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TREE SPECIES DIVERSITY IN A POST-BUSHFIRE DISTURBED DRY SEMI-DECIDUOUS FOREST: IMPLICATIONS TO RESTORATION ECOLOGY

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ABSTRACT
Recurrent bushfires and other anthropogenic disturbances have resulted in greater proportion of the original dry semi-deciduous forest cover of Ghana being converted to savannah woodland. There is conscientious effort to restore degraded portions of this forest zone through various reforestation programs. However, little emphasis has been placed on passive restoration through natural regeneration. This study described tree species composition and diversity after recovery of dry semi-deciduous forest from recurrent bushfires. Various measures of tree species diversity indices were employed in the study. The results indicated that *Ficus exasperta, Albizia spp*, *Terminalia superba*, *Morinda lucida*, *Antiaris toxicaria, and Blighia unijugata* had the high Importance Value Index (IVI) in the four sites investigated. The values of indices of similarities of tree species composition among four sites were within the range of 50%-78% indicating low dissimilarities in tree species composition between sites. High Family Impotence Values (FIV) was recorded by Fabaceae, Moraceae, Bombaceae and Combretaceae. There were relatively high tree species richness and diversity. The implementation of effective fire prevention and exclusion measures in the dry semi-deciduous forest zone over longer period of time will facilitate the recovery of most degraded portions through natural regeneration.

KEYWORDS: bushfires, species diversity, dry forest.

INTRODUCTION
Tropical dry forests constitute 42% of all the tropical forest types, yet less than 67% of the original forest area has been removed due to anthropogenic and other disturbances (Holdridge, 1967; Murphy and Lugo, 1986; Miles *et al*., 2006). In Ghana, the tropical dry semideciduous forest ecosystem covers an area of approximately 2,144,000 ha (FAO 2002) and is one of the most highly disturbed ecosystems in the country. This ecological zone has been classified into two main types (the Fire zone and Inner zone sub-types) based on the intensity and frequency of fires, and annual precipitation; (Hall and Swaine, 1976, 1981; Swaine, 1992). The dry semi-deciduous forest zone, which accounts for 8.98 % of the forest cover in the country, is rapidly disappearing and is being converted into savannah habitat as result of periodic bushfires and other anthropogenic disturbances (Hawthorne, 1994; Nsiah-Gyabaah, 1996).The impact of periodic bushfires on flora diversity is grave for tree species like *Pericopsis elata* (African teak), *Milicia excelsa*, *Khaya anthotheca* and *Argomuellera macrophylla* and black star endemic species *Talbotiella gentii*. These species are unique to the dry semi-deciduous forest zone; they are absent other Ghanaian forest types (Hall and Swaine, 1981; MES, 2002). Bushfires have also led to a reduction in the numbers of some mammals and birds species that are habitat specific (Agyeman *et al*., 2003). The changes created in the physical environment in the dry semi-deciduous forest ecosystem from the impact of bushfires favor colonization of fire resistant species (Goldammer, 1993; Gillespie *et al*., 2000), especially invasive broad-leaved weed such as *Chromolaena odorata* and native grasses like *Pennisetum purpureum, Panicum maximum* and *Imperata cylindrica*. *Chromolaena odorata* has been implicated to create conducive microenvironment for other opportunistic and generalist weed colonizers to the detriment of native tree species (Honu and Dang, 2000). Invariably, these weeds, especially *Chromolaena odorata,* suppress initiation of natural regeneration and alter tree species diversity as well as composition (Swaine *et al*., 1997; Honu and Dang, 2000; Awanyo, 2011). The effects of plant invasions following alteration from fire regimes have been well documented for many ecosystems (Mack and D'Antonio, 1998; D'Antonio, 2000). In general, competition from grasses can prevent natural regeneration of many forest tree species, especially the small-seeded ones, and in the process affecting plant community composition (Nepstad *et al*., 1990, 1996; Hooper *et al*., 2002).

In the dry semi-deciduous forest ecosystem, the presence of perturbation in the soil and the microclimatic environments due to weed and recurrent fires with accompanying slow down in natural regeneration, usually necessitate forest restoration. In Ghana, restoration activities usually involve reforestation or afforestation. However, reforestation of degraded or disturbed environment is considered to be a very expensive option. In view of this, natural regeneration and fire prevention through mass education of local communities and the use of greenbelt or firebreaks at the fringes of undisturbed forest reserves have been recommended (Agyeman *et al*., 2003). However, there is little information or studies on tree species diversity in relation to the characteristic of recovery from bushfires and other disturbances in dry semi-deciduous ecological zone of Ghana. This study described tree species composition and diversity following recovery from recurrent bushfire disturbances. In addition, this study seeks to provide a baseline data on specific native tree species necessary for rehabilitation and restoration of this area.

METHODOLOGY

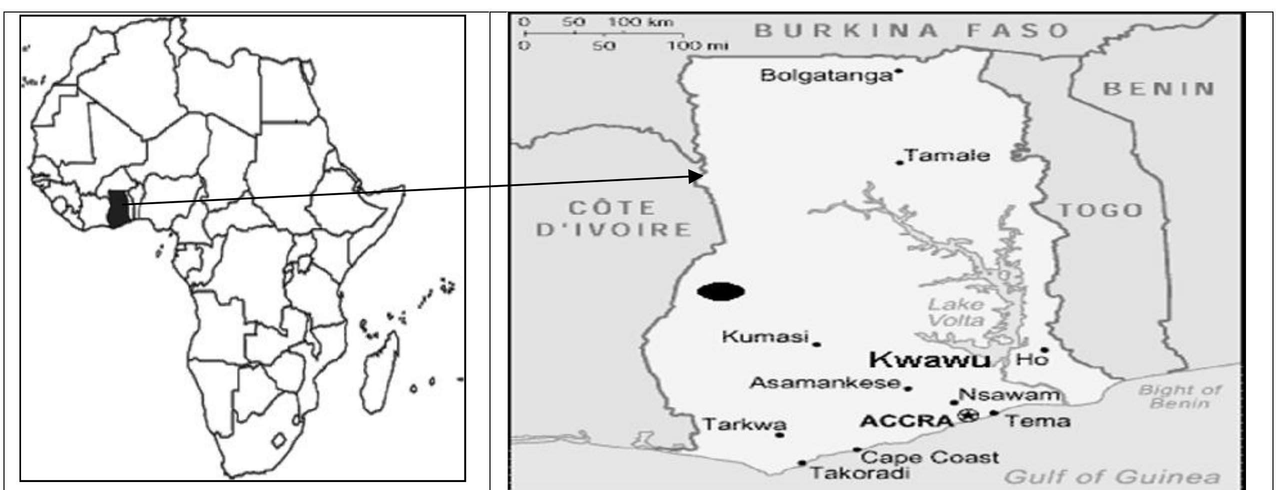
Study area

The study was conducted in Pamu-Berekum Forest Reserve, Dormaa West District of Brong Ahafo Region in the dry semi-deciduous ecological zone of Ghana. The forest reserve covers an area of 189.1km^2. Data were collected from four locations within the forest reserve, namely: Twumkrom (07°22´11´´N, 2°48´21´´W), Abonsrakrom 07°21´21´´N, 2°49´10´´W), Ntabene1 (07°27´42´´N, 2°51´11´´W) and Ntabene 2 (07°26´69´´N, 2°51´ 17´´W) in year 2010 (Fig. 1).The study area is characterized by bimodal annual rainfall (1250-1500mm) pattern with the peak between May and July. Pamu-Berekum and its' environ records mean annual maximum and minimum temperatures of approximately 32°C and 25°C respectively. The area is generally undulated, with moderately well drained soils and altitude of approximately 295m above sea level. The soil types are mostly of forest ochrosols and oxysols (Brammer, 1962).

Sampling and data analyses

Four permanent plots of dimension 100m x 100m and three replicates were established in all the study areas by Forestry Research Institute of Ghana (FORIG) in 2000 to monitor the effect of disruption in periodic bushfires on regeneration, recruitment, diversity of tree species and successional dynamics over time.

However, care was taken to ensure that the area was protected from recurrent bushfires during the 10 year period under consideration through the establishment of green belt and active fire protection by guards. For the purposes of data collection, the permanent plot at each location was divided into 25 subplots of 20m x 20m. 15 subplots were randomly sampled. These plots were systematically inventoried for tree species with diameter at breast height (dbh) $\geq$ 5cm. In addition, the species were identified and classified according to binomial nomenclature by systematician at Forest Research Institute of Ghana (FORIG). The dbh values were converted to a basal area values for specific species per hectare. However, to descriptively evaluate the species composition for each plot at different locations the Importance Value Index (IVI) and Family Importance value (FIV) were computed (Gonzalez-Rivas *et al*., 2006). The various measures of diversity employed in this investigation were Shannon-Wiener's diversity index Margalef's species richness index and Shannon evenness (Magurran, 2004). Similarities and dissimilarities of tree species composition amongst the four communities were investigated with Sorensen's of similarity index following the procedure of Magurran (1988). All statistical analyses were performed with XLSTAT-Pro (Addinsoft, 2009) on Microsoft Excel platform.



Key : Pamu Berekum Forest Reserve

FIGURE 1. Location of the study area in Ghana: The deep black oval-shaped area highlighted on the map represents the location of Pamu-Berekum Forest Reserve. (Source: adopted and modified from Bartle, 2012 and Photographer-Resource, 2012)

RESULTS

Tree species composition

In all, we recorded 49 species tree from 40 genera and 23 families in the four plots from four sites in Pamu-Berekum forest reserve (Table 1). At Abonsrakrom plot, *Terminalia superba* recorded the highest importance value index (IVI), basal area and other performance indicators of stand characteristics considered in the analyses. This was followed by *Morinda lucida* and *Bombax buonopozense*. The least performing species among the top ten species recorded in Abonsrakrom was *Ficus exasperata* (Table 2). Contrary to expectation, *Ficus exasperata* recorded the highest IVI values in the remaining three sites, which was very interesting. Moreover, on Twumkrom, Ntabene 1and Ntabene 2, *Morinda lucida* recorded the second highest IVI values next to *Ficus exasperata*. Amongst the top ten species on Twumkrom, Ntabene 1and Ntabene 2, the least performing trees species with respect to IVI and other stand characteristics were *Blighia unijugata* and *Trema occidentalis*. *Blighia unijugata* recorded lowest IVI values at both Twumkrom and Ntabene.

TABLE 1. List of species recorded after 10 years of recovery from periodic wildfires in the study area

Family/Subfamily	Genus	Species
Anacardiaceae	*Lannea*	*kerstingii*
Apocynaceae	*Alstonia*	*boonei*
	Holarrhena	*floribunda*
	Rauvolfia	*vomitoria*
Bignoniaceae	*Newbouldia*	*lavis*
	Spathodea	*campanulata*
Bombaceae	*Bombax*	*buonopozense*
Bombaceae	*Ceiba*	*pentandra*
Boraginaceae	*Cordia*	*millenia*
	Cordia	*senegalensis*
Caesalpiniodeae	*Afzelia*	*africana*
	Berlinia	*spp*
	Dialium	*dinklagei*
	Senna	*siamea*
Caricaceae	*Carica*	*papaye*
Combretaceae	*Terminalia*	*ivorensis*
Combretaceae	*Terminalia*	*superba*
Euphorbiaceae	*Alchornea*	*cordifolia*
	Magaritaria	*discoidea*
	Mareya	*micrantha*
Faboideae	*Amphimas*	*pterocarpoides*
Meliaceae	*Entandrophragma*	*angolensis*
	Khaya	*anthotheca*
	Khaya	*ivorensis*
	Trichilia	*monodelpha*
Mimosoideae	*Albizia*	*adianthifolia*
	Albizia	*ferruginea*
	Albizia	*glaberrima*
	Albizia	*zygia*
	Pentaclethra	*macrophylla*
	Tetrapleura	*tetraptera*
	Xylia	*evansii*
Moraceae	*Antiaris*	*toxicaria*
	Ficus	*capensis*
	Ficus	*exasperata*
	Ficus	*sur*
	Milicia	*excelsa*
	Morus	*mesozygia*
Myristicaceae	*Pycnanthus*	*angolensis*
Palmaceae	*Elaeis*	*guineensis*
Papilionaceae	*Baphia*	*nitida*
	Milletia	*zechiana*
	Pericopsis	*elata*
Salicaceae	*Homalium*	*letestui*
Sapindaceae	*Blighia*	*sapida*
	Blighia	*unijugata*
Sterculiaceae	*Nesogordonia*	*papaverifera*
Tiliaceae	*Christiana*	*tragacantha*
Ulmaceae	*Trema*	*occidentalis*

TABLE 2. Importance Value Index (IVI) of ten most abundant species, with corresponding structural characteristics at the sites.

Species	**Abonsrakrom**				
	Basal Area (m^2/ha)	**Relative Dominance (%)**	**Relative Density (%)**	**Relative Frequency (%)**	**IVI**
Terminalia superba	0.1776	11.06	10.53	11.69	33.27
Morinda lucida	0.1442	8.97	10.53	11.69	31.19
Bombax buonopozense	0.1472	9.17	7.37	7.79	24.32
Khaya ivorensis	0.0846	5.27	8.42	9.09	22.78
Amphimas pterocarpoides	0.0810	5.04	8.42	9.09	22.56
Sterculia tragacantha	0.1188	7.40	6.32	6.49	20.21
Albizia zygia	0.1416	8.81	5.26	5.19	19.28
Antiaris toxicaria	0.0546	3.40	6.31	6.49	16.21
Ceiba pentandra	0.1640	10.21	3.16	2.60	15.96
Ficus exasperata	0.0451	2.81	5.26	5.19	13.27
	Twumkrom				
Ficus exasperata	0.4619	14.68	18.70	8.56	42.41
Morinda lucida	0.3082	9.80	6.87	7.28	24.26
Terminalia superba	0.2946	9.37	5.72	6.63	22.03
Ceiba pentandra	0.4237	13.47	2.29	2.70	18.93
Khaya ivorensis	0.2119	6.73	6.73	5.14	17.81
Sterculia tragacantha	0.1203	3.82	6.49	2.29	17.71
Antiaris toxicaria	0.1661	5.28	6.10	5.67	17.12
Vernonia amygdalina	0.0681	2.17	4.19	4.83	13.78
Trema occidentalis	0.1119	3.56	4.20	4.83	12.70
Blighia unijugata	0.0858	2.73	4.58	4.92	12.32
	Ntabene 1				
Ficus exasperata	1.0664	31.51	35.15	19.41	87.15
Morinda lucida	0.5446	16.09	10.95	13.31	40.90
Antiaris toxicaria	0.4509	13.31	12.10	14.75	40.62
Albizia adianthifolia	0.4035	11.92	7.78	9.48	29.60
Khaya ivorensis	0.0842	2.49	3.74	4.55	10.87
Terminalia superba	0.1695	5.01	2.31	2.87	10.35
Baphia nitida	0.0446	1.31	4.03	4.94	9.49
Trema occidentalis	0.1017	3.01	2.88	2.50	8.40
Sterculia tragacantha	0.0661	1.95	2.88	3.50	8.32
Blighia unijugata	0.0821	2.43	2.59	3.22	7.05
Ficus exasperta	0.9354	22.95	29.75	28.27	80.97
Morinda lucida	0.9555	23.44	17.56	16.84	57.84
Antiaris toxicaria	0.8427	20.67	16.85	16.19	53.71
Albizia adianthifolia	0.1712	4.20	4.30	4.22	12.72
Ceiba pentandra	0.3223	7.91	1.43	1.65	10.99
Blighia unijugata	0.0705	1.73	3.58	3.71	9.03
Ficus capensis	0.0651	1.60	3.23	3.27	8.09
Khaya ivorensis	0.0705	1.73	2.87	2.90	7.50
Albizia ferruginea	0.0899	2.21	2.51	2.60	7.31
Trema occidentalis	0.1054	2.59	2.15	2.29	7.03

Another striking result was that *Antiaris toxicaria* recorded the third highest IVI values on both Ntabene 1 and Ntabene 2 plots, whereas in the case Twumkrom the third position was recorded by *Terminalia superba*. In general, species which recorded high IVI values also registered corresponding high basal area, relative dominance, relative density and relative frequency values. *Albizia* species of subfamily Mimosoideae featured prominently in all the study sites. This is worthy of note because of the tremendous role played by members of this genus in nitrogen fixation, especially in degraded environments such dry semi-deciduous forest where bushfires are rampant and nitrogen is considered to be deficient in their soils. *Ficus exasperata* stood out as the most abundant species with respect to basal area, relative dominance, relative density and relative frequency during the period under consideration at three of the four sites inventoried. *Ceiba pentandra* and *Bombax buonopozense* occurred at relatively small numbers in all the four locations. However, because of large dbh sizes, this profoundly reflected in the magnitude of the basal area and subsequent FIV values of Bombaceae (Table 3). On the family scale, the families with the highest number of species in the study area were Mimosoideae and Moraceae. Moraceae recorded fives species belonging three genera, which was followed by Mimosoideae that on average registered three species from two genera (Table 3).

TABLE 3. Family Impotence Value (FIV) of ten top families in the four sites.

Location/Site	Family/Subfamily	Genus	Species	N/Ha	FIV
Abonsrakrom	Meliaceae	2	3	110	40.07
	Bombaceae	2	2	80	39.31
	Combretaceae	2	2	100	33.68
	Mimosoideae	2	2	50	29.31
	Moraceae	2	2	90	26.98
	Sterculiaceae	2	2	70	26.91
	Rubiaceae	1	1	90	24.19
	Faboideae	1	1	70	18.09
	Papilionaceae	2	2	40	17.64
	Myristicaceae	1	1	20	12.65
Twumkrom	Moraceae	3	4	386	59.53
	Bombaceae	2	2	87	24.42
	Mimosoideae	3	4	130	22.99
	Rubiaceae	1	1	170	19.76
	Meliaceae	2	2	144	19.29
	Caesalpiniodeae	3	3	177	18.96
	Combretaceae	1	1	155	18.17
	Sterculiaceae	2	2	196	17.39
	Sapindaceae	1	2	214	17.29
	Apocynaceae	2	2	105	14.41
Ntabene 1	Moraceae	3	5	1098	114.72
	Mimosoideae	3	3	307	31.39
	Rubiaceae	1	1	308	30.38
	Euphorbiaceae	3	3	118	14.62
	Meliaceae	2	2	151	13.71
	Papilionaceae	2	2	174	13.25
	Sterculiaceae	2	2	110	11.91
	Combretaceae	1	1	82	10.65
	Bombaceae	2	2	58	10.40
	Bignoniaceae	2	2	53	9.62
Ntabene 2	Mimosoideae	2	4	1008	83.42
	Papilionaceae	2	2	517	49.16
	Combretaceae	1	1	480	41.36
	Moraceae	3	5	214	29.20
	Apocyanceae	2	2	202	20.91
	Sapindaceae	1	2	111	14.68
	Meliaceae	2	2	129	13.45
	Sterculiaceae	2	2	63	12.35
	Euphorbiaceae	2	2	91	11.28
	Bombaceae	2	2	62	11.24

The Fabaceae subfamily inventoried in study area were Caesalpiniodeae and Papilionaceae. Caesalpiniodeae recorded three genera and three species. However at Abonsrakrom site, Meliaceae recorded the highest FIV value with corresponding highest number of species, followed by Bombaceae and Combretaceae in descending order. Myristicaceae recorded the lowest FIV value among the top ten families observed in Abonsrakrom plots. However, Moraceae registered the highest FIV values and number of species at both Twumkrom and Ntabene 1. These were followed by Bombaceae and Mimosoideae in Twumkrom and Ntabene 1, respectively. The lowest FIV values were recorded by Bignoniaceae and Apocyanceae, specifically at Ntabene 1 and Twumkrom, respectively. At Ntabene 2 study site, the family group that recorded the highest FIV was Mimosoideae and Papilionaceae of the subfamily Fabaceae. In fact, Moraceae was the family with the highest number of species at this location, recording five species from three genera, followed by family Mimosoideae with two genera and three species. The family with lowest FIV value at Ntabene 2 was Bombaceae. The most common families in terms of frequency or prevalence in the all the study area were Moraceae and subfamilies of Fabaceae.

Tree species diversity and similarity in composition

The results of various measures of diversity employed to evaluate tree species diversity for the four sites studied are presented in Table 4. In general, there were relatively slight differences in tree species richness across the four study sites. Margalef's index of species richness gives an indication as to number of individual species present in relation to their richness at each site or at community level. From cursory look, Twumkrom (6.29) recorded the highest species richness based on Margalef's index of species richness; which was followed by Ntabene 1, with species evenness value of 4.96.

TABLE 4. Diversity measures of tree species enumerated at four sites.

Location/Site	Margalef's Species richness $d=(S-1)/lnN_i$	Shannon Evenness $J'=H'/lnS$	Shannon Diversity index $H'=-\Sigma P_i lnP_i$
Abonsrakrom	4.67	0.93	2.87
Twumkrom	6.29	0.86	3.09
Ntabene 1	4.96	0.78	2.42
Ntabene 2	4.44	0.73	2.37

*Most of the results were run off into two decimal places or two significant figures

Ntabene 2 plot recorded the least tree species richness value of 4.44. There was wide variation among the sites with respect to the evenness of trees species composition. The Shannon index of evenness ranged from 0.93 to 0.73, with Abonsrakrom and Ntabene 2 recording the highest and lowest values, respectively (Table 4). Twumkrom recorded highest tree diversity (3.09), this was followed by Abonsrakrom and lest diverse tree species was recorded by Ntabene 2. These results suggest that Twumkrom site has high tree species diversity compared to other sites evaluated in this study. Similarities of the species composition amongst the sites were investigated using Sorensen similarity index. The results indicated wide variability in similarity index of species composition ranging from 50% to 78% (Table 4).The highest similarity index (78%) was recorded between Abonsrakrom and Twumkrom, and the lowest (50%) between Abonsrakrom and Ntabene 1. The second highest value was recorded between Twumkrom and Ntabene 2. There were direct relationships between similarity and dissimilarity values; hence sites that recorded high similarity index values invariable registered corresponding low dissimilarity values (Table 5). Thus, the highest dissimilarity value (50%) was recorded between Abonsrakrom and Ntabene 1.

TABLE 5.Similarities and dissimilarities (%) of species composition amongst the four sites studied. The results are based on Sorensen's similarity index.

Location/Site	Abonsrakrom	Twumkrom	Ntabene 1	Ntabene 2
Abonsrakrom	--	78 (22)	50 (50)	63 (37)
Twumkrom	78 (22)[#]	--	58 (42)	68 (32)
Ntabene 1	50 (50)	58 (42)	--	64 (36)
Ntabene 2	63 (37)	68 (32)	64 (36)	--

[#]Note: All the values in the brackets represent dissimilarities values of the studied sites. Both similarities and dissimilarities values are expressed as percentage.

DISCUSSION

Tree species composition

The overall observation from the study suggests that passive intervention through control and management of anthropogenic mediated bushfires will facilitate possible recovery of greater proportion of the dry semideciduous forest zone. Cessation of periodic bushfires could convert the degraded area from grasses dominated savannah wood land to more functioning transitional tree dominated secondary forest ecosystem. If fires are suppress over longer period of time and in the absence of selective pressure from these fires test part of these degraded forest types could recover by going through necessary successional mechanisms (Rundel, 1981; Kruger, 1983; Lavorel, 1999). Passive restoration effort through fire control management systems is a suitable restoration strategy under conditions whereby the soils have not been degraded beyond recovery levels. Restoration through fire exclusion is only possible if there are adequate amount of tree seeds in the soil seedbank and there are no perturbations to inhibit natural recovery (Holl, 1998). The 49 tree species from 40 genera and 23 families identified or inventoried in the four sites in the Pamu-Berekum forest reserve, 6 tree species have large basal area notably, *Ficus species*, *Terminalia superba*, *Morinda lucida*, *Bombax buonopozense*, *Antiaris toxicaria* and *Albizia adianthifolia*. This is an indication of potential rapid growth in diameter. These species may be ideal candidates for active restoration of degraded dry semideciduous forest ecosystem either through reforestation or afforestation. This is under premise that the rapid growth rates exhibited by these underlisted species confer some level of adaptation to enable them to survive the prevailing harsh environmental conditions such as desiccation, low soil fertility and weeds competition (Swaine, 1992; Lieberman and Li, 1992). The number of families, genera and species observed in this study fall within the range reported elsewhere for dry semideciduous forest ecotypes (Gentry, 1988; Sabogal and Valerio, 1998). The most common tree species in the studied sites were *Ficus species*, *Terminalia superba, Morinda lucida, Antiaris toxicaria, Blighia unijugata and Albizia species*. The high proportion of tree species belonging to Fabaceae family and its subfamilies reported in all the sites in this study is not uncommon in dry semideciduous forests (Gillespie *et al*., 2000; Gonzalez-Rivas *et al*., 2006).The prevalence of *Ficus species, Terminalia superba, Morinda lucida, Antiaris toxicaria, Blighia unijugata and Albizia species* on all the study plots may be due to presence of certain morphological or physiological attributes that facilitate their pioneering role in the early successional phase of recovery of fire-degraded dry semi-deciduous secondary forest (Swaine and Hall, 1983). For instance the seeds of pioneer tree species like *Terminalia* and *Albizia* are easily dispersed by wind, which accounts for their initial success in colonizing new clearings (Swaine and Hall, 1983). *Terminalia* has been described as large (megaphanerophyte) fast growing pioneer species, which maintains annual growth diameter in excess of 2cm (Swaine and Hall, 1983). Species belonging to Fabaceae (*eg*. *Albizia species* and *Baphia nitida*) have been reported to increase nitrogen levels in degraded soils through actives fixation and/or incorporation of biomass into the soil medium (Drechsel *et al*., 1991; Swaine *et al*,. 2005; Swaine *et al*., 2007). Due to their nitrogen fixing ability, they could be used as pioneer species for the restoration or rehabilitation of degraded and overexplioted forests (Diabate *et al*., 2005). In general, soils in tropics are usually deficient in nitrogen which is exacerbated by periodic bushfires that contribute to further loss of soil nitrogen. It has been suggested that Fabaceae group modifies the soil microenvironment and thus facilitates in recruiting other tree species to the site (Camargo-Ricalde, 2002). *Albizia adianthifolia* in particular has been reported to suppress invasion of obnoxious weeds like *Chromoneana odorata* (Henri, 2008) and this mechanism will facilitate natural regeneration. However, Moraceae species of genera such as *Ficus* and *Antiaris* have fast growth habit which enable them to out- compete weeds in disturbed ecosystem. Other tree species found to be prevalent in all the study sites were *Sterculia tragacantha* and *Trema occidentalis*; despite their low IVI and other indices. However, they have significant role to play to ensure ecosystem functioning at community level. *Trema occidentalis* is pioneer species and it is usually associated with anthropogenic disturbed forest ecosystem (Swaine and Hall, 1983). *Trema occidentalis* normally occupies gaps and exhibit fast growth rate, an adaptation which enables it to overcome weed competition. It has been suggested that *Trema occidentalis* modifies the immediate environment and makes it more conducive for the colonization by diverse tree species (Swaine and Hall, 1983).

Tree species diversity and similarity in composition

To understand the differences in recovery with respect to species composition, the study compared species richness, evenness and diversity of all the four sites. Various measures of diversity indices were computed to evaluate the nature of tree species composition and diversity across these four study sites. There were relatively slight differences in species richness (range: between 4 and 6 Margalef's index) amongst the four sites. These values were lower than those of other tropical dry forests (*e.g.* Gonzalez-Rivas *et al*., 2006). In addition, the total of 49 different tree species recorded on the plots of recovered fire-degraded sites in this study falls below the range of other studies (*e.g*. Gillespie and Jafre,2003; Levesque *et al*., 2011). Perhaps successional changes at the study sites are at their infantile stages and still on-going and thus yet to attain the stable climax state. Obviously, ten years is a short duration to confer any fundamental difference in species composition and richness. Recurrent bushfires could eliminate most of the original native tree seeds meant for natural regeneration from soil seedbank, thus reducing tree species richness and diversity (*e.g.* Nepstad *et al*., 1990). In fact, most of the common species enumerated in the study produce seeds which are easily dispersed by wind. However, wide differences in species evenness indices were observed across the four sites, depicting heterogeneous tree species communities. In addition, the results of species suggest that tree species composition is more evenly distributed on the plots of Abonsrakrom site than other sites. One key issue is that evenness depends on the amount of vegetation sampled (Hurlbet, 1971). However, in terms of similarities in species composition amongst the four sites the values recorded range between 50% to 78%. These results suggest that tree species composition from early natural regeneration and colonizers might have persisted on the sites to maturity and contributed to successional process. However, most of these species are early light demanding pioneer species characteristics of early phase succession after disruption in recurrent wildfires (Finegan, 1996). Furthermore, the dynamics of natural regeneration at all the four sites is almost the same leading to formation of plant communities comparable in composition.

In view of common physical elements of the area, the observed variation in tree species diversity might be due to spatial heterogeneity. The most key factors are the distance of Twumkrom and Abonsrakrom plots to partially degraded remnant forest, which might have served as source of seed dispersal to the sites (*e.g.* Hooper *et al*., 2002) and other intrinsic factors limiting recruitment. Nevertheless, the values recorded for most of the indices are comparable with those of other studies conducted elsewhere (Gonzalez-Rivas *et al*., 2006; Sagar and Singh, 2006; Tripathi and Reynald, 2010; Verma and Kapoor, 2011). In particular, the values of Shannon diversity index in this study fall within the acceptable limits of diversity investigations (Magurran, 2004).The general observation is that upon cessation of recurrent bushfires, most of the degraded dry semi-deciduous forest zone could revert from current grasses dominated woody land to native vegetation given adequate time to recover.

CONCLUSION

In conclusion, the predominant economic tree species identified in the study sites could be further evaluated and used in restoration and/or reforestation of dry semideciduous forest zone. Future restoration and reforestation efforts to mitigate forest degradation in dry semideciduous forest zone should consider the use of species such as *Ficus spp., Albizia spp., Terminalia superba, Morinda lucida, Antiaris toxicaria, and Blighia unijugata* to catalyze natural forest regeneration and to foster recruitment of other diverse native tree species. The presence of tree species from families such as Fabaceae, Moraceae, Bombaceae and Combretaceae are of critical importance to natural regeneration, establishment, and recruitment of other native tree species and subsequent self sustaining of succession. The goal of any restoration project should not only emphasis on forest recovery, but native tree species composition. Finally, the prevention of recurrent bushfires in the disturbed dry semideciduous forest zone will facilitate natural regeneration of these forests. This could be achieved through mass public education of local farmers about dangerous effects bushfires on forest resources and establishment green firebreaks at the fringes of forest reserves in the country.

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