International Research Journal of Natural Sciences
Vol.3, No.2, pp.24-38, June 2015
Published by European Centre for Research Training and Development UK (www.eajournals.org)

NATURAL REGENERATION DIVERSITY AND COMPOSITION OF NATIVE TREE SPECIES UNDER MONO-CULTURE, MIXED- CULTURE PLANTATION AND NATURAL FOREST

Akoto, S. D.[1]; Asare, A.[1*]; Gyabaa, G.[2]
[1]Department of Environmental Management, School of Natural Resources, University of Energy and Natural Resources (UENR), Sunyani, Ghana
[2]Forestry Services Division (FSD), Kumasi, Ghana
***Corresponding author: UENR P.O. Box 214, Sunyani**

ABSTRACT: *The study purposed to evaluate the natural regeneration diversity, and composition under monoculture, mixed-culture plantation and nature reserve. A 100m x 100m plot was randomly laid in each area. Each plot was subdivided into 50m x50m and further divided into 10m x10m plot. Fifteen 10mx10m plots were randomly selected from each 50mx50m plot. The results showed that the natural regeneration and composition of native species were not significantly different ($p>0.05$) between the mixed and the monoculture plantation, and also between the mixed-culture and nature reserve, however, the species diversity and composition differed significantly ($p<0.05$) between the nature reserve and the monoculture plantation. Green Star species was highest in all the three areas whereas the Scarlet Star species was the least. None of the species enumerated was of global importance i.e. neither a Black Star nor Gold Star species. Blue Star species (Breviea leptosperma) was found only in the nature research. However, Scarlet, Red, Pink and Green Star species were found distributed proportionally across the three different areas.*

KEYWORDS: Natural regeneration, monoculture, mixed-culture

INTRODUCTION

Ghana lost approximately 80% of its forest cover (Opoku, 2006), destroying biodiversity as well as crucial sources of livelihood for the rural populations. Most of the indigenous species like, *Milicia excelsa* and *Milicia regia*, the mahoganies (*Khaya* and *Entandrophragma* species), *Pericopsis elata, Nauclea diderrichii*, and *Triplochiton scleroxylon* which, mainly generate substantial revenues for Ghana's economy, have drastically reduced over the past decades due to conversion to agriculture, wanton logging, wildfires, firewood collection and charcoal production, mining, population pressure and poorly defined land and resource tenure (Benhin and Barbier, 2004). There is evidence that these indigenous species could be restored through plantation development (Kelty, 2006). According to Eckehard *et al*., (2008), there are a lot of evidences which suggest that plantation establishment improves biological diversity. However, most queries raised against the establishment of plantation are usually centered around their negative effects on biodiversity and the tendency of exotic species used for plantation to allegedly displacing valuable indigenous tree species (Sayer *et al*., 2004). In some cases plantation establishments are seen as a threat to biodiversity Cossalter and Pye-Smith, (2003) and are considered to be rarely contribute significantly to restoration of landscape biodiversity compared to natural forest (Stephens and

ISSN 2053-4108(Print), ISSN 2053-4116(Online)

Wagner, 2007). The goal of this study was to identify and quantify native species regeneration diversity and composition under monoculture, mixed-culture plantation and nature reserve. Through this study, a more solid basis for the development of forest management systems appropriate for biodiversity conservation will be created, which in turn may lead to the reconsideration and adjustment of the present forest management systems in Ghana.

MATERIALS AND METHODS

Study area description

The study area, Anwhiaso North Forest Reserve is located in the Western part of Ghana, between latitude 6° N, 19° N and longitude 2° W, 16° W with an area 3.6 sq-km. The lowest and the highest points in the reserve are 350m above sea level and 660m above sea level respectively. A gently rolling landscape is found over lower Birimian rocks. The topography is rugged and hilly and located in the equatorial climate with the annual rainfall average between 1200mm and 1500mm. The average temperature throughout the year is about 26°C. The geology for the district is dominated by the Precambrian Metamorphic rocks of the Birrimian and Tarkwain formation.

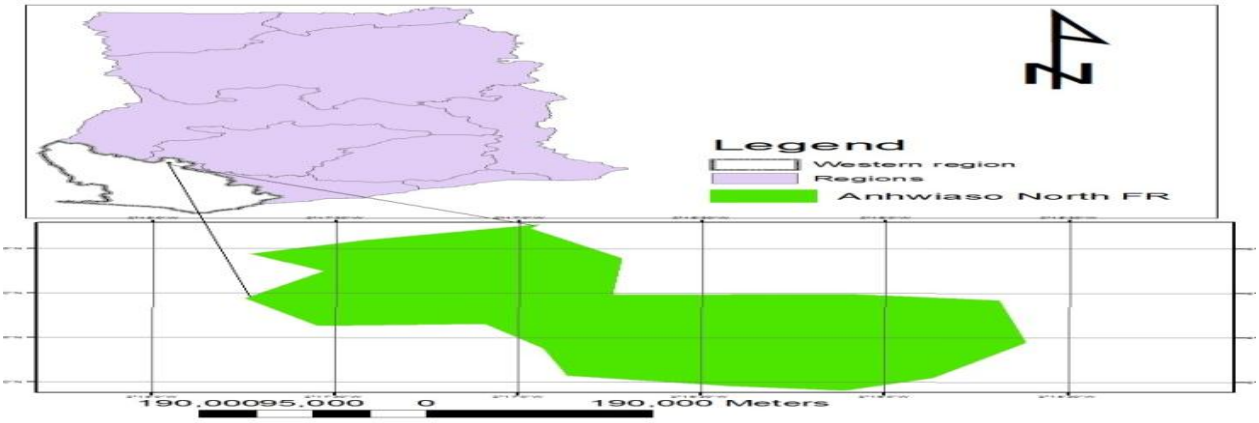

Figure 1 Map of Ghana showing Anwhiaso North Forest Reserve

Sampling design

One hectare (100m x100m) plot was randomly laid in the mono-plantation (*Cedrella odorata*) and subdivided into four 50m x 50m sub-plots. Each 50m x 50m plot was further divided into 10m x 10m sub-plots making a total of twenty five subplots in every 50m x 50m plot. Simple random sampling technique was used to select fifteen (15) of the 10m x 10m plots from every 50m x 50m plot. The same procedure was repeated in the mixed plantation and the nature reserve.

Native species identification and count

From each selected 10mx10m plot, all naturally regenerated native species were identified and counted in the mono, mixed plantation and the nature reserve with the help of a local botanist and

ISSN 2053-4108(Print), ISSN 2053-4116(Online)

assisted by Hawthorne and Gyakari (2006) photo guide for the forest trees in Ghana. Dead species were not considered due to difficulties in identifying them. To avoid making mistakes in identifying natural regeneration native species, plants ≥10cm dbh were not considered as regeneration variables.

Data analysis

In this study, the Shannon index (H') was used as a measure of diversity. This index takes both species abundance and species richness into account, is sensitive to changes in the importance of the rarest class (Heuse`rr, 1998) and is the most commonly used index (Kent and Coker, 1996). The Shannon diversity index is calculated using the formula: $H' = -\sum_{1=i}^{s} pi \ln pi$,where **s** equals to the number of species, *pi* equals the proportion of individuals or the abundance of the *ith* species expressed as a proportion of total cover and Ln equals the Log base **n.** In addition, Simpson's index (D) was used as a measure of species dominance, and the Shannon evenness (E) was also used as a measure of evenness of spread. The Simpson's index is defined as $D = \left(\frac{n_i(n_i-1)}{N(N-1)}\right)$, where ni = the number of individuals in the ith species, N= the total number of individuals. As biodiversity increases, the Simpson's index decreases. Therefore, to get a clear picture of species dominance, *D' = 1-D* was used. The Shannon evenness index is defined as $E = H'/H_{max} = H'/lnS$, where (H') is the observed diversity, H_{max} equal to maximum diversity (i.e the natural logarithm of the total number of species). General Linear Multivariate Analysis of the IBM SPSS software was used to compare means of species followed by a post hoc Fisher's LSD test. Descriptive statistics (frequencies and percentage) generated through the IBM SPSS software, were also used to analyse the data.

RESULTS AND DISCUSSION

Measurement of species diversity and composition in monoculture, mixed-culture plantation and nature reserve

Species composition

Forman and Godron, (1986) defined species composition as the particular species present in a particular area. The individual composition of species sampled with scientific, local, family names, total counts, star ratings as well as species frequencies for the three different vegetation types are presented in **Table 1, 2, and 3**. A total count of 143, 185 and 156 of naturally regenerated tree species were enumerated in the monoculture, mixed-culture plantation and the nature reserve area respectively. Thirty-nine (39) different species belonging to 17 families were counted in the monoculture, 38 different species from 18 families were recorded from the mixed-culture plantation whereas 53 species belonging to 21 families were also obtained from the nature reserve. Sixteen (16) different species (*Albizia zygia, Amphimas pterocarpus, Antiaris toxicaria, Bombax buonopozense, Ceiba pentandra, Chrysophyllum perpulchrum, Mansonia altissima, Morus mesozygia, Nauclea diderrichii, Nesogordomia papaverifera, Newbouldia laevis, Pycnanthus angolensis, Terminalia superba, Tetraprura tetraptera, Trichilia monodelpha, and Triplochiton*

ISSN 2053-4108(Print), ISSN 2053-4116(Online)

scleroxylon) were found common in the three different vegetation types **(Table 1, 2 and 3)** whilst *Albizia adianthifolia, Blighia sapida, Clerislopholis patens, Daniella ogea, Ficus exasperate, Margoritaria discoidea, Milicia excels, Spathodea campanulata, Sterculia oblonga,* and *Sterculia tragacantha* occurred only in monoculture and mixed-culture plantation. *Chrysophyllum subnudum, Albizia ferruginia, Discoglypremna coloneura, Distermonanthus banthamianus, Musanga cecropioides, Pseudospondia microcarpa, Ricinodendron heudolotii, Trichidia prievriana* and *Turraeanthus africanum* also appeared only in monoculture and nature reserve whereas *Celtis mildbreadii, Celtis zenkeri, Cleidion gabonicum, Funtumia elastic, Lannea welwitshii, Marianthus arboreus, Piptadeniastrum africana, Pterygota marcrocarpa, Trilepsium madagascariense* and *Zanthoxylum leprieurii* occurred only in mixed-plantation and nature reserve. In addition, some species were only identified in one or two of the vegetation types: *Trema orientalis, Baphia nitida, Ravoluria vomitoria,* and *Terminalia ivorensis* were found only in the monoculture plantation. *Ficus sur* was also unique in mixed-culture plantation whereas *Entandrophragma angolense, Antrocaryon micraster, Breviea leptosperma, Chrysophyllum giganteum, Chrysophyllum albidum, Cola gigantean, Cylicodiscus gabunensis, Entandrophragma utile, Guarea cedrata, Hannoa cleiliana, Khaya ivorensis, Klainedoxa gabonensis, Monodora myristea, Petersianthus macrocapus,* and *Treculia africana* were found only in the nature reserve area. Sorensen's coefficient similarity index (SCSI) or Turn over index was used for the pairwise comparison of species composition of the three different vegetation types and the results presented in (**Table 4)**. According to Kormondy, (2003); Kreb, (2001), if the SCSI value is less than 0.5, the two areas are considered as dissimilar and if the value is greater than 0.5 the two areas are considered as similar in species composition. The SCSI (0.80) showed similar species composition between monoculture and mixed-culture plantation. The species composition between the mixed-culture planation and the nature reserve was also similar (0.56). However, the species composition between the monoculture plantation and the nature reserve was completely different (0.49). The different natural regenerated species composition between the monoculture plantation and the nature reserve could be attributed to differences in environmental conditions, topography, seed bank, composition of mycorrhizal community, seed rain as well as soil type; could be considered as important variables in shaping natural regeneration of native plant species. This is in agreement with Strusaker, (1997) assertion that these variables could be considered in shaping regeneration of species. Kent and Coker, (1996) also reported that ecosystem and community stability is ultimately dependent on environmental stability.

ISSN 2053-4108(Print), ISSN 2053-4116(Online)

Table 1 Species identified in the monoculture Plantation of Cedrella odorata

Scientific name	Local name	Family	Star ratings	Frequency
Albizia adianthifolia	Pampena	Leguminosae	Green	1
Albizia ferruginea	Awiemfosamina	Leguminosae	Scarlet	2
Albizia zygia	Okoro	Leguminosae	Pink	7
Amphimas pterocarpus	Yaya	Leguminosae	Red	3
Antiaris toxicaria	Kyenkyen	Moraceae	Red	19
Baphia nitida	Odwene	Leguminosae	Green	1
Blighia sapida	Akye	Sapindaceae	Green	6
Bombax buonopozense	Akonkodie	Bombacaceae	Pink	3
Ceiba pentandra	Onyina	Bombacaceae	Red	10
Chrysophyllum subnudum	Adasama	Sapotaceae	Red	1
Chrysophyllum perpulchrum	Atabene	Sapotaceae	Pink	1
Cleistopholis patens	Ngonenkyene	Annonaceae	Green	3
Daniellia ogea	Shedua	Leguminosae	Red	2
Discoglypremna coloneura	Fetefre	Euphorbiceae	Green	1
Disternunathus benthamianus	Bonsamdua	Leguminosae	Red	2
Ficus exasperata	Nyankyerene	Moraceae	Green	30
Mansonia altissima	Opronoo	Malvaceae	Red	1
Margaritaria discoidea	Papea	Euphorbiceae	Green	1
Milicia excelsa	Odum	Moraceae	Scarlet	3
Morus mesozygia	Wonton	Moraceae	Red	1
Musanga cecropioides	Odwuma	Cecropiaceae	Green	1
Nauclea diderrichii	Kusia	Rubiaceae	Scarlet	1
Nesogordonia papaverifera	Danta	Malvaceae	Pink	1
Newbouldia laevis	Sesemasa	Bignoniaceae	Green	3
Pseudospondias microcarpa	Akatawani	Anarcadiaceae	Green	2
Pycnanthus angolensis	Otie	Myristicaceae	Red	3
Rauvolfia vomitoria	Kakapenpen	Apocynaceae	Green	2
Ricinodendron heudolotii	Wama	Euphorbiceae	Pink	1
Trema orientalis	Sesea	Ulmaceae	Green	1
Spathodea campanulata	Akuakuo-Ninsuo	Bignoniaceae	Green	3
Sterculia oblonga	Ohaa	Malvaceae	Pink	1
Sterculia tragacantha	Sofo	Malvaceae	Green	16
Terminalia ivorensis	Emire	Combretaceae	Red	2
Terminalia superba	Ofram	Combretaceae	Red	1
Tetraprura tetraptera	Prekese	Leguminosae	Green	1
Trichidia prievriana	Kakadikuro	Apocynaceae	Green	1
Trichilia monodelpha	Tanuro	Meliaceae	Green	2

ISSN 2053-4108(Print), ISSN 2053-4116(Online)

Triplochiton scleroxylon	Wawa	Malvaceae	Scarlet	2
Turraeanthus africanus	Avodire	Meliaceae	Red	1
Total				**143**

Table 2 Species identified in the mixed-culture plantation

Scientific name	Local name	Family	Star ratings	Frequency
Albizia adianthifolia	Pampena	Leguminosae	Green	2
Albizia zygia	Okoro	Leguminosae	Pink	5
Alstonia boonei	Nyamedua	Apocynaceae	Green	1
Amphimas pterocarpus	Yaya	Leguminosae	Red	6
Antiaris toxicaria	Kyenkyen	Moraceae	Red	26
Blighia sapida	Akye	Sapindaceae	Green	9
Bombax buonopozense	Akonkodie	Bombacaceae	Pink	4
Ceiba pentandra	Onyina	Bombacaceae	Red	13
Celtis mildbreadii	Esafufuo	Ulmaceae	Pink	5
Celtis zenkeri	Esakokoo	Ulmaceae	Pink	1
Chrysophyllum purpulchrum	Atabene	Sapotaceae	Pink	1
Cleidion gabonicum	Mpwuo	Euphorbiceae	Green	3
Cleistopholis patens	Ngonenkyene	Annonaceae	Green	3
Daniella ogea	Shedua	Leguminosae	Red	5
Ficus sur	Domini	Moraceae	Green	4
Ficus exasperata	Nyankyerene	Moraceae	Green	17
Funtumia elastica	Funtum	Apocynaceae	Green	12
Lannea welwitshii	Kumanini	Anarcadiaceae	Green	2
Mansonia altissima	Opronoo	Malvaceae	Red	1
Margaritaria discoidea	Papea	Euphorbiceae	Green	1
Myrianthus arboreus	Nyankuma-bere	Cecropiaceae	Green	1
Milicia excelsa	Odum	Moraceae	Scarlet	3
Morus mesozygia	Wonton	Moraceae	Red	2
Nauclea diderrichii	Kusia	Rubiaceae	Scarlet	6
Nesogordonia papaverifera	Danta	Malvaceae	Pink	5
Newbouldia laevis	Sesemasa	Bignoniaceae	Green	8
Piptadeniastrum africanum	Dahoma	Leguminosae	Scarlet	1
Pterygota marcrocarpa	Koto/ Kyereye	Malvaceae	Scarlet	8

ISSN 2053-4108(Print), ISSN 2053-4116(Online)

Pycnanthus angolensis	Otie	Myristicaceae	Red	2
Spathodea campanulata	Akuakuo-Ninsuo	Bignoniaceae	Green	3
Sterculia oblonga	Ohaa	Malvaceae	Pink	1
Sterculia tragacantha	Sofo	Malvaceae	Green	6
Terminalia superba	Ofram	Combretaceae	Red	2
Tetraprura tetraptera	Prekese	Leguminosae	Green	1
Trichilia monodelpha	Tanuro	Meliaceae	Green	8
Trilepsium madagascariense	Okure	Moraceae	Green	1
Triplochiton scleroxylon	Wawa	Malvaceae	Scarlet	3
Zanthoxylum leprieurii	Oyaa	Rutaceae	Green	3
Total				**185**

Table 3 Species identified in the nature reserve

Scientific name	Local name	Family	Star ratings	Frequency
Albizia ferruginea	Awiemfosamina	Leguminosae	Scarlet	**1**
Albizia zygia	Okoro	Leguminosae	Pink	**6**
Alstonia boonei	Nyamedua	Apocynaceae	Green	**5**
Amphimas pterocarpus	Yaya	Leguminosae	Red	**1**
Antiaris toxicaria	Kyenkyen	Moraceae	Red	**9**
Antrocaryon micraster	Aprukuma	Anarcadiaceae	Pink	**1**
Bombax buonopozense	Akonkodie	Bombacaceae	Pink	**4**
Breviea leptosperma	Kakaben	Sapotaceae	Blue	**2**
Ceiba pentandra	Onyina	Bombacaceae	Red	**3**
Celtis mildbreadii	Esafufuo	Ulmaceae	Pink	**9**
Celtis zenkeri	Esakokoo	Ulmaceae	Pink	**6**
Chrysophyllum giganteum	Kumfena	Sapotaceae	Red	**1**
Chrysophyllum subnudum	Adasama	Sapotaceae	Green	**1**
Chrysophyllum albidum	Akasaa	Sapotaceae	Green	**3**
Chrysophyllum perpulchrum	Atabene	Sapotaceae	Green	**1**
Cleidion gabonicum	Mpwuo	Euphorbiceae	Green	**6**
Cola gigantea	Watapuo	Malvaceae	Green	**2**
Cylicodiscus gabunensis	Denya	Leguminosae	Pink	**3**
Discoglypremna coloneura	Fetefre	Euphorbiceae	Green	**1**
Distemonanthus banthamianus	Bonsamdua	Leguminosae	Red	**1**
Entandrophragma angolense	Edinam	Meliaceae	Scarlet	**1**
Entandrophragma utile	Efobrodedwo	Meliaceae	Scarlet	**1**
Funtumia elastica	Funtum	Apocynaceae	Green	**5**
Guarea cedrata	Kwabohoro	Meliaceae	Red	**3**

ISSN 2053-4108(Print), ISSN 2053-4116(Online)

Hannoa klaineana	Fotie	Simaroubaceae	Green	**1**
Khaya ivorensis	Dubini	Meliaceae	Scarlet	**1**
Klainedoxa gabonensis	Kroma	Irvingiaceae	Pink	**2**
Lannea welwitshii	Kumanini	Anarcadiaceae	Green	**1**
Mansonia altissima	Opronoo	Malvaceae	Red	**5**
Myrianthus arboreus	Nyankuma-bere	Cecropiaceae	Green	**1**
Monodora myristea	Widiaba	Annonaceae	Green	**2**
Morus mesozygia	Wonton	Moraceae	Red	**1**
Musanga cecropioides	Odwuma	Cecropiaceae	Green	**4**
Nauclea diderrichii	Kusia	Rubiaceae	Scarlet	**2**
Nesogordonia papaverifera	Danta	Malvaceae	Pink	**7**
Newbouldia laevis	Sesemasa	Bignoniaceae	Green	**7**
Petersianthus macrocapus	Esia	Lecythidaceae	Red	**5**
Piptadenistrum africanum	Dahoma	Leguminosae	Scarlet	**3**
Pseudospondias microcarpa	Akatawani	Anarcadiaceae	Green	**1**
Pterygota marcrocarpa	Koto/ Kyereye	Malvaceae	Scarlet	**2**
Pycnanthus angolensis	Otie	Myristicaceae	Red	**1**
Ricinodendron heudolotii	Wama	Euphorbiceae	Pink	**5**
Sterculia rhinopetela	Wawabima	Malvaceae	Pink	**3**
Strombosia glaucescense	Afena	Olacaceae	Pink	**1**
Terminalia superba	Ofram	Combretaceae	Red	**5**
Tetraprura tetraptera	Prekese	Leguminosae	Green	**1**
Treculia africana	Brebretim	Moraceae	Green	**1**
Trichidia prievriana	Kakadikuro	Apocynaceae	Green	**3**
Trichilia monodelpha	Tanuro	Meliaceae	Green	**6**
Trilepsium madagascariense	Okure	Moraceae	Green	**1**
Triplochiton scleroxylon	Wawa	Malvaceae	Scarlet	**4**
Turraeanthus africanus	Avodire	Meliaceae	Pink	**1**
Zanthoxylum leprieurii	Oyaa	Rutaceae	Green	**3**
Total				**156**

ISSN 2053-4108(Print), ISSN 2053-4116(Online)

Table 4 Sorenson's index of natural regeneration of native species in monoculture, mixed-culture and nature reserve

Plantation types combinations	Sorenson's coefficient similarity index
Monoculture and Mixed-culture	0.80
Monoculture and Nature reserve	0.49
Mixed-culture and Nature reserve	0.56

NB: Areas with Sorenson's coefficient index <0.5 are considered different in species composition

Species diversity estimation in monoculture, mixed-culture and nature reserve area

Table 5 shows the Shannon index (H'), Simpson's index (1-D) and Shannon Evenness (E) for the three vegetation types. The mean Shannon diversity indexes (H') for nature reserve, mixed-culture and monoculture plantation were 2.36±0.43, 2.09±0.48 and 1.86±0.42 respectively. The mean Simpson's index (1-D) of 0.890±0.07, 0.846±0.08, and 0.815±0.07 were also obtained for the nature reserve, mixed-culture and monoculture planation respectively. The Shannon Evenness for the nature reserve was 0.979 with a range of 1 - 0.92, mixed-culture plantation was 0.952 ranging from 0.89 to 1 whereas the evenness for the monoculture plantation was 0.941 with a range of 0.86 – 1. The indices when subjected to analysis of variance test across the different vegetation types revealed a significant difference with Shannon index (H') significant at $p<0.05$, $F(2)=3.88$, the Simpson's index (1-D) was significant at $p<0.05$, $F(2)=3.39$ and the mean Shannon Evenness comparison was also significant at $p<0.05$, $F(2)=3.61$ **(Table 5)**. Fisher's pairwise comparison test revealed that all the three indices did not differ significantly ($p>0.05$) between the mixed and the monoculture plantation, suggesting that both have the same diversity, species richness, dominance and evenness. This observation contradicted Carnevale and Montagnini (2002), who found higher species diversity in mixed-culture plantation than monoculture. Perhaps, the impact of monoculture plantation on biodiversity may depend on the type of species used in establishing the mono-plantation. Moreover, the three indices also did not differ significantly ($p>0.05$) between the mixed-culture plantation and the nature reserve. This could be due to the fact that the mixed plantation provided conditions similar to the conditions prevailing in the nature reserve. This observation is consistent with Stephens and Wagner, (2007), who found that mixed plantation, is capable of providing suitable habitat with structural and understorey conditions even similar to that which pertain in natural forests. However, the three indices revealed that the nature reserve is significantly ($p<0.05$) higher than the monoculture plantation in terms of diversity, species richness, dominance and evenness **(Table 5)**.

ISSN 2053-4108(Print), ISSN 2053-4116(Online)

Table 5 Fisher's multiple comparison tests of Shannon diversity index, Simpson's index and Shannon evenness

Vegetation types		Shannon Diversity index (H')	Shannon Evenness (E)	Simpson's Index (1-D)
Mono plantation	**Mean**	**1.8592b**	**0.9408b**	**0.815b**
	Std. Deviation	0.42146	0.0469	0.07279
	Minimum	1.1	0.86	0.67
	Maximum	2.35	1	0.89
Mixed plantation	**Mean**	**2.0854ab**	**0.952ab**	**0.846ab**
	Std. Deviation	0.47779	0.03663	0.07559
	Minimum	1.24	0.89	0.67
	Maximum	2.82	1	0.93
Nature reserve	**Mean**	**2.3636a**	**0.9792a**	**0.8899a**
	Std. Deviation	0.4282	0.022	0.06629
	Minimum	1.27	0.92	0.69
	Maximum	2.9	1	0.94
	df	2	2	2
	F-ratio	3.88	3.61	3.39
	P-value	**0.031**	**0.038**	**0.046**

Means with the same letters are not significant at α = 0.05 significance level

3.2 Natural regeneration species distribution in monoculture, mixed-culture and nature reserve area according to family

Table 6 shows the species distribution according to families. In terms of families that contributed to species natural regeneration in monoculture plantation, Leguminosae is the most species-rich group recording 8 different species (21%) out of the total number of 39 species identified, followed by Malvaceae accounting for 13%, of the total species, Moraceae accounting for 10%, and Euphorbiaceae contributed 8% of the total species.

ISSN 2053-4108(Print), ISSN 2053-4116(Online)

Table 6 Tree species distribution in monoculture, mixed-culture and nature reserve area according to family

Families	Monoculture plantation		Mixed culture plantation		Nature reserve	
	NO. of species	%	NO. of species	%	NO. of species	%
Anarcadiaceae	1	3	1	3	3	6
Annonaceae	1	3	1	3	1	2
Apocynaceae	2	5	2	5	3	6
Bignoniaceae	2	5	2	5	1	2
Bombacaceae	2	5	2	5	2	4
Cecropiaceae	1	3	1	3	2	4
Combretaceae	2	5	1	3	1	2
Euphorbiceae	3	8	2	5	3	6
Leguminosae	8	21	6	16	7	13
Irvingiaceae	0	0	0	0	1	2
Malvaceae	5	13	6	16	6	11
Lecythidaceae	0	0	0	0	1	2
Meliaceae	2	5	1	3	6	11
Moraceae	4	10	6	16	4	8
Myristicaceae	1	3	1	3	1	2
Rubiaceae	1	3	1	3	1	2
Sapindaceae	1	3	1	3	0	0
Rutaceae	0	0	1	3	1	2
Sapotaceae	2	5	1	3	5	9
Olacaceae	0	0	0	0	1	2
Ulmaceae	1	3	2	5	2	4
Simaroubaceae	0	0	0	0	1	2
Total	**39**		**38**		**53**	

Apocynaceae, Bignoniaceae, Bombacaceae, Combretaceae, Meliaceae and Sapotaceae each accounted for 5% of the species in monoculture plantation, with the rest of the families each accounting for at most 3%**.** In the mixed planation, Leguminosae, Malvaceae, and Moraceae, each accounting for 16% of the total number of species identified (38 species), followed by five families: Apocynaceae, Bignoniaceae, Bombacaceae, Euphorbiaceae and Ulmaceae accounting for 5% each, with the rest of the families each accounting for at most 3%**.** Leguminosae is again the most species-rich family contributed 13% of the total number of species (53 species) enumerated in the nature reserve area, followed by Malvaceae and Meliaceae each contributing for 11% of the total species, Sapotaceae contributed 9%, and Moraceae accounting for 8%.

ISSN 2053-4108(Print), ISSN 2053-4116(Online)

Anarcadiaceae, Apocynaceae and Euphorbiaceae, each accounting for 6% of the species whilst the rest of the families each accounting for at most 4% of the species**.** In addition, Irvingiaceae, Lecythidaceae, Olacaceae and Simaroubaceae were found only in the nature reserve whilst Sapindaceae appeared only in monoculture and mixed plantation. It is clearly evident from the results that the family compositions in the monoculture and mixed-culture plantation were same (**Table 6)**.

Conservation status of the naturally regenerated understorey species in monoculture, mixed-culture and nature reserve

The star ratings for the individual regenerated species in the monoculture, mixed-culture and the nature reserve are presented in **Figure 2, 3 and 4** respectively. The Green Star species dominated the three vegetation types with 17 species representing 43.6% of the total number of species in the monoculture plantation, 18 species (47.4%) in the mixed-culture planation, 21 species (39.6%) out of 53 total species counted in the nature reserve area. The high dominance of the Green Star species in the three areas could be due to the fact that these species area dominant in Ghana and are of no conservation concern according to (Hawthorne and Gyakari, 2006). The Red Star species in the monoculture, mixed-culture and nature reserve area were 30.8% (12 species), 21.1% (8 species) and 20.8% (11 species) respectively. These species are common in Ghana but are under pressure from exploitation and therefore need careful control (Hawthorne and Abu-Juam, 1995). Pink Star species inventoried in the monoculture, mixed-culture plantation and the nature reserve were 15.4% (6 species), 18.4% (7 species) and 22.6% (12 species) respectively. The Pink Star species according to Hawthorne and Abu-Juam, (1995) are the tree species in Ghana that are common and moderately exploited as timber. The increasing order of Scarlet Star rating in the study area was nature reserve (8 species (15.1%)) > mixed-culture (5 species 13.2%)) > monoculture (4 species (10.3)).

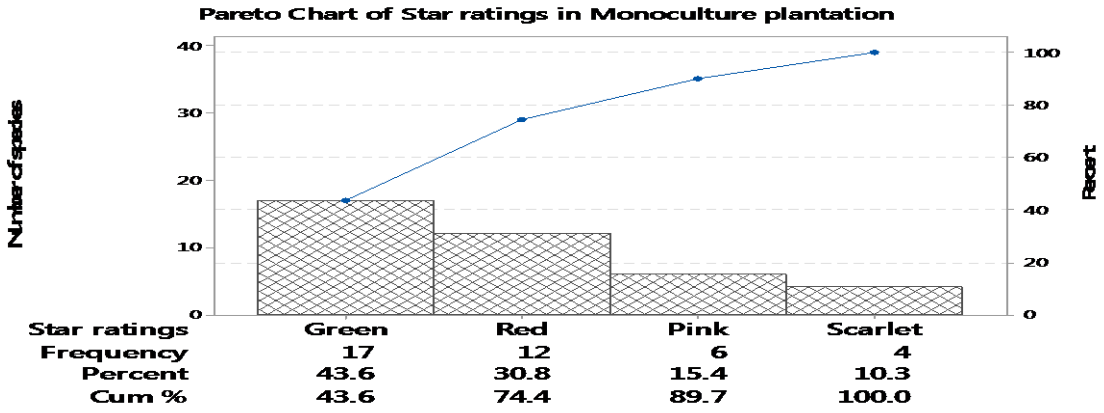

Figure 2 Number of species in each star rating category in monoculture plantation

The low proportion of Scarlet Star species in the monoculture and mixed-culture planation compared to the nature reserve could be due to heavy exploitation Hawthorne and Gyakari, (2006) in these areas in the past. According to Hawthorne and Abu-Juam, (1995), Scarlet Star species are

ISSN 2053-4108(Print), ISSN 2053-4116(Online)

those that are common but under serious pressure from heavy exploitation and therefore exploitation is now restricted. The study recorded only one Blue Star species (*Breviea leptosperma*) from the nature reserve area. No Blue Star was identified in both monoculture and mixed-culture planation. The least proportion of Blue Star species identified in the nature and it's totally absent in both monoculture and mixed-culture planation could be due to the fact that though it is widespread internationally but it is of rarity in Ghana according to Hawthorne and Gyakari, (2006) and therefore need conservation concern.

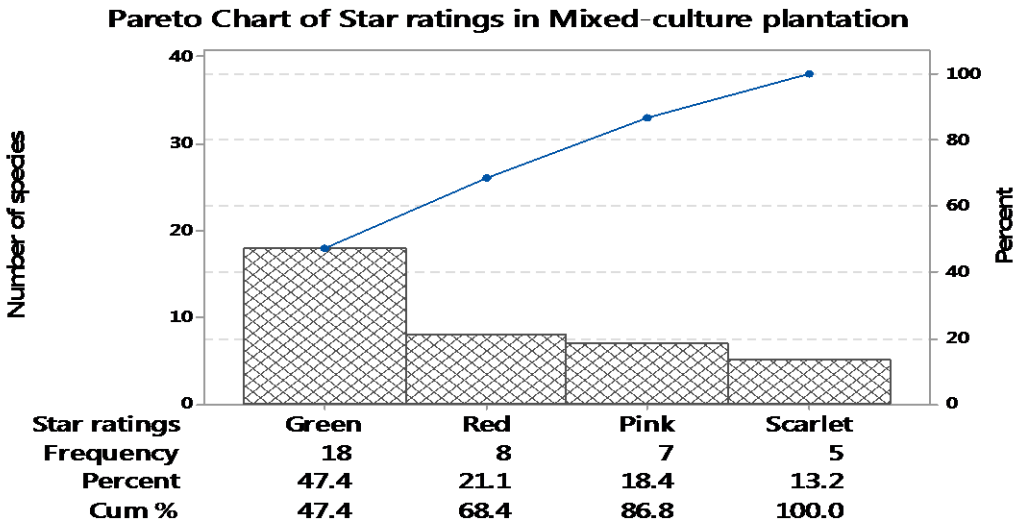

Figure 3 Number of species in each star rating category in mixed-culture plantation

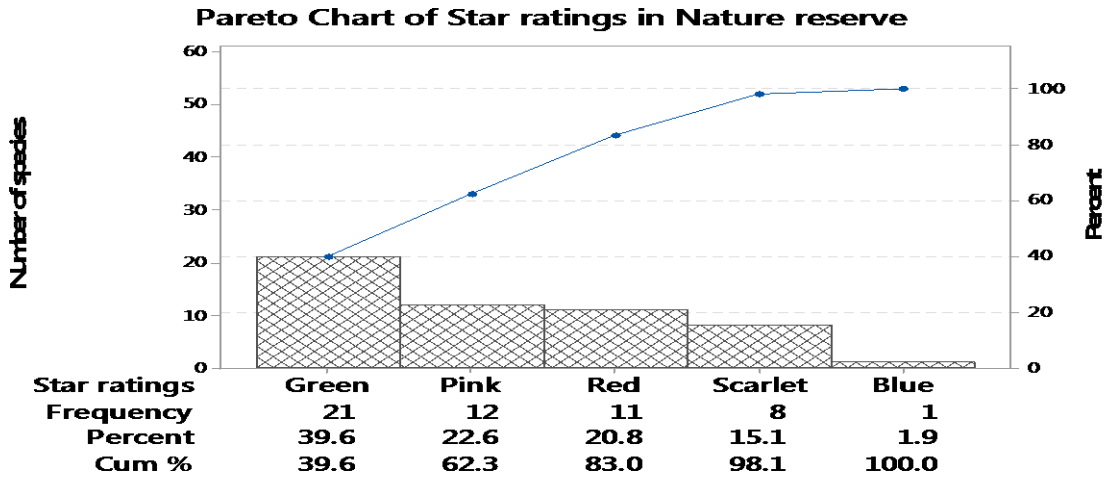

Figure 4 Number of species in each star rating category in nature reserve area

ISSN 2053-4108(Print), ISSN 2053-4116(Online)

CONCLUSION

The study aimed to evaluate the natural regeneration diversity of native species in monoculture plantation, mixed-culture and nature reserve. A total of 39 different species belonging to 17 families were counted in the monoculture, 38 species from 18 families were recorded from the mixed-culture plantation whereas 53 species belonging to 21 families were also obtained from the nature reserve. Fisher's pairwise comparison test showed no statistical ($p>0.05$) difference for the three indices (Shannon index, Simpson's index and Shannon Evenness) between the mixed and the monoculture plantation, and also between the mixed-culture and nature reserve areas, suggesting that both have the same diversity, species richness, dominance and evenness. However, the three indices revealed that the nature reserve is significantly ($p<0.05$) higher than the monoculture plantation in terms of diversity, species richness, dominance and evenness. Leguminosae and Malvaceae were the most dominant families in all the three different areas. In addition, Irvingiaceae, Lecythidaceae, Olacaceae and Simaroubaceae were found only in the nature reserve whilst Sapindaceae appeared only in monoculture and mixed plantation. Sixteen (16) different species were found common in the three different areas. However, *Trema orientalis*, *Baphia nitida, Ravoluria vomitoria,* and *Terminalia ivorensis* were found only in the monoculture plantation. *Ficus sur* was also unique in the mixed-culture plantation whereas *Entandrophragma angolense, Antrocaryon micraster, Breviea leptosperma, Chrysophyllum giganteum, Chrysophyllum albidum, Cola gigantean, Cylicodiscus gabunensis, Entandrophragma utile, Guarea cedrata, Hannoa cleiliana, Khaya ivorensis, Klainedoxa gabonensis, Monodora myristea, Petersianthus macrocapus,* and *Treculia africana* were found only in the nature reserve area. The species composition comparison between the monoculture and mixed-culture plantation (0.80) and between the mixed-culture planation and the nature reserve (0.56) were similar as revealed by the Sorensen's coefficient similarity index. However, the species composition between the monoculture plantation and the nature reserve was completely different (0.49). Green Star species recorded the highest star rating species in all the three areas and the least star rating in all the areas was the Scarlet Star species. None of the species enumerated was of global importance i.e. neither a Black Star nor Gold Star species. Blue Star species were found only in the nature reserve area but were not found in mono and mixed-culture plantation. However, Scarlet, Red, Pink and Green Star species were found distributed proportionally across the different vegetation types.

REFERENCES

Benhin, J.K.A., Barbier, E.B. (2004). Structural Adjustment Programme, Deforestation and Biodiversity Loss in Ghana. *Environmental and Resource Economics*, 27: 337-366

Carnevale, N.J., Montagnini, F. (2002). Facilitating Regeneration of Secondary Forestwith the Use of Mixed and Pure plantation of Indigenous Tree Species.*ForestEcology and Management*, 163: 217-227

Eckehard, G.B., Jacket, H., Parrotta, J.A., Quine, C.P., Sayer, J. (2008). Plantation forests and biodiversity: oxymoron or opportunity? *Biodivers. Conserv.*, 17: 925-951

ISSN 2053-4108(Print), ISSN 2053-4116(Online)

Forman R.T.T. and Godron M., (1986). Landscape ecology. John Wiley & sons, Inc. NewYork, Chichester, Brisbane, Toronto, Singapore, pp 4-527

Hawthone W.D. and Abu-Juam (1995). Forest Protection in Ghana. Forest Inventory and Management project report. Kumasi, Forestry Department,Gland, IUCN.

Hawthorne, W.D. and Gyakari N., (2006). Photoguide for the forest trees of Ghana. A tree-spotter's field guide for identifying the largest trees. Oxford Forestry Institute. 432pp.

Heusèrr M.J.J., (1998). Putting diversity indices into practice. In: Proceedings of the conference on Assessment of Biodiversity for Improved Forest Planning, 7-11 October 1996, held in Monte Verità, Switzerland, pp. 173

Kelty, M. (2006). The Role of Species Mixtures in Plantation Forestry. *Forest Ecology and Management*, 233: 195-204

Kent M. and Coker P. (1996). Vegetation description and analysis. John Wiley & sons. New York Chichester Brisbane Toronto Singapore, pp 14-15, 96-105

Kormondy, E. J (2003). Concept of ecology. 4th Ed. India. Pearson Education Inc.

Krebs, C. J. (2001). Ecology; the experimental analysis of distribution and abundance. 5th Ed. USA. The University of British Columbia.

Opoku, K. (2006). *Forest Governance in Ghana: An NGO Perspective*. A report produced for FERN by Forest Watch Ghana, March 2006. www.fern.org. FERN: Brussels.

Sayer, J., Chokkalingam, U., Poulsen, J. (2004). The Restoration of Forest Biodiversity and Ecological Values. *Forest Ecology and Management*, 201: 3-11

Stephens, S.S., Wagner, M.R. (2007). Forest Plantation and Biodiversity: a fresh perspective. *Journal of Forestry*, pp. 307-313

Struhsaker, T. T. (1997). *Ecology of an African Rain Forest: Logging in Kibale and the conflict between conservation and exploitation*. Gainesville, University press of Florida.

Acknowledgements

To the Almighty God for the wisdom and to Dr. D.E.K.A Siaw, Dr. Simon Abugre, Mr. I.K. Abebrese, Dr. Kwame Twum-Ampofo and Mr. Owusu-Prempeh Nat, for their support in several phases of the study.

ISSN 2053-4108(Print), ISSN 2053-4116(Online)