



PATTERNS OF PLANT COMMUNITY FORMATION AND VEGETATION STRUCTURE IN THE AFRO-ALPINE VEGETATION OF SIMIEN MOUNTAINS NATIONAL PARK, ETHIOPIA

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ABSTRACT

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This study was conducted in Simien Mountains National Park, Northwest Ethiopia with the objective of evaluating the patterns of plant community formation and vegetation structure in the afro- alpine vegetation. The data were collected from stratified mountains by using systematic sampling in each stratum from October to November 2015. A total 62 (20 m x20 m) main plots were sampled. In each main plot five (1m x1m) subplots, one at each corner and one at the center, were used to collect data for herbaceous species. In each plot, data on plant species identity, abundance, height and Diameter at Breast Height (DBH) were recorded. Collected specimens were identified at field and also at National Herbarium, Addis Ababa University. Plant community analysis was performed using R version 3.1.3. Sorensen's similarity coefficient was used to detect dissimilarities among communities. Shannon - Wiener diversity index was computed to describe species diversity of the plant community types. Results showed that a total of 86 plant species representing 34 families and 63 genera were recorded from which 90.7 % were herbs, 7% shrubs and 2.3 % trees. Asteraceae is the species richest family whereas Poaceae is the dominant. Three plant community types were recognized from cluster analysis. Species richness, diversity and evenness varied among the plant communities. Analysis of population structure of the dominant species revealed various patterns. Because this afro-alpine area has varied habitat heterogeneity, separate plant community regimes need separate planning and implementing (management) measures for sustainability of the vegetation.

Contribution/Originality: This study contributes in the existing literature by providing basic information for other researchers regarding the patterns of plant community formation and vegetation structure in the afro-alpine vegetation of Simien Mountains National Park, Ethiopia. Moreover this study documents the patterns of plant community formation and population structures of the Simien Mountains National Park within the study period.

1. INTRODUCTION

Ethiopia is rich in vegetation diversification largely due to high range of altitudinal variation; ranging from 110 m below sea level at Dalol to 4543m above sea level at Simien Mountains National Park peak (Ras Dejen). Thus, the vegetation is extremely complex due to great variations in altitude resulting in great spatial differences in moisture regimes as well as temperatures (Zerihun, 1999). The country is one of the origin as well as center of

biodiversity and possesses six thousand to seven thousand vascular plants (Azene, 2007). Different authors studied Ethiopian vegetation at different times, and came up with different conclusions (Fichtl and Admasu, 1994; Azene, 2007; USAID, 2008; Kelbessa and Demissew, 2014). This shows that the enumeration of plant species and study of vegetation communities in the country is not yet completed. Recognition of plant communities helps in recommending appropriate management regimes for each community type, which helps in planning and implementing conservation strategies and sustainable utilization of plant resources. Plant communities show spatial and temporal heterogeneity across landscapes. Studying patterns and distribution of plant communities on landscapes is, thus, a crucial task. Besides, examination of patterns of population structures could provide valuable information about their regeneration and recruitment status that could be further employed for devising conservation and management strategies (Teketay, 2005).

In Simien Mountains National Park (SMNP), studies have been made for more than four decades as the park is one of the first established sites in the country. Most of the studies were on fauna when compared to flora. However, patterns of plant community formation in relation to species distribution and examination of patterns of population structures in the sub-afro and afro- alpine vegetation are not yet studied. So, the objective of this work was to assess the patterns of plant community formation and population structures in these vegetation areas of the Simien Mountains National Park.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

The Simien Mountains National Park (SMNP), where the study was conducted, is located in Northwest Ethiopia in Amhara National Regional State in North Gondar Administrative Zone (Fig.1). The park was established in 1966 following the recommendation or report of United Nation for Education, Science and Cultural Organization (UNESCO) mission sent to Ethiopia in 1965 (Amhara National Regional State, 2009).

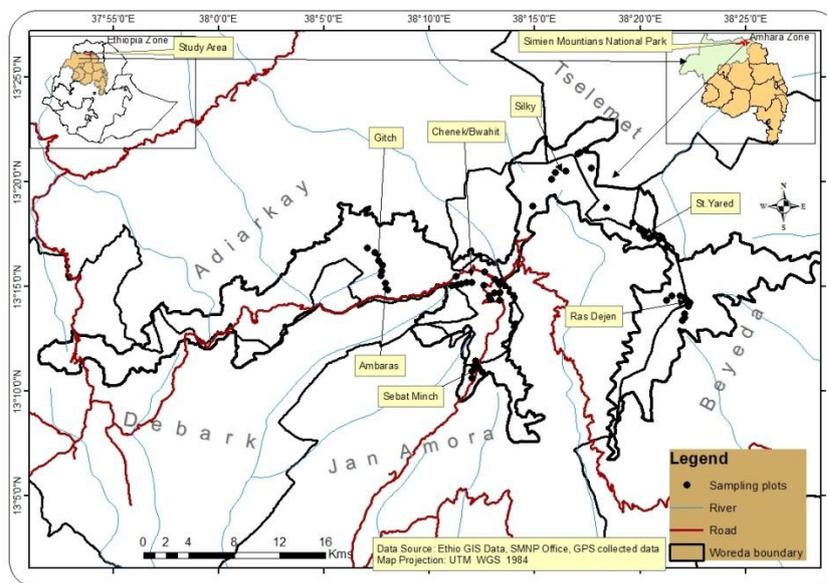


Figure-1. Map of the Study Area with Sampling Sites

Source: Center for Development and Environment, University of Bern, Switzerland, 2010 with amendment

The present SMNP extends from 37°51'26.36"E to 38° 29'27.59"E longitude and from 13°06'44.09 " N to 13°23'07.85" N latitude. The total area of the site is now about 412 km². The current altitudinal variation of SMNP is from 1900 m to 4543 m above sea level (ANRS, 2006). The former elevation range was 2600 m to 4400 m during the inscription of the site by UNESCO (ANRS, 2009). Because of this high range of altitudinal variation temperature and soil variations are high. The Climate of SMNP is characterized by a wet and dry season, with

about 75% of annual rainfall between June and September. Annual average rainfall of the area at about an elevation of 3600 m is around 1500 mm. Temperature is relatively constant throughout the year; however there is huge diurnal variation ranging from a minimum of -2°C to -4 °C at night to a maximum of 11°C to 18°C during the day (ANRS, 2009).

Soil types of the SMNP vary greatly, humicandosols being the dominant of the area. In the range of altitude 2500-3500 meter above sea level, shallow andosols and lithosols are commonly found. Soil types that occur below 3000 meter above sea level are haplicphaezems associated with cambisols and lithosols. Soils at steep slopes are largely degraded by erosion (Hurni, 1986). On the other hand, based on the study made by FAO (1982) characteristics soil types of the SMNP are lithic leptosols (42%), Eutriccambisols (31%) and Dystricpodzoluvisols (26%) and Humicnitosols (1%). The park was extremely degraded during the Italian invasion, frequent attack from Eritrea (Puff and Nemomissa, 2005) and during civil war. Latter, it became world site endangered in 1996 (ANRS, 2009). The main reason to be endangered was declination of wildlife population due to poaching and habitats restriction.

2.2. Vegetation Sampling and Specimen Identification

Vegetation was sampled systematically from seven stratified mountains during flowering time (mid October – mid November 2015) for ease of identification and to get herbs that would disappear during dry season. Taking samples was started being at the top of each stratified mountains in eight directions (North, Northeast, East, Southeast, South, Southwest, West and Northwest) at every 100 m elevation following the protocol of Tilahun *et al.* (2015).

Vegetation and terrain variable (slope, aspect and elevation) data were collected using 400 m² (20 m x 20 m) study plots. All plant species encountered in each sample plot were recorded using vernacular names and using codes. Slope, aspect and elevation were measured using Silva Clinometer, Rectal compass and Garmin 60 GPS respectively, at the center of each plot. To sample cover abundance of herbaceous species, five 1 m² (1 m x 1m) subplots were laid one at each corner and one at center of each main plot. Aspect was coded as follows N=0, NE=1, E=2, SE=3, S=4, SW=3.3, W=2.5, NW=1.3 and Ridge top=4. In the lower altitude (up to 3800 meter above sea level) where trees found, circumferences of all adult woody species (in each main plot) at breast height (about 1.3m) were measured and conversion to diameter at breast height (DBH) was made later. Adult woody plants with height greater than 2 m were measured using normal tape meter and clinometer respectively.

A total of 62 plots were laid and percent cover of all species was estimated and latter converted 1-9 modified Braun-Blanquet scale which is widely accepted scale because of better accuracy. Specimen identification was made at field level. Those plants which were not identified in the field were recorded by their vernacular names, collected, dried and pressed for latter identification using Honeybee Flora (Fichtl and Admasu, 1994) Flora of Ethiopia and Eritrea (Hedberg and Edwards, 1989; Hedberg and Edwards, 1995; Edwards *et al.*, 1997; Edwards *et al.*, 2000; Hedberg *et al.*, 2003; Mesfin, 2004; Hedberg *et al.*, 2006) and Plants of Simien (Puff and Nemomissa, 2005). Some specimens were identified by comparing with the authentic specimens in the National Herbarium, Addis Ababa University.

3. DATA ANALYSIS

3.1. Plant Community Analysis

Plant community type classification was determined by polythetic hierarchical agglomerative cluster analysis using statistical software R version 3.1.3. For the cluster analysis and subsequent characterization of the communities, abundance data of 62 plots and 86 species were used. Similarity ratio was used to determine the resemblance function and the Ward's method to minimize the total within group mean square or residual squares (Tongeren, 1995). The community types identified from the cluster analysis were further refined in a synoptic

table and species occurrences are summarized as a synoptic-cover abundance values (Maarel *et al.*, 1987). Dominant species of each community type were identified based on their synoptic values. Finally, the community types were named based on two dominant species.

3.2. Species Diversity Richness and Evenness Analysis

Species richness, diversity and evenness were analyzed using Shannon-Wiener indices.

$$H' = - \sum_{i=1}^S P_i \ln P_i$$

Where H' = Shannon diversity index, S = the number of species, P_i = the proportion of individuals or the abundance of the i^{th} species expressed as a proportion of total cover and \ln = log base n (Kent, 2012).

Evenness is calculated as: $E = H'/H'_{\text{max}}$ where E = evenness. Statistical software R version 3.1.3 was used for the diversity indices analyses.

3.3. Species Composition Similarity between Communities

Similarity of species composition among afro- alpine plant community was assessed by the help of Sorensen's similarity index ($S_s = 2a/2a+b+c$), where S_s = Sorensen's coefficient (index), a = number of species shared between communities, b = number of species found in the first community and c = number of species found in the second community (Kent, 2012; Zerihun, 2012).

3.4. Vegetation Structure

Analyses of vegetation structure were restricted in the lower altitude of the afro-alpine vegetation. Among the three plant communities the one located in the lower elevation (community 3) was with woody species in which structural analysis carried out. Tree DBH, height, density and frequency were used in the analyses of vegetation structure.

DBH was calculated from circumference of woody species measured by normal tape meter at height of 1.3 meter and converted to DBH by $D = C/\pi$, where D = Diameter, C = circumference and $\pi = 3.14$. Then it was categorized in to six classes (cm). Tree height was calculated in such a way that $H = D * \tan \theta + h_1$, where H = tree height, D = distance from tree to an individual who is measuring the tree top by a clinometer (observer), θ = angle from the observer to tree top and h_1 = the height of tree equal to the eyes of the observer. Then it was categorized in to five classes (m). Density was measured by count of woody species per 400m² then extrapolated to hectare (ha). Frequency was measured by species occurrence in each plot. Composition and structure of woody species were summarized using Excel spread sheet (2010).

4. RESULTS AND DISCUSSION

4.1. Floristic Composition in SMNP Afro-alpine Vegetation

The floristic analyses of the study area yielded 86 species (Appendix) distributed in 63 genera and 34 families; the species-richest family was Asteraceae (16 genera, 21 species), followed by Poaceae (7 genera, 11 species). Though Asteraceae had the highest number of species (Fig. 2), species belonging to Poaceae had high cover abundance, *Festuca sp.* being the most dominant. Such a distribution (high number of Asteraceae) was similar to the findings of Haile *et al.* (2008) in the afro-montane and afro-alpine areas of Bale Mountains and Getinet (2014) in SMSP. The dominance of Poaceae was also proved the findings by Puff and Nemomissa (2005) in SMNP.

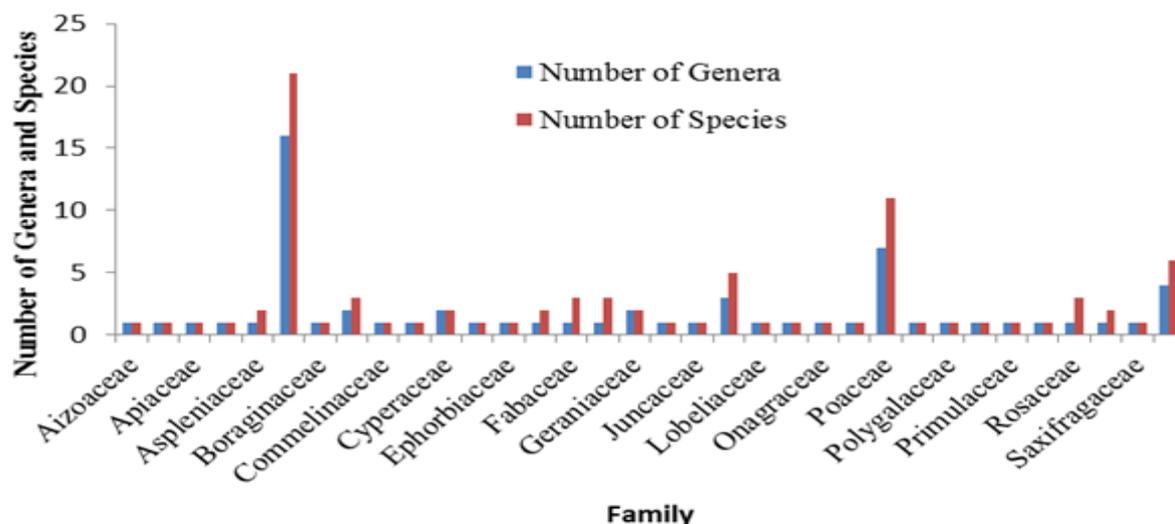


Figure-2. Family contribution of afro-alpine vegetation composition.

Source: Field Data:

The presence of high number of species of Asteraceae family could be due morpho-physiological adaptation in the harsh afro-alpine habitat. In addition, their phenology including timing of flowering for pollination and dispersal ability might help them to adapt.

The afro alpine vegetation was found to be dominated by herbs, which constituted about 90.7% followed by shrubs (7%) and the remaining (2.3%) were tree species. *Erica arborea* and *Hypericum revolutum* were the dominant tree species. This shows that the number of herbs increase when going up in the altitude range if not too high to be frequently frosted. When compared to the work of Haile *et al.* (2008) where herbs were 79%, shrubs 11% and trees 2.6% in the BMNP dry fromontane (in the altitude range of 3010-3410 meter above sea level), present finding showed herbs to be more abundant. Khan *et al.* (2011) also found that increment in herbaceous species was positively correlated with altitude in Pakistan. The Herbs mainly belonged to Poaceae and Asteraceae families. This indicates that species of these two families are cold and dry condition tolerant and adapted to the afro-alpine environments.

4.2. Afro- Alpine Plant Community Types

Hierarchical cluster analysis of the data set of the study area generated three plant community types from 62 plots and 86 plant species cover abundance (Fig. 3).The analysis was based on the synoptic abundance value of the species. Synoptic cover abundance value of each species was determined following synoptic cover abundance value determination procedure using R-statistical software package. The results of the analysis of the synoptic cover abundance values for the most important species are shown in table 1.

Table-1. Synoptic cover abundance value, bold with dominants greater than the value of 1

| | Cluster 1 | Cluster 2 | Cluster 3 |
|------------------------|-------------|-------------|-------------|
| Agrostissclerophylla | 6.40 | 0.22 | 0.00 |
| Agrostisquinquesta | 3.27 | 2.33 | 1.36 |
| Trifoliumcryptopodium | 2.67 | 1.97 | 2.45 |
| Helichrysumcitrispinum | 2.27 | 2.67 | 1.27 |
| Alchemillamicrobetula | 1.53 | 3.36 | 1.82 |
| Dianthoserisschimperi | 1.13 | 2.19 | 0.27 |
| Saturejasimensis | 1.13 | 0.36 | 2.91 |
| Cerastiumoctandrum | 1.00 | 1.42 | 0.64 |
| Andropogon lima | 1.00 | 0.44 | 2.64 |
| Saturejaabyssinica | 1.00 | 0.36 | 0.00 |
| Saginaafroalpina | 0.87 | 0.67 | 0.09 |
| Festucamacrophylla | 0.73 | 5.97 | 5.64 |
| Helichrysumsplendidum | 0.67 | 0.33 | 0.55 |
| Ranunculus oreophytes | 0.60 | 0.17 | 0.00 |
| Agrostisdiffusa | 0.47 | 0.53 | 0.45 |
| Lobelia rhynchopetalum | 0.40 | 1.86 | 3.27 |
| Cotulaabyssinica | 0.40 | 0.31 | 0.18 |
| Festucaabyssinica | 0.33 | 0.33 | 0.00 |
| Hypericumrevolutum | 0.33 | 0.00 | 1.00 |
| Thymus schimperi | 0.27 | 0.17 | 2.36 |
| Trifoliumacaule | 0.20 | 1.67 | 3.36 |
| Senecionanus | 0.20 | 0.56 | 0.00 |
| Swertialugardae | 0.20 | 0.31 | 0.18 |
| Alchemillapedata | 0.13 | 0.56 | 1.73 |
| Crassulaschimperi | 0.13 | 0.00 | 0.00 |
| Saxifragasp. | 0.13 | 0.00 | 0.00 |
| Bartsialongiflora | 0.07 | 0.42 | 0.09 |
| Salviamerjamie | 0.07 | 0.33 | 0.09 |
| Swertiaabyssinica | 0.07 | 0.33 | 0.09 |
| Ericaarborea | 0.07 | 0.19 | 6.45 |

Source: Field Data

The name of the community was assigned after two dominant species with highest mean cover abundance that represents the community types. The formulation of Cluster ID helped to know the distribution of plots in each community type (Table 2).

Table-2. Distribution of plots in the plant communities and average elevation

| Communities | Average Alt. | Plots in each community | No of plots |
|-------------|--------------|--------------------------------------|-------------|
| 1 | 4214 | 1-12,15-17 | 15 |
| 2 | 4138 | 13,14,18,19,24-45,47-53,55,56 and 62 | 36 |
| 3 | 3655.5 | 20-23,46,54,57-61 | 11 |

Source: Field Data

4.2.1. *Agrostis Sclerophylla*–*Agrostis Quinquesta* Plant Community Type

The lowest species distribution was found in this community type which was about 39 species (Table 3) and was the second in number of plots 15 (Table 2). This community type was found in the altitudinal range 3990 – 4438 meter above sea level with an elevation difference of 448 m. This community type was distributed in moderate slopes and alpine meadows.

Some of the dominant plant species in this community were *Trifolium cryptopodium*, *Helichrysum citrispinum*, *Alchemilla microbetula*, *Dianthoseris schimperi*, *Satureja simensis*, *Cerastium octandrum*, *Andropogon lima* and *Satureja abyssinica*. *Antherica sp* and *Salvia merjamie* were rare in this community. This plant community type and community type 3 were separated by type 2 in the middle.

4.2.2. *Festuca Macrophylla–Alchemilla Microbetula* Plant Community Type

This community type contained the highest number of plots 36 (58.06%) and was found in the altitudinal range 3724 – 4552 meter above sea level. The elevation difference was very high compared from the other two, which was about 828m and hence the number of species were very high in this community which was about 57. This community overlapped with the first plant community type in elevation and hence shared some more species with the first and few with the third plant community types. This shows that the plant community change was continuum as described by Smith and Young (1987).

The most representative plant species in this community were *Helichrysum citrispinum* which was dominant shrub in the study area, and *Dianthoseris schimperi*, *Cerastium octandrum*, *Agrostis quinquesta*, *Trifolium cryptopodium*, *Lobelia rhynchopetalum* and *Trifolium accaule* which were herbs found in a considerable abundance. *Polygala abyssinica* and *Erodium moschatum* were few of the rare species. This community type did not show clear transitional shift from type one since the elevation range was overlapped.

4.2.3. *Erica arborea–Festuca macrophylla* plant community type

This community was found in the altitudinal range 3508 – 3803 meter above sea level with an elevation difference of 295 revealing the narrowest range and most of the plots were favored to Northwest directions. Plant species in this community were distributed in lower altitudes of the afro-alpine vegetation and comprised of the least number of plots 11 (17.75%) (Table 2) and second number of species next to the second plant community type (Table 3). This plant community type showed clear transition from type two. The upper strata of this plant community types was covered by the tree species of *Erica arborea* and few individuals of *Hypericum revolutum*. The most dominant plant species that compose this community are *Trifolium accaule*, *Lobelia rhynchopetalum*, *Thymus schimperi*, *Alchemilla pedata*, *Andropogon lima*, *Satureja simensis*, *Alchemilla abyssinica*, *Hypericum revolutum*, *Agrostis quinquesta*, *Trifolium cryptopodium*, *Helichrysum citrispinum*, *Alchemilla microbetula* and *Thymus serulatus*. *Plantago lanceolata* and *Hedbergia abyssinica* were some of uncommon species in this plant community.

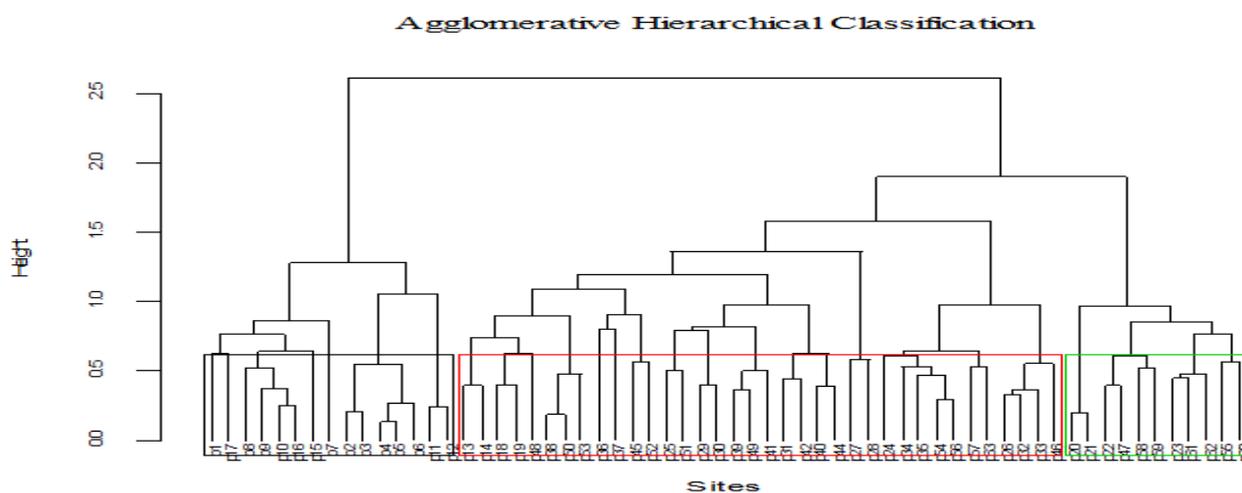


Figure-3. Dendrogram for afro- alpine plant community from Hierarchical Cluster analysis

Source: Field Data

4.3. The Afro- Alpines Plant Communities Richness, Diversity and Evenness

The richness, diversity and evenness of the plant communities in the study area were analyzed using Shannon - Wiener indices (Table 3). The second plant community type was the richest while the third community was evenly distributed.

Table-3. Richness, Diversity and Evenness Comparison of the plant community types

| Communities | Richness | H' | Shannon | Evenness |
|-------------|----------|------|---------|----------|
| 1 | 39 | 2.85 | 0.778 | |
| 2 | 57 | 3.15 | 0.780 | |
| 3 | 50 | 3.13 | 0.799 | |

Source: Field Data

Species diversity was high in the second plant community type due to wide elevation range. When altitude increases the species composition became poor as it is seen in the plant community type one. This type of species distribution was also revealed by the work of Khan *et al.* (2011) in the elevation range 2450-4100 meter above sea level in Pakistan.

4.4. Species Composition Similarities between Communities

Comparison between two communities was done at a time based on Sorensen's similarity coefficients (Table 4). Similarity coefficients indicated that the first plant community type and the second plant community type were more similar than the other two (59%). Thirty one species shared between the two communities with a combined difference of 43 species. The more shared and the less combined difference in species presence in these communities could be due to the overlap in altitudinal range. The first and the third plant community types did not have altitudinal overlap as a result of which the two communities shared the least number of species (highest dissimilarity). In these plant communities there were 21 shared species and a combined difference of 38 species.

Table-4. Communities species composition Comparison based on Sorensen's similarity index

| | C1 | C2 | C3 |
|----|------|------|------|
| C1 | 1.00 | 0.59 | 0.53 |
| C2 | | 1.00 | 0.56 |
| C3 | | | 1.00 |

C = community Source: Field Data

4.5. Vegetation Structure

There were woody plant species dominated by *Erica arborea* interspaced by *Hypericum revolutum* in ten plots; the rest 52 plots were occupied almost by herbs. In this study the tree line was found to be above 3800 meter above sea level. In some places, *E. arborea* and *H. revolutum* were found at 4100 in the form of shrubs. This finding confirmed the work of Jacob *et al.* (2014) where they have found tree line in tropical African highlands not to show shift except in SMNP. The tree line in SMNP is 3700 meter above sea level (ANRS, 2009). This could be probably due to global warming and park management improvement. The structure of the vegetation, in this case, is based on *E. arborea* and *H. revolutum*.

4.5.1. DBH

The DBH was classified into six categories from the measurements of 370 trees/ shrubs.

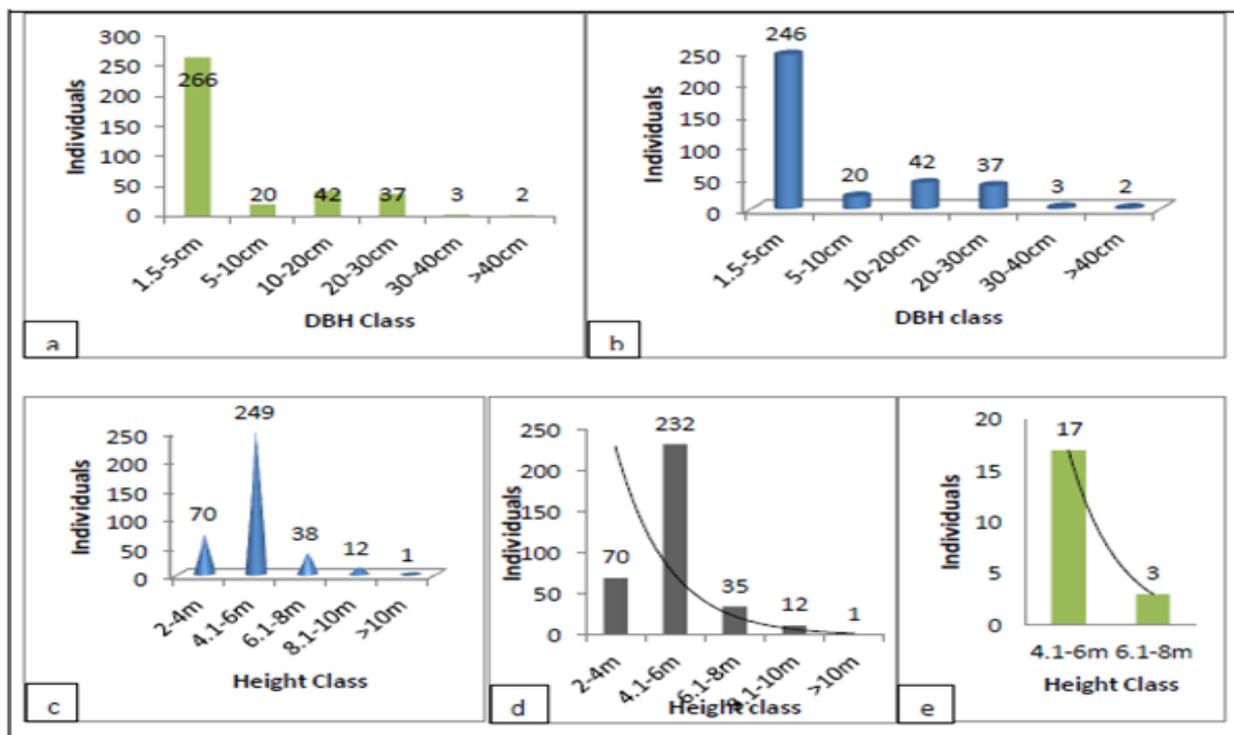


Figure-4. DBH and Height class distributions of *E. arborea* and *H. revolutum*

Source: Field Data

About 72% of the DBH lied under the category of 1.5 – 5cm (Fig. 4a). This could be due to the improvement of the park management in the last years after the conflict in the area got rid of. Together with this the global warming may played the role for plants to grow in the upper parts of the mountains. The DBH class of *H. revolutum* is found in only one class which was the lowest group. In most of the study area this species is dominant in its seedling and sapling stages as can be clearly seen from previously farmed plots of lands and even in farming lands. But later became dominated by *E. arborea*. On the other hand the dominant species DBH class is a bit similar to the woody species class (Fig. 4.b).

4.5.2. Height

The height distribution was classified into five categories (Fig. 4.c). About 66.3% of the height distribution of the woody species is in the range of 4.1 – 6 m followed by the second largest class of 2 – 4 m which is about 18.9%. This indicates that the park is getting more forested in relation to the past times. The height of the plants increases when getting down till the impact of the villagers seen.

The height categories of *H. revolutum* fall in to two groups (Fig. 4.e). This species is found following streams and relatively in meadow (flat) areas. So the number is very few when compared to that of *E. arborea*. Because of this the structure is very different from that of woody species. This shows that the contribution of this species to the height distribution of the woody species is very little.

The height class of *E. arborea* is a bit similar to that of woody species height class due to the dominance of this species (Fig. 4.d). About 94.6% of height was contributed by this species. This is because the species grows on the cracks of rocks and in most places that is not favorable for other woody species.

4.5.3. Density

In the upper most parts of the mountains the vegetation cover was very less and rather it was dominated by sandy soil and rock. This could be due to non-permanent snow cover that makes unfavorable condition for plants to grow up. Going down to the bottoms of the mountains the cover of herbs and shrubs increased. The most

frequently observed shrub species was *H. citrispinum* which is Asteraceae. Below the elevation of 4100m tree species in the form of shrubs (too dwarf) appear dominating down and at elevation of 3900m shows normal growth form.

For herbs, that dominate the upper most part of the afro-alpine vegetation, abundance cover was taken rather than count per area. Density was calculated for lower altitude of the study site where trees and shrub were measured for height and DBH. Three hundred seventy *Erica arborea* (being dominant) and *Hypericum revolutum* were measured for height and DBH in ten plots. Based on this, density analysis was made which was found to be 925/ha between the altitudinal range of 3500 – 3900 meter above sea level with DBH ≥ 1.5 cm and height ≥ 2 m. Density decreased going down to lower altitude which is not natural phenomenon but because of the pressure which was characterized by many stumps increased.

4.5.4. Frequency

The most frequent plant species was *F. macrophylla*, which occurred in 47 quadrates followed by *Alchemilla microbetula* occurred in 43 quadrates. In case of woody species, *E. arborea* was found to be more frequent which was found in 13 quadrates. The other tree species *H. revolutum* was found in 3 quadrates. Among the shrubs *H. citrispinum* was found to be the most frequent species. On the other hand the least frequent species were many that occurred in only one quadrate. Some of these species were *Antheri casp*, *Agrocharis melanantha*, *Rumex nepalensis* and *Polygala abyssinica*.

5. CONCLUSION

Compared to other similar afro-alpine vegetation, plant species composition, diversity and richness were found to be relatively higher. Such features could be due to terrain variables resulting in habitat heterogeneity which suit for different plant species association. In relation to other afro- alpine of Africa, woody plant species distribution in the study area is shifted up to the higher elevation. This could be largely due to management improvement of the protected area rather than global warming. As a result of the difficulty of the study area, a new species, which was difficult to be identified at the National Herbarium level properly but could be either *Conyza* or *Pulcaria sp.* that belonged to Asteraceae family was recorded which was not registered in the floristic region before. From this it can be inferred that further exhaustive botanical exploration would result in additional new records in the floristic region.

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Appendix: Afro-Alpine Plant species list of the study area

| Habit | Family | Species |
|-------|------------------|--------------------------------------|
| Herb | Apiaceae | <i>Agrocharismelanantha</i> |
| Herb | Poaceae | <i>Agrostisdiffusa</i> |
| Herb | Poaceae | <i>Agrostisquinquesta</i> |
| Herb | Poaceae | <i>Agrostissclerophylla</i> |
| Herb | Rosaceae | <i>Alchemillaabyssinica</i> |
| Herb | Rosaceae | <i>Alchemillamicrobetula</i> |
| Herb | Rosaceae | <i>Alchemillapedata</i> |
| Herb | Poaceae | <i>Andropogon lima</i> |
| Herb | Asteraceae | <i>Anthemistigrensis</i> |
| Herb | Anthericaeae | <i>Anthericasp</i> |
| Herb | Asteraceae | <i>Artemisia abyssinica</i> |
| Herb | Aspleniaceae | <i>Aspleniumaethiopicum</i> |
| Herb | Aspleniaceae | <i>Aspleniumprotensum</i> |
| Herb | Scrophulariaceae | <i>Bartsiadecurva</i> |
| Herb | Scrophulariaceae | <i>Bartsialongiflora</i> |
| Herb | Poaceae | <i>Bromusleptoclados</i> |
| Herb | Asteraceae | <i>Cardusnyassanus</i> |
| Herb | Asteraceae | <i>Cardusschimperi</i> |
| Herb | Cyperaceae | <i>Carexmonostachya</i> |
| Herb | Caryophyllaceae | <i>Cerastiumoctandrum</i> |
| Herb | Asteraceae | <i>Cineraria sebalzii</i> |
| Shrub | Asteraceae | <i>Conyzaspinosa</i> |
| Herb | Asteraceae | <i>Cotulaabyssinica</i> |
| Herb | Asteraceae | <i>Cotulacryptocephala</i> |
| herb | Crassulaceae | <i>Crassulaschimperi</i> |
| Herb | Commelinaceae | <i>Cyanotispolyrrhiza</i> |
| Herb | Cyperaceae | <i>Cyperusdichrostachyus</i> |
| Herb | Poaceae | <i>Deschampsiaflexuosa</i> |
| Herb | Asteraceae | <i>Dianthoserisschimperi</i> |
| Herb | Asteraceae | <i>Dicrocephalachrysanthemifolia</i> |
| Herb | Onagraceae | <i>Epilobiumstereophyllum</i> |
| Tree | Ericaceae | <i>Erica arborea</i> |
| Shrub | Ericaceae | <i>Erica tenuipilsa</i> |
| Herb | Geraniaceae | <i>Erodiummoschatum</i> |
| Herb | Ephorbiaceae | <i>Euphorbia Schimperi</i> |
| Herb | Poaceae | <i>Festucaabyssinica</i> |
| Herb | Poaceae | <i>Festucamacrophylla</i> |
| Herb | Poaceae | <i>Festucasimensis</i> |
| Herb | Rubiaceae | <i>Galiumacrophylum</i> |
| Herb | Rubiaceae | <i>Galiumsimensis</i> |
| Herb | Geraniaceae | <i>Geranium aculeolatum</i> |
| Herb | Asteraceae | <i>Gnaphaliumtweediae</i> |
| Herb | Asteraceae | <i>Haplocarpharuppellii</i> |
| Herb | Asteraceae | <i>Haplocarphaschimperi</i> |
| Herb | Scrophulariaceae | <i>Hedbergiaabyssinica</i> |

| | | |
|-------|------------------|-------------------------------|
| Shrub | Asteraceae | <i>Helichrysumcitrispinum</i> |
| Shrub | Asteraceae | <i>Helichrysumhorridum</i> |
| Herb | Asteraceae | <i>Helichrysumsplendidum</i> |
| Tree | Hypericaceae | <i>Hypericumrevolutum</i> |
| Herb | Asteraceae | <i>Inulaconfertiflora</i> |
| Herb | Asphodelaceae | <i>Kniphofiafoliosa</i> |
| Herb | Lobeliaceae | <i>Lobelia rhynchopetalum</i> |
| Herb | Poaceae | <i>Loliumsp</i> |
| Herb | Juncaceae | <i>Luzulaabyssinica</i> |
| Herb | Malvaceae | <i>Malvaverticillata</i> |
| Herb | Boraginaceae | <i>Myosotisvestergrenii</i> |
| Herb | Oxalidaceae | <i>Oxalis procumbens</i> |
| Herb | Poaceae | <i>Poaannua</i> |
| Herb | Plantaginaceae | <i>Plantagolanceolata</i> |
| Herb | Polygalaceae | <i>Polygala abyssinica</i> |
| Herb | Primulaceae | <i>Primulaverticillata</i> |
| Shrub | Asteraceae | <i>Pulicariasp</i> |
| Herb | Ranunculaceae | <i>Ranunculus oreophytes</i> |
| Herb | Polygonaceae | <i>Rumexnepalensis</i> |
| Herb | Caryophyllaceae | <i>Saginaabyssica</i> |
| Herb | Caryophyllaceae | <i>Saginaafroalpina</i> |
| Herb | Lamiaceae | <i>Salvia merjamie</i> |
| Herb | Lamiaceae | <i>Saturejaabyssinica</i> |
| Herb | Lamiaceae | <i>Saturejasimensis</i> |
| Herb | Saxifragaceae | <i>Saxifragasp</i> |
| Herb | Dipsacaceae | <i>Scabiosa columbaria</i> |
| Herb | Asteraceae | <i>Seneciofresenii</i> |
| Herb | Asteraceae | <i>Senecionanus</i> |
| Herb | Aizoaceae | <i>Silenemacrosolen</i> |
| Herb | Asteraceae | <i>Sonchusmelanolepis</i> |
| Herb | Gentianaceae | <i>Swertiaabyssinica</i> |
| Herb | Gentianaceae | <i>Swertialugardae</i> |
| Herb | Gentianaceae | <i>Swertiaschimperi</i> |
| Herb | Lamiaceae | <i>Thymus schimperi</i> |
| Herb | Lamiaceae | <i>Thymus serulatus</i> |
| Herb | Fabaceae | <i>Trifoliummultinervae</i> |
| Herb | Fabaceae | <i>Trifoliumacaule</i> |
| Herb | Fabaceae | <i>Trifoliumcryptopodium</i> |
| Shrub | Scrophulariaceae | <i>Verbascumsp</i> |
| Herb | Scrophulariaceae | <i>Veronica abyssinica</i> |
| Herb | Scrophulariaceae | <i>Veronica glandulosa</i> |

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