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The impact of elevation and disturbance on plant communities of zerat forest, central Ethiopia

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Abstract
An ecological study was conducted in Zerat Afromontane Forest in North Showa Zone of Ethiopia. Systematic sampling was used to collect vegetation data from 66 sample plots of size 20 x 20 m. The altitude of each sample plot was measured using Garmin GPS. Anthropogenic disturbance in each plot was estimated using the following scales: 0 = no disturbance, 1 = slightly disturbed, 2 = moderately disturbed and 3 = highly disturbed. R statistical package was used to analyze the data. A total of 156 plants belonging to 67 families were identified. Cluster analysis revealed that there were three plant communities in the study area. Analysis of variance showed that plant distribution in Zerat forest was significantly related with altitude and disturbance. As disturbance has considerable influence on the plant communities, mitigation of disturbance should be one of the main measures that need to take into account in conservation planning in the study site.

Keywords: systematic sampling, altitude, disturbance, cluster analysis

1. Introduction

The Eastern Afromontane biodiversity hotspot is one of the 34 biodiversity hotspots, which was first recognized as globally important for species conservation [23] when the number of global hotspots was increased from 25 to 34. It includes mountain ranges in Eastern Africa and the Arabian Peninsula. The Eastern Afromontane biodiversity hotspot houses about 7600 plant species, of which more than 2350 are endemic. Ethiopian highlands, which belong to the Eastern Afromontane biodiversity hotspot, harbor an estimated 5200 plant species, of which at least 200 are endemic. Nearly 40 percent of the Eastern Afromontane biodiversity hotspot occurs in Ethiopia [3]. Thus, the Ethiopian highlands include part of the world's biodiversity hotspots but one of the most degraded ones [22]. The degradation of the highlands of Ethiopia is partly because of the fact that the majority of subsistence agriculture practicing population resides in the highlands.

Concerns about increasing loss of biodiversity and the resulting degradation of ecosystem services have stimulated several studies [26] specifically; a central concern of vegetation ecologists has been investigation of the factors that affect species distributions and community composition [25] and correlation of vegetation with environmental factors [7]. Various researchers [5, 33, 9, 1, 18, 4, 31] underscored that investigations on vegetation composition, distribution patterns and on the factors that account for plant distribution patterns is an important input for conservation planning. However, there is no study on impact of environmental and disturbance variables on plant distribution in Zerat Forest, Central Ethiopia. This study was therefore conceived to investigate the impacts of elevation and disturbance on plant communities of the study area.

2. Materials and Methods

2.1 Location of the Study Area

Zerat forest is found in Menz Mamma district in North Shoa Zone of Amhara Regional State of Ethiopia. The forest occurs within coordinates of 10º11′247″-10º12′707″N and 39º46′154″-39º46′992″E. The topography of the area is steep and dissected by ravines and gorges through which rivers and streams tumble down the eastern escarpment of the Great Rift Valley. The forest is found on very steep slopes in narrow valleys mostly facing to the East. The area is bounded by a steep escarpment of the Rift Valley in the East and low-lying agricultural areas of Menz in the West (Figure 1). The study area is characterized by bimodal rainfall distribution. The main rainy season is from June to September and the short rainy season is from February to April. The average annual rainfall and mean annual average temperature of the area is 1050 mm and 12.5^{0}C, respectively [10].

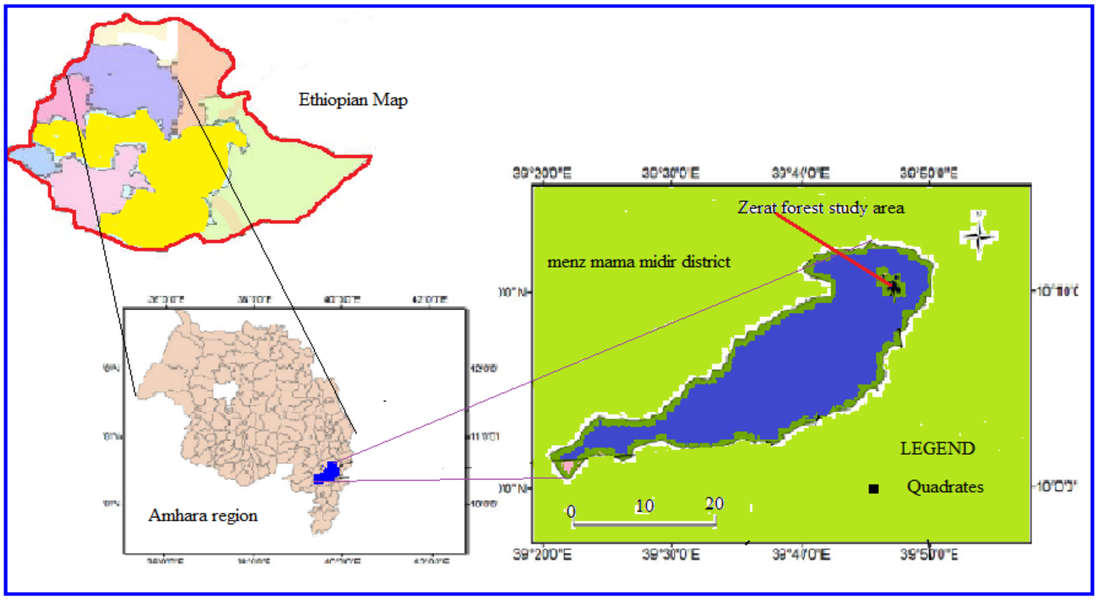

Fig 1: Map of the study area. 'A' shows location of Amhara regional state in Ethiopia. 'B' shows the location of Menz Mamma district in Amhara Regional State. 'C' shows the location of the study area in Menz Mamma district.

2.2 Sampling Technique

Systematic sampling was used to collect floristic and structural data. The first plot was located randomly at lowest altitude, and then the remaining plots were established at 50m intervals along altitudinal transect. Transects were spaced 1km apart. A total of 66 sample plots were established along transect lines. Plots of size 20 x 20 m (400m^2) were used for collection of floristic and structural data. From each 20 x 20 m plot, local name (or voucher specimen code if the local name was not known), height, number of individuals and cover abundance of all trees having DBH > 2 cm were recorded. The height, number of individuals and cover abundance of shrubs, younger trees and woody climbers with DBH 1.5-2 cm were collected from subplots of size 5 x 5 m which were laid at five different locations of the main plots. Within 5 x 5 m subplots, 2 x 2 m plots were laid to collect cover-abundance data of herbaceous plants [10].

Elevation and geographical co-ordinates were measured using Garmin GPS. Besides, the intensity of anthropogenic disturbance in each plot was estimated using the following scale: 0 = no disturbance, 1 = slightly disturbed, 2 = moderately disturbed and 3 = highly disturbed. Cover-abundance values were estimated using the modified Braun Blanquet scales [37].

Voucher specimens were collected for all plant species and were identified at National Herbarium (ETH). The nomenclature of the plants was based on the published volumes of the Flora of Ethiopia and Eritrea [13, 15-17].

2.3 Data Analysis

Classification and ordination methods were used to describe vegetation types and to examine the relationship between vegetation types and environmental variables. R statistical package [29], was used for cluster and ordination analysis. Indicator species analysis was performed to find indicator species characterizing the communities. Indicator species analysis was performed in R using package labdsv [10, 32]. Box plots and analysis of variance were used to assess the relationships between plant communities and elevation as well as disturbance intensity.

3. Results and Discussion

3.1 Floristic Composition and Plant Communities of Zerat Forest

One hundred fifty six plant species belonging to 67 families were identified in the study area. Asteraceae is the most dominant family in the study area. Similarly, [34] reported the dominance of Asteraceae in dry afromontane vegetation of Ethiopia. Fabaceae, Lamiaceae and Euphorbiaceae were represented by equal number of species in the study area. Families such as Poaceae, Rosaceae, Cyperaceae, Polygalaceae, Rutaceae, Boraginaceae, Oleaceae, Apocynaceae, Rubiaceae, Scrophulariaceae, Solanaceae and Myrsinaceae were also represented in the flora of the study area [10]. Cluster analysis revealed that there were three plant communities in the Zerat Forest which are shown in Figure 2. Similarly, nonmetric multidimensional scaling (NMDS) resulted in an ordination diagram in which the configuration of the study plots closely matches with the result of the cluster analysis as shown in Figure 3.

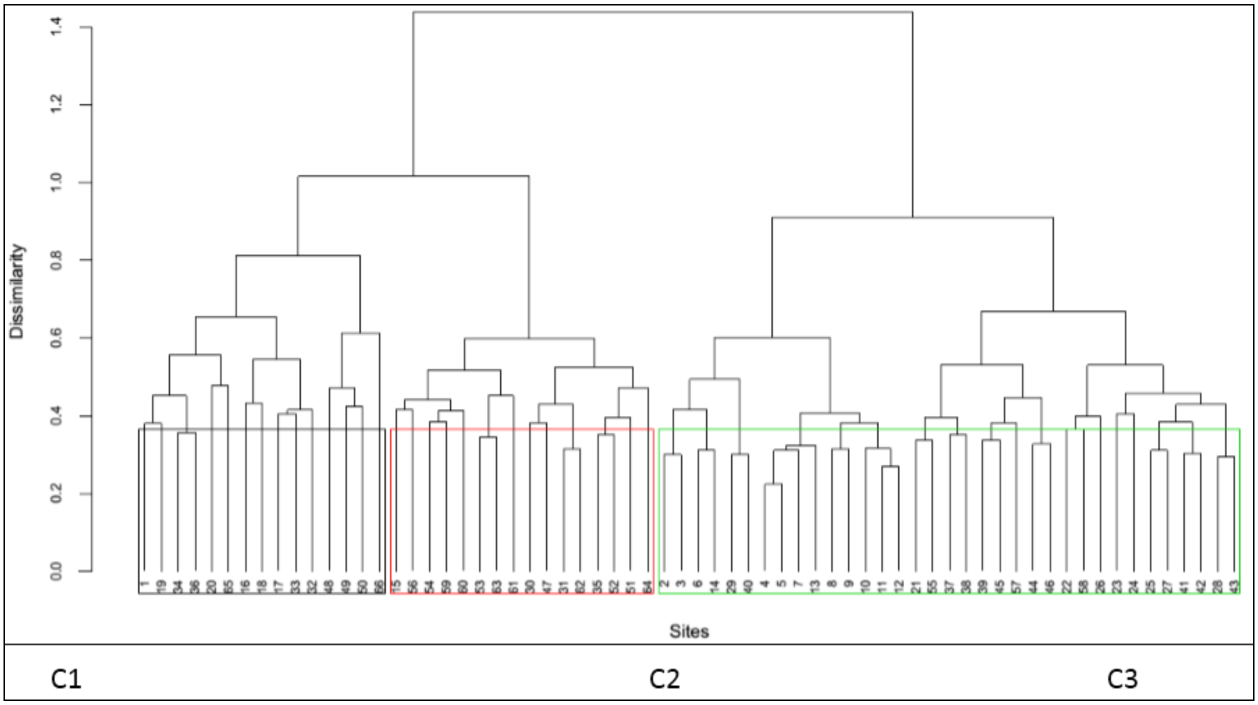

Fig 2: Denrogram showing plant communities in Zerat Forest. C1-C3 represents the three plant communities of the study area [10].

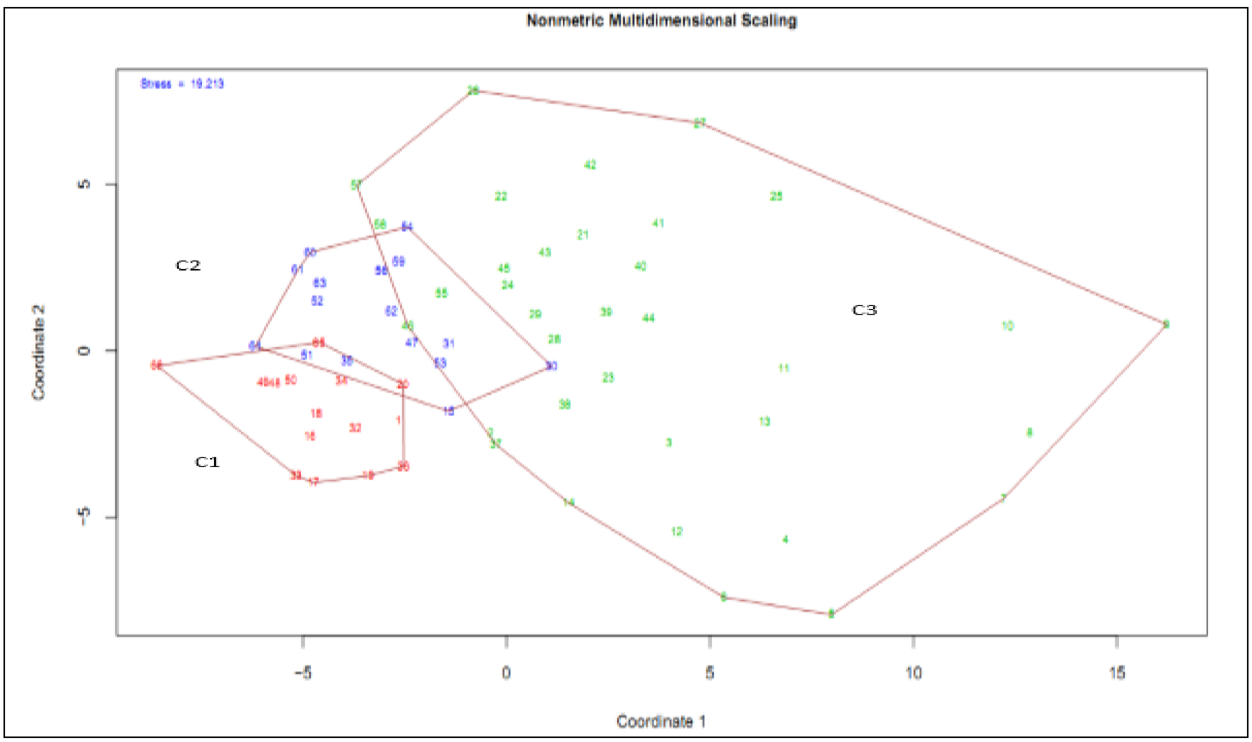

Fig 3: The configuration of the study plots in NMDS ordination diagram in which the three plant communities recognized in the study area distinctively shown. This configuration is based on floristic similarity of the plots.

The species with highest indicator values were used for naming the communities. Hence, the plant communities identified in the study area were: *Juniperus procera* community type, *Senecio gigas-Scorpiurus muricatus* community and *Maytenus obscura- Chenopodium album* community type were identified in the study area. Each of the communities has the characteristic / indicator species which are presented in Table 1 [10].

The species listed in Table 1 show strong preferential distributions in the communities identified by cluster analysis. The probability value gives the probability of finding higher indicator value and if this probability is low, the species is a significant indicator [12].

Table 1: Species with significant indicator values (in percentage) in each community. The indicator values of the species were considered as significant if the respective probability values were less than 0.05 [12].

Name of species	Community	Indicator value	Probability
Juniperus procera	1	30.72	0.040
Senecio gigas	2	58.97	0.001
Scorpiurus muricatus	2	58.51	0.001
Verbascum sinaiticum	2	57.01	0.001
Ricinus communis	2	53.51	0.001
Citrus aurantifolia	2	49.72	0.002
Buddleja polystachya	2	48.65	0.001
Euphorbia prostrata	2	48.52	0.001
Lippia adoensis	2	47.44	0.002
Maytenus obscura	3	45.2	0.004
Chenopodium album	3	40.61	0.020
Maesa lanceolata	3	25.95	0.027

3.2 The Relationship between Plant Communities and Elevation

Boxplots of the elevation of each plant community is presented in Figure 4. It shows that there is considerable variation in altitude amongst the plant communities of the study area. Hence, elevation has notable impact on plant community formation in Zerat Forest.

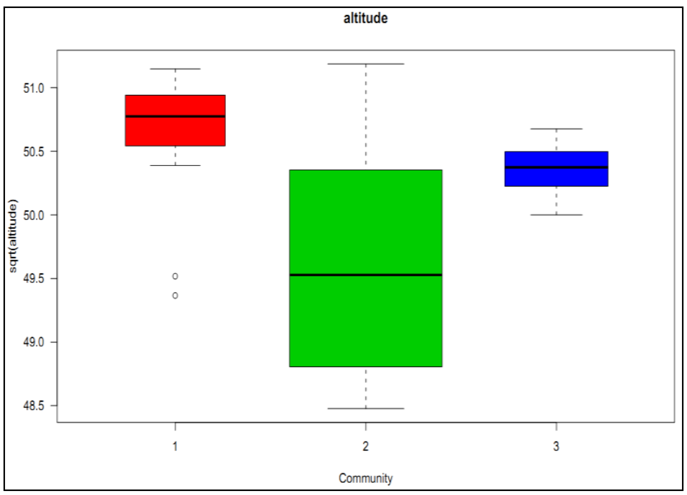

Fig 4: Boxplot of community types vs. elevation. The y-axis represents the square root of the altitude of the study plots.

The significance of variation in elevation of the plant communities was assessed using ANOVA and the result of analysis of variance is presented in Table 2.

Table 2: ANOVA result for altitude in relation to plant communities

Source	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Altitude	2	144661	72330	17.103	0.00
Residual	63	266427	4229		

The F-value in Table 2 is greater than 1 and the p-value is less than 0.05. Hence, the variability between the community means (in elevation) was greater than that we would expect by chance alone. If none of the communities had significant relation with elevation, then the variation in elevation between plots within a community could be the same as the variation in elevation between plots in different communities and hence F-value could nearly be 1. Therefore, the plant communities of the study area significantly differ in elevation. The implication is that altitude has considerable impact on distribution pattern of plant communities.

Several researchers discussed the relation between topographic variables and distribution of plant communities [8, 35, 6]. Topographic variables such as altitude cause a notable variation in species composition. This is because topographic variability causes an assortment of microhabitat variability [24] and hence are considered as major parameters in ecological specialization [2].

However, topographic variables do not have direct physiological influence on species unlike factors such as temperature and soil nutrients [30, 27, 19, 20]. For instance, altitudinal species distributions are due to factors which change in conjunction with altitude that include air pressure, temperature and precipitation that in turn determine the type of vegetation to be supported [27]. Furthermore, altitudinal change is also accompanied by changes in other environmental parameters such as soil texture, nutrients, etc which affect the structure and composition of the vegetation [30]. For example, [11] reported that the soils at higher elevations are poor in nitrogen and phosphorous which can have an impact on type of vegetation to be supported.

3.3 Relation between Disturbance and the Plant Communities

As it was the case for elevation, there was a considerable pattern of variation in disturbance between the plant communities of the study area (Figure 5).

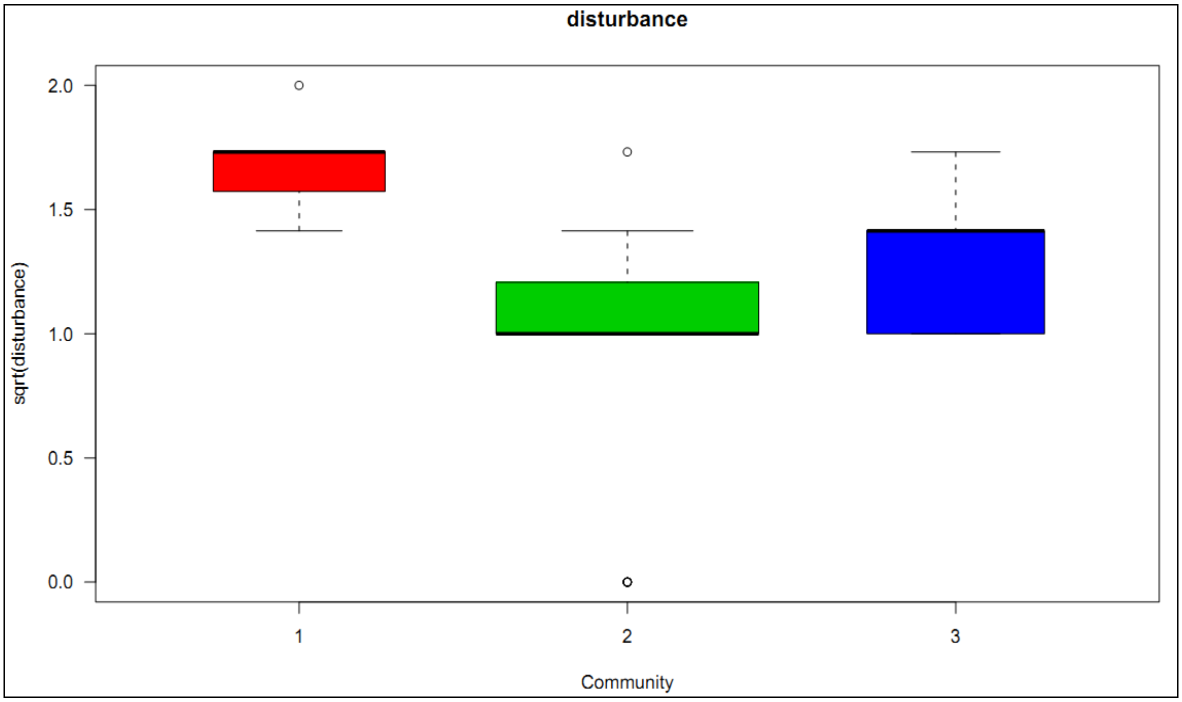

Fig 5: Boxplot of community types vs. disturbance. The y-axis represents the square root of disturbance values.

The significance of variation in disturbance amongst the communities was assessed using ANOVA and the result of analysis of variance is presented in Table 3.

Table 3: Analysis of variance table using disturbance as predictor.

Source	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Disturbance	2	30.950	15.4750	34.112	0.00
Residual	63	28.580	0.4537		

In Table 3, F-value greater than 1 and p-value less than 0.05. Hence, the variability between the community means (in disturbance) was greater than that we would expect by chance implying that disturbance has a significant relation with the plant community formations in the Zerat Forest.

The ANOVA revealed that disturbance has a significant role in plant community formation in the study area. Disturbance governs community patterns by altering the environment and resource distributions, creating enabling conditions for the establishment of new species or minimizing populations of established species [14, 25]. It influences the soil, nutrient and water conditions [28] which in turn determine the type of vegetation to be supported. Disturbance also alters the stability and diversity of ecosystems as it reduces invasion resistance while eliminating the buffering effect of high diversity [21]. Thus, disturbance affects plant distribution owing to its effect on resource and environmental conditions as well as its effect on invasion resistance.

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