Effect of Soil Nutrients on Tree Diversity in Different Habitats of Bjagchog Gewog under Chukha Dzongkhag, Bhutan

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Abstract

The effect of soil nutrients on tree diversity in different habitats was assessed in Bjagchog under Chukha Dzongkhag with the aim to assess tree species diversity, determine the relationship between tree diversity and soil nutrients in different habitats, and assess people's knowledge on the effect of soil nutrients on tree diversity in the study area. Tree species data were collected systematically from a total of 30 plots (10 plots of 20 x 20m in each habitat type) along a transect line with 100m between each plot. Representative soil data was obtained from 15 plots for nutrient analysis. A random sampling method was used to collect social data. A total of 45 tree species from 34 different genera and 25 families were recorded in the study area. The highest species number (n=20), tree diversity, uniformity, and richness were recorded from the semi-disturbed habitat (H=2.54, J=0.85 & Dmg=3.58). One-way ANOVA showed a significant difference in tree species diversity between different habitats (p=0.002). Spearman's rho correlation test showed a significant correlation between species number and altitude. CCA biplot showed that soil-K was the most influential edaphic factor for the tree species maximum. The chi-square test found no significant association between gender, age, and annual income with the effect of tree diversity on soil nutrients ($p > 0.05$)

Keywords: Diversity, habitats, soil nutrients, tree species.

Background

Bhutan maintains approximately 71% forest cover, which is one of the main livelihood sources for rural and semi-urban people (Mukhia et al., 2011). They provide multiple ecosystem services such as species protection, soil erosion control, and habitat maintenance for many plant and animal species (Armenteras et al., 2009). Forests in Bhutan, however, face increasing threats from habitat fragmentation and loss of ecosystem diversity due to increasing human encroachment (Tenzin and Hasenauer, 2016). Much of the forest in Bhutan is under government regulation and it can, therefore, be classified as natural and partially disturbed forest in terms of human disturbance and accessibility (Dhital, 2009). The natural forests are not managed and there is negligible to limited human intervention in such areas. On the other hand, the partially disturbed forests are closer to communities, more accessible to people, and managed under specific management plans (Moktan et al., 2009). Due to the country's rapid population growth and industrialization, however, most forests in Bhutan are undergoing rampant degradation, resulting in the loss of several tree species. Species diversity can be driven by edaphic factors, with many studies reporting a significant relationship between tree diversity and soil nutrient availability. According to Laban et al. (2018) biodiversity is associated with higher soil nutrients and soil stability. Considering that Bhutan's forests are an important national resource and part of the country's heritage, it is pertinent that the relationship between tree diversity and soil nutrient content, which can help maintain the country's rich biodiversity, be understood.

There is limited studies on the biodiversity of disturbed and undisturbed areas of Bhutan's subtropical deciduous forests (Tenzin and Hasenauer, 2016) and due to the lack of information on the relationship between soil nutrients and tree diversity in tropical and subtropical forests (Nadeau and Sullivan, 2015) of Bhutan, the current study aims to address these limitations and assess tree diversity in relation to soil nutrient availability in different habitats in Bjagchog Gewog under Chukha Dzongkhag.

Materials and Methods

Study area

Chukha Dzongkhag lies at latitude 27.0784N and longitude 89.4742E along the southern foothills of the Bhutanese Himalayas (Saha et al., 2021) (Figure 1). Its altitude ranges from 200 - 3500 meters above sea level (Royal Government of Bhutan [RGoB], 2021). The Dzongkhag has a total area of 186,149ha, with 81% (151,164ha) of the total area covered by forest (Department of Forest and Park Services [DoFPs], 2018). According to the National Center for Hydrology and Meteorology ([NCHM], 2017), the annual average temperature ranges from 19°C to 29°C with a total annual rainfall of about 4979mm.

The study was conducted in Bjagchog Gewog, which has an area of 140.6km^2 and a population of 1,797 people. There are 12 villages and 238 households in Bjagchog. The altitude ranges from 1500 - 2500 meters above sea level (RGoB, 2018).

Sampling design

The study area was stratified into three different habitat types, namely disturbed forest, partially disturbed forest area, and undisturbed natural forest. The stratification of different habitats was based on preliminary information obtained from forest officials and local population in the study area. Stratification help obtain a representative population from each stratum (Elfil and Negida, 2017).

In each stratum/habitat type, 10 20 x 20m squares were plotted systematically along the transect line at regular intervals of 100m between plots, with the first as a random plot (Shacha et al., 2021). With 10 plots in each habitat type, a total of 30 plots were evaluated to investigate the effect of soil nutrients on tree diversity in different habitat types. In each sample plot, all trees with a minimum DBH of 10 cm were counted (DoFPs, 2018).

Social data collection

The selection of the interviewees for the qualitative data collection per habitat type was carried out using a random sample procedure. A semi-structured questionnaire was designed to gather social information about people's knowledge of the relationship between tree species diversity and soil nutrient content. The total number of households in each habitat type was recorded during the pre-survey, which accounted for a total of 70 households. A sample size of 60 respondents was determined using the statistical formula of Taro

Yamane's (Israel, 2003):

$$n = N/1 + N(e)^2$$

Where n = Sample size; N = whole population and e = sampling error

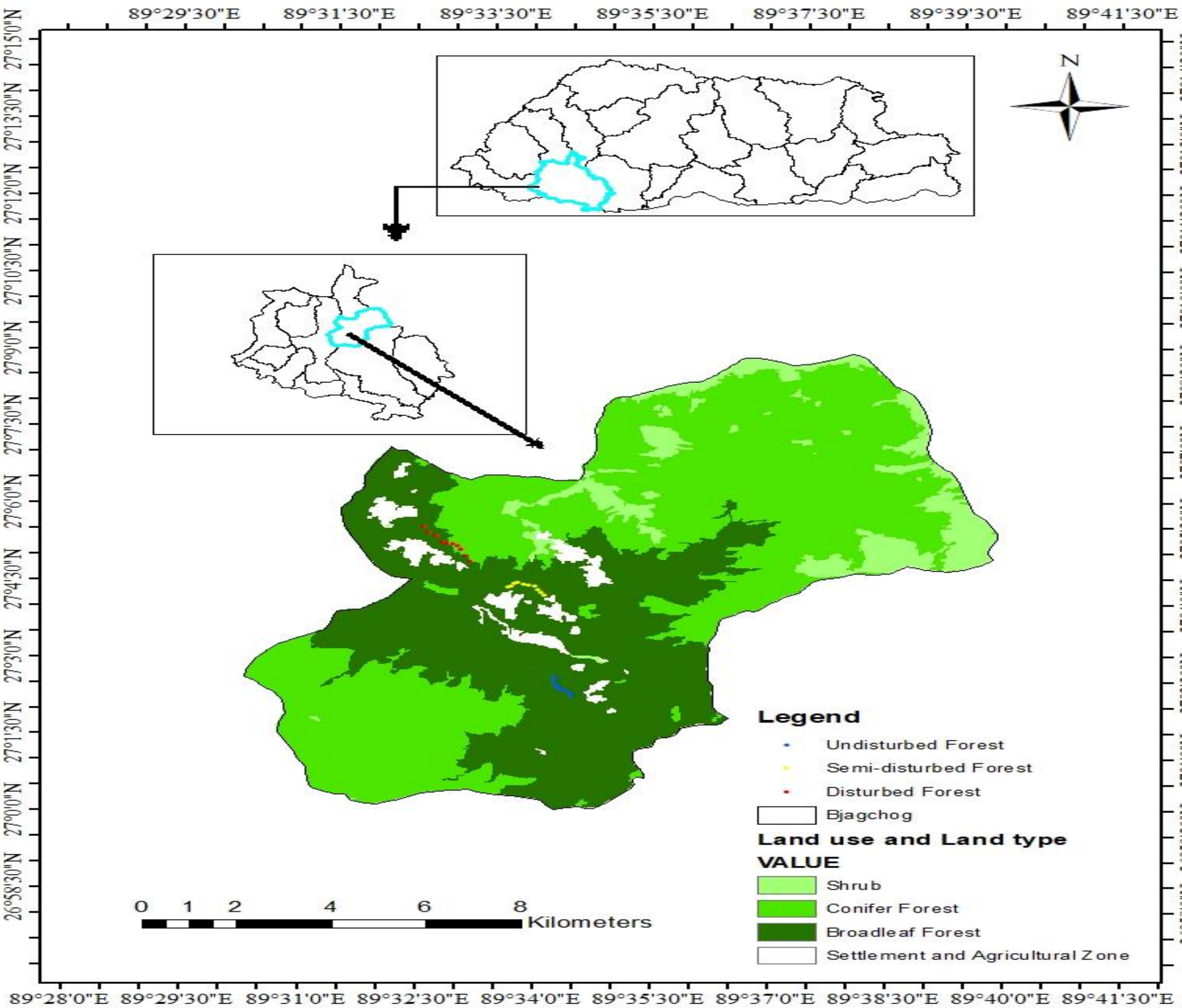

Figure 1. Map showing study area

Tree species identification

Known tree species were identified in the field, while those unidentified species were referred to Flora of Bhutan for identification. Relevant online sources such as the Flora Archive of Bhutan on Facebook and the Bhutan Biodiversity Portal were accessed and a few plant professionals were consulted to confirm tree species. The local population was also approached to help identify plant species.

Soil sample collection and laboratory analysis

Representative soil samples were collected using a 3.5cm radius and 30cm depth auger (Shacha et al., 2021). A total of 15 mixed soil samples (five of each habitat type) were collected from a total of 30 sample plots for nutrient analysis. The soil samples were then air dried and passed through a 2mm and a 0.5mm sieve to remove any soil aggregate.

Data analysis

The preliminary data collected from the field was entered into Microsoft Excel for cleaning and sorting. The Shannon diversity index (H), Pielous index (J), Margalefs index (Dmg), and Sorensons index of similarity (S) were used to calculate species diversity, uniformity, species richness, and beta diversity in different habitats, respectively.

Social data were compiled and coded in Microsoft Excel and analyzed in SPSS. A chi-square test of independence was performed to test the association between gender, age, annual income, and the effect of tree diversity on soil nutrients. ANOVA test was performed in SPSS to compare species richness in different habitat types. Spearman's Rho test was performed to assess the correlation between soil nutrients, count, and elevation. CCA was also performed to assess the correlation of tree species recorded in the study area with soil nutrients and elevation.

Results and Discussion

Tree species composition in different habitats

A total of 45 tree species from 34 different genera and 25 families were recorded from the three different habitats in the study area. Fagaceae was the most dominant family (n=7), followed by Lauraceae (n=5),Betulaceae, and Ericaceae (n=3) (Figure 2).

Species rarefaction curve

The species reduction curve shows that a higher number of species were recorded from the semi-disturbed habitat with 20 species as compared to the undisturbed habitat with 18 species, and the lowest number of species was recorded from the disturbed habitat with 17 species (Figure 3), supported by the mid- Domain effect hypothesis, where the mid-elevation sites usually have greater species richness (Sahu et al., 2019).

Tree species diversity, evenness, and richness in different habitats

Tree diversity, uniformity, and richness were the highest for semi-disturbed habitats (H=2.54, J=0.85, Dmg=3.58) and lowest for disturbed habitats (H=2.10, J=0.74, Dmg = 2.84) (Table 1). Similar results were reported by Akram et al. (2019) in which the environmental conditions of the site were well maintained to ensure effective plant growth even after potential damage to the forest from various anthropogenic activities. In addition to different intensities of human disturbances, the results also agree with the findings of Xu et al. (2017), where mid-elevation locations show greater diversity and uniformity than locations at higher and lower elevations, regardless of the extent of anthropogenic disturbance in those areas. On the other hand, the lower biodiversity, richness, and evenness in the disturbed forest is the result of human disturbances such as deforestation, which lead to a rapid decline in biodiversity (Borah et al., 2014).

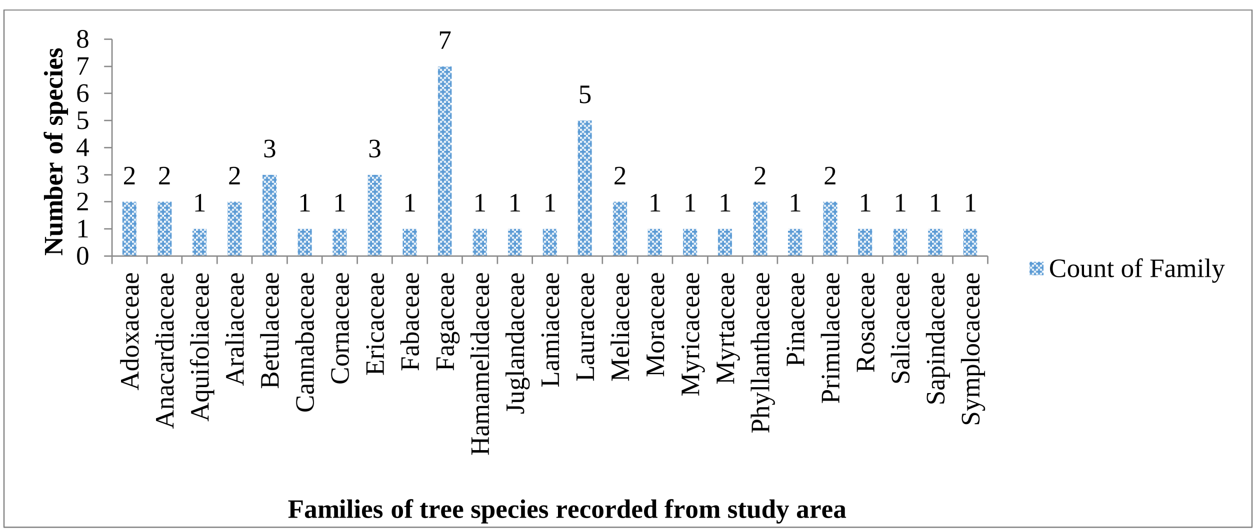

Figure 2. Family distribution of tree species in the study area

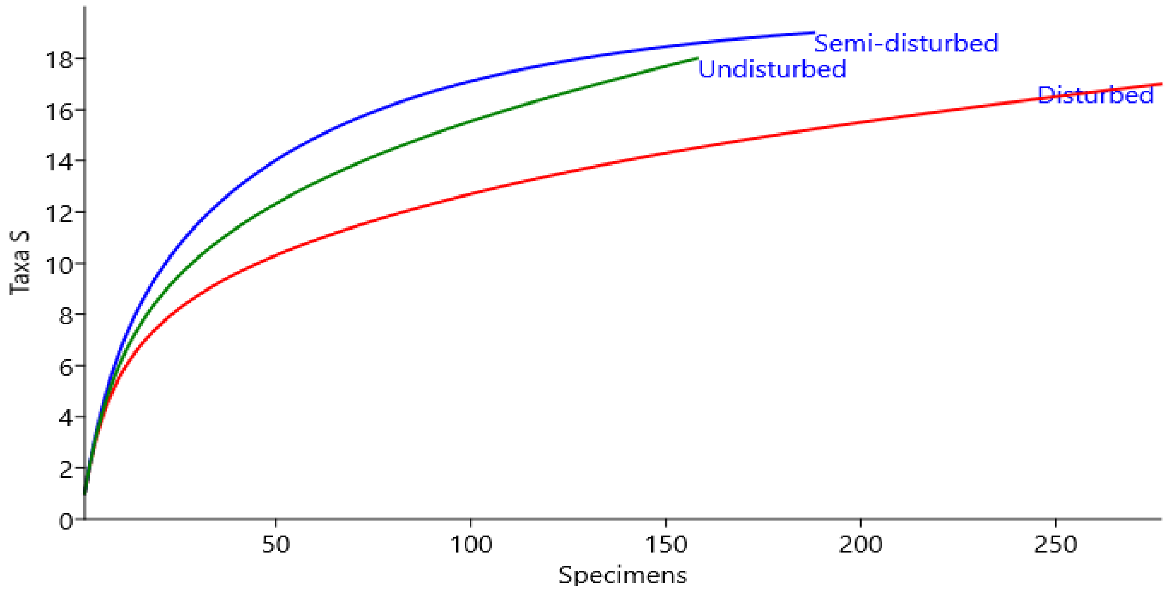

Figure 3. Species rarefaction curve

Table 1.Tree diversity indices in different types of habitats

Habitat types	Disturbed	Semi-disturbed	Undisturbed
Shannon diversity (*H'*)	2.10	2.54	2.28
Pielou's evenness (*J'*)	.74	.85	.79
Margalef's richness (*Dmg*)	2.84	3.58	3.35

Comparing species composition among three different habitats

Sorenson's similarity and dissimilarity indices across habitat types showed greater similarity of species composition between disturbed and semi-disturbed habitats (27%), followed by undisturbed and semi-disturbed habitat types (26%) (Figure 4). However, there was a higher percentage of dissimilarity between the species growing in the disturbed and undisturbed habitat, with a Sorenson's dissimilarity index of 89%. The major differences in species composition between disturbed and undisturbed habitats in the current study may be mainly due to differences in elevation between the two zones, in addition to varying degrees of human disturbance.

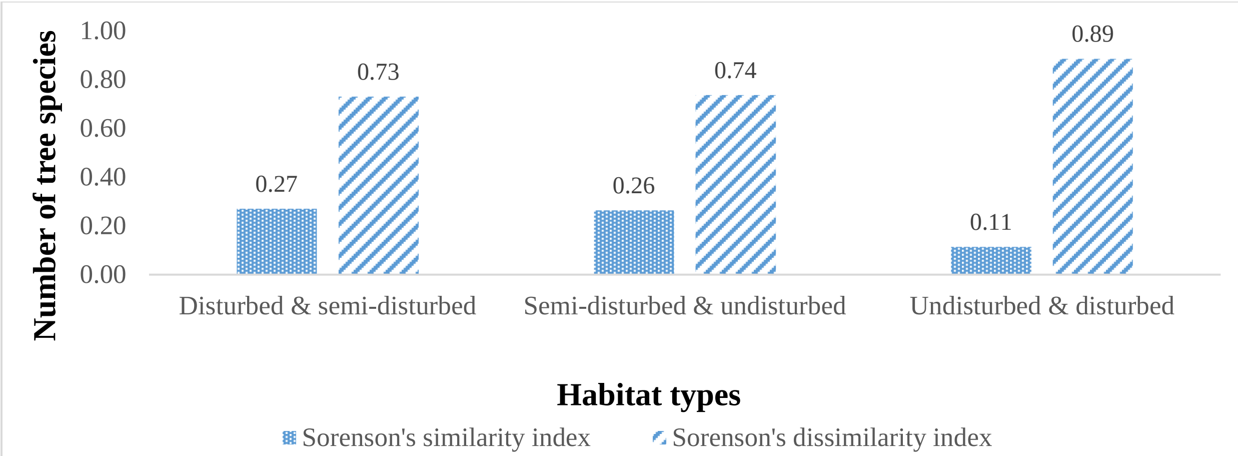

Figure 4. Similarity and dissimilarity of species in different habitat types

Soil nutrient assessment

The current study area ranged from an altitude of 1843.40 to 2542.10m above sea level. with a mean of 2144.05 (SE ± 51.53) (Table 2). The study found that most tree species grew in a soil pH range of 3.84 to 5.44, with a mean pH of 4.56 (SE ±.13). The results were supported by a study by Gentili et al. (2018) in which the best plant growth was observed at a soil pH between 5 and 7. Soil nitrogen ranged from 0.12% - 0.34%, with a mean of 0.24% (SE ±.02) and soil P ranged from 0.33% - 2.11%, with a mean of 0.96% (SE ±.16).

Table 2. Soil nutrient attributes of the study area

	Elevation	SOC (%)	Soil Moisture (%)	Soil N (%)	Soil P	Soil K	Soil pH	SOM (%)
N	15	15	15	15	15	15	15	15
Min	1843.40	1.45	13.64	.12	.33	8.90	3.84	2.50
Max	2542.10	3.91	55.76	.34	2.11	34.20	5.44	6.73
Sum	62177.54	42.22	496.86	3.62	14.4	252.6	68.4	72.61
Mean	2144.05	2.81	33.12	.24	.96	16.84	4.56	4.84
Std. error	51.53	.20	3.23	.02	.16	2.02	.13	.34
Variance	76995.40	.58	156.58	0	.37	61.22	.25	1.73
Stand. dev	277.48	.76	12.51	.07	.61	7.82	.50	1.31
Median	2047.20	2.54	32.28	.22	.68	13.90	4.51	4.38
25 percentile	1881.50	2.40	24.38	.21	.48	11.00	4.21	4.12
75 percentile	2489.41	3.42	41.24	.29	1.56	20.90	5.07	5.89
Skewness	.48	-.20	.33	-.18	.95	1.20	.42	-.20

Kurtosis	-1.61	-.82	-.30	-.73	-.63	.58	-.95	-.83
Geom. mean	2127.26	2.71	30.79	.23	.80	15.42	4.54	4.66
Coeff. var	12.94	27.13	37.78	27.83	63.34	46.46	11.03	27.16

Soil nutrients in different types of habitat

Soil nutrient analysis performed among the three different habitat types revealed higher levels of SOC (3.33%), SOM (5.73%), soil moisture (40.58%), nitrogen (0.29%), phosphorus (1.19 ppm) and pH (4.97) in the undisturbed habitat than in the disturbed and semi-disturbed habitats (Figures 5, 6, 7 & 8). Other studies have shown similar higher soil nutrient levels in the undisturbed forests of Rudraprayag and Pauri of Uttarakhand in the central Himalayas (Semwal et al., 2009). The higher nutrient levels in the undisturbed habitat can also be attributed to a higher rate of decomposition and litter production at this site (Sharma et al., 2017).

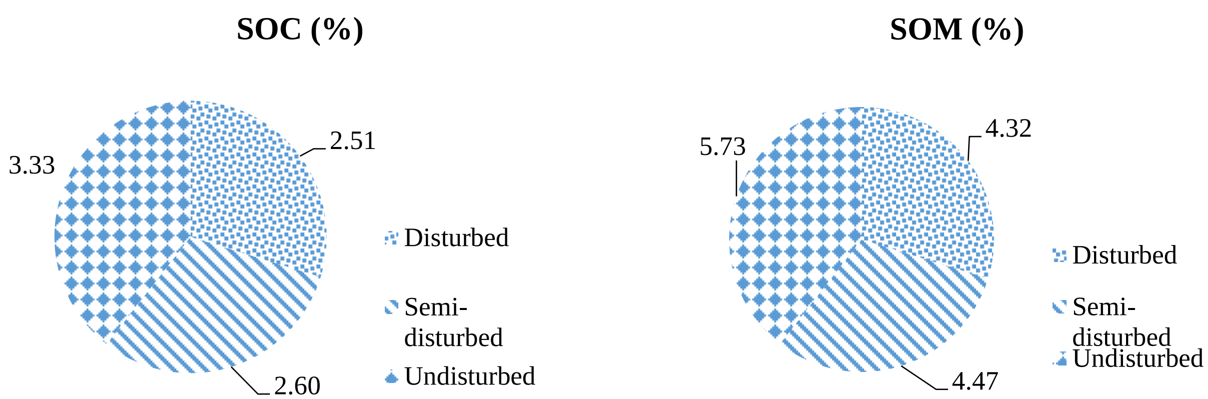

Figure 5. SOC and SOM in different habitats

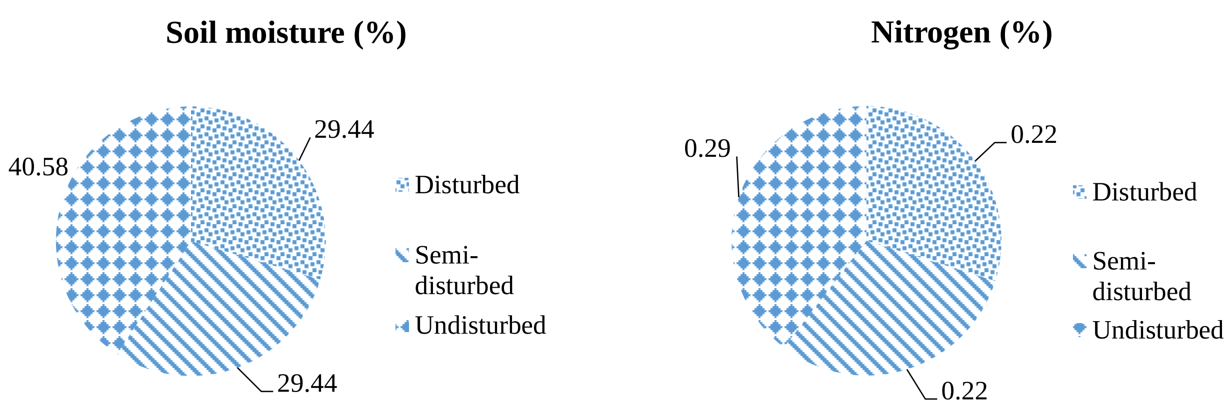

Figure 6. Soil moisture and Nitrogen in different habitats

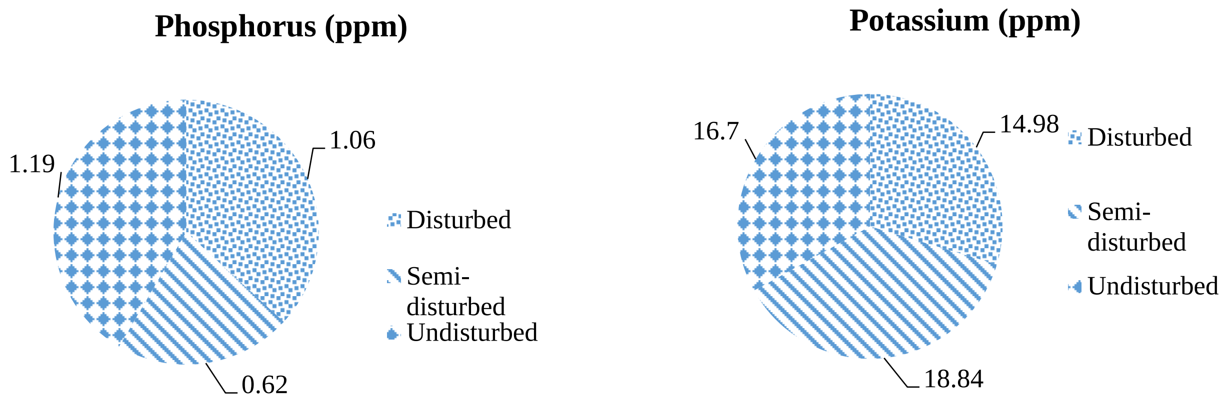

Figure 7. Phosphorus and Potassium in different habitats

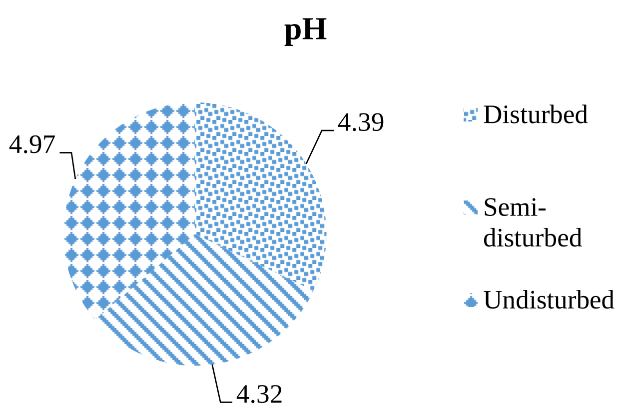

Figure 8. Soil pH in three habitat types

Tree diversity between three different habitat types

Table 3. One-way ANOVA for comparing diversity between different types of habitats

	SS	***Df***	***MS***	***F***	***Sig.***
Between Groups	1.078	2	.539	8.080	.002
Within Groups	1.802	27	.067		
Total	2.880	29			

One-way ANOVA showed a significant difference in tree species diversity between the three habitat types (F(2,27)=8.080, p=0.002) (Table 3), supported by Borah et al. (2014) who also found significant differences in diversity between different habitat types ($p < 0.05$). The Bonferroni test under the post hoc table showed that the diversity between disturbed and undisturbed habitats was highly significant (p=0.004) as compared to the diversity between semi-disturbed and undisturbed habitats (p=0.007). This could be due to larger differences in the intensity of human disturbance between disturbed and undisturbed habitats than between semi-disturbed and undisturbed forest types.

Relationship between species count, elevation, and soil parameters

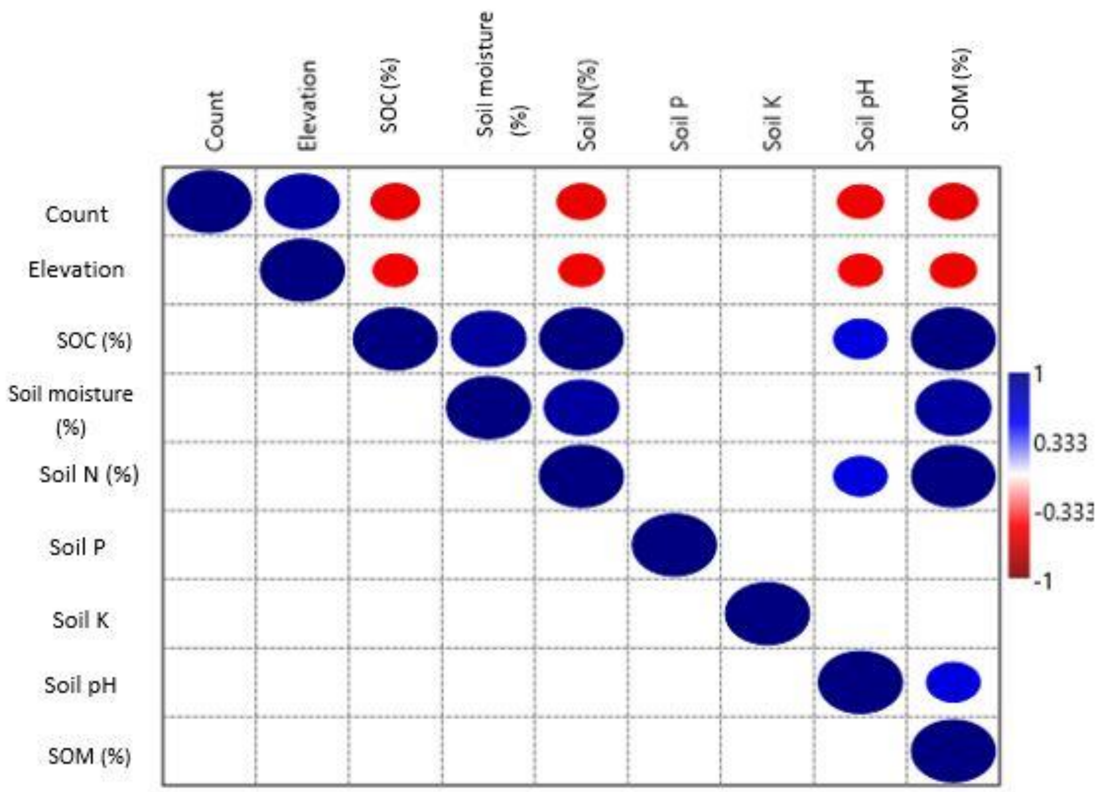

Figure 9. Spearman’s rho correlation coefficient

Spearman's rho correlation test, performed between tree species number, elevation, and soil parameters, found that there was a significant, strong, and positive correlation between species number and elevation (Figure 9). This means that the number of species increased with increasing altitude, which is consistent with the results of Yang et al. (2021) in which species composition was found higher between middle and higher altitudes. However, a negative correlation between species number, SOC, N, soil pH and SOM was observed. Similarly, a negative correlation between altitude, SOC, N, soil pH and SOM was also observv

Correlation between tree species, elevation, and soil variables (CCA)

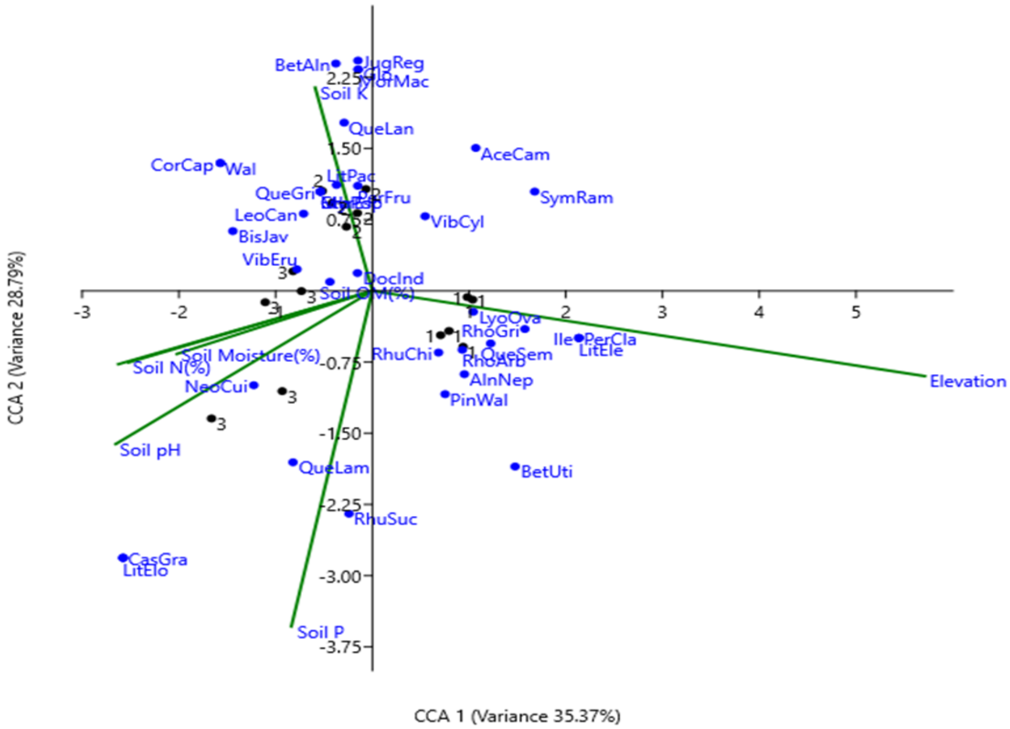

Figure 10. Canonical correspondence analysis showing correlation between species elevation, and soil variables.

A canonical correspondence analysis performed to examine the relationship between tree species, elevation, and soil variables revealed that the tree species distribution in the study area was mainly influenced by soil K followed by elevation (Figure 10). Other edaphic factors such as soil moisture, soil N, soil pH, and soil P were found to affect the distribution of only a few species. The results of the current study were supported by Thammanu et al. (2021), who found that environmental factors such as altitude and soil moisture were significantly associated with higher species diversity.

Socio-economic characteristics of respondents

Based on the demographic information in Table 4, 38.33% of the respondents were female and 61.67% were male. Respondents were divided into two age groups, with 33.33% falling into the under 40 age categories. The majority of respondents had no education with an illiteracy rate of 71.67%.

Respondents' income statistics showed that only 31.67% had an annual income equal to or greater than Nu. 100,000.

Demographic parameters	Respondents	Frequency	Percentage
Gender	Male	37	61.67
	Female	23	38.33
	Total	60	100.00
Age	<40	20	33.33
	>=40	40	66.67
	Total	60	100.00
Education	Not educated	43	71.67
	Primary	12	20.00
	Secondary	4	6.67
	College	1	1.67
	Total	60	100.00
Income	<100,000	41	68.33
	>=100,000	19	31.67
	Total	60	100.00

Table 4. Demographic details of the respondents

Association between genders, age, annual income, and effect of tree diversity on soil nutrients

The chi-square test of independence showed no significant association between gender (p=0.26), age (p=0.84), and annual income (p=0.97) of respondents with the effect of tree diversity on soil nutrients (Table 5). Similar results were reported by Wartenberg et al. (2018) on gender. Odendo et al. (2010) also found that the age variable had no significant impact on people's perceptions of the effect of soil nutrients on tree diversity.

	Yes **n (%)**	**No** **n (%)**	**X^2**	**p-value**
Gender				
Male	29 (65.9)	8 (50)		
Female	15 (34.1)	8 (50)	1.256	.26
Age				
<40	15 (34.1)	5(31.3)		
>=40	29 (65.9)	11 (68.7)	.043	.84
Annual income				

<100,000	30 (68.2)	11 (68.7)		
>=100,000	14 (31.8)	5 (31.3)	.002	.97

Table 5. Chi-square table of association between genders, age, annual income, and effect of tree diversity on soil nutrients

Assessment of willingness to plant trees beneficial to the ecosystem

Table 6 shows that more men (63%) than women (37%) were willing to plant trees beneficial to the ecosystem. The finding differs significantly from the study by Ureta et al. (2016) in which females prefer to plant trees that are beneficial to the ecosystem than males. This could be due to differences in the total number of men and women interviewed in the two different studies, with fewer female respondents interviewed in the current study. Unlike in Liang et al. (2018), in which a higher literacy rate was associated with higher environmental awareness, the lack of difference here could be due to the higher illiteracy rate among current respondents.

Table 6. Association between gender, age, annual income, and education level with willingness to plant trees beneficial to ecosystem

	Yes **n (%)**	**No** **n (%)**
Gender		
Male	29 (63)	8 (57.1)
Female	17 (37)	6 (42.9)
Age		
<40	16 (34.8)	4(28.6)
>=40	30 (65.2)	10 (71.4)
Annual income		
<100,000	32 (69.6)	9 (64.3)
>=100,000	14 (30.4)	5(35.7)
Education level		
Not educated	33 (71.7)	10 (71.4)
Educated	13 (28.3)	4 (28.6)

Conclusion

A total of 45 tree species from 34 different genera and 25 families from the disturbed, semi-disturbed and undisturbed habitats of the study area were recorded. Fagaceae was the most dominant family in the study area. Semi-disturbed habitats showed the highest species number (n = 20), tree diversity, uniformity, and richness (H = 2.54, J = 0.85, and Dmg = 3.58), supporting the mid-domain hypothesis. The highest Sorensens similarity index (26%) was found between disturbed and semi-disturbed habitats in the study area. Soil nutrient analysis of different habitat types showed higher SOC (3.33%), SOM (5.73%), soil moisture (40.58%), nitrogen (0.29%), phosphorus (1.19 ppm) and pH (4 ,97) in the undisturbed habitat than the disturbed and semi-disturbed habitats. The one-way ANOVA showed that there was a significant difference in tree species diversity between the three habitat types (p=0.002). Spearman's rho correlation coefficient showed that there was a significant, strong, and positive correlation between species number and altitude. The CCA performed showed that the majority of tree species were affected by Soil-K. The chi-square test of independence showed no significant association between sex, age, and annual income with the effect of tree diversity on soil nutrients.

The time available for data collection limited the area coverage of this study. Data were collected during the winter season alone and, therefore, it is unlikely that the current study covered the full extent of tree species in the study area. A more comprehensive comparative study of tree diversity and its impact on soil nutrient content in different seasons using a larger sampling area to generate more detailed and valid data for reference is, therefore, highly recommended for the future.

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