Species composition, stand structure and carbon sequestration of dry zone vegetation in Minwuntaung Wildlife Sanctuary, Sagaing Region, Myanmar

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Abstract

To study the species composition, stand structure and carbon sequestration of dry zone forest in Minwuntaung Wildlife Sanctuary, sixty sample plots (50x50m) and (30x30m) at three different areas (central, southern and northern) were established and observed in June 2013. A total of 68 species representing 49 genera and 27 families were recorded in central area, 53 species, 47 genera and 25 families were recorded in southern area and 40 species, 36 genera and 23 families were recorded in northern area. Among the three study area, central area possesses the highest diversity value (H' = 4.50, D = 0.93), southern area has the second highest diversity value (H' = 4.21, D = 0.90), and northern area with the lowest diversity value (H' = 3.66, D = 0.88). As a result of Shannon Wiener evenness (E), the plant species in central area (0.74) were more evenly distributed among the species than the southern area (0.73) and the northern area 0.67. Importance value index (IVI) of major tree species was described by ranking order. Depending on IVI value, ecologically successful species were *Terminalia oliveri*, *Tectona hamiltoniana*, *Terminalia crenulata*, *Grewia eriocarpa* and *Eriolaena candollei*. In horizontal structure, tree density and basal area of gbh (5-15 cm) occurs 1132 n ha^{-1}, 1.29 m^2 ha^{-1} in central area, 1058 n ha^{-1}, 0.97 m^2 ha^{-1} in southern area and 1568 n ha^{-1}, 1.31 m^2 ha^{-1} in northern area. According to Pearson's correlation, elevation and soil nutrients appear to be the most important factors, which strongly correlated on species diversity, species richness and stem density of the study area. The mean total carbon stocks of tree in central, southern and northern area were estimated 11.92±4.35 ton ha^{-1}, 29.12±5.8 ton ha^{-1} and 16.38±2.28 ton ha^{-1}. The total carbon stock was statistically significant different among the three area ($p < 0.05$). The mean total soil carbon (up to 30 cm) storage in central area (30.63±3.3ton ha^{-1}) scored the lowest value than southern area (31.62±3.4ton ha^{-1}) and northern area (37.18±1.8ton ha^{-1}). The mean soil carbon was not significantly different among the three study area (F = 1.346, p = 0.294).

Keywords: species composition, diversity, stand structure, dry zone forest

Introduction

Arid and semi-arid regions of Myanmar can be found in the central part of the country and are collectively known as Dry Zone of Myanmar. It is located in the central part of Myanmar between 19˙ 20' and 22˙ 50' North and longitude 93˙ 40' and 96˙ 30' East covering three civil administrative regions of lower Sagaing Division, Mandalay Division and Magway Division. The area of the Dry Zone is 8,724,184 ha (Oo *et al*., 2006). More than half of the total land area of Myanmar is still covered with vast and diverse forests, but the central part (about 10% of the area) is barren, having little forest cover. This part is received less than 1000 mm of annual rainfall (Forest Department, 1999). The annual deforestation rate in the dry zone is 2.07% (Myint, 1995), higher than the national average of 0.64% (Forest Department, 1999). Tropical dry forest constitutes the largest proportion of tropical forests in the world (Brown and Lugo 1980, 1982), but is also the most endangered (Janzen 1988a, b).

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Tropical dry forests occur in frost-free areas with lower rainfall (250–1800 mm), higher mean annual bio-temperature (>17°C), higher rainfall seasonality (3–8 months of drought), and a higher ratio of potential evapotranspiration to precipitation (>1) than in wet forests (Murphy & Lugo, 1986 a; Gerhardt & Hytteborn, 1992). Forestry in the Dry Zone is defined as "management of trees and shrubs to improve the livelihood and quality of life for rural people in dry land environments". It includes traditional forestry practices, horticulture, livestock and wildlife management. The applications of dry zone forestry include production of wood for fuel, poles and building materials and that of fodder for cattle. Moreover, it is used to modify microclimates which can improve agricultural crop production (Folliott, 1995).

An ecosystem is a major structural and functional unit of ecology. The structure of an ecosystem is related to its species diversity: more complex ecosystem and the higher species diversity (Smith, 1966). A vegetation is the sum total of plant covering an area which generally consists of a number of communities. A community is an association of different population of organisms that live and interact together in the same place at the same time. Forest vegetation is influenced by a number of abiotic and biotic environmental factors (Weaver and Clements, 1966). A number of qualitative and quantitative indices of species diversity have been proposed by several workers (Simpson, 1949, Shannon and Wiener, 1963). Tropical forests constitute the most diverse communities on the earth. Forest plays a relevant role as a natural process in global carbon cycle. Forest ecosystem includes two carbon pools: biomass and soils (Kurz *et al*., 1992). The biomass carbon represents all living tree and plant biomass; the soil C pool includes detritus, forest floor coarse woody debris and soil organic matters (IPCC, 2000). Most terrestrial carbon storage is in tree trunks, branches, foliage, and roots which is often called biomass. It is believed that the goal of reducing carbon sources and increasing the carbon sink can be achieved efficiently by protecting and conserving the carbon pools in existing forests (Brown *et al*., 1996). Terrestrial vegetation and soil represents important sources and sinks of atmospheric carbon (Watson *et al*., 2000), with land use change accounting for 24 % of net annual anthropogenic emission of greenhouse gases to the atmosphere (Prentice *et al*., 2001). These forests are disappearing at alarming rates to deforestation for extraction of timber and other forests products. The objective of the present study is to describe species composition, species diversity, species richness and evenness and stand structure and carbon sequestration in the study area.

Methodology

Description of Study area

Minwuntaung Wildlife Sanctuary is located in Sagaing Township, Sagaing Region. It lies between 95˙ 52' 30" and 96˙ 5' 0" E longitude and between 21˙ 55' 0" and 22˙ 12' 30" N latitudes. Minwuntaung Wildlife Sanctuary is 206 km^2 and protected since 1972 (Fig.1). The region experiences three seasons a year: summer (February–April), the rainy season (May–October), and winter (November–January). According to the nearest rain gauge station in Sagaing, the region receives an annual rainfall 910 mm and the average monthly temperature is about 28.5°C (Fig. 2). The lowest and highest elevation was 75 and 410 m, respectively. The soil type of the area consists of Rhodic ferrosols.

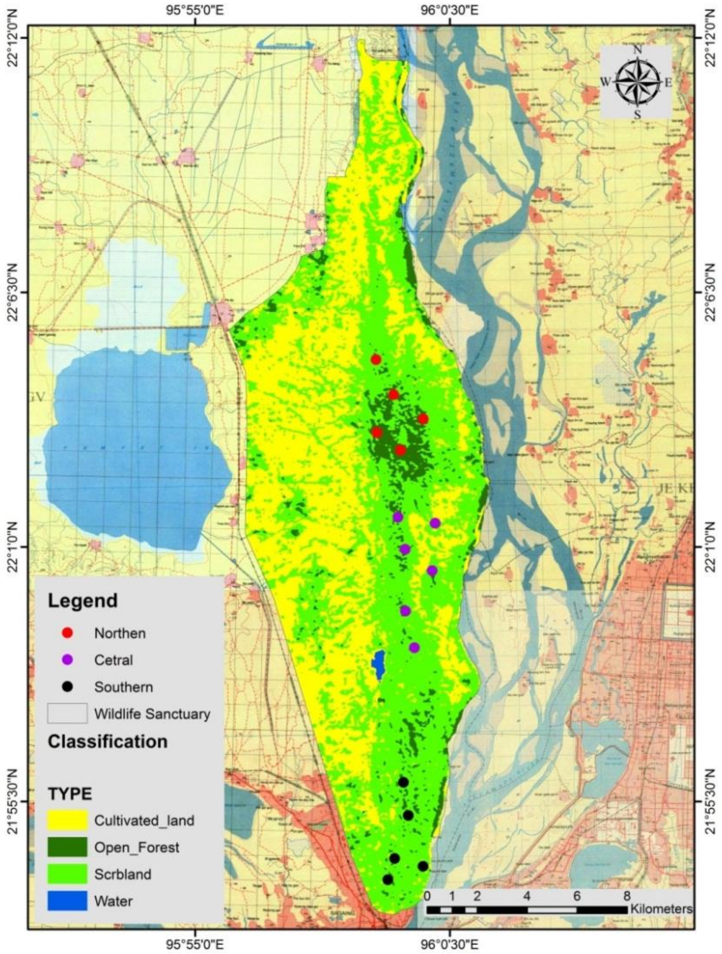

Figure 1. Location map of study area

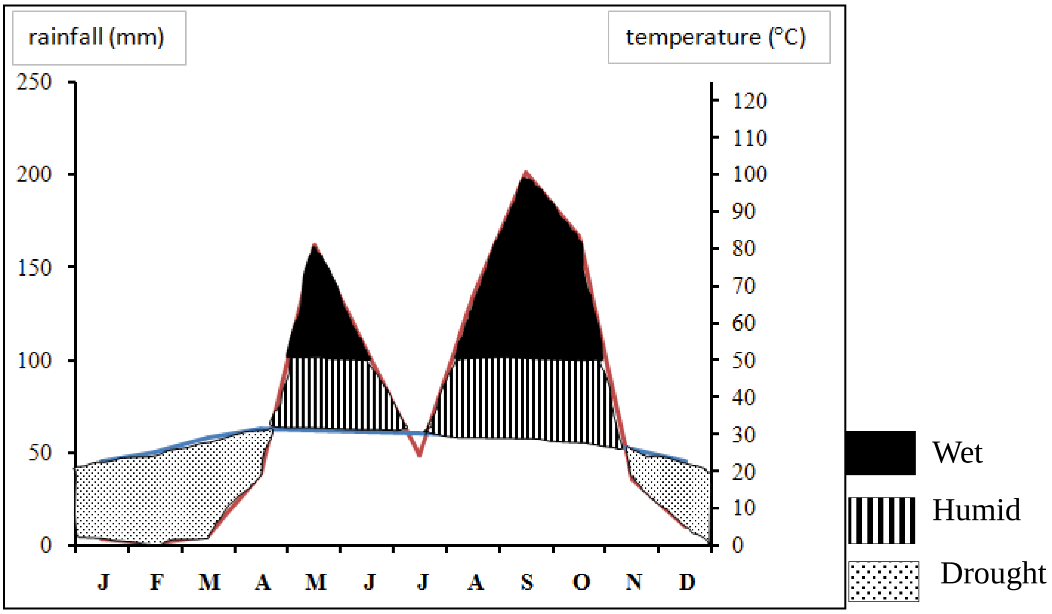

Figure 2. Climatic diagram of the study area (2003-2015)

Data collection

To elucidate species composition and stand structure, sixteen quardrats (50x50 m and 30x30 m) in three areas were chosen subjectively in ecologically and physiognomically representatives from lower to higher elevation to cover the whole area Figure 1.

The central area includes six sample plots such as *Atalantia monophylla* stand and *Dalbergia paniculata* stand are located near Yega village. *Terminalia oliveri* stand is situated at Natyehtut monastery area. *Carissa spinarum*, *Acacia catechu* and *Rhus paniculata* stands are laid at Damathukhataungnyo Taung. These plots are situated at an elevation between 124 - 185 m.

The southern area includes five sample plots such as *Terminalia oliveri* stand and *Rhus paniculata* stand are located at Padamya Taung. The *Terminalia oliveri* and *Tectona hamiltoniana* stand and *Terminalia oliveri* and *Bridelia retusa* stand are laid near Swunooponnyashin and Sinboe pagoda and *Bridelia retusa* and *Atalantia monophylla* stand are situated near Moekoat monastery. These plots are located at an elevation between 119 - 249 m.

The northern area includes five sample plots such as *Eriolaena candollei* and *Terminalia crenulata* stand and *Terminalia crenulata* and *Grewia eriocarpa* stand are situated at Nattaung area. The *Terminalia crenulata* and *Lannea coromandelica* stand and *Terminalia crenulata* stand are located at Shwemyintintaung. *Tectona* *hamiltoniana* stand is laid near Shwekyintawya monastery. These plots are positioned at between 115 - 408 m.

Data analysis

Plant specimens were collected, pressed, dried and matched by checking “A Checklist of Trees, Shrubs, Herbs and Climber of Myanmar” (Kress *et al*., 2003), “Angiosperm Flora of Pondaung Ponnya Range Between Pauk and Kyauk Htu Township” (Thet Naing Oo, 2010) and “ Floristic Study of Angiospermae on Shwebo Township” (Khin Hnin Yee, 2010); APG III classification system and verified by literature cited in “Flora of British India” Vol. (I-II), (Hooker, 1875-1879); and “Flora of Ceylon” Vol. (I-XIII) (Dassanayake, 1980-2001).

The field data collected was analyzed for number of species, stem density (trees) per hectare, basal area per hectare. Quantitative analysis of dominance and their relative values of frequency, density and basal area were calculated and summed to get Importance Value Index. Population structure of tree species were analyzed across fixed gbh classes. Quantitative analysis of dominance and their relative values of frequency, density and basal area were calculated and summed to get Importance Value Index. Jackknife estimate of species richness was also adopted in order to estimate the species richness per study area. The estimate is based on the observed frequency of rare species in the study sites. The species richness was estimated using the Jackknife estimator (Heltshe and Forrester, 1983), which is based on the observed frequency of rare species in the community. $\hat{S} = S + \left[\frac{n-1}{n}\right]^k$ $\hat{S}$ = Jackknife estimate of species richness, *S* = observed total number of species in “n” sample plots**,** *n* = Total number of plots sample**,** *k* = number of unique species. In order to provide quantitative estimate of plant diversity and its main parameters, Simpson’s index $D = 1 - \sum_{i=1}^{s}(p_i)^2$ (Magurran, 1988; Simpson, 1949) and Shannon’s index $H = -\sum_{i=1}^{s}(p_i)(log_2 p_i)$ (Magurran, 1988; Pielou, 1975; Shannon and Weaver, 1949) were used. Shannon’s diversity index places more weight on the rare species while Simpson’s diversity index gives more weight to those species which occur more frequently (Lamprecht, 1989; Magurran, 1988). Evenness was calculated by Shannon-Wiener function, 1963. $E = \frac{H}{H_{max}}$ $H_{max} = Log_2 S$.

Estimating of above and below ground biomass

A tree's carbon resources are composed of above ground and below carbon in the tree. Above ground biomass of the study area was estimated using the biomass regression equation developed by Brown *et al*., (1989). Biomass regression equation of Brown *et al*., (1989) was used in this study because based on range in dbh (3 - 30 cm) and rainfall data (< 900 mm/year) for dry zones. The biomass regression model of Brown *et al*., (1989) is as follows:

$$Y = 1\hat{0}\{-0.535 + \log 10(BA)\}$$

Where, Y is biomass per tree in Kg and *BA* is the basal area in cm^2.

Based on the empirical data of this study, the ratio of belowground biomass was estimated as 0.28 % of aboveground biomass (Mokany *et al*., 2006). A carbon content of default value of 0.5 was used to estimate the carbon content of tree biomass as the proposed by the IPCC (1996).

Collection of soil sample

To collect soil sample, five points were systematically selected from each stand. Soil samples were collected from soil depths of 0 - 15 cm and 15 - 30 cm from all selected points of each study stand. Different stands of representative soil samples were collected to measure the soil organic carbon (SOC). Different soil samples were collected for the analysis of soil physical and chemical properties.

Analysis of soil sample

Soil samples were tested in the soil laboratory of the Department of Agriculture (land use) in Yangon and Yezin in Naypyidaw, Myanmar. Before conducting soil analysis, soil samples were sieved in a 2 mm mesh wire size, cleaned and air-dried for 48 hours in the laboratory until it reaching a constant weight.

Three soil fractions (sand, silt, and clay) were determined using the pipette method. Soil moisture content was measured by taking the difference between the weight before and after oven-drying at 105 ˚C for 24 hours.

$$\text{Moisture contents (\%)} = \frac{\text{fresh weght - dry weight}}{\text{dry weight}} \times 100$$

Major cations such as potassium and available potassium were analyzed using Atomic Absorption Spectrophotometer (GBC 932 plus). Soil pH was measured using de-ionized water as a solvent (soil: water = 1: 2.5). Soil bulk density (g cm^{-3}) was determined by getting the quotient of the dry weight of soil (g) and bulk volume of soil (cm^3).

Determination of soil organic carbon (SOC)

To estimate the soil organic matter (SOM) content, soil samples were analyzed by loss-on-ignition (LOI) method and a conversion factor of 0.58 was used to convert SOM to SOC (Nelson and Sommers, 1996). The loss-on-ignition method for the determination of organic matter involves the heated destruction of all organic matter in the soil or sediment. A known weight of sample is placed in a ceramic crucible which is then heated to between 350 and 440 ˚C overnight (Blume *et al.*, 1990; Nelson and Sommers, 1996; ASTM, 2000). The sample is then cooled in a desiccator and weighted. Organic matter content is calculated as follows:

$$\text{Organic matter content (\%)} = \frac{\text{weight before ignition - weight after ignition}}{\text{weight before ignition}} \times 100$$

Statistical analysis

All statistical analysis for comparing the mean values of biomass and carbon storage was performed by SPSS version 16.0. A one way analysis of variance ANOVA was used to test the differences between carbon storage of tree as well as soil organic carbon storage among the study area.

Results

Species diversity, richness and composition

In the central area, a total of 2170 individuals, representing 68 species, 58 genera and 24 families were recorded. The dominant families of tree species were Fabaceae (11 species), Rubiaceae and Verbenaceae (7 species each), Euphobiaceae (6 species), Anacardiaceae and Malvaceae (4 species each) (Table 1). A total of 1357 individuals, representing 53 species, 46 genera and 23 families were recorded in the southern area. The dominant families of tree species were Fabaceae (8 species), Euphobiaceae and Verbenaceae (5 species each), Rubiaceae (4 species), Anarcardiaceae, Apocynaceae and Malvaceae (3 species each) (Table 2). In the northern area, a total of 2608 individuals, representing 44 species, 39 genera and 19 families were recorded. The dominant families of tree species were Fabaceae (7 species), Verbenaceae, Euphobiaceae and Rubiaceae (4 species each), and Malvaceae and Anarcardiaceae (3 species each) (Table 3).

Among the three study area, central area possesses the highest diversity value (H' = 4.50, D = 0.93), southern area has the second highest diversity value (H' = 4.21, D = 0.90), and northern area with the lowest diversity value (H '= 3.66, D = 0.88) (Table 4). As a result of Shannon Wiener evenness (E), the plant species in central area (0.74) were more evenly distributed among the species than that in the southern area (0.73) and the northern area 0.67 (Table 4). The Jackknife estimator for species richness of trees showed that central area occupied the highest number of species richness (68.92) and families richness (27.95), southern area has the second highest number of species richness (53.85) and families richness (25.88), and northern area with the lowest number of species richness (44.93) and families richness (23.93) (Table 4). The results of Pearson's correlation between stand parameters and the environmental variables of the study area are shown in Table 5. According to the Pearson's correlation, significant negative correlations were found between stem density and Shannon Wiener diversity ($p<0.01$), between Shannon Wiener diversity and elevation ($p<0.05$), between Shannon Wiener diversity and organic matter ($p<0.01$), between Simpsons index and total nitrogen and also potassium ($p<0.05$), Shannon evenness and available phosphorus ($p<0.05$) and between Jackknife species richness and total nitrogen ($p<0.01$). Stem density was significantly correlated with elevation ($p<0.05$) as well as organic matter ($p<0.01$) of the study area.

Table 1. Ranking of dominant family by number of species composition in central area

No.	Family Name	no. of genera	no. of species	no. of individuals
1	Fabaceae	11	13	490
2	Rubiaceae	7	7	138
3	Verbenaceae	5	7	293
4	Euphobiaceae	6	6	86
5	Anacardiaceae	4	4	234
6	Malvaceae	3	4	67
7	Bignoniaceae	2	3	16
8	Combretaceae	2	3	308
9	Others	18	21	538
	Total	58	68	2170

Table 2. Ranking of dominant family by number of species composition in southern area

No.	Family Name	no. of genera	no. of species	no. of individuals
1	Fabaceae	5	8	71
2	Euphorbiaceae	5	5	204
3	Verbenaceae	5	5	167
4	Rubiaceae	4	4	31
5	Anacardiaceae	3	3	202
6	Apocynaceae	3	3	58
7	Malvaceae	2	3	39
8	Combretaceae	1	2	321
9	Others	18	20	264
	Total	46	53	1357

Table 3. Ranking of dominant family by number of species composition in northern area

No.	Family Name	no. of genera	no. of species	no. of individuals
1	Fabaceae	6	7	309
2	Verbenaceae	3	4	181
3	Euphorbiaceae	3	4	45
4	Rubiaceae	3	4	6
5	Malvaceae	3	3	633
6	Anacardiaceae	3	3	162
7	Combretaceae	1	2	760
8	Annonaceae	2	2	86
9	Others	15	15	426
	Total	39	44	2608

Table 4. Comparisons of species richness and diversity among three study areas

Parameters	Central area	Southern area	Northern area
Species richness	68.92	53.85	44.93
Family richness	27.95	25.88	23.93
Shannon-Wiener diversity index (H)	4.50	4.21	3.66
Simpson’s diversity index(D)	0.93	0.90	0.88
Simpson’s evenness (E)	0.74	0.73	0.67

Table 5. Pearson's correlation between stand parameter and environmental factors of the study area

Variables	SWI	ELE	pH	MC	OM	N	P	K	Sand	Silt	Clay
Shannon Wienner Index	1	**-1.000***	0.902	-0.88	**-1.000****	-0.949	-0.928	-0.976	0.992	-0.991	0.067
Simpson Index	0.958	-0.966	0.739	-0.98	-0.954	**-1.000***	-0.782	**-0.997***	0.914	-0.911	0.351
Shannon Evenness	0.94	-0.93	0.995	-0.667	-0.945	-0.786	**-0.999***	-0.844	0.976	-0.978	-0.276
Jacknife Species Richness	0.948	-0.957	0.717	-0.986	-0.944	**-1.000****	-0.762	-0.995	0.9	-0.897	0.381
Stem Density(n ha^{-1})	**-1.000****	**0.999***	-0.905	0.877	**1.000****	0.947	0.931	0.974	-0.993	0.992	-0.06
Basal Area (m^2 ha^{-1})	-0.827	0.843	-0.503	0.995	0.82	0.962	0.559	0.93	-0.75	0.745	-0.616

** Correlation is significant at the 0.01 level.* Correlation is significant at the 0.05 level.

Note: ELE = Elevation, pH = Soil pH, MC = Moisture content, OM = Organic matter, N = Total nitrogen, P = Available phosphorus, K = Potassium

Stand structure

Horizontal stand structure

In central area, *Lannea coromandelica* species was observed to be the biggest tree (≥ 115 cm gbh) which was 3.03 % of the total species (Table 6). There were 62 species in lower class (5 - 15 cm gbh) which were 92.42 % of the total species. Tree density, basal area and species richness of gbh (5 - 15 cm) were 1132 n ha^{-1}, 1.29 m^2 ha^{-1} and 46 n ha^{-1} (Table 9).

In the southern area, 3 species were to be the biggest tree (≥ 115 cm gbh) which was 5.66 % of the total species (Table 7). These species were *Azadirachta indica*, *Lannea coromandelica* and *Terminalia oliveri*. There were 44 species in lower class (5 - 15 cm gbh) which were 82.02 % of the total species. Tree density, basal area and species richness of gbh (5 - 15 cm) was 1058 n ha^{-1}, 0.97 m^2 ha^{-1} and 57 n ha^{-1} (Table 9).

In the northern area, 2 species was to be the biggest tree (≥ 115 cm) which were 4.55 % of the total species (Table 8). These species were *Balanites aegyptica* and *Tamarindus indica*. There were 40 species in lower class (5 - 15 cm gbh) which were 90.91 % of the total species. Tree density, basal area and species richness of gbh (5 - 15 cm) was 1568 n ha^{-1}, 1.31 m^2 ha^{-1} and 32 n ha^{-1} (Table 9).

Vertical stand structure

Stratification or vertical structure of the community determines the different growth forms. This stratification is determined by the species diversity and age structure of a site, and affects the composition of the understory as well as tree growth due to competition for light and other resources.

In the central area, sixty species (42.84 % of total individuals) was found in the height class of < 3 m; forty seven species (39.02 % of total individuals) was found in the height class of 3 - 6 m; fifteen species (11.80 % of total individuals) was found in the height class of 6 - 9 m; and seven species (4.92 % of total individuals) was found in the height class of 9 - 12 m. These species were *Dalbergia kurzii*, *Dalbergia paniculata*, *Millettia multiflora*, *Tectona hamiltoniana*, *Terminalia oliveri*, *Spondias pinnata* and *Vitex limonifolia*. Three species (1.42 % of total individuals) was found in the height class of ≥ 12 m: *Lannea coromandelica*, *Tectona hamiltoniana* and *Terminalia oliveri* (Table 10).

In the southern area, forty two species (57.33 % of total individuals) was found in the height class of < 3 m; thirty three species (21.37 % of total individuals) was found in the height class of 3 - 6 m; twenty species (12.01 % of total individuals) was found in the height class of 6 - 9 m; and fifteen species (8.55 % of total individuals) was found in the height class of 9 - 12 m. Some of these were *Azadirachta indica*, *Dalbergia kurzii*, *Dalbergia paniculata*, *Lannea coromandelica*, *Phyllanthus albizzioides*, *Tectona hamiltoniana*, *Terminalia oliveri*, *Spondias pinnata*, *Vitex limonifolia* and *Millettia multiflora*. Two species (0.74 % of total individuals) was found in the height class of ≥ 12 m. They were *Chukrasia velutina* and *Terminalia oliveri* (Table 10).

In the northern area, forty species (69.27 % of total individuals) was found in the height class of < 3 m; twenty nine species (23.49 % of total individuals) was found in the height class of 3 - 6 m; seventeen species (5.90 % of total individuals) was found in the height class of 6 - 9 m; and eight species (1.23 % of total individuals) was found in the height class of 9 - 12 m. These species were *Atalantia monophylla*, *Balanites aegyptica*, *Grewia eriocarpa*, *Lannea coromandelica*, *Miliusa velutina*, *Tamarindus indica*, *Tectona hamiltoniana* and *Terminalia oliveri*. Two species (0.11 % of total individuals) was found in the height class of ≥ 12 m. These species were *Balanites aegyptica* and *Tectona hamiltoniana* (Table 10).

Table 6. Population density of tree species across gbh class interval in central area

gbh (cm)	Total no. of individual	No. of species	% of total species
5 - 15	1543	62	92.42
16 - 25	344	38	53.03
26 - 35	129	17	31.82
36 - 45	68	16	27.27
46 - 55	32	11	21.21
56 - 65	32	6	9.09
66 - 75	11	1	6.06
76 - 85	4	1	1.52
86 - 95	5	2	4.55
96 - 105	1	1	3.03
106 - 115	-	-	-
≥ 116	1	1	3.03

Table 7. Population density of tree species across gbh class interval in southern area

gbh (cm)	Total no. of individual	No. of species	% of total species
5 - 15	815	44	83.02
16 - 25	184	28	52.83
26 - 35	148	20	37.74
36 - 45	86	13	24.53
46 - 55	53	14	26.42
56 - 65	30	8	15.09
66 - 75	19	8	15.09
76 - 85	7	5	9.43
86 - 95	6	3	5.66
96 - 105	3	3	5.66
106 - 115	2	2	3.77
≥ 116	4	3	5.66

Table 8. Population density of tree species across gbh class interval in northern area

gbh (cm)	Total no. of individual	No. of species	% of total species
5 - 15	1960	40	90.91
16 - 25	346	22	50.00
26 - 35	171	15	34.09
36 - 45	66	11	25.00
46 - 55	28	10	22.73
56 - 65	15	6	13.64
66 - 75	10	4	9.09
76 - 85	4	2	4.55
86 - 95	3	2	4.55
96 - 105	1	1	2.27
106 - 115	2	2	4.55
≥ 116	2	2	4.55

Table 9. Distribution of species, tree density and basal area of horizontal structure in central, southern and northern area

gbh (cm)	Central area			Southern area			Northern area		
	BA/ha	TD	SR	BA/ha	TD	SR	BA/ha	TD	SR
5 - 15	1.29	1135	46	0.97	1058	57	1.31	1568	32
16 - 25	0.97	253	28	1.00	239	36	1.21	277	18
26 - 35	0.63	95	13	1.68	192	26	1.21	137	12
36 - 45	0.66	50	12	1.66	112	17	0.74	53	9
46 - 55	0.44	24	8	1.51	69	18	0.69	22	8
56 - 65	0.62	24	4	1.37	39	10	0.47	12	5
66 - 75	0.31	8	1	1.28	25	10	0.31	8	3
76 - 85	0.15	3	1	0.19	9	6	0.18	3	2
86 - 95	0.23	4	1	0.53	8	4	0.19	2	2
96 - 105	0.06	1	1	0.32	4	4	0.06	1	1
106 - 115	-	-	-	0.42	3	3	0.17	2	2
≥ 116	0.08	1	1	0.88	5	4	0.31	2	2

BA = Basal area (m^2 ha^{-1}), TD = Tree density (n ha^{-1}), SR = Species richness (n ha^{-1})

Table 10. Population of tree species in vertical structure of central, southern and northern area

Height Class (m)	Central			Southern			Northern		
	NS	NI	TI (%)	NS	NI	TI (%)	NS	NI	TI (%)
< 3	60	1194	42.84	42	778	57.33	40	1808	69.27
3 - 6	47	696	39.02	33	290	21.37	29	613	23.49
6 - 9	15	155	11.80	20	163	12.01	17	154	5.90
9 - 12	7	93	4.92	15	116	8.55	8	32	1.23
≥ 12	3	32	1.42	2	10	0.74	2	3	0.11

NS = No. of species, NI = No. of individual, TI (%) = % of total individual

Importance Value Index (IVI)

Ten leading species in term of IVI were shown in Figures 3 - 5. The central area is dominated by *Terminalia oliveri*, with the highest of 59.49 %, the second most dominant species is *Tectona hamiltoniana* (IVI = 26.07 %) and *Hiptage benghalensis* (IVI = 23.26 %) is third (Figure 3). The southern area was dominated by *Terminalia oliveri*, with the highest of 76.60 %, the second most important species was *Bridelia retusa* (IVI = 25.47 %) and *Tectona hamiltoniana* (IVI = 21.12 %) was third (Figure 4). The northern area was dominated by *Terminalia crenulata*, with the highest of 63.10 %, the second most important species was *Tectona hamiltoniana* (IVI = 31.79 %) and *Grewia eriocarpa* (IVI = 31.70 %) was third (Figure 5).

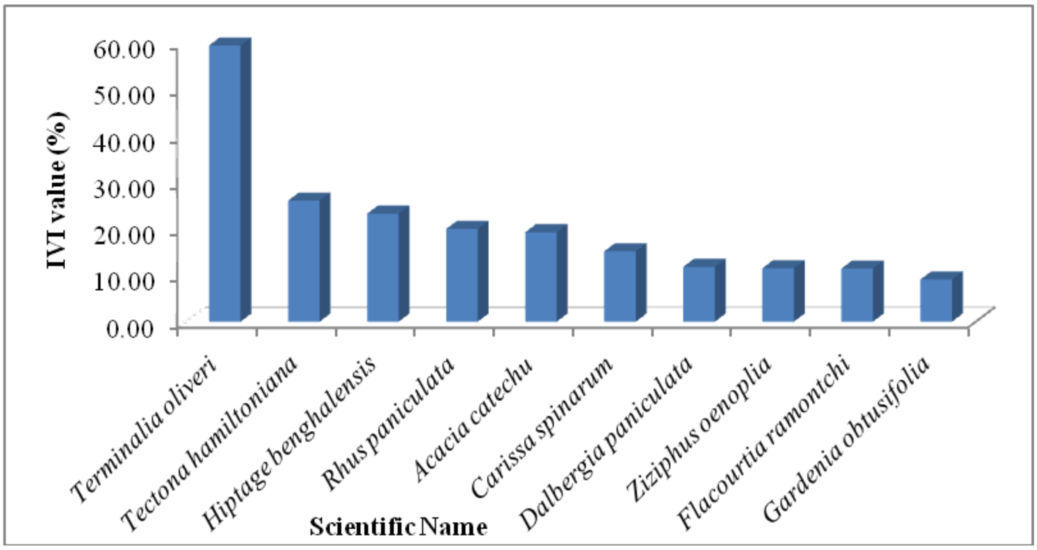

Figure 3. Importance value index of top ten species in central area

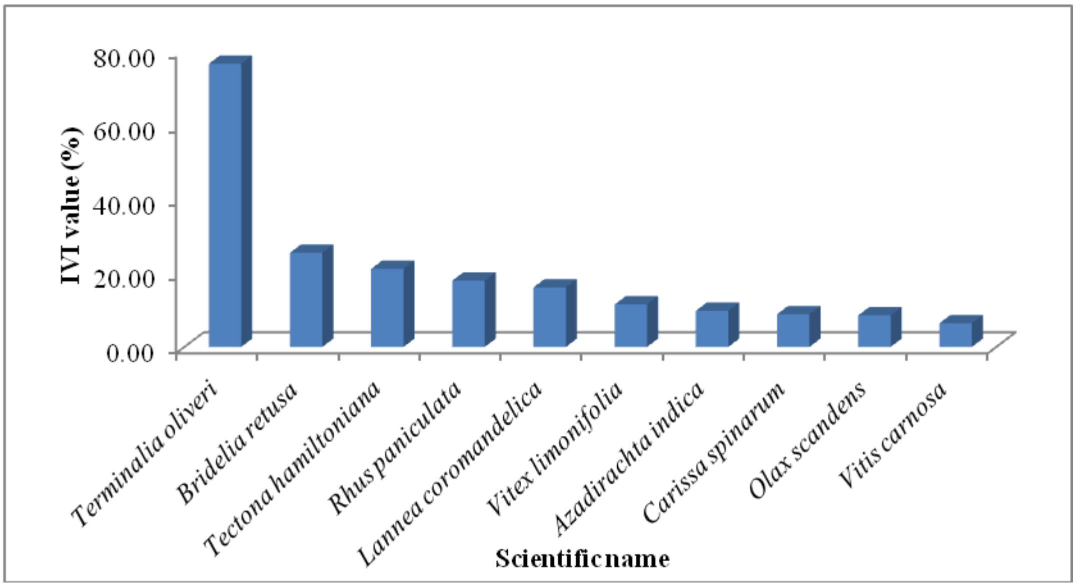

Figure 4. Importance value index of top ten species in southern area

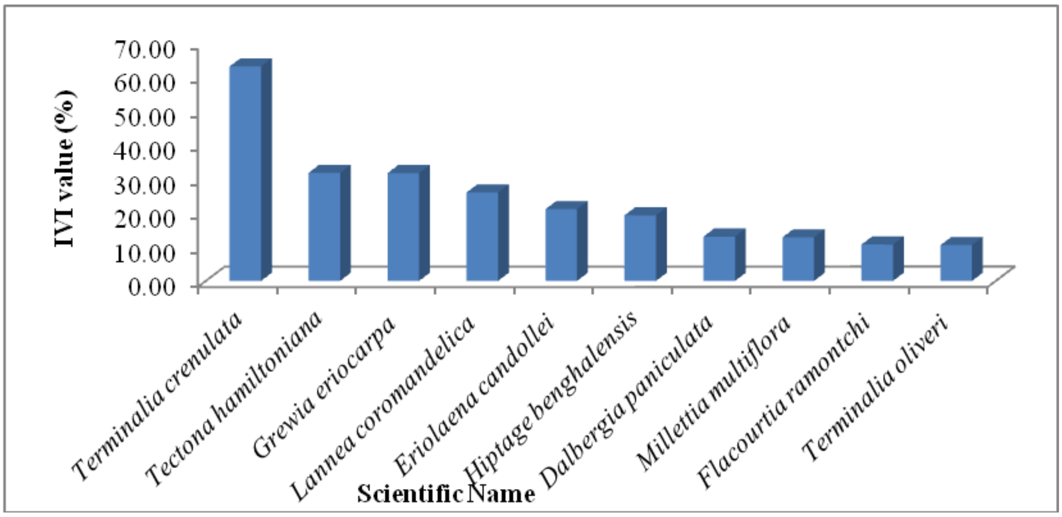

Figure 5. Importance value index of top ten species in northern area

Above and below ground biomass

In central area, the highest total biomass of *Terminalia oliveri* stand was estimated 66.44 ton ha^{-1}, of which the above ground biomass comprised 51.91 ton ha^{-1} and the below ground biomass comprised 14.53 ton ha^{-1} (Table 11). In southern area, the highest total biomass of *Terminalia oliveri* and *Tectona hamiltoniana* stand was estimated 77.37 ton ha^{-1}, of which the above ground biomass comprised 60.45 ton ha^{-1} and the below ground biomass comprised 16.93 ton ha^{-1} (Table 12). In northern area, the highest total biomass of *Tectona hamiltoniana* stand was estimated 49.34 ton ha^{-1}, of which the above ground biomass comprised 38.55 ton ha^{-1} and the below ground biomass comprised 10.79 ton ha^{-1} (Table 13). The mean total biomass of tree in central, southern and northern area was estimated 23.84±8.7 ton ha^{-1}, 58.24±11.75 ton ha^{-1} and 32.76±4.54 ton ha^{-1}. Among the three area, the southern area scored the greatest mean total biomass, however, the total biomass was statistically significant different among the three areas ($p < 0.05$) (Figure 6).

Table 11. Above and below ground biomass (ton ha^{-1}) of central area

Study stands	Central area		
	AG Biomass	BG Biomass	Total Biomass
Terminalia oliveri stand	51.91	14.53	66.44
Atalantia monophylla stand	17.76	4.97	22.73
Dalbergia paniculata stand	13.39	3.75	17.13
Rhus paniculata stand	11.37	3.18	14.55
Acacia catechu stand	9.59	2.68	12.27
Carissa spinarum stand	7.76	2.17	9.93
Total	111.77	31.29	143.06

Table 12. Above and below ground biomass (ton ha^{-1}) of southern area

Study stands	Southern area		
	AG Biomass	BG Biomass	Total Biomass
Terminalia oliveri and *Tectona hamiltoniana* stand	60.45	16.93	77.37
Terminalia oliveri stand	57.05	15.97	73.02
Bridelia retusa and *Atalantia monophylla* stand	53.44	14.96	68.41
Terminalia oliveri and *Bridelia retusa* stand	46.65	13.06	59.72
Rhus paniculata stand	9.91	2.78	12.69
Total	227.51	63.70	291.21

Table 13. Above and below ground biomass (ton ha^{-1}) of northern area

Study stands	Northern area		
	AG Biomass	BG Biomass	Total Biomass
Tectona hamiltoniana stand	38.55	10.79	49.34
Terminalia crenulata and *Lannea coromandelica* stand	27.00	7.56	34.56
Terminalia crenulata stand	23.77	6.66	30.43
Eriolaena candollei and *Terminalia crenulata* stand	20.68	5.79	26.47
Terminalia crenulata and *Grewia eriocarpa* stand	17.96	5.03	22.99
Total	127.96	35.83	163.78

Above and below ground carbon stocks

In central area, the highest total carbon of *Terminalia oliveri* stand was estimated 33.22 ton ha^{-1}, of which the above ground carbon comprised 25.95 ton ha^{-1} and the below ground carbon comprised 7.27 ton ha^{-1} (Table 14). In southern area, the highest total carbon of *Terminalia oliveri* and *Tectona hamiltoniana* stand was estimated 38.69 ton ha^{-1}, of which the above ground carbon comprised 30.22 ton ha^{-1} and the below ground carbon comprised 8.46 ton ha^{-1} (Table 15). In northern area, the highest total carbon of *Tectona hamiltoniana* stand was estimated 24.67 ton ha^{-1}, of which the above ground carbon comprised 19.27 ton ha^{-1} and the below ground carbon comprised 5.40 ton ha^{-1} (Table 16). The mean total carbon stocks of tree in central, southern and northern area were estimated 11.92±4.35 ton ha^{-1}, 29.12±5.8 ton ha^{-1} and 16.38±2.28 ton ha^{-1}. Among the three areas, the southern area scored the greatest mean total carbon stock, however, the total carbon stock was statistically significant different among the three areas ($p < 0.05$) (Figure 6).

Table 14. Above and below ground carbon (ton ha^{-1}) of central area

Study stands	Central area		
	AG Carbon	BG Carbon	Total carbon stock
Terminalia oliveri stand	25.95	7.27	33.22
Atalantia monophylla stand	8.88	2.49	11.37
Dalbergia paniculata stand	6.69	1.87	8.57
Rhus paniculata stand	5.68	1.59	7.28
Acacia catechu stand	4.79	1.34	6.13
Carissa spinarum stand	3.88	1.09	4.97
Total	55.88	15.65	71.53

Table 15. Above and below ground carbon (ton ha^{-1}) of southern area

Study stands	Southern area		
	AG Carbon	BG Carbon	Total carbon stock
Terminalia oliveri and *Tectona hamiltoniana* stand	30.22	8.46	38.69
Terminalia oliveri stand	28.52	7.99	36.51
Bridelia retusa and *Atalantia monophylla* stand	26.72	7.48	34.20
Terminalia oliveri and *Bridelia retusa* stand	23.33	6.53	29.86
Rhus paniculata stand	4.96	1.39	6.35
Total	113.76	31.85	145.61

Table 16. Above and below ground carbon (ton ha^{-1}) of northern area

Study stands	Northern area		
	AG Carbon	BG Carbon	Total carbon stock
Tectona hamiltoniana stand	19.27	5.40	24.67
Terminalia crenulata and *Lannea coromandelica* stand	13.50	3.78	17.28
Terminalia crenulata stand	11.89	3.33	15.21
Eriolaena candollei and *Terminalia crenulata* stand	10.34	2.90	13.24
Terminalia crenulata and *Grewia eriocarpa* stand	8.98	2.51	11.49
Total	63.98	17.91	81.89

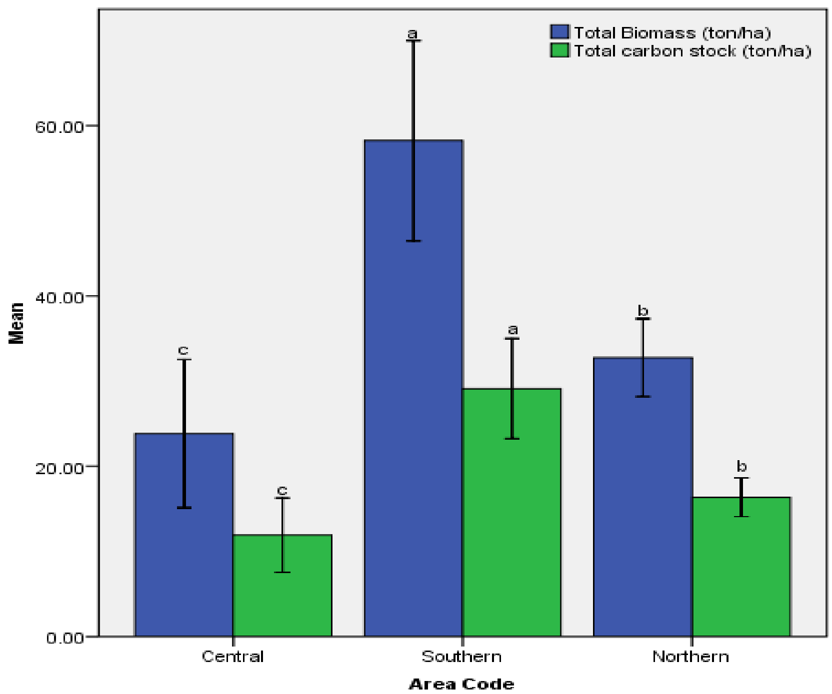

Figure 6. Mean total biomass and carbon stock of central, southern and northern area. The bars represent standard error of mean.

Distribution of above ground biomass and carbon over the gbh classes

Above ground biomass and carbon distribution from each of gbh classes in the central, southern and northern area are shown in Figure 7. The larger gbh class stored a larger stock of above ground biomass whereas small amounts of above ground biomass have been stocked by small gbh class. In central area, the above ground biomass and carbon showed that the highest value (22.52 ton ha^{-1}, 11.26 ton ha^{-1}) was recorded in the gbh range of 55 - 65 cm where small number of tree density representing larger girth (Figure 7). In southern area, the highest above ground biomass and carbon stock (51.46 ton ha^{-1}, 25.73 ton ha^{-1}) was recorded in the largest gbh class (≥ 105 cm) followed by 28.10 ton ha^{-1} and 14.05 ton ha^{-1} in the gbh of 65 - 75 cm (Figure 7). In northern area, the highest above ground biomass and carbon stock (33.89 ton ha^{-1}, 16.94 ton ha^{-1}) was recorded in the largest gbh class (≥ 105 cm) followed by 15.03 ton ha^{-1} and 7.52 ton ha^{-1} in the gbh of 25 - 35 cm (Figure 7).

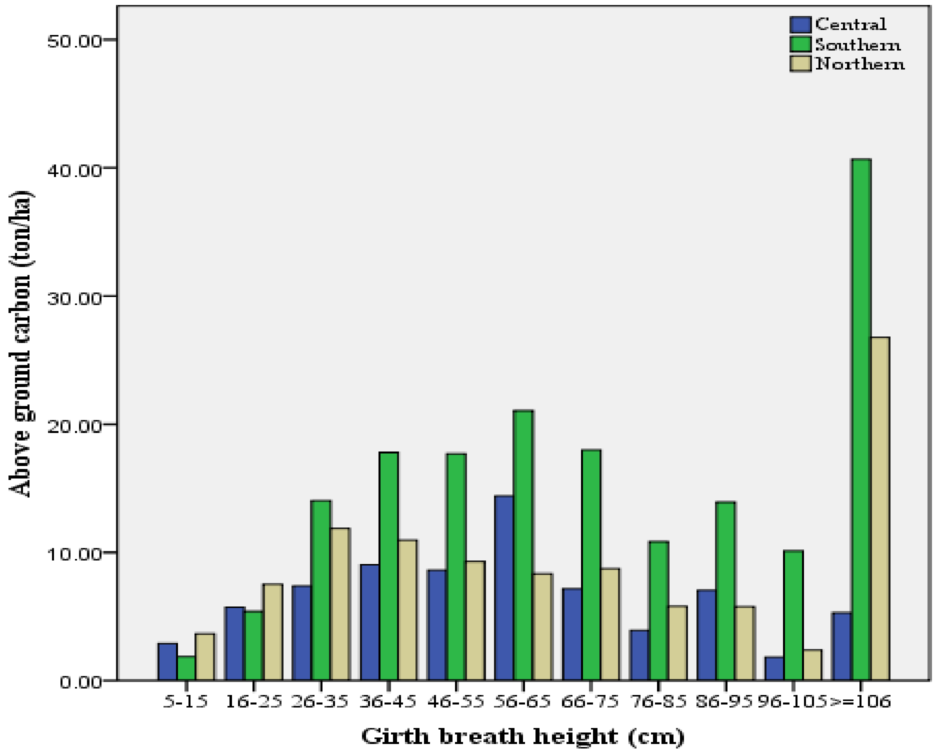

Figure 7. Above ground carbon stock over the gbh classes of central, southern and northern area

Soil bulk density

The soil bulk density for each of stand at a depth of 0 - 15 cm and 15 - 30 cm are given in Table 23. Soil bulk density under *Atalantia monophylla* stand (1.09, 1.43

g cm^{-3}), *Dalbergia paniculata* stand (1.27, 1.41 g cm^{-3}) and *Tectona hamiltoniana* stand (1.29, 1.38 g cm^{-3}) were greater compact soil than other stands. The average soil bulk density scored from 1.21, 1.24 and 1.13 g cm^{-3} in central, southern and northern area respectively. ANOVA showed that soil bulk density was not significantly different among the three areas (F = 0.995, p = 0.396). Soil organic carbon decreased with increasing soil depth; conversely, bulk density increased with depth in all study area.

Table 23. Soil bulk density of study stands

Study stands/ soil depth	Soil bulk density (g cm^{-3})	
	0-15 cm	15-30 cm
Acacia catechu stand	1.08	1.19
Atalantia monophylla stand	1.09	1.43
Bridelia retusa and *Atalantia monophylla* stand	1.12	1.15
Carissa spinarum stand	1.09	1.31
Dalbergia paniculata stand	1.27	1.41
Eriolaena candollei and *Terminalia crenulata* stand	0.93	1.19
Rhus paniculata stand	1.42	1.29
Tectona hamiltoniana stand	1.29	1.38
Terminalia crenulata stand	1.1	1.1
Terminalia crenulata and *Lannea coromandelica* stand	1.1	1.1
Terminalia oliveri stand	1.05	0.96
Terminalia oliveri and *Bridelia retusa* stand	1.05	0.96
Terminalia crenulata and *Grewia eriocarpa* stand	0.91	1.12

Soil organic carbon storage of the study area

In central area, the highest total soil organic carbon (top 0 - 15 and 15 - 30 cm) storage of the *Rhus paniculata* stand was 50.65 and 39.28 ton ha^{-1} followed by *Acacia catechu* stand was 37.58 and 32.09 ton ha^{-1} and *Atalantia monophylla* stand was 30.35 and 26.13 ton ha^{-1} (Table 20). In southern area, the highest total soil organic carbon (top 0 - 15 and 15 - 30 cm) storage of the *Rhus paniculata* stand was 50.65 and 39.28 ton ha^{-1} followed by the *Terminalia oliveri* and *Tectona hamiltoniana* stand was 32.55 and 30.02 ton ha^{-1} and *Terminalia oliveri* stand was 36.54 and 19.21 ton ha^{-1} (Table 21). In northern area, the highest total soil organic carbon (top 0 - 15 and 15 - 30 cm) storage of *Terminalia crenulata* stand and *Terminalia crenulata* and *Lannea coromandelica* stand were 43.07 and 39.24 ton ha^{-1} followed by *Eriolaena candollei* and *Terminalia crenulata* stand was 36.41 and 36.24 ton ha^{-1} and *Terminalia crenulata* and *Grewia eriocarpa* stand was 34.04 and 31.18 ton ha^{-1} (Table 22).

The mean total soil organic carbon (up to 30 cm) storage in central area (30.63±3.3 ton ha^{-1}) scored the lowest value than southern area (31.62±3.4 ton ha^{-1}) and northern area (37.18±1.8 ton ha^{-1}). ANOVA showed that the mean soil organic carbon was not significantly different among the three study area ($F = 1.346$, $p = 0.294$) (Figure 8).

Table 20. Soil organic carbon (ton ha^{-1}) storage of central area

Study stand	Soil carbon		Total soil carbon
	0-15 cm	15-30 cm	
Rhus paniculata stand	50.65	39.28	89.93
Acacia catechu stand	37.58	32.09	69.68
Atalantia monophylla stand	30.35	26.13	56.47
Terminalia oliveri stand	36.54	19.21	55.75
Dalbergia paniculata stand	29.83	18.40	48.23
Carissa spinarum stand	30.35	17.10	47.44

Table 21. Soil organic carbon (ton ha^{-1}) storage of southern area

Study stand	Soil carbon		Total soil carbon
	0-15 cm	15-30 cm	
Rhus paniculata stand	50.65	39.28	89.93
Terminalia oliveri and *Tectona hamiltoniana* stand	32.55	30.02	62.56
Terminalia oliveri stand	36.54	19.21	55.75
Terminalia oliveri and *Bridelia retusa* stand	36.54	19.21	55.75
Bridelia retusa and *Atalantia monophylla* stand	31.18	21.01	52.19

Table 22. Soil organic carbon (ton ha^{-1}) storage of northern area

Study stand	Soil carbon		Total soil carbon
	0-15 cm	15-30 cm	
Terminalia crenulata and *Lannea coromandelica* stand	43.07	39.24	82.30
Terminalia crenulata stand	43.07	39.24	82.30
Eriolaena candollei and *Terminalia crenulata* stand	36.41	36.24	72.65
Terminalia crenulata and *Grewia eriocarpa* stand	34.04	31.18	65.22
Tectona hamiltoniana stand	32.55	30.02	62.56

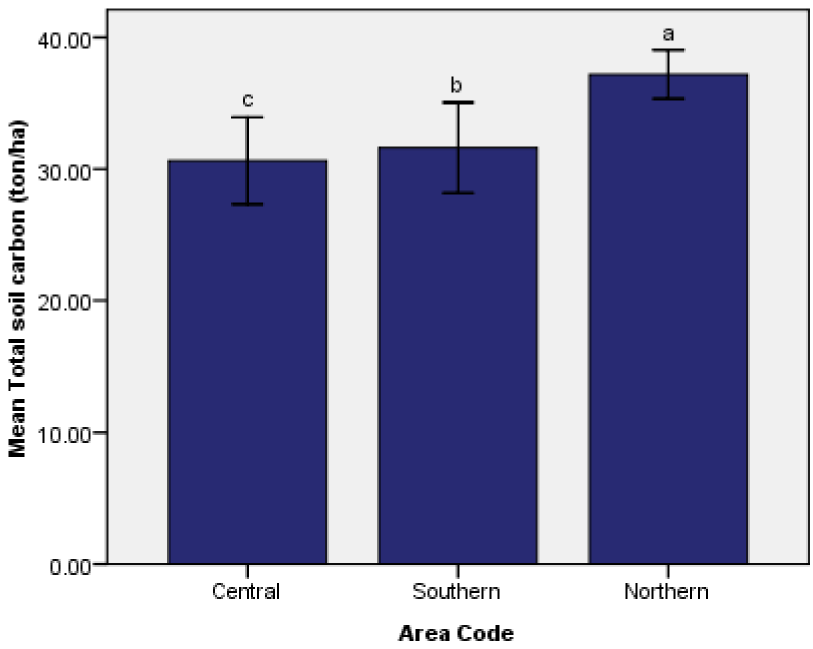

Figure 8. Mean total soil organic carbon of central, southern and northern area. The bars represent standard error of mean.

Discussion and Conclusion

In this part of study, species composition and stand structure of Minwuntaung Wildlife Sanctuary were investigated. Three areas were chosen with six sample plots in central area and five sample plots in each of southern and northern area to cover the whole area. In central area, 24 families comprising 58 genera, 68 species and 2170 individuals were recorded; 23 families contributing 46 genera, 53 species and 1357 individuals were represented in southern area, whereas 19 families represented by 39 genera, 44 species with 2608 individuals were found in northern area. The most abundant families in the study area are Fabaceae, Rubiaceae, Verbenaceae, Euphobiaceae, Anarcardiaceae, Malvaceae and Combretaceae. These study area are compared with that other dry zone forest of Sagaing Region, which represents 17 - 50 tree species in Powin Taung Reserved Forest (Thiri Nyo, 2011). Myat Su Hlaing (2011) reported a range of 42 - 54 tree species in Shinmataung Reserved Forest of Magway Region. In the central dry zone, the highest species richness was 70 - 90 tree species in Shwesettaw Wildlife Sanctuary (Khin Maung Htay, 2014). However, the tropical dry forest of Santa Rosa National Park of Central America had species richness of as low as 25 - 65 species (Sorensen, 1998).

The species diversity (Shannon-Wiener index (H'), Simpsons index (D)) of central area (4.50, 0.93), southern area (4.21, 0.90) and northern area (3.66, 0.88) was higher than Shinmataung Reserved Forest in Magway Region where the diversity value was 3.98, 0.89 in main hill and 3.83, 0.87 in surrounding area (Myat Su Hlaing, 2011), but very similar with species diversity of Powin Taung Reserved Forest, Sagaing Region where the diversity value was 4.41, 0.92 (Thiri Nyo, 2011) but less than 4.93, 0.94 diversity value of Shwesettaw Wildlife Sanctuary (Khin Maung Htay, 2014). When compared to other dry forest of India, the result of the present study area higher than Shannon-Wiener index ranged from 1.6 - 2.2 value of Sivagangai district of Tamil Nadu (Sundaranpandian *et al.*, 2013) and 0 - 1.28 value of West Bengal (Joshi, 2012) due to altitude, climatic condition and anthropogenic pressure. The altitude of the study area is 408 m, Powintaung Reserved Forest is about 351 m, Shinmataung Reserved Forest is about 525 m and Shwesettaw Wildlife Sanctuary is about 600 m. The study area received mean annual rainfall of 910 mm, Powintaung Reserved Forest of 735mm, Shinmataung Reserved Forest of 548 mm and Shwesettaw Wildlife Sanctuary of 790 mm. These results agreed with Tsiourlis *et al*., 2009; they reported that altitude, climate and the anthropogenic pressure have been identified as the most important factors determining the structure and the floristic composition of the vegetation. According to Pearson's correlation, elevation and soil nutrients appear to be the most important factors, which strongly correlated on species diversity, species richness and stem density of the study area.

The important value index indicates the extent of dominance of a species in the structure of a forest stand (Curtis and McIntosh, 1951). It is stated that species with the greatest important value are the leading dominants of the forest. The highest IVI and the most dominant species show *Terminalia oliveri* (59.49 %), *Tectona hamiltoniana* (26.37 %) and *Hiptage benghalensis* (23.36 %) in central area, *Terminalia oliveri* (76.60 %), *Bridelia retusa* (25.47 %) and *Tectona hamiltoniana* (21.12 %) in southern area and *Terminalia crenulata* (63.10 %), *Grewia eriocarpa* (31.79 %) and *Eriolaena candollei* (31.70 %) in northern area are ecologically important species. *Terminalia oliveri*, *Tectona hamiltoniana* and *Terminalia crenulata* possessed the highest relative density and relative dominance in the study area. Therefore these species may be regarded as the representative and ecologically successful species in the study area. In other dry zone forests, eight species of the highest IVI values were similar to the species of ecologically significant top ten IVI from Powin Taung Reserved Forest (Thiri Nyo, 2011) and Shinmataung Reserved Forest (Myat Su Hlaing, 2011). These species are *Terminalia oliveri*, *Tectona hamiltoniana*, *Terminalia crenulata, Acacia catechu, Atalantia monophylla*, *Lannea coromandelica*, *Bridelia retusa*, *Hiptage benghalensis*. The coefficient of similarity between these two forests was 67 %. Moreover *Terminalia oliveri*, *Tectona hamiltonian, Terminalia crenulata* and *Acacia catechu*, *Lannea coromandelica, Bridelia retusa*, *Hiptage benghalensis* and *Dalbergia paniculata* were also similar to ecologically significant species of Shwesettaw Wildlife Sanctuary, Magway Region by (Khin Maung Htay, 2014). The coefficient of similarity between these two forests was 60 %.

The forest structure is evident from the structural variables (mean gbh, canopy height and density) that the age of older forest cannot be predicted from their structure due to the leveling off of many variables (Sorensen, 1998). Tree distribution by height class intervals shows that total number of individuals in the class of > 3m was more species than the other classes. In the study area, the presence of high species composition was found in smaller classes. In horizontal structure, tree density and basal area of gbh (5 - 15 cm) occurs 1132 n ha^{-1}, 1.29 m^2 ha^{-1} in central area, 1058 n ha^{-1}, 0.97 m^2 ha^{-1} in southern area and 1568 n ha^{-1}, 1.31 m^2 ha^{-1}in northern area. The basal area obtained in the present area ranges between 5.43 - 11.86 m^2 ha^{-1}; with this value, is greater than dry zone of Shinmataung Reserved Forest (3.56 - 6.68 m^2 ha^{-1}), but lower than that of 21.61 - 24.57 m^2 ha^{-1} and girth class ranges 30 - 211cm for Shwesettaw Wildlife Sanctuary. Mani and Parthasarathy (2006) stated that the basal area is used as one of the important aspect for studying the forest vegetation structure. This is consistent of many of other dry forests, which is characterized by the presence of large number of lower girth class individuals. This observation is evident from the girth class distribution in the area that exhibited a typical reverse ‘J’ trend with maximum individuals occupying lower girth classes, indicating a good generation status of the forest (Table 9). Manokaran and Lafrankie (1990) stated that a higher density of small size individuals can be attributed to the open canopy and lower density of the larger size individuals.

The results from this study showed the range of total biomass in southern, northern and central area as 291.21, 163.78 and 143.06 ton ha^{-1}, with carbon sequestration as 145.61, 81.89 and 71.53 ton ha^{-1} respectively. The comparison of total biomass accumulation and carbon sequestration in the three areas showed the largest biomass in southern area and the lowest biomass in central area because southern area was old forest and the illegal logging have been strictly controlled by monk. Among these stands, *Terminalia oliveri* and *Tectona hamiltoniana* stand have contributed for the greatest total carbon stock (24.67 - 38.69 ton ha^{-1}) in the study area. These results are agreed with Chaturvedi *et al*., (2011) stated that *Terminalia* species stated more than 10 ton ha^{-1} carbon density in tropical dry forest in India due to larger basal area and stem density. Terakunpisut *et al*., (2007) reported above ground biomass data of tropical rain forest at Ton Mai Yak station, dry evergreen forest at KP 27 station and mixed deciduous forest at Pong Phu Ron station of Thailand as 275.46, 140.58 and 96.28 ton ha^{-1}, with calculated carbon sequestration as 137.73 ton ha^{-1}, 70.29 and 48.14 ton ha^{-1}. Sundarapandian *et al*., (2013) summarized the total biomass estimates of tropical dry forest in Tamil Nadu of India ranged from 67.85 ton ha^{-1} to 117.98 ton $ha^{-1}$and tropical deciduous forest in Ratchaburi Province, Thailand ranged from 30.95 ton $ha^{-1}$to 91.96 ton ha^{-1} (Chaiyo *et al*., 2011) and mixed deciduous forest in Western Region, Thailand estimated 77.54 ton ha^{-1} (Chaiyo *et al*., 2012) are lower than the present study area. According to Murphy and Lugo (1986), the global range of aboveground carbon density for tropical dry forest is 14 to 123 ton ha^{-1}. The aboveground carbon stock of the present study area (55.88 - 113.76 ton ha^{-1}) are well within the limits of other tropical dry forests in India and elsewhere (Chaturvedi *et al*., 2011; Chen *et al*., 2003; Hughes *et al*., 2000; Návar, 2009; Ogawa *et al*., 1965; Singh and Singh, 1991).

Overall, the study area had estimated the range of total carbon stock 71.53 - 145.61ton ha^{-1} within 44 years. Carbon sequestration varies among forest types and ages of forest and carbon sequestration potential relies on tree size class. In the study area, the dominant size class at 5 - 15 cm was accounted for 1135, 1058 and 1568 n ha^{-1} at central, southern and northern area respectively. On the other hand, this size class of all area had the lowest carbon accumulation that comprised 2.28, 1.19 and 2.32 ton ha^{-1} due to low basal area. Kumar (2011) made an attempt to compute the above ground carbon stocks of homegarden trees (> 20 cm gbh) in central Kerela, India and average above ground standing stocks of carbon ranged from 16 to 36 ton ha^{-1} whereby the standing carbon stock of the present study is greater than this value. The most above ground biomass accumulation was found in big trees of size class at ≥ 115 cm. Because these trees had the highest stem volume and large diameter, they also had the lowest number of tree densities. These results agreed with Seta and

Demissew (2014); they stated that the canopy tree with wider diameter classes have a higher above ground biomass as compared to the smaller diameter class.

The soil organic carbon storage of *Rhus paniculata* stand scored the highest value among these stands. Soil organic carbon is concentrated in the upper 30 cm of the soil (Batjes, 1996; Tian *et al*., 2002). The mean soil organic carbon (up to 30 cm) storage in central area 30.63 ton ha^{-1}, southern area 31.62 ton ha^{-1} scored the lowest value than northern area 37.18 ton ha^{-1} due to soil texture, soil type and forest type. The mean soil organic carbon stock of the study area ranges 30.63 - 37.18 ton ha^{-1} up to 30 cm soil depth. Compared with tropical dry forest in Tamil Nadu of India (33.36 ton ha^{-1}) (Sundarapandian, 2013) are lower than the present area and tropical dry forest of Madhyab Pradesh of India (63.4 - 68.8 ton ha^{-1}) (Tamgadge *et al*., 2000) was greater than the present area due to soil texture, elevation and forest density. In the study area, soils organic carbon stored two times more than carbon in plant. Ravindranath *et al*., (1997) reported that the ratio of soil organic carbon and biomass carbon was in the range of 0.7 to 2. Kaul (2010) indicated that in the plantations, the carbon content in the soil was almost double the biomass carbon. This result agreed with Post *et al*., (1990) and Davidson *et al*., (2000); they reported that the ratio between soil organic carbon and biomass carbon is 2.4 to 3 times in the terrestrial ecosystem. However, in the tropical forest, the carbon in the soil is roughly equivalent to or less than the above ground biomass due to degradation (Ramanchandran *et al*., 2007). The fact that the soil organic carbon content was higher than the above ground biomass carbon indicates that the sequestered soil organic carbon came from the original vegetation in the past before exploitation due to litter production and harvest residues, the carbon stock in soil also increased, thereby substantially enhancing the carbon sink function of forests.

RECOMMENDATION

The phytosociological survey should be carried out in all forests, to understand the actual vegetation and simulate potential natural vegetation. It will be valuable for the restoration, conservation and management of natural vegetation resources. Clear felling, burning and transformation into other land use pattern affect not only on forest but also on the whole ecosystem that is why such kind of activities should be avoided. The restoration of natural forest is beneficial for balance of natural environment and for local peoples' requirement. Experimental restoration efforts should be promoted to identify the suitable technique and site for individual species. Not only monoculture but also poly-culture based on phytosociological results should be practiced to create a natural vegetation environment. The systematic land use system should be implemented by creating a buffer forest in terms of effective protection, restoration and sustainable utilization of forest resources. The restoration for natural forest is important for an ecosystem management, but on the other hand buffer forest is better for local peoples' requirement. International collaboration and cooperation of forest conservation and restoration should be enhanced in term of technical and financial supports.

The result of the study indicated that the dry zone vegetation of Minwuntaung Wildlife Sanctuary had moderately tree species diversity, composition and dominated by small size class at 5 - 15 cm gbh in secondary stage of development, indicating that the forest was heavily exploited and affected in the previous period, but good regeneration is in process at the present time. In dry zone area, the patterns of rural livelihoods depend in a range of ways on forests. The major causes of deforestation was particularly fuel wood, pastures and tree fodder, posts and poles for construction and sale, a wide range of non-timber forest products (including wild foods and medicines) which can provide both seasonal incomes and a safety net function. Forests also provide local people with a range of ecosystem services, particularly water supply for domestic use and agriculture, soil nutrient cycling and storm protection. Forest carbon emissions and sequestration are also relevant in establishment and management of forest plantations, logging, forest management, deforestation, forest degradation, and desertification. Biomass measurements are destined to increase in coming years to meet the needs of carbon stock estimations and understand the contribution made by terrestrial ecosystems to the carbon cycle. Thus, if carbon sequestration is considered as a priority, establishment of forest plantations in the degraded forests could be more effective in sequestering carbon within a short period of time. Therefore, to improve the natural diversity and structure of the forest, to minimize the influence of the surrounding communities and utilize the forest resources sustainably for present and future generation, the following points are made as recommendation:

1. The community forestry program should be implemented by collaboration with local Forest Department. This program can reduce deforestation and help local people's livelihoods.

2. Initiate enrichment plantation program of those most leading dominant and ecologically significant species because of the adaptation of environmental conditions and the use of selective cutting by local peoples (e.g. *Terminalia oliveri*, *Tectona hamiltoniana*, *Terminalia crenulata*).

3. Knowledge of the structure, function and important of forest ecosystems should be communicated by all possible ways at local, national and international levels.

4. Educational programmes should be provided to train scientists, planners, managers and the general public and to encourage an awareness of the importance of forest ecosystems.

5. Raising environmental awareness of the local people on the values of forest resources and ecological consequences of deforestation, making resource extraction and utilization at a minimal level, would serve as long-term conservation measures to sustain the sites and their resources.

6. Research should be conducted to collect data on the quantity, distribution and partitioning of carbon of different forest types in the different ecological regions, and assessment and monitoring of any changes taking place over time should also be carried out regularly.

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