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FLORISTIC COMPOSITION AND COMMUNITY ANALYSIS OF WOODY PLANTS IN HALLIDEGHIE WILDLIFE RESERVE, NORTH-EAST ETHIOPIA

***ADDISU ASEFA,[1] ALI SEID[2] AND AHMED ENDRIS[1, 2]**
[1]Ethiopian Wildlife Conservation Authority, Addis Ababa, Ethiopia
[2]Bahir Dar University, College of Science, Department of Biology, Bahir Dar, Ethiopia
* Corresponding author: Email: aa.mitiku@gmail.com

Abstract
This study was conducted in the Hallideghie Wildlife Reserve (HWR), North-East Ethiopia, with the aim to describe woody species composition and community types in the area. Vegetation data were collected from 66 (20 m × 20 m) plots established along five transect lines that were stratified across major vegetation types. Community types were identified using cluster analysis, and species richness, evenness and diversity were computed and compared among community types. A total of 53 woody plant species belonging to 32 genera and 16 families were identified. Fabaceae, with 16 species (~30%) and seven genera (22%), was the most dominant woody plant family in the reserve, while the majority of the families were represented by one or two species and genera. Five community types were identified in the reserve, which not only differed in their species composition, but also in their species richness, evenness and Shannon diversity. These findings may indicate that the different community types have been subjected to varying types and levels of abiotic and biotic factors. Prosopis juliflora, an invasive alien species, appeared to be one of the most dominant woody species, at least, in two of the five community types, indicating that this species is, and will be, likely posing serious threats to vegetation and ecosystem of the reserve. In conclusion, this study has provided the first useful ecological information on vegetation composition and diversity in the HWR that would serve as an input for management decisions.

Key Word: *Conservation, Diversity, Invasive species, Prosopis juliflora, Semi-arid savanna, Threat*

Introduction

Tropical forests and woodlands are the most species-rich terrestrial ecosystem on Earth, supporting up to 70% of plant and animal species, but are being lost at an alarming rate due to ever-increasing human populations and corresponding land use changes (Pimm *et al*., 1995; Game *et al*., 2013). Such unprecedented rate of deforestation results in rapid transformations in plant and animal communities, which drastically alters ecological processes and adversely impacts human societies (Pimm *et al*., 1995; Lemenih and Tadesse, 2010). Consequently, having adequate ecological information on patterns in distribution and diversity of plant and animal species and their responses to natural and human disturbances is an important step to enable managers make effective decisions related to mitigation of such human-induced impacts on biodiversity (Game *et al*., 2013).

Although Ethiopia has been recognized as the centre of diversity and endemism of floral and faunal species, the country has been facing serious conservation challenges (Soromessa *et al*., 2004; Awas, 2007). Ethiopia's human population growth rate is among the highest in the world, currently estimated at 2.6% per year (World Bank, 2013), causing rapid and widespread conversion of natural habitats for settlements, cultivation, livestock grazing and charcoal and firewood harvesting (Campbell, 1991; Asefa *et al*., 2015; Endris *et al*., 2017). Consequently, 18.6% reduction of forest cover was recorded only between 1990 and 2010 (FAO, 2010). Currently, relatively intact natural habitats are restricted to some legally protected areas such as National Parks, Wildlife Reserves and National Priority Forest Areas and in socio-culturally protected religious sites (Soromessa *et al*., 2004). However, as is true of protected areas of several tropical developing countries (Bruner *et al*., 2006), biodiversity conservation efforts in most of such legally designated Ethiopia's protected areas has been remained ineffective (Asefa *et al*., 2015).

Hallideghie Wildlife Reserve (HWR) was established in 1965 to conserve the remnant population of the globally endangered Gravy's zebra (*Equus gravii*) (Kebede *et al*., 2012). The reserve represents one of the few wildlife protected areas in Ethiopia where large populations of ungulates, such as Beisa oryx (*Oryx beisa*) and Soemmering's gazelle (*Gazella soemmeringi*) occur (Tadesse, 2009; Kebede *et al*., 2012). In addition to its significance for biodiversity conservation, HWR area is also the major seasonal communal livestock grazing land for the surrounding Afar and Somali pastoral communities (Tadesse, 2009; Kebede *et al*., 2012). Recognizing the biological and ecological importance of the reserve, it is currently proposed to upgrade its protection status to a National Park (Endris *et al*., 2017). Despite its immense importance, the reserve has been subjected to a number of conservation incompatible threats, including deforestation, unregulated livestock grazing, uncontrolled fire, invasion of alien plant species and native bush encroachment (Kebede *et al*., 2012; Endris *et al*., 2017). These threats, individually or interactively, are expected to lead to: i) decreased abundance and cover of ecologically and economically important native plant species, ii) change in overall species diversity and composition, and iii) promoted expansion of invasive alien species, particularly, *Prosopis juliflora* (Endris *et al*., 2017). Thus, having scientifically sound ecological information on vegetation of the reserve is particularly important for developing management plan that would ensure sustainable conservation of biodiversity and socio-economic status of the local communities through regulated natural resources use (Bleher *et al*., 2006; Bruner *et al*., 2006; Asefa *et al*., 2015). However, studies on vegetation diversity and composition of the reserve have been lacking. The specific objectives of this study were, therefore, to i) describe floristic composition of woody plants, ii) identify woody plant community types, and iii) assess species diversity and composition of the different plant communities in the HWR.

Materials and Methods

Study Area

The study was conducted in the Hallideghie Wildlife Reserve, which is located in the northern region of the Ethiopian Great Rift Valley (between 8°30' and 9°30' N, and 39°30' and 40°30' E) (Figure 1). The reserve covers an area of 1,832 km^2 and altitude ranges from 700 m to 945 m a.s.l (Kebede *et al*., 2012). The area is characterized by a semiarid ecosystem with annual rainfall ranging between 400 and 700 mm. The mean seasonal temperature ranges from 25 to 30°C, but the daily maximum temperature may be as high as 38°C in June, while the minimum daily temperature can drop to 15°C in December (Gemechu, 1977).

HWR is dominated by grassland plain with high mountains rising on the eastern border. The vegetation of the reserve consists of Acacia woodland, grasslands, bush/shrub land, reverie forest and deciduous woodland (Tadesse, 2009; Endris *et al*., 2017). In addition to hosting Ethiopia's largest population of the globally endangered Grevy's zebra (Kebede *et al*., 2012), HWR is home to ~31 and ~213 species of mammals and birds, respectively (EWNHS, 1996).

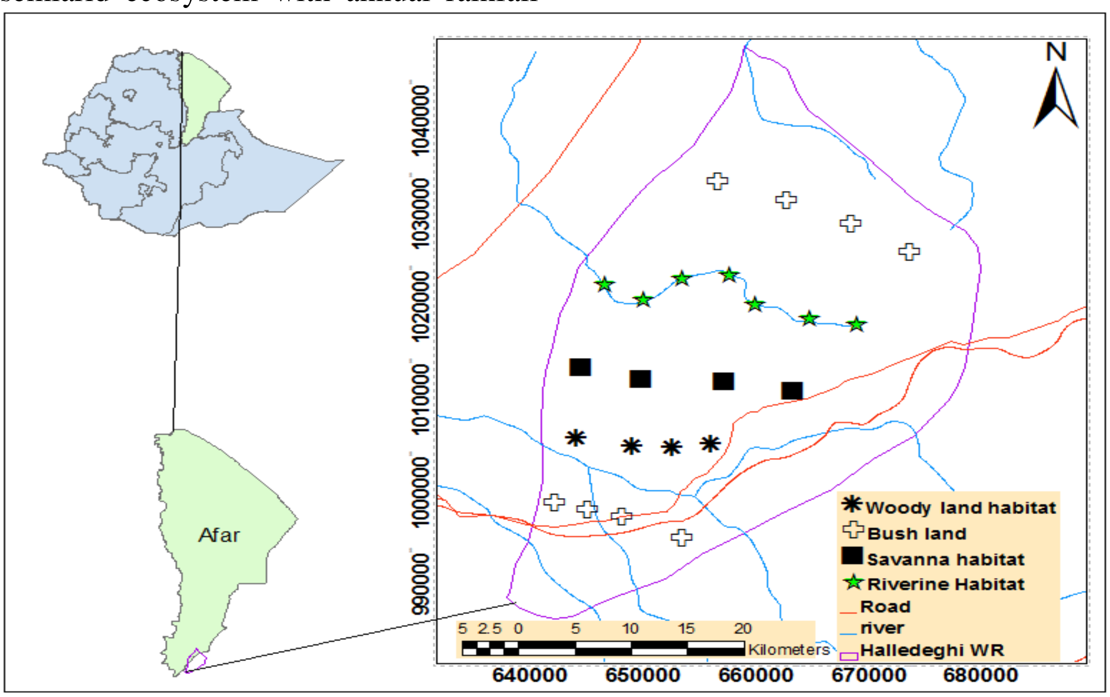

Figure 1: Map showing the location of the study area.

Data Collection

Field data were collected from 6 - 17 September 2015. A total of five line transects of about 2.4-3.0 km long were established systematically along altitudinal gradient and stratified across vegetation types so as to ensure that representatives samples were taken from all major vegetation types occurring in the area. Along each transect, twelve to fifteen 20 m × 20 m quadrates (totaling to 66 quadrates) were established at about 200 m distance interval for sampling tree species. The number of transects and quadrates sampled in each vegetation type were: one transect in each of the savanna woodland (12 quadrates), riverine forest (12) and deciduous woodland (15), and two transects in the bush/shrubland vegetation (27 quadrates). Within each main plot, five 5 m × 5 m subplots were set up, four at each corners and one at the centre, to collect data on shrubs and lianas and the mean values of these five subplots were usedfor analysis. GPS locations of each transect and quadrates were fed in to Garmin 60 GPS and used for navigation to sampling points.

In each sample plot, tree (with stem diameter at breast height >2 cm and height >1.5 m), shrub and liana species were recorded, and their number of stems counted and canopy cover visually estimated. Trees, shrubs and lianas were defined following the descriptions of Muller-Dombois and Ellenberg (1974) and Van der Maarel (1979). Altitude of each sampling plot was measured using Garmin 60 GPS unit. In addition, following Bleher *et al*. (2006) and Asefa *et al.* (2015), disturbance condition of the reserve was assessed by recording in each quadrate the presence and degree of different disturbance indicators (grazing/browsing, fuel wood collection, fire burning, charcoal production, etc). Species identifications were made both at field using Ethiopian floral guidebooks (Fichtl and Adi, 1994; Tesemma, 2007), and at The National Herbarium, Addis Ababa University, where collected voucher specimens were deposited.

Data Analysis

Floristic Composition and Diversity

As only three species of lianas were encountered across the entire quadrates they were combined with shrubs. Woody species diversity of the reserve and of each community type was determined using three different diversity indexes: species richness (*S*), evenness (*J'*), and Shannon diversity index (*H'*) (Magurran, 2004). The latter two indices were computed using the library package in R-program software, version 3.0.2 (The R Core Team, 2013). Species richness was computed using the software EstimateS (Colwell, 2012). Chao 2 richness estimator (that estimates total species richness of a particular area, including species might be present but not recorded during the data collection) was used to assess sampling completeness (Colwell, 2012). Preliminary analysis indicated that community types differed both in their sample sizes (between 9 and 17 quadrates; see Figure 3) and sampling completeness (from 58% for community type II to 94% for community type III). Thus, following Colwell (2012), extrapolation method (that minimizes the effect of such differences on species richness) was used to estimate and compare species richness at standardized sample sizes. Extrapolations were made up to twice the sample size of the community type with the largest sample size.

Identification of Plant Community Types

Data on estimated percent cover of each woody species in each quadrate were converted into modified 1-9 Braun-

Blanquet cover-abundance scale and used for community analysis (Van der Maarel, 1979). Hierarchical Cluster Analysis procedure in The R-program, version 3.0.2, software package (The R Core Team, 2013) was used to classify the woody plant species into community types. Sorensen`s similarity indexes were computed between each possible pair of the community types to determine the degree of similarities in their species composition. Then, analysis of similarity (ANOSIM) was conducted in Primer software to test whether the differences in species composition among the vegetation types were significant (Clarke and Gorley, 2006). In this analysis, Global R values were used to test the significance of dissimilarities between each pair of vegetation types; the closer the value of R value is to 1, the more dissimilar the two vegetation types are (Clarke and Gorley, 2006). Once the community types were identified and their distinctness was confirmed by the ANOSIM tests, then characteristic indicator species—species with high and significant indicator values—of each community type were identified using Dufrene and Legender’s (1997) indicator value analysis procedure in IndVal software. The naming of communities was made after two to three characteristic species with higher significant indicator values.

Results and Discussion

Overall Floristic Composition

A total of 53 woody plant species belonging to 32 genera and 16 families were identified in the study area (Endris *et al*., 2017). Output of Chao 2 richness estimator indicated the presence of 55 species in the reserve, suggesting that ~96% of the species present in the area were sampled and only 2 species (4% of total expected species) were missed during the data collection. Evenness and Shannon diversity indexes of overall species diversity of woody plants in the reserve were 0.77 and 2.91, respectively. These results show that the number of woody plant species in HWR is lower than what have been reported from other sites in Ethiopia, including from Nech Sar National Park (Shimelis *et al*., 2010), Awash National Park (Yohannes *et al*., 2013), Taltalle woodland (Lemessa, 2009), and Dollo Mena woodland vegetation (Didita *et al*., 2010), but higher than that from Dilfaqar National Park (Mekonnen, 2006) and Yangudi Rasa National Park (Beyene, 2010).

With 16 species (~30% of the total species), Fabaceae was the most species-rich woody plant family in the reserve, followed by Tiliaceae (8 species; ~15%), and half of the total families were represented by only one or two species (Table 1). Fabacae was also the most genus-rich plant family (contained seven genera; ~22% of the total genera) in the reserve, followed by Euphorbiaceae (four genera; ~13%) (Table 1). The high species richness of Fabaceae family in the present study area is in agreement with several previous reports from semiarid savanna ecosystem of Ethiopia (e.g. Beyene, 2010; Belayneh *et al*., 2011; Bekele *et al*., 2014) and these findings are attributed to the fact that family Fabaceae contains drought resistant, deciduous and spiny species that are well adapted to the prevailing drought conditions of the Rift valley region. The most species-rich genus was *Acacia* (9 species), followed by *Grewia* (8 species) and Ziziphus (3 species).

These three genera contained over one-third (38%) of the total species recorded in the study area, while nearly half (25 genera; 47%) of the total genera had only one species (Table 1).

In terms of growth form, trees and shrubs were represented by 14 (26% of the total species) and 37 (74%) species, respectively (Endris *et al.*, 2017). Out of the total woody plant species three were exotic: *Prosopis juliflora* (Fabaceae), *Parkinsonia aculeatea* (Fabaceae) and *Calotropis procera* (Asclepiadaceae). *P. juliflora* has particularly been claimed as a notorious invasive species and together with native encroaching species, such as *Acacia oerfota* and *Acacia mellifera*, are threatening natural ecosystems and pastoralists' life in the region (Tadesse, 2009). As a result of its superior competitive ability for nutrients and light reaching the grass layer, the disastrous consequences of *P. juliflora* on ecosystems have been reported to be reducing cover and diversity of grass and other native plant species (Kebede *et al.*, 2012; Endris *et al.*, 2017).

Table 1: Number (and percent) of genera and species represented in the top seven families (with >2 species) and number of species represented in the top seven genera (with >1 species) in the HWR.

Family					Genus		
Name	No. genera	Percent	No. species	Percent	Name	No. species	Percent
Fabaceae	7	22	16	30	*Acacia*	9	17
Tiliaceae	1	3	8	15	*Grewia*	8	15
Capparidaceae	3	9	5	9	*Ziziphus*	3	6
Euphorbiaceae	4	13	4	7	*Maura*	2	4
Rhamnaceae	2	6	4	7	*Cadaba*	2	4
Boraginaceae	2	6	3	6	*Solanum*	2	4
Solanaceae	2	6	3	6	*Balanites*	2	4
Sum	21	65	43	80		28	53

Plant Community Types

Results of the cluster analysis indicated five woody plant community types could be recognized in HWR (Figure 2); namely: *A. mellifera–A. oerfota*, *Acacia nilotica–Ziziphus pubescens*, *Acacia senegal - Ehretia obtusifolia*, *P. juliflora - Balanites aegyptiaca*, and *Dobera glabra-Grewia villosa*. Based on Sorenson's similarity index (SI), similarity in species composition among the community types ranged between 49% (between community type II vs III) to 78% (between community type I and V), with greater than 60% similarity index values for most (8 of 10) of possible pair-wise computations made (Table 2). Despite such considerable similarity in species composition among most of the community types, results of ANOSIM indicated that each community type were significantly different from one another in terms of their species composition (in all cases, Global R-values = 0.26-0.66, P <0.05; Table 2). These findings suggest that, although there were several species that were common to two or more community types, the community types identified by the cluster classification are valid and reliable inferences would be drawn from the subsequent community comparisons made.

Indicator values and degree of association of species to the different community types were presented on Table 3, and the five community types were briefly described in the following subtopics.

Table 2: Sorensen's similarity index values (in %; above the diagonal from top left to bottom right) and Global R values of the ANOSIM (below the diagonal) between each pair of the five woody plant communities in the HWR

Community type					
	Com. I	Com. II	Com. III	Com. IV	Com. V
Com. I		71	64	68	78
Com. II	0.63		49	59	75
Com. III	0.44	0.66		64	69
Com. IV	0.68	0.33	0.37		68
Com. V	0.5	0.59	0.26	0.66	

Note: All Global R values provided in the table show significant differences (at $P < 0.05$) between each possible pairs.

Community Type I: Acacia mellifera - Acacia oerfota

This community type was recorded in 17 sampling plots, between altitudinal ranges of 786 m and 925 m a.s.l (Figure 2). It occurs mainly at the northern and eastern part of the reserve in bush land and savanna habitats. *A. mellifera* and *A. oerfota* were the most dominant species of this community type, and hence these two species and *G. villosa* were found to be indicator species of the community type (Table 3). *P. juliflora* was swiftly invading vegetation of this community type, especially along valleys or sedimentary areas. This community forms one of the most disturbed woody plant communities of the reserve where the ground cover of the vegetation was mostly changed from grasses to unpalatable herbs.

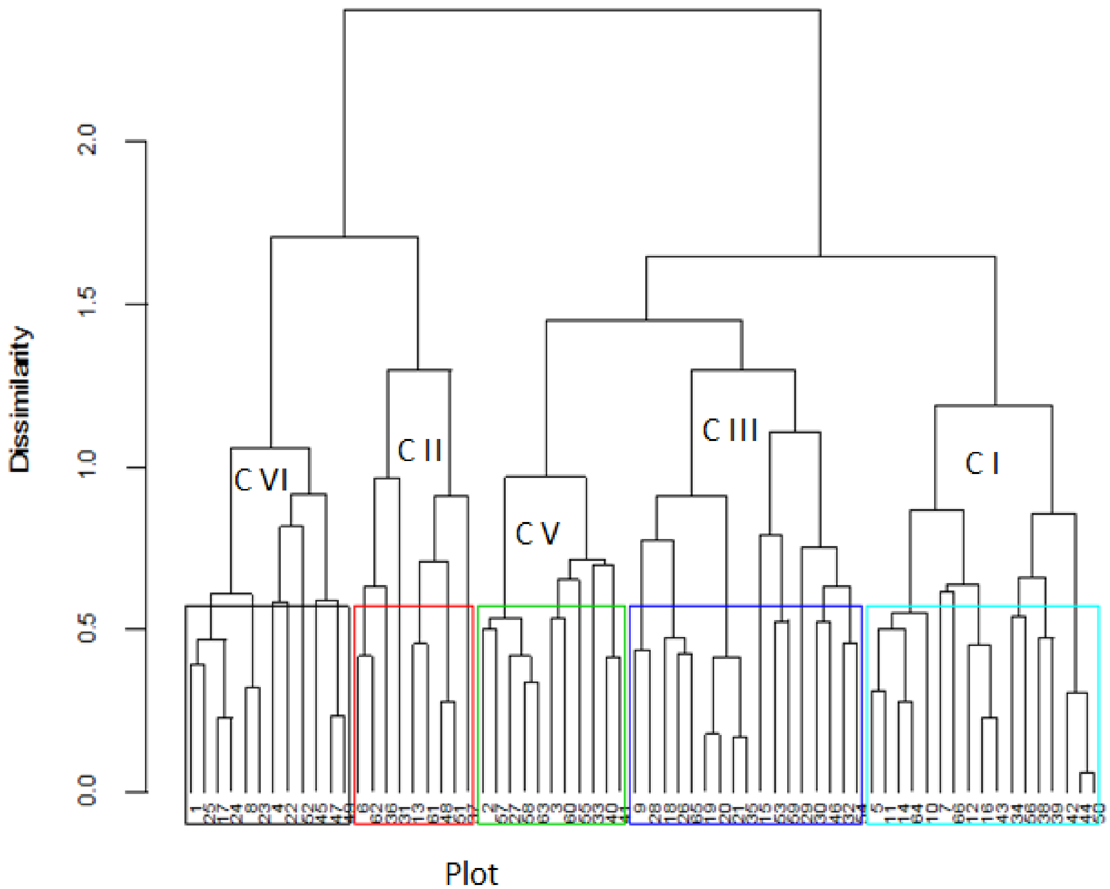

Figure 2: Dendrogram showing plant community types of the study area (C I = community type 1; C II = community 2; C III = community 3; C IV = community 4; C V = community 5).

Community Type II: Acacia nilotica – Ziziphus pubescens

This community type was recorded between 827 m to 917 m a.s.l., in 9 sampling plots (Figure 2). It occurred mainly in the southeastern and western sections of the reserve in the deciduous woodland and riverine habitat types. The community had five indicator species: *Acacia tortilis, G. villosa, Acacia abyssinica, C. tomentosa* and *G. bicolor* (Table 3).

Community Type III: Acacia senegal - Ehretia obtusifolia

This community type occurred mainly at the central part of the reserve, in the bush land and savanna habitat types where human-disturbances were relatively moderate. It was encountered in 17 sampling plots between altitudinal ranges of 785 m to 917 m a.s.l (Figure 2). The four dominant indicator species of this community were *A. senegal, A. oerfota, E. obtusifolia* and *C. rotundifolia* (Table 3). Other woody plant species found in association with this community were *G. bicolor, Grewia tanax, G. villosa, Berchemia discolor, E. abyssinia, Phyllanthus sp.* and *Jasminum abyssinicum.*

Community Type IV: Prosopis juliflora - Balanites aegyptiaca

This community type occurred between the altitudinal ranges of 834 m and 907 m a.s.l and recorded in 12 sample plots (Figure 2) in the northern and northwestern parts of the reserve, near the tar road taking Awash town to Djibouti, mainly in the savanna habitat type of the reserve. The four indicator species of this community were *P. juliflora, Acacia oerfata, B. aegyptiaca* and *A. senegal* (Table 3). *P. juliflora* has also been reported as one of the most dominant indicator species in the Dilfaqar, Yangudi Rasa and Awash National Parks (Mekonnen, 2006; Beyene, 2010; Yohanness *et al*., 2013).

Community Type V: Dobera glabra – Grewia villosa

This community type occurred in the western part of the reserve, near Awash Arba town, in the deciduous woodland habitat type. It was recorded in 11 plots (Figure 2) between altitude of 882 m and 914 m a.s.l. at sloppy areas where human activities, such as livestock grazing/browsing and tree/shrub cutting, were minimal. This community had three dominant indicator species, *G. villosa, G. tanax* and *D. glabra* (Table 3).

Table 3: Characteristic species of and their indicator values in each community type

	Communities				
Species	C I	C II	C III	C IV	C V
Acacia mellifera	**7.33**	3.18	1.12	0.56	4.71
Acacia oerfota	**3.25**	0.36	2.29	2.22	1.76
Prosopis juliflora	**2**	0.73	1.18	3.56	1.47
Grewia villosa	**1.67**	1.91	0.65	0.33	2.12
Acacia tortilis	**1**	6.73	2.24	4.11	0.53
Balanites aegyptiaca	**1**	0.45	1.12	2.89	1.18
Acacia tortilis	1	**6.73**	2.24	4.11	0.53
Acacia senegal	0.25	**3.45**	7.47	0	4.21
Acacia mellifera	7.33	**3.18**	1.12	0.56	4.71
Grewia villosa	1.67	**1.91**	0.65	0.33	2.12
Acacia abyssinica	0	**1.64**	0.35	0.78	0
Capparis tomentosa	0.42	**1.36**	0	1.56	1.06
Grewia bicolor	0.5	**1.18**	1.06	0.56	1.06
Ziziphus pubescens	0	**1.18**	0	0	0.53
Acacia nilotica	0	**1.09**	0	0	0
Acacia senegal	0.25	3.45	**7.47**	0	4.21
Ehretia obtusifolia	0.83	0	**2.53**	0.56	0.94
Acacia oerfota	3.25	0.36	**2.29**	2.22	1.76
Acacia tortilis	1	6.73	**2.24**	4.11	0.53
Cadaba rotundifolia	0.33	0.45	**2**	1.44	0.18
Prosopis juliflora	2	0.73	**1.18**	3.56	1.47
Acacia mellifera	7.33	3.18	**1.12**	0.56	4.71
Balanites aegyptiaca	1	0.45	**1.12**	2.89	1.18

Acacia tortilis	1	6.73	2.24	**4.11**	0.53
Prosopis juliflora	2	0.73	1.18	**3.56**	1.47
Balanites aegyptiaca	1	0.45	1.12	**2.89**	1.18
Acacia oerfota	3.25	0.36	2.29	**2.22**	1.76
Capparis tomentosa	0.42	1.36	0	**1.56**	1.06
Cadaba rotundifolia	0.33	0.45	2	**1.44**	0.18
Acacia mellifera	7.33	3.18	1.12	0.56	**4.71**
Acacia senegal	0.25	3.45	7.47	0	**3.21**
Grewia villosa	1.67	1.91	0.65	0.33	**2.12**
Acacia oerfota	3.25	0.36	2.29	2.22	**1.76**
Prosopis juliflora	2	0.73	1.18	3.56	**1.47**
Dobera glabra	0	0	0	0	**1.41**
Grewia tanax	0.17	0.55	0.76	0.44	**1.24**
Balanites aegyptiaca	1	0.45	1.12	2.89	**1.18**

Species Diversity of the Woody Plant Communities

Both observed (30 species) and estimated (based on extrapolation; 33 species) species richness values showed that community type I had the highest number of species, while the lowest number of observed species was in community type II (18 species) and lowest estimated richness in community type IV (24 species) (Figure 3). However, community type I had the lowest evenness index value (0.69), while community type II (0.95) had the highest. The highest (2.77) and lowest (2.34) Shannon diversity index values were found for community type V and community I, respectively (Figure 3). These results support the notion that using different suits of diversity measures enables one to better reveal existing real pattern of diversity across community types (Magurran, 2004). Magurran (2004) and Aye *et al*. (2014) pointed out that estimation of diversity of any biological community provides important information about the number of and the rarity and commonness of species in that community and to examine the underlying ecological processes that caused the observed patterns. For example, similar to the case of community I in the present study, higher species richness is usually the result of favorable environmental conditions that allow the co-existence of several species, while lower evenness arises from anthropogenic disturbances such as selective logging (Belayneh *et al*., 2011).

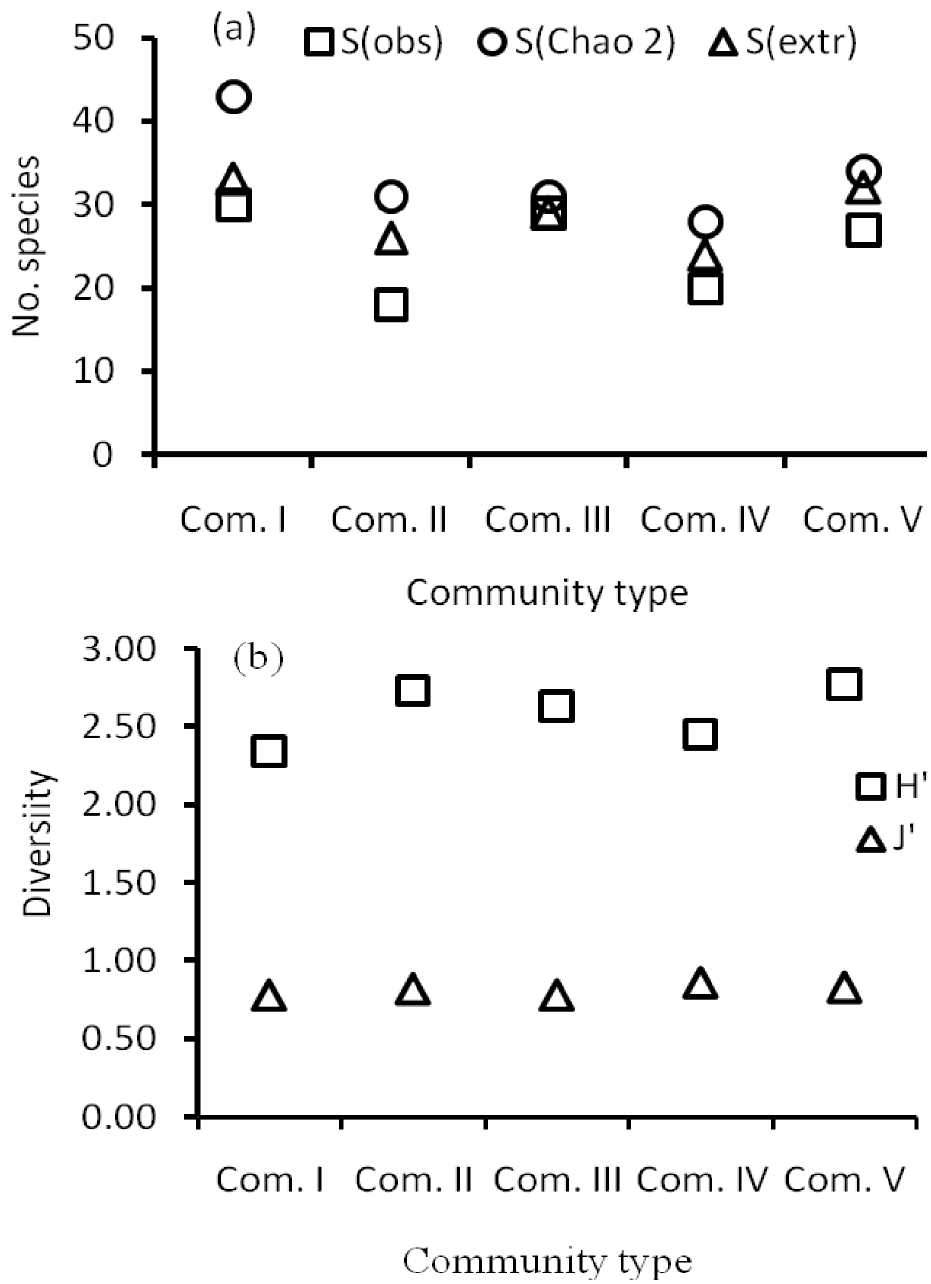

Figure 3: Species richness (a) and diversity (b) of the five woody plant community types identified in the HWR. Richness values presented were observed [S(obs)] and estimated based on Chao 2 [S(Chao2)] and extrapolated [S(extr], and for diversity were values of Shannon index (H') and evenness (J').

Conclusion

The considerable dissimilarity in species composition found among the communities is interesting from conservation point of view, because the different community types play complementary roles for the conservation of diverse species and ecosystem functioning and service provisioning of the reserve. Overall, this study has provided the first useful ecological information on vegetation composition and diversity in the HWR that would be used as an input for making effective management decisions related to conservation of the reserve. Despite the invaluable importance of reserve for biodiversity conservation and socio-economic development of the local communities, unregulated livestock grazing and browsing, rapidly expanding invasion of *P. juliflora*, and bush encroachment are becoming the most top threats to ecosystem of the area. Thus, urgent integrated management measures (e.g. how to regulate grazing use, eradication/controlling mechanisms for the invasive *J. juliflora*, etc) should be in place to promote sustainable conservation and utilization of the area.

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