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THE NATURAL VEGETATION OF BABILE ELEPHANT SANCTUARY, EASTERN ETHIOPIA: IMPLICATIONS FOR BIODIVERSITY CONSERVATION

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ABSTRACT: A floristic analysis of the natural vegetation was carried out in the Babile Elephant Sanctuary (BES), in semi-arid part of eastern Ethiopia. A total of 75 quadrats, each 400 m^2, were analyzed following a stratified sampling design. A total of 237 plant species, belonging to 155 genera and 57 families, were identified. Fabaceae was represented by the highest number of species (i.e., 36 species; 15.1%). Six community types were identified using the TWINSPAN program. These are: I. *Tamarindus indica*; II. *Acacia robusta*; III. *Acacia seyal* - Balanites aegyptiaca; IV. *Acacia senegal* - *Acalypha fruticosa*; V. *Terminalia brownii* - *Boswellia neglecta* and VI. *Acacia bussie* - *Grewia tenax* types. A total basal area of 17.8 m2/ha, and a density of 385 ± 114.2 (S.E.) individuals ha-1 were calculated for 67 woody species (22 trees, 36 shrubs and 9 climbers); the mean density of trees was 32 ± 9.96, shrubs 619 ± 203.3 and climbers 315 ± 103.4 individuals ha^{-1}. A very high impact was imposed by the invasive species *Lantana camara*, which had a density of 2794.6 individuals ha^{-1}. In general, the vegetation of the sanctuary was threatened by human encroachment, intensification of commercialized farming and invasive species. Therefore, as the habitat for the only known population of the isolated, ecologically distinct subspecies population of the elephant (*Loxodonta africana orleansi*), the BES should be afforded the highest conservation priority as a matter of urgency.

Key words/phrases: Babile Elephant Sanctuary, Community types, Conservation, Floristic analysis, Species diversity.

INTRODUCTION

Ecosystems in general and specific habitats in particular are being degraded and species and genetic diversity are being lost at an alarming and unprecedented rate (Farah, 1997). The decline of vegetation cover is one of the most serious environmental issues facing mankind today. Ethiopia is facing severe degradation in this respect in both the highlands and the lowlands. This is mainly because of the current population growth of around 3% per year (CSA, 2005), and, as a result, the incessant need for agricultural land. The present estimated area of drylands in Ethiopia, where the crisis is more severe, is over 75 million ha, which is about 66% of the total area of

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the country (EFAP, 1994). Of this, 25 million ha is covered with woodlands and bushlands. These enormous areas of dryland vegetation resources are facing serious problems of degradation.

Protected areas cover approximately 14% of the country‘s surface area (Hillman, 1993). There are 9 national parks, 3 sanctuaries, 8 wildlife reserves and 18 controlled hunting areas covering an area of about 194,000 km^2 (IUCN, 1992). However, except few, most of the protected areas exist only on paper. According to IUCN (1992), of the total protected areas, only 30,316 km^2 (2.5%) is actively managed. All of these protected areas have been mainly established primarily for the conservation of endemic wildlife. However, although Ethiopia's high biodiversity is mainly due to its high plant species diversity (Tadesse Woldemariam, 2003); no conservation area focusing primarily on plants has been established in the country.

Babile Elephant Sanctuary is situated in the semi-arid part of east Ethiopia, in Oromia and Somali National Regional States. The sanctuary was established to protect the only known population of the isolated, ecologically distinct subspecies *Loxodonta africana orleansi* (Barnest *et al*., 1999). As a result of mass influx of a large number of farmers and their livestock from the east and north, the home range of elephants in Babile has shrunk by about 65.5% since 1976 (Yirmed Demeke *et al*., 2006). Although it has been designated as the largest sanctuary for elephants (6984 km^2) in the country, there has been no systematic ecological study conducted on it until recently.

The objective of this study was to identify and document the plant species present, determine the plant community types, analyze the diversity and density of woody species, and recommend possible conservation measures.

MATERIALS AND METHODS

Study area

Babile Elephant Sanctuary, in the eastern lowlands of Ethiopia, is part of the Somali-Masai centre of endemism. The underlying rocks are mainly marine in origin and soils are characterized by xerosols and yermosols which are indicative of aridity. The sanctuary is situated at about 560 km from Addis Ababa, in Oromiya and Somali Regional states. The sanctuary lies between 08°22'30"- 09°00'30" N, and 42°01'10"-43°05'50" E, and elevation ranges between 850 m and 1785 m a.s.l.

Four main drainage river valleys (Fafem, Daketa, Erer and Gobele) rise from Garamuleta-Gursum highlands, and these extend southwards through the sanctuary to join Wabi Shebelle River Basin (Fig. 1). This study was carried in the Erer valley, which is the largest part of the Babile Elephant Sanctuary.

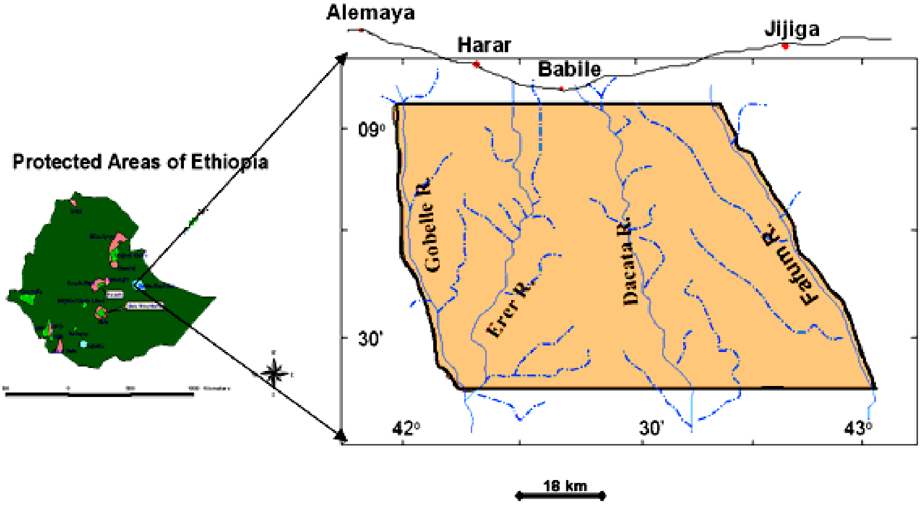

Fig. 1. Map of the Babile Elephant Sanctuary (rivers and nearby towns).

The mean annual temperature is about 19.6^0 C, while the mean annual rainfall is 702.9 mm $year^{-1}$. Rainfall is bimodal occurring from March to April (short rain season) and June to September (long rain season).

Data collection

Vegetation data collection was carried out between September 2005 and April 2006. Stratified sampling design was used as described by Krebs (1989) based on the different formation types prevalent in the study area. Twelve representative sites were selected by visual observation on the basis of homogeneity in floristic composition, and data collected systematically.

A total of 75 sampling plots were established. The size of the major plots for tree species was 20 m x 20 m, as recommended by Kent and Coker (1992). In each sample plot, all tree species with diameter at breast height (DBH) ≥ 2.5 cm and height ≥ 1.5 m were recorded and their cover estimated following Mueller-Dombois and Ellenberg (1974). Within the 400 m^2, five sub-plots of (5 m x 5 m) were set up, four at each corner and one at the centre, to collect data on shrubs and climbers and the mean value of these five subplots were used in the analysis. Within each 25 m^2 sub-plots, five 1 m x 1 m sub-plot was used to collect data on the species diversity and richness of herb and grass species including estimate of their percentage cover.

Plant species were recorded and voucher specimens of plant species were collected and deposited at the National Herbarium (ETH), Addis Ababa University. The nomenclature of plant names in this study followed the published volumes of Flora of Ethiopia and Eritrea (Hedberg and Edwards, 1989, 1995; Edwards *et al*., 1995, 1997, 2000; Hedberg *et al*., 2006), and by comparing with authentic specimens at the National Herbarium (ETH), Addis Ababa University.

Data analysis

Plant community types were analyzed using the program TWINSPAN (Hill *et al*., 1975; Hill, 1994). Species richness, evenness and Shannon-Weiner Diversity Index were analyzed using Biodiversity professional software program version 2 (Niel, 1997). Basal area (BA) is the cross-sectional area of tree stems at diameter at breast height. It is a measure of dominance (Lamprecht, 1989) and was calculated by using the following formula:

$$BA=\Pi d^2/4$$, where d is diameter at breast height.

Importance Value Indices (IVI) were analyzed for woody species, and similarity coefficient between community types were assessed using Sorensen's similarity index as recommended by Kent and Coker (1992).

RESULTS

Floristic composition

A total of 237 plant species in 155 genera and 57 families were identified (A complete list of plant species can be provided upon request). Fabaceae had 36 (15.1%) species, followed by Poaceae, 19 species (8.0%), Asteraceae, 15 species (6.3%), Acanthaceae, 14 species (5.9%) species, Tiliaceae, 12 species (5.0%), Euphorbiaceae, 10 species (4.2%), Malvaceae, 10 species (4.2%), Lamiaceae, 11 species (4.64%), Convolvulaceae, 9 species (3.8%), Asclepiadaceae, 8 species (3.4%); Amaranthaceae, Boraginaceae, and Capparidaceae each had 6 species (2.5%); Rubiaceae, Sapindaceae and Solanaceae each had 4 species (1.7%); Burseraceae, Anacardiaceae, and Sterculiaceae had each 3 species (1.3%), 18 families had 2 species each (accounting to a total of 15.2%), and 22 families were represented by only 1 species each (accounting to 9.2% in total). From the total plant species, 102 (42.9%) were herbs, 58 (24.8%) shrubs, 32 (13.4%) trees, 20(8.4%) grasses, 17 (7.1%) climbers, 5(2.1%) shrub/trees, 2 (0.8%) ferns and 1 (0.4%) is epiphyte.

Plant community types

The following six plant community types were identified and named after one or two of the dominant species and/or characteristic species occurring in each group using the relative magnitude of mean cover abundance (Table 1).

Community 1. *Tamarindus indica* community type occurs in the riverine forest of lower Erer River. The altitudinal range is between 1150- 1260 m a.s.l. Indicator tree species with a significant cover value is *Tamarindus indica.* Other tree species in this community type are *Balanites aegyptiaca, Acacia robusta*, *Oncoba spinosa*, and *Opuntia ficus indica*. Shruby species include *Acacia brevispica* and *Capparis tomentosa*. *Pentarrhinum somalensis* is the major climber species in this community. The field layer is characterized by *Achyranthes aspera, Plumbago zeylanica, Solanum nigrum, Abutilon bidentatum, Commelina stephaniniana,* and *Panicum monticolum.* Expansion of agriculture was observed within this community. The surface feature is mainly loam soil.

Community 2. *Acacia robusta-Acokanthera schimperi* community type occurred in the riverine forest of upper Erer River. The altitudinal range is between 1200 and 1250 m a.s.l. The dominant tree species are *Acacia robusta* and *Acokanthera schimperi*. Shruby species include *Senna singueana* and *Solanum incanum*. An exotic shrubby species, *Lantana camara*, was the most serious threat observed in this community. *Commicarpus sinuatus* is the common climber. Understorey layer is occupied by *Abutilon bidentatum, Hibiscus dogolensis, Justicia diclipteroides, Hibiscus micrantus*, and *Setaria verticillata*. An expansion of agricultural activity was observed along this community. The surface feature is loam soil.

Community 3. *Acacia seyal -Balanites aegyptiaca* community type occurs in the *Acacia* woodland. The altitudinal range is between 1200 and 1330 m a.s.l. The dominant tree species with significant cover value are *Acacia seyal* and *Balanites aegyptiaca.* The common tree species are *Acacia tortilis* and *Acacia melifera*. Less abundant trees are *Acacia senegal* and *Acalypha fruticosa*. Shruby species in this community include *Acacia oerfota, Capparis sepiaria, Carissa spinarum, Euphorbia burgeri, Chionothrix latifolia*, *Acalypha fruticosa* and *Barleria eranthemoides*. The field layer is mainly characterized *by Blepharis maderaspatensis, Dichrostachys cinerea, Digitaris ternata, Indigofera parviflora, Ipomea obscura, Ocimum forskolei,* *Eragrostis aspera,* and *Eragrostis papposa. Periploca linearifolia* is the common climber in this community. The surface feature is mainly sandy.

Table 1. Synoptic table to identify indicator species having high mean cover abundance value.

Community groups	C1	C2	C3	C4	C5	C6
Community size*	5	10	21	19	10	10
Tamarindus indica	5.4	0.0	0.0	0.0	0.0	0.0
Capparis tomentosa	3.6	0.0	0.8	1.3	0.0	0.0
Oncoba spinosa	4.0	0.0	0.0	0.0	0.0	0.0
Panicum monticolum	2.8	3.0	0.0	0.0	0.0	0.0
Acacia robusta	3.0	8.7	0.0	0.0	0.0	0.0
Acokanthera schimperi	0.0	4.6	0.5	0.0	0.0	0.0
Solanum incanum	0.0	2.4	0.0	0.8	0.0	0.0
Balanites aegyptiaca	2.2	0.3	5.6	0.4	0.0	0.5
Acacia tortilis	0.0	0.0	4.9	0.8	4.1	1.9
Acacia seyal	0.0	0.0	3.6	0.0	0.0	0.0
Ipomea obscura	0.0	0.0	2.4	0.7	1.2	0.9
Acalypha fruticosa	1.4	2.0	2.1	6.8	1.5	1.8
Acacia senegal	0.0	2.1	2.2	6.7	2.2	1.8
Acacia mellifera	0.0	1.6	3.5	5.4	4.3	2.7
Grewia bicolor	0.0	0.0	0.0	2.3	0.3	2.2
Terminalia brownii	0.0	0.0	0.0	0.0	5.2	2.5
Boswellia neglecta	0.0	0.0	0.0	0.0	5.0	1.8
Rhus natalensis	0.0	0.0	0.0	0.0	4.1	0.5
Crabbea volutina	0.0	0.0	0.0	0.0	3.4	0.5
Berchemia discolor	0.0	0.0	1.1	0.0	2.8	1.5
Grewia schweinfurthii	0.0	0.0	0.0	0.0	3.2	0.0
Acacia bussei	0.0	0.0	1.8	0.6	1.8	4.8
Commiphora schimperi	0.0	0.0	0.0	0.0	2.2	3.2
Grewia tenax	0.0	0.0	0.0	1.7	2.2	4.2
Cenchrus ciliaris	0.0	0.0	0.0	0.9	0.6	2.8
Opuntia ficus-indica	3.4	3.6	2.2	2.3	3.5	1.2

* Number of quadrats grouped in each community type.

Community 4. *Acalypha fruticosa - Acacia senegal* community type occurs in *Acacia* deciduous bushland and thicket. The altitudinal range is between 1240 and 1290 m a.s.l. The dominant species with significant cover value are *Acacia senegal* and *Acalypha fruticosa.* Shruby species in this community include *Acacia brevispica, Grewia bicolor, Grewia flavescens, Acacia mellifera* and *Opuntia stricta*. Less abundant shrubs are *Agava sisalana, Aloe pirottae, Plicosepalus curviflorus, Euphorbia cryptospinosa,* and *Plectranthus puberulentus* and scattered trees are *Acacia etbaica, Euphorbia abyssinica*, and *Opuntia ficus-indica.* The common climber species are *Buckollia volubilis, Crotalaria quartiniana, Cryptostegia grandiflora,* and *Sarcostema viminale. Hibiscus micranthus, Chamaecrista mimosoides, Chloris virgata, Dicoma tomentosa, Indigofera hochstetteri, Justicia flava* and *Plectranthus barbatus* are the abundant species of understorey layer. The surface feature is both sandy and rocky.

Community 5. *Terminalia brownii-Boswellia neglecta* community type occurred in the woodland. The altitudinal range is between 1250 and 1350 m a.s.l. The dominant trees are *Terminalia brownii* and *Boswellia neglecta.* The common trees and shrubs are *Acacia melifera, A. tortilis, Berchemia discolor, Commiphora erythraea, Commiphora schimperi, Grewia schweinfurthii,*and *Rhus natalensis.* The climbers are *Dolichos trilobus* and *Cryptostegia grandiflora*. The field layer is composed of *Crabbea velutina*, *Blepharis maderaspatensis, Gutenbergia rueppelli, Indigofera brevicalyx, Kohautia caespitosa* and *Barleria eranthemoides*. The surface feature in most part is rocky.

Community 6. *Acacia bussie-Grewia tenax* community type occurred in the *Acacia–Commiphora* woodland at the altitudinal range between 1150 and 1250 m a.s.l. The dominant trees and shrubs in this community are *Acacia bussie* and *Grewia tenax.* Less abundant trees and shrubs are *Commiphora schimperi, Balanites glabra, Grewia flavescens, Combretum molle, Acacia albida, Berchemia discolor, Acacia brevispica, Acacia mellifera*. *Terminalia brownii, Grewia ferruginea* and *Grewia erythrea.* Climbers are *Capparis fascicilaris, Cissus rotundifolia,* and *Jasminum eminii*. The field layer is composed of *Blepharis edulis, Cenchrus ciliaris, Chloris pycnothrix, Corchorus tridens, Leucas martinicensis, Melinis repens, Ocimum gratissimum, Plectranthus rupestris* and *Enteropogon macrostachyus*. *Actiniopteris dimorpha* and *Adiantum capillus-veneris* are ferns in this community. The surface feature is mainly rocky.

Floristic diversity

The overall plant diversity (Shannon Diversity index) and evenness was 3.55 and 0.72, respectively. Species richness ranged from 31 up to 79 where the least was from community 2 and highest from community 3. Community 2 had the least species evenness value (0.59) whereas community 5 had the highest (0.83). The Shannon-Weiner index ranged from 2.10 up to 3.44 where the least was for community 2 and highest for community 3 (Table 2).

Table 2. Species richness, evenness and diversity in the six plant community types.

Communities	Richness (N)	Evenness (E)	Diversity (H')	H'Max
1	31	0.70	2.44	3.43
2	34	0.59	2.10	3.52
3	79	0.78	3.44	4.36
4	71	0.72	3.10	4.26
5	59	0.83	3.39	4.10
6	58	0.80	3.25	4.00

The three formation types stratified for sampling purpose showed differences in species richness, evenness and diversity (Table 3).

Table 3. The diversity, richness and evenness of plant species in the three formation types.

Parameters	Riverine	Woodland	Bushland and thicket
Diversity (H')	2.23	3.24	3.10
Richness (N)	36	110	71
Evenness (E)	0.62	0.68	0.72
H'max	3.58	4.7	4.26

Floristic similarity

Results from Sorensen's similarity coefficient analysis indicated high similarities between communities 1 and 2 (58%), 3 and 4 (57%), and 5 and 6 (54%). Communities with low in-between similarities were communities 1 and 5 (15%), 1 and 6 (18%), 2 and 5 (23%), 2 and 6 (25%), and 1and 4 (29%) (Table 4).

Table 4. Sorensen's similarity coefficient among the six community types.

Communities	1	2	3	4	5	6
1	-					
2	0.58	-				
3	0.30	0.32	-			
4	0.29	0.31	0.57	-		
5	0.15	0.23	0.43	0.42	-	
6	0.18	0.25	0.41	0.40	0.54	-

Woody species density

The total density of woody species was 19,991 individuals ha^{-1}, whereas the total density of trees was 394 individuals ha^{-1} (2.7% of the total density); shrubs 17,460 individuals ha^{-1} (86.3%) and climbers 2,137 individuals ha^{-1} (11%). The mean density of trees, shrubs and climbers is shown in Table 5. Six species: *Opuntia stricta* (26.5%), *Acacia senegal* (9.77%), *A. brevispica* (8.76%), *Euphorbia burgeri* (6.44%), *Acacia mellifera* (4.94%), and *Grewia tenax* (4.19%) constituted about 60.6% of the total density of the woody species (Table 6).

Table 5. The mean density of trees, shrubs and climbers in the study area.

Habit	Mean ± S.E. individuals ha^{-1}	Minimum individuals ha^{-1}	Maximum individuals ha^{-1}	Number of species
Trees	32 ± 9.96	3	167	22
Shrubs	619 ± 203.3	64	3843	36
Climbers	315 ± 103.4	53	835	9
Total	385 ± 114.2	3	3843	67

Table 6. Importance Value Indices (IVI) of some dominant woody species.

Scientific name	Habit	freq	Dens/ha	BA m^2/ha	Rfre	Rden	Rdom	IVI
Acacia robusta	T	15	100.7	7.006	1.300	0.39	39.3	41.0
Opuntia stricta	Sh	57	3842.7	0.963	4.939	26.50	5.4	36.8
Acacia senegal	Sh	52	2522.7	0.191	4.506	9.77	1.1	15.3
Acacia brevispica	Sh	59	2261.3	0.180	5.113	8.76	1.0	14.9
Tamarindus indica	T	5	15.7	2.462	0.433	0.06	13.8	14.3
Opuntia ficus-indica	T	50	216.7	1.130	4.333	0.84	6.3	11.5
Acacia mellifera	Sh	50	1274.7	0.260	4.333	4.94	1.5	10.7
Euphorbia burgeri	Sh	36	1664.0	0.191	3.120	6.44	1.1	10.6
Lanthana camara	Sh	41	2794.6	0.09	3.8	6.1	1.3	8.9
Acacia bussei	T	40	47.3	0.917	3.466	0.18	5.2	8.8
Grewia tenax	Sh	35	1082.7	0.112	3.033	4.19	0.6	7.9
Acacia tortilis	T	36	41.3	0.702	3.120	0.16	3.9	7.2
Terminalia brownii	T	12	34.3	0.762	1.040	0.13	4.3	5.5
Balanites glabra	T	33	33.7	0.369	2.860	0.13	2.1	5.1
Grewia ferruginea	Sh	32	496.0	0.020	2.773	1.92	0.1	4.8
Grewia flavescens	Sh	32	384.0	0.008	2.773	1.49	0.0	4.3
Balanites aegyptiaca	T	28	31.0	0.262	2.426	0.12	1.5	4.0
Grewia bicolor	Sh	20	410.7	0.015	1.733	1.59	0.1	3.4
Capparis tomentosa	Sh	18	266.7	0.120	1.560	1.03	0.7	3.3
Berchemia discolor	T	17	15.3	0.268	1.473	0.06	1.5	3.0
Capparis fasicularis	Sh	13	293.3	0.120	1.127	1.14	0.7	2.9
Dichrostachys cinerea	Sh	15	325.3	0.021	1.300	1.26	0.1	2.7
Acokanthera schimperi	Sh	14	309.3	0.043	1.213	1.20	0.2	2.7
Acacia seyal	T	5	30.0	0.341	0.433	0.12	1.9	2.5
Acacia albida	T	19	11.3	0.105	1.646	0.04	0.6	2.3
Boswellia neglecta	T	11	30.7	0.204	0.953	0.12	1.1	2.2
Grewia schweinfurthii	Sh	5	208.0	0.025	0.433	0.81	0.1	1.4
Acacia etbaica	T	10	7.7	0.072	0.867	0.03	0.4	1.3
Commiphora schimperi	T	10	18.0	0.058	0.867	0.07	0.3	1.3

Habit; T = tree; Sh = shrub; Cl = climber; S/T = shrub/tree.

Density was calculated for woody species in each community types. While community 4 was the highest in terms of shrub density (14,579 individuals ha^{-1}) and community 1 was the lowest (1360 individuals ha^{-1}), the inverse was true with regards to trees; community 4 was the lowest in terms of tree density (198 individuals ha^{-1}) and community 1 was the highest (550 individuals ha^{-1}) (Fig. 2).

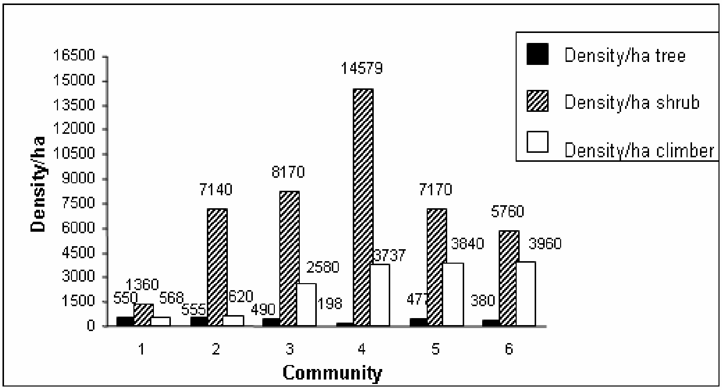

Fig. 2. Density ha^{-1} of trees, shrubs and climbers in the six community types.

The three formation types that were stratified for sampling purpose showed significant differences in density of individuals per hectare of trees, shrubs and climbers (Fig. 3).

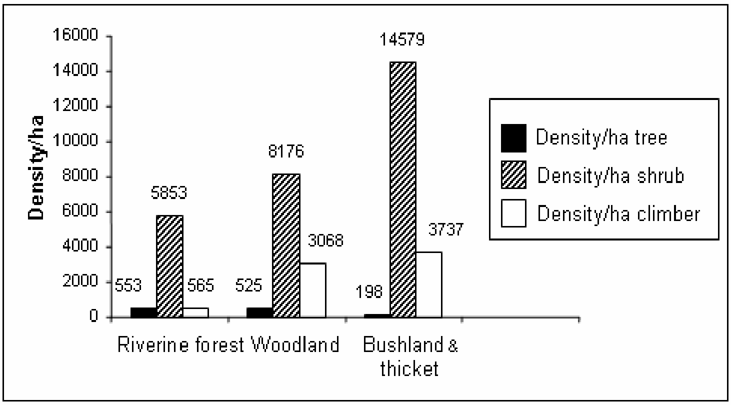

Fig. 3. Density ha^{-1} of trees, shrubs and climbers in the three-formation types.

Basal Area (BA) and Importance Value Indices (IVI) of woody species

The total BA of the woody species in the study area was 17.8 m^2/ha. The highest proportion of the mean BA was covered by *Acacia robusta* (7.01m^2/ha), followed by *Tamarindus indica* (2.46 m^2/ha) and *Opuntia-ficus indica* (1.13 m^2/ha) (Table 6).

Out of the 67 woody species documented in this study area about 29 woody plant species had IVI > 1.0 (Table 6). The remaining 38 woody plant species had IVI < 1.0.

DISCUSSION

Floristic composition

The overall species richness of a given vegetation type can give a general impression of their diversity (Tadesse Woldemariam, 2003). In this regard, the species richness in the Erer valley was higher than the nearby valley, Daketa valley, which was reported to have 202 species belonging to 54 families (Demel Teketay, 1995), and Nechsar National Park, where 199 plant species belonging to 42 families were reported by Tamirat Andargie (2001). Fabaceae, Poaceae and Asteraceae were the three most dominant families having a total of 70 species that accounted for 30% of the floristic composition of the study area. The family Fabaceae contains drought tolerant, deciduous and spiny species that are well adapted to the prevailing drought conditions of the study area.

Community types

Community 1 and 2 are from the riverine forest. Expansion of agricultural activities, tree cutting, and over-browsing were the serious impacts affecting these communities, yet, these two community types were important features of the sanctuary.

Community 3, 5 and 6 are from the woodland formation type. The sampled quadrats from 5 different sites of the woodlands were clustered into three groups forming three plant communities that showed the internal heterogeneity in the woodland of the study area. Soil, altitude, surface feature and anthropogenic factors might contribute for the difference in species composition among these community types.

Community 4 is from the bushland and thicket that occupies the largest part of the sanctuary. This community was stratified as bushland and thicket formation type at the beginning of the study. All the quadrats from 4 different sites of the bushland and thickets were clustered into one group forming one plant community where the two dominant species were *Acacia senegal* and *Acalypha fruticosa.* This might be due to the internal homogeneity in the bushland and thicket. Even these most dominant species in this community were observed in all community types with different densities. This may show the expansion of this vegetation type in the study area which may lead to the formation of homogeneous vegetation stand throughout the sanctuary.

Sorensen's similarity coefficient analysis indicated that there was high similarity between communities 1 and 2, followed by communities 3 and 4, and communities 5 and 6 (Table 4). This could be due to the more number of common species between these pair of communities.

Species diversity

The overall species diversity value showed high value which indicated high diversity in the study area. However the evenness was less. Lower evenness indicates the dominance of few species in the area (Feyera Senbeta, 2006). Accordingly, species of *Opuntia stricta, O. ficus-indica, Acalypha fruticosa, Acacia senegal, A. mellifera* and *A. brevispica* were highly dominant. Diversity and evenness of species in plant communities was used to interpret the relative variation of the community indices and explain the underlying reasons for the differences among communities. The six communities showed variation in their species richness, evenness and diversity (Table 2). This difference is the function of different factors like habitat heterogeneity, disturbance and edaphic factors which may contribute more for the difference.

The low species richness and evenness in community 1 and 2 may be due to the high-level disturbance factors. Similarly, Feyera Senbeta (2006) stated that the low species richness and evenness in the Maji forest was due to anthropogenic disturbances, such as burning, grazing, and wood collection. Accordingly, the highest agricultural expansion, tree cutting and over-browsing along the Erer River could be explaination for the reduction in the species richness and evenness in community types 1 and 2. The highest species richness and diversity was observed in community 3 where there was little agricultural activity and low human settlement. However, the selective cutting of trees may have resulted in unevenness in species distribution in this community.

The second highest species richness but less diversity and evenness were obtained in community 4. This shows the high level of disturbance in this community. For example, the least evenness could be explained in terms of the dominance of some species in the area. In community 4 species of *Acacai senegal, Acalypha fruticosa* and *Acacia mellifera* were the most dominant. It might be the less palatable nature, dispersal mechanisms such as wind, and environmental factors contribute for the domination of these species in this community. However, as was observed during the field studies, in this community, very high population of livestock was seen browsing and more settlement villages were established. Therefore, the high-level disturbance that can lead to less evenness and diversity of this community could be the cumulative effect of these factors.

Communities 5 and 6 had high evenness and diversity but less species richness. High evenness in these communities indicates little dominance by any single species but repeated coexistence of species over all quadrats. Relatively lower species richness may be attributed for slope and surface features which influence run-off and drainage. These two communities are from the woodland where some parts are from the hillsides where the surface feature is rocky and sloppy. Due to inconvenience for settlement and agriculture, less human disturbance was observed in these communities. This might be the reason for the relative high evenness and diversity.

Woody species density

The difference in density of woody species between riverine forest, woodlands and bushlands could be attributed to the differences in size of the woody species in these three formation types. Large sized trees and shrubs were recorded from the riverine forest (Communities 1 and 2). Medium sized woody species were recorded from woodland formation types (Communities 3, 5 and 6) where most tree species lost high DBH classes due to exploitation.

The bushland and thicket (community 4) is dominated by small sized woody species that contributed for the highest density of individuals per hectare. The least density of the most important tree species like *Tamarindus indica, Balanites aegyptiaca, Berchemia discolor, Acacia albida, Acacia etbaica, Sterculia africana, Salvadora perisca, Commiphora erythraea, Acacia nilotica* and *Combretum molle* could be due to selective exploitation for their multipurpose value by the local communities. Whereas the highest densities of small sized shrubs and climbers such as, *Opuntia stricta, Acalypha fruticosa, Acacia brevispica* and *Acacia senegal* could be due to the less palatable or unpalatable nature of these plant species by both livestock and elephants in the sanctuary. Another most probable factor may be specialization of the different species to different dispersal agents. Some plant species may have a wide range of dispersal mechanisms and/or rapid reproduction strategies. In general, in the study area, stochastic processes most likely determined the dominance of these species.

Basal Area (BA) and Importance Value Index (IVI) of woody species

The normal value of basal area for virgin tropical forests in Africa is 23 – 37 m^2 ha^{-1} (Lamprecht, 1989). Therefore, it could be said that the basal area ha^{-1} coverage of the study area is less. About 80% of the dominance was accounted by ten woody species. These are *Acacia robusta, Tamarindus indica, Opuntia ficus-indica, Acacia bussei, Terminalia brownii, Acacia tortilis, Balanites glabra, Acacia seyal, Berchemia discolor* and *Balanites aegyptiaca* (Table 6) where their density is 566 individuals ha^{-1} or only 2.2% of the total density of woody species. These tree species are the top browsed species by elephants as well as among the multipurpose woody species. Perhaps it is due to their relatively high dominance value in the sanctuary that these species afforded the higher feed demand of the elephants and livestock. However, if the current anthropogenic threat on these tree species continues, their density will lower down and then their dominance cannot be able to support the highest feed demand of the resident elephants.

The Importance Value Index (IVI) is useful to compare the ecological significance of species (Lamprecht, 1989). Trees and shrubs with IVI > 10 could be considered as an important species in the BES with respect to ecological management plan for intervention. Most multipurpose woody species like *Acacia tortilis, Acacia bussei, Balanites aegyptiaca, Berchemia discolor, Commiphora erythraea,* and *Acacia etbaica* resulted in IVI < 10. Their lower IVI may indicate that these woody species are threatened and in need of immediate conservation measure. About 57% of the woody species in the study area had IVI < 1 that can indicate the significance of initiating conservation measure in the sanctuary.

In general, the floristic analysis revealed that there was high species richness in the study area. However, as an elephant sanctuary, the densities and BAs of woody species were less. Shrubs were found to be more dominant than trees which may not be able to support the highest feed demand of the residing elephants. Moreover, investment pressure, uncontrolled agricultural expansion, human settlement, invasive species and excessive tree cutting could lead to an irreversible change in the function of this natural vegetation.

Therefore, management action should be developed to reverse or at least to stabilize the present trend in the sanctuary. For rehabilitation and proper management of the area, soil seed bank study, phenology, and seed ecology (seed production, dispersal, germination and predation) are required. Since rehabilitation of the vegetation is possible through natural regeneration, knowledge on the composition and density of the soil seed bank, status and pattern of seedling recruitment, and population distribution is very important. Rehabilitation could be achieved through artificial methods such as direct sowing, enrichment planting and direct planting.

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