Hindawi
International Journal of Ecology
Volume 2021, Article ID 6628282, 13 pages
https://doi.org/10.1155/2021/6628282

Research Article

The Effects of Landscape Change on Plant Diversity and Structure in the Bale Mountains National Park, Southeastern Ethiopia

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Received 22 November 2020; Revised 19 February 2021; Accepted 1 March 2021; Published 9 March 2021

Academic Editor: Isabel Marques

Bale Mountains National Park is one of the protected areas in Ethiopia that holds the largest area of Afroalpine habitat in Africa and the second largest stand of moist tropical forest. Nevertheless, human settlements, overgrazing, and recurrent fire are the main problems in the park. This study aimed to determine the effects of human-induced landscape change in floristic composition and structure in the park. The vegetation data were collected systematically from 96 sample plots laid along 24 line transects in the edge and interior habitats of the six land cover types. Vegetation composition and landscape structural analysis were made using *R* software version 3.5.2 and FRAGSTATS version 4.2.1, respectively. Patch number was strong and positively affected species richness ($r = -0.90$, $p < 0.05$), diversity ($r = -0.96$, $p < 0.01$), and basal area ($r = -0.96$, $p < 0.001$), whereas mean patch size was strong and negatively influenced species richness ($r = 0.95$, $p < 0.05$), diversity ($r = 0.87$, $p < 0.05$), and basal area ($r = 0.82$, $p < 0.05$). The overall species richness, Shannon diversity index, and Margalef index were significantly higher in the edge habitat; however, the mean basal area of woody species was significantly higher in the interior habitat at $p < 0.05$. This study uncovered that the park is floristically rich and diverse, and it provides a variety of ecological and economic benefits to the surrounding community and to the nation at large. However, these benefits are gradually declining due to the high level of anthropogenic activities in the park. Thus, integrated environmental management strategy that blends with sustainable use of natural resources should be implemented to minimize the threats.

1. Introduction

Landscapes all over the world are alarmingly changed and fragmented due to anthropogenic factors such as urbanization, agricultural expansion, forest fire, and climate change [1, 2]. Most of the global changes responsible for the reduction in population and biodiversity are exacerbated by fragmentation [3, 4]. The primary causes of global biodiversity reduction are the destruction and degradation of natural ecosystems [5]. Predominantly, habitat loss and fragmentation are presently the main threats to terrestrial biodiversity [6]. Moreover, habitat fragmentation can affect the species interactions and community composition, as invasive or pest species, and may substitute the original species pool and increase the transmission and prevalence of the disease in small fragments [7]. Moreover, the species richness and abundance usually decrease with reduced patch size [8]. As landscapes become more fragmented, patch diversity increases with subsequent increase in the edge, exotic, and generalist species and ultimately leads to the reduction in landscape quality as habitat for species [9]. Accordingly, species richness in interior habitat, particularly indigenous and specialist species, tends to decrease [10]. The number of species existing in a patch tends to rise with patch size up to a certain limit, and the types of species found also tend to vary in size [8]. Size and shape interact to influence the amount of interior area remaining in a particular habitat fragment [2].

Tropical montane ecosystem is one of the hot spot ecosystems on Earth that comprises more than 200,000 species of flowering plants [11, 12]. The Ethiopian highland, which is located in the tropical region, encompasses over 50% of the Afromontane vegetation in Africa [13]. A suitable geographical position, a wide range of altitude, a high amount of rainfall, and a wide range of temperature variations equip the area with huge ecological diversity and a wealth of biological resources [14]. However, severe deforestation coupled with the cultivation of steep marginal lands, overgrazing, and sociopolitical uncertainty has resulted in rigorous land degradation over large areas of the country [15]. The overdependence of the country's economy on agricultural production and the existence of more than 80% of the population in the highlands [16, 17] mainly contribute to the degradation of ecological resources and biodiversity loss.

The mountainous landscape and the mosaic of natural vegetation in the Bale Mountains have considerable economic, recreational, esthetic, and scientific importance [14]. The Bale Mountains National Park (BMNP) is the most significant conservation area situated in this region of Ethiopia and established in 1969 to preserve the endemic and indigenous floras and faunas in the area [18, 19]. It is one of the 34 International Biodiversity Hotspots and meets the requirements for the World Heritage Site and Biosphere Reserve Listing [20]. However, the park is facing a critical challenge from the illegal settlement and overgrazing and that leads to the change in its landscape structure and function. As a result, the habitats in the park are changing and the provision of ecological services from it is substantially reduced. Consequently, no research provides detailed information about the landscape structure and its potential impact on vegetation composition and structure in the park. Therefore, this research was aimed to analyze the potential impact of landscape change in floristic composition, diversity, and structure in the BMNP. Particularly, a comparative analysis was made among the edge and interior habitats of the park.

2. Materials and Methods

2.1. Study Area Description. BMNP is located within the geographic bounds of 6°53′08″N latitude and 39°44′03″E longitude and 400 km southeast of Addis Ababa, Ethiopia (Figure 1). It comprehends a wide range of habitats between 1450 m and 4377 m altitude. The park holds the largest area of Afroalpine habitat (about 1000 km^2) above 3000 m asl in Africa and the second largest stand of moist tropical forest [21]. It is one of the 34 International Biodiversity Hotspots and also qualifies for World Heritage Site and Biosphere Reserve Listing [22]. It received rainfall that ranged from 520 to 2370 mm annually [23], and the distributional pattern is bimodal with heavy rains from July to October (highest peak in August) and small rains from March to June (highest peak in April). The mean monthly minimum and maximum temperatures are 5.6°C and 21.4°C, respectively. Its soil is fertile silty loam of reddish-brown to black clay soils dominated by Vertic Cambisols and Leptosols [24].

2.2. Vegetation Sampling Design. From 13 to 20 November 2018, a reconnaissance survey was conducted to get insights into the vegetation physiognomy and establish sampling sites in the study area. Following, the actual fieldwork was performed in the dry season between November 2019 and January 2020. A total of 96 sample plots (20×20 m) were systematically laid along 24 line transects in eight directions along three altitudinal gradients at 100 m elevational differences as it maximizes the distance between plots and minimizes spatial correlation among the observations [25]. To make a comparison between the vegetation data, an equal number of sample plots have been laid on the edge and interior habitats following Daye [26].

2.3. Species Identification. Plant species in the nested plots were identified at the field with the help of local peoples (for vernacular names) and by referring different volumes of Flora of Ethiopia and Eritrea books [27, 28]. For the species that were difficult to identify in the field, representative specimens were cut, numbered, and pressed at the site. The collections were named using folk taxonomy, and identification of formal taxonomy was determined using the voucher specimens at the National Herbarium, Addis Ababa University.

2.4. Floristic Composition and Structure. The most commonly used diversity indices of species richness (S), Simpson index (D), Shannon–Wiener index (H'), Pielou's evenness index (J'), Whittaker β-diversity (β_w), Margalef index (D_M), and Berger–Parker index (d) were computed to analyze the patterns of plant diversity in the edge and interior habitats following Magurran [29] and Økland [30] using equations (1)–(4):

$$H' = -\sum_{i=1}^{s} P_i \ln P_i, \quad (1)$$

where H' is the Shannon diversity index, P_i is the proportion of individuals, and ln is the natural logarithm.

$$J = \frac{H'}{H_{\max}}, \quad (2)$$

where $H_{\max}$ is the maximum level of diversity possible within a given population (ln S) and S is species richness.

$$\beta - \text{diversity} = \frac{a + c}{2a + b + c}, \quad (3)$$

where a is the number of shared species in two sites and b and c are the numbers of species unique to each site.

The Margalef diversity index (D_M) was computed using the following formula:

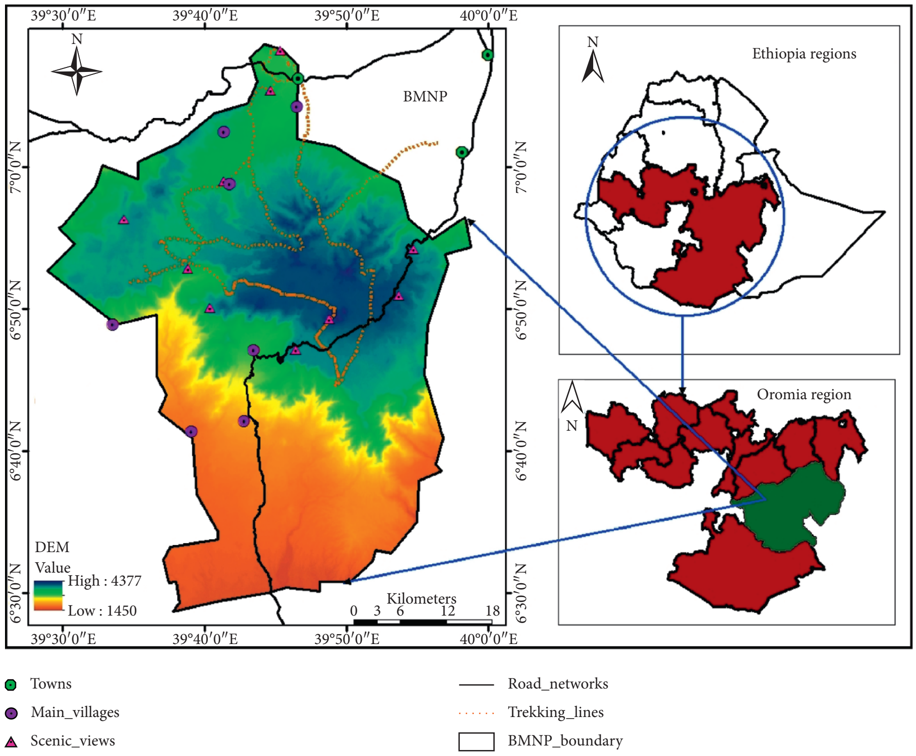

Figure 1: Location map of the study area.

$$D_M = \frac{s-1}{\ln N}, \quad (4)$$

where D_M is the Margalef diversity index, S is the number of species, and N is the total number of individuals in the sample.

The woody species density, frequency, dominance, and their relative values in the interior and edge habitats were computed to obtain the important value index and describe the woody species structure following Ellenberg and Mueller-Dombois [31] and Martin [32] using equations (5)–(8). Moreover, DBH, tree height, and basal area were analyzed to determine the population structure following Kitessa et al. [33] and Van der Maarel [34]:

$$\mathrm{BA} = \frac{\pi d^2}{4}, \quad (5)$$

where BA is the basal area, $\pi = 3.14$, and d is the DBH (cm).

$$\mathrm{Fr} = \frac{P_i}{\sum_{i=1}^{s} P_i} \times 100, \quad (6)$$

where Fr is the frequency of a species and P_i is the number of plots in which the i^{th} species occurred.

$$R_{\text{de}} = \frac{n_i}{\sum_{i=1}^{s} n_i} \times 100, \quad (7)$$

where R_{de} is the relative density and n_i is the number of individuals of the i^{th} species.

$$\mathrm{IVI} = R_{\text{de}} + R_{\text{Fr}} + R_{\text{Do}}, \quad (8)$$

where IVI is the importance value index, R_{de} is the relative density, R_{Fr} is the relative frequency, and R_{Do} is the relative dominance.

2.5. Measurement of Landscape Structure. Landsat images of the years 1985, 1995, 2005, and 2017 were processed using ArcGIS version 10.3 to produce time-series datasets of land use/land cover. Then, eight landscape indices were analyzed using the processed land use/land cover data following McGarigal et al. [35] and Smiraglia et al. [36]. The indices include patch number (PN), mean patch size (AREA_MN), total core area (TCA), edge density (ED), area-weighted mean shape index (SHAPE_AM), mean Euclidean nearest neighbor distance (ENN_MN), and interspersion and juxtaposition index (IJI). Edge habitat was identified by deducting 50 m from the edge of each vegetation type. FRAGSTATS software version 4.2.1 was used to compute the landscape patterns in each land cover class and the entire landscape [37]. The two-way analysis of variance (two-way ANOVA) and linear regression analysis were made to test significant differences between fragmentation indices and species composition and structure parameters following the post hoc Tukey's highly significance difference (Tukey's HSD) test at 5% significance level using PAST software version 4.02 [38].

3. Results and Discussion

3.1. Landscape Structure Change. The analysis of landscape structure in this study revealed that the habitats in the BMNP are progressively transformed. The area has shown an increase in PN by 40.2% and a decrease in AREA_MN by

28.7% from 1985 to 2017. According to Oertli et al. [39], the high number of separated patches in a habitat indicates a high level of fragmentation. Across the entire study period, SHAPE_AM, which indicates the complexity of patch shape, increased by 18.8%. A higher perimeter-area relationship characterizes the rapid rate of fragmentation in the landscape [40]. Moreover, there was inconsistency in the values of ED; however, it was increased by 22.3% over the study period. As it was emphasized by McGarigal [37], the oscillation of ED indicated a major reduction in the spatial heterogeneity of the landscape. Conversely, the study area has shown a declining trend in TCA by 10.6% from 1985 to 2017. This was due to the escalated level of disturbances in the study area. As it was reported by Kidane et al. [41], the most dominant practices in the Bale Mountains, especially after 1995, were the upward expansion of agriculture and enrichment plantation.

The isolation of patches within the landscape of the study area was increased from 105.22 m to 111.94 m overtime (Table 1). This result is in agreement with the result reported by Tolessa et al. [42] in the central highlands of Ethiopia and Daye [26] in Southwest Ethiopia. Conversely, the intermixing of patches in the study area showed an overall declining trend from 95.38 to 86.77 over the study period. This result showed that the BMNP constitutes more scattered patches compared to other similar areas studied by Posada Posada [43] and Tolessa et al. [42].

3.2. Overall Floristic Composition and Structure. A total of 205 plant species belonging to 71 families and 153 genera were recorded (Table 2). Of these, 50 species were trees, 52 were shrubs, 12 were lianas, and 91 were herbs. Asteraceae was the most dominant family with 31 species, followed by Fabaceae with 11 species. Conversely, *Helichrysum* was the most abundant genus with 9 species, followed by *Alchemilla* and *Trifolium* with 5 species each. Twenty endemic species, including *Euphorbia dumalis* S. Carter, *Lobelia rhynchopetalum* Hemsl., and *Thymus schimperi* subsp. *Schimperi* Ronniger was identified in this study. The overall Shannon diversity and evenness index of the study area were 4.34 and 0.81, respectively. This indicated that the study area was more diverse compared to other similar vegetation areas including Bonga forest [44], *Agama* forest [45], and Munessa forest [13]. Conversely, the total density of seedlings, saplings, and mature trees in the study area was 8751, 4413, and 1567 individuals ha^{-1}, respectively. This was lower than other comparable areas such as Kuandisha forest [46] and Wof-Washa forest [47]. The ratios of seedling to mature tree, sapling to mature tree, and seedling to sapling were 5.58, 2.82, and 1.98, respectively. This shows the recruitment potential of the forest is relatively higher [48].

Woody species density with DBH°>°2 cm was 1567 individuals ha^{-1}. This was relatively higher compared to other similar vegetation areas such as the Wof-Washa forest [48] and *Agama* forest [45]. The most frequent woody species was *Croton macrostachyus* Hochst. ex Del with 81% frequency followed by *Juniperus procera* L. (79%), *Podocarpus falcatus* (Thunb) C.N (63%), and *Hagenia abyssinica* (Bruce) J.F. Gmel (60%). Conversely, the total basal area of woody species was 170.26 $m^2\,ha^{-1}$, and it was considerably higher compared to other similar vegetation areas in Ethiopia. About 75% of the basal area was contributed by five tree species such as *Juniperus procera* (46.71 $m^2\,ha^{-1}$), *Syzygium guineense* (Willd.) DC (24.76 $m^2\,ha^{-1}$), *Cordia africana* Lam (20.95 $m^2\,ha^{-1}$), *Hagenia abyssinica* (18.47 $m^2\,ha^{-1}$), and *Ehretia cymose* Thonn (15.86 $m^2\,ha^{-1}$). Consequently, *Juniperus procera* was the dominant woody species with an IVI of 26.43. The species with higher IVI values in the study area was among the characteristic species in similar vegetation types in Ethiopia [49, 50].

3.3. Floristic Composition and Structure in the Edge and Interior Habitat. A total of 136 species belonging to 111 genera and 59 families were identified in the edge habitats of the sampled patches, whereas 117 species that belonging to 84 genera and 40 families were recorded in the interior habitats. From the identified life forms, 19 species were trees, 22 species were shrubs, 86 species were herbs, and 7 species were lianas in the edge habitats, whereas 28 species were trees, 21 species were shrubs, 57 species were herbs, and 11 species were lianas in the interior habitats. The overall means (±SE) species richness (35 ± 4.2), Shannon diversity index (2.93 ± 0.17), and Margalef index (5.68 ± 0.69) of the edge habitat were significantly higher compared to the interior habitat at $p < 0.05$ (Table 3). These variations could be due to the differences in site productivity, habitat heterogeneity, and disturbance factors [44, 51] or the invasion of exotic plant species [52]. However, the woody species richness in the interior habitat (28) was significantly higher than the edge (17). Moreover, the evenness index in the interior habitats (0.83 ± 0.04) was higher, but not significant, than the edge habitat (0.79 ± 0.05). This result was in agreement with the finding in [53]. Abiotic factors, seed predation, loss of pollinators and seed dispersers, and tree mortality were reported as the common causes for the differences in woody species composition between the edge and interior habitats [53, 54]. The computed Sorensen's similarity index depicted that the number of species in the edge habitats was 45% similar to the species in the interior habitats. This value indicated that the similarity between the edge and interior habitat was weak [13]. The mean density of seedling (995.42 ± 19.27 individuals ha^{-1}), sapling (509.29 ± 9.06 individuals ha^{-1}), and mature trees (187.60 ± 4.70 individuals ha^{-1}) in the interior habitat was significantly higher compared to the edge. This indicates that the recruitment potential of the interior forest was significantly higher compared to the edge habitat [48]. This could be due to the increased mortality rates of seedling, sapling, and mature trees in the edge habitats [53, 55].

The mean woody species density in the interior habitat (85 ± 22.17 stems ha^{-1}) was significantly higher compared to the edge habitat (70 ± 16.53 stems ha^{-1}) at $p < 0.05$ (Figure 2(a); Tables 4 and 5). This could be due to the selective cutting of trees for timber production, house construction, and firewood in the edge habitats, which ultimately leads to a reduction in the density of large trees

Table 1: Landscape structural characteristic of the BMNP from 1985 to 2017.

Year	NP	AREA_MN (ha)	SHAPE_AM	TCA (km^2)	ED (m/m^2)	ENN_MN (m)	IJI (%)
1985	25864	8.42	24.97	1568.91	60.53	107.27	77.69
1995	30582	7.12	24.12	1489.10	69.18	105.22	79.29
2005	29329	7.42	29.36	1471.02	66.44	111.94	70.78
2017	36267	6.00	29.67	1402.59	74.02	109.21	75.46
%	40.22	−28.68	18.83	−10.60	22.28	1.81	−2.87

Note. The negative sign of percentage implies a decreasing trend, and the positive sign implies an increasing trend.

Table 2: List of plant species identified in the BMNP.

Scientific name	Family	Local name (Or.)	Habit	Coll. no.
Acacia oerfota (Forssk.) Schweinf.	Fabaceae	Wanga	S	AM168
Acacia senegal (L.) Willd.	Celastraceae	Karxafa	S	AM172
Achyranthes aspera L.	Amaranthaceae	Roppe, Qorsa Waranssa	H	AM094
Agrostis sclerophylla C.E. Hubb.	Poaceae	Mergeseri	H	AM009
Ajuga bracteosa Wall. ex Benth. in Wall.	Lamiaceae	—	H	AM078
Albizia gummifera (J. F. Gmel.) C.A.Sm.	Mimosaceae	Karchofe	T	AM174
Alchemilla abyssinica Fresen.	Rosaceae	Hindriff	H	AM043
Alchemilla cryptantha Steud. ex A Rich.	Rosaceae	Hindriff	H	AM159
Alchemilla haumanii Rothm.	Rosaceae	—	H	AM055
Alchemilla pedata A. Rich.	Rosaceae	Hindriff, Indriif	H	AM017
Alchemilla rothii Oliv.	Rosaceae	—	H	AM052
Alepidea peduncularis Steud. ex A. Rich.	Apiaceae	—	H	AM060
Allophyllus macrobotrys Gilg	Sapindaceae	Abara	T	AM131
Allophylus abyssinicus (Hochst.) Radlk.	Sapindaceae	Sarara	T	AM178
Anaptychia liucomeleana Wain.	Physciaceae	Lichen	H	AM054
Annona reticulata L.	Annonaceae	Gishta	T	AM161
Anthemis tigreensis J. Gay ex A. Rich.	Asteraceae	—	H	AM012
Argemone mexicana L.	Papaveraceae	Qore Haree	H	AM018
Artemisia afra Jacq. ex Willd.	Asteraceae	Tepenea, Tepeno	H	AM007
Asparagus africanus Lam.	Asparagaceae	Seriti	S	AM199
Asplenium aethiopicum (Burm.f.) Bech.	Aspleniaceae	Qumbuta	H	AM155
Astragalus atropilosulus (Hochst.) Bange	Fabaceae	Hara	E	AM037
Bidens macroptera (Sch. Bip. ex Chiov.) Mesfin	Asteraceae	Hade gola	H	AM040
Blyttia fruticulosum (Decne.) D.V.Field	Apocynaceae	Homba	H(clim)	AM122
Brachycorythis buchananii (Schltr.) Rolfe	Orchidaceae	Shumbura gala	H	AM066
Bromus pectinatus Thunb.	Poaceae	Alanmuressa	H	AM106
Calpurnia aurea (Ait.) Benth.	Fabaceae	Cheekata	S	AM167
Carduus leptacanthus Fresen.	Asteraceae	Qore Haree	H	AM107
Carduus nyassanus (S. Moore) R.E. Fries	Asteraceae	Qore Haree	H	AM033
Carissa edulis (Forssk.) Vahl	Apocynaceae	Hagamssa(Or), Agam(Amh)	S	AM181
Carissa spinarum L.	Apocynaceae	Harangma	S	AM200
Casimiroa edulis La Llave & Lex.	Rutaceae	Kasmira	T	AM163
Catha edulis (Vahl) Forssk. ex Endl.	Celastraceae	Jimaa	S	AM143
Celtis africana Burm.f.	Ulmaceae	Meteqamma	T	AM116
Centella asiatica (L.) Urb.	Apiaceae	Balee, Qudu	H	AM064
Cerastium afromontanum T.C.E. Fr. & Weim.	Caryophyllaceae	Duqusha chuffa	H	AM087
Citrus aurantifolia (Christm.) Swingle	Rutaceae	Lomii	S	AM186
Citrus sinensis (L.) Osbeck	Rutaceae	Burtukana	S	AM187
Clematis hirsuta Perr. & Guill.	Ranunculaceae	Fitii	Li	AM114
Coffea arabica L.	Rubiaceae	Buuna	S	AM121
Combretum ghasalense Engl. & Diels	Combretaceae	Dhandhaasa	T	AM190
Commelina africana L.	Commelinaceae	Gura Jarsa	H	AM020
Cordia africana Lam.	Boraginaceae	Wodessa	T	AM160
Craterostigma plantagineum Hochstetter	Scrophulariaceae	—	H	AM102
Crepis carbonaria Sch. Bip.	Asteraceae	Marga Hoffi	H	AM025
Crepis ruepellii Sch. Bip.	Asteraceae	—	H	AM071
Crotolaria agatiflora Schweinf. Sub.sp. ErlangeriBak. F.	Fabaceae	Shashamane	S	AM201
Croton macrostachyus Hochst. ex Del.	Euphorbiaceae	Makkannisa	T	AM119
Cuscuta kilimanjari Oliv.	Convolvulaceae	Segeniti	H(clim)	AM098

Table 2: Continued.

Scientific name	Family	Local name (Or.)	Habit	Coll. no.
Cycniopsis humifusa (Forssk.) Engl.	Scrophulariaceae	—	H	AM080
Cynoglossum amplifolium Hochst. ex DC.	Boraginaceae	Qarccabbaa	H	AM081
Cynoglossum coeruleum Hochst.	Boraginaceae	Qarccabbaa	H	AM026
Cynoglossum lanceolatum Forssk.	Boraginaceae	—	H	AM058
Cyperus schimperianus Steud.	Cyperaceae	Alando	H	AM023
Dianthoseris schimperi A. Rich	Asteraceae	—	H	AM056
Dicrocephala integrifolia (L.f.) Kuntze	Asteraceae	—	H	AM105
Diospyros abyssinica (Hiern) F. White	Ebenaceae	Lookoo	T	AM153
Diospyros mespiliformis Hochst. ex A.DC	Ebenaceae	Kolati	T	AM176
Discopodium eremanthum Chiov.	Solanaceae	Meraro	S	AM084
Dracaena afromontana Mildbr.	Dracaenaceae	Ruukeessa	T	AM194
Echinops hoehnelii Schweinf.	Asteraceae	Qore Haree	S	AM099
Echinops macrochaetus Fresen.	Asteraceae	Tuqa, Qoree	H	AM036
Ehretia cymosa Thonn.	Boraginaceae	Ulaagaa	T	AM135
Elaeodendron buchananii (Loes) Loes.	Celasteraceae	Xilloo	T	AM137
Entada abyssinica Steudel ex A. Rich.	Mimosoideae	Kontir	S	AM075
Erica arborea L.	Ericaceae	Satoo	S/T	AM073
Erica trimera (Engl.) Beentje	Ericaceae	—	S	AM065
Erythrina brucei Schweinf.	Fabaceae	Waleensu	T	AM175
Euclea schimperi (A.DC.) Dandy	Ebenaceae	Miheesa	T	AM164
Euphorbia depauperata A. Rich.	Euphorbiaceae	Guri Xixiqo	H	AM010
Euphorbia dumalis S. Carter	Euphorbiaceae	Gurii	S	AM090
Eurynchium pulchellum (Hedw.) Jenn.	Brachytheciaceae	Hasufe (O), Mosses (E)	E	AM044
Euryops prostratus B. Nordenst.	Asteraceae	—	S	AM051
Fagaropsis angolensis (Engl.) Milne	Rutaceae	Siisaa	T	AM150
Ferula communis L.	Apiaceae	Gnida	H	AM014
Festuca abyssinica A.Rich.	Poaceae	—	H	AM062
Ficus vasta Forssk.	Moraceae	Qiltu	T	AM169
Filicium decipiens (Wight & Am.) Thw.	Sapindaceae	Caanaa	T	AM156
Flacourtia indica (Burm.f.) Merr.	Salicaceae	Hokoku	S	AM180
Galium simense Fresen.	Rubiaceae	Maxxane	H	AM016
Geranium arabicum Forssk.	Geraniaceae	Bucha	H	AM068
Geranium kilimandscharicum Engl.	Geraniaceae	Balee Tiqo	H	AM097
Gouania longispicata Engl.	Rhamnaceae	Wayebossaa	H(clim)	AM128
Grevillea robusta A. Cunn. ex R. Br.	Proteaceae	Grevillea	T	AM170
Gynura pseudochina (L.) DC.	Asteraceae	Raffu	H	AM101
Habenaria peristyloides A. Rich.	Orchidaceae	Kerkashaw	H	AM112
Hagenia abyssinica (Bruce) J.F. Gmel.	Rosaceae	Hexxoo	T	AM082
Haplocarpha rueppellii (Sch. Bip.) Beauv.	Asteraceae	—	H	AM113
Hebenstretia angolensis Rolfe	Scrophulariaceae	—	H	AM104
Hebenstretia dentata L.	Scrophulariaceae	—	H	AM032
Helichrysum citrispinum Del.	Asteraceae	—	S	AM042
Helichrysum foetidum (L.) Moench.	Asteraceae	—	H	AM011
Helichrysum formosissimum (Sch.Bip.) Sch.Bip. ex A.Rich.	Asteraceae	—	S	AM063
Helichrysum globosum A. Rich.	Asteraceae	—	H	AM024
Helichrysum gofense Cufod.	Asteraceae	—	H	AM006
Helichrysum harenensis Mesfin.	Asteraceae	Ufea/Hoffii	H	AM039
Helichrysum quartitianum A. Rich.	Asteraceae	Agadena	H	AM095
Helichrysum schimperi (Sch. Bip. ex A. Rich.) Moeser	Asteraceae	Badubera	H	AM048
Helichrysum splendidum (Thunb.) Less.	Asteraceae	Badubera	S	AM001
Hibiscus calyphyllus Cavan.	Malvaceae	Hincinni	H	AM146
Hippocratea africana (Willd.) Loes.	Celasteraceae	Gaguro	H(clim)	AM145
Hippocratea goetzei Loes	Celasteraceae	Gaalee Gaguro	H(clim)	AM152
Hippocratea pallens Planchon ex Oliver	Celasteraceae	Xara'a	H(clim)	AM147
Hydrocotyle mannii Hook.f.	Apiaceae	—	H	AM072
Hypericum peplidifolium A. Rich.	Hypericaceae		H	AM035
Hypericum revolutum Vahl	Hypericaceae	Geremba	T/S	AM002
Hypericum scioanum Chiov.	Hypericaceae	—	H	AM031
Inula confertiflora A. Rich.	Asteraceae	Haxxawii	S	AM197
Jasminum abyssinicum Hochst. ex Dc	Oleaceae	Dikii	H(clim)	AM123

Table 2: Continued.

Scientific name	Family	Local name (Or.)	Habit	Coll. no.
Juniperus procera L.	Cupressaceae	Hindessa	T	AM083
Kalanchoe petitiana A. Rich.	Crassulaceae	—	S	AM103
Kniphofia foliosa Hochst.	Asphodelaceae	Lela	H	AM008
Kniphofia insignis Rendle	Asphodelaceae	Lela Xixiqo	H	AM027
Kniphofia isoetifolia Steud. ex Hochst.	Asphodelaceae	Lela Xixiqo	H	AM013
Landolphia buchananii (Hall.f.) Stapf	Apocynaceae	Homba	H(clim)	AM151
Lannea schimperi (Hochst. ex A.Rich.) Engl.	Anacardiaceae	Andarku	S	AM185
Leonotis ocymifolia (Burm.f.) Iwarsson	Lamiaceae	Bokolu	S	AM202
Lepidotrichilia volkensii (Gurke) Leroy	Meliaceae	Saakarro	T	AM148
Leucaena leucocephala (Lam.) de Wit	Mimosoideae	Lucinaa	S	AM189
Lobelia rhyncopetalum Hemsl.	Lobeliaceae	Taruurra(O), Jibra(Am)	S	AM041
Macaranga capensis (Baill.) Sim	Euphorbiaceae	Argoo	T	AM140
Malva verticillata L.	Malvaceae	Lita	S	AM029
Mangifera indica L.	Anacardiaceae	Mango	T	AM162
Margaritaria discoidea (Baill.) Webster	Phyllanthaceae	Bulala	T	AM141
Maytenus arbutifolia (A. Rich.) Wilczek	Celastraceae	Kombolcha	T	AM173
Maytenus obscura (A. Rich.) Cuf.	Celastraceae	Kombolcha, Duqusha (Or.)	S	AM091
Maytenus undata (Thunb.) Blakelock	Celastraceae	Kombolcha	S	AM100
Melia azedarach L.	Meliaceae	Kinin zaf	T	AM191
Mimusops kummel A.DC.	Sapotaceae	Qolati	T	AM120
Moraea schimperi (Hochst.) Pic.-Serm.	Iridaceae	Loga	S	AM115
Myrsine africana L.	Myrsinaceae	Qachamo	S	AM203
Myrsine melanophoeos (L.) R. Br.	Myrsinaceae	Tuullaa	T	AM074
Nepeta azurea R.Br. ex Benth.	Lamiaceae	—	S	AM003
Ocotea kenyensis (Chiov.) Robyns & Wilczek	Lauraceae	Gigicha	T	AM118
Oldenlandia herbacea (L.) Roxb.	Rubiaceae	Omachessaa	H	AM028
Olea capensis L.ssp. macrocarpa (C.H.Wright)Verdc.	Oleaceae	Gagama	T	AM132
Olea europaea L. subsp. cuspidata (Wall.ex G.Don)	Oleaceae	Ejerssaa	T	AM157
Olea welwitschii (Knobl.) Gilg. & Schellenb.	Oleaceae	Onomaa	T	AM134
Osyris compressa (P.J.Bergius) A.DC.	Santalaceae	Waatoo	S	AM183
Osyris quadripartita Decne.	Santalaceae	Karo	S	AM198
Pentaschistis minor (Ballard & C.E.Hubb.) Ballard & C.E.Hubb.	Poaceae	—	H	AM061
Phytolacca dodecandra L´Herit.	Phytolaccaceae	Handode	H(clim)	AM205
Piliostigma thonningii (Schum.)	Fabaceae	Lilluu	T	AM165
Plantago africana Verdc.	Plantaginaceae	Qinxaa, Baallee	H	AM045
Podocarpus falcatus (Thunb) C.N	Podocarpaceae	Birbirssaa	T	AM130
Poecilostachys oplismeoides (Hack.) W.D.Clayton	Poaceae	Daaffa	H	AM144
Polygala steudneri Chod.	Polygalaceae	Grisa/Garasita	H	AM005
Polyscias fulva (Hiern) Harms	Araliaceae	Kooribaa	T	AM139
Polystichum ammifolium (Poir.) C.Chr.	Dryopteridaceae	Qumbuta, Gammanyee	H	AM069
Pouteria adolfi-friederici (Engl.) Baehni	Sapotaceae	Guduba	T	AM138
Pseudognaphalium luteo-album (L.) Hilliard and Burtt	Asteraceae	—	H	AM070
Psidium guajava L.	Myrtaceae	Zeytuna	S	AM177
Psychotria orophila Petit	Rubiaceae	Ulaagaa	S	AM154
Psydrax schimperiana Spermacoce L.	Rubiaceae	Galle	T	AM149
Pteris confusa (Lansgd & Fisch.) Kuhn	Pteridaceae	Qumbuta	H	AM126
Ranunculus multifidus Forssk.	Ranunculaceae	Sherif	H	AM077
Rapanea melanophloeos (L.) Mez	Myrsinaceae	Tulla	T	AM196
Rhus natalensis (Bernh. ex Krauss) F.A.Barkley	Anacardiaceae	Dabaqaa	S	AM171
Ricinus communis L.	Euphorbiaceae	Koboo, Gulo	S	AM179
Rosa abyssinica Lindley	Rosaceae	Gora	S	AM093
Rubus erlangeri Engl.	Rosaceae	Hato	S	AM004
Rubus steudneri Schwienf.	Rosaceae	Gora	S	AM086
Rumex abyssinicus Jacq.	Polygonaceae	Shabee Haga	H	AM050
Rumex nepalensis Spreng.	Polygonaceae	Shabee	H	AM021
Rytidosperma subulata (A. Rich.) Cope	Poaceae	Marga Hori, Qecha	H	AM110
Salvia merjame Forssk.	Lamiaceae	Okotu	S	AM015
Salvia nilotica Jacq.	Lamiaceae	Okotu	H	AM030
Sanicula elata Buch. -Ham. ex D.Don	Apiaceae	Galee Simbira, Sidissa	H	AM079
Satureja simensis (Benth.) Briq.	Lamiaceae	Toshimbata	H	AM049

Table 2: Continued.

Scientific name	Family	Local name (Or.)	Habit	Coll. no.
Scabiosa columbaria L.	Dipsacaceae	Anamuro	H	AM067
Schefflera abyssinica Forst. & Forst. f.,	Araliaceae	Gatamee	T	AM136
Schefflera volkensii (Engl.) Harms	Araliaceae	Ansha	T	AM204
Schinus molle L.	Anacardiaceae	Qondabarbere	T	AM166
Senecio ochrocarpus Oliv. and Hiern	Asteraceae	Agadena	H	AM046
Senecio ragazzii Chiov.	Asteraceae	Agadena	H	AM089
Senecio schultzii Hochst. ex A.Rich.	Asteraceae	—	H	AM057
Setaria megaphylla (Steud.) T.Durand & Schinz.	Poaceae	Sookora	H	AM127
Solanum anguivi Lam.	Solanaceae	Mujule Worabessa	S	AM111
Solanum garae Friis	Solanaceae	—	S	AM085
Solanum marginatum L.f.	Solanaceae	Hidii	S	AM076
Spathodea campanulata (S.nilotica)	Bignoniaceae	Horoqa	T	AM182
Sporobolus africanus (Poir.) Robyns and Tournay	Poaceae	Marga Hilensa (Or)	H	AM088
Sporobolus pyramidalis P.Beauv.	Poaceae	Chita	H	AM124
Stellaria sennii Chiov.	Caryophyllaceae	Duqushu, Dinbiba	H	AM108
Strychnos mitis S. Moore	Loganiaceae	Muluqaa	T	AM133
Swertia lugardae Bullock	Gentianaceae	—	H	AM053
Syzygium guineense (Willd.) DC.	Myrtaceae	Badeesa	T	AM117
Teclea nobilis Del.	Rutaceae	Hadheessa	T	AM184
Thymus schimperi Ronniger	Lamiaceae	Tossigne	H	AM047
Trema orientalis (L.) Bl.	Ulmaceae	Tala'aa	T	AM188
Trifolium acaule Steud. ex A.Rich.	Fabaceae	—	H	AM059
Trifolium rueppellianum Fresen.	Fabaceae	Sidissa (Maget)	H	AM092
Trifolium semipilosum Fresen.	Fabaceae	Sidissa	H	AM019
Trifolium simense Fresen.	Fabaceae	—	H	AM034
Trifolium substerraneum L.	Fabaceae	Sidisa (O), Alfalfa(E)	H	AM038
Triumfetta pentandra A. Rich	Malvaceae	Gurbii	H(clim)	AM125
Ursinia nana DC.	Asteraceae	Qinxxa	H	AM022
Urtica dioecia L.	Urticaceae	Dobi(Or), Sama(Amh)	S	AM158
Urtica simensis Steudel	Urticaceae	Dobii	H	AM109
Vepris dainellii (Pichi-Serm.) Kokwaro	Rutaceae	Arabe	T	AM129
Vernonia amygdalina Del.	Asteraceae	Ebicha	S	AM192
*Vernonia auriculifera*Hiern.	Asteraceae	Rejii	S	AM193
Warburgia ugandensis Sprague	Canellaceae	Bifi, kanafa	T	AM142
Zehneria scabra (Linn.f.) Sond.	Cucurbitaceae	Harola	H(clim)	AM096
*Ziziphus abyssinica*A.Rich.	Rhamnaceae	Kankura	S	AM195

H, herb; S, shrub; T, tree; Li, liana; H (clim), herbaceous climber; E, epiphyte; PH, parasitic herb; Or., Oromifa; Coll. no., collection number.

and greater canopy openness [56]. Moreover, the seedlings are most affected by edge effect due to their sensitivity to environmental changes and biotic interactions [57, 58]. Conversely, the mean basal area of woody species in the interior habitat ($11.16 \pm 1.82\,m^2\,ha^{-1}$) was significantly higher than the edge habitat ($3.99 \pm 0.54\,m^2\,ha^{-1}$) at $p < 0.05$ (Figure 2(b); Tables 4 and 5). This was due to the significantly higher mean DBH (78.62 ± 4.56 cm, $p < 0.001$) and height (33.63 ± 2.71 m, $p < 0.05$) of woody species [59] in the interior habitat than the edge. There were 27.32% of larger diameter individual tree species with DBH > 100 cm recorded in the interior habitat, whereas 4.09% of individuals with DBH > 100 cm were identified in the edge habitat. Microenvironmental conditions such as high temperature, low relative humidity, high wind force, low soil nutrient, and litter moisture in the edge habitats may contribute to the changes in tree abundance and distribution in the forest [60, 61].

Juniperus procera was the dominant woody species in the edge habitat with an IVI of 32.49, whereas *Croton macrostachyus* was dominant in the interior habitat with an IVI of 40.61 (Tables 5 and 6). Accordingly, *Juniperus procera, Hagenia abyssinica,* and *Syzygium guineense* were identified as generalists that abundantly occurred in both edge and interior habitats, whereas *Hypericum revolutum* Vahl. was identified as marginalized species that characteristically dominated the edge habitats [62, 63]. However, no woody species was found as a specialist that typically occurred in the interior habitats.

Table 3: Mean (±SE) values of species richness and diversity indices.

Diversity indices	Edge habitat	Interior habitat
Species richness (S)	35 ± 4.2^a	29 ± 3.6^b
Simpson index (D)	0.10 ± 0.02	0.11 ± 0.03
Shannon–Wiener index (H')	2.93 ± 0.17^a	2.43 ± 0.11^b
Pielou's evenness index (J')	0.79 ± 0.05	0.83 ± 0.04
Whittaker β-diversity (β_w)	1.83 ± 0.26	1.34 ± 0.31
Margalef index (D_M)	5.68 ± 0.69^a	3.72 ± 0.92^b
Berger–Parker index (d)	0.19 ± 0.03	0.24 ± 0.04

Note. Values with different letters indicate significant differences between habitats ($p = 0.05$).

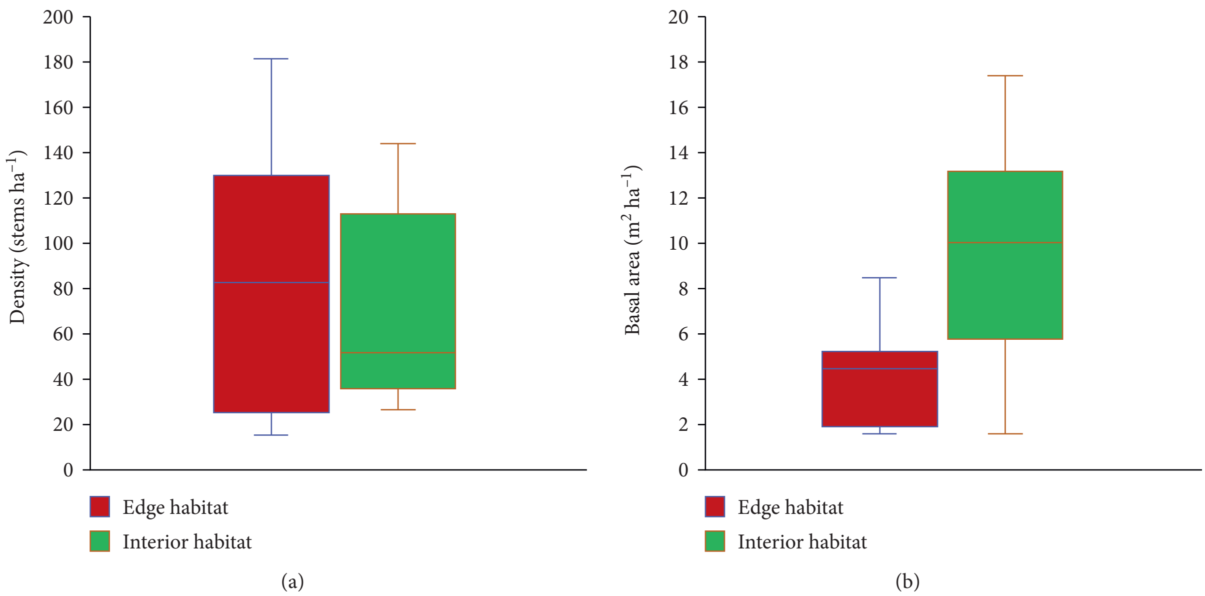

Figure 2: Box plot showing woody species density (a) and basal area (b) in the habitats.

Table 4: Woody species structure in the edge habitats of the BMNP.

Species	Abundance	Basal area (m^2 ha^{-1})	Density (stem ha^{-1})	Relative density	Relative frequency	Relative dominance	IVI
Celtis africana	12	1.94	9	1.79	6.35	5.18	13.32
Cordia africana	10	4.15	8	1.49	4.76	14.81	21.06
Croton macrostachyus	22	2.34	17	3.28	6.35	6.27	15.90
Diospyros abyssinica	3	0.95	2	0.45	1.59	5.08	7.12
Ehretia cymosa	12	7.31	9	1.79	4.76	15.64	22.19
Hagenia abyssinica	32	6.84	25	4.78	7.94	14.62	27.34
Hypericum revolutum	174	1.93	136	25.97	11.11	2.95	40.03
Juniperus procera	90	6.63	70	13.43	12.70	8.87	35.00
Lepidotrichilia volkensii	4	0.48	3	0.60	3.17	2.59	6.36
Macaranga capensis	6	0.44	5	0.90	3.17	2.34	6.41
Maytenus undata	54	0.00	42	8.06	4.76	0.00	12.82
Myrsine melanophoeos	170	0.28	133	25.37	7.94	0.61	33.92
Olea capensis	4	1.08	3	0.60	4.76	5.78	11.14
Olea welwitschii	6	0.17	5	0.90	1.59	1.79	4.27
Podocarpus falcatus	40	0.68	31	5.97	12.70	1.21	19.88
Pouteria adolfi-friederici	3	0.19	2	0.45	1.59	2.01	4.05
Syzygium guineense	28	6.70	22	4.18	4.76	10.24	19.18
Total	670	42.13	523	100	100	100	300

IVI: importance value index.

3.4. Effects of Landscape Change in Floristic Composition and Structure. The computed regression analysis among the landscape indices and species composition and structural parameters in this study revealed that only PN and AREA_MN significantly affected both the species composition and structural properties of the study area. Accordingly, PN was strong and negatively affected the overall species richness ($r = -0.90$, $p < 0.05$) and Shannon diversity index ($r = -0.96$, $p < 0.01$) (Table 7). Conversely, the overall species richness ($r = 0.95$, $p < 0.05$) and Shannon diversity ($r = 0.87$, $p < 0.05$) have shown strong and positive correlation with AREA_MN. This implies that as the number of fragmented habitats increases, species richness and diversity, particularly interior-dependent species, decreases. However, edge-dependent species comfortably flourished. One of the consequences of habitat fragmentation is an increase in the proportional abundance of the edge influenced habitat and its adverse impacts on interior-sensitive species [64]. Undoubtedly, while some species (e.g., habitat specialists) suffer from fragmentation, others benefit from it (e.g., generalists and edge species) [65]. Consequently, PN was strong and negatively correlated with AREA_MN

Table 5: Woody species structure in the interior habitats of the BMNP.

Species	Abundance	Basal area (m^2 ha^{-1})	Density (stem ha^{-1})	Relative density	Relative frequency	Relative dominance	IVI
Allophylus macrobotrys	6	0.71	5	0.79	2.86	1.76	5.41
Celtis africana	16	0.25	13	2.12	3.81	0.46	6.39
Croton macrostachyus	142	8.64	111	18.81	6.67	9.15	34.62
Diospyros abyssinica	4	0.08	3	0.53	1.90	0.58	3.01
Ehretia cymosa	74	0.83	58	9.80	4.76	2.06	16.62
Erica arborea	3	0.02	2	0.45	1.59	0.17	2.20
Elaeodendron buchananii	18	0.42	14	2.38	4.76	0.62	7.77
Fagaropsis angolensis	3	0.02	2	0.40	0.95	0.18	1.53
Hagenia abyssinica	40	10.43	31	5.30	7.62	9.67	22.58
Hypericum revolutum	8	0.05	6	1.06	6.67	0.18	7.90
Juniperus procera	128	31.54	100	16.95	7.62	29.24	53.81
Lepidotrichilia volkensii	4	0.01	3	0.53	0.95	0.11	1.59
Macaranga capensis	6	0.03	5	0.79	1.90	0.12	2.82
Margaritaria discoidea	4	0.03	3	0.53	1.90	0.13	2.56
Maytenus undata	49	0.06	38	6.49	2.86	0.16	9.50
Mimusops kummel	3	0.04	2	0.40	0.95	0.27	1.62
Myrsine melanophoeos	32	0.10	25	4.24	1.90	0.37	6.51
Ocotea kenyensis	32	1.13	25	4.24	6.67	1.20	12.10
Olea europaea	8	0.72	6	1.06	1.90	1.77	4.73
Olea welwitschii	6	0.17	5	0.79	2.86	1.24	4.89
Podocarpus falcatus	78	6.66	61	10.33	7.62	6.18	24.13
Polyscias fulva	3	0.24	2	0.40	0.95	1.79	3.14
Pouteria adolfi-friederici	8	2.61	6	1.06	3.81	4.83	9.70
Psydrax schimperiana	4	0.08	3	0.53	1.90	0.31	2.74
Schefflera abyssinica	3	0.20	2	0.40	0.95	1.49	2.84
Strychnos mitis	28	0.28	22	3.71	3.81	0.52	8.04
Syzygium guineense	35	9.55	27	4.64	6.67	23.60	34.90
Vepris dainellii	4	0.25	3	0.53	1.90	0.94	3.37
Warburgia ugandensis	6	0.25	5	0.79	1.90	0.94	3.64
Total	755	75.41	590	100	100	100	300

IVI: importance value index.

Table 6: IVI of woody species in the edge and interior habitats.

Species	Relative density (%)		Relative frequency (%)		Relative dominance (%)		IVI	
	Edge	Interior	Edge	Interior	Edge	Interior	Edge	Interior
Juniperus procera	11.72	20.13	8.79	11.94	11.98	25.03	32.49	37.10
Croton macrostachyus	2.86	22.33	4.40	10.45	8.47	7.83	15.73	40.61
Hagenia abyssinica	5.21	5.03	5.49	11.94	19.76	8.28	30.47	25.25
Syzygium guineense	3.65	5.35	7.69	4.48	13.84	20.21	25.18	30.03
Podocarpus falcatus	5.21	12.26	6.59	11.94	1.64	5.29	13.44	29.49
Myrsine melanophoeos	22.14	5.03	5.49	2.99	0.82	0.31	28.45	8.33
Ehretia cymosa	1.56	11.64	3.30	7.46	4.01	9.29	8.87	28.38
Hypericum revolutum	22.66	—	7.69	—	3.99	—	34.34	—
Cordia africana	1.57	—	4.48	—	8.79	—	14.84	—
Ocotea kenyensis	4.17	—	7.69	—	2.33	—	14.19	—

($r = -0.71$, $p < 0.001$). This implies that as the PN increases, the area of fragments decreases; as a result, small fragments contain a smaller species richness and lower species density than large fragments [66]. Large areas of habitat tend to support more individuals and, hence, more species [67].

Besides, modifying the spatial pattern of the landscape habitat size reduction and increase in isolation cause an alteration in the dispersal rate, affecting survival and mortality of individuals [8]. Many population and community changes in habitat fragments were commonly attributed to edge effects [66]. Interior species may be affected by the size decrease in their habitat, by edge effect, and by competition with generalists [68, 69]. The most threatened endemic species due to edge effect in the BMNP were *Helichrysum harennense* Mesfin, *Kniphofia insignis* Rendle, *Rubus erlangeri* Engl., and *Vepris dainellii* Pichi Serm

Table 7: Pearson's correlation coefficient between the landscape indices and floristic composition and structural parameters.

S	1										
H'	0.95*	1									
BA	0.96*	0.94*	1								
Density	0.99**	0.90*	0.93*	1							
PN	−0.90*	−0.96*	−0.96**	−0.84*	1						
AREA_MN	0.95*	0.87*	0.82*	0.72*	−0.71***	1					
SHAPE_AM	−0.42	−0.64	−0.53	−0.28	0.48*	−0.01	1				
COA	−0.56	−0.37	0.34	0.66	−0.87*	0.41	−0.79***	1			
ED	0.65	0.78	−0.77	−0.54	0.54*	−0.91	0.25	−0.16	1		
ENN_MN	−0.37	−0.56	−0.59	−0.28	0.77***	−0.26	0.73**	−0.81***	0.04	1	
IJI	−0.42	−0.28	−0.32	−0.37	0.58*	−0.59**	0.37	−0.61	0.37	0.1732	1
	S	H'	BA	Density	PN	AREA_MN	SHAPE_AM	COA	ED	ENN_MN	IJI

Note. The star indicates significant level between values (* $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$).

Kokwaro. Also, the most common invasive species in the study area favored by edge effect was *Achyranthes aspera* L., which is also common in the disturbed forests and forest edges of the dry Afromontane forests and moist Afromontane forests in Ethiopia [70]. The gradual decline in the more sensitive species may induce a species turnover in fragments and cascade effects [62, 63].

Among the landscape indices computed, only PN and AREA_MN significantly affected some of the floristic structural properties assessed. Thus, the PN was strong and negatively affected the woody species density ($r = -0.84$, $p < 0.05$) and basal area ($r = -0.96$, $p < 0.01$), as well as AREA_MN was strong and positively affected the density ($r = 0.71$, $p < 0.05$) and basal area ($r = 0.82$, $p < 0.05$) of woody species. Habitat destruction, isolation, and transformation affect the structure and dynamics of populations, communities, and ecosystems, as well as ecological processes [71]. Generally, as AREA_MN and COA of patches increase, species richness, diversity, evenness, woody species density, basal area, DBH, and height also increase. However, as PN, SHAPE_MN, ED, ENN_MN, and IJI of patches increase, floristic composition and structural variables decrease. This implies that the landscape composition and configuration change may potentially affect the vegetation composition and structure of a particular area.

4. Conclusion

This study recognized that the Bale Mountains National Park has a diverse biodiversity and is an ecologically significant area. It contains a variety of life forms with good ecological integration. It also harbors a number of endemic floras and faunas. However, currently, anthropogenic disturbances strongly impaired the plant species composition and structure as well as the overall ecological integrity of the landscape. The progressive settlement and agricultural land expansion at the expense of natural forest and grassland coupled with human-induced recurrent fire and livestock grazing in park became a potential threat to the landscape structure. This was due to the escalated human and livestock population and their corresponding demands and necessities increment in the park. Both the floristic composition and structure were affected by the expansion of edge habitat and shrinkage of interior habitat. Species richness and diversity were higher in the edge habitat, whereas density, frequency, and basal area were higher in the interior habitat. Therefore, maintenance of the habitats heterogeneity in the park is essential for long-term population persistence. Moreover, human activities in the park should be banned and settlements in the park should be relocated to other areas to avoid their potential impacts on the floras and faunas. Finally, studies on microenvironmental factors such as light availability, air and soil temperature, humidity, and soil nutrients along the edge and interior gradient should be conducted to determine their effect on species richness, composition, and structure.

Data Availability

The data used to support the findings of this study are included within this paper.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Acknowledgments

The authors would like to express their special thanks to the Ethiopian Wildlife Authority for giving permission to conduct this study on-site.

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