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Research Article

Effect of Species Diversity and Forest Structure on Soil Chemical Properties of Gatira George's Church Forest and Gemeshat Natural Forest, in North East Ethiopia

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ABSTRACT

The remnant forests located near Woregessa town, North Eastern Ethiopia were studied to determine the spatial variability of Species diversity and forest structure on soil chemical properties to provide information for sustainable management. A total of 60 and 9 quadrats, measuring 20 m × 20 m each, were established along line transects lying 100 m far apart were used to collect tree data across Gemeshat natural forest and Gatira George's church forest using stratified random sampling respectively. In each major plot, subplots 5 m × 5 m for shrubs data, and 2 m × 2 m were established at the center and corner for seedlings and saplings data respectively. Altitude and forest area was measured using GPS and QGIS 2.18 using ground forest boundaries collected point data respectively. DBH, basal area, and IVI were used for vegetation structure. The ratio of seedling, sapling and tree numbers were used for regeneration study. In both remnant forests, sixty-four species, representing 40 families were recorded. The most diverse family was Euphorbiaceae. The higher species diversity was observed in Gemeshat natural forest than Gatira George's church forest. Soil physio-chemical properties (Soil moisture, soil pH, OC, OM, TN and available P) decrease as soil depth increase and significantly different between two remnant forests at $P<0.05$. The present finding imply to further study Soil seed bank, seed rain, reproduction biology, the medicinal value of woody species and appropriate conservation measures for sustainable use of the forest resources in both forests are recommended.

Keywords: Quadrat; Physio-chemical properties; Deforestation; Biodiversity; Reproduction

INTRODUCTION

Ethiopia is one of the top 25 biodiversity-rich countries as the major center of diversity and endemism for several plant species in the world, due to its great geographical diversity, elevation, vegetation, and soil types and also diverse climate [1,2]. Woody plants constitute about 1000 species out of which 300 are trees [3].

According to MEFCC [4], current Ethiopia's forest cover is 15.5% which includes enormous areas of forest, dense wood lands, and bamboo and plantation forests of the country.

The deforestation rate and forest degradation activities have accelerated the loss of biological diversity [5].The annual deforestation rate ranges from 80,000 to 200,000 ha per year [6]. According to the report of Desta, about 20,000 ha of forests are annually cut in Amhara region for fuel, logging, and construction purposes [7]. This has contributed to the current low forest area, i.e.; only 60,688 ha state natural forest and 2.4 million ha public forests, which are not properly demarcated and managed [8].

The study areas have been rich in flora, fauna and bird species (personal observation). However, remnant forest has been pressurized by the surrounding society through in appropriate land use, the increase in settlement expansion nearby dwellers and also an increase in deforestation in associated with landslide. Soil erosion is a serious problem in the study areas [9]. Some Indigenous trees such as *Podocarpus falcatus, Juniperus procera, Olea europaea L. subsp. cuspidata* and others have regeneration variation across the study areas, implies the difference in the soil characteristics affects the plant distribution, diversity and regeneration in the area [10-12]. This is due to local people's high dependency on forests, alarming rate of population growth, forest degradation, and desertification. Other environmental problems, reduction of agricultural

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productivity and limited government budgets make the researches on tree dynamics an urgent targeting research [13].

Very few remnant forests remain today due to human activities [14]. Remnant forests are secondary forests composed of indigenous tree and shrubs still remaining in natural and church forests under conservation practice [15,16]. Remnant forests have a clear effect on the species diversity, species composition, and ecology of the species [17]. Secondary forest is naturally regenerated forest that revealed clearly affected visible indications of human activities [16]. Church forests are serving as *in-situ* conservation and hotspot sites for biodiversity resources [1].

The flora of North wollo is the least known still now, mainly due to lack of access [18]. Currently, forest species management on a sustainable basis is the main aim of conservation biodiversity [19]. The soil characteristics affect forest structure, and vegetation variation. The presence of appropriate data on forest is a vital requirement for protection, conservation, management and planning for sustainable development [20]. Therefore, it is important to prioritize biodiversity conservation sites by taking conservation activities which are basic and useful for the forests as well as the surroundings a study on forest structure is vital to know past management and to set management intervention [21,22]. In this paper, we have studied species diversity, forest structure, and regeneration status of two different forests to establish a relation between species diversity, forest structure, and regeneration. Therefore, study on species diversity, forest structure, and regeneration status of remnant forests are essential element to clearly imagine the environmental factors affecting the vegetation of an area and also the base for defining appropriate conservation strategies before losing potential to provide ecosystem services.

MATERIALS AND METHODS

Site and forest description

The studies were carried out on two sites namely Gemeshat forest and Gatira Georg's church forest, located in Habru district, North Wollo zone, Amhara, Ethiopia. Geographically, the sites are located between 39°59'69"E-39°64'70"E longitude and latitude 11°54'.16" N to 11°57'.27"N latitude. Its altitudinal range is between 1996 m to 2433 m a. s. l (Figure 1).

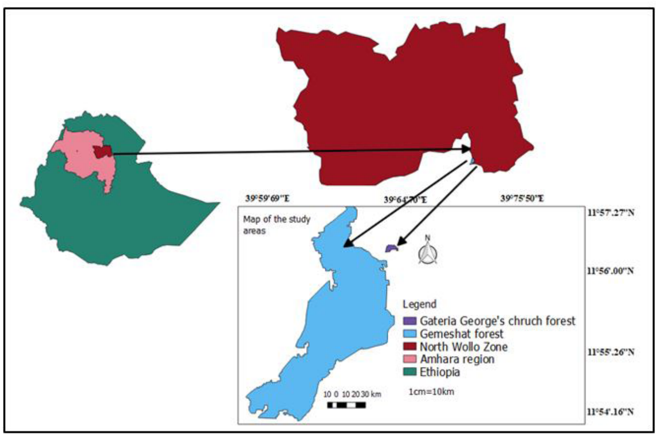

Figure 1: Map of the study areas. **Note:** (■) Gatira George's church forest, (■) Gameshat forest, (■) North Wollo Zone, (■) Amhara region, (■) Ethiopia.

The mean annual rainfall and temperature of the study area is 923 mm and 27°C respectively [23,24].

Gemeshat and Gatira George's church forest

Gemeshat forest is protected by forest guards employed by Habru district administration. Currently, the forest area is covered by indigenous trees accounts 527 ha in Gemshat natural forest and 2.4 ha in Gatira George's church forest (Forest areas known using QGIS 2.18 and GPS points taken from each boundary of forest types). People's livelihood is dependent on traditional agricultural practice of cultivating Onions, Tef and maize with unplanned irrigation by diverting water from the main stream [24].

Wildlife: As information gained from forest foreman, forest guards, and local community indicates the forests are home for many wild animals and bird species. The mammals are Geleda (*Theropithecus gelada*), Spotted hyena (*Crucuta crocuta*), common Jackal (*Canis aureus*), Abyssinian hare (*Lepush abessinicus*), Kilpspringer (*Oreotragus oreotragus*) and bird species covered by Abyssinian langclaw, white winged swallow chat, yellow fronted parrot, Harwood's Francolin, Abyssinian cat bird and Black-headed Siskin respectively.

Sampling methods

Systematic sampling methods were employed for vegetation data in both Gatira George's and Gemeshat forest (Figure 2). Quadrat sizes of 20 m × 20 m were used for both remnant forests located on the same agro ecology lying 100 m far apart were used for shrub and tree data following altitudinal gradient. Sample plots along three line transect in Gatira George's forest were laid systematically in a concentric way at every 50 m along transect lines, which were 50 m apart from each other. In Gemeshat forest, the sample plots were established systematically along ten lines transects at every 100 m interval between quadrates and transects [25]. The distance between transects equally for each study sites by entering 20 m from the edge of the forest. The total sample plots for church and Gemeshat forests were 9 m and 60 m respectively. The difference in the distance between transects line of the remnant forests were to capture the difference existed in forest area and altitudinal gradient and to increase precision of woody species diversity, structure, regeneration and soil characteristics. Sample plots of 20 m × 20 m (400 m^2) were for trees of height >5 m and DBH>10 cm. Five sub plot of 5 m × 5 m (25 m^2) were laid for shrubs with height 0.5 m-5 m [10,16]. Five smaller plot of 2 m × 2 m (4 m^2) also used for seedling DBH<2.5 and height <2 m and sapling >2 m with DBH<10 cm at the four corners and one at the center for tree regeneration study [10,26].

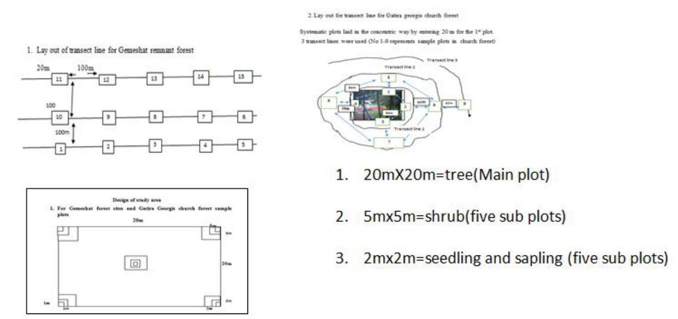

Figure 2: Design of sampling layout. (1) For Gemeshat forest (2) For Gatira George's church forest.

Gatira George's forest is owned by Ethiopian Orthodox Church while Gemeshat forests belong to the government. The altitudinal ranges for Gemehsat and Gatira George's forest are in 1996-2433 meters above sea level (m a.s.l) and 2013 m-2065 m a.s.l respectively.

Method of data collection

Vegetation inventory and species diversity: The vegetation data's were collected from October 29, 2017 to Jan, 14, 2018. In each quadrat, the name of species and number of individual species encountered in Gatira George's church forest and Gemeshat natural forests were recorded and their growth habit described.

Vegetation parameters were studied by laying out 50 and 9 plots of 20 m × 20 m size for trees along a line transect for Gemeshat and Gatira George's forest respectively. All trees ≥ 2 cm diameter at breast height (DBH=1.37 m from ground) were recorded in each quadrat. The vegetation data collection was first named using folk taxonomy as field identification. Then, formal taxonomic identification to species level was made later using photographed sample plants and compared with published volumes of the flora of Ethiopia and Eriteria and Natural Database for Africa (NDA) software [27]. Moreover, for specimens that were difficult to identify in the field, voucher samples were collected, pressed, and submitted for proper identification and botanical nomenclature at the National Herbarium, at Addis Ababa University.

Species diversity is calculated using Shannon's diversity index [28].

$$H' = -\sum \frac{ni}{N} \times 1n \frac{ni}{N} \quad (1)$$

The Simpson index is calculated using [29,30].

$$D = 1 - \sum pi2 \quad (2)$$

Species evenness is calculated using the equation [28].

$$J = \frac{H'}{H_{\max}} = \frac{H = -\sum \frac{ni}{N} \times 1n \frac{ni}{N}}{\ln s} \quad (3)$$

The Sorenson's Similarity Coefficient (SC) is calculated using [31].

$$SC = \frac{2c}{a+b+c} \times 100 \quad (4)$$

Forest structure: The tree density, diameter at breast height, and basal area were measured, recorded and used for description of vegetative structure as follows.

The importance value index is calculated using [29].

Importance value index=Relative density+Relative frequency+Relative basal area (5)

For the purpose of the study "seedlings", "saplings" and "mature trees/shrubs" were defined as plants with heights less than 1 m, 1 m–2 m with DBH <10 cm and greater than 2 m and DBH >10 cm respectively.

Soil sample collection: The status of soil between the selected forest sites were considered using soil physical properties (soil moisture content) and soil chemical properties (Soil pH, Organic carbon, Organic matter, total Nitrogen and available phosphorous). The sampled soils were taken along the altitudinal gradient to investigate soil physical and chemical properties correlation to woody species diversity, structure, and regeneration of remnant forests. These samples were air dried and mixed to ground with mortar and pestles. Then the grounded soil samples were sieved with 2 mm meish sieve for required soil analysis. Finally, the collected soil sample from the remnant forests was analyzed at Laboratory of Sirinka Agricultural research center. Soil pH was determined using soil pH (Soil pH meter). Soil Organic Carbon (SOC) and organic matter was determined using the Walkley and Black [32]. Total N and available phosphorous were determined using Kjeldahl method and Olsen et al., [33]. The organic matter content was determined by calculating Soil OC from the relationship of OM% i.e., OM%=SOC × 1.724 (I.e. the Warkley and Black method) as suggested by Jackson [34].

Data analysis: The forest structure and soil data was analyzed Using SPSS 16 and Microsoft Excel; 2013.The result of the analysis was summarized and presented using tables, pie chart and bar graphs.

The data obtained from the soil analysis was also subjected to an independent t-test for each sample depth separately to detect its attributes on the forest structure and species diversity between Gatira George's church forest and Gemeshat natural forest respectively.

Pearson linear correlation was calculated to determine correlation between the tested soil properties at two soil depth with forest structure and species diversity for both forest sites. Correlation between forest structures and species diversity attributes and soil variables were analyzed by statistical analysis package SPSS 16.

RESULTS AND DISCUSSION

Forest structure and species diversity

In both forests, species are almost uniformly distributed over the area but Gatira George's church forest showed an inequitable distribution and lower richness. Although, environmental population density of Gemeshat natural forest was relatively high due to large size of the forest and its accessibility whereas lowest population density of Gatira George's church forest may be associated with small size of the forest and some biotic disturbances like expansion of human settlement around the church during early forest formation. Diversity index of the present study lies within the range reported for tropical forests (between 1.5 and 4.5) which was lowest (2.88) for Gatira George's church forest and highest (3.3) in Gemeshat natural forest (Table 1). If it is close to 4.5, it implies more diverse [28]. The difference in species diversity between the remnant forests and comparable sites is due to the difference in site heterogeneity, altitude, temperature and soil. This implies more species diversity in Gemeshat natural forest than Gatira George's church forest. However, the result is lower than reported for Zegie pensula (H'=3.72, E=0.84), Sesa Mariam (H'=3.82, E=0.85 and Zengena remnant forests and yilat natural forests (higher H'=2.94 and lower E=0.84 reported by Alemayehu, Sisay, Birhanu et al., [35,36].

Table 1: Physiological description and Sorensen similarity coefficient of the remnant forests.

Study parameters	Gatira George's church forest	Gemeshat natural forest
Number of genera	34	60
Number of species	34	60
Number of families	27	38
Density (stems ha^{-1})	1156	4540
Basal area(m^2 ha^{-1})	7.86	17.4

Mean diameter(cm)	6.77	5.8
Shannon diversity index	2.88	3.3
Simpson diversity index	0.92	0.95
Species evenness	0.82	0.8
Sorensen similarity coefficient		
Gatira George's church forest	1	
Gemeshat natural forest	63.2	1

The total woody plants density was reportedly 3 001 and 2 850 trees/ha for Tara Gedam and Abebaye forests Haileab et al. [25]. which is larger than Gatira George's c church forest while it is less than Gemeshat natural forest (Tables 1). The total basal area of woody species were also reported 115.36 $m^2 \cdot ha^{-1}$ and 49.45 $m^2 \cdot ha^{-1}$ for Tara Gedam and Abebaye forests respectively, which are larger than both the present study areas.

The total number of species and life forms recorded in Gatira George's church forest is comparable with church forests in South Gonder (greater than Hiruy=31, equal to Debresena=34, less than Dengolt=36 and Gibtsawit=35, and Dengolt=36 reported by Alemayehu [37]. The total number of tree species recorded from remnant forest of north wollo also comparable with remnant forest of Wof-Washa and Zengena remnant Forests reported by Desalegn et al., and Gebremicael et al., [38,39].

Totally 38 and 27 families and, 60 and 34 Genera and 60 and 34 species were identified in Gemeshat forest and Gatira George's forests respectively. Among these 23 families, 27 genera and 27 species are common to both forest types. The most frequent families are Euphorbiaceae (6 species), Fabaceae, Oleaceae and Lamiaceae (4 species each), Rosaceae, Rubiaceae, Sapindaceae and Tiliaceae (3 species each), Anacardiaceae, Loganiaceae and Moraceae (2 species each) accounts 2.5%, 7.5%, 10% and 7.5% share in the study areas respectively. Twenty nine families were represented by only one species (72.5%) as shown in Table 2. The tree density ranges from 1156 stem ha^{-1} – 4540 stem ha^{-1} and basal area ranged from 7.86-17.4 m^2 ha^{-1} from degraded to natural forest, respectively. Gemeshat natural forest appears to be older than Gatira George's church forest as the tree population was extended up to a relatively high density with mean height of 5.68 cm leading to basal area per hectare.

Accordingly, the ratio of individuals with DBH between 10 cm and 20 cm (a) to DBH>20 cm (b) was 2.15 and 6 for Gatira George's church forest and Gemeshat natural forest respectively (Table 2). This indicates that the proportion of medium-sized individuals of (DBH between 10 cm and 20 cm) is larger than the large sized individuals (DBH>20 cm). When compare ratio (a/b DBH) of Gatira George's church forest is lower than Gemeshat natural forest. The remnant forests had more a/b ratio values than Berbere and Bodit forest indicating that there is more predominance of trees in the lower DBH class. When compare ratio (a/b DBH) of Gatira George's church forest is lower than Gemeshat natural forest (Table 2). The remnant forests had more a/b ratio values than Berbere and Bodit forest indicating that there is more predominance of trees in the lower DBH class.

Table 2: Comparison of total densities with DBH 10-20 cm (a) with DBH >20 cm (b) across remnant forests of North Wollo, Ethiopia.

Forest		Density		Ratio	Source
		(a)	(b)		
Gatira George's church forest		77.8	36.2	2.15	Present study
Gemeshat natural forest		453.3	75.5	6	Present study
Berbere forest		216.6	140.6	1.56	(Tesfaye et al., 2017)
Bale mountain national park	Adelle	413	164	2.52	(Haile et al., 2008)
	Boditi	256	114	1.56	

Soil characteristics

Physico-chemical properties of the two forest soils were significantly different (Table 3). Moisture content, soil pH, OC, OM, TN and available phosphorus of any forest may have significantly influenced nutrient availability to forest community. With this regards, Gatira George's church forest has higher value in Moisture content, soil pH, OC, OM, TN and available phosphorus whereas Gemeshat forest has lowest nutrient availability. The result implies that the Gatira George's church forest was higher in the availability of soil nutrients in OC, OM, soil pH, total N and available p as well as soil moisture content than Gemeshat forest. This intern helps the site suitable for the regeneration of Celtis africana and Olea europaea better than Gemeshat forest sites. This is due to, the species diversity and identity match with species site condition, soil characteristics and soil ecosystem functions in which similarly reported by Manette, Robin and Morin et al., [17,40]. The other reason due to the difference in nutrient is the presence of landslide, erosion, livestock grasing and human distance in Gemeshat forest. When the Gemeshat forest kept free from human and domestic animal interference inside the forest area, it will restore the soil fertlity to maintain species diversity and protect tree species similarly reported by Haileab, et al. [25,41]. Site matters for the difference in both Gatira George's church forest and Gemeshat natural forests of the soil characteristics. This result is similar to the work of [10].

Table 3: Soil physicochemical properties of Gatira George's church forest and Gemeshat natural forests. N: Nitrogen, P=phosphorous, 0C: Organic carbon, OM: Organic matter.

Soil parameters	Gatira George's church forest	Gemeshat natural forest	P-values
Moisture content (%)	26.4 ± 1.5a	15 ± 1.04b	0
Soil pH	6.78 ± 0.03	6.4 ± 0.06	0.044
Organic carbon (%)	2.76 ± 0.1	2.16 ± 0.07	0.004
Organic matter (%)	4.76 ± 0.17	3.72 ± 0.13	0.003
Total N (%)	0.42 ± 0.03	0.36 ± 0.01	0.151
Available P(Ug g-1)	50 ± 1.5a	37 ± 1.04b	0

Correlation between species diversity and forest structure with soil properties

Pearson's correlation coefficients between forest structure attributes (Density, basal area, species richness and diversity indices) and six soil variables were studied (Tables 4 and 5). Basal area was positively correlated with available phosphorus ($r<0.741$, $p<0.05$). Moisture content, pH, OC, OM and TN at 15 cm-30 cm soil depth are the main factors affecting species basal area in Gatira George's church forest. TN was positively correlated with p ($r=0.681$, $p<0.05$) at 0 cm-15 cm soil depth. In some tropical forests, consistent correlations among some composition and structure characteristics of the number of individuals and the species richness of tree species [42]. Among the ten variables, basal area ha^{-1} was significantly positively correlated with available phosphorus at ($p<0.05$). Moisture content was significantly negatively correlated with available phosphorus ($p<0.05$) in Gatira George's at 0 cm-15 cm soil depth (Table 4).

Many studies have found available phosphorus at 0 cm-15 cm soil depth is the main factors affecting the variation in species basal area [43]. In the present study, forest vegetation was found more closely associated with available Phosphorus. Soil properties are the major controlling agents for species distribution in tropical forest [44].

According to Ceccon et al., water soil availability is considered a key factor for the regeneration, survival and growth of seedling communities in tropical forests [45].

The highest change of OM with depth under forest land (Tables 4 and 5) might be attributed to continuous accumulation of un-decayed and partially decomposed plant and animal residues mainly in the surface soils of forest land, high rate of interception and infiltration and/or absence of erosion [46].

Soil pH, available P and K are the main factors affecting the variation in species richness in degraded forest [43]. Summarized explanation of forest structure and soil properties correlation results of the present study could be that soil conditions differs between the forest types. The finding is in line with the reports of Wardle et al., which states that forest composition not only affects soil but that soil properties also govern forest composition and species diversity [47].

According to George et al., tree density and diversity are correlated with soil OC and fertility [48]. With this regards, the present study also implies the same trends in correlation of vegetation structure and soil (Tables 4 and 5).

Pearson's correlation coefficients between forest structure attributes (Density, basal cover, species richness and diversity indices) and six soil variables were studied (Tables 6 and 7). Topsoil layer had significantly greater in pH, OC, OM and TN than sub soil at Gemeshat natural forest. Hence, the correlation among the selected soil properties also varies with soil depth. This section offers information on the relationship among the soil properties with depth. Organic matter was correlated positively significantly with most of soil properties. Density was significantly positively correlated with basal area and species richness in Gemeshat natural forest at ($p<0.001$).Species diversity was significantly positively correlated with species diversity index in Gemeshat natural forest at ($p<0.001$). Among the ten variables basal area ha^{-1} was significantly positively correlated with moisture content, OC, OM and total nitrogen ($p<0.01$) and with pH at ($p<0.05$) respectively. The presence of positive correlation between soil nutrients such as MC and pH. MC was positively correlated with pH ($r=0.27$, $P<0.05$) (Table 6). It was also positively correlated with OC and OM ($r=0.346$ and $r=0.381$ at $p<0.01$) at 0-15 cm soil depths but it was negatively not significantly correlated with pH at 15-30 cm soil depth ($r=-0.37$, $p>0.05$), pH was positively correlated with OC and OM ($r=0.31$ and $r=0.309$, $p<0.05$) respectively. Organic carbon (OC) was highly positively correlated with OM and TN at 0 cm-15 cm soil depth ($r=0.999$ and $r=0.434$, for both $p<0.01$) respectively. Organic Matter (OM) also highly positively correlated with TN at 0 cm-15 cm soil depth ($r=0.442$, $p<0.01$).

Forest stand does not increase species diversity, instead forest structure increase species diversity Fredrich and Andrea, which is similar to the present study (Tables 6 and 7) [49].

Table 4: Corrrelation analysis of soil properties (0-15 cm soil depth) on forest structure and diversity of woody species in Gatira George's church forest.

		Density	BA	Spp R	Spp D	MC	pH	OC	OM	TN	P
Density	Pearson Correlation	1									
	Sig. (2-tailed)										
BA	Pearson Correlation	-0.07	1								
	Sig. (2-tailed)	0.87									
Spp R	Pearson Correlation	0.93**	-0.1	1							
	Sig. (2-tailed)	0	0.9								
Spp D	Pearson Correlation	0.693*	-0.1	0.797*	1						
	Sig. (2-tailed)	0.04	0.8	0.01							
MC	Pearson Correlation	-0.38	-0.3	-0.4	-0.5	1					
	Sig. (2-tailed)	0.32	0.4	0.29	0.2						
pH	Pearson Correlation	0.585	-0.2	0.579	0.38	-0.09	1				
	Sig. (2-tailed)	0.1	0.7	0.1	0.3	0.82					
OC	Pearson Correlation	0.401	0.21	0.179	0.36	-0.6	0.317	1			
	Sig. (2-tailed)	0.28	0.6	0.65	0.3	0.09	0.41				

OM	Pearson Correlation	0.402	0.21	0.178	0.35	-0.6	0.317	1.000**	1		
	Sig. (2-tailed)	0.28	0.6	0.65	0.4	0.09	0.41	0			
TN	Pearson Correlation	-0.12	0.56	-0.17	0.05	-0.47	0.128	0.66	0.656	1	
	Sig. (2-tailed)	0.77	0.1	0.67	0.9	0.2	0.74	0.1	0.06		
P	Pearson Correlation	0.256	.741*	0.285	0.51	-.668*	0.079	0.59	0.589	.681*	1
	Sig. (2-tailed)	0.51	0	0.46	0.2	0.05	0.84	0.1	0.1	0.04	

Note: **-Correlation is significant at the 0.01 level (2-tailed), *-Correlation is significant at the 0.05 level (2-tailed), Density-(stems ha^{-1}), BA-(Basal area m^2 ha^{-1}), Spp R-species richness, Spp D-Species diversity, MC-(moisture content %), pH-(soil pH),OC-(Organic carbon %),OM-(Organic matter %),TN-(total nitrogen), P-(available phosphorus).

Table 5: Correlation analysis of soil properties (15 cm-30 cm soil depth) on forest structure and diversity of woody species in Gatira George's church forest.

		Density	BA	SppR	SppD	MC	pH	OC	OM	TN	P
Density	Pearson Correlation	1									
	Sig. (2-tailed)										
BA	Pearson Correlation	-0.07	1								
	Sig. (2-tailed)	0.87									
SppR	Pearson Correlation	.930**	-0.1	1							
	Sig. (2-tailed)	0	0.9								
SppD	Pearson Correlation	.693*	-0.1	.797*	1						
	Sig. (2-tailed)	0.04	0.8	0.01							
MC	Pearson Correlation	-0.66	-0.3	-0.58	-0.6	1					
	Sig. (2-tailed)	0.06	0.4	0.1	0.1						
pH	Pearson Correlation	0.505	0.13	0.605	.884**	-0.37	1				
	Sig. (2-tailed)	0.17	0.7	0.08	0	0.32					
OC	Pearson Correlation	0.394	0.29	0.292	0.45	-0.28	0.502	1			
	Sig. (2-tailed)	0.29	0.4	0.45	0.2	0.46	0.168				
OM	Pearson Correlation	0.392	0.29	0.289	0.44	-0.28	0.502	1.000**	1		
	Sig. (2-tailed)	0.3	0.4	0.45	0.2	0.47	0.168	0			
TN	Pearson Correlation	-0.4	-0	-0.54	-0.5	0.25	-0.48	0.356	0.36	1	
	Sig. (2-tailed)	0.29	1	0.13	0.2	0.51	0.188	0.35	0.35		
P	Pearson Correlation	0.079	0.43	-0.01	-0.5	-0.09	-0.55	-0.28	-0.28	0.02	1
	Sig. (2-tailed)	0.84	0.3	0.98	0.1	0.8	0.125	0.47	0.47	1	

Note: **-Correlation is significant at the 0.01 level (2-tailed), *-Correlation is significant at the 0.05 level (2-tailed), Density-(stems ha^{-1}),BA-(Basal area m^2 ha^{-1}), Spp R-species richness, Spp D-Species diversity, MC-(moisture content %), pH-(soil pH), OC-(Organic carbon %),OM-(Organic matter %),TN(total nitrogen), P-(available phosphorus).

Table 6: Correlation analysis of soil properties (0-15 cm) effect on the structure and diversity of woody species at Gemeshat forest.

		Density	BA	Spp R	Spp D	MC	pH	OC	OM	TN
Density	Pearson Correlation	1								
	Sig. (2-tailed)									
BA	Pearson Correlation	.456**	1							
	Sig. (2-tailed)	0								
Spp R	Pearson Correlation	.540**	.277*	1						
	Sig. (2-tailed)	0	0							
SPP D	Pearson Correlation	0.1	0	.367**	1					
	Sig. (2-tailed)	0	0.8	0						
MC	Pearson Correlation	0.2	.472**	0	-0.1	1				
	Sig. (2-tailed)	0	0	1	0.4					

pH	Pearson Correlation	0.2	.268*	0	-0.1	.270*	1			
	Sig. (2-tailed)	0	0	1	0.3	0				
OC	Pearson Correlation	0.2	.493**	0.1	-0.2	.338**	.316*	1		
	Sig. (2-tailed)	0	0	0	0.1	0	0			
OM	Pearson Correlation	0.2	.485**	0.1	-0.2	.346**	.309*	.999**	1	
	Sig. (2-tailed)	0	0	0	0.1	0	0	0		
TN	Pearson Correlation	0.1	.430**	0.2	0	.381**	0.2	.434**	.442**	1
	Sig. (2-tailed)	0	0	0	1	0	0.2	0	0	
P	Pearson Correlation	0	-0.1	0	0	0	0.1	0	-0.2	0
	Sig. (2-tailed)	0	0.6	1	1	0	0.4	0.1	0.1	1

Note: **-Correlation is significant at the 0.01 level (2-tailed) and *-Correlation is significant at the 0.05 level (2-tailed).

Table 7: Correlation analysis of soil properties (15-30 cm) effect on the structure and diversity of woody species at Gemeshat forest.

		Density	BA	SppR	SppD	MC	pH	OC	OM	TN	P
Density	Pearson Correlation	1									
	Sig. (2-tailed)										
BA	Pearson Correlation	0	1								
	Sig. (2-tailed)	1									
SppR	Pearson Correlation	.930**	-0.1	1							
	Sig. (2-tailed)	0	0.9								
SppD	Pearson Correlation	.693*	-0.1	.797*	1						
	Sig. (2-tailed)	0	0.8	0							
MC	Pearson Correlation	-1	-0.3	-1	-0.6	1					
	Sig. (2-tailed)	0	0.4	0	0.1						
pH	Pearson Correlation	0.5	0.13	0.6	.884**	0	1				
	Sig. (2-tailed)	0	0.7	0	0	0					
OC	Pearson Correlation	0.4	0.29	0.3	0.45	0	0.5	1			
	Sig. (2-tailed)	0	0.4	0	0.2	0	0.2				
OM	Pearson Correlation	0.4	0.29	0.3	0.44	0	0.5	1.000**	1		
	Sig. (2-tailed)	0	0.4	0	0.2	0	0.2	0			
TN	Pearson Correlation	0	0	-1	-0.5	0.3	0	0.4	0.36	1	
	Sig. (2-tailed)	0	1	0	0.2	1	0.2	0.3	0.4		
P	Pearson Correlation	0.1	0.43	0	-0.5	0	-1	0	-0.3	0	1
	Sig. (2-tailed)	1	0.3	1	0.1	1	0.1	0.5	0.5	1	

Note: **-Correlation is significant at the 0.01 level (2-tailed) and *-Correlation is significant at the 0.05 level (2-tailed).

Soil Nitrogen (N) increased fine root biomass, possibly because Nitrogen is needed for Phosphorus absorption by roots. The soil fertility especially phosphorus strongly limits forest stock; low Phosphorus availability may cause strong environmental filtering, which in turn results in a small set of dominant species [50]. In other words, plant diversity is capable to reduce the risk of phosphorus releases in runoff [51].

Soil pH, total Nitrogen and Available Phosphorus decrease as soil depth increases in all remnant forest sites. This result is similar to the report [52,53], as topsoil depth decreases, the potential for survival and growth of woody vegetation decreases. The ideal pH of the remnant forest sites are within the ranges for tree species is 5.5-6.5, which is supported by the reports [54,56].

More number of species and higher species diversity is occurred in Gemeshat natural forest than Gatira George's church forest, which is related to soil nutrient availability at both soil depths. Similarly showed the soil nutrient plays important role in the distribution of plant communities [57].

As explained in the result (Tables 4 and 6), Soil pH and total Nitrogen with species diversity had significant relation and the relation is positive at 0 cm-15 cm soil depth. There is contradicting report as strong effects of soil fertility and species traits that determine resource acquisition and conservation, but not of species diversity [58-61].

CONCLUSION

Even if, Soil properties and forest structure are closely related to each other, the two remnant forests had showed significant variation at P<0.05 in soil properties such as moisture content, pH, OC, OM, and available phosphorus. The variation was higher in Gatira George's church forest than Gemeshat natural forest, soil moisture, soil ph, OC, OM, TN and available P decrease as soil depth increases.

The higher basal area, density and diversity index were recorded in Gemeshat natural forest than Gatira George's church forest. There is significantly positively correlation noticed between species diversity and forest structure with soil properties Gatira George's church forest, which implies Gatira George's church forest plays pivotal role in conservation of species and marinating the soil fertility as it is coined with spiritual laws and keep the sanctions of God, and hence kept more endemic and indigenous species in a small plot of land. But, the larger trees in Gemeshat natural forest were under huge pressure and the forest degraded in the soil nutrients than Gatira George's church forest due to overexploitation for different purpose.

It can be concluded that the protection of the remnant forests has a positive effect on restoring the species diversity, structure, and soil fertility of the remnant forests.

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