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RESEARCH PAPER

Edaphic correlates of tree species diversity, composition, and distribution in an eastern arc biodiversity hotspot, Tanzania

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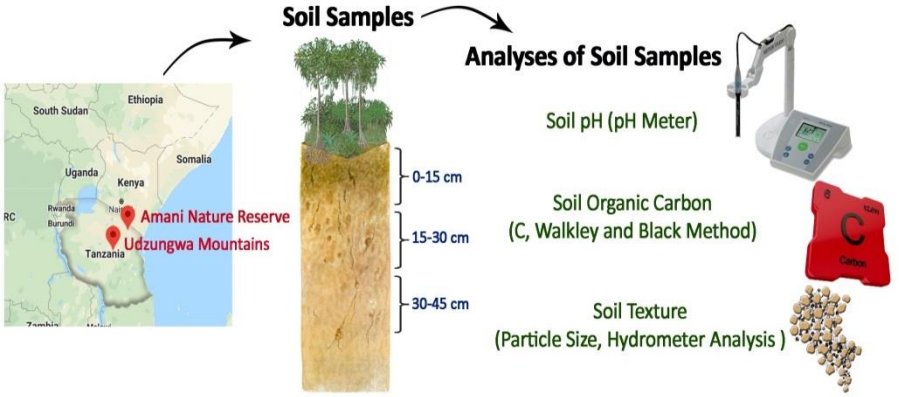
Highlights

- There is a direct relationship between soil and vegetation.
- As a habitat for micro-macro organisms, the soil is of crucial importance.
- The forest is the sole biodiversity hotspots home for many species.
- Soil properties affect the performance and shape of soil communities.

Graphical Abstract



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Abstract

This study explored the edaphic correlates of tree species diversity, composition, and distribution in the Amani Nature Reserve (ANR) and Udzungwa Mountains (UMF). Using canonical correspondence analysis, different ecological gradients explained plant community patterns. In ANR, species richness decreased significantly with pH ($r = -0.383$, $p = 0.03$; $r = -0.422$, $p = 0.016$) at 0-15 cm and 30-45 cm depth respectively and percentage coarse silt at 30 cm ($r = -0.416$, $p = 0.018$). Further, species richness and diversity increased along a gradient of percentage organic carbon ($r = 0.35$ and $r = 0.22$) respectively and decreased with bulk density ($r = -0.24$ and -0.29 at 15 and 30 cm respectively) in UMF. There was pronounced variation in edaphic correlates of tree community patterns between sites. Soil pH was the strongest edaphic correlate of species composition and distribution in ANR while percentage organic carbon was a strong edaphic correlate in UMF. Stronger effects by soil pH indicate the influence of soil chemical properties in the study sites. Variation in the influence of edaphic correlates to tree community patterns between the two sites suggests a need for site-specific assessment of edaphic properties.

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1. Introduction

The Eastern Arc Mountains (EAMs) sustain specific tree communities that are biologically richest on Earth and experience augmenting pressures mainly from logging and agriculture. Understanding the factors that affect EAMs tree diversity is essential for practical assessment of the potential threats as well as conservation planning on species survival at variable spatial scales (Burgess et al., 2007). Despite extensive studies assessed tree community composition and diversity in large geographically scale in EAMs (Lovett, 1998; Lovett et al., 2006; Burgess et al., 2007; Burgess et al., 2010), fewer focused on variation at smaller landscape scales (Lovett, 1998; Lovett, 1999; Lovett et al., 2006). Also, empirical studies linking edaphic factors to species diversity and distribution in these sites are scarce. Analysis of edaphic correlates is essential for improving understanding of the processes that drive the diversity, abundance, distribution, and coexistence of tropical tree species. The agreement resulted based on the responses of individual species to individual resources in whole tree communities (Huth and Ditzer, 2001; Paoli et al., 2006).

There is a direct relationship between soil and vegetation. So that soil provides required necessities including nutrient, moisture, and anchorage for the plant to grow up effectively. Besides, vegetation protects soil from soil erosion and suppresses, and helps to maintain soil nutrient through litter accumulation and subsequent decay (nutrient cycling). The plant also influences soil characteristics such as volumetric water content and texture, which indirectly affect vegetation structure, productivity, and floristic composition (Brant et al., 2006). On the other hand, the soil is essential for ecosystem sustainability. It supplies nutrients for roots and moderated temperatures. As a habitat for micro- and macro-organisms, the land is of crucial importance (Diaz et al., 1999; Peaucelle et al., 2017).

Soil properties and other abiotic factors (e.g., climate-driven responses) demonstrate plant tolerance and utilization of resources, which is different in plant species. These differences suggest a driving mechanism of species coexistence in similar environments. Also, they can discuss wide-scale compositional differences along multiple resource gradients (Kashian et al., 2003). If the local species pool passes through abiotic filters, then the remaining species undergo further filtering by biotic interactions and disturbance effects. Biotic factors such as overstory tree density can influence the community composition because understory species differ in their ability to tolerate stresses imposed by competitive trees. (Laughlin et al., 2005). The factors are closely interconnected, with vegetation having a pivotal role in soil processes. Particularly, documents evidence that tree species can manage nutrient cycling via litter inputs and uptake (Scharenbroch and Bockheim, 2007; Weand et al., 2010). Global change influences distribution by the shift in site temperature, precipitation regime, and nitrogen (N) availability. In ecotonal zones, different forest types may occupy a similar location; Tree species manipulation is particularly relevant. So, management procedures could effect particular forest types, for instance, on its C storage capacity, among other criteria (Jandl et al., 2007; Vesterdal et al., 2008; Gill and Finzi, 2016).

The present research aimed at linking edaphic factors to the composition, distribution, and diversity of tree species in ANR and UMF. Specifically, the study explored the structure, disposition, and variety of tree species and their edaphic correlate at each site and the link between edaphic variables and topographic features. The study also explored relationships between species diversity and edaphic variables and between community-wide and species-specific composition and distribution with edaphic variables at the two sites.

2. Materials and Methods

2.1. Study areas

The EAMs located near the Indian Ocean coast, are crystalline mountains, which stretched between the Taita Hills in South-East Kenya to the Udzungwa Mountains in South-Central Tanzania (Lovett, 1998; Burgess et al., 2007). Located between latitudes 3°2' S and 8°51' S and longitudes 34°49' E and 38°20' E, approximately, the EAMs range from sea level up to 2635 m in altitude. There are 13 blocks in EAMs, namely: Taita Hills, including Kasigau in Kenya, North Pare, South Pare, West Usambara, East Usambara, Nguu, Nguru, Uluguru, Ukaguru,

Rubeho, Malundwe, Udzungwa, and Mahenge in Tanzania. Of the world's most significant concentrations of biodiversity are harbored in the mentioned 13 blocks chain across a series of fragile sites (Brooks et al., 2002).

The forests are the sole biodiversity hotspots home for many species found no shelter anywhere and store one hundred million tons of carbon which otherwise might be released into the atmosphere and lead to climate change (Burgess et al., 2007; Buisson and Grenouillet, 2009). The EAMs are nationally and internationally recognized as being of exceptional biodiversity value with high endemism in many species (McCain and Colwell, 2011). The EAMs contain at least 800 endemic plant species accounting for more than 25% of the plant species, ten endemic mammals, 19 endemic birds, 31 endemic reptiles, and 40 endemic amphibians. The 2006 IUCN Red List reports 78 vertebrate species as threatened, including eight critically endangered species in the EAMs. 20 out of 21 species of African violet grown in the EAMs are endemic (Burgess et al., 2007). The EAMs forests have recently indicated to be UNESCO World Heritage site (http://whc.unesco.org/), and currently receive special increasing international attention based on the United Nations REDD Programme (Burgess et al., 2010).

The first study area was the Amani Nature Reserve (ANR), which is part of the East Usambara Forests (Fig. 1). The ANR in the East Usambara Mountains located between latitudes 5°14' and 5°04' S and longitudes 38°30' and 38°40' E. The altitude of ANR is 1500 m, with extensive plateau from 800-1000 m. The forests at the lower Elevation are classified as lowland forests while at upper Elevation as upper montane forests. These mountains, as one of the most biologically diverse forests in Africa, are considerable in endemism of at least 22% of plant species, contributing to their status. The rainfall pattern is bimodal with a minor rainy season in November and the primary rain season in April (Lovett, 1998).

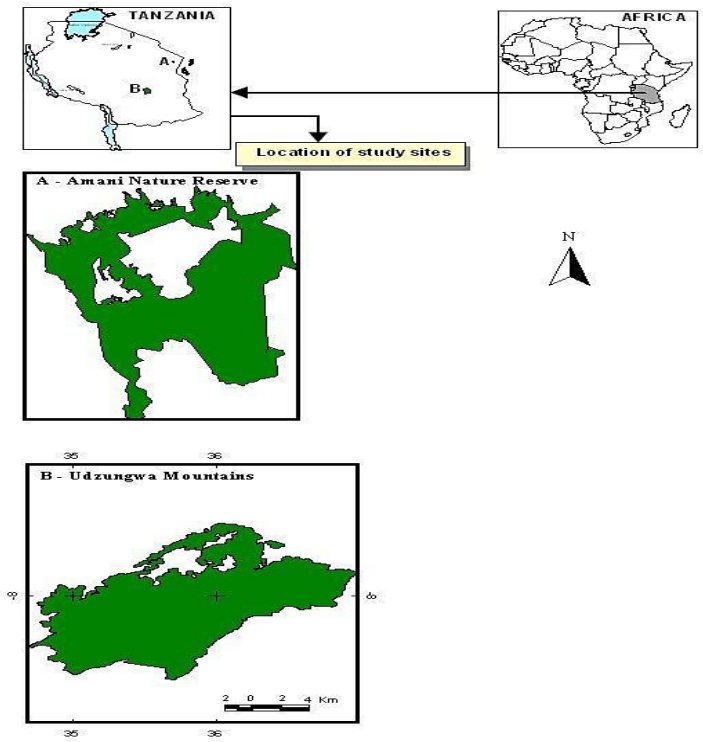

Fig. 1. Location of Amani Nature Reserve and the Udzungwa Mountains.

The second study area was the Udzungwa Mountain block (UMF) (Fig. 1). UMF is located 7°40′ S to 8°40′ S and 35°10′ E to 36°50′ E (Barelli et al., 2015). Field survey in this block conducted in Udzungwa Mountains National Park (UMNP), Nyanganje Forest Reserve (NFR), and Udzungwa Scarp Forest Reserve in Kilombero and Kilolo Districts. The Udzungwa Mountains are the largest block of the EAMs, covering about 10 000 km^2 (Rodgers and Homewood, 1982). It was founded on the southern end of the EAMs chain. Udzungwa Mountain's highest point, Luhombero Peak, rises to 2800 m (Zilihona and Nummelin, 2001). Rainfall is variable based on topography and distance from the Indian Ocean. The eastern slopes in front of the Indian Ocean have

more than 2000 mm annually, while the western slopes received approximately 600 mm precipitation annually. The rainfall pattern is unimodal, falling between November and May (Lovett, 1999). The eastern slope of the Udzungwa Mountains is of the few areas left in the Afrotropical region where one can find a continuous moist forest cover from lowland (300 m) to mountains (2500 m).

Soils are sandy-loams or sandy-clay-loams (Lovett et al., 2006). The Udzungwa Mountains National Park covers much of the north-eastern part of the Udzungwa Mountains with an area of 1960 km^2. Nyanganje Forest Reserve is located between latitudes 7056' and 804' S and longitudes 36039' and 36050' E, 15 km^2 northeast of Ifakara Township. The reserve covers the southeast foothills of the Udzungwa Mountains.

2.2. Plot establishment

Plots were established along with the altitudinal range from the lowland to montane forests of the ANR and UMF. The areas were stratified by Elevation into lowland (< 800 m), submontane (800–1400 m), montane (1400-1800 m), and upper montane (> 1800 m) (Lovett, 1998). In each stratum, transects were systematically laid to cover as much variation as possible, and rectangular plots each 0.02ha (20 m x 10 m) were laid along transects. This is small enough to keep environmental factors and forest structure homogeneous within-plots (Kluge et al., 2006). To minimize and maximize within-plot and between-plot variations, respectively, plots were stretched in their long axes perpendicular to the slope.

2.3. Vegetation data and soil sampling

In each plot, plant species were recorded both in their scientific (botanical), and local names, and additionally the DBH for all trees were measured. The information collected was used in subsequent assessment of species composition, richness, diversity, and associated plant communities. Diameters at Breast Height (DBHs) for all trees were measured; large trees were measured using diameter tape, while for small trees, veneer caliper was used. The DBH for buttressed trees was measured above the buttress, and additionally, the occurrence of all other plant species (shrubs and herbs) was assessed. Tree measurements were done following the standard vegetation monitoring protocol of the Tropical Ecology, Assessment, and Monitoring (TEAM) Initiative (Aprile and Lorandi, 2012). Other parameters recorded include plot location and Elevation using GPS for each plot. Species were identified using both local and botanical names. Voucher specimens of unidentified species were collected for further identification .

The soil was sampled at 0-15, 15-30, and 30-45 cm depths at the four corners and the center of each plot. The samples were mixed to make one composite sample for each depth. At each depth, about 500 g of soil was collected for laboratory analysis. For bulk density investigation, the sampling was done using cores of known volume at each depth (Bouman et al., 1995).

2.4. Laboratory analyses of soil samples

Soil analysis was conducted at the Forest Biology laboratory of the Sokoine University of Agriculture. Before analysis, the samples were air-dried at room temperature, ground, and sieved using a 2 mm mesh. Soil pH was measured electrometrically by a mixture of 10 g of soil and 25 ml of distilled water (i.e., a ratio of 1:2.5 w/v). Samples were then shaken lengthwise in a horizontal position at 150 rpm for 30 minutes. Readings were taken when the pH meter was stable.

Soil organic carbon (C) was analyzed in all samples in the topsoil (0-15 cm). Soil from the other two depths (15-30 and 30-45 cm) was mixed to form composite samples at 15-45 cm depth. Thus a composite sample (15-45 cm) was analyzed for soil organic carbon. Soil organic content was measured according to Walkley and Black method. Soil organic matter was oxidized at a temperature of approximately 120 °C with a mix of concentrated sulphuric acid and potassium dichromate (wet combustion). The excess potassium dichromate was titrated against ferrous sulphate with diphenylamine as an indicator (Turner, 2008). Before titration, phosphoric acid was added to form a complex with the interfering iron (III), providing a sharp color change of the indicator. Data from titration results were used to calculate the amount (percentage) of organic C in soil

samples. All samples were analyzed for soil texture. Soil texture (particle size) was measured by hydrometer analysis. This method is identified using the Stokes' law based on the relation between the velocities of free-falling spherical soil particles in water. The viscosity of water is affected by temperature. Therefore, correction is necessary when measurements are not done at a standard temperature of 20 °C. A mixture of 50 g of soil sample was mixed with 100 ml of distilled water (i.e., a ratio of 1:2 w/v) and shaken for 2 hours. For each example, hydrometer and thermometer readings were taken every 40 seconds, 4 minutes, and 2 hours. From these data, percentage sand, silt, and clay were calculated. Soil samples collected by cores were used to determine bulk density. The samples were oven-dried at 105 °C. Bulk density was then determined as a measure of the dry weight per unit volume (g/cm^3).

2.5. Data analysis

2.5.1. Multivariate analysis

Canonical Correspondence Analysis (CCA) was applied to determine variation patterns in tree species distribution presented by the environmental variables recorded. CCA was done on species abundance matrix (computed as basal areas for each species in the primary model) (Table 1). Apart from community structure, species diversity (Shannon Index) and species richness were also ordinated to edaphic variables.

A second matrix/environmental matrix consisted of edaphic and topographic variables (soil data and Elevation). Edaphic variables in the second matrix were simplified and coded in meaningful symbols (Table 2). Canonical Correspondence Analysis ordinations are done using the PC ORD version 5.0.

Table 1. Matrix composition in CCA.

		ANR	**UMF**
Matrix	Rows/Columns	All species	All species
	Plots	32	51
Main	Species	159	195
	Plots	32	51
Second	Variables	24	16

Table 2. Codes and units used for some of the analyzed edaphic variables.

Variable	**Units**	**Code**	**Depth (cm)**	**Remarks**
Moisture Content	%	MC15	0 -15	
Moisture Content	%	MC30	15 -30	
Moisture Content	%	MC45	30 -45	
Bulk Density	g/cm^3	BD15	0 -15	
Bulk Density	g/cm^3	BD30	15 -30	
Bulk Density	g/cm^3	BD45	30 -45	
Silt	%	S15	0 -15	
Silt	%	S30	15 -30	
Silt	%	S45	30 -45	
Organic Carbon	%	Cts		Topsoil samples from (0-15 cm)
Organic Carbon	%	Css		Composite sample for the three soil depths
Sand	%	Sandcom		Composite sample for the three soil depths
Silt	%	Cscom		Composite sample for the three soil depths
Silt	%	Fscom		Composite sample for the three soil depths
Clay	%	Claycom		Composite sample for the three soil depths

2.5.2. Species diversity

Species richness was computed as the total number of species in each plot. Species diversity for each parcel was calculated using the Shannon-Wiener Diversity Index (H'). Shannon-Weiner Index (H') = - ∑(pi) (*ln*pi) (summing from 1 to S) Where S is the total number of species in the sample, pi is the proportion of all individuals in the example that belong to species I and *ln*pi is the natural logarithm of pi.

3. Results and Discussion

3.1. Edaphic correlates of tree species diversity

Species diversity correlated significantly with some edaphic variables (Table 3). In ANR, species richness correlated negatively with pH at 0-15 and 30-45 cm depth (r = -0.383, p = 0.03; r = -0.422, p = 0.016). Species richness also correlated negatively with percentage coarse silt at 30 cm (r = -0.416, p = 0.018). Furthermore, species richness and diversity correlated positively with elevation (r = 0.475, p = 0.006; r = 0.35, p = 0.05).Further, species richness and diversity increased along a gradient of percentage organic carbon (r = 0.35 and r = 0.22), respectively and decreased with bulk density (r = -0.24 and -0.29 at 15 and 30 cm respectively) in UMF.

Table 3. Correlation of edaphic variables to tree species diversity in ANR and UMF.

		ANR			UMF	
Variable	**Units**	**R**	**H**	**Variable**	**R**	**H**
MC15	%	0.033	0.006	MC15	0.014	-0.09
BD15	g/cm³	-0.04	0.023	BD15	**-0.24**	-0.07
MC30	%	-0.03	0.048	MC30	0.082	0.012
BD30	g/cm³	-0.18	-0.19	BD30	**-0.29**	-0.18
MC45	%	-0.14	-0.13	MC45	-0.08	-0.04
BD45	g/cm³	-0.18	**-0.24**	BD45	-0.09	-0.08
Cts	%	0.127	0.089	Cts	0.167	-0.02
Css	%	0.004	-0.01	Css	**0.349**	**0.223**
pH15		**-0.38**	**-0.32**	pH15	-0.13	-0.06
pH30		-0.21	-0.15	pH30	-0.06	0.001
pH45		**-0.42**	**-0.33**	pH45	-0.03	-0.06
Sand15	%	0.02	-0.07	Sandcom	-0.09	-0.17
S15	%	-0.16	**-0.28**	Scom	-0.17	-0.14
Clay15	%	0.104	0.235	Claycom	0.109	0.191
Sand30	%	0.251	0.172	ELEV	0.186	0.119
S30	%	**-0.42**	**-0.33**	-	-	-
Clay30	%	-0.1	-0.04	-	-	-
Sand45	%	-0.003	-0.07	-	-	-
S45	%	-0.06	0.011	-	-	-
Clay45	%	0.003	0.03	-	-	-
ELEV	%	**0.475**	**0.35**	-	-	-

Note: Correlations are "intraset correlations". The environmental variables are defined in Table 1. Most of the variables didn't show significant correlations. Bold numbers are slightly stronger coefficients. R = Species richness and H = Shannon-Wiener diversity index. Empty cells are because soil texture at UMF was analyzed from composite samples.

Biplot scores indicated that axis 1 explains better patterns and is positively correlated with percentage silt and Elevation (i.e., a gradient of percentage silt and Elevation, which means axis 1 represents variations associated with Elevation and coarse sediment) (Fig. 2) in ANR. Projecting the plots on the first CCA axis in

ANR showed that species richness and Shannon Index decreased along axis 1 (Figs. 3a and b). Since axis 1 represents variations associated with Elevation, species diversity decreased with Elevation.

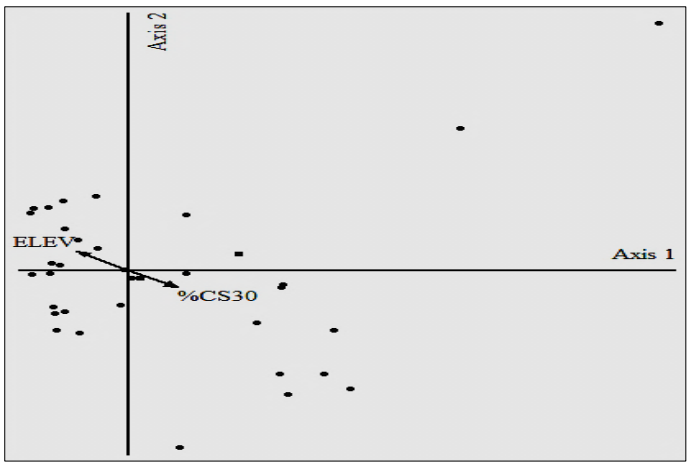

Fig. 2. Biplot diagram of the CCA on species richness and diversity by environmental parameters in ANR. ELEV and %CS30 are Elevation and percentage silt at 30 cm depth, respectively.

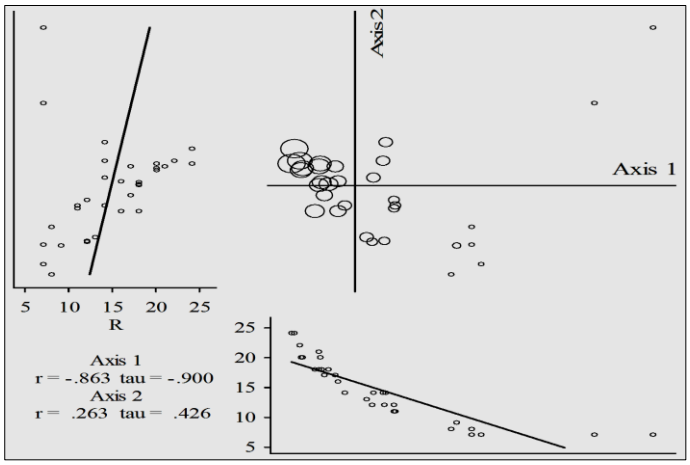

Fig. 3a. Bivariate relationship between species richness (R) and CCA axes in ANR. Axis 1 explained (Elevation) better patterns in species richness and was negatively correlated with species richness.

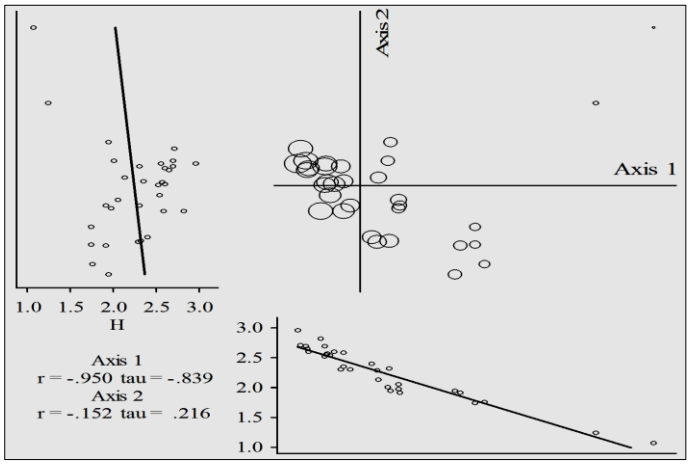

Fig. 3b. Bivariate relationship between Shannon Index (H) and CCA axes in ANR.Axis 1 (Elevation) explains better patterns in species diversity and is negatively correlated with Shannon Index.

On the other hand, little variations were explained by the three CCA axes on the ordination of diversity indices in UMF and Axis 1 explained only 32.1%, while axis 2 and 3 explained 9.9 and 0%, respectively. CCA

biplot indicated that the first axis was strongly correlated to the percentage of soil organic carbon and bulk density (Fig. 4). Projecting the points on the first CCA axis in ANR showed that species richness and diversity (Shannon Index) increased along axis 1 (Figs. 5a and b).

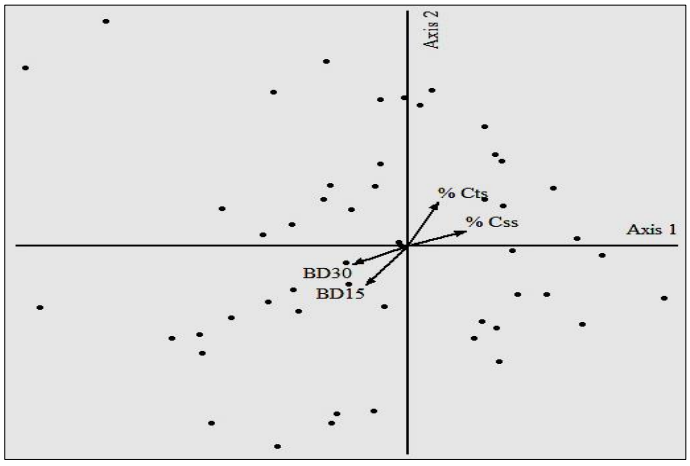

Fig. 4. Biplot diagram of the CCA on species richness and diversity by environmental parameters in UMF. BD30, BD15, Cts, and CSS are bulk density at 30 cm, bulk density at 15 cm, organic carbon of topsoil, and organic carbon of subsoil, respectively.

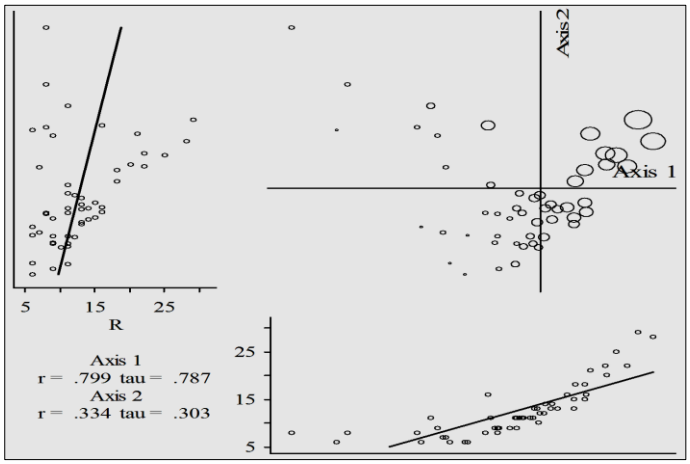

Fig. 5a. Bivariate relationship between species richness (R) and CCA axes in UMF. Axis 1 explains better patterns and is positively correlated with species richness.

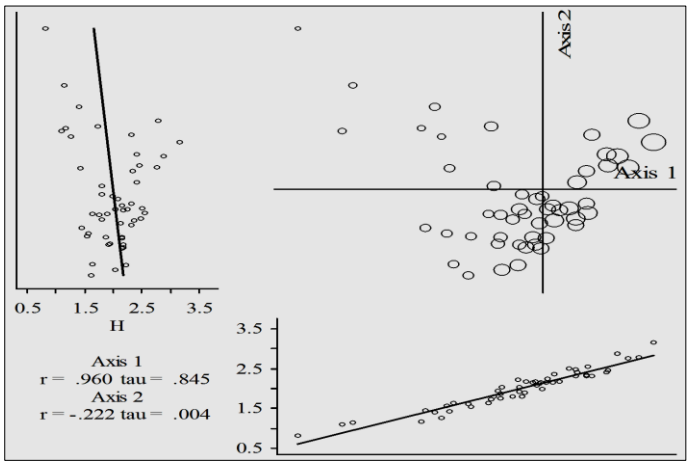

Fig. 5b. Bivariate relationship between Shannon Index (H) and CCA axes in UMF.Axis 1 explains better patterns and is positively correlated with Shannon Index

One of the few edaphic variables that showed significant relationships with species diversity in ANR, pH, and percentage silt correlated negatively with species richness (i.e. species richness decreased with pH and percentage silt). Generally, the soil was more acidic at ANR than UMF. Soil properties, including temperature, pH, moisture, and texture, affect the performance and shape of soil microbial communities (Griffiths et al., 2011). On the other hand, soil microbial communities control essential ecosystem processes such as carbon and nitrogen cycling (Balser and Firestone, 2005; Abella and Covington, 2006; Troy and Wilson, 2006) and thus affect diversity patterns of tree species in spatial and temporal scales. The biplot scores indicated that axis one was strongly correlated with percentage silt and Elevation; thus, axis 1 represents a gradient of Elevation and percentage silt. Therefore in ANR, species richness and diversity decreased along an angle of Elevation and percentage silt. Similar analysis indicated that species richness and diversity increased along a gradient of percentage organic carbon and bulk density while dominance decreased in UMF. Thus, there are mixed responses in the diversity of tree species along elevation and edaphic gradients, resulting from the complex interactions of biotic and abiotic components of the environment.

3.2. Edaphic correlates of tree species composition and distribution

In both sites, most of the variations were explained by axes 1 and 2, and species-environmental correlations were high in all axes. The relationship of each variable for three axes is presented in Table 4. Axes with the most top associations explain better patterns than those with lower correlations and therefore are chosen to represent an ecological pattern. For example, axis 2 describes a better model and is negatively correlated with %MC15 in ANR, whereas axis 1 explains a better design and is positively correlated with %MC30 in UMF. The CCA biplot of species and environmental variables (Figs. 6 and 7) demonstrates the relationship between tree species distribution and ecological variables (Park et al., 2019). In ANR, the sample scores on the first CCA axis were closely related to the percentage of sand and clay at 15-30 cm depth. However, in the second axis, pH in all soil depths was the strongest correlate of the sample scores. In UMF percentage moisture, bulk density and pH in all soil depths correlated strongly to the sample scores, and additionally percentage organic carbon of the topsoil and percentage clay found to be the strongest edaphic correlates (Table 4; Figs. 6 and 7).

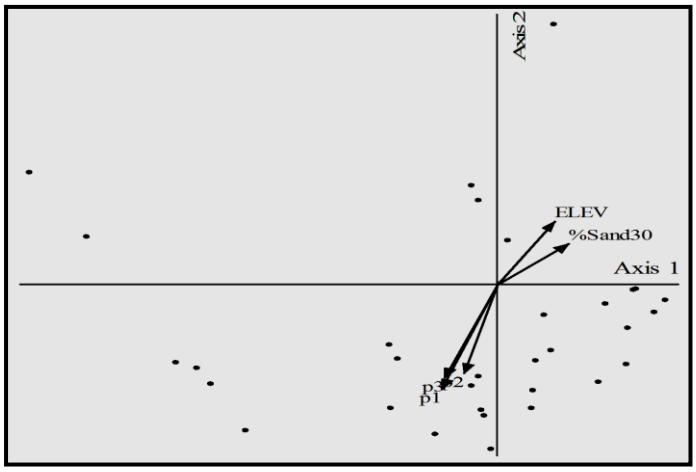

Fig. 6. CCA of plots using Basal Areas of 159 tree species in the 32 sample plots in ANR. ELEV, %Sand30, p1, p2, and p3 are Elevation, percentage sand at 30 cm, pH at 15 cm pH at 30, and pH at 45 cm, respectively. For clarity, plots are not labeled.

The overall influence of edaphic factors on species composition and distribution in ANR and UMF is generally similar at the community level (with all species) and species-specific (with the most dominant species) analysis. Soil pH, texture, and moisture characteristics are the main edaphic factors that influence and drive species composition and distribution. With few exceptions, a clear distributional continuum of species occurrence was observed across edaphic gradients in ANR and UMF. Studies conducted in other blocks of the EAMs revealed soil pH and percent clay to be the strongest correlation of community composition with the individual mountain range. These studies

reported the communities to occur under a combination of factors ranging from clay soils in lower elevations and on sandy clay to sandy clay loam soils in higher elevations forming a complex of local heterogeneity in topographic and edaphic factors. Such complexity has also been observed in temperate plantation forests in northern Arizona, USA (Laughlin and Abella, 2007). Elsewhere in the tropics, plant community patterns have been affected by complex local heterogeneity in topographic and edaphic factors.

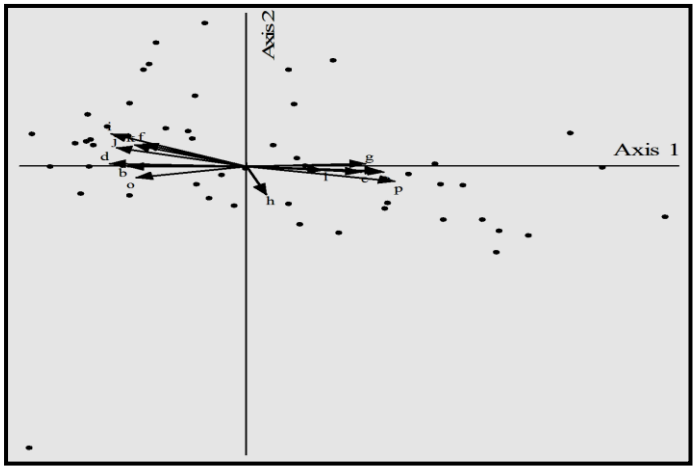

Fig. 7. CCA of plots using Basal Areas of 195 tree species in the 51 sample plots in UMF. Letters b, c, d, e, f, g, h, i, j, k, l, o, and p are bulk density at 15cm, percentage moisture at 30 cm, bulk density at 30 cm, percentage moisture at 45 cm, bulk density at 45 cm, percentage carbon of topsoil, percentage carbon of subsoil, pH at 15 cm, pH at 30 cm, pH at 45 cm, percentage sand of composite sample, percentage clay of composite sample and Elevation, respectively. For clarity, plots are not labeled.

Table 4. Correlation coefficients between environmental variables and CCA axes for tree species in ANR and UMF.

			ANR				**UMF**	
Variable	Units	Axis 1	Axis 2	Axis 3	Variable	Axis 1	Axis 2	Axis 3
MC15	%	0.159	-0.36	-0.212	MC15	**0.801**	-0.052	0.084
BD15	g/cm³	0.352	-0.088	-0.346	BD15	**-0.712**	-0.003	0.246
MC30	%	0.237	-0.188	-0.234	MC30	**0.818**	-0.073	0.185
BD30	g/cm³	0.091	-0.006	-0.148	BD30	**-0.818**	0.033	0.042
MC45	%	0.133	-0.284	-0.091	MC45	**0.678**	-0.071	-0.074
BD45	g/cm³	0.126	-0.079	0.024	BD45	**-0.618**	0.296	0.277
Cts	%	0.037	0.106	0.384	Cts	**0.707**	0.042	0.034
Css	%	-0.217	0.195	0.16	Css	0.113	-0.356	-0.359
pH15		-0.411	**-0.805**	-0.167	pH15	**-0.812**	0.424	0.131
pH30		-0.247	**-0.679**	-0.233	pH30	**-0.783**	0.249	0.262
pH45		-0.388	**-0.717**	-0.045	pH45	**-0.668**	0.281	0.184
Sand15	%	0.064	0.418	0.302	Sandcom	0.459	-0.042	-0.343
S15	%	-0.04	-0.319	-0.075	Scom	0.067	0.203	**0.534**
Clay15	%	-0.189	-0.205	-0.496	Claycom	**-0.662**	-0.145	0.206
Sand30	%	**0.515**	0.317	0.234	ELEV	**0.885**	-0.183	-0.352
S30	%	-0.25	0.036	-0.06	-	-	-	-
Clay30	%	**-0.505**	-0.431	-0.294	-	-	-	-
Sand45	%	0.125	0.437	0.059	-	-	-	-
S45	%	-0.067	-0.05	-0.032	-	-	-	-
Clay45	%	-0.12	-0.368	-0.039	-	-	-	-
ELEV	%	0.417	0.485	0.308	-	-	-	-

3.3. Soil pH and plant communities

The present study has indicated the significance of soil pH in determining plant distribution patterns. Similar studies in the EAMs have demonstrated the influence of soil pH on plant distribution patterns. Of 14 edaphic factors as significant correlations of plant community composition in Ulugurus and Usambaras, only percent clay and soil pH were the most reliable correlates. These findings signify the influence of soil pH in plant communities of the EAMs.

Soil pH measurements are usually used to identify the nutritional conditions of vegetation in a defined site, for example, in describing the ecological behavior of tree species (Härdtle et al., 2004). Some plants grow better in acidic soils, while others need alkaline soils. However, in the present study, tree communities correlated with acidic to slightly acidic soils in both sites.

4. Conclusion

The influence of edaphic factors is crucial in determining plant community patterns in the EAM. These factors cause mixed (variables) responses in plant communities resulting in observed vegetation patterns. Soil pH strong effect indicates the influence of soil chemical properties. Variation in edaphic correlates of tree community patterns between the two sites suggests a need for site-specific assessment of edaphic properties (further analysis carried in other blocks). Conservation planners are advised to consider the influence of edaphic factors in their biodiversity conservation plans.

The study could not analyze all-important soil parameters due to financial constraints. Considering the low pH observed in some locations of the study sites, analysis of N, P, K, Ca, CEC, and Exchangeable Al3+ could have further implications on results and discussions. Soils from 15-30 and 30-45 cm were mixed to form composite samples. These depths have different physical and chemical properties, e.g., soil organic matter (SOM). A separate analysis of samples from these depths could also have further implications for the findings.

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