IMPACT OF RE-FORESTATION OF A RE-GROWTH SECONDARY FOREST WITH *TECTONA GRANDIS* (L.) TEN YEARS AFTER ON UNDERSTORY SPECIES COMPOSITION AND DISTRIBUTION IN ILE-IFE, SOUTHWESTERN NIGERIA

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ABSTRACT

Understory species composition, density, diversity, and tree population structure were studied in a *Tectona grandis* plantation 10 years after establishment and compared with a re-growth secondary forest of tropical forest zone in Southwestern Nigeria. The total number of understorey species in the re-growth secondary forest was 28 while 23 species were recorded in the *Tectona grandis* plantation. The numbers of shrub and climber species in the re-growth secondary forest were higher (nine) than the plantation stand (five); however, the number of herbaceous species remained the same in both the plantation and the re-growth secondary forest, The dominant understorey species in the re-growth secondary forest were *Asystasia gangetica* which got reduced from 70 (26.5%) to 13 (12.3%) in the plantation; *Combretum racemosum* from 29 (12.2%) to 6 (5.7%); *Cyathula achyranthiodes.* from 25 (10.5%) to 5 (4.7%); *Setaria barbata* from 17 (7.1%) to 6 (5.7%). The families most abundantly represented in the plantation were Acanthaceae, Combretaceae and Papilionaceae while the family most abundantly represented in the re-growth secondary forest were Acanthaceae, Combretaceae and Amaranthaceae. In the re-growth secondary forest, lower dbh (0 - 20 cm) classes showed higher density while intermediate girth dbh class (41-60 cm) had the higher density in the plantation. In general, the forest stand had more density of trees in each dbh class with a peak in the intermediate girth class. The study reveals that the establishment of *Tectona grandis* ten years after, in a re-growth secondary forest, has altered the understory composition and structure.

Key words: *Species Diversity; Species Composition; Under storey; Girth Size-Class; Plantation; Re-growth Secondary Forest*

INTRODUCTION

A total of 7,895 plant species from 338 families and 2,215 genera have been identified in Nigeria (FGN, 2006). Of these, 205 are endemic; the ninth highest number among the African countries. It has also been reported that there are 560 native tree species in Nigeria, 16 of which are critically endangered as listed in the IUCN Red list, 18 are endangered while 138 are vulnerable. In addition, out of 4,715 vascular plant species numbered in Nigeria, 205 are endemic while 170 are threatened (IUCN, 2004). The great diversity of plant species found in Nigeria is related to the diversity of ecosystems and habitats as well as the tropical climate in the country. However, despite the biological richness of Nigeria, these species are faced with threats and extinction. The following factors; agricultural activities, bush burning, fuel wood collection, logging, grazing and gathering have been reported as threats and pressure on biological diversity in Nigeria. The massive rate of deforestation is a direct cause of biodiversity loss. Nigeria has been reported to have the highest rate of deforestation of primary forests between 2000 and 2005 (FAO, 2005).

Widespread deforestation and degradation of natural habitats have contributed heavily to the loss of species (Brooks *et al.* 2002; Pimm *et al.* 1995). Over the years, large areas of tropical lowland rainforest in Africa have been cleared for agriculture or converted to plantations of fast growing exotics (e.g. oil palm, cocoa and rubber). Land-use change has been projected to have one of the largest global impacts on biodiversity (Chapin *et al.,* 2000; Sala *et al.,* 2000). The number of species occurring in different habitats is greatly determined by the type and intensity of land use. This applies particularly to arable land, forest and plantations on which humans have an impact. Therefore, the need to restore and conserve the species and the ecosystems cannot be over-emphasized. Many studies have pointed this out (Herdberg and Herdberg, 1968; Richardson, 1970; UNESCO, 1973; UNEP/FAO, 1975), and particularly in Nigeria (Charter, 1968; Okali, 1975; Ola-Adams and Iyamabo, 1977; Roche, 1973).

The conservation of lowland tropical rainforests is critical for the preservation of their biological diversity and also for their role in climate stabilization as major carbon stores, for erosion prevention and for global and local water balance. As part of the effort to restore the lost forest vegetation and address some of the consequences of deforestation especially on loss of biodiversity, wide-scale planting of tree crops like *Tectona grandis* and *Elaesis guinensis* was embarked upon by the Authority of the Obafemi Awolowo University, Ile-Ife at various sites of the University estate 10 years ago (August, 2001) through the Reforestation Project. Also because of the ongoing process of species loss through deforestation and change in land use, maintaining biodiversity has become an important challenge.

Plantation and its replacement on the re-growth secondary forest could have many effects on natural fauna and flora composition, soil changes and changes in plant species composition and entrance or biological extinction of some native species (Moraghebi *et al.,* 2005; Pilehvar, 2007; Roostami and Pourbabaei, 2007; Vatani, 2006). Studies have shown that plantations can speed recovery of biodiversity and promote woody species regeneration on re-growth secondary forest lands in tropical regions by speeding up forest succession processes, increase of soil fertility and improving site conditions (Bernhard-Reversat, 2001; Cusack and Montagnini, 2004). The proximity to natural forest, seed dispersal characteristics and site qualities influence has been reported to affect regeneration (Koonkhunthod *et al.,* 2007).

High species diversity of the forest depended on small trees in lower layers. The understory plants have been reported to be a major component of forest ecosystems and play an important role in many ecological functions and processes (Nagaike *et al.,* 2006; Roberts, 2002; Yirdaw, 2001). Therefore, conservation of small trees in lower layers, especially bottom layer, is indispensable for sound maintenance of forests (Feroz *et al.,* 2006; Hagihara *et al.,* 2008). The potentials of this tree crop plantation in maintaining biological diversity are yet to be fully assessed in this part of the world.

The objectives of this paper were to (i) quantify and document the understorey species diversity (ii) examine diameter distributions in this plantation and compare with a re-growth secondary forest in the vicinity in order to increase our understanding of the recruitment, establishment and succession of woody species following re-forestation. The following key questions were addressed: (1) How does the understorey species richness and composition differ in the plantation and the re-growth secondary forestland? (2) To what extent has reforestation been able to address the issue of biodiversity loss?

MATERIALS AND METHODS

Study Area

The study was conducted at the Obafemi Awolowo University Estate, Ile-Ife, Osun state, Nigeria (7° 29' N, 4° 34' E). Ile-Ife lies between Latitude 7^0 32' N and Longitude 4^0 31' E. The elevation of Ife ranges from 215 m to 457 m above sea level (Hall, 1969). The site for this study is located on Latitude 07^0 31.311' N and Longitude 04^0 30.983' E in Obafemi Awolowo University, Ile-Ife. The elevation of the area ranges from 243m to 274m above the sea level. Figure 1A and 1B shows the *Tectona grandis* plantation and re-growth secondary forest sites respectively.

The climate of the area is a tropical type with two prominent seasons, the rainy and dry seasons. The dry season is short, usually lasting 4 months from November to March and the longer rainy season prevails during the remaining months. The annual rainfall averages 1413 mm yr^{-1} in a 5-year survey (Duncan, 1974) and it showed two peaks, one in July and the other in September. The mean annual temperature ranges from 22.5 ^{0}C to 31.4 ^{0}C (Duncan, 1974). The relative humidity in the early morning is generally high, usually over 90% throughout the year. At mid-day, it is rather lower, around 80% in the wet season as low as 50 -60 % in the dry season (Hall, 1969).

The soil of the area is derived from material of old basement complex which is made up of granitic metamorphosised sedimentary rock (Hall, 1969). The soils are moderately to strongly leached and have low to medium humus content, weakly acid to neutral surface layers and moderately to strongly acid sub-soils (Smyth and Montgomery, 1962). The soils which are usually acidic contain less than 10% clay which is mainly kaolinite and hence are characterized by low cation exchange capacity and low water holding capacity (Ayodele, 1986). The soil has been classified as lixisols, FAO/UNESCO (1974) and utisols (USDA, 1975).

The original vegetation of Ile-Ife is lowland rainforest as climax vegetation (Keay, 1959). The forest sub-type is dry deciduous forest (Onochie, 1979). The vegetation of the areas has been described as the Guineo-Congolian drier forest type (White, 1983). Most of the original lowland rain forests are however being massively destroyed leaving remnant of re-growth secondary forest scattered around. Tree crop plantations like *Theobroma cacao, Cola nitida, Tectona grandis, Elaeis* *guineensis* are now common around the area.

Sampling Procedure

Four sample plots 25 m × 25 m, two plots in *Tectona grandis* and two plots in a nearby re-growth secondary forest were used for comparison. The plots were laid out with a measuring tape and demarcated by narrow cut lines.

Data Collection and Analysis

The measurement was done in March (dry season month). For each site, all the woody species were identified, counted, and their density per plot were determined in each plot. The diameters at breast height (dbh) = 10 cm of all the identified woody species were measured. Five line transects were systematically laid at every 5 m mark in each plot and a quadrant of 50 cm x 50 cm placed at every 5 m point to identify and quantify all the understorey plant species present in each plot. All the plants encountered in the quadrants were identified with the help of IFE Herbarium for proper identification and also using *Flora of West Tropical Africa* (Hutchinson and Dalziel, 1954-72). Floristic composition, densities, diversity, distribution and population structure of the trees and the understorey plants were determined using the following: species richness, diversity indices; Shannon-Wiener index, Simpson's Index and species evenness (E) (Pieolus index).

The Diversity index H' of each sampled plot was calculated using the method prescribed by Shannon and Wiener index (1963) as:

$$H = -\Sigma \, Pi \ln Pi$$

Where Pi is the relative abundance proportion of i species and ln = Natural logarithm

Eveness index (Pieolus, 1966) also calculated thus:

$$E = \frac{H}{\ln S}$$

Where S is the total species number in each plantation, H is the diversity index and ln= natural logarithm.

Simpson Index of diversity (1-D) which gives the probability that two randomly selected individuals in a zone belong to different subspecies and D is calculated thus:

$$D = \frac{\Sigma \, n_i(n_i - 1)}{N\,(N-1)}$$

Where n_i is the total number of individuals of species i which are counted/ encountered, and N is the total number of all individuals counted/ encountered.

The degree of similarity in species composition between plantations and a nearby re-growth secondary forest was compared using Jaccard's Index of similarity:

$$\text{Jaccard's Index (J)} = J/r \times 100$$

Where j is the number of species found in both the plantation and the re-growth forest land.
r is the number of species found in only one or the other.

Data Analysis

T-test analysis was used to test for significant different treatment effects (plantation and re-growth forest) on species diversity, Simpson index of similarity and evenness across the plots. Descriptive analysis was also employed to explain some of the parameters determined. The statistical analyses were performed using SPSS 13.0 model.

RESULTS

Floristic Composition and Richness

Results revealed a total of 18 families distributed into 23 species and 23 genera in the plantation and 21 families distributed into 21 species and 28 genera in the re-growth forest. Basal area was 17.78 m^2 ha^{-1} and 10.05 m^2 ha^{-1} in the plantation and re-growth secondary forest respectively and they are significantly different ($p = 0.0025$). The stem density in the re-growth secondary forest was found to be higher (3,808 ha^{-1}) than the recorded density in the plantation (1,696 ha^{-1}) (Table 1). The number of shrub species was higher in the re-growth secondary forest (nine) than in the plantation stand (five), while the number of herbaceous species remained similar (seven) in the two study sites. Two grass species (higher in occurrence), five climbers and four tree saplings were encountered in the *Tectona grandis* plantation; while one grass species, nine climbers and two tree saplings were found in the re-growth secondary forest (Figure 2, Table 2).

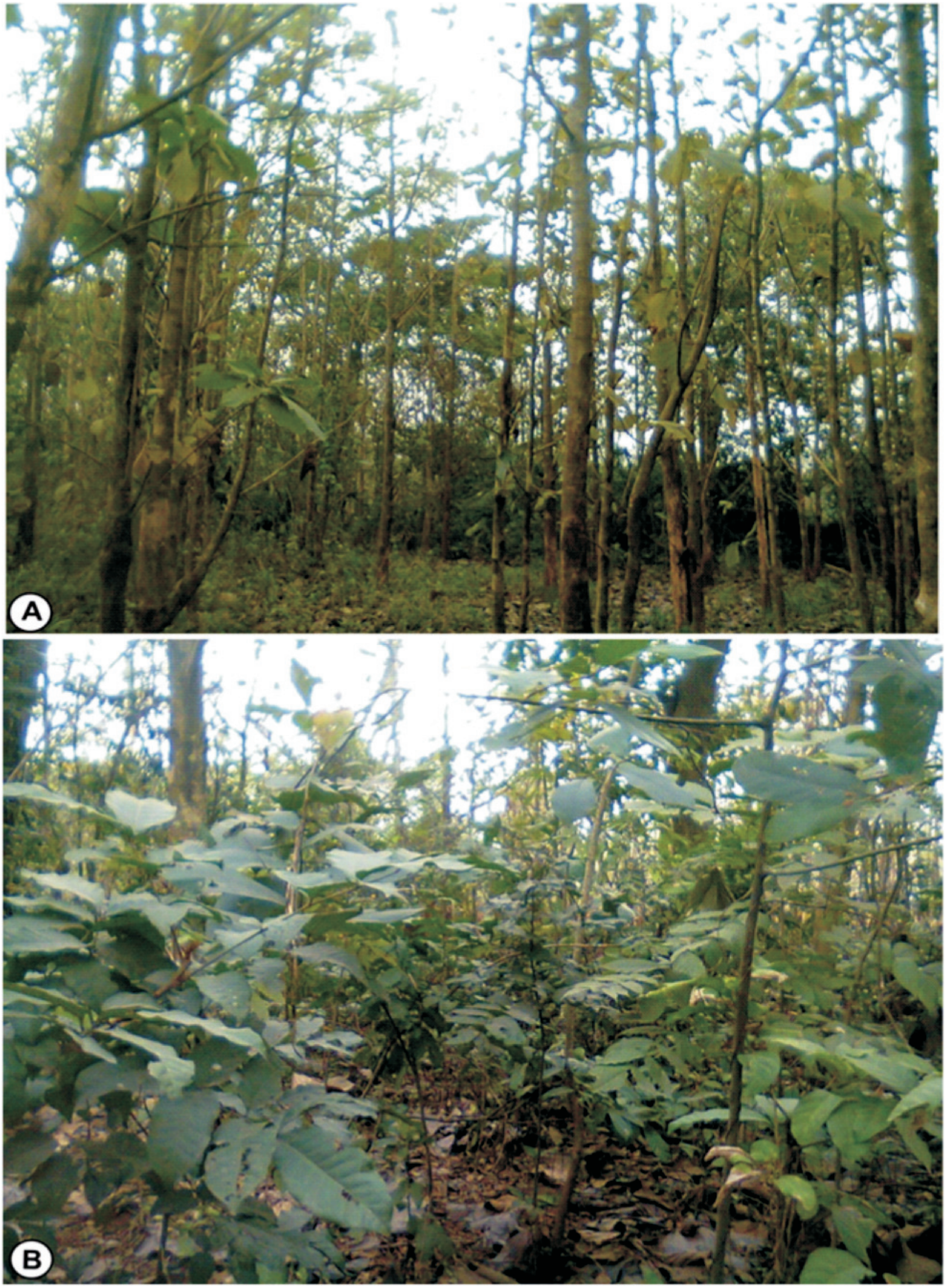

Figure 1: Photograph of the Study Sites (A) *Tectona grandis* Plantation and (B) Re-growth Secondary Forest

Table 1: Vegetation Parameters Measured in *Tectona Grandis* Plantation and the Re-growth Secondary Forest at Obafemi Awolowo University, Ile-Ife.

Vegetation Parameters	Study Sites	
	Tectona grandis plantation	Re-growth secondary forest
Understory species		
Numbers of Species	23	28
Number of Families	18	21
Number of Genus	23	28
Woody species		
Basal area m^2 ha^{-1}	17.78	10.05
Stem density ha^{-1}	1696	3808

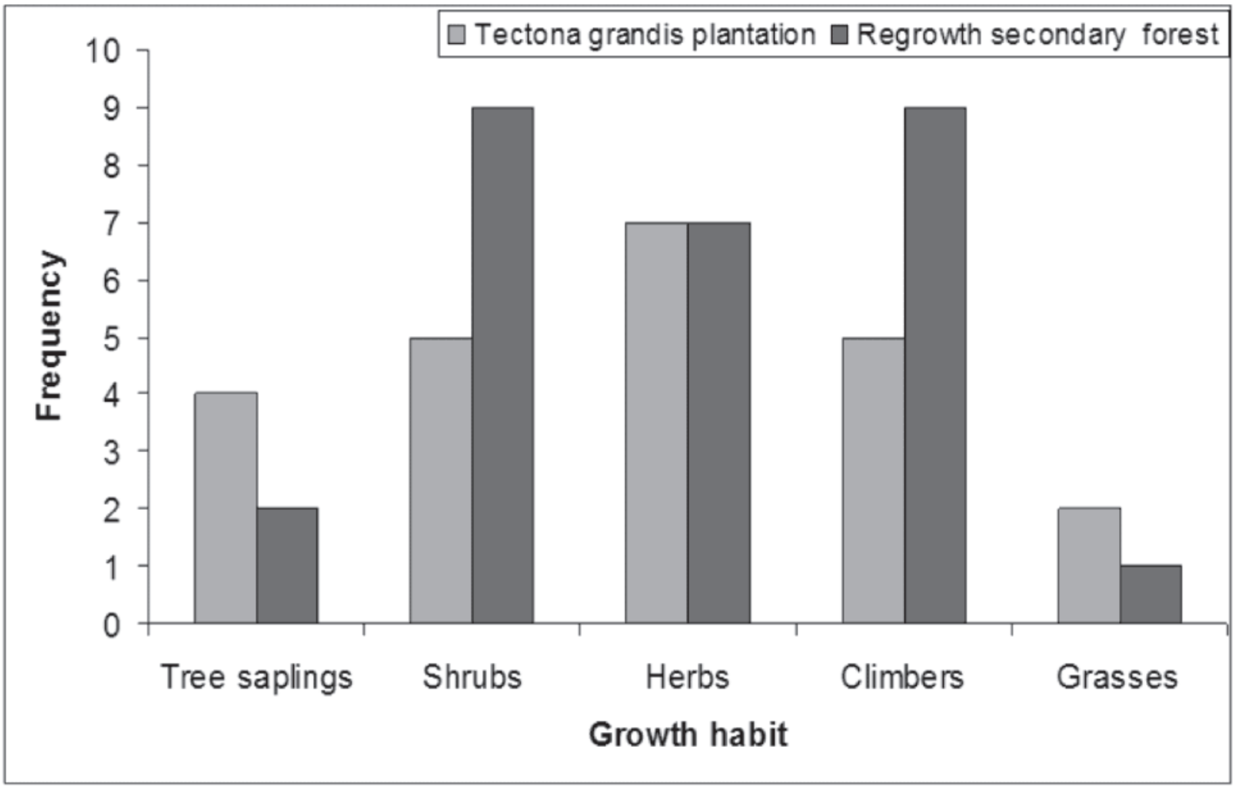

Figure 2: Growth Form of Understory Species Identified in the Re-growth and the *Tectona Grandis* Plantation at Obafemi Awolowo University, Ile-Ife.

Table 2: Comparison of Species Composition and Families in *Tectona Grandis* Plantation and Re-growth Secondary Forest at Obafemi Awolowo University, Ile-Ife.

Species composition	Family	Re-growth Forest	*Tectona grandis* Plantation
Herb			
Asystacia gangetica	Acanthaceae	70 (29.41)	13 (12.26)
Carica papaya	Caricaceae	-	2 (1.89)
Chromolaena odorata	Asteraceae	6 (2.52)	30 (28.30)
Commelina binnese	Commelinaceae	-	8 (7.55)
Commelina benghalenses	Commelinaceae	5 (2.10)	-
Cyathula achyranthiodes	Amaranthaceae	25 (10.50)	5 (4.72)
Nelsonia canescens	Acanthaceae	1 (0.42)	-
Phaulopsis barteri	Acanthaceae	1 (0.42)	-
Phaulopsis facilata	Acanthaceae	-	2 (1.89)
Talinum triangulare	Portulaceae	8 (3.36)	1 (0.94)
Shrubs			
Alchornea cordifolia	Euphorbiaceae	-	1 (0.94)
Allophylus africana	Sapindaceae	1 (0.42)	1 (0.94)
Capolobia lutea	Polygalaceae	1 (0.42)	-
Combretum racemosa	Combretaceae	29 (12.18)	6(5.60)
Euphorbia spp	Euphorbiaceae	-	2 (1.89)
Mallotus oppositifolius	Euphorbiaceae	3 (1.26)	-
Microdesmus puberula	Pandaceae	1 (0.42)	-
Mimosa pudica	Mimosaceae	-	1 (0.94)
Rauvolfia vomitoria	Apocynaceae	1 (0.42)	-
Securinega virosa	Euphorbiaceae	4 (1.68)	-
Sphenocentrum jollyanum	Menispermaceae	1 (0.42)	-
Tithonia diversifolia	Compositaceae	1 (0.42)	-
Climbers			
Baissea subsessilis	Apocynaceae	6 (2.52)	-
Cissus arguta	Vitaceae	6 (2.52)	3 (2.83)
Discorea bulbifera	Dioscoreaceae	6 (2.52)	1 (0.94)
Ipomoea involucrata	Convolvulaceae	6 (2.52)	-
Jateorhiza micrantha	Menispermaceae	6 (2.52)	-
Mondia whitei	Periplocaceae	8 (3.36)	5 (4.72)
Paulina pinnata	Sapindaceae	10 (4.20)	2 (1.89)
Triclisia subcordata	Menispermaceae	1 (0.42)	-
Vigna spp	Papilionaceae	8 (3.36)	12 (11.32)
Tree samplings			
Blighia unijugata	Sapindaceae	8 (3.36)	
Manihot glaziovii	Euphorbiaceae	-	1 (0.94)
Markhamia tomentosa	Bigmonaceae	-	1 (0.94)
Psidium guajava	Myrtaceae	1 (0.42)	-
Trema orientalis	Ulmaceae	-	1 (0.94)
Voacanga africana	Apocynaceae	-	1 (0.94)
Grasses			
Panicum maximum	Poaceae	-	1 (0.94)
Setaria barbata	Poaceae	17 (7.14)	6 (5.66)

Values in Bracket Stand for Percentage Frequency

The dominant understorey species in the re-growth secondary forest were *Asystasia Gangetica,* which got reduced from 70 (26.5%) to 13 (12.3%) in the plantation; *Combretum racemosa* from 29 (12.2%) to 6 (5.7%); *Cyathula Achyranthiodes* from 25 (10.5%) to 5 (4.7 %); *Setaria barbata (grass species)* from 17 (7.1%) to 6 (5.7%) (Table 2). The families most abundantly represented in the plantation were Acanthaceae, Combretaceae, Papilionaceae while the families most abundantly represented in re-growth secondary forest were Acanthaceae, Combretaceae and Amaranthaceae.

Results of diversity measurements in the understorey species related to Shannon Wiener, Simpson's index and the Evenness measures in plantation and re-growth secondary forest are shown in Figure 3. Shannon's Species Diversity Index showed that the re-growth secondary forest had higher diversity (H = 2.59) as compared to that of the plantation stand (H = 2.50). Pielou's Evenness Index revealed that the plantation stand had more consistency in species distribution. Re-growth secondary forest had lower evenness index (E = 0.47) compared to the plantation stand which had higher evenness (E = 0.54; Figure 3). Jaccard's similarity index between the two stands revealed that these stands had similarities to some extent (12, 44.4%) in understorey species composition which is more dominant in climbers and shrubs component as evidenced in Table 2. Results showed that there were no significant differences between species diversity indices, Shannon wiener (P= 0.2424), Simpson (P=0.4180) while evenness index was found to be significantly different at 10 % (P = 0.0908) level in the plantation areas compared with the re-growth secondary forest.

In the re-growth secondary forest lower dbh class (0-20 cm) showed higher density (Figure 4) than that of all other dbh girth classes in the plantation (41-100 cm). A trend of straight line relationship (R^2 = 0.75) between density and diameter (negative linear curve) was observed in the re-growth secondary forest while the plantation stand showed a normal distribution relationship (R^2 = 0.72). In the plantation, trees with intermediate dbh class (41-60 cm) showed highest density per ha than all other dbh classes. Individuals of the lowest dbh class (0-20 cm) showed higher tree density per hectare in the re-growth secondary forest followed by other dbh classes in the order of 21-40 cm > 41- 60 cm > 61-80 cm. In general, the plantation stand showed more density of trees than forest in each dbh classes, particularly the intermediate girth class (41-60 cm), except for individuals with lowest girth class (0-20 cm; Figure 4).

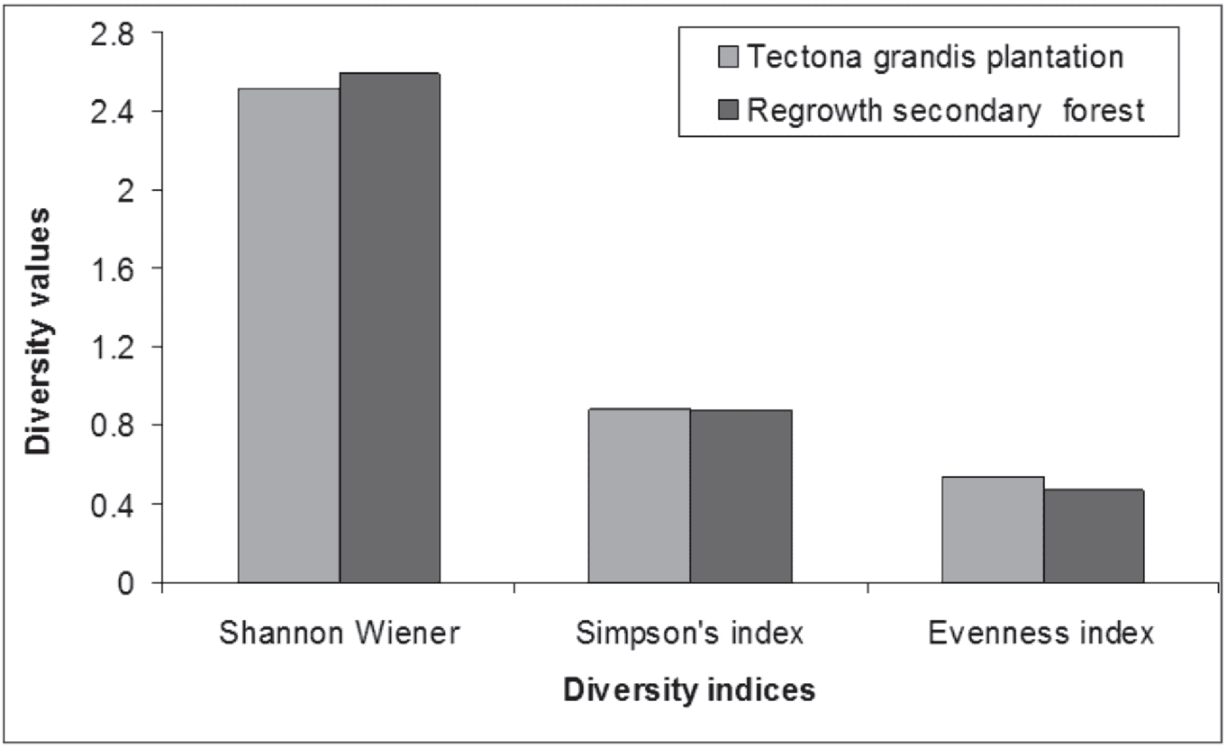

Figure 3: Comparison of Species Diversity Indices Measured across the *Tectona Grandis* Plantation and Re-growth Secondary Forest Study Sites at Obafemi Awolowo University, Ile-Ife.

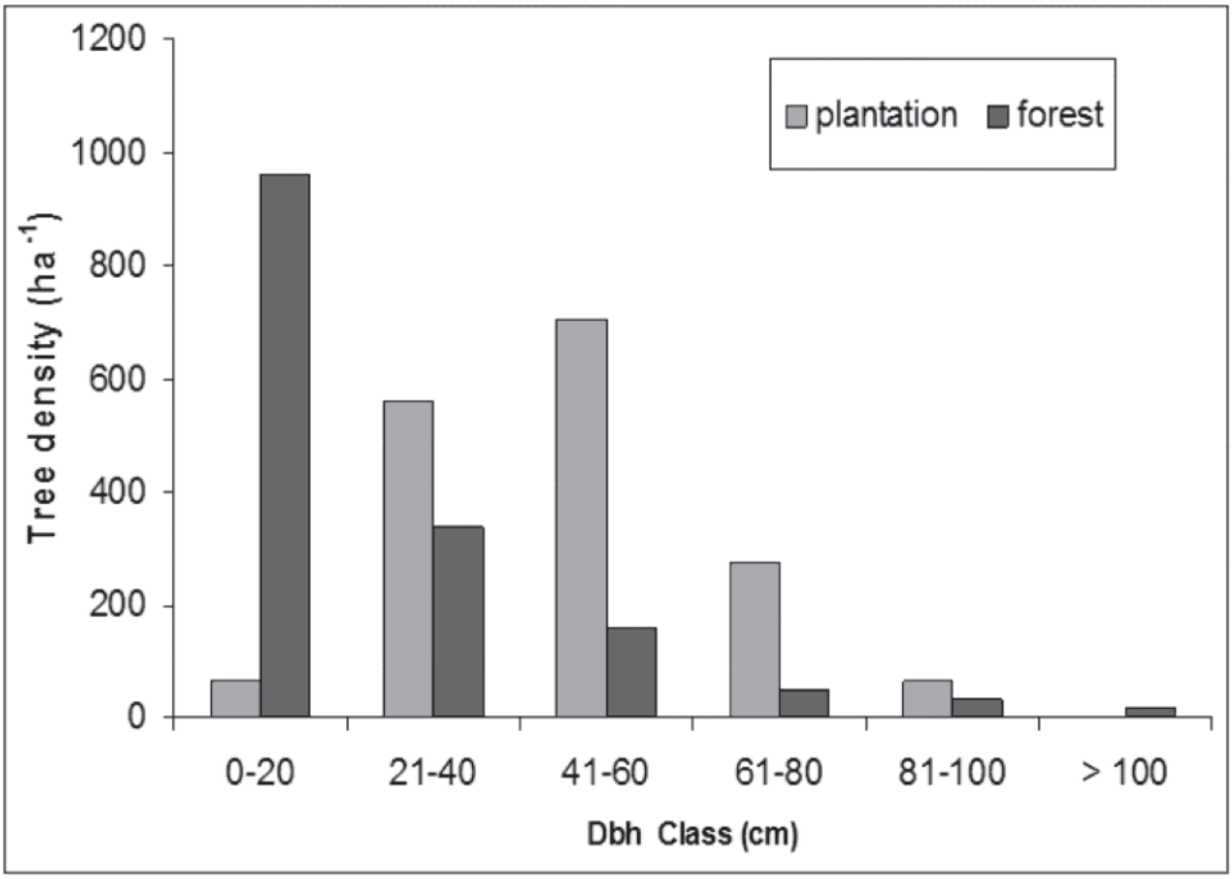

Figure 4: Tree Density-diameter Distribution of Trees in the *Tectona Grandis* Plantation Stand and the Re-growth Secondary Forest Ten Years after Establishment.

DISCUSSION

Species Composition and Richness

The aim of this study was to quantify understorey species diversity in *Tectona grandis* plantation 10 years after establishment to restore a re-growth secondary forest. The higher number of undergrowth species (richness) recorded in the re-growth secondary forest might be related to the level of disturbance and canopy cover at the sites. The re-growth secondary forest is less disturbed compared to plantation (land preparation and the planting process at the establishment stage), the re-growth secondary forest is already undergoing successional process and this might have accounted for the higher understorey species recorded at the re-growth secondary forest sites. The canopy cover of the plantation is higher and this might not be favourable to the growth of understorey species because of low light availability that can inhibit seedling emergence. This is consistent with a number of other studies which have reported that the overall cover and biomass of forest understorey vegetation often dramatically increases with canopy opening (Ehrenreich and Crosby, 1960; Stone and Wolfe, 1996). Ogunleye *et al.,* (2004) in their study on forest, plantation and re-growth secondary forest in Nigeria, have also reported higher undergrowth species in the re-growth secondary forest. This however, is in contrast to the other studies in plantation where higher understorey species richness has been reported (Ares *et al.,* 2010; Dodson *et al.,* 2008; Odiwe *et al.,* 2012; Metlen and Fiedler, 2006; Thysell and Carey, 2001; Wienk *et al.,* 2004; Zenner *et al.,* 2006). The higher understorey species in the plantation has been attributed to various forms of disturbance like thinning and grazing.

Higher number of climbers and shrub species recorded in the re-growth secondary forest compared to *Tectona grandis* plantation follows the findings of Ewel and Bigelow (1996) who reported that during the first 5 years of post slash and burn succession, there was decrease in herbaceous vines, increase in shrubs and trees and a dramatic increase in epiphytes as the plants aged. The result of higher number of shrubs and some herbaceous species that were recorded in this study is similar to the findings of Lü *et al.*, (2011) and Tchouto *et al.* (2006), who found that the shrub layer was the most species-rich in all the strata of the Campo-Ma'an rain forest in Cameroon tropical forest. The predominance of shrubs and climbers in the re-growth secondary forest could be as a result of higher proportion of light in the re-growth secondary forest which favours them compared with the herbaceous plants. From our result, re-growth secondary forest has more grasses than the plantation, the presence of higher number (frequency) of grasses, especially *Setaria barbata* is an indication of more canopy openings since grasses can only thrive in an open area where more light is available. This observation is consistent with the results of Holl *et al*., (2000) and Hoper *et al.,* (2004) where it was reported that vines, ferns and persistent grasses can impede establishment and growth of woody shrubs and trees in abandoned pastures. The dominance of Acanthaceae family in herbaceous species is consistent with the findings of Richards (1996) where Acanthaceae in addition to other families has been reported to be dominant families of ground herbs in tropical rain forests

Species Diversity

The higher Shannon-wiener index diversity in the re-growth secondary forest might be connected with the higher value of species richness. This result is in agreement with the findings of Ogunleye *et al*., (2004) where higher species diversity was recorded in the re-growth secondary forest compared with plantation. Lower species diversity have also been reported in the plantations in some other studies (Munoz-Reinoso, 2004; Pourbabaei and Roostami, 2007; Roberts, 2002; Yirdaw, 2001). However, this is in contrast to the findings of Odiwe *et al*., (2012), Koonkhunthod *et al*., (2007), Nagaike (2002), Nagaike *et al*., (2006); Poorbabaei and Poorrahmati (2009), who have all reported higher species diversity in the plantations compared with the forest. The higher evenness distribution in the plantation understorey might be linked to the fact that trees are planted at a defined spacing and this created a micro-climate environment that might have influenced the growth and regeneration of the understorey species. Studies where evenness values are higher in plantations as obtained in this study are available in literature (Vatani, 2006; Memarian *et al.,* 2007, Koonkhunthod *et al.,* 2007).

The presence of certain common species (12) and higher value of similarity (44.4%) in the plantation and the re-growth secondary forest may be due to similarity of the stands (in terms of resource availability, similar environmental condition and similar mode of propagation and dispersal), thereby making it possible for the species to invade and survive (Davies *et al.,* 2005; Levine, 2000; Stohlgren *et al*, 1999; Lalfakawma *et al*., 2009).

Lower common species between plantations and secondary forest had earlier been reported by Odiwe *et al*. (2012). Occurrence of more tree species (especially *Blighia unijugata*) in the plantations than the re-growth secondary forest might indicate a potential of using plantations for restoring biodiversity of tree species in the studied sites. This position must however be treated with caution since is not really clear cut and there is need to carry out more studies to ascertain this position. The higher density of lower dbh class (0-20 cm) in the re-growth secondary forest might indicate that the site is highly disturbed and high removal of higher girth sizes (Golf and West, 1975; Lorimer *et al*., 2001) while the higher intermediate (41-50) dbh classes in the plantation could be as a result of the fact that the trees were planted in the plantation and that they have not been harvested since establishment. This is similar to the findings of Lalfakawma *et al.,* (2009), Saxena *et al*., (1984), and Souza (1979), where mortality and lower removal rate across the intermediate classes has been reported.

Straight line relationship (negative linear curve) between the understory species density (plant ha^{-1}) and diameter size classes in the re-growth secondary forest is in agreement with the findings of Lalfakawma *et al.* (2009), Rao (1990), Schmeiz and Lindsey (1965), while the plantation did not conform with this relationship (normal distribution curve). The reason for this has been explained above. Higher basal area recorded in the plantation compared to the re-growth secondary forest can be attributed to the trees of bigger sizes that are of uniform girth sizes in the plantation. This contradicts the findings of Poorbabaei and Poorrahmati (2009) where a lower basal area in the *Tectona grandis* plantation was reported. The higher stem density (ha^{-1}) recorded in the re-growth forest can be contributed to the higher number of species recorded at the sites. The general pattern of girth size distribution in both *Tectona grandis* and the re-growth secondary forest is an indication that the sites are disturbed though the level of disturbance differs. One can therefore conclude that the study sites are still growing; they are not yet matured.

CONCLUSION

It can be inferred from the present study that diversity of understorey species is closely affected by the land use change, species diversity increases in the re-growth secondary forest compared with the *Tectona grandis* plantation. It is obvious that re-forestation with *Tectona grandis* plantation has an appreciable effect on species richness and composition, with less number of shrubs, and climbers being present. The purpose of carrying out this study is to provide information on the species richness and composition, compared with re-growth secondary forest with the aim of providing information on the composition and distribution of understorey species because little attention has been paid to the understorey vegetation in the process of biodiversity conservation in the tropical forests. As observed, some of the understory species identified in the re-growth secondary forest have decreased in the plantation, especially tree species.

There is still need for more research to be carried out, especially to the impact of seasonal changes on the distribution and composition of the understorey species and the role of different understorey species (shrubs, herbs, grasses, climbers) in nutrient cycling in the systems.

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