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Research Article

Pattern of Plant Community Distribution along the Elevational Gradient and Anthropogenic Disturbance in Gole Forest, Ethiopia

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Vegetation-environment relationships are usually studied along elevational gradient. The patterns of plant community distribution in Gole forest, Ethiopia, were studied along elevational gradient and disturbances. Disturbances were recorded following the elevational gradient. For vegetation data collection, 62 sample plots of size 20×20 m were established along an elevational gradient (2728–3480 m.a.s.l). Data on species composition and environmental variables were measured and recorded in each plot. The elevation of each sample plot was measured using Garmin GPS. Anthropogenic disturbances in each plot were estimated using the following scales: 0 = no disturbance, 1 = slightly disturbed, 2 = moderately disturbed, and 3 = highly disturbed. *R* statistical package was used for cluster and ordination analysis. Boxplots and analysis of variance were used to assess the relationships between plant communities and environmental variables. Sorensen's similarity coefficient was used to detect similarities and dissimilarities among communities. A total of 114 plant species belonging to 57 families and 94 genera were identified. Five plant community types were identified using agglomerative hierarchical cluster analysis. Every plant community had differences in composition and environmental variables. The variation in plant community distributions was significantly related to elevation and disturbance. Plant community distribution was negatively correlated with elevation ($P < 0.05$) and also with disturbance ($P < 0.05$). Sorensen's similarity index showed that there was a difference in the distribution of plant species composition among the communities. The difference in plant community distribution of Gole forest was significantly related to elevation. Disturbances also have a considerable influence on the plant communities and mitigation of disturbance should be the main measure that needs to be taken into account in conservation planning in the study area.

1. Introduction

Vegetation-environment relationships are usually studied along gradients. The concept of environmental gradients has been a cornerstone in the development of ecological theory [1]. Spatial and temporal patterns of vegetation change are influenced by a multitude of factors, including physical environment, land use history, prior disturbance, and initial vegetation composition [2]. Species-environment relationships are the most important data needed to understand vegetation patterns on forest landscapes [3–5]. Plant species sharing similar environmental affinities occupy similar sites across the landscape [6]. Thus, the variation in plant communities and species diversity is linked to environmental gradients [7].

Elevation is one of the decisive factors shaping the spatial patterns of vegetation and species diversity. There is a significant relationship between community structure, composition, and species diversity with elevation gradient and other environmental variables [2, 8]. Different species of plants require different factors in order to survive [5, 9]. Mountain ecosystems around the globe are known for their high biological diversity and usually have distinct biological communities (i.e., plant community) and high level of endemism due to their topography [7].

The vegetation types of Ethiopia are highly diverse, ranging from afro-alpine to desert [10]. This is due to a great geographical diversity with high and rugged mountains, flat-topped plateaus, deep gorges, river valleys, and plains [11], which ranges from 116 m below sea level at Dallol

Depression (Afar) to the highest mountain, Ras Dashen (Gondar), 4,620 meters above sea level [10, 12]. In Ethiopia, elevation plays a major role in plant species diversity and floristic formations [10]. As elsewhere in the tropics, anthropogenic factors and an extreme climate have severely influenced the abiotic and biotic components of forest ecosystems [13].

The forest types and plant species distribution within the Eastern Afromontane biodiversity hotspot are relatively well known for the Eastern Arc Mountains in Kenya and Tanzania, but the montane forests of Ethiopia have so far been described mainly on the basis of herbarium specimens or qualitative field observations; only very few quantitative surveys exist [13]. The investigations of vegetation composition, distribution patterns, and other factors that account for plant distribution patterns are an important input for conservation planning. However, studies have not been made before on the type of plant communities and the factors governing the distribution of plant communities in Gole forest, Ethiopia. Therefore, the present study (1) identifies the type of plant community in Gole forest, (2) relates the distribution pattern of plant communities with an elevational gradient, (3) describes the impact of disturbance on plant community distribution, and (4) explores the impact of environmental (elevation) and disturbance variables on species richness.

2. Materials and Methods

2.1. Description of the Study Area. The study was conducted in Gole natural forest which is found in Dodola woreda, West Arsi Zone of Oromia Regional State, Ethiopia. It is located in the southeast part of the country, 320 km away from the capital city Addis Ababa. The study area is found between latitude 6°51′ and 6°53′ N and longitude between 39°11′ and 39°12′E, east of Dodola town in Deneba kebele. The area is characterized by undulating land features, including mountains, flat lands holding pastures and agricultural fields, and valleys having pasture fields. The altitudinal range of the study area is between 2728 and 3480 m.a.s.l (Figure 1). The study area is characterized by bimodal rainfall distribution with the main rainy season between June to September and the short rainy season during the months of March and April. The average annual rainfall is 855 mm and the annual average temperature is 17°C [14].

2.2. Methods.

2.3. Sampling Technique. Data on species composition and environmental variables were measured and recorded in each plot. Along with elevation gradients of 2728–3480 m.a.s.l, 62 sample plots having a design of size 20 × 20 m were established at a distance of 100 m between each plot along six transect lines, which was laid side by side starting from the top of the mountain. Vegetation data collection and sampling techniques were as stated in the work of Boehmer and Temam [14] that focus on species composition, structure, and regeneration status of Gole forest (http://www.alliedacademies.org/journal-agricultural-science-botany/ISSN: 2591-7897). To determine the environmental factors that govern the distribution of plant community types, elevation and geographical coordinates were measured using Garmin GPS at the center of each plot. The types of disturbances were recorded from each plot. The intensity of anthropogenic disturbance in each plot was estimated as a sum (cumulative effect) of the following parameters: Grazing/browsing intensity which was estimated based on the following scales: 0 = no disturbance; 1 = slight; 2 = moderate; 3 = heavily and 4 = destructive [15, 16], the number of trees and shrubs cut, the number of foot trails, and the number of seedlings trampled. Cover-abundance values were estimated using the modified Braun Blanquet scales [17].

2.4. Data Analysis. Classification and ordination methods were used to describe vegetation types and to examine the relationship between vegetation types and environmental variables. The ordination method expresses the relationships between samples, species, and environmental variables. The classification technique identified the discontinuities in the vegetation and delimited the stands into clusters having similar vegetation composition. This was supported by the significant contrasts found between clusters, as shown by Tukey's family error rate test. Vegetation data were analyzed using agglomerative hierarchical cluster analysis with similarity ratio as a resemblance index and Ward's linkage method to identify vegetation assemblages in plant community types. Similarity ratio is one of the similarity indices which measure the similarity or dissimilarity between vegetation samples or quadrats/plots. The choice of a distance measure is an ecological, not a statistical decision. Ward's linkage method uses analysis of a variance approach to evaluate the distances between clusters. This method attempts to eliminate the differences in total abundance among sample units. In addition, Ward's method minimizes the total within-group mean of squares or residual sum of squares [18].

R statistical package [19] 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 [20]. Boxplots and one-way analysis of variance (ANOVA) were used to assess the relationships between plant communities and elevation and plant communities with disturbance intensity. A square root (sqrt) is used to normalize the data, stabilize the variance, and give more power. Tukey's test was performed to detect significant differences among the different means of the environmental parameters of each community type. Sorenson's index of similarity (Ss) was computed to assess the floristic similarity between communities.

3. Results and Discussion

3.1. Floristic Composition. A total of 114 species of vascular plants, belonging to 94 genera and 57 families were recorded from 62 plots laid in the forest (Table 1). The families with the highest number of species were Asteraceae, represented by 21 species, followed by Acanthaceae (5 species),

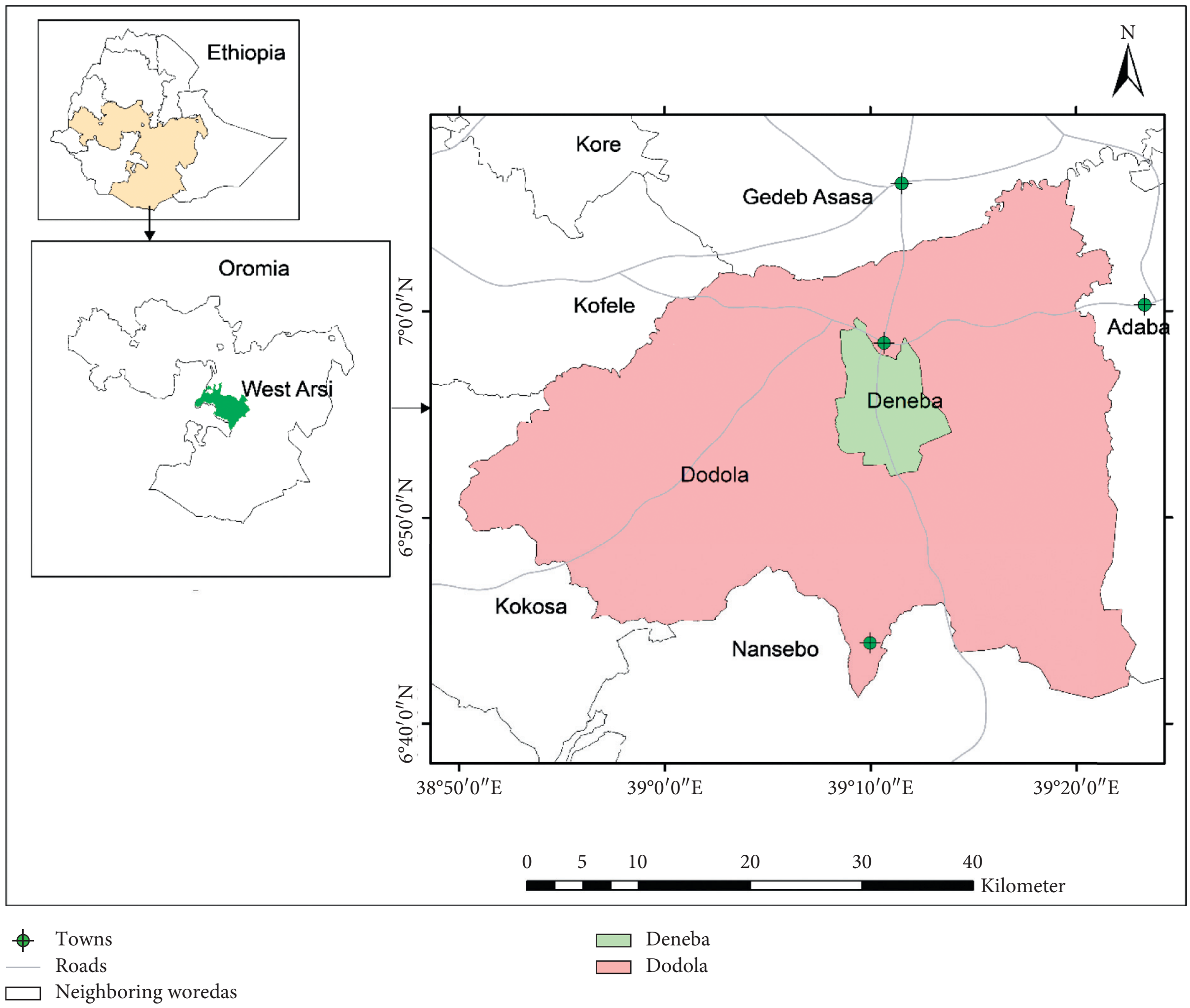

Figure 1: Location map of the study area (Gole forest), Ethiopia.

Lamiaceae (5 species) and Rosaceae (5 species), Cyperaceae (4 species), and Poaceae (4 species). The remaining families were represented by three to one species each [14]. The species were composed of 25 trees, 27 shrubs, 43 herb, 11 climber, 6 grass, and 2 fern species. 17 species have been recorded to be endemic to Ethiopia. From the endemic species, herbs constitute 58.82%, shrubs 35.29%, and climbers 5.88%. The presence of these endemic species in the forest shows the importance of the conservation process of this forest.

3.2. Vegetation Community Classification. Five plant community types (clusters) were determined on the basis of plots grouping by similarity. The five plant communities were designated as C1, C2, C3, C4, and C5, as shown in the dendrogram (Figure 2). The plots that are grouped into one cluster are more similar in species composition and closely related in elevation than the other group of plots that are placed in the other clusters. The community types varied in size, ranging from 4–17 plots and 27–78 species. The highest plot numbers and species were found in community type 4 (C4), whereas the least in community 1(C1).

Each of these plant communities is characterized by a group of plants that show a strong preferential distribution in the respective community. Table 2 presents the list of species with significant indicator values in each community. The species with the highest indicator values were used for naming the communities. Hence, the plant communities identified in the study area were: *Erica arborea- Conyza spinosa* community type, which is composed of 4 quadrats and 27 species, *Hypericum revolutum* community type composed of 16 quadrats and 50 species, *Hagenia abyssinica-Myrsine melanophloeos-Juniperus procera* community type composed of 11 quadrats and 40 species, *Nuxia congista-Myrsine africana-Osyris quadripartita* community type composed of 17 quadrats and 78 species and *Podocarpus falcatus-Mytenus arbutifolia-Dovyalis abyssinica* community type of 14 quadrats and 75 species were identified in the study area. Each of the communities has the characteristic/indicator species that are presented in Table 2. The indicator species show strong preferential distributions in the communities identified by cluster analysis. The indicator values of the species were considered significant if the respective probability values were less than 0.05 [21].

Table 1: List of plants species recorded from the study area (Gole forest).

No.	Scientific name	Local name	Family	Habit
1	Acanthus sennii *Chiov.*	Sookooru	Acanthaceae	Sh
2	Achyranthes aspera *(L.)*	Gerbebo	Amaranthaceae	H
3	Agave sisalana *Perr.ex Eng*	qaacaa	Agavaceae	H
4	Allophyllus abyssinica *(Hochest) Radel*		Spindaceae	T
5	Alepidea longifolia *E.Mey*	Logaa	Apiaceae	H
6	Arisaema schimperianum *Schott*	Budhee	Araceae	H
7	Arundinaria alpina *K.Schum*		Poaceae	T out
8	Aspargus africanus *Lam.*	Seritii	Aspargaceae	C
9	Berula erecta *(Hudson) Coville*	Gonde	Apiaceae	H
10	Bidens pachyloma *(Oliv& Heirn)*	Qinxaa	Asteraceae	H
11	Buddleja polystachya *Fresen*	Bulchana	Scrophulariaceae	T
12	Bursama abyssinica *Fresen.*		Melianthaceae	Sh
13	Calamagrostis epigejos *(L.) Roth*	Maxaa	Poaceae	G
14	Carduus camaecephalus *(Vatke) Oliv.& Heirn*	Canaa babaxee	Asteraceae	H
15	Carduus nyassanus *R.E Fries*	Qoree bosoonaa	Asteraceae	H
16	Caucanthus auriculatus *Forssk*	Dikii	Malpighiaceae	C
17	Clematis hirsuta *Perr.& Guill.*	Fitii	Ranunculaceae	C
18	Conyza spinosa *Sch.Bip.ex A.Rich*	Hamaresaa	Asteraceae	Sh
19	Crepis rueppelli *Sch.Bip*		Asteraceae	H
20	Crinum abyssinicum *Hochst.ex A.Rich*	Lacee	Amaryllidaceae	H
21	Cyanotis berbata *D. Don*	Daluma	Commelinaceae	H
22	Cyanoglossum amplifolium *Hochst*	Qorich michi	Boraginaceae	H
23	Cyanoglossum geometricum *(Back&Write) Edward*	Maxxanee	Boraginaceae	H
24	Cyphostemma adenocaule *(Steud.ex A.Rich)*	Sinoolee	Vitaceae	C
25	Cyprus fischerianus *A.Rich*	Qunii	Cyperaceae	G
26	Cyprus dichroostachyus *A.Rich*	Arbegedo	Cyperaceae	G
27	Cyprus rotundus *L.*		Cyperacaea	G
28	Digitaria abyssinica *Hochst. ex A.Rich*	Ura sar	Poaceae	G
29	Discopodium pennnervum *Hochst*		Solanaceae	Sh
30	Dombeya torida *(J.F.Gmel) P.Bamps*	Danisa	Sterculiaceae	T
31	Dovyalis abyssinica *(A.Rich) Warb*		Flacourtiaceae	Sh
32	Dryopteris anthamantica *(Kuntze) Kuntze*		Aspidiaceae	F
33	Dryopteris inaequalis *(Schlecht) Kuntze*	kumbuutaa	Aspidiaceae	F
34	Echinops ellenbekii *D .Hoffm*	koshoshila	Asteraceae	Sh out
35	Echinops longisetus A.Rich	Qore haree	Asteraceae	H
36	Ekebergia capensis *Sparrm*	Anonuu	Miliaceae	T
37	Erica arborea *L.*	Sato	Ericaceae	T
38	Euphorbia schimperiana *Scheele*	Gurii	Euphorbiacaea	H
39	Festuca abyssinica *Hochst.ex A.Rich*		Poaceae	G
40	Ficus sur *Forssk.*		Moraceae	T
41	Galiniera saxifraga *(Hochst) Bridson*	korralaa	Rubiaceae	T
42	Girardinia bullosa *(Steudel) Wedd.*	Dobi arbo	Urticaceae	H
43	Gnaphalium rubriflorum *Hilliard*	badubera	Asteraceae	H
44	Gomphocarpus integer *(NE.Br)*	Halmalaa	Asclepiadaceae	H
45	Guizotia scabra *(Vis) Chiov.*	Hada	Asteraceae	H
46	Hagenia abyssinica *(Bruce) J.F.Gmel*		Rosaceae	T
47	Haplocarpha schimperi *Sch.Bip*	Canaa	Asteraceae	H
48	Helichrysum foetidum *Moench*		Asteraceae	H
49	Helichrysum formosissmum *(Sch.Bip) A.Rich*	Handadhama	Asteraceae	H
50	Helichrysum splendidum *(Thumb) Less.*	Xuqa	Asteraceae	H
51	Hypericum peplidifolium *A.Rich*	Geremba merga	Hypericaceae	H
52	Hypericum revolutum *Vohl*		Hypericaceae	T
53	Hypoestes triflora *(Forssk) Roem. & Schult*	Dobi laaleesaa	Acanthaceae	H
54	Ilex mitis *(L.) Radik*	Amshiqa	Aquifoliaceae	T
55	Inula conifertiflora *A.Rich*	Haxawii	Asteraceae	Sh
56	Ipomoea involucrata *Beauv.*	Hadhname	Convolvulaceae	C
57	Isoglossa somalensis *Lindau*	Cafaraa	Acanthaceae	Sh
58	Isolepis setacea *(L.) R.Bir*	Gemegna	Cyperaceae	H
59	Jasminum abyssinicum *Hochst ex. Endi*	Haroolaa	Oleaceae	C
60	Juniperus procera *Hochst ex Endl*		Cuprussaceae	T

Table 1: Continued.

No.	Scientific name	Local name	Family	Habit
61	Kalanchoe petitiana *A.Rich*		Crassulaceae	H
62	Kniphofia foliosa *Hochst*	Lelaa	Asphodelaceeae	H
63	Lantana trifolia *L.*	Kese	Verbnaceae	Sh
64	Maesa lanceolata *Forssk.*		Myrisinaceae	T
65	Mikaniopsis clematoides *(A.Rich) M.Radh*	Qarqoraa	Asteraceae	C
66	Minulopsis solmisii *Schwan*	Herayee	Acanthaceae	H
67	Myosotis abyssinica *Bois & Revt*	Qarcabaa	Boraginaceae	H
68	Myrica salcifolia *A.Rich*	Xonaa/shinet	Myricaceae	T out
69	Myrsine africana *L.*		Myrisinaceae	Sh
70	Myrsine melanophloeos *(L.) R.Br*		Myrisinaceae	T
71	Mytenus addat *(Loes) Sebsebe*	Qarxame/Atat	Celasteraceae	Sh
72	Mytenus arbutifolia *R.Wilczek*		Celastraceae	T
73	Nuxia cogista *R.Br.ex.Fresen*	Bixanaa	Stilbaceae	T
74	Ocimum lamiifolium *Hochst ex Benth.*	Damakese	Lamiaceae	Sh out
75	Ocimum urticifolium *Roth.*	Hubunee	Lamiaceae	Sh
76	Olea europea Sub sp.cuspidata (*Well ex.G.Don) c.f*		Oleaceae	T
77	Olea hochstetteri *Back.*	Ejersa dhalaa	Oleaceae	T out
78	Olinia rachetiana *A.Jussieu*	Gunaa/sole	Oliniaceae	T
79	Osyris quadripartita *Decn*	Kaaro/qerest	Santalaceae	Sh
80	Periploca linearifolia *Quart-Dill. & A.Rich*	anannoo	Asclepiadaceae	C
81	Phytolaca dodecandra *L′ Her't*		Phytolacaceae	Sh
82	Pittosporum abyssinicum *Dilile*	Araa	Pittosporaceae	T
83	Plantago lanceolata *L.*	Qarxobii	Plantaginaceae	H
84	Plectranthus punctatus *L'Herit*	Gogoro	Lamiaceae	H
85	Podocarpus falcatus *(Thunb) Mirb*		Podocarpaceae	T
86	Prunus africana *(Hook. f) Spreng*	Suke	Rosaceae	T
87	Pterolobium stellantum *(Forssk.) Brenan*	Sokooru gaalee	Acanthaceae	C
88	Rhamnus staddo *A.Rich*	Qadidaa	Rhamnaceae	T/sh
89	Rhamnus prinoids *L'Herit*		Rhamnaceae	Sh
90	Rhus vulgaris *Mikle*	Xaaxeesaa	Anacsrdiaceae	Sh
91	Rosa abyssinica *Lindley*		Rosaceae	Sh
92	Rubus apetalus *Poir.*	Gora/Enjori	Rosaceae	Sh
93	Rubus steudneri *Schweinf.*	Gora hagena	Rosaceae	Sh
94	Rumex nepalensis *Spreng*	Shabee	Polygonaceae	H
95	Satureja biflora *(Hom. ex Don) Brif.*	Xoshmaxaa	Lamiaceae	H
96	Scadoxus multiflorus *(Martyn) Raf.*	Arfaasaa	Amaryllidacaea	H
97	Schefflera volkensii *(Engl.) Horms*	Ansha	Araliaceae	T
98	Senecio freseni *Sch. Bip ex oliv.*	Agedenaa	Asteraceae	H
99	Senecio myriocephalum *Sch. Bip.ex A.Rich*		Asteraceae	H
100	Sida schimperiana *Hochst.ex A.Rich*	Enchakire	Malvaceae	Sh
101	Solanecio gigas *(Vitke)C.jeffrey*	Yeshikoko gomen	Asteraceae	Sh
102	Solanum giganteum *Jacq.*		Solanaceae	Sh
103	Solanum indicum *L.f*	Hidi oromo	Solanaceae	Sh
104	Stellaria sennii *Chiov.*	Duqushaa	Cryophyllaceae	H
105	Stephania abyssinica *(Dillon&A.Rich).Walp*	kalaalaa	Minispermaceae	C
106	Thymus schimperi *Ronn.*	Tosign	Lamiaceae	H
107	Tragia brevipes *Pax*	Laaleesaa	Euphorbiaceae	H
108	Trifolium calocephalum *Fresen*	Gosa siidisaa	Fabaceae	H
109	Trifolium quartinianum *A.Rich*	Sidiisaa	Fabaceae	H
110	Urera hypselodendron *(A.Rich) Wedd.*	Haalilaa	Urticaceae	C
111	Urtica simensis *Steud.*		Urticaceae	H
112	Vernonia adoensis *Sch.Bip ex Walp*	Ye feres zeng	Asteraceae	Sh out
113	Vernonia amygdalina *Del. in cail.*	Ebicha	Asteraceae	Sh out
114	Vernonia myriantha *Hook.f*	Rejii	Asteraceae	Sh

C = Climbers, Sh = Shrubs, T = Trees, H = Herbs, F = Ferns and out = found out of quadrat.

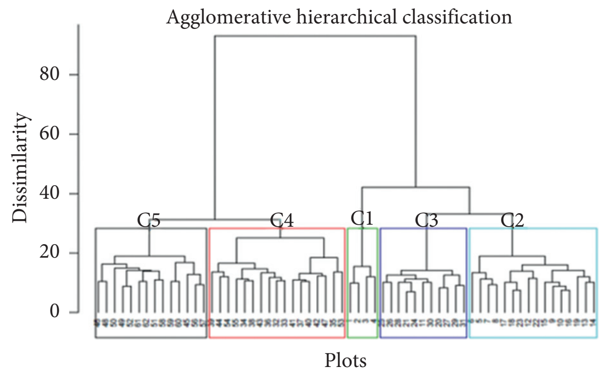

Figure 2: Dendrogram of the vegetation data obtained from hierarchical cluster analysis.

Table 2: Indicator species in each community with significant indicator values (%).

Species	Community	Indicator value (%)	P value
Erica arborea	1	65.91	0.001
Conyza spinosa	1	46.85	0.002
Hypericum revolutum	2	46.36	0.003
Hagenia abyssnica	3	43.59	0.009
Myrsine melanophloeos	3	34.49	0.002
Juniperus procera	3	31.16	0.001
Myrsine africana	4	72.37	0.001
Osyris qudripartita	4	40.64	0.007
Nuxia congista	4	38.96	0.007
Podocarpus falcatus	5	76.76	0.001
Mytenus arbutifolia	5	59.95	0.001
Dovyalis abyssinica	5	53.97	0.002

3.3. Community-Environment Relationship. Environmental factors such as elevation, disturbance, etc., affect species distribution, diversity, and richness. The classification technique identifies the discontinuity in vegetation, and the major discrimination in vegetation distribution among the plant communities in this study was most strongly controlled by altitude and disturbances.

Elevation has a remarkable impact on Gole forest plant community formation. The Boxplots of the elevation/altitude of each plant community show that there is considerable variation in elevation among the plant communities in the study area (Figure 3).

The classification identifies the discontinuity in the vegetation type of the communities, and this is supported by the significant contrasts found between communities, as shown by Tukey's test. The comparison of plant communities with each other based on elevation shows that plant community one was significantly different from community two, three, four, and five, and vice versa (Figure 3). Community type one (*Erica arborea-Conyza spinossa* community) was recorded at the highest elevation (3388-3480) compared to community five (*Podocarpus falcatus-Mytenus arbutifolia-Dovyalis abyssinica* community) which is found in the lowest elevation (2728–2863 m a. s.l.) and the other community two (*Hypericum revolutum* community), three (*Hagenia abyssinica-Myrsine melanophloeos-Juniperus procera* community), and four (*Nuxia congista-Myrsine africana-Osyris quadripartita* community) are found between this two community.

The significance of variation in elevation of the plant communities was assessed using ANOVA. The analysis of variance shows that the distribution of the five plant communities was significantly different across elevation (mean square = 168.39, $D.f = 4$, $F < 2.2e{-}16^{***}$, correlation is significant at $P < 0.05$). This implies that elevation has a considerable impact on the distribution pattern of plant communities.

Topographic variables such as elevation indicate the availability of resources required by plants and influence environmental conditions of a particular site, thus causing a prominent variation in species composition. Elevation determines the distribution pattern of vegetation or communities in the site and hence is considered as a major parameter in ecological specialization [22–24]. The elevation species distributions are due to factors which change in conjunction with an elevation that include air pressure, temperature, and precipitation that in turn determine the type of vegetation [25].

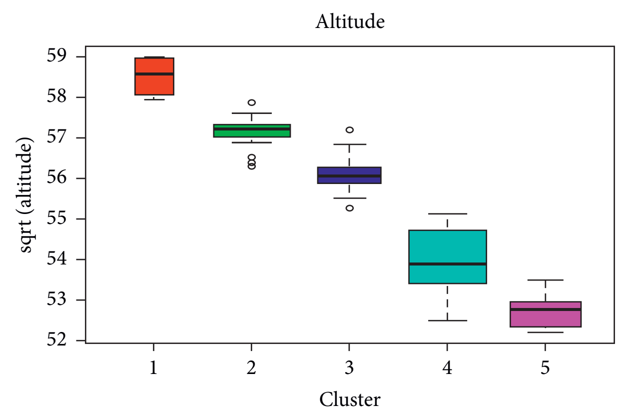

Figure 3: Boxplots of the association of plant community types with altitude/elevation.

3.4. Relation between Disturbance and Plant Communities. There was a considerable variation in disturbance between the plant communities of the study area (Figure 4).

The result of ANOVA indicates that there is a significant difference in disturbance level among plant Communities (mean square = 2.9228, $D.f = 4$, $F < 0.02871^{*}$ Correlation is significant at $P < 0.05$).

In community one (*Erica arborea* community type), which is found at the upper elevation, there is less disturbance as compared to Community five (*Podocarpus falcatus-Mytenus arbutifolia-Dovyalis abyssinica* Community type), which is found at the lowest elevation. In communities two and three, there are relatively high levels of disturbance than communities one and four but less level of disturbance than community five. Community three has a high level of disturbance than community four but less level of disturbance

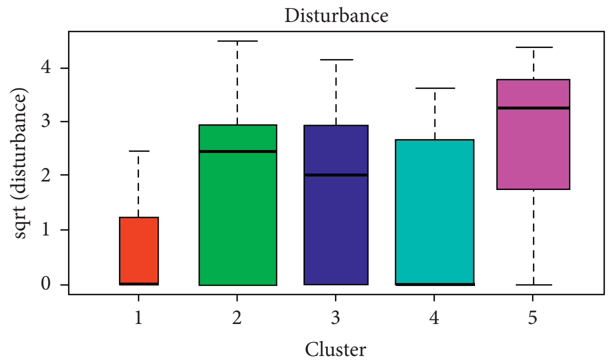

FIGURE 4: Boxplot showing the association of disturbance with plant community types.

TABLE 3: Species richness among the five plant communities in Gole forest.

Communities	No. of species	Altitudinal range
Community_1	27	3388–3480
Community_2	50	3173–3350
Community_3	40	3050–3275
Community_4	78	2758–3040
Community_5	75	2728–2863

than community five, while community four has less level of disturbance than community five. A high level of disturbances was recorded in community five. This can be attached to the high human interference because of the proximity of the community to human settlement and high overgrazing and overbrowsing by domestic stocks.

Intermediate level of disturbance was recorded in communities two and three. In these communities, woody species were cut down for charcoal and timber production. The low level of disturbance was in communities one and four; community one was found far from human settlement and community four was mainly dominated by shrubs which cannot grow to a high height and DBH class which is less valuable for human use. It is dominated by *Osyris quadripartita* and *Myrsine africana*. This species is a less valuable woody species for commercial purposes and also resistant to wild animals and livestock grazing.

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 [26]. Disturbance also alters the stability and diversity of ecosystems as it reduces invasion resistance while eliminating the buffering effect of high diversity [27].

As indicated by Boehmer and Temam [14], the distribution of plant species among the communities in the study area shows the highest similarity between communities four and five (59%), three and four (44%), and two and three (41%) and the lowest similarity was observed between communities one and five (11%). This is due to the existence of quadrats adjacent to each other and similarity in altitudes. This shows that communities having nearly similar altitudes have more species in common than communities occupying different altitudes. As Oksanen [28] states that, if two sites have similar vegetation, they have a similar environment and if two sites have different vegetation, they have a different environment.

3.5. Species Richness of the Communities in relation to Environmental Variables. The species richness of the plant communities was high in community four (78), followed by community five (75), two (50), and three (40), while community one (27) was the least in species richness (Table 3).

The highest species richness in community **4** is due to intermediate altitude, fewer disturbances, and covered with less valuable woody species (shrubs) for commercial purposes and also resistance to wild animal and livestock grazing. In community **5,** the lower altitude makes moderate conditions for rapid resource acquisition, which is favorable for most plant growth. However, in communities **3** and **2,** the species richness decreases due to disturbance and increasing altitude. While in community **1,** species richness was reduced due to increasing altitude leading to ecophysiological constraints. These could be the possible reasons for the declining of species richness and diversity with increasing altitude [29].

4. Conclusion

The present study describes the distribution of plant community types along an altitudinal gradient and disturbances in Gole forest. Understanding the environmental factors that govern plant community distribution is important in planning and implementing plant conservation and management strategies. Five plant community types have been distinguished and related to measured environmental variables. The main variation in the distribution of plant communities in the Gole forest was due to the altitudinal gradient and disturbances. There are differences in species richness among the plant communities. Finally, the distribution of plant communities and species richness was affected by elevation and disturbance. Therefore, considering the environmental factors is important for implementing plant conservation and management strategies.

Data Availability

The raw data used to support the findings of this study have been deposited in the Dryad repository https://doi.org/10.5061/dryad.zcrjdfn74.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Supplementary Materials

The MSC Data file contains the raw data which are used to support the findings of this study. (*Supplementary Materials*)

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