Understorey Vegetation Assessment in *Gmelina arborea* (Roxb.) Plantations of Different Ages in Omo Forest Reserve, Southwestern Nigeria

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Abstract: Understorey vegetation helps to conserve soils in tree plantations thereby enhancing natural forest regeneration (NFR). Although, NFR has been extensively studied, there is paucity of knowledge on understorey vegetation under single species tree plantations. The study, therefore, investigated the understorey vegetation under *Gmelina arborea* plantations of different ages in Ogun State, South-western Nigeria. Ten quadrats of 20m x 25m were established randomly in *Gmelina arborea* plantations of 5, 22, 29 years and natural forest (NF). In each 20m x 25m quadrats, five sub-quadrats of 1m x 1m were delimited whereby species of understorey vegetation were identified and counted. These information was thereafter used to compute population of individual species, species richness, and diversity of understorey vegetation. Descriptive statistics was used to describe the results while analysis of variance was used to determine significant variation in the understorey parameters at $p<0.05$. Findings showed that species composition of understorey vegetation comprised of 94 species and the total population was 1,910. Species composition of understorey vegetation comprised of 51 families with Euphorbiaceae having the dominance. The mean population of individual per understorey species was 54.1, 55.9 and 60.8 in the gmelina plantations of 5, 22 and 29 years respectively while NF had 20.2 species. Population of individual species varied significantly among gmelina plantations ($F_{0.05}=3.051$). Mean species richness and diversity were higher in gmelina plantations than NF. The study recommended that higher species richness of understorey vegetation in gmelina plantations should be maintained to sustainably conserve wildlife habitat and understorey biodiversity.

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1. Introduction

Tropical forests constitute the most diverse plant communities on earth. These forests are disappearing at alarming rates owing to deforestation for extraction of timber and other forests products (Devi and Yadava, 2006). The problem with the forest ecosystem often does not get time to recover adequately because the human onslaught never stops (Singh, Gupta and Singh, 2013). Most of the native trees have been endangered and some are even tending towards extinction and because of this, the issue of having plantation of exotic trees came to the fore in many tropical countries. Exotic tree species are introduced species from other regions and they are widespread in tropical and subtropical countries since they are popular as reforestation species even in a forest degraded environments (Nylan, 1996); due to their ability to adapt easily to variable site conditions while many are considered economically viable because of their fast growth characteristic. Today, some plantations of exotic and indigenous species have been established in Nigeria and prominent among the exotic species are *Tectona grandis*, *Gmelina arborea*, *Eucalyptus globulus*, *Ciderella odorata* and *Pinus sp.* while the indigenous ones include *Nauclea diderichii*, *Triplochiton scleroxylon*, *Terminalia ivorensis* and *Terminalia superba* (Adekunle *et al.*, 2011).

Plantation forestry of fast-growing exotic species for erosion control through crown cover and litter production as well as for fuelwood production is very demanding in Nigeria (Ogbonna and Nzegbule, 2009). Thus, tree plantations improve the productive potentials of degraded lands and are substitute for unmanaged natural stands with their diminishing wood resources (Evans, 2002). Research on tree plantations in many countries have reported site deterioration, largely expressed as soil erosion. The cause according to Ball, Pandley and Hirai (1999), is the lack of understorey or undergrowth in relatively dense single-species, even-aged tree plantations, made worse by fires in the dry season which burn the leaf litter and leave the soil surface unprotected from heavy rains, particularly at the beginning of the rainy season before the overstorey vegetation develops new leaves. Owing to the versatility of gmelina as an industrial raw material, it has become one of the most widely planted species in the tropics (Nwoboshi, 1994).

There is widespread notion that the use of exotic tree species for reforestation causes negative ecological effects. Dogra *et al.* (2009) compared the understorey vegetation in *Eucalyptus citriodora* and *Pinus roxburghii* plantations in India whereby shrub, herbs, and grass of different families, genera and species were identified and it was also discovered that the species composition under *Eucalyptus citriodora* was higher than that of *Pinus roxgurghii*. Parsakhoo (2009) employed correlation and regression statistics to determine how tree canopy cover and elevation at sea level have affected the understorey herbaceous cover and trees stock growth. No attempt has so far been made to compare the composition, evenness and diversity of understorey vegetation in relation to tree growth characteristics under the *Gmelina arborea* of different ages. Lu, Yin and Tang (2010) affirmed that studies on vascular plants in tropical forests have focused on trees whereas the understorey remains the least understood. Against this background, this study therefore investigated the effects of gmelina stands of different ages on understorey vegetation in the Omo Forest Reserve, South Western Nigeria.

2. Methodology

The study area was Omo Forest Reserve, Ijebu area of Ogun State in the South-western Nigeria. Omo Forest Reserve is located between latitudes 6^{o} 35'N and 7^{o} 05'N and longitudes 4^{o} 19'E and 4^{o} 40'E (Figure 1). It is about 135 km North-East of Lagos and 80 km East of Ijebu-Ode. It covers an area of about 130,500 hectares of land and about 640 hectares of land in the north central part of the reserve had been designated as a Strict Nature Reserve (SNR) since 1946 (Badejo and Ola-Adams, 2000). The vegetation of Omo Forest Reserve is a mixed moist semi-deciduous rainforest. The study area is dominated by tree forms ranging in size from shrubs to exceedingly tall members. Among the trees are those famous for their timbers such as *Milicia excelsa, Terminalia superba, Terminalia ivorensis, Khaya ivorensis* and *Piptandeniastrum afrcanum*. Apart from trees, the study area is also composed of herbs, climbers, epiphytes, stranglers, saprophytes and parasites (Adamson, 1996). The study area is underlain by metamorphic rocks of the Basement Complex, the great majority of which are very ancient, being of Pre-Cambrian age (Badejo and Ola-Adams, 2000). According Akindele (1991), the topography of the study area is gently to strongly undulating with an average altitude ranging from about 120 to 480m above sea level. The uneven topography is characterized by numerous small hills which are dissected by tributaries of the Shasha, Owena and Oni Rivers.

The soil of the study area is ferruginous tropical soil that is formed from the Basement Complex and generally, the soil of the area is characterized by low water table (Okali, 1987). The climate is the humid sub-equatorial type (Aweto, 1981). The rainfall amount exhibit bi-modal peaks which characterizes the variational trend of rainfall in the study area. The first maximum occurs in July with a mean value of (195.88mm) and the second maximum occurs in September with a mean value of (230.41mm) and the annual rainfall ranges between 1300mm to 1600 mm (Ogolo and Adeyemi, 2009).

Ten quadrats of 20m x 25m were randomly laid on the 2008 (5 years), 1991 (22 years), 1984 (29 years) gmelina stands and natural forest for data collection between August and November 2013 and thus, a total of 40 plots were laid. Equal number of quadrats was established in both gmelina plantations and natural forest to have equal sampling plots so that comparative analysis in the understorey vegetation parameters can be possible. Five 1 m x 1 m sub-quadrats were delimited in each 20 m x 25 m quadrat within which understorey vegetation was inventoried and identified (Ali and Malik, 2010). Thus, fifty plots were sampled in each Gmelina plantations and natural forest.

The understorey vegetation comprises of trees, shrubs, herbs, grasses, climbers, creepers, woody climber and woody herb. The data were used for computation of analytical understorey vegetation features such as species composition, population of individual species, species diversity, species richness, species evenness, and similarity index following standard phyto-sociological methods as given by Lu, Yin and Tang (2010). Species composition of understorey vegetation was determined by identifying the plant species while the population of individual species was determined by direct counting of the population of each species. The species diversity index was computed using Simpson's index (Simpson, 1949). The species richness was determined using Margalef's index (Margalef, 1958). The species richness was calculated to determine the sensitivity of these ecosystems and their resident species. Similarity index of the understorey vegetation between plantations was determined using Sorensen's formula (Sorensen, 1948). Descriptive statistics was used to describe the mean values of understorey vegetation parameters while analysis of variance was used to determine the significant variation in the understorey vegetation parameters.

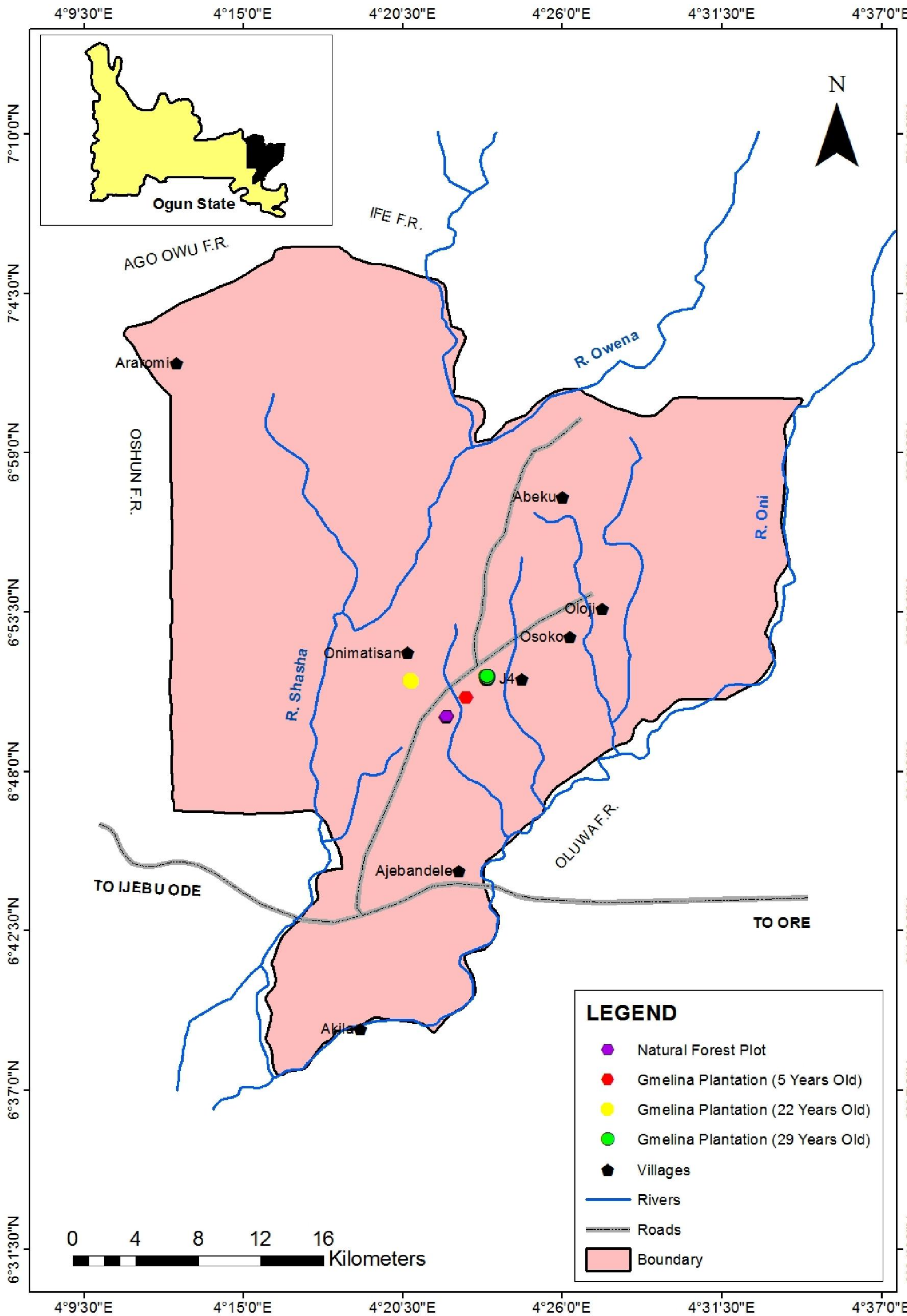

Figure 1: Omo Forest Reserve showing different ages of *G. arborea* plantations

3. Results

Species composition and number of individuals per species of understorey vegetation under gmelina plantations and natural forest

The species composition of understorey vegetation comprised of ninety four (94) species and the total population was 1,910 (Table 1). The total population of species of understorey increased with the increasing age of gmelina plantations. The mean number of individual per species was 54.1, 55.9 and 60.8 in the gmelina plantation of 5 years, 22 years and 29 years respectively while that of natural forest which had a mean number of individual per species of 20.2 (Table 1). *Chromolaena odorata* had the highest number of individuals per species (232), *Gmelina arborea* wildlings had 114 and *Funtumia elastica* had 104. Each of *Alternanthera sessilis*, *Anthocleista nobilis*, *Dioscorea mangenotiana*, *Glyphea brevis*, *Lonchocarpus cyanescens*, *Parquetina nigrescens*, *Spondias audit*, *Spondias mombin*, *Terminalia superba* and *Triplochiton scleroxylon* were the least. There was a significant difference in the number of species of understorey vegetation among the gmelina plantations of different ages ($F_{0.05}$=3.05, $p<0.05$) (Table 1).

The species composition of undergrowth vegetation in the entire study area comprised of 51 families (Table 2). In gmelina plantation of 5 years, Papilionaceae was highest with frequency of 5, followed by Euphobiaceae and Moraceae with frequency of 4 each (Table 2). Papilionaceae was the highest with frequency of 4 in gmelina plantation of 22 years followed by Sapindaceae, Combretaceae and Apocynaceae with frequency of 3 while Dioscoreaceae, Euphobiaceae, Moraceae and Rubiaceae had frequency of 2 (Table 2). Under gmelina plantation of 29 years, Apocynaceae and Euphorbiaceae had the highest frequency of 4, followed by Sapindaceae with frequency of 3 while each of Commlinaceae, Rubiaceae, Papilionaceae and Moraceae had frequency of 2 (Table 3). The dominant families of understorey vegetation under natural forest were Apocynaceae, Dioscoreaceae and Sapindaceae; followed by Ulmaceae, Rubiaceae, Papilionaceae and Mimosaeae with frequency of 2 (Table 2). Generally, the families that recorded the least species composition of understorey vegetation in the entire study area were Agavaceae, Cucurbitaceae, Ebenaceae, Loganiaceae, Melasiomataceae, Solanaceae and Tiliaceae (Table 2).

Table 1: Species composition and number of individuals per species of understorey vegetation under gmelina of different ages and natural forest

S/N	Species	Gmelina (5years)	Gmelina (22years)	Gmelina (29years)	Natural Forest
1	*Abrus precatorius*	4	4	4	-
2	*Acasia camerunensis*	-	-	1	1
3	*Adenia lobata*	-	-	29	1
4	*Albizia ferruginea*	-	-	-	1
5	*Alchornea cordifolia*	6	-	9	11
6	*Alstonia boonei*	-	2	5	-
7	*Alternanthera sessilis*	19	6	1	2
8	*Alternanthera sp*	-	-	-	1
9	*Anchomanes difformis*	-	3	4	4
10	*Anthocleista nobilis*	-	-	-	1
11	*Aristolochia sp*	-	3	3	-
12	*Aspilia africana*	73	-	-	-
13	*Baphia nitida*	9	3	12	3
14	*Blighia sapida*	-	4	3	6
15	*Blighia unijugata*	-	1	11	2
16	*Bridelia micrantha*	7	2	2	-
17	*Calopogonium mucunoides*	41	-	-	-
18	*Capsicum frutescens*	-	-	5	-
19	*Carpolobia lutea*	-	5	9	7
20	*Ceiba pentandra*	-	49	3	-
21	*Celtis mildbraedii*	-	2	28	-
22	*Centrosema pubescence*	62	19	-	-
23	*Chassalia kolly*	-	2	49	13
24	*Chromolaena odorata*	72	91	69	-

S/N	Species	Gmelina (5years)	Gmelina (22years)	Gmelina (29years)	Natural Forest
25	*Cissampelos owariensis*	-	1	10	-
26	*Cissus petiolata*	-	1	3	3
27	*Cleistopholis patens*	-	2	9	2
28	*Cnestis ferruginea*	6	54	18	7
29	*Combretum hispidum*	-	2	-	-
30	*Combretum racemosum*	2	5	5	1
31	*Combretum zenkeri*	-	2	-	-
32	*Commelina benghalensis*	1	-	4	-
33	*Culcasia scandens*	-	13	3	6
34	*Cyperus esculentus*	2	-	-	-
35	*Deinbollia pinnata*	-	1	5	4
36	*Desmodium scorpiurus*	3	-	-	-
37	*Dialium guineense*	7	4	5	1
38	*Dimorphochlamys mannii*	-	-	4	-
39	*Dioscorea bulbifera*	12	6	3	1
40	*Dioscorea mangenotiana*	-	-	-	1
41	*Dioscorea smilacifolia*	1	3	-	1
42	*Diospyros germinate*	-	-	-	2
43	*Diplazium sammatii*	-	1	4	14
44	*Dissotis rotundifolia*	-	-	6	-
45	*Dracaena arborea*	-	-	3	-
46	*Elaeis guineensis*	-	9	3	3
47	*Emilia coccinea*	-	-	-	8
48	*Enthradophragma angolensis*	-	3	3	-
49	*Eucalyptus globules*	-	-	-	2
50	*Ficus capensis*	4	-	-	-
51	*Ficus exasperata*	10	-	2	-
52	*Ficus mucuso*	1	2	-	-
53	*Ficus vogelii*	-	1	-	1
54	*Funtumia elastica*	-	42	39	23
55	*Glypheaa brevis*	-	-	-	1
56	*Gmelina arborea*	-	66	48	-
57	*Harungana madagascariensis*	22	-	4	5
58	*Icacina trichanta*	12	60	8	17
59	*Leea guineensis*	-	1	10	-
60	*Leptoderris brachyptera*	-	1	3	1
61	*Lonchocarpus cyanescens*	-	1	-	-
62	*Manihot esculenta*	3	-	-	-
63	*Milicia excelsa*	2	-	-	-
64	*Morinda lucida*	-	3	5	-
65	*Musanga cecropoides*	-	-	3	-
66	*Napolea vogelii*	10	2	1	-
67	*Palisota hirsute*	-	10	23	4
68	*Parquetina nigrescens*	-	-	-	1
69	*Peninsetum purpureum*	89	-	-	-
70	*Phyllanthus discoideus*	19	-	-	-
71	*Phyllanthus reticulates*	-	-	5	-
72	*Piper guineense*	-	-	-	7
73	*Piper umbellatum*	-	-	25	-
74	*Psidium guajava*	2	-	1	-
75	*Rauwolfia vomitoria*	5	8	29	10
76	*Ritchiea capparoides*	-	3	4	1

S/N	Species	Gmelina (5years)	Gmelina (22years)	Gmelina (29years)	Natural Forest
77	*Secamone afzelii*	4	19	5	-
78	*Senna hirsute*	4	-	-	-
79	*Sida acuta*	19	-	-	-
80	*Smilax anceps*	-	9	11	3
81	*Sphenocentrum jollyanum*	-	6	3	4
82	*Spondias audit*	-	1	-	-
83	*Spondias mombin*	-	-	-	1
84	*Stachytarpheta jamaicensis*	2	-	-	-
85	*Sterculia tragacantha*	2	-	-	-
86	*Strophanthus hispidus*	-	-	26	9
87	*Tephrosia bracteolata*	4	-	-	-
88	*Terminalia superba*	-	-	-	2
89	*Tetracarpidium conophorum*	-	-	-	2
90	*Tragia benthami*	-	19	2	-
91	*Trema orientalis*	-	-	8	-
92	*Triplochiton scleroxylon*	-	-	-	1
93	*Urena lobata*	-	-	4	-
94	*Zanthoxylum zanthoxyloides*	-	2	4	-
	Total	541	559	608	202
	Mean	54.1	55.9	60.8	20.2

($F_{\text{Number of species}}$=3.051; p=0.018)

Table 2: Summary of families of undergrowth vegetation under gmelina and natural forest

S/N	Family	Gmelina (5 years)	Gmelina (22 years)	Gmelina (29 years)	Natural Forest
1	Agavaceae	0	0	1	0
2	Amarathanceae	1	1	1	2
3	Anacardiaceae	0	1	0	1
4	Annonaceae	0	1	1	1
5	Apocynaceae	1	3	4	3
6	Araceae	0	2	2	2
7	Arecaceae	0	1	1	1
8	Aristolochiaceae	0	1	1	0
9	Asclepiadaceae	1	1	1	1
10	Asteraceae	2	0	0	1
11	Asteraceae	0	1	1	0
12	Bombacaceae	0	1	1	0
13	Caesalpiniaceae	2	1	1	1
14	Capparaceae	0	1	1	1
15	Combretaceae	1	3	1	2
16	Commelinaceae	1	1	2	1
17	Connaraceae	1	1	1	1
18	Cucurbitaceae	0	0	1	0
19	Dioscoreaceae	2	2	1	3
20	Dryocteridaceae	0	1	1	1
21	Ebenaceae	0	0	0	1
22	Euphorbiaceae	4	2	4	2
23	Fabaceae	1	1	1	0
24	Hypericaceae	1	0	1	1
25	Icacinaceae	1	1	1	1
26	Lecythidaceae	1	1	1	0
27	Leeaceae	0	1	1	0
28	Loganiaceae	0	0	0	1

S/N	Family	Gmelina (5 years)	Gmelina (22 years)	Gmelina (29 years)	Natural Forest
29	Malvaceae	1	0	1	0
30	Melasiomataceae	0	0	1	0
31	Meliaceae	0	1	1	0
32	Menisoermaceae	0	1	1	0
33	Menispermaceae	0	1	1	1
34	Mimosaceae	0	0	1	2
35	Moraceae	4	2	2	1
36	Myrtaceae	1	0	1	1
37	Papilionaceae	5	4	2	2
38	Passifloraceae	0	0	1	1
39	Piperaceae	0	0	1	1
40	Poaceae	2	0	0	0
41	Polygalaceae	0	1	1	1
42	Rubiaceae	0	2	2	1
43	Rutaceae	0	1	1	0
44	Sapindaceae	0	3	3	3
45	Smilacaceae	0	1	1	1
46	Solanaceae	0	0	1	0
47	Sterculiaceae	1	0	0	1
48	Tiliaceae	0	0	0	1
49	Ulmaceae	0	1	2	0
50	Verbenaceae	1	1	1	0
51	Vitaceae	0	1	1	1
	Total	35	49	58	46

Source: Author's analysis, 2015

Life forms of understorey vegetation

The species composition in the entire study area had 11 life forms in a total population of 188 species of undergrowth vegetation (Table 4). Tree recorded the highest composition of 42.0% (79), followed by shrub which had 14.4% (27) and woody climber had 13.3% (25). Herbaceous climber had 9.0% (17), and woody herb had 6.9% (13) while herbaceous creeper recorded 1 (0.5%) (Table 4). A total of 18.6% (35), 26.1% (49) and 24.4% (46) different species of understorey vegetation were recorded in the gmelina plantations of 5 years, 22 years and 29 years respectively (Table 4). Considering the distribution of life forms under gmelina plantations and natural forest generally, tree recorded the highest and followed by shrubs but grass was very rare and found only in gmelina plantation of 5 years (Table 4).

Table 3: Life form of species of undergrowth vegetation in gmelina plantations and natural forest

Life Form	Gmelina of 5 years	Gmelina of 22 years	Gmelina of 29 years	Natural forest	Total
Vine	2 (5.7)	2 (4.1)	1 (1.7)	3 (6.5)	8 (4.3)
Fleshy climber	0 (0.0)	1 (2.0)	1 (1.7)	1 (2.2)	3 (1.6)
Fleshy herb	1 (2.9)	1 (2.0)	3 (5.2)	2 (4.3)	7 (3.7)
Grass	2 (5.7)	0 (0.0)	0 (0.0)	0 (0.0)	2 (1.1)
Herb	2 (5.7)	1 (2.0)	1 (1.7)	2 (4.3)	6 (3.2)
Herbaceous climber	4 (11.4)	5 (10.2)	5 (8.6)	3 (6.5)	17 (9.0)
Herbaceous creeper	0 (0.0)	0 (0.0)	1 (1.7)	0 (0.0)	1 (0.5)
Shrub	6 (17.1)	6 (12.2)	9 (15.5)	6 (13.0)	27 (14.4)
Tree	13 (37.1)	22 (44.9)	25 (43.1)	19 (41.3)	79 (42.0)
Woody climber	2 (5.7)	8 (16.3)	8 (13.8)	7 (15.2)	25 (13.3)
Woody herb	3 (8.6)	3 (6.1)	4 (6.9)	3 (6.5)	13 (6.9)
Total	35 (100.0)	49 (100.0)	58 (100.0)	46 (100.0)	188 (100.0)

Percentage (%) in parentheses

Species diversity, richness and similarity index of understorey vegetation species

The mean species diversity of understorey vegetation in gmelina plantations of 5 years, 22 years, 29 years and natural forest was 0.9063, 0.9008, 0.9525 and 0.9375 respectively (Table 5), thus slight variation existed in the species diversity among the gmelina plantations. The species diversity was high in all the landuse types but higher in the oldest gmelina plantations. The mean species richness of understorey vegetation in gmelina plantation of 5 years was 3.3; gmelina plantation of 22 years was 4.0 while gmelina plantation of 29 years was 5.9 and under natural forest was also 3.4 (Table 5). The Sorensen's similarity index in the understorey vegetation between gmelina plantations of 5 years and 22 years was 1.87%; between gmelina plantations of 5 years and 29 years was 1.67%; and between gmelina plantations of 5 years and natural forest was 1.24% (Table 6). Similarly, the similarity index in the understorey vegetation between gmelina plantations of 22 years and 29 years was 2.82%; and between gmelina plantations of 22 years and natural forest was 2.22% (Table 6). The similarity index of understorey vegetation between gmelina plantation of 29 years and natural forest was 2.17% (Table 6).

Table 5: Species diversity, richness of undergrowth vegetation under gmelina plantations and natural forest

Understorey vegetation paramater	Gmelina of 5 years	Gmelina of 22 years	Gmelina of 29 years	Natural Forest
Species diversity	0.9077±0.02	0.9008±0.03	0.9525±0.02	0.9375±0.05
Species richness	3.3±0.4	4.0±0.7	5.9±1.2	3.4±1.2

Table 6: Sorensen's Similarity Index (SID) of undergrowth vegetation among Gmelina plantations and natural forest

Landuse	Gmelina (5years)		Gmelina (22years)		Gmelina (29years)		Natural Forest	
	SID	SID (%)	SID	SID (%)	SID	SID (%)	SID	SID (%)
Gmelina (5 years)	1	100						
Gmelina (22 years)	0.0187	1.87	1	100				
Gmelina (29 years)	0.0167	1.67	0.0282	2.82	1	100		
Natural Forest	0.0124	1.24	0.0222	2.22	0.0217	2.17	1	100

4. Discussions

Number of individual species of understorey vegetation among the gmelina plantations significantly varied. This may be attributed to the crown diameter of gmelina plantation at varying ages which may cause differences in the photosynthetic process. Barbier, Gosselin and Balandier (2008) and Strong (2011) reported that canopy trees may influence understorey species composition in an individual or collective manner. Odiwe, Olowoyo and Ajiboye (2012) also reported that higher canopy cover of plantation might not be favourable to the growth of understorey species because of low light availability that can inhibit seedling emergence. The results of the analysis 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 (Stone and Wolfe, 1996; Odiwe, Olowoyo and Ajiboye, 2012). Charbonneau and Fahrig (2004) in Parsakhoo (2009) added that site scale canopy openness should favour the germination and growth of herbaceous species and at the landscape scale the presence of open canopy should increase the seed rain and therefore the colonization rate of forest sites by herbaceous species. Similarly, overstorey structure and composition, soil nutrient and moisture availability, succession history, forest management strategies, throughfall light and fragmentation contribute to the variation in the understorey vegetation (Felton *et al.*, 2006; Lu, Yin and Tang, 2010; Zhang *et al.,* 2011). Furthermore, findings showed that understorey species population in the gmelina plantations was more than natural forest. However, Binkley and Resh (1998) noted that tree plantations improve the microclimate for the establishment of native species in the understorey.

The finding on the dominant families of undergrowth vegetation was slightly similar to the results of Lu, Yin and Tang (2010) whereby five families, Euphorbiaceae, Annonaceae, Lauraceae, Sapindaceae and Meliaceae, were among the dominant undergrowth vegetation in the tropical seasonal rainforest of Xishuangbanna, SW China. Euphorbiaceae and Sapindaceae were also among the dominant families in this study which indicated that the seedlings and wildlings of gmelina families must have contributed strongly to the composition of the understorey in this forest. Odiwe, Olowoyo and Ajiboye (2012) reported that Euphorbiaceae, Papiloniaceae, Rubiaceae and Asteraceae are the most dominant families in the tropical rainforest of Nigeria. Soladoye *et al*. (2005) viewed that Euphorbiaceae was one of the dominant families of biodiversity in the Southwestern Nigeria.

The study of Dogra *et al*. (2009) on understorey vegetation in exotic and indigenous tree plantations in

Shivalik Hills of N.W. Indian Himalayas is similar to the findings of this study in terms of the predominance of shrubs as a life form of understorey vegetation. The high species diversity of understorey vegetation suggests a greater number of successful species of understorey vegetation and a more stable ecosystem. Moreover, this is a reflection of high plant species diversity in the tropical ecosystem. According to Devi and Yadava (2006), tropical forests constitute the most diverse plant communities on earth. In addition, Peters (1996) in Ogunleye *et al.* (2004) agreed that the most fundamental and known characteristics of tropical forests is the great species richness or large number of plant species per unit area. The species diversity is similar to the study of Allen, Bernal and Moulton (1996) which showed that pine flatwood (*Pinus elliotti*), in their seral stage, showed higher plant diversity than younger stands in Southeastern United States. The result could be attributed to the reduction in the crown diameter as gmelina plantation grows older. The less species diversity of understorey vegetation in the younger gmelina plantation may be due to weeding which is required during the early stage of gmelina plantation (Hossain, 1999).

Findings also revealed that species richness slightly increased with increasing age of gmelina plantations. The variation of species richness of understorey vegetation in the gmelina plantations may be due to nutrient cycling, maintenance of hydrological cycle, canopy cover, overstorey species composition, light intensity available for ground vegetation, kind of disturbances and organic matter decomposition (Singh, 2013). The higher number of undergrowth species richness recorded in the plantations is contrary to the findings of Poorbabaei and Poorrahmati (2009), where natural forest was reported to have higher species richness. The increase in the species richness with increasing age of gmelina plantation is similar to the findings of Laughlin *et al.* (2007) in Smith (2011) reporting that species richness was lowest when the forest overstorey was densest. The higher similarity index exhibited by gmelina plantations of older ages with natural forest signified the fact that tropical rainforest has tendency of conserving and maintaining biodiversity (Devi and Yadava, 2006). Furthermore, the lower similarity index between the youngest gmelina plantation (5 years) and other plots may be due to the differences in insolation and soil nutrients availability between the plots.

5. Conclusion and Recommendations

The understorey vegetation in gmelina plantations of different ages thrived well in the older gmelina plantations as the number of individual species, species diversity and species richness of understorey vegetation in the gmelina plantations of 22 and 29 years were high. The study recommended that higher species richness of understorey vegetation in gmelina plantations should be maintained to sustainably conserve wildlife habitat and understorey biodiversity.

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