration potential of the tree species and inadequate management (Sanchez- Azofeifa *et al*. 2005). Thus, the need to set priorities for conservation of tree diversity has become inevitable. A sustained regeneration and growth status of seedlings of all species in the presence of older plant is required for sustained existence of any forest community (Taylor and Zisheng, 2008). Understanding tropical forest ecology is critical for the development of appropriate conservation strategies, given that tropical forest can be considered the forest of the future (NPC 2006).
The objectives of this research will be:

- To evaluate the local availability and productivity of indigenous species most of which are threaten.
- To assess the initial performance of the tested species after planting.

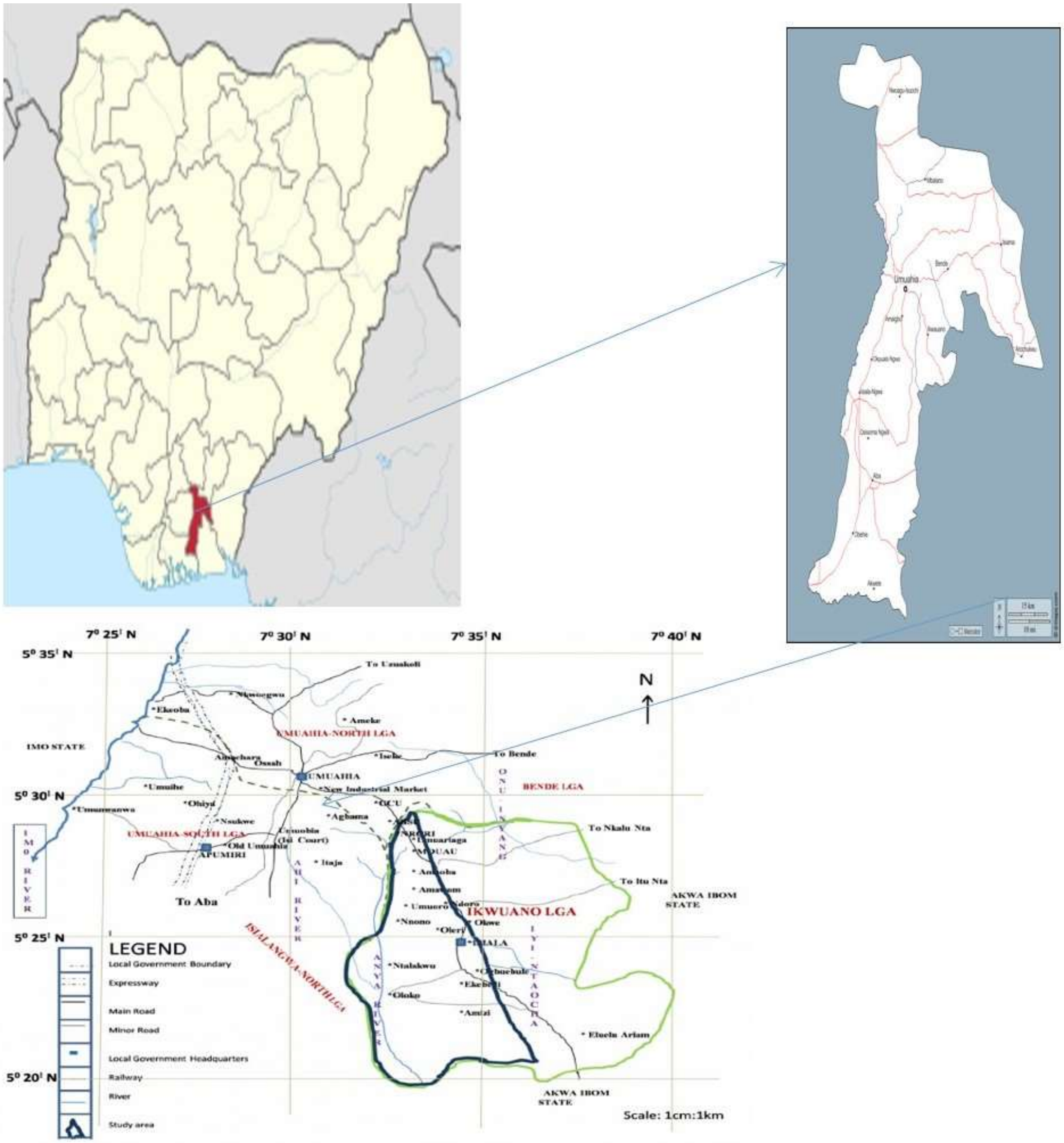
This research will therefore contribute to policy and program deliberation about developing forestry opportunity that will contributes to alternative land use in tropical rain forest of Abia state Nigeria.

MATERIALS AND METHOD

Study Area

Abia State is located between latitude $4^0$40 and $6^0 14^1$N and longitude $7^0 10^1$ and 8^0 east. It occupies about 5,834 square kilometer, with a population of 2,883,999 made up of 1,434,193 (55%) males and 1,399,806 (45%) Females (NPC 2006). The state is bounded on the North and Southeast by Anambra, Enugu and Ebonyi State. On the West of Abia is Imo State, to the East and Southeast are Cross River and Akwa Ibom State respectively, and to the South is River State.

Emphasis is on Michael Okpara University of Agriculture Umudike with a relic Forest situated at the center of the University campus. Umudike is situated in Ikwuano Local Government Area of the state where they are predominantly a farming community. The University is situated within the deltaic marine sediments of Cretaceous to recent age, between latitude 5°28'N and 5°30'N and between longitude 7°31'E and 7°33'E. It is part of the sub-equatorial belt with its' wet season from Mid-April to October and dry season from November to Mid-April, and has double maxima rainfall peaks in July and September. The area is characterized by high temperatures of about 29^0–31^0C and high relative humidity values of over 70%. The forest is situated about 1km from the University school gate. At the north of the relic forest is the Senator Pius Anyim auditorium, in the south by animal farms of the University, on the east is the University male hostels and in the west is the tar road between the College of sciences and the University power house. It is a true representative of the rainforest of which Abia State geographically is among. The forest occupied an area of about $200m^2$. It has various types of vegetation found within the rainforest region they range from climbers, patches of grasses, and various tree species. Most of the tree species within the forest are endangered because of construction that is ongoing within the University. At the entrance of the forest after the Pius Anyim auditorium is a forest plantation, the trees for the plantation are *Dacroyeds edulis* and *Irvingia garbonensis,* most of the trees identified within the forest are *Fragara species*, *Triplochiton scleroxylon, Afzelia spp., Astonia broonie, Milicia excels, Nauclea diderrichii, Pericopsis elata, Pterocarpu spp., Mansonia altissima, Ellusia guinesis, Piptadeniastrum africanum* the trees species the researcher introduce into the forest were *Khaya ivoriensis, Anthonotha macrophylla,* and *Bracystigia eurycoma.*



MATERIALS AND METHODS

Method of Tree species selection

A comprehensive enumeration of plant species in the forest was carried-out after the feasibility survey was done and it was found that there are some indigenous trees species that are endangered or non-existent within the forest this position was arrived at after assessing the species distribution and observed that some native species which were supposed to be in the forest but were not present or have less than 2 (two) stance per hectare. It was on this bases that the choice of selecting the species to be included in this study. Three (3) species where identified for this trial, they were: *Entandrophragma cylindricum, Terminalia ivoriensis, Terminalia superba*. Seeds of these three native species were collected from Forestry Research Institute of Nigeria (FRIN) situated at Ikwano LGA of Abia State Nigeria and nursed at the nursery site of Michael Okpara University Umudike Department of Forestry and Environmental Resource Management.

Experimental design and layout

The seedlings of these selected species were transplanted in the field in June 2011 using a Randomized Complete Block Design with five blocks. Each block had five experimental plots, and all the three (3) species where represented within the five blocks and also in all the sub-plot making a total of 750 species as a replicate within each block. The spacing between blocks was 2m, plot size was 10m x10m, and the space between trees in a plot was 2m. In each plot, 30 trees were planted, and the collected seedlings were taken as a sample for data collection the three (3) selected species were then planted against each plot. Each sub-plot within the block consist of 6rows x 6columns thus each sub-plot has 50 trees of one selected species. Therefore there were 250 seedlings of each species or totaling 1250 seedlings for all selected species.

After planting, the site was protected from human interferences for the duration of the study. Transplanted seedlings plots were neither irrigated nor fertilized. Survival, height (from ground level to the tip of the plant) and diameter at breast height (DBH) were recorded every 3 years from March 2016 up to December 2023. Subsequent to the randomized block design.

Growth Performance of the Different Species Stand Combinations

Heights (m) of each seedling were measured using measuring rod. Other parameters such as volume, survival percentage, stand density; mean annual increments and the basal area were estimated using the following formulae:

Tree Volume = *a x Bdbh x H* ……………........[1]

Where:

A = is the stem form factor
DBH = is the diameter at breast height
H = is the total height
The value of "a" was set to 0.5 (Loría 2000).
Stand density, survival rate and the basal area were estimated as reported by Nkyi (2007)
The basal area (m^2/ha) 0.00007854 = × dbh^2
0.00007854 is a constant,

$$\text{Stand Density} = \frac{\text{Number of trees in a plot}}{\text{The area of plot}} \times 10000m^2 \quad \text{.......[2]}$$

Statistical Analysis:

The data was analyzed discretely for height, root collar diameter and survival. Analysis of variance (ANOVA) was conducted using the Statistical Package for Social Sciences (SPSS Version 10) with the following model of analysis:

$Y_{ij}k = u + S_i + Y_j + e_{ij}k$ ………………………[3]

Where:

$Y_{ij}k$ = is the dependent variable (e.g. height)
U = is the overall mean
S_i = is the effect of species
Y_j = is the effect of year
$e_{ij}k$ = is the random error.

Statistical differences between treatment means they were assessed using the Tukey Studentised Range test. The tree species were selected based on an earlier rapid ecological survey that was carried out at the relic forest in order to restore the species which according to past records were occurring in good numbers in the forest but subsequently has been endangered, Albertson and Kocher (2001), Ricardo *et al.* (2019) and Richards (2016), These species were well appropriate for planting in sufficiently large breaks or in open areas and therefore are potential contenders for an enrichment planting.

To quantify tree survival, we calculated the survival function S(t) over time using the nonparametric Kaplan–Meier estimator (Harrell 2001), which gives the probability of an individual seedling surviving to time t, the time since the commencement of the experiment:

$S(t) = \pi t_i \leq t(1-d_i/n)$…………………............[9]

Where:

Ti = is the time interval,
Di = is the number of deaths that occur in the interval ti,
Ni = is the number of seedlings that are alive at the end of the interval ti, and
Π = is the product operator across all cases less than or equal to t.
The total number of plants per species that survived was calculated as:

$$\text{Survival \%} = \frac{\text{no of seedling survived}}{\text{Total no of seedling planted}} \times 100\% \text{ .... [10]}$$

The statistical analysis was done by using R-statistical software and language (Chen *et al*. 2011), DBH was normalized using a log transformation, while percentage canopy cover and percentage live crown were normalized using an arcsin()^2 transformation, logistic regression was done to analyze mortality data (Packer and Clay, 2000), and multiple linear regression in conjunction with regression tree was used to analyze growth measure data (DBH, percentage canopy cover, percentage live crown) (Gregg *et al*., 2003). Regression trees was used as a visual aid in determining significant interaction effects (De'ath and Fabricius 2000). A two-way (ANOVA) with an error term for years planted (age) was also done to test for an interaction between species and stock while accounting for the blocked sampling design (Pena-Claros *et al*. 2008).

RESULTS AND DISCUSSION

Analysis of the Soil Physicochemical Properties under various Age Stands in Sub- Plot (I) of the Relic Forest of Mouau

Figure 1 presented the initial laboratory analysis of soil sample collected from the relic forest of MOUAU in plot 1. The soil analysis indicated that the textural class of the soil is sandy-loam. Both the organic carbon and organic matter in the soil were low with level of 0.76% and 1.61% respectively; this is because organic matter was above or below the critical level of 2.00% as described by (Umeri *et al.,* 2017). Based on the result, total nitrogen available in the soil is 0.08% which is lower than the critical level of 0.15% (Umeri *et al.,* 2017) Also, the insufficiency of nitrogen effects the growth of Indigenous plant seedlings by causing a retardation of their growth and lead to chlorosis that could be seen in the leaves of the seedlings. The available phosphorus is neede for in photosynthesis, respiration, energy storage and transfer, cell division and enlargement is approximately 2.86% in the soil which is well considered to be low because it is below the critical level of 8.50% (Umeri *et al.* 2017) Nevertheless, some micronutrients were high in concentrati0on such as Iron (Fe) having 18.0 mg/kg that is five times above the critical level of 3.50 mg/kg, that is required in the production of chlorophyll; and also component of many enzymes associated with the energy transfer and fixation of lignin formation (Umeri *et al.* 2017). Zinc (Zn) is crucial for protein synthesis and growth parameter and had a positive effect on the seedlings in terms of leaf production and leaf area, zn level in the soil was 48.2 mg/kg was and is above the critical level of 1.0 mg/kg (Umeri *et al.,* 2017).

Results of the Preliminary Assessment of Growth Performance as Affected by Soil types on the Study of the Indigenous Species.

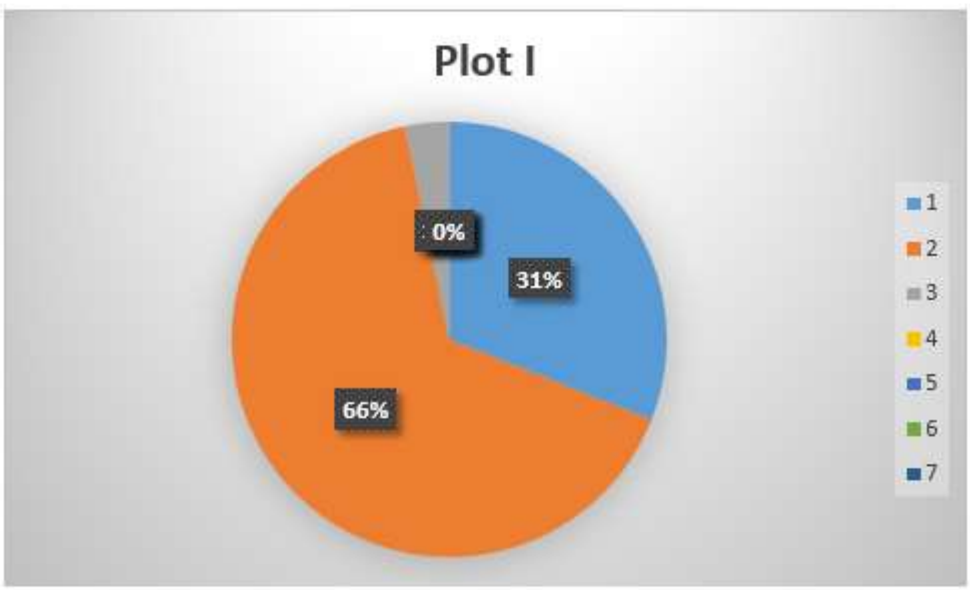


Figure 4.1.1: Nutrients Compositions of the Relic Forest of Mouau in Plot 1

Key:
1 – 0.76%
2 – 1.61%
3 – 0.08%
4 – 2.86 mg/kg
5 – 3.44 mol/kg
6 - 48.2mg/kg
7–18.0mg/kg

Analysis of the Soil Physicochemical Properties under various Age Stands in Sub-Plot (II) of the Relic Forest of Mouau

The figure II also presented the laboratory analysis of soil sample collected from the relic forest of MOUAU. The analysis shown that the textural class of the soil is also sandy-loam. Both the organic carbon and organic matter in the soil are low with 0.48% and 0.75% respectively; this is also because organic matter is below the critical level of 2.00% (Umeri *et al.* 2017). Nitrogen that helps in the formation of amino-acids and the building of protein is necessary for plant cell division. On the other hand, based on the result above, total nitrogen available in the soil is 0.4% that is above the critical level of 0.15%, thereby having an effect on the growth of plants by causing speedy growth and chlorosis that was perceived among the seedlings of plants in plot III of the relic forest through the growth parameters evaluated. The available phosphorus that is involved in photosynthesis, respiration, energy storage and transfer, cell division and enlargement, that was also the promoters of root formation were also roughly 8.87 mg/kg in the soil and is considered a little bit high because it is also a little higher than the critical level of 8.50 mg/kg (Umeri *et al.* 2017). In relation to the growth of the seedlings, it helped in enhancing the growth of the seedlings in the terms of stem diameters when compared to the seedlings in other areas of the forest. Likewise, Iron (Fe), that is involved in the production of chlorophyll, which is also a constituent of many enzymes associated with the energy transfer and fixation of lignin formation in plants is available as 91.6 mg/kg that is also considered high because it is above the critical level of 3.50 mg/kg (Umeri *et al.* 2017). Zinc which took part in the regulation of growth among the seedlings of the area covered and essential for protein synthesis as in good health as growth regulation is about 17.80 mg/kg in the soil which is above the critical level of 8.50 mg/kg (Umeri *et al.* 2017).

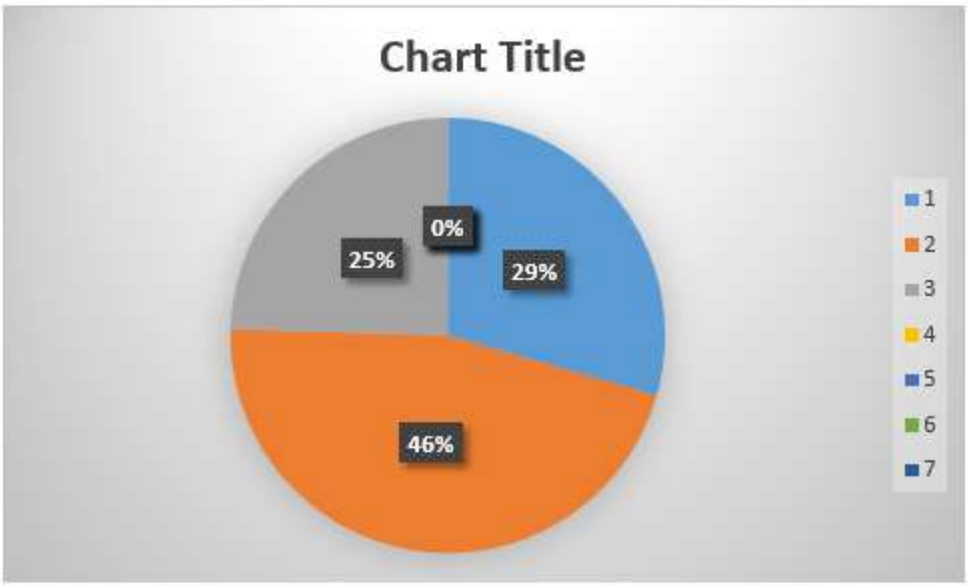


Figure 4.1.2: Nutrients Compositions of the Relic Forest of MOUAU in Plot II

Key:
1 – 0.48%
2 – 0.75%
3 – 0.40%
4 – 8.87 mg/kg
5 – 15.06 mol/kg
6 – 17.80 mg/kg
7 – 91.6 mg/kg

Analysis of the Soil Physicochemical Properties under various Age Stands in Sub-Plot (III) of the Relic Forest of Mouau

The figure III also presented the laboratory analysis of soil sample collected from plot III of the relic forest of MOUAU. The soil analysis also discovered that the textural class of the soil is also a sandy-loam soil. Both the organic carbon and organic matter in the soil are low with 7.71% and 3.30% respectively and this organic matter is above the critical level of 2.00% (Ayeni and Adeleye 2011). Total Nitrogen which helps in the formation of aminoacids is 0.006% which is far below the critical level of 2.00%. Considering the performance of the seedlings from this plots, the suitability of nitrogen had a very serious advantageous effect on the growth of plants in terms of leaf area, collar diameter, plant height, nodes, leave area index and the numbers of leaves per plant when compared to the seedlings of other plots. Phosphorus (P) that is concern in photosynthesis, respiration, energy storage and transfer is high about 13.7 mg/kg in the soil is also above the critical level of 8.50% (Ayeni and Adeleye 2011). Iron (Fe), that helps in the production of chlorophyll also ascribed to the seedlings growth in terms of collar diameter. Magnesium (Mg), that is available is 4.6 mol/kg, which is above the critical level of 3.50 mol/kg, it helped in providing essential carbohydrate and nitrogen metabolism and also aid in preventing wilting in plants. Also, Zinc (Zn) that is crucial for protein synthesis and growth regulation had a positive effect on the seedlings by enhancing their growth in terms of leaf area and leaf production is about 89.6 mg/kg in the soil which is above the critical level of 8.50 mg/kg (Ayeni and Adeleye 2011).

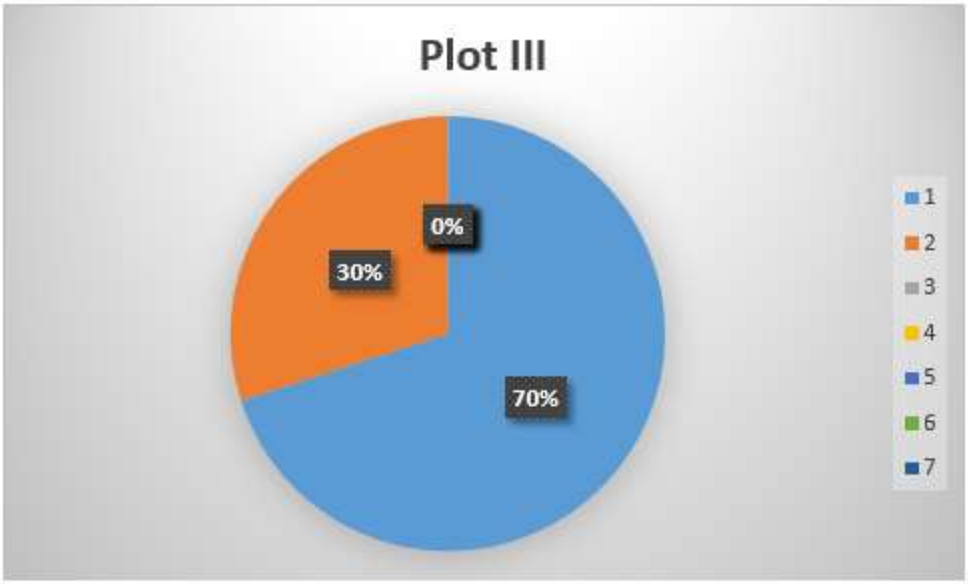


Figure 4.1.3: Nutrients Compositions of the Relic Forest of MOUAU in Plot III

Key:
1 – 7.71%
2 – 3.30%
3 – 0.01%
4 – 13.7 mg/kg
5 – 4.6 mol/kg
6 – 14.0 mg/kg
7 – 89.6 mg/kg

Analysis of the Soil Physicochemical Properties under various Age Stands in Sub-Plot (VI) of the Relic Forest of Mouau

In Figure IV below it revealed the laboratory analysis of soil sample collected from the relic forest of MOUAU in plot IV. The soil analysis revealed that the textural class of the soil is sandy-loam soil. Both the organic carbon and organic matter in the soil were low with 0.48% and 0.76% respectively; this is because organic matter was below the critical level of 2.00% as reported by (Ayeni and Adeleye 2011). Nitrogen that supports in the formation of aminobuilding of protein is required for plant cell division. Though, built on the result, total nitrogen available in the soil is 0.42% that is above the critical level of 0.15% (Ayeni and Adeleye 2011). Also, the scantiness of nitrogen had an effect on the growth of seedlings in plot IV of the relic forest by causing a decrease in their growth and also chlorosis which could be seen in the collar diameter of the seedlings. The available phosphorus that is tangled in photosynthesis, respiration, energy storage and transfer, cell division and enlargement is about 5.99 mg/kg in the soil that is considered low because it is below the critical level of 8.50 mg/kg (Ayeni and Adeleye 2011). Though, micronutrients are high with Iron (Fe) having 81.26 mg/kg, that is above the critical level of 3.50 mg/kg, that is important in the production of chlorophyll, and also component of many enzymes associated with the energy transfer and fixation of lignin formation (Agboola and Ayodele, 2005). Zinc (Zn) is useful for protein synthesis and growth regulation and had a positive effect on the seedlings in terms of leaf production and leaf area, 17.76 mg/kg was gained which is above the critical level of 1.0 mg/kg ((Ayeni and Adeleye 2011).

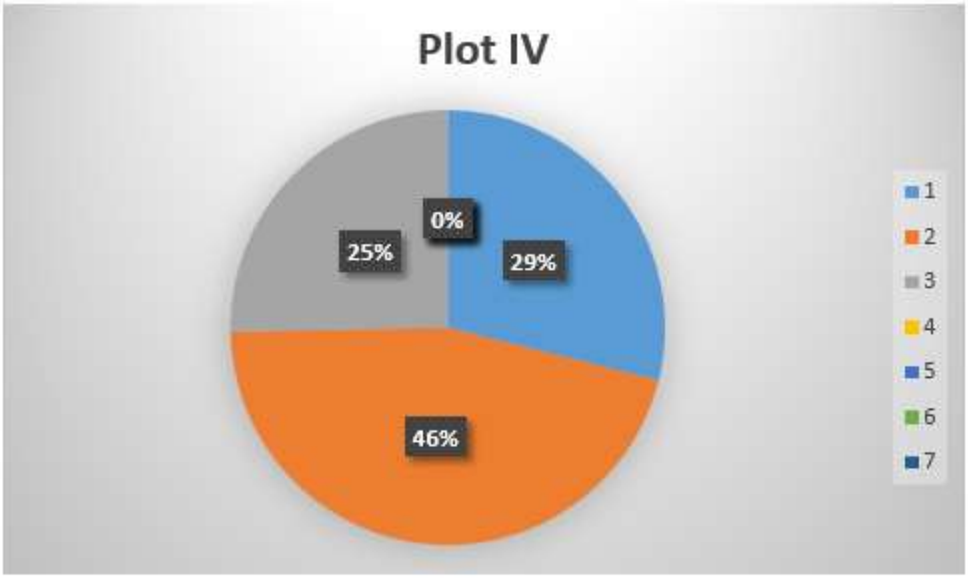


Figure 4.1.4: Nutrients Compositions of the Relic Forest of MOUAU in Plot IV

Key:
1 – 0.48%
2 – 0.76%
3 – 0.42%
4 – 5.99 mg/kg
5 – 11.53 mol/kg
6 – 17.76 mg/kg
7 – 81.26 mg/kg

Analysis of the Soil Physicochemical Properties under various Age Stands in Sub-Plot (V) of the Relic Forest of Mouau

Figure V also exhibited the laboratory analysis of soil sample collected from the relic forest of MOUAU in plot V. The soil analysis indicated that the textural class of the soil is sandy-loam soil. Both the organic carbon and organic matter in the soil were low with 0.34% and 0.72% respectively; this is because organic matter was below the critical level of 2.00 as reported by (Ayeni and Adeleye 2011). Nitrogen which helps in the formation of amino-building of protein is necessary for plant cell division. However, based on the result, total nitrogen available in the soil is 0.6% which is above the critical level of 0.15% (Ayeni and Adeleye 2011). Also, the scantiness of nitrogen had an effect on the growth of seedlings planted in plot V of the relic forest in MOUAU by causing a decrease in their growth and also chlorosis that could be seen in the collar diameter of the seedlings. The available phosphorus that is contained in photosynthesis, respiration, energy storage and transfer, cell division and enlargement is approximately 6.79 mg/kg in the soil which is considered low because it is below the critical level of 8.50 mg/kg (Ayeni and Adeleye 2011). Although, micronutrients are high with Iron (Fe) having 97.42 mg/kg, that is above the critical level of 3.50 mg/kg, and is important in the production of chlorophyll, and also component of many enzymes associated with the energy transfer and fixation of lignin formation (Ayeni and Adeleye 2011). Zinc (Zn) is crucial for protein synthesis and growth regulation and had a positive effect on the seedlings in terms of leaf production and leaf area, 16.55 mg/kg was obtained, this is also above the critical level of 1.0 mg/kg (Ayeni and Adeleye 2011)

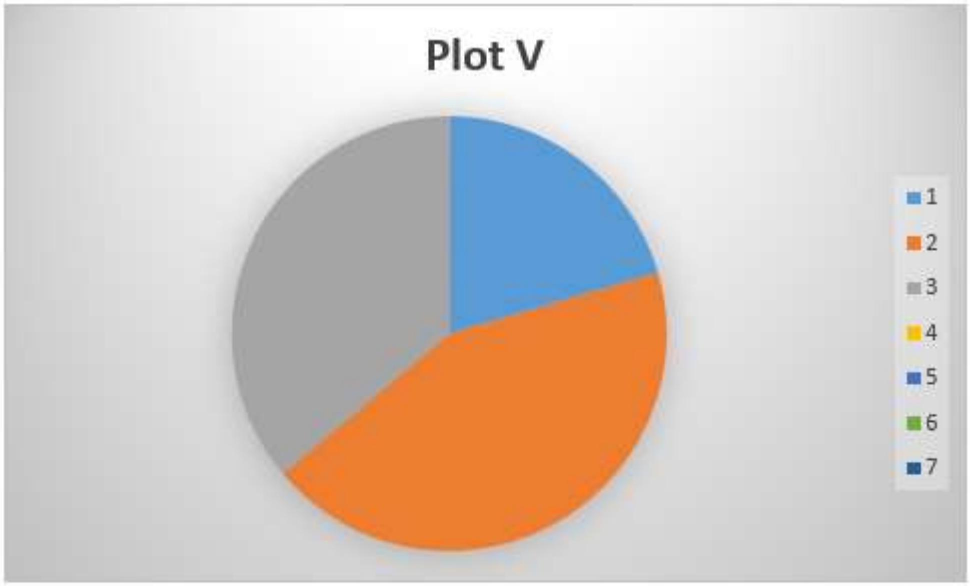


Figure 4.1.5: Nutrients Compositions of the Relic Forest of MOUAU in Plot V

Key:
1 – 0.34%
2 – 0.72%
3 – 0.60%
4 – 6.79 mg/kg
5 – 84.66 mol/kg
6 – 16.55mg/kg
7 – 97.42 mg/kg

Nutrient Composition of Various Sample Plot in the Relic Forest of Michael Okpara University of Agriculture Umudike (MOUAU)

	Soil PR. Org. %	Org. Matter %	N %	P mg/kg	Mg mol/kg	Zn mg/kg	Fe mg/kg	Standard Deviation (SD) %
Plot I	0.76%	1.61%	0.08%	2.86	3.44	48.2	18.0	17.5
Plot II	0.48%	0.75%	0.4%	8.87	15.06	17.80	91.6	32.68
Plot III	7.71%	3.30%	0.006%	13.7	4.6	14.0	89.6	31.57
Plot IV	0.48%	0.76%	0.42%	5.99	11.53	17.76	81.26	29.13
Plot V	0.34%	0.72%	0.6%	6.79	84.66	16.55	97.42	42.51

Analysis of the Tree Growth Performance of different Parameters in 9 years of Experiment of the three (3) Species under consideration

Mean Diameter at Breast Height (DBH)

The values for the mean diameter ranges from 0.25 to 2.24 cm in 2016, in 2019 the mean diameter was from 0.49 to 2.35 cm and in 2023 the mean diameter ranges from 0.45 to 2.29 cm *T. superba,* has the highest mean in 2016 which recorded 2.35 cm, while the species that recorded the lowest growth performance in terms of mean diameter was *E. cylindricum* they recorded 0.25 cm in 2016, other species like *T. ivoriensis* recorded a gradual growth between 0.36 and 1.51 between 2016 to 2023 respectively (table 4.2). However, the growth performance of *T. ivoriensis* increase a little from 0.35 in 2019 to 0.93 and 0.64 cm

Mean Height of Trees

The values for mean height ranges from 0.24m to 50.02m from 2016 to 2023, *T. superba* has about 41.47m in 2014, 53.10m in 2015 and 47.28m in 2016, followed by *T. ivoriensis* with 48.00m in 2016, 52.10m in 2019 and 50.04m in 2023 respectively, this were the two species that was increasing in height rapidly. However, other species like*, E. cylindricum* recorded a very slow rate in height even though their rate of survival was encouraging their mean height was between 0.24m to 7.48m. Though the research did not emphasis on climate but from indication it shows that 2015 recorded a very rapid growth performance in all the species because of favorable climate as shown in table 4.2.

Mean Nodes of the Tree Species

The mean values for the tree Nodes varied from 1.50 to 6.58 from 2016 to 2023, the species that recorded the highest increments in the number of Nodes were *T. superba* with 2.87 in 2016, 6.58 in 2019 and 4.60 in 2023, this was followed by *T. ivorensis* with 3.90 in 2016, 6.25 in 2019, and 5.08 in 2023 and lastly *E. cylindrica* with 4.46 in 2016, 5.92 in 2019 and 5.19 in 2023 respectively..

Mean Leaf Numbers

Significantly lowest leaf number was recorded at sub-plot 2 with 1.75% and the tree species was *T. ivorensis*. But at 10.20% significantly maximum leaf number was recorded for *T. superba* in 2016 at sub-plot 5, other plant species such as*, E. cylindricum,* has a leaf number of between 4.60% in 2016, 3.14% in 2019 and 6.81% in 2023 for *T. superba,* 2.00% in 2016, 4.56% in 2019 and 3.20% 2023 for *E. cylindricum*, 5.08% in 2016, 7.60% in 2019 and 6.53% 2023 respectively (table 4.2)

Mean Leaves Area Index (LAI)

Maximum LAI was recorded in sub-plot 3 and 5 with 15.05 and 11.24 between 2016 and 2019 for *T. superba,* it was followed by 5.76, 6.43, and 6.07 from 2016 to 2023 for *T. ivorensis* and minimum LAI was 1.66, 1.74, and 1.69 between 2016 to 2023 for *E. cylindricum* respectively (table4.2).**Descriptive Statistics and Comparison Tests of the Indigenous Tree Species in the Relic Forest of Mouau for Three Years of the Experiment**

s/n	**Names of Species.**	**Yrs of planting**	**Nos. of trees per plot**	**Mean and Standard deviation of the measured parameters**														
				DBH (cm) from 2016-2023			**Height (m) 2016-2023**			**Nodes 2016-2023**			**No.s of Leave 2016-2023**			**Leaves area Index 2016-2023**		
				16	**19**	23	16	19	23	16	19	23	16	19	23	16	19	23
1	*Terminalia superba*	2013	5	0.40 (0.065)	**0**.49 (0.076)	0.45 (0.082)	0.24 (0.034)	7.48 (2.708)	3.65 (4.077)	2.89 (1.652)	6.58 (1.205)	4.60 (2.355)	3.14 (1.869)	6.81 (1.203)	4.87 (2.431)	7.84 (4.310)	15.05 (4.945)	11.24 (5.845)
2	*Entandrophragma cylindricum*	2013	5	0.25 (0. 041)	1.38 (0.213)	0.78 (0.589)	1.23 (0.265)	4.72 (1.339)	2.87 (1.983)	2.75 (.439)	4.56 (0.759)	3.60 (1.095)	2.00 (0.717)	4.56 (1.435)	3.20 (1.698)	1.66 (0.334)	1.74 (0.519)	1.69 (0. 429)
3	*Terminalia ivoriensis*	2013	5	0.36 (0.081)	0.93 (0.578)	0.64 (0.499)	0.26 (0.101)	7.14 (3.036)	3.70 (4.067)	1.50 (0.655)	3.67 (0.828)	2.58 (1.319)	1.75 (0.692)	5.36 (1.417)	3.56 (2.129)	5.71 (3.722)	6.43 (2.809)	6.07 (3.294)

Source: from the field in 2017. The figures in the bracket are the standard deviation

The Survival Rate of the different Trees Height

In table 4.3.1 the survival rate of tree species was significantly different at (p<0.05). The highest survived species among the indigenous species used for experiment was *Terminalia ivorensis* 38.87% which was recorded in the months of December at the4 years of field trial, however, this was followed by *Terminalia superba* with 32.52% also in the months of December following also the four (4) years of the field trial, other species like*, Entandrophragma cylindricum and* recorded about 13.52% respectively. (Yitebitu 2014) reported some indigenous tree species in the rain forest region are quit resistance to most environmental damages like drought, shades from the tall canopies, poor soil nutrient etc. this findings was similar to the observation of this present study. Highly significant variation was among the trees at survival rate in different period of assessment after planting table 4.3.2 and figure 4.3.2. Analysis of variance reveals that variation in height among the species planted were highly significant at (p<0.05) after 3 years of age at the study site. The height growth trend as shown in table 4.3.2 and fig. 3 shows that *T. superba* 81.76%, *E. cylindricum* 87.66% and *T. ivorensis* 83.33% were rapid in height at the first year of 2014/2015 but subsequently the growth got stunted as the year advance to 2019/2023. Moreso, (Arowosoge 2015) stated that apart from indicating productivity height may also be seen as a measure of enrichment evaluation of trees in the environment as tall trees usually been better adapted to the site than shorter trees. Khaya species could also play a greater importance in the enrichment process especially during periods of drought or in areas where nutrient resources are not available.

However, studies also shows that fast growth seedlings like *T. ivorensis* and *T. superba* seedlings are important indicator in terms of determining the situation of growth response especially in the first growing period and it is commonly assumed that the early fast growth rate of tropical trees reflect productivity status of the trees (Baris *et al.,* 2006).

Table 4.3.2: Mean Survival Rate in (%) for Height of the Indigenous Tree Species Planted at the Relic Forest of Mouau between (2014/2015-2016/2017)

Tree species	**Age of seedling after planting in (%)**		
	(2013/2016)	**(2016/2019)**	**(2019/2023)**
T.s	81.76[a]	79.02[a]	62.35[a]
E.c	87.66[a]	83.63[a]	73.93[a]
T.i	83.83[a]	73.83[a]	70.21[a]
LSD(0.05)	10.79	13.9	11.07
C.V (%)	7.3	10	7.8
Mean	85.3	72.5	79.6
P<value	<0.001	<0.001	<0.001

N.B: Mean in columns with the same letters are not significantly different using LSD
C.V: Coefficient of Variation.,
LSD: Least Significant Differernt

Growth performance and productivity of the various species combinations

The differences in growth parameters of the tree species in the relic Forest of Michael Okpara University of Agriculture Umudike such as Height, Diameter, Number of leaves, Nodes and the Leaf Area Index (LAI) could be ascribed to species morphological and physiological differences, genetic adaptations as well as the physical environment (Berli *et al.* 2013). Therefore, in an enrichment planting with large gaps or spaces which will create less competition between species, such as the performance of *T. ivorensis* and *T. superba* has pointed to their compatibility, and their morphological and genetic adaptation were good for enrichment planting which were use as indigenous tree species.

Generally, growth performance with respect to average diameter, average height, average leaf number, average Node, and average leaf area index (LAI) for *K. ivorensis* and *B. eurycoma* in two species grouping was higher as related to other species combinations. This is because *T. superba* and *T. ivorensis* in the relic forest were considered as fast-growing species compared to *E. cylindricum* which were also of indigenous tree species in the rain forest belt of Abia State Nigeria (Hawthorne *et al.,* 2012; Orwa *et al*., 2009). Accordingly, competitions amongst them in diverse stands for growth resources have the potential to lessen the growth of the other species (Petit & Montagnini, 2006). The result of this study shows a declining trend in productivity of *E. cylindricum* as the species combination increases. So, the greater the inter-specific competition between the *K. ivorensis* and *T. superba* and other species in varied combinations, the lesser their productivity (Forrester *et al*., 2018).

Similarly, the other species that also perform as the second best was *E. cylindricum* in all their growth parameters, this is because of less inter-specific competition between them. Growth reduced as the constituent trees increases in the various species mixtures. Tree species rivalries for growth resources (both soil and environmental resources) in the relic forest were the key factors that determine the growth and productivity of species. Several of these factors accounted for variances detected in the study in relation to their stand density, survival rate, height, diameter and other parameters. The interrelation of trees species in which one species exerts a negative effect on growth or mortality of the other elucidates competition (Furuta & Aloo, 2009; Boyden *et al*., 2008). *K. ivorensis* and *T. superba* are light-demanding species which needs good amount of sunlight radiations to grow well, therefore the inter-specific rivalry and other species particularly light and other growth resources may have been the course were their growth performance accounting for its rich performance within the species grouping (Potvin & Dutielleul, 2009; Petit & Montagnini, 2006). Similarly, increase structure and biological resemblances of *T. ivorensis* and *T. superba* and other tree species could intensify rivalry between these species which caused an improvement in the growth and productivity the trees in the relic forest (Boyden *et al*., 2008). Chichinye *et al.* (2020) opines that *T. ivorensis* and *T. superba* are indigenous tree species used for enrichment planting of the forest will do well as they are planted in mixtures with other growing species because they are considered as fast growing species. Their interaction with the others four species, being a fast-growing species were injurious to the growth of others four species. According to Opuni (2008), assumed that when a species are in competition for mostly environmental factors like, light, nutrient, water, carbon etc. they slow in their growth performance. Orwa *et al*., (2009) point out that *E. cylindricum* have the ability to displace indigenous plants by blocking out sunlight with its leaves. The gaps created by *K. ivorensis* and *T. superba* have resulted to good survival percentage and stand density which has generated rivalry between the species. This study agreed with that of (Lamprecht, 2018) who detected that tree species made use of available space, soil resources and environmental factors to grow. Nketia (2002) heightened that the correct spacing of trees when enriching the forest affects the total output in growth parameters such as tree diameter, tree height, and numbers of leaf, Nodes and leaf area index (LAI).

CONCLUSION

This study has provided basic information on indigenous forest conservation practices that will engender positive socio-economic and political interventions towards improving forest conservation efforts in Abia State. It was discovered that Enrichment planting involving the use of indigenous tree species will aids in the protection of local flora, accelerate forest development and enhance wildlife.

Recommendations

1. The indigenous conservation practices operational in the State should be integrated with the scientific approaches to produce a synergy that will promote effective forest conservation.
2. Government and other development agencies should support and provide forestry extension agents to the rural farmers to educate them on enrichment practice with indigenous tree species as well as best logging and forest products harvesting techniques to reduce damage and losses

REFERENCES

Ådjers, G., Hadengganan, S., Kuusipalo, J., Nuryanto, K., Vesa, L. (2015). Enrichment planting of Dipterocarp in logged-over forests: effect of width, direction and maintenance method of planting line on selected Shorea species. Forest Ecology and Management, 73: 217-277

Agboola AA, Ayodele OJ.(2005). Prospects and problems of using soil testing for adoption of fertilizer use in Ekiti-Akoko agricultural development project area. In processing's of workshop on appropriate technologies for farmers in Semi-Arid West Africa, Ohm HW, JG Nagy (Eds) Purdue University, West Lafeyette; pp. 123-136.

Akinnifesi, F.K., Ajayi, O.C., Sileshi, G., Chirwa, P., Chianu, J. (2010). Fertilizer trees for sustainable food security in the maize-based production systems of East and Southern Africa region: a review. Journal of Agronomy for Sustainable Development No. 30: pp 615-629.

Albertson, RC and Kocher T (2001). Assessing morphological differences in an adaptive trait: A landmark-based morphometric approach, Journal of Experimental Zoology Vol. 289(6,) pp. 385 – 403, DOI:10.1002/jez.1020

Appanah, S. and Weinland, G. (2016). Experience with planting Dipterocarps in Peninsular Malaysia. Dipterocarp forest ecosystems: towards sustainable management. World Scientific Singapore. pp. 411-445.

Arowosoge OG (2015). Local People's Perception of Forest Resources Conservation in Ekiti State, Nigeria. Journal of Environmental Science and Engineering B, Vol. 4 pp. 132-140.

Ayeni LS. and Adeleye EO. (2011). Soil nutrient status and nutrient interactions as influenced by agro wastes and mineral fertilizer in an incubation study in the Southwest Nigeria. International Journal of Soil Science, Vol. 6 (1): pp. 60-68

Barlow J., Toby AG., Ivanei SA and Avita-Pires TCS (2007): Quantifying the Biodiversity value of Tropical Primary, Secondary and Plantation Forest. Proceeding of the National Academy of

Sciences. 104(47) pp.185555-60. DOI: 1073/pnas0703333104.

Baris O, Gulluce M, Sahin F, Ozer H, Kilic H, Ozkan H, Sokmen M, and Ozbek T (2006). Biological activities of the essential oil and methanol extract of Achillea Biebersteinii Afan. (Asteraceae). Turk. J. Biol. Vol. 30: pp. 65-73.

Berli, F. J, Alonso, R, Bressan-Smith, R. and Bottini, R. (2013) "UV-B impairs growth and gas exchange in grapevines grown in high altitude," *Physiologia Plantarum*, vol. 149(1), pp. 127–140

Boyden S, Binkley D and Senock R (2008) Competition and facilitation between Eucalyptus and nitrogen-fixing Falcataria in relation to soil fertility. Ecology Vol. 86(4), pp. 992–1001

Bremer, L.L. and Farley, K.A. (2010). Does Plantation Forestry Restore Biodiversity or Create Green Deserts? A Synthesis of the Effects of Land-Use Transitions on Plant Species Richness. Biodiversity and Conservation, 19, 3893-3915. https://doi.org/10.1007/s10531-010-9936-4

Chen, Y.; Jiang, W.; Yang, Y. ; Chen, X.; Peng, M., Chen, X., 2011. Effect of several baits on the gonadal development in *Penaeus vannamei* Boone parent prawns. J. South. Agric., 42 (8): 987-990

Chichinye A, Geldenhuys CJ, Chirwa PW (2020). Analysis of growth rings to determine age and mean radial growth of selected Baikiaea-Guibourtia-Pterocarpus species from regrowth stands after pole/ firewood harvesting and abandoned crop fields, north-western Zimbabwe, Journal of Ecology and Natural Development, Vol. 12(3), pp 129-139

De'ath, G. and Fabricius, K.E. (2000) Classification and Regression Trees: A Powerful yet Simple Technique for Ecological Data Analysis. Ecology, Vol. 81, pp. 3178-3192. https://doi.org/10.1890/0012-9658(2000)081[3178:CARTAP]2.0.CO;2

Federal Government of Nigeria (2016). Economic Recovery and Growth plan 2017-2020 available at: http//www.nationalplanning.gov.ng/images/docs/FRGPs20%20CLEANS%20COPYpdf.

Forrester D, Westlake,D, Killian M, Antonopoulou V, McCann M, Thurnham A, Thomas R, Waits C, Whittaker C, and Hutchison D (2018). A randomized controlled trial of training in Motivational Interviewing for child protection, Children and Youth Services Review, Vol. 88, pp. 180-190

Furuta K and Aloo IK (2009) Between-tree distance and spread of the Sakhalin Fir Aphid (Cinara todocola Inouye) (Hom. Aphididae) within a plantation. J Appl Entomol, V0l. 117(1–5): pp. 64–71

Gibson, L., Lee TM., Koh LP., and Brook BW. (2011) Primary Forests Are Irreplaceable for Sustaining Tropical Biodiversity. Nature, 478, 378-381. https://doi.org/10.1038/nature10425

Gregg EW, Cauley JA, Stone, K, Thompson TJ, Bauer DC, Cummings SR, Ensrud, KE (2003). Relationship of changes in physical activity and mortality among older women, Jama, Vol. 289(18), pp. 2379-86. doi: 10.1001/jama.289.18.2379

Harrell, FE. (2001) Regression Modeling Strategies: With Applications to Linear Models, Logistic Regression, and Survival Analysis. Springer-Verlag, New York. http://dx.doi.org/10.1007/978-1-4757-3462-1

Hawthorne, WD, Sheil, D, Agyeman VK and Juam MA (2012), Logging scars in Ghanaian high forest: Towards improved models for sustainable production, Forest Ecology and Management , Vol. 271: pp. 27–36, DOI:10.1016/j.foreco.2012.01.036

Jonášová, M., Jikta Z., Miroslav S., and Jan W (2006) *Development of the spruce natural regeneration on mountain sites in the Šumava Mts.***,** Journal of Forest Science, 52(10): 446–456.

Lamprecht A., Paul H., R0osa M., Caldazo F., Lorite J., Mesh JM., Steinbuer K., Winkler M. (2021): Changes in Plant Diversity in a Water limited and Isolated High Mountain Range (Sierra Nevada Spain). Alphine Botany. 131(6045) DOI 10.1007/s00035-021-00246-x

Lundgren, B. O., and J. B. Raintree, (2014). Sustained Agroforestry. In B. Nestel (ed.) Agricultural Research for Development: Potential and Challenges in Asia. ISNAR, The Hague, Netherlands. Pp 37 - 49.

Miles L, Newton AC, Defies RS, Ravilious C (2006). A Global overview of the Conservation status of Tropical Forest, Journal of Biogeography, Vol.33 No. 3, pp 491-505

National Population Commission (NPC) (2006) Nigeria National Census: Population Distribution by Sex, State, LGAs and Senatorial District: 2006 Census Priority Tables (Vol)3 http://www.population.gov.ng/index.php/publication/140-popn-distri-by-sex-state-jgas-and-senatorial-distr-2006

Orwa, C.; Mutua, A.; Kindt, R.; Jamnadass, R and Anthony, S., (2009). Agroforestree Database: a tree reference and selection guide version 4.0. World Agroforestry Centre, Kenya

Opuni FE (2008) Khaya grandifoliola C.DC. In Louppe D, Oteng-Amoako AA, Brink M (eds) Plant resources of Tropical Africa 7(1). Timbers 1. PROTA Foundation, Wageningen, Netherlends/ Backhuys Publishers, Leiden, Netherlands/CTA, Wageningen, Netherlands, pp 329–333

Packer A and Clay K (2000). Soil pathogens and spatial patterns of seedling mortality in a temperate tree, Nature, Vol. 16,-404(6775), pp. 278-81. doi: 10.1038/35005072.

Peña-Claros, M, Peters, E.M., Justiniano, M.J,. Justiniano M.J. and Bongers F (2008). Regeneration of commercial tree species following silvicultural treatments in a moist tropical forest, Forest Ecology and Management Vol. 255(3), pp. 1283-1293 DOI:10.1016/j.foreco.2007.10.033

Petit B, and Montagnini F (2006) Growth in pure and mixed plantations of tree species used in reforesting rural areas of the humid region of Costa Rica, Central America. For Ecol Manage Vol. 233, pp. 338–343

Potvin C, and Dutilleul P (2009) Neighborhood effects and size-asymmetric competition in a plantation varying in diversity. Ecology Vol. 90(2): pp. 321–327

Ricardo FD, Lucia Č, Snehal K, Karishma S.K, Bahare S, Antonio B, Maria RC, Hubert A, Katarzyna DS, Martyna L, Saulo RT, Veruska CA de Souza, Javad SR, Henrique DM C, Natália M, and Célia FR (2019). Advances in Chemical and Biological Methods to Identify Microorganisms—From Past to Present, Microorganisms.; Vol. 7(5): pp. 130.

Richards JC (2016). Introduction, RELC Journal, Vol. 47(1), pp. 3-4

Sánchez-Azofeifa GA, Mauricio Quesada, Jon Paul Rodríguez, Jafet M. Nassar,Kathryn E. Stoner,Alicia Castillo, Theresa Garvin, Egleé L. Zent (2005). Research Priorities for Neotropical Dry Forests, Journal of Bio Tropica, Vol. 37, Issue 4. pp 477-485

Sarrailh JM, Ayrault N (2001). Rehabilitation of Nickel Mining sites in New Caledonia. Unasylva 207(52):16-20

Siralli H., and Tarrella SA (2023): The role of secondary forest in the survival and growth of native species: Tree planting field experiment in the delta of the Paraná River (Argentina). Forest Ecology and Management. Vol. 546(15) pp. 121-329

Sodhi NS., Zhang Q., Han R., and Zan F (2011): Effect of Artificial Afforestation and Successional stage on a Lowland Forest Bird Community in Southern China. Forest Ecology and Management. Vol. 201(11) pp. 1738-1749

Taylor AH, Reld DG, Zisheng Q and Jinchu H (2008). Spatial patterns and environmental associates of bamboo (Bashania fangiana Yi) after mass-flowering in southwestern China, Bulletin of the Torrey Botanical Club 118(3), 1991, pp. 247-254

Umeri, C. Onyemekonwu R.C. and Moseri H. (2017). Evaluation of physical and chemical properties of some selected soils in mangrove swamp zones of Delta State, Nigeria, Archives of Agriculture and Environmental Science Vol. 2 (2), pp. 92-97

Yitebitu M (2014) Recommended Agroforestry/Multipurpose Trees for Borana lowland/midland and their production techniques. Subreport No. 4

Yirdaw, E., and Lukanen, O., 2003. Native woody species diversity in Eucalyptus globulus Labill. ssp. globulus plantations in the Ethiopian highlands. Biodiversity and Conservation 12, 567-582.

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