Advances in Research

18(3): 1-14, 2019; Article no.AIR.47163
ISSN: 2348-0394, NLM ID: 101666096

Canonical Correlation Analysis across Vegetation and Soil Properties of the Disturbed and Undisturbed Coastal Forest Ecosystems

Elly Josephat Ligate[1*] and Can Chen[2]

[1]Department of Biosciences, Sokoine University of Agriculture, Morogoro, Tanzania.
[2]College of Forestry, Fujian Agriculture and Forestry University, Fuzhou, P.R. China.

Authors' contributions

This work was carried out in collaboration between both authors. Author EJL designed the study, performed the statistical analysis and wrote the first draft of the manuscript. Authors CC managed the analyses of the study. Authors EJL and CC managed the literature searches. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AIR/2019/v18i330093
Editor(s):
(1) José Alberto Duarte Moller Center for Advanced Materials Research Complejo Industrial Chihuahua, Mexico.
Reviewers:
(1) Rahim Foroughbakhch, University of Nuevo Leon, Mexico.
(2) Chukwu, Onyekachi, University of Ibadan, Ibadan, Nigeria.
Complete Peer review History: http://www.sdiarticle3.com/review-history/47163

Original Research Article

Received 10 November 2018
Accepted 19 February 2019
Published 09 March 2019

ABSTRACT

This study presents comparative initial information about canonical correlation across forest stand parameters, diversity indices and soil properties in undisturbed forest sites (IFS), agriculture disturbed sites (ADS) and livestock disturbed sites (DGS). Data were collected from Uzigua Forest Reserve in Tanzania. Forty- seven sample plots of 25 m × 25 m were randomly established on IFS, ADS and DGS from which tree inventory data and 141 soil samples were drawn. Data were subjected into Canoco windows 4.5 software for multivariate analyses and comparisons across IFS, ADS and DGS. The correlation of tree stand parameters (TSP) and soil physical properties (SPP) were F=1.207, *p*=0.242 in IFS, F=2.400, *p*=0.012 in ADS and F=0.529, *p*=0.938 in DGS. For soluble bases and TSP were F=2.448, *p*=0.018 in IFS, F=0.687, *p*=0.790 in ADS and F=0.743, *p*=0.808 in DGS. Carbon, nitrogen and potassium (CNP) and TSP were F=0.816, *p*=0.572 in IFS, F=0.687, *p*=0.790 in ADS and F=0.070, *p*=0.020 in DGS. The SPP and Shannon indices had F=1.103,

**Corresponding author: E-mail: ligateelly@yahoo.com;*

p<0.388 in IFS, F=0.520, *p*=0.714 in ADS and F=0.932, *p*=0.444 in DGS. The SPP and Independent Value Index (IVI) were F=0.042, *p*=0.996 in IFS, F=0.819, *p*=0.620 in ADS and F=0.633, *p*=0.724 in DGS. Soluble bases and equitability were F=0.119, *p*=0.968 in IFS, F=0.001, *p*=0.001 in ADS and F=0.011, *p*=0.001 in DGS. The CNP and IVI had F=4.246, *p*=0.014 in IFS, F=2.729, *p*=0.018 in ADS and F=2.007, *p*=0.060 in DGS. The mean higher canonical correlation in the non-disturbed sites indicates that crop-agriculture and livestock grazing affect the interplays between forest vegetation and soil properties. Therefore, human activity disturbs the structure and soil properties.

Keywords: Canonical-correlation; disturbance; forest structure; species diversity; soil properties.

1. INTRODUCTION

Knowledge about the influence of human activities on forest structures and the correlation of vegetation (i.e. trees as used in this study) parameters and soil properties is important in forest ecosystem management [1]. This knowledge is crucial because vegetation in forest ecosystems has direct influence on soil conditions [2,3]. Nevertheless, information about the reciprocal relationships across tree stand parameters, diversity indices and composition, and soil physical and chemical properties in the tropical coastal forests is lacking [4,5]. This deficit is contributing in jeopardizing the whole process of tropical coastal forests management. Therefore, this study was conducted to address the missing relationship between vegetation structure and soil properties of the disturbed (by farming and livestock grazing) coastal forest ecosystems [1,6,7].

Different processes and activities occurring in forest ecosystems affect forest structural parameters by providing favorable or unfavorable conditions [2,6]. Disturbances affect the ecological relationship between forest vegetation and soils [8,9,10,11]. In essence, human induced disturbances bring soil degradation, which is defined in this study as any physical or chemical alteration of the soils caused by different operations in forest ecosystems [1]. Disturbances in soils directly affect forest structures (i.e. the spatial arrangements/diversity of various components of forest ecosystems) [7,12,13]. These disturbances affect the number of trees, heights of different canopy levels, diameter, spatial distribution, basal area, volume and species composition [14,15,16,17].

Although disturbances are reported to disrupt the settings of ecological components, ecologically they are sometimes essential processes, at some levels of intensity and periodicity for the long-term sustainability and productivity of forest ecosystems [5]. In this case, the impacts of disturbances are not uniform. Thus, establishing the direction of disturbances on forest structure diversity and soil properties still is a challenge because other studies show that the structure and diversity of tree species between undisturbed and disturbed forests sometimes are not significant [3]. Indeed, a study by Merganic [4] shows that natural forests are not influenced by anthropogenic activities but by conditions of abiotic environment. However, these documentations have not mirrored the status and interplays between tree structures and soil properties in the disturbed and undisturbed tropical coastal forests.

Therefore, this study was conducted based on the fact that there is relationship across above-ground forest structures and soil physical and chemical properties [7]. This relationship is real based on the fact that the above-ground forest status determines the below-ground forest systems and vice versa through process, which accelerates soil erosion, oxidation and destruction of biomass [6]. In respect to soils, anthropogenic activities especially those involving clearance of forests (exposing soils to erosion), loss of organic matter and other necessary elements useful for vegetation growth [7]. These activities affect soil properties by influencing the biological and geochemical processes at different depths after human disturbances, as results, all these processes affect vegetation statuses and functions [7].

The above-ground forest disturbances are related with under-ground status because there is a close relationship between forest and land use management on species diversity and soils conditions [9]. For example, low species diversity in disturbed areas is associated with low values of soil elements such as carbon, nitrogen and phosphorus [10]. Thus, there is a strong relationship between disturbances on plant species composition and impacts on soil parameters [18,19]. Understanding the impacts of human activities on the coastal forests of

Tanzania is crucial because these activities have affected the structure and biodiversity of these forests for more than 50 years [8]. It is obvious that human activities affected the coastal biodiversity, which is composed of over 10,000 plant species, hundreds of which are recognized as nationally endemic [20,21,22]. Indeed, crop agriculture and livestock grazing have been considered in this work by being major activities, which threaten species diversity along the coastal zone of Tanzania [23,24]. These activities are forms of land uses, which have caused variation in habitat conditions characterized by biogeography and disturbance levels, which in turns affect part or entire coastal ecosystems [3,14,25].

It is important to find correlations between trees parameters, which are found above-ground and soil properties, which represent the below-ground forests variables so as to understand their interplays. This understanding is important in gauging the dynamics of the above-ground forests structure and environmental variables [11]. The study focused on agriculture and livestock grazing disturbances on forests ecosystems since these forms of land uses cause high scale severity in soils and vegetation properties [21,26]. Indeed, these activities are accompanied by clearing/cutting trees for intensive production of agricultural products. As a result, these activities expose vulnerability of the coastal ecosystem to disturbances effects [12]. Moreover, livestock grazing affects species composition and ecosystem function by feeding and trampling on vegetation [13]. The impacts of agriculture and livestock grazing are large especially when there is agriculture intensification and reduced grazing areas [27,28]. Within low carrying capacity of the forests ecosystems, farming activities and livestock grazing destroy plant species and destruct soils [28]. In addition, these activities expose the land to erosion and nutrients loss [13,27,28]. Therefore, it is imperative to establish information about forest structure and soil relationship in forest management as vegetation and soils are interconnected and exert interdependent effects on each other [3,4].

This work presents the basic information on how the existing forest species are canonically correlated with the soil properties. This is the first kind of study done on the disturbed coastal forest ecosystems after human activities disturbances exclusion. This study was guided by hypothesis which states that, there is positive relationship between the above-ground forest structures and soil properties subjected into different management practices along the tropical coastal forest ecosystems. Furthermore, the study sought to answer the following question: How forest parameters (density, height, basal area and volume, and species composition and diversity) are canonically correlated with bulk density, soil texture, soluble and non-soluble bases across undisturbed forest, crop-agriculture and livestock disturbed sites?

2. MATERIALS AND METHODS

2.1 Description of the Study Area

This study was conducted in Uzigua Forest Reserve (UFR) found in Bagamoyo and Chalinze Districts, Pwani Region in the Coastal Zone of Tanzania Mainland (Fig. 1). The reserve coverage area is 24,730 ha [14]. This forest was purposely selected to represent other forests along the coastal, which have been encroached mainly for crop-agriculture and livestock grazing. Certainly, this forest is within 100 km from the coast of Indian Ocean, and thus, is considered to be among the tropical coastal forests in East Africa [15]. This forest reserve is supposed to be completely restricted from human use, serving for catchment and biodiversity conservation [14]. Unfortunately, due to poor protection and surrounding settlements, the entire forest is affected by anthropogenic activities such as harvesting trees for fuel-wood, fodder, grazing pressure and encroachments for agriculture. These activities are threatening this forest like many other coastal forests, which are documented to harbor diverse plant species that make them, and hence included as one of the 34-world biodiversity hotspots that need special conservation measures [29,30].

Uzigua forest reserve is located in the tropical and sub-humid area with 700 mm to 1000 mm rainfall. October to May is a wet season while June to September is dry [31]. The annual minimum temperature is 22.4°C while the annual maximum temperature is 31.7°C [14]. The soils are well-drained, red sand clay, loamy with brown friable top soils covered by more or less decomposed litter. The area is undulating with continuous hills with altitude ranging from 400 to 600 meters above sea level (masl) [16]. However, the current climate change and variability along the coast greatly influence temperature, rainfall, and the distribution pattern of plant species in these tropical coastal forests.

Therefore, the composition of the forest fragments at large [16].

The vegetation in coastal zone specifically the UFR is diverse, characterized wit h open coastal woodland dominated with *Acacia, Brachystegia*, *Combretum*, *Terminalia, Diospyrus* and *Albizia* species [14]. Also, herbs and grasses are found and grow up to 1.5 m high; dominating the ground cover. Some of the common indigenous species still existing in the reserve and some remnant sites of the degraded lands are *Combretum molle*, *Tamarindus indica* and *Dombeya* sp. [16].

2.2 Data Collection

Data collection was conducted by stratification field inventory approaches [21,32]. Land use classification was carried out to determine the land uses based on human activities mainly crop-agriculture (ADS), livestock grazing (DGS) and undisturbed forest sites (IFS). These land uses were obtained from satellite images and by using normalized difference vegetation index.

2.3 Collection and Analysis of Vegetation Data

Sites for plot establishment and collection of data were randomly selected. Seventy (70) small quadrants of 25 m × 25 m size were established for collection of adult tree data. Within these plots, 2 m × 2 m subplots were established for collection of seedlings, saplings and shrubs data [33,34]. From these plots, stems with a diameter of ≥ 20 cm at breast height (dbh) (approximately 1.34 m above the ground) were categorized as tree species. All tree species with < 20 cm were considered as regenerates in the following subdivisions (i) seedlings involved only trees with < 0. 40 m height; (ii) saplings included trees from ≥ 0.40 m to <1 m heights and (iii) shrubs represented woody species with a diameter of ≥ 10 cm thickness and the height ranging from ≥ 1 m to ≤ 5 m as adopted from [34,35].

2.4 Trees Stand Parameters' Analysis

Trees found in the study area were identified at species level using field guidebooks with the help of local and qualified botanists. From tree species checklists (i) a number of live trees per unit area (N/ha), (ii) basal area (BA) of live trees (m^2/ha), and (iii) volume of live trees (m^3ha^{-1}) were calculated following a methodology laid down by [17]. Computation of BA was carried by $BA = ((dbh)^2 \times \pi)/4$ where dbh=diameter at breast height and π = 3.14; the volume was calculated as $v = ghf$; where v=volume estimation (m^3/ha), g=basal area of the tree/seedling/saplings (m^2/ha), h=height of the tree (m) and f=form factor (0.5). This form factor was used as an average for natural forest factor, which ranges between 0.4 and 0.6 [36]. The computed values for each tree stand parameter were subjected to Canoco 4.5 data analysis software for correlation calculations.

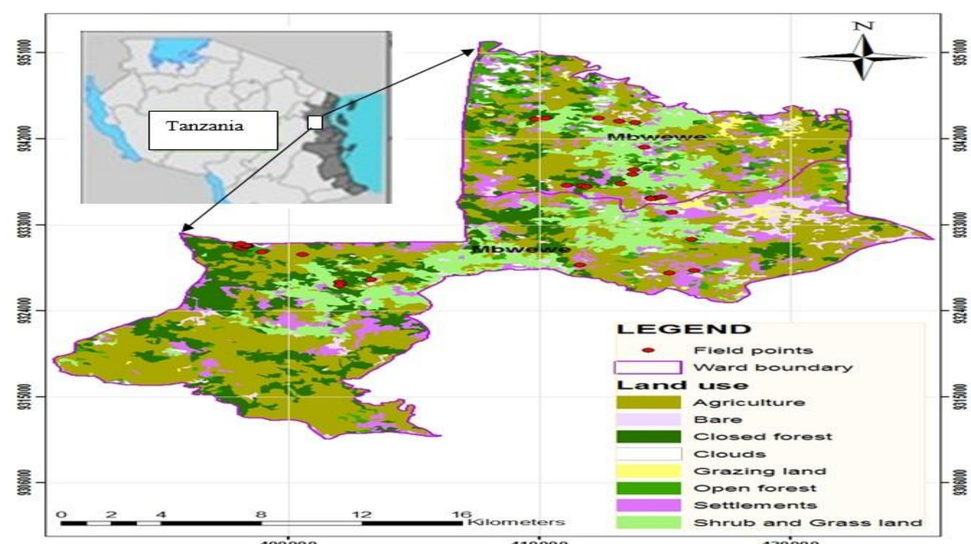

Fig. 1. A map of the study area [16]

2.5 Trees Diversity Indices Analysis

The study computed species diversity indices for all species. Included in diversity indices analyses were the Shannon-Weiner diversity, Shannon-Weiner equitability, Simpson diversity and importance value index (IVI). Each of the diversity components were computed as follows: (i) Shannon-Weiner diversity index was computed as $H' = \Sigma Pi \times \ln Pi$, where H is the index of diversity; *Pi* is the decimal fraction of a relative basal area, and ∑ is the summation symbol [23], (ii) Equitability (evenness) index calculated as $H'E = H'/Hmax$, where H_{max} defined as InS (species richness). (iii) Simpson index was computed as $D = \sum(ni/N)^2$, where D is the index of dominance, ni is the number of individuals of species 'i' in the sample, *N* is the total number of individuals (all species) in the sample and ∑=the summation symbol [37], (iv) The IVI of tree species was obtained from the sum of the relative frequency, density and basal area [18].

2.6 Collection of Soil Samples

Soil samples were collected from same plots, which were used for collection of vegetation data. Forty-seven (25 m × 25 m) sampling plots on each of the land use classes (IFS, ADS and DGS) were established from which a total of 141 soil samples were drawn. The samples were collected by using the Edelman auger at 1-30cm (topsoil) [1,19,24]. The samples in each quadrant were then mixed together to make one composite sample to eliminate variability. Fresh air and oven-dried weights were determined and further laboratory analyses were conducted for each soil parameter.

2.7 Determination of Soil Chemical Properties

The determination of total nitrogen (TN) followed the Kjeldahl acid-digestion procedures [20,21] (ii) Soil total carbon were analysed by the Walkley-Black Procedures. Potassium Dichromate ($K_2Cr_2O_2$) and concentrated Sulphuric Acid (H_2SO_4) were used to produce the reaction and products as shown in this chemical equation: $2Cr_2O_7^{2-}$ +3C° +16H^+→4Cr^{3+} + 3CO_2 + 8H_2O [19]. In computing the results, a correction factor of 1.33 was applied to adjust the organic carbon recovery since Walkley-Black combustion procedures gives incomplete oxidation. Available P was determined by the Bray-II method [24]. The Ammonium Acetate (1 M NH4OAc) (pH 7.0) was used to extract exchangeable calcium (Ca), potassium (K) magnesium (Mg) and sodium (Na). Then K content was determined by using flame photometer while Ethylenediaminetetraacetic acid (EDTA) titration was done to measure Ca and Mg [20].

2.8 Determination of Physical Properties

Bulk density was calculated as the dry weight of soil divided by its volume (gcm^3) [21]. Soil samples were sieved through a 2 mm sieve and then soil texture (ST) (silt = 2-20 μm, clay < 2 μm) were determined by using the pipette method [21]. The resulting data were presented as percentage sand, silt and clay by plotting the percentage ratio of each textural class using the ST triangle [22]. For the determination of electrical conductivity (EC), the preparation of 1:5 (soil: water) was done and the solution was put in rotary shaker for one hour. Then this solution was put in the centrifuge at 8000 to 10000 rotation per minute, for about 10 minutes then a clear solution was decanted and the EC was measured in the decanted solution after calibrating the instrument by means of Potassium Chloride (0.01M KCl). The EC meter was used to get EC values [38,39,27].

2.9 Multivariate Data Analysis

The tree and soil data were subjected into Canoco software following the procedures in Leps and Smilauer [25] In this work, detrended canonical correspondence analysis (DCCA) was used to obtain multiple linear regressions and optimal linear combination between tree parameters and soil variables. The computation of these variables in the DCCA facilitated the possibility to test the null models by Monte-Carlo permutation on each set of data. Indeed, DCCA produced the results that are much more informative about species and environmental variables reactions [40,41]. The F-ratio was used to test the significance of correlation at 5% confidence interval.

3. RESULTS

The models of plant species parameters were summarized as a function of environmental variables (physical and chemical properties of soil) and the correlation of significance for each set of variables. By using the F-ratio, it was possible to show which parameters are the most important by ranking their values in each sets of correlation. The following acronyms were used across the tables of results[1].

3.1 Tree Stand Parameters and Soil Physical Properties

There were strong positive correlation between soil physical properties (SPP) and tree stand parameters (TSP) across the land uses. The Monte Carlo test of significance of all canonical axes in IFS was F=2.400, *p*<0.012 for STP and SPP. In ADS, the F- test was 0.529, *p*=0.938. In DGS, the significance of all canonical axes was F=1.207, *p*=0.242. The species- environment correlation between STP and SPP for individual axis had the average values in the order of 0.435, 0.248 and 0.338 for IFS, ADS and DGS respectively (Table 1).

3.2 Tree Stand Parameters and Soil Chemical Properties

The canonical multivariate data analysis showed a Monte Carlo test of significance of all canonical axes between the correlation of soluble bases (Ca, Mg, K and Na) and tree stand parameters (density, height, basal area and volume (TSP)) as F=2.448, *p*=0.018 in IFS, F=0.687, *p*=0.790 in ADS and F=0.743, *p*=0.808 in DGS. The average species- environmental correction was 0.338 in IFS, 0.305 in ADS and 0.288 in DGS (Table 2). The Monte Carlo test of significance of all the canonical axes for the correlation between non-soluble elements (carbon, nitrogen and phosphorus-(CNP)) and TSP were F=0.816, *p*=0.572 in IFS, F=0.687, *p*=0.790 and F=0.070, *p*=0.020 in DGS. The average of species- environmental correlations was 0.47 in IFS, 0.223 in ADS and 0.392 in DGS (Table 3).

3.3 Diversity Indices and Soil Physical Properties

The multivariate diversity indices had a positive correlation with soil physical properties (SPP). The canonical Monte Carlo tests of significance of all canonical axes in the correlation between SPP and Shannon index showed that F=1.103, *p*<0.388 in IFS, F=0.520, *p*=0.714 in ADS and F=0.932, *p*=0.444 in DGS. The average species-environmental correlation between SPP and Shannon index was 0.248 in IFS, 0.085 in ADS and 0.1475 in DGS (Table 4).

The canonical correlation between SPP and equitability showed that F=0.093, *p*=0.978. The results showed zero correlation between SPP and equitability in ADS and DGS. Indeed, the species-environment correlation was almost zero in ADS and DGS (Table 5). Interestingly, the canonical correlation between SPP and IVI showed that F=0.042, *p*=0.996 in IFS, F=0.819, *p*=0.620 in ADS and F=0.633, *p*=0.724 in DGS. The average of species-environmental correlation between SPP and IVI was 0.015 in IFS, 0.098 in ADS and 0.083 in DGS (Table 6).

3.4 Diversity Indices and Soil Chemical Properties

The canonical results showed that there were weak but positive correlations between soil chemical properties and diversity indices. The correlation between soluble bases and Shannon showed a correlation as in (Table 7) across IFS, ADS and DGS land uses. The Monte Carlo test of all the canonical axes showed that F=0.574, *p*=0.680 in IFS, F=0.410, *p*=0.804 in ADS and F=0.910, *p*=0.480 in DGS. Similarly, the results showed a weak correlation between soluble bases and equitability across the land uses (Table 8). The canonical test of significance for all canonical axes between soluble bases and equitability showed that F=0.119, *p*=0.968 in IFS while ADS had F=0.001, *p*=0.001 in DGS the results showed that F=0.011, *p* =0.001. There were positive correlations between soluble bases and IVI (Table 9). In IFS, F=0.083, *p*=0.986, in ADS, F=0.750, *p*=0.664 while in DGS F=0.374, *p*=0.956.

The canonical correlation was positive between CNP and Shannon index across IFS, ADS and DGS (Table 10). The correlations value was F=0.127, *p*=0.002 in IFS, F=0.254, *p*=0.002 in ADS and F=0.097, *p*=0.002 in DGS. There were almost no established correlations between CNP and equitability across IFS, ADS and DGS (Table 11). The CNP and IVI had positive correlation as shown in (Table 12). The test of significance of all the canonical axes were F=4.246, *p*=0.014 in IFS, F=2.729, *p*=0.018 in ADS and F= 2.007, *p*=0.060 in DGS.

[1] SPP=Soil physical properties, TSP=Tree Stand Parameters, IFS=Coastal Forest Sites, ADS=Agriculture Disturbed sites, IVI=Importance Value Index, EV=Eigen values, LG=Lengths of gradient, SEC=Species-environment correlations, CPVS=Cumulative percentage variance of species data, CPVSER=Cumulative percentage variance of species-environment relation.

Table 1. Canonical correlation between soil physical properties and tree stand parameters across land uses

Axes	SPP vs. TSP in IFS				SPP vs. TSP in ADS				SPP vs. TSP in DGS			
	1	2	3	4	1	2	3	4	1	2	3	4
EV	0.02	0.00	0.00	0.00	0.01	0.01	0	0	0.01	0.00	0.00	0.00
LG	0.36	0.19	0.11	0.19	0.19	0.14	0.08	0.08	0.31	0.21	0.15	0.15
SEC	0.55	0.45	0.42	0.32	0.36	0.25	0.18	0.20	0.45	0.36	0.26	0.28
CPVS	13.60	14.60	14.90	15.00	3.70	4.10	4.20	4.30	4.30	4.60	4.90	5.00
CPVSER	70.90	83.60	0.00	0.00	58.60	74.50	0.00	0.00	61.90	75.20	0.00	0.00

Table 2. Canonical correlation between soluble base and tree stand parameters

Axes	Soluble bases and TSP in IFS				Soluble bases and TSP in ADS				Soluble bases and TSP in DGS			
	1	2	3	4	1	2	3	4	1	2	3	4
EV	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00
LG	0.31	0.21	0.15	0.15	0.24	0.07	0.17	0.17	0.24	0.07	0.17	0.17
SEC	0.45	0.36	0.26	0.28	0.42	0.25	0.23	0.25	0.42	0.25	0.23	0.25
CPVS	4.30	4.60	4.90	5.00	4.00	4.40	4.40	4.40	4.00	4.40	4.40	4.40
CPVSER	61.90	75.20	0.00	0.00	71.50	80.40	0.00	0.00	71.50	80.40	0.00	0.00

Table 3. Canonical correlation between CNP and tree stand parameters

Axes	CNP vs. TSP in IFS				CNP vs. TSP in ADS				CNP vs. TSP in DGS			
	1	2	3	4	1	2	3	4	1	2	3	4
EV	0.00	0.00	0.00	0.04	0.01	0.00	0.00	0.04	0.01	0.00	0.00	0.03
LG	0.16	0.10	0.04	0.68	0.27	0.09	0.14	0.78	0.34	0.23	0.24	0.87
SEC	0.48	0.21	0.19	0.01	0.36	0.26	0.28	0.01	0.57	0.49	0.49	0.02
CPVS	2.70	4.20	4.40	42.80	6.20	6.60	6.80	34.20	8.10	8.90	9.10	28.80
CPVSER	49.50	77.50	0.00	0.00	85.50	89.70	0.00	0.00	88.00	94.10	0.00	0.00

Table 4. Canonical correlation between soil physical properties and shannon index

Axes	SPP vs. Shannon in IFS				SPP vs. Shannon in ADS				SPP vs. Shannon in DGS			
	1	2	3	4	1	2	3	4	1	2	3	4
EV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LG	0.02	0.00	0.09	0.09	0.01	0.00	0.05	0.05	0.05	0.05	0.10	0.10
SEC	0.31	0.34	0.33	0.01	0.22	0.01	0.01	0.00	0.29	0.29	0.01	0.00
CPVS	9.70	9.70	90.70	91.30	4.80	4.80	83.70	94.10	8.30	8.50	95.80	95.30
CPVSER	99.80	0.00	0.00	0.00	100.00	0.00	0.00	0.00	172.20	100.00	0.00	0.00

Table 5. Canonical correlation between soil physical properties and equitability

Axes	SPP vs. Equitability in IFS				SPP vs. Equitability in ADS				SPP vs. Equitability in DGS			
	1	2	3	4	1	2	3	4	1	2	3	4
EV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LG	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SEC	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CPVS	0.90	0.90	94.10	99.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CPVSER	99.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 6. Canonical correlation between soil physical properties and independent value index

Axes	SPP vs. IVI in IFS				SPP vs. IVI in ADS				SPP vs. IVI in DGS			
	1	2	3	4	1	2	3	4	1	2	3	4
EV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LG	0.02	0.00	0.16	0.16	0.01	0.00	0.03	0.03	0.04	0.01	0.21	0.16
SEC	0.06	0.00	0.00	0.00	0.39	0.00	0.00	0.00	0.26	0.07	0.00	0.00
CPVS	0.40	0.40	87.90	95.50	7.10	7.10	57.40	79.90	3.50	3.60	50.20	69.00
CPVSER	90.90	0.00	0.00	0.00	96.50	0.00	0.00	0.00	93.50	100.00	0.00	0.00

Table 7. Canonical correlation between soil bases and shannon index

Axes	Soluble bases vs. Shannon in IFS				Soluble bases vs. Shannon in ADS				Soluble bases vs. Shannon in DGS			
	1	2	3	4	1	2	3	4	1	2	3	4
EV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LG	0.01	0.01	0.09	0.09	0.01	0.00	0.05	0.05	0.01	0.00	0.05	0.05
SEC	0.18	0.18	0.00	0.00	0.28	0.00	0.00	0.00	0.28	0.00	0.00	0.00
CPVS	3.00	3.30	78.90	89.60	7.80	7.80	96.40	95.80	7.80	7.80	96.40	95.80
CPVSER	92.90	92.00	0.00	0.00	94.00	0.00	0.00	0.00	90.00	0.00	0.00	0.00

Table 8. Canonical correlation between soluble bases and equitability

Axes	Soluble bases vs. Equitability in IFS				Soluble bases vs. Equitability in ADS				Soluble bases vs. Equitability in DGS			
	1	2	3	4	1	2	3	4	1	2	3	4
EV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LG	0.00	0.00	0.03	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00
SEC	0.06	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CPVS	0.30	0.30	84.40	99.10	3.20	3.20	97.60	92.20	0.00	0.00	0.00	0.00
CPVSER	84.70	0.00	0.00	0.00	99.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 9. Canonical correlation between soluble bases and independent value index

Axes	Soluble bases vs. IVI in IFS				Soluble bases vs. IVI in ADS				Soluble bases vs. IVI in DGS			
	1	2	3	4	1	2	3	4	1	2	3	4
EV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LG	0.03	0.02	0.21	0.15	0.03	0.02	0.21	0.15	0.08	0.08	0.06	0.06
SEC	0.27	0.14	0.00	0.00	0.27	0.14	0.00	0.00	0.99	0.99	0.00	0.00
CPVS	3.20	3.70	59.60	79.60	3.20	3.70	59.60	79.60	97.40	98.60	99.50	99.10
CPVSER	76.90	98.00	0.00	0.00	76.90	98.00	0.00	0.00	97.00	98.00	0.00	0.00

Table 10. Canonical correlation between CNP and shannon index

Axes	CNP vs. Shannon in IFS				CNP vs. Shannon in ADS				CNP vs. Shannon in DGS			
	1	2	3	4	1	2	3	4	1	2	3	4
EV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LG	0.08	0.08	0.06	0.06	0.05	0.05	0.05	0.05	0.10	0.10	0.10	0.10
SEC	0.99	0.99	0.00	0.00	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00
CPVS	97.40	98.60	99.50	91.10	99.30	99.50	99.80	99.10	99.70	99.00	99.10	89.20
CPVSER	73.70	90.00	0.00	0.00	75.70	90.00	0.00	0.00	90.80	90.00	0.00	0.00

Table 11. Canonical correlation between CNP and equitability

Axes	CNP vs. Equitability in IFS				CNP vs. Equitability in ADS				CNP vs. Equitability in DGS			
	1	2	3	4	1	2	3	4	1	2	3	4
EV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LG	0.02	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SEC	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CPVS	23.50	23.50	90.50	97.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CPVSER	90.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 12. Canonical correlation between CNP and IVI

Axes	CNP vs. IVI in IFS				CNP vs. IVI in ADS				CNP vs. IVI in ADS			
	1	2	3	4	1	2	3	4	1	2	3	4
EV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LG	0.10	0.10	0.16	0.16	0.01	0.01	0.03	0.03	0.06	0.03	0.19	0.17
SEC	0.48	0.48	0.00	0.00	0.52	0.24	0.00	0.00	0.46	0.19	0.00	0.00
CPVS	23.30	23.60	90.20	98.00	14.20	16.40	56.10	76.00	11.10	11.60	43.10	60.10
CPVSER	77.00	90.00	0.00	0.00	87.70	90.00	0.00	0.00	89.50	90.00	0.00	0.00

4. DISCUSSION

4.1 Correlation between Stand and Soil Properties

The canonical correlation between sets of variables studied in this work has revealed various outcomes. The significant canonical variation between the above ground forest structure and soil properties across the studied sites shows that tropical forests vary due to the interaction between floristic and environmental properties [40,41]. The heterogeneity in correlation indicates that not all forest structures and diversity indices respond equally to soil parameters. The results indicate that there are some direct and indirect relations between the above and below ground forest ecosystems as documented in [40]. From these findings, it is obvious that any disturbances on environment affect stand and soil physical properties. Indeed, these findings in this view supports [41,26].

The ecological interpretation of the gradients represented by the canonical axes shows that majority of plants positively correlated with soil properties supporting the findings in [38]. These results can be used to suggest that any alternation of soil physical properties in the tropical coastal forests affects species welfare, which in turn has influence on soil properties (i.e. bulk density, electric conductivity and soil texture in this work) in agreement with [10]. From these findings, it can be predicted that any land use change, which affects the tree stand parameters has some impacts on soil nutrients [9,27]. It is from this predicted and established reciprocal relationship where the results revealed strong correlation of stand parameters in closed forest site than in the disturbed ones. Therefore, for proper management of coastal tropical forests, management programs for both the below and above grounds must consider ecosystems concurrently.

4.2 Correlation between Diversity and Soil Properties

There was positive correlation between diversity indices with soil chemical properties (soil nutrients) and soil physical properties as well as equitability and nutrients across land uses. These correlation values show that soil and above ground forest properties are characterized by the same dynamics directions in the coastal forests like in many other forest ecosystems [28,41]. The positive correlations in Shannon index and soluble bases, Shannon and soil physical properties, equitability and soil physical properties, independent value index and soil physical properties are important in showing that each kind of forest diversity is affected by soil factors contrary to observations made in [39]. This controversy is possibly resulting from variations in geographical locations and nature of vegetation. Regardless of this controversy, it should be noted that the relationship across soil properties and diversity indices can be used to indicate the direction of vegetation and soil interplays. The relationship indicate that vegetation influences the chemical and soil physical properties [27].

The low correlations between trees stand parameters and soluble bases unlike that observed across carbon, nitrogen and phosphorus might be useful to predict that loss of vegetation affects more the non-soluble nutrients than soluble bases. For this prediction to qualify, it requires more studies to understand the impacts on each other as documented in many tropical forests [28]. Interestingly, these variations can contribute into interpreting soil and diversity dynamics and complexity in agreement with [42,40]. Conversely, the observation trees stand parameters had no significant correlation with soluble bases agree the results of [39]. The implication of these findings in forest management is that some nutrients are affected more than others during and after disturbances. Moreover, it shows that different nutrients in different locale are affected differently; hence, production of nutrients during and post disturbances requires temporally and spatially set assessments. Therefore it is hard to permanently establish nutrients status as supported in [3,4].

However, lack of correlation across tree density, heights, basal area and volume, and soluble bases should be considered with some precautions in the sense that tree growth in forests is highly influenced by elements such as Ca, Mg, K, Na concentration [43]. Meaning that, any impacts on vegetation have impacts on soil soluble bases supporting [29]. Therefore, this study come up with the observation that more work needed to be done particularly investigating the reasons for lack of correlation between tress stand parameters and some diversity indices (more specifically the equitability and independent value index) with soluble bases as were not discovered in this study. In this case, this study partially suggests the use of correlation between equaitability and simposns to explain and predict the interpplays between tropical coastal forests above ground structures in relations to soluble bases status.

The correlations between vegetation and soil properties established in this study indicate that disturbances cause changes on above ground species, which in turn have impacts on soil properties. The magnitude of impacts mostly likely differ across a set of nutrients and prevailing locale charactersitics. Therefore, the use of information on the relationship between above ground and soil properties to suggest management operations in forest is important but some precautions, which address a full range of the above and below ground forests ecosystems welfare, are required. With this suggested remarks, certain parameters such as higher Shannon-Weiner could be used as a good indicator of abundant regenerating vegetation in the disturbed sites after exclusion agreeing with the results in [30] unlike equitability or Simpsons index.

5. CONCLUSIONS

The canonical multivariate data analysis between forest structure (species variables) and soil properties (environmental variables) showed significant positive correlation across the land uses. The mean average shows that there is higher positive relationship in non-disturbed sites than the disturbed ones. The established correlations are the results of variations in forests ecosystem management, which bring forest disturbances emanating from crop-agriculture and livestock grazing. The correlations across tree stand parameters, diversity indices and soil properties established in this study set a ground, which is useful to make some predictions of forest structures and soil statuses dynamics in the tropical forest ecosystems. In addition, these correlations can also be used to inform foresters, environmentalists, agriculturists, livestock keepers and police makers that management efforts and plans of coastal forests must focus on addressing the below and above ground forests structures.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Curran MP, Heninger RL, Maynard DG, Powers RF. Harvesting effects on soils, tree growth, and long-term productivity of West Forests. For. Prod. Focus. 2003;3-15.
2. Kalaba FK, Quinn CH, Dougill AJ, Vinya R. Floristic composition, species diversity and carbon storage in charcoal and agriculture fallows and management implications in Miombo woodlands of Zambia. For. Ecol. Manage. 2013;304(2013):99–109.
3. Huang W, Pohjonen V, Johansson S, M. Nashanda. Species diversity, forest structure and species composition in Tanzanian tropical forests. For. Ecol. Manage. 2003;173(14):11–24.
4. Merganic J, Merganicova K, Marusak R, Audolenska V. Plant diversity of forests. Forest Ecosystems – More than Just Trees. 1990;2012:28.
5. Averill RD, Larson L, Kaveland J, Wargo PM, Williams J, Bellinger M. Disturbance processes and ecosystem management. Washington DC, USA; 1994.
6. Chu T, Guo X. Remote sensing techniques in monitoring post-fire effects and patterns of forest recovery in boreal forest regions: A review. Remote Sens. 2013;6(1):470–520.
7. Chen X, Li BL. Change in soil carbon and nutrient storage after human disturbance of a primary Korean pine forest in Northeast China. For. Ecol. Manage. 2003;186:197–206.
8. Kimaro J, Lulandala L. Human influences on tree diversity and composition of a coastal forest ecosystem: The case of Ngumburuni Forest Reserve, Rufiji, Tanzania. Int. J. For. Res. 2013;1–7.
9. Martin Š, Daniel V, Aytekin E, Radim M. The effect of coppice management on the structure, tree growth and soil nutrients in temperate Turkey. J. For. Sci. 2016;61(1): 27–34.
10. Ojoyi M, Mutanga M, Odindi J, Aynekulu E, Abdel-Rahman E. The effect of forest fragmentation on tree species abundance and diversity in the Eastern Arc Mountains of Tanzania. Appl. Ecol. Environ. Res. 2015;13(2):307–324.
11. Rayfield B, Anand M, Laurence S. Assessing simple versus complex restoration strategies for industrially disturbed forests. Restor. Ecol. 2005;13(4): 639–650.

12. Attiwill PM. The disturbance of forest ecosystems: The ecological basis for conservative management. For. Ecol. Manage. 1994;63(2–3):247–300.
13. Ayers MP, Lombardero MJ. Assessing the consequences of global change for forest disturbance from herbivores and pathogens. Sci. Total Environ. 2000;262: 263–286.
14. URT. National forest resources monitoring and assessment of Tanzania Mainland; Ministry of Natural Resources & Tourism, Tanzania Forest Services Agency in collaboration with the Government of Finland and Food and Agriculture Organization (FAO) of the United Nat. Dar es Salaam, Tanzania; 2015.
15. Godoy FL, Tabor K, Burgess ND, Mbilinyi BP, Kashaigili JJ, Steininger MK. Deforestation and CO_2 emissions in coastal Tanzania from 1990 to 2007. Environ. Conserv. 2012;39(01):62–71.
16. Ligate EJ, Chen C, Wu C. Estimation of carbon stock in the regenerating tree species of the intact and disturbed forest sites in Tanzania. 2018;8(2):80–95.
17. Hitimana J, Kiyiapi JL, Njunge JT. Forest structure characteristics in disturbed and undisturbed sites of Mt. Elgon Moist Lower Montane Forest, western Kenya. For. Ecol. Manage. 2004;194(1–3):269–291.
18. Curtis JT. The vegetation of Wisconsin: An ordination of plant communities. University of Wisconsin Press, Madison, Wisconsin, USA. 1959;1959.
19. Walkley A, Black IA. An examination of the Degtjareff method for determining organic carbon in soils: Effect of variations in digestion conditions and of inorganic soil constituents. Soil Sci. 1934;63:251–263.
20. Moreira A, Fageria NK. Soil Chemical Attributes of Amazonas State, Brazil. Commun. Soil Sci. Plant Anal. 2009;40: 2912–2925.
21. Burt R. Soil Survey Laboratory Methods Manual; Soil survey investigations report No. 42, Version 4.0 November 2004; USDA-Natural Resources Conservation Service (NRCS). Lincoln, Nebrasca; 2004.
22. Tanah V, Hutan J. Soil properties and variation between three forest types in Tropical Watershed Forest of Chini Lake. Peninsular Malaysia. Sains Malaysiana. 2015;43(11):1635–1643.
23. Shannon CE, Wiener W. The mathematical theory of communication. University of Illinois Press, Urbana; 1963.
24. Bray R, Kurtz L. Determination of total, organic, and available forms of phosphorus in soils. Soil Science. Soil Sci. 1945;59(1): 39–46.
25. Leps J, Smilauer P. Multivariate analysis of ecological data using CANOCO. New York: Cambridge University Press; 2003.
26. Delang CO, Li WM. Eological Succession on fallowed shifting cultivation fields. A review of the literature. Forest Structure, Springer Briefs in Ecology. 2013;132.
27. Gairola S, Ghildiyal CMSSK. Chemical properties of soils in relation to forest composition in moist temperate valley slopes of Garhwal Himalaya, India. Environmentalist; 2012.
28. Guilherme FAG, Ferreira TO, Assis MA, Torrado PV, Morellato LPC. Soil profile, relief features and their relation to structure and distribution of Brazilian Atlantic rain forest trees. Sci. Agric. 2012;69(1):61–69.
29. Maynard DG, Paré D, Thiffault E, Lafleur B, Hogg KE, Kishchuk B. How do natural disturbances and human activities affect soils and tree nutrition and growth in the Canadian boreal forest? Environ. Rev. 2014;22(2):161–178.
30. Gairola S, Sharma CM, Ghildiyal SK, Suyal S. Chemical properties of soils in relation to forest composition in moist temperate valley slopes of Garhwal Himalaya, India. Environmentalist. 2012;32(4):512–523.
31. Ligate EJ, Chen C, Wu C. Estimation of carbon stock in the regenerating tree species of the intact and disturbed forest sites in Tanzania. 2018;8(2):80–95.
32. Jayakumar S, Kim SS, Heo J. Floristic inventory and diversity assessment - a critical review. Proceedings of the International Academy of Ecology and Environmental Sciences. 2011;1:151–168.
33. Fang Z, Bao W, Yan X, Liu X. Understory structure and vascular plant diversity in naturally regenerated deciduous forests and spruce plantations on similar clear-cuts: Implications for forest regeneration strategy selection. Forests. 2014;5(4): 715–743.
34. Bharathi S, Prasad AGD. Regeneration status of tree composition in the sacred groves of Mercara, Central Western Ghats. Euro. J. Exp. Bio. 2015;5(10):29–40.
35. Lü XT, Yin JX, Tang JW. Structure,tree species diversity and composition of tropical seasonal rainforests in xishuangbanna, south-west china. J. Trop. For. Sci. 2010;22(3):260–270.

36. Kijazi M, Lusambo L, Matura S, Seki H. Green economy in biosphere reserves; Biodiversity survey in East Usambara Biosphere Reserve Tanga Region, Tanzania. Dar es Salaam, Tanzania; 2014.
37. Simpson EH. Measurement of diversity. Nature. 1949;163:688.
38. Ichikogu VI. Relationships between soil and vegetation structural properties of secondary forest regenerating in degraded rubber plantation in the Niger Delta area of Nigeria. An Int. Multidiscip. Journal, Ethiop. 2014;8(34):123–139.
39. Nadeau MB, Sullivan TP. Relationship between plant biodiversity and soil fertility in a mature tropical forest, Costa Rica. Int. J. For. Res. 2015;1–13.
40. Wagg C, Bender SF, Widmer F, van der Heijden MGA. Soil biodiversity and soil community composition determine ecosystem multifunctionality. Proc. Natl. Acad. Sci. 2014;111(14):5266–5270.
41. Mbwambo L, Valkonen S, Kuutti V. Structure and dynamics of miombo woodland stands at Kitulangalo Forest Reserve, Tanzania: Working Papers of the Finnish Forest Research Institute. 2008;98: 10–19.
42. Nizam MS, Jeffri AR, Latiff A. Structure of tree communities and their association with soil properties in two fan-palm dominated forests of east coast Peninsular Malaysia. Trop. Ecol. 2013;54(2):213–226.
43. Pal S, Panwar P, Bhardwaj DR. Soil quality under forest compared to other land-uses in acid soil of north western Himalaya, India. Ann. For. Res. 2013;56(1):187–198.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle3.com/review-history/47163