Floristic diversity, regeneration status and vegetation structure of the woodland vegetation in Metema area, Amhara National Regional State, Northwestern Ethiopia

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Abstract
The study was conducted in 2008 in the broad-leaved deciduous woodland of Metema in the northwestern Amhara regional state, Ethiopia to determine plant species composition, diversity, regeneration status and population structure. A selective approach with a systematic sampling design was used. A total of 74 quadrats, each with the size of 25 m x 25 m at an interval of 150 m to 200 m were laid along the established transect lines, following the homogeneity of the vegetation. For the assessment of seedling and sapling, two subquadrats each with the size of 2 m x 5 m were established at opposite sides of every baseline. For herbaceous, five subquadrats each with the size of 1 m x 1 m were established at four corners and center of every quadrant. Results indicated that 87 vascular species belonging to 74 genera and 36 families were identified. Fabaceae was the dominant family with 16 (18.39%) species in 13 genera. The Shannon Weiner diversity index and evenness were 3.67 and 0.82, respectively, which implied that the area was endowed with rich floral diversity with good distribution pattern. The population structure in cumulative diameter class frequency distribution revealed inverted-J-shape with very high decrease in diameter class two, which is an indication of poor population status. The analysis of selected species also resulted in four general patterns i.e., interrupted Inverted-J-shape, J-shape, Bell-shape and Irregular-shape. Although the area showed good floral diversity and evenness, woody species including *Sterculea setigera*, *Boswellia papyrifera* and *Pterocarpus lucens* were the most critically hampered ones in their population status and hence research and/or development interventions have to be done to mitigate the problem the sooner possible.

Key words: Equitability, diversity, dryland, Metema woodland, population structure, regeneration.

Introduction

The available information on the forest resources of Ethiopia is very limited on location, extent and volume of the standing growing stock, annual growth rates and the depletion rate of the resources. The forests and woodlands have, however, been declining both in size (deforestation) and quality (degradation) (EFAP, 1994). It is a common scenery that Ethiopia's indigenous forest trees and shrubs are dwindling at escalating rate as a result of high population pressure and its related consequences like the need for agricultural land, settlement, fuel wood, house construction, income generation, and for other so many needs and wants. Besides, absence of strong forest policy adding with the change in the climatic condition of the country made the problem worse, especially in the arid and semiarid regions of Ethiopia.

Four broad vegetation types can be distinguished for the arid and semiarid regions of Ethiopia (Friis, 1992). These are broad-leaved deciduous woodland, small-leaved deciduous woodland, lowland dry forest, and lowland semi-desert and desert vegetation. Increasing human pressure in recent years in the drylands is initiating the rapid advance of desertification. Furthermore, the effects of global climate change, which prevails in the dryland regions, are further intensifying problems in dry regions making them more arid, vulnerable and difficult for habitation (Akimaliev, 2005).

Metema area is one of such dryland areas of Ethiopia located in the Northwestern part of Amhara Regional State of the country. Like other dryland areas of the country, land degradation is rife in Metema area because of over exploitation of the woodlands and farming the fragile lands. Transgression of agriculture towards the natural woodland, burning and overgrazing resulted in the clearing of woodlands. This in turn accelerated soil erosion and destroyed the soil and floristic diversity of the area (Sisay Asfaw, 2006).

Several researches have been undertaken by several researchers (Sisay Asfaw, 2006) to address these problems of the area. However, most of these studies were focused on only woody species with a special emphasis on the production, population structure and soil seed bank and alternative land use options for frankincense producing species. Baseline information is lacking on the general plant diversity, composition, population structures and other ecological perspectives which profoundly could contribute to the formulation of development and management plan for plant species growing in the area. Therefore, this research activity was intended to address this research gap. The objective of the study was, therefore, to study the plant species diversity, regeneration status and vegetation structure of the woodland vegetation of Metema area.

Materials and methods

The study area

The study was conducted in 2008 in the Metema district in North Gondar Zone of the Amhara National Regional State of Ethiopia. It is located at 36°17' E and 12° 39' N with an altitudinal range of 550 to 1608 meter above sea level (m a.s.l). According to the National Meteorological Agency of Ethiopia (2009), the annual rainfall of Metema ranges from 514.4 to 1128 mm with a mean annual rainfall of 924.2 mm. The mean monthly minimum and maximum temperature of Metema district are 19.31^{O}C and 35.65 ^{O}C, respectively. The mean annual temperature is 32.98 ^{O}C.

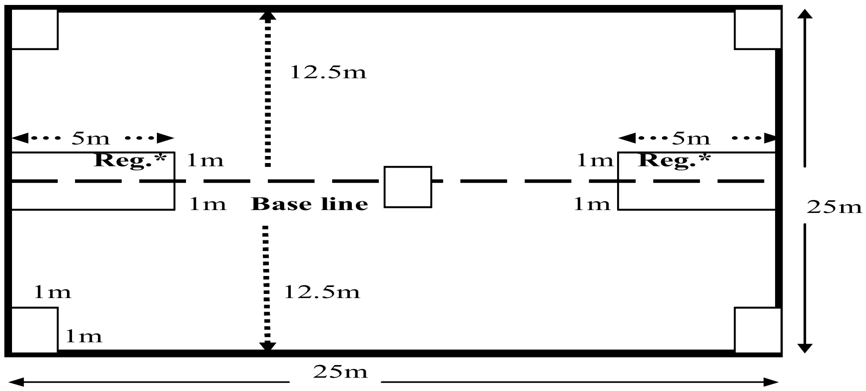
Data collection

Sampling design

A systematic sampling method was employed for the study. Quadrats of 25 m x 25 m (625 m^2) were placed next to each other at the interval of 150 m to 200 m, following the homogeneity of the vegetation. Trees and shrubs were assessed in the main quadrat while seedling and sapling in two subquadrats of 2 m x 5 m laid at the beginning and the end of the baseline on opposite sides of the main quadrat. For the herbaceous species and soil sampling, a total of five subquadrats with the area of 1 m X 1 m were laid within each main quadrat in a way that four subquadrats at the corner and one at the center (Figure 1).

Vegetation data collection

All the plant species in all quadrats were recorded but the cover abundance of all the vascular plants in each quadrat were estimated using the visual judgment. Trees and shrubs, taller than 2 m and more than 2 cm in diameter were measured for height and diameter at breast height (DBH). Regeneration assessment was made through counting of each species in the two subquadrats of 2 m x 5 m. In all quadrats, additional trees and shrubs outside the quadrat boundaries within 10-15 m and field layer species were collected and noted as present. The collected plant specimens with their vernacular names were taken to the National Herbarium of Addis Ababa University for identification. Then, specimens were dried and identified using authenticated specimens and referring to the published volumes of Flora of Ethiopia and Eritrea.



Note: Reg.=regeneration assessment*

Figure 2. Sampling design for the plant diversity, regeneration status and vegetation structure of the Woodland Vegetation.

Vegetation data analysis

Floristic composition

Species composition: Species richness is a biologically appropriate measure of alpha diversity and is usually expressed as number of species per sample unit (Whittaker, 1972). The number of species (species richness) was determined by summing up the number of species identified directly in the field and in the National Herbarium.

Plant diversity and equitability analysis

Shannon-Weiner diversity index was used to infer about the total Metema floristic diversity and evenness. For analysis, the cover-abundance value of each encountered species was used.

Structural data analysis

Importance Value Index (IVI) is an index computed from relative density, relative dominance and relative frequency, which describes the structural role of a species in a stand. It is useful for making comparisons among stands in reference to species composition and stand structure (Pichette and Gillespie, 1999). IVI permits a comparison of the ecological significance of species in a given forest type. IVI was calculated following Pichette and Gillespie (1999) formula.

Population Structure: Population structure of tree stem diameter distribution has been used to infer past disturbances, regeneration patterns and successional trends in tree populations (Demel Teketay, 1997; Tamrat Bekele, 1994). Height and diameter frequency distribution of all tree and shrub species were employed to determine population structure of the vegetation. Each species encountered in a quadrat were grouped into a diameter class of 4 cm and height of 2 m and structure of the species were depicted using frequency histogram of both diameter and height class distributions following Peters (1996).

Regeneration Status: The regeneration status of woody species was summarized based on the total count of seedling and sapling of each species across all quadrats and presented in tables and frequency histograms.

Results

Floristic Composition

A total of 87 vascular plant species were identified from 74 quadrates in the Metema woodland vegetation between the altitudinal ranges of 728 m and 932 m a.s.l. These species belonged to 36 families and 74 genera. The five dominant families occurring in the area were 16 (18.39%) species of Fabaceae in 13 genera, 9 (10.34%) species of Poaceae in 8 genera, 7 (8.05%) species of Combretaceae in 3 genera, 5 (5.75%) species of Acanthaceae in 5 genera and 5 (5.75%) species of Asteraceae in 5 genera.

With regard to the growth habits of the identified species, 42 (48.28%) species were herbs, 3 (3.45%) species were climbers, 3 (3.45%) species were shrubs, 13 (14.94%) species were shrub or trees and 26 (29.89%) species were trees.

Species diversity, richness and equitability

The Shannon diversity of the Metema vegetation was found to be 3.67 reflecting good diversity. The 87 species encountered in the area were distributed evenly with the Shannon evenness value of 0.82 and small dominancy (0.04).

Vegetation Structure

Density, diameter and height of woody species

A total of 1743 individuals of woody plants (376.86 individuals per ha) were encountered from 74 studied quadrates (Table 1). The first six woody species with the highest density were *Sterculea setigera, Boswellia papyrifera, Anogeissus leiocarrpa, Lannea fruticosa, Dichrostachys cinerea, and Pterocarpus lucens*. The cumulative diameter class distribution pattern was broken reverse J-shape, which revealed that there was a very high decrease in density of the second diameter class. Generally, the density of woody individuals decreased with increasing diameter classes. However, 56% of the total individuals were restricted between the first and fourth classes of diameter whereas, about 30% and 14% of the density were found to be in the middle diameter classes (between fifth and eigth) and in the higher diameter classes (between ninth and twelfth), respectively (Figure 2). Similarly, the density distribution of woody individuals in different height classes showed decrease in density with increasing height classes (Figure 3) and yet there was a very high decrease in density of class two, three, four and five diameter classes.

Table 8. Importance value indices for woody species.

Species	Density(No. individuals/ha)	Relative Density (%)	Relative Frequency (%)	Relative Basal Area (%)	IVI (%)	IVI Rank
Acacia polyacantha	8.22	2.18	2.41	0.15	4.74	19
Acacia seyal	6.05	1.61	1.77	0.60	2.53	24
Acacia sieberiana	3.68	0.98	1.27	0.49	2.73	23
Albizia lophantha	4.76	1.26	1.77	1.60	4.63	20
Albizia melanoxylon	0.43	0.11	0.25	0.33	0.69	33
Anogeissus leiocarrpa	38.49	10.21	6.71	16.13	23.86	3
Balanites aegyptiaca	2.16	0.57	1.14	0.16	1.87	28
Boscia mossambicensis	0.43	0.11	0.25	0.00	0.36	37
Boswellia papyrifera	52.76	14	7.22	19.08	40.28	2
Boswellia pirottae	2.16	0.57	0.76	1.07	2.40	25
Bridelia micrantha	0.86	0.23	0.51	0.00	0.74	32
Calotropis procera	0.65	0.17	0.25	0.00	0.42	36
Combretum adenogonium	9.51	2.52	4.81	1.31	8.64	9
Combretum collinum	13.41	3.56	4.43	2.60	10.58	6
Combretum hartmannianum	0.43	0.11	0.25	0.07	0.43	35
Combretum molle	9.30	2.47	2.53	0.60	5.59	17
Combretum sp.	8.43	2.24	3.92	1.45	7.60	10
Dalbergia melanoxylon	12.76	3.38	3.67	0.39	7.44	11
Dichrostachys cinerea	22.27	5.91	4.3	0.19	10.39	7
Diospyros abyssinica	1.08	0.29	0.38	1.64	2.31	26
Ficus sycomorus	1.30	0.34	0.76	0.00	1.10	31
Ficus thonningii	1.08	0.29	0.63	0.66	1.58	29
Flueggea virosa	14.27	3.79	2.41	0.00	6.19	16
Gardenia ternifolia	6.49	1.72	1.9	0.00	3.62	22
Grewia bicolor	1.30	0.34	0.76	0.16	1.26	30
Lannea fruticosa	29.84	7.92	8.23	7.03	23.17	4
Lonchocarpus laxiflorus	0.65	0.17	0.25	0.06	0.48	34
Maytenus senegalensis	0.22	0.06	0.13	0.00	0.19	39
Maytenus undata	12.97	3.44	3.29	0.54	7.27	12
Ochna leucophloeos	12.11	3.21	3.04	0.07	6.32	15
Piliostigma thonningii	0.22	0.06	0.13	0.10	0.29	38
Pterocarpus lucens	17.73	4.7	5.95	8.90	19.55	5
Sterculea setigera	27.24	7.23	6.71	30.53	44.46	1
Stereospermum kunthianum	15.78	4.19	4.68	0.27	9.13	8
Strychnos innocua	13.19	3.5	2	0.92	6.42	14
Tamarindus indica	0.22	0.06	0.13	0.00	0.19	39
Terminalia laxiflora	6.27	1.66	3.04	2.48	7.18	13
Ximenia americana	6.27	1.66	2.66	0.18	4.50	21
Ziziphus abyssinica	8.65	2.29	2.91	0.16	5.36	18
Ziziphus spina-christi	3.24	0.86	1.14	0.06	2.06	27
Total	376.86	100	100	100.00	300.00	

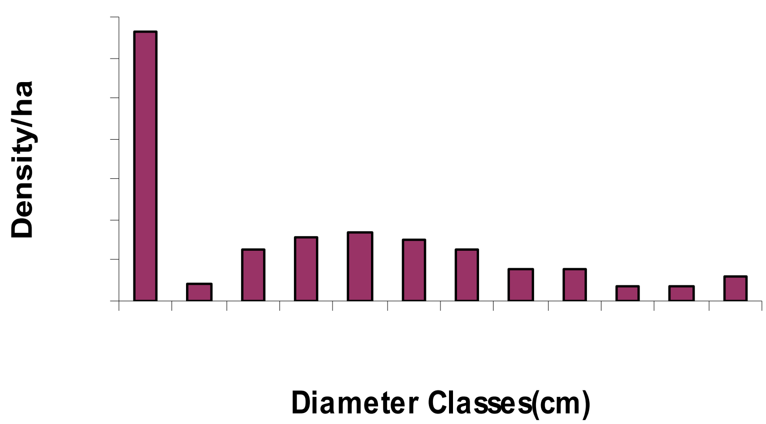


Figure 3. Cumulative diameter class frequency distribution of woody species.

Diameter class: 1= 0-4cm, 2 = 4-8cm, 3 = 8-12 cm, 4 = 12-16 cm, 5 = 16-20 cm, 6 = 20-24 cm, 7 = 24-28 cm, 8 = 28-32 cm, 9 = 32-36 cm, 10 = 36-40 cm, 11 = 40-44 cm, and 12 = >44 cm.

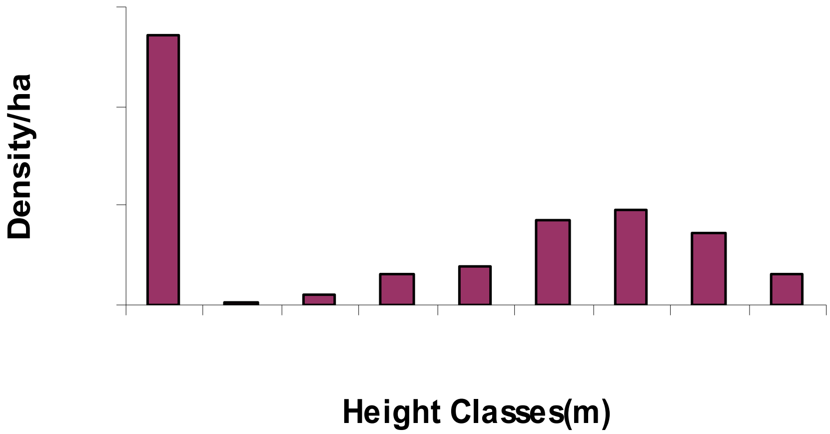


Figure 4. Cumulative height class frequency distribution of woody species.

Height class: 1 = 0-2 m, 2 = 2-4 m, 3 = 4-6 m, 4 = 6-8 m, 5 = 8-10 m, 6 = 10-12 m, 7 = 12-14 m, 8 =14-16 m and 9 = >16 m.

Basal area and importance value index (IVI)

The basal area of all woody species was 42.54 m^2 ha^{-1}. The following species made the largest contribution to the basal area: *Sterculea setigera* (30.53%), *Boswellia papyrifera* (19.08%), *Anogeissus leiocarrpa* (16.13%), *Pterocarpus lucens* (8.9%), *Lannea fruticosa* (7.03%), *Combretum collinum* (2.6%) and *Terminalia laxiflora* (2.48%) but the other remaining species contributed to only 13.25% (Table 1).

The nine most important woody species with the highest IVI and contributed to over 63% of the total IVI in decreasing order were *Sterculea setigera* (44.46%), *Boswellia papyrifera* (40.28%), *Anogeissus leiocarrpa* (23.86%), *Lannea fruticosa* (23.17%), *Pterocarpus lucens* (19.55%), *Combretum collinum* (10.58%), *Dichrostachys cinerea* (10.39), *Stereospermum kunthianum* (9.13%), and *Cobretum adenogonium* (8.64%). Whereas, *Piliostigma thonningii, Tamarindus indica, Maytenus senegalensis*, and others have a small contribution to the total IVI (Table 1).

Population structure of woody species

The population structure of selected species from the Metema woodland vegetation fell into one of four general diameter class distribution patterns. These are: 1) interrupted Inverted-

J-shape, which seemed to show a pattern where species frequency distribution had the highest frequency in the lower diameter classes and a gradual decrease towards the higher classes, still, showing either a complete absent or a very high decrease in density somewhere in the lower classes or middle classes. 2) J-shape, which showed a type of frequency distribution in which there was a low number of individuals in the lower diameter classes but increased towards the higher diameter classes. 3) Bell-shape, which showed a type of frequency distribution in which a number of individuals in the middle classes were high and decreased towards the lower and higher diameter classes. 4) Irregular-shape, which seemed a bell-shape distribution pattern but a complete absent of individuals in class two and three and a fair representation of individuals in class one. These patterns were illustrated by the six dominant species that had been selected based on their importance value indices. Accordingly, *Anogeissus leiocarrpa, Combretum collinum and Lannea fruticosa* were depicted an interrupted Inverted-J-shape pattern (Figure 4(b), (c) and (e)). *Sterculea setigera* (Figure 4(a)) depicted a J-shape pattern, while *Boswellia papyrifera* and *Pterocarpus lucens* (Figure 4(d) and (f)) fell in the bell-shape and irregular-shape patterns, respectively.

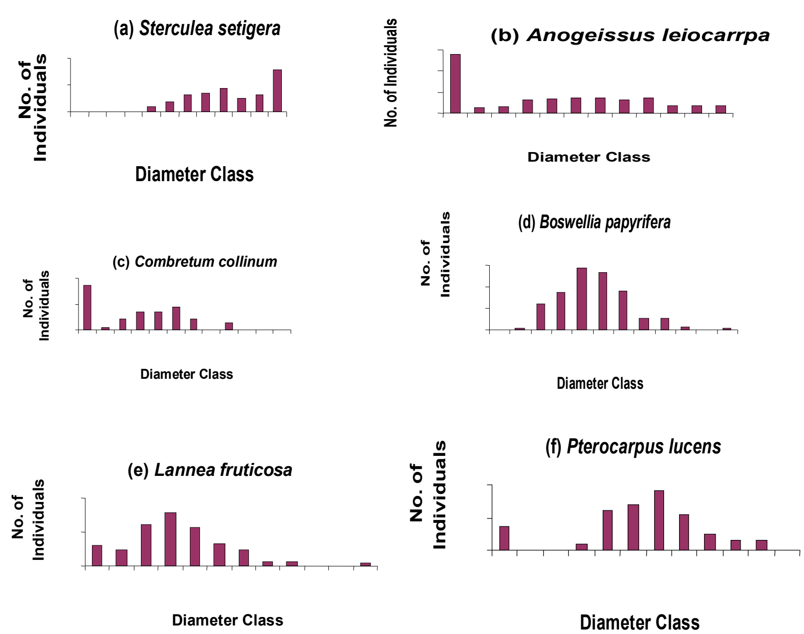


Figure 5. Diameter class frequency distribution of selected tree species.

Diameter class: 1= 0-4cm, 2 = 4-8cm, 3 = 8-12 cm, 4 = 12-16 cm, 5 = 16-20 cm, 6 = 20-24 cm, 7 = 24-28 cm, 8 = 28-32 cm, 9 = 32-36 cm, 10 = 36-40 cm, 11 = 40-44 cm, and 12 = >44 cm.

On the other hand, the patterns of height class distribution fell into three categories. These were: 1) interrupted inverted-J-shape, which seemed to show a pattern where species frequency distribution had the highest frequency in the lower height classes and a gradual decrease towards the higher classes, still showing either a complete absent or a very high decrease in density somewhere in the lower classes or middle classes, 2) J-shape, which showed a type of frequency distribution in which there was a low number of individuals in the lower height classes but increased towards the higher height classes, 3) nearly bell-shape, which showed a type of frequency distribution in which a number of individuals in the middle classes were high, and decreased towards the lower and higher height classes, 4) Irregular-shape, which generally seemed a broken J-shape distribution pattern where there is increase in density of individuals only limited in and towards higher height classes but still showing a very high decrease in density in class eight and nine. Accordingly, *Boswellia papyrifera* (Figure 5 (d)) depicted a J-shape pattern while *Anogeissus leiocarrpa* and *Combretum collinum* (Figure 5(b) and (c)) fell in interrupted inverted-J-shape pattern. *Lannea fruticosa* (Figure 5(e)) showed nearly bell-shape distribution pattern. *Sterculea setigera* and *Pterocarpus lucens* (Figure 5 (a) and (f)) revealed an Irregular-shape.

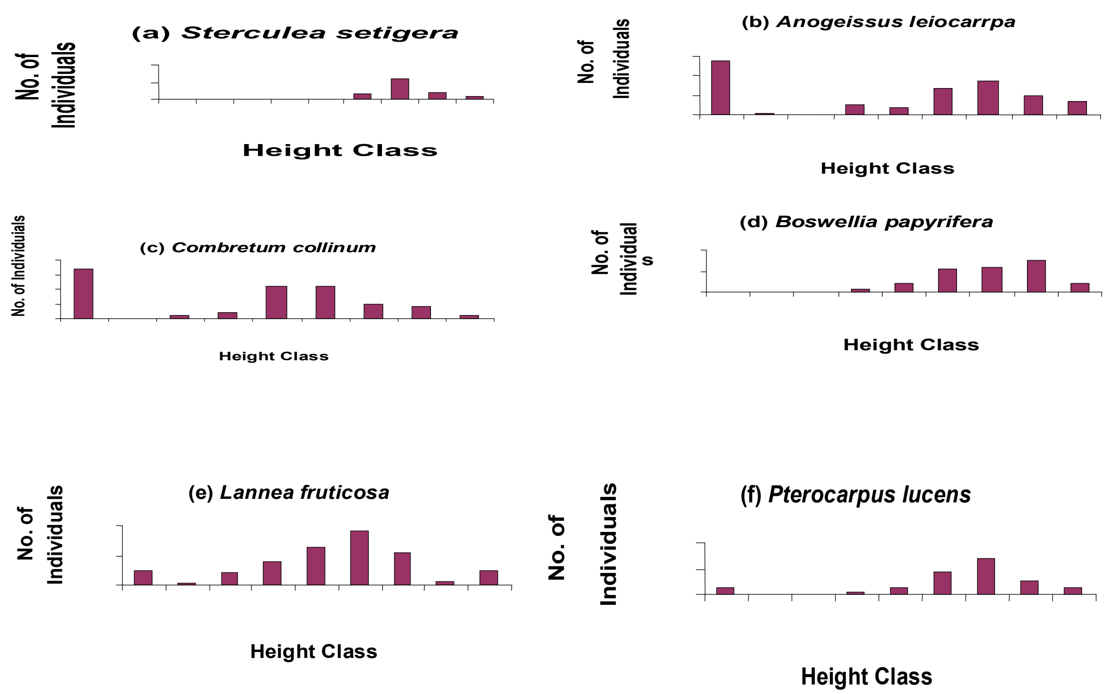


Figure 6. Height class frequency distribution of selected tree species. Height class: (1 = 0 - 2 m; 2 = 2 - 4 m; 3 = 4 - 6 m; 4 = 6 - 8 m; 5 = 8 - 10 m; 6 = 10 - 12 m; 7 = 12 - 14 m; 8 =14 - 16 m and 9 = ≥16 m).

Regeneration status

A total of 556 individual seedlings (120 individuals ha^{-1}) belonging to 26 species were counted from all quadrates, while a total of 86 individual saplings (14 individuals ha^{-1}) were counted for 19 species. Accordingly, the following species made the largest contribution to the seedling counts per hectare: *Dichrostachys cinerea* (18.81), *Flueggea virosa* (13.84), *Stereospermum kunthianum* (11.24), *Anogeissus leiocarrpa* (10.38), and *Ochna leucophloeos* (11.46). On the other hand, *Dichrostachys cinerea* (5.19), *Anogeissus leiocarrpa* (1.73), *Acacia polyacantha* (1.73), *Dalbergia melanoxylon* (1.51) and *Stereospermum kunthianum* (1.30) contributed the largest proportion of sapling counts. Generally, *Dichrostachys cinerea*, *Anogeissus leiocarrpa, Ochna leucophloeos, Acacia polyacantha, Dalbergia melanoxylon* and *Stereospermum kunthianum* were found to be good in recruitment status relative to other species.

Discussions

Floristic composition

Floristic composition of a given vegetation can be described in terms of its richness in species, abundance, dominance, and frequency (Lamprecht, 1989). In this study, a total of 87 species including climbers, herbs, shrubs and tree were encountered in the Metema woodland vegetation. Out of all the species, *Smithia abyssinica* and *Boswellia pirottae* were found to be endemic to Ethiopia. However, *Boswellia pirottae* was found to be one of the endemic plant species of Ethiopia which is endangered (Ensermu Kelbessa, 1992). The diversity and evenness of the Metema woodland vegetation using Shannon-Weiner diversity index were found to be 3.67 and 0.82, respectively. According to Kent and Coker (1992), the Shannon-Weiner diversity index normally varies between 1.5 and 3.5 and rarely exceeds 4.5. The low Shannon evenness is an indication of the existence of unbalanced distribution of the individuals of species encountered at a given study area. However, the study result showed the area is with good diversity and more or less even representation of individuals of all species was encountered in the studied quadrates.

Population structure

Species-abundance measures are ways of expressing not only the relative richness but also evenness and thereby assessing diversity (Barnes *et al*., 1998). In this study, a total of 376.86 individuals ha^{-1} of woody plants were encountered from all quadrates. *Sterculea setigera*, *Boswellia papyrifera*, *Anogeissus leiocarrpa, Lannea fruticosa, Dichrostachys cinerea* and *Pterocarpus lucens* were the most abundant species while species like *Albizia melanoxylon*, *Combretum hartmannianum*, *Boscia mossambicensis*, *Piliostigma thonningii, Tamarindus indica*, and *Maytenus senegalensis* were poorly reckoned in this regard. Generally speaking, only few species were dominating the woodland in their abundance while many of the species were very rare or low in their abundance. The result reflects either adverse environmental situations or random distribution of available resource in the woodland (Miranda *et al*., 2002 as cited by Feyera Senbeta *et al*., 2007). It can be further inferred that the woody plants were distributed in uneven manner may be due to inability of individuals to cope up harsh environmental condition (e.g. high temperature, low rainfall regime), human disturbance, livestock trampling and grazing, and other biotic and abiotic impairments in the area.

Basal area provides the measure of the relative importance of the species than simple stem count. Species with largest contribution in dominance value could be considered as the most important species in the study vegetation. Otherwise, in most cases shrubs could be the dominant species if only we consider density as a measure to indicate the overall dominance of the species (Adefires Worku, 1992 and 2006; Simon Shibru and Girma Balcha, 2004). In this study, basal area analysis across individual species revealed that there was high domination by very few species. *Sterculea setigera* was the dominant species followed by other species like *Boswellia papyrifera*, *Anogeissus leiocarrpa*, *Pterocarpus lucens*, *Lannea fruticosa*, *Combretum collinum* and *Terminalia laxiflora*. The remaining species in total contributed little relative basal area. This implies that just the above mentioned seven species are the most ecologically important woody species in Metema.

Frequency reflects the pattern of distribution and gives an approximate indication of the heterogeneity of a stand (Lamprecht, 1989; Haileab Zegeye *et al*., 2006). The results of frequency showed that there was relatively fair presence of certain species in most of quadrates. The highest relative frequency was scored by *Lannea fruticosa*, which was relatively low as compared to the highest relative density and the highest relative basal area scored by *Boswellia papyrifera* and *Sterculea setigera*, respectively. This implied that due to the fact that scores of frequency were shared among species, the highest frequency became low. In other words, it can be concluded that there were fair presence of many species in most of the quadrates. These might be due to the fact that these species might have a wide range of seed dispersal mechanisms like by wind, livestock, wild animal, birds and the like. According to Lamprecht (1989), stands that yield more or less the same IVI for the characteristic species indicate the existence of the same or at least similar stand composition and structure, site requirements and comparable dynamics among species. In contrary to this, almost all species in this study showed variation in terms of IVI, showing different ecological importance of each species in the woodland.

Information on the population structure of a tree species indicates the history of the past disturbance to that species and the environment and hence, used to forecast the future trend of the population of that particular species (Tamrat Bekele, 1994; Demel Teketay, 1997). In this study, it revealed that the cumulative diameter class frequency distribution of woody individuals in an interrupted reverse-J-shape pattern, there was a very high decrease in density of diameter class two. However, the analysis of selected species fell in four different patterns i.e. interrupted J-shape, bell-shape, irregular-shape and J-shape. According to previous studies (Silvertown, 1982; Silvertown and Doust, 1993; Mekuria *et al*., 1999; Alemnew Aleligne, 2001; Alemayehu Wassie, 2002; Getachew Tesfaye *et al*., 2002), a reverse J-shape distribution pattern was considered as an indication of stable population status or good regeneration status. In this study, however, both cumulative diameter class distribution of individual woody plants and selected species resulted in patterns showing a hampered regeneration profiles. The cumulative one showed nearly reverse J-shape with a very high decrease in density at the second diameter class, reflecting the hampered regeneration profiles in the area. This tells that there had been a selective removal of small diameter class individuals either by local dwellers for some purpose (e.g. for fencing and fuel wood), or by livestock (trampling or browsing), or might be other biotic impairments like termite attack. In most cases, this diameter class is the most susceptible and palatable age of individuals and this might be the reason that made individuals unable to cope up with any disturbance encountered. Similarly, *Anogeissus leiocarrpa*, *Combretum collinum* and *Lannea fruticosa* were depicted in an interrupted reverse-J-shape. *Anogeissus leiocarrpa* and *Combretum collinum* revealed a very high decrease in density at diameter class two and three, while *Lannea Fruticosa* in density of the diameter class one and two. *Boswellia papyrifera* was depicted in bell-shape pattern that is the reflection of a discontinuous or irregular recruitment. This species is one of the most economically important species in producing frankincense to the local farmers. It was hardly common to see untapped stems of *Boswellia papyrifera* in the studied quadrates. This might be one of the most important reasons that made the species retard from its normal recruitment status. *Sterculea setigera* fell in J-shape distribution pattern, which is considered as reflection of severe limitation on the regeneration for some reason (Peters, 1996). This study noted that *Sterculea setigera* was one of the most important multipurpose tree species used for like fodder especially during the dry season at times when there is forage scarcity. This study also noted that the peels of this species used as chewing gum by local kids. Moreover, some termite dunes piled under this tree and felled logs. *Pterocarpus lucens* also showed an irregular-shape with complete absent of individuals in diameter class two and three. This also reflects a hampered regeneration status of the species due to possible reasons like human disturbance, livestock trampling or browsing, and some other biotic and abiotic impairment in the area.

Similarly, the pattern of the cumulative height class distribution of all woody species showed interrupted reverse J-shape like the pattern revealed by the cumulative diameter class distribution. A reverse-J-shape height class distribution pattern was considered as a normal type of distribution indicating continuous or good regeneration revealed by stable population (Getachew Tesfaye and Abiyot Berhanu, 2006; Feyera Senbeta *et al*., 2007). However, both the cumulative and selected species analysis of this study depicted in different patterns that reflect the hampered regeneration profile. Accordingly, *Anogeissus* *leiocarrpa* and *Combretum collinum* revealed an interrupted J-shape while *Lannea fruticosa* in bell-shape pattern. *Sterculea setigera* and *Pterocarpus lucens* fell in irregular-shape while *Boswellia papyrifera* in J-shape. This might be due to similar reasons for diameter class distribution. Generally, only *Anogeissus leiocarrpa* and *Combretum collinum* were similar in both diameter class and height class distribution, showing an interrupted J-shape. The other species showed a higher density shift towards the middle and higher height classes than showed in diameter class distribution. This is evident that species are to be different in their density distribution patterns across height and diameter classes.

Conclusions and Recommendations

The study in the broad-leaved deciduous woodland of Metema revealed that Metema has high floristic composition and diversity with good distribution. The study came across 42 herbs, 42 woody species and 3 climbers. However, the results of woody species revealed that only few species scored high density and basal area. Both the cumulative diameter and height class frequency distribution patterns of woody individuals resulted in an interrupted inverted-J-shape, which is the reflection of a more or less poor regeneration profile in the area. Similarly, the population structure of the six selected important species showed that all were in poor regeneration status, though the degree of the problem varies from species to species. *Sterculea setigera* was the most critically hampered species followed by *Boswellia papyrifera* and *Pterocarpus lucens*.

Based on the results it was recommended that urgent research and/or development action should be considered to circumvent and address the problems faced, especially on those species poorly scored and reckoned in their regeneration status and importance value index for instance, *Sterculea setigera, Boswellia papyrifera, Pterocarpus lucens, Boswellia pirottae, Tamarindus indica, and Terminalia laxiflora*. Research on seed viability of the problematic species, their seed raining mechanisms and problems, their seedling establishment mechanisms and problems, soil seed bank analysis and other possible ways to identify specific problems of the species that made them unable to regenerate should be done.

Devising environmentally-friendly strategy for effective scaling up of products and productivity of those economically important tree species growing in the area such as *Boswellia papyrifera* and *Boswellia pirottae* should be given attention, so that this in turn will contribute to the conservation and development of other floral species in the area. Finally, further research has to be done to fill gaps of this research, especially investigation in the area of socio-economic and ethnobotanical perspectives should be considered.

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