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APPLICATION OF REGRESSION MODEL TO IDENTIFY A PARAMETER THAT BEST DEFINES SPECIES DIVERSITY IN THE COASTAL FORESTS OF TANZANIA

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ABSTRACT

Coastal forests of Tanzania are diverse in plant species that make them included as part of the 34 world biodiversity hotspots. This study aimed at determining plant species diversity, richness, and evenness as well as to identify the parameter that best defines plant species diversity in the three coastal forests; namely Zaraninge, Kazimzumbwi and Pande. Transect method was used for vegetation data collection and subjected to Analysis of variance and regression techniques. The plant species composition among forests ranged between 75 and 146 with a significantly lower diversity index in Zaraninge (2.057 ± 0.112) than those in Pande (2.415 ± 0.022) and Kazimzumbwi (2.578 ± 0.092) forests. The plant species were more evenly distributed in Zaraninge (0.488 ± 0.004) than in Pande (0.452 ± 0.016) and Kazimzumbwi (0.457 ± 0.025) with no significant difference among them. The species richness per plot was significantly lower in Zaraninge forest (14 ± 1) than Kazimzumbwi forest (20 ± 2). Data on evenness and richness were correlated with plant diversity indices at different levels. A perfect positive correlated occurs with evenness (r =1) but lower with richness (Zaraninge, r = 0.88; Pande, r = 0.91 and r = 0.79 for Kazimzumbwi). This implies that richness and evenness parameters portray different ecological interpretations of the biodiversity value within an ecosystem and cannot be used interchangeably. Regression models showed that species evenness significantly determined plant species diversity, whereas richness was not significant. This study concludes that evenness stands a better chance of being the best predictor of change in plant species diversity and therefore an adequate measure of the coastal forests' conservation value than richness.

Key words: Coastal forest, conservation, diversity, evenness, richness, regression model

INTRODUCTION

Coastal forests of Tanzania are part of the East African coastal forest belt covering the southern coast of Kenya and throughout the coastal strip of Tanzania including the forests in the Islands of Zanzibar and Pemba and the northern parts of Mozambique (Burgess et al. 2000, WWF 2002). These forests are characterized by a mosaic but localized habitat types (Burgess and Clarke 2000), that have prevented a wide range of plant species distribution. The presence of species with habitat restrictions makes coastal forests of East Africa being included as part of the 34 world biodiversity hotspots (Myers 2002). Plant species surviving within fragmented habitats or localized within a single forest are regarded as paleo-endemic due to long term isolation from other population within an ecosystem. Because of high species diversity characterized by high levels of endemism, an appropriate interpretation of plant species diversity needs to be established to form the basis of conserving the East African coastal forests' ecosystem.

Species diversity and abundance are among the most important themes in ecology and biodiversity conservation (Watanabe and Suzuki 2008). However, there is lack of an appropriate meaning of species diversity and its ecological interpretation at different habitats (Kent and Coker 1992), making the concept hard to apply (Magurran 2004). The definition of plant species diversity has two basic components: species richness which is the number of plant species and the plant species evenness or equitability which is the way individuals of each species are distributed within a given plant community (Kent and Coker 1992, Magurran 2004, Hamilton 2005). Efforts have been made to establish indices that can be used to describe the biodiversity conservation importance of an ecosystem (Bock *et al.* 2007). The species richness, evenness and various measurements of abundance and rarity are key components of species diversity, which describe the conservation value of a particular ecosystem (Gaston and Spicer 1998). A number of ecological studies established "the plant species richness" as a criterion of how an ecosystem is biologically diverse (Clarke and Dickson 1995). This is because species richness is the easiest biodiversity parameter to quantify and frequently used as a measure for conservation considerations in the coastal forests of Tanzania. However, diversity in terms of relative abundance (evenness) or spatial patterns among individuals of the species in various localities is less considered in many studies. Stirling and Wilsey (2001) and Ma (2005) pointed out that species richness alone could be a misleading indicator of phytodiversity conservation perspective if it does not include other key attributes of species assemblages. Describing the species diversity using a single value compromises much of the details of the plant community structure (Hamilton 2005). Biodiversity assessment in coastal forests ecosystem in Tanzania may have benefited from similar parameters. Clarke and Dickinson (1995) reported that coastal forests are diverse in plant species; this general conclusion was based on species richness encountered per field surveyed. In semi-arid ecosystems in Tanzania, where livestock grazing pressure influence plant species diversity, the species evenness becomes the most important than species richness (Mligo 2006). Balanced ecosystems (such as Serengeti National Parks) where plant-animal interactions are in a dynamic equilibrium, species diversity is defined by both number of species and relative abundance (Mligo 2015). Which ecological parameters "either species richness or evenness" best defines species diversity in the coastal forests of Tanzania. The efforts to conserve coastal forests with large number of species restricted in specialized habitats can be well placed provided an appropriate definition and interpretation of plant species diversity are established. The purpose of this study was to determine the plant species diversity, richness and evenness, and identify the suitable parameters that provide the best definition and interpretation of plant species diversity. The assumption was that richness and evenness each provides the same interpretation of plant species diversity in coastal forests of Tanzania.

MATERIAL AND METHODS

Location of the study area

Three coastal forests namely; Pande, Kazimzumbwi and Zaraninge Forests were selected for the purpose of this study (Figure 1). These forests are found between longitudes 38^0 30' to 39^0 6'E and latitudes 5^0 40' to 7^0 0S'. To the east, the forests border the Indian Ocean; to the north is Tanga region, the Lindi region to the south and Morogoro region to the west. The climate is one of the most important natural influences on the vegetation structure and growth in the coastal area (Clarke and Burgess 2000). The climate of the coastal area is largely tropical, though some of the southern areas are almost subtropical. There are two rainy seasons where the long rains occur between April and June and short rains occur between November and December in the north, which may be described as a bimodal rainfall pattern. The highest amount of rainfall received in these coastal forests is 2,000 millimeters/annum and the lowest amount being 500 millimeters/annum (Frazier 1993). The highest average annual rainfall ever recorded in these coastal forests is 1100 millimeters/year (Burgess and Clarke 2000) with temperatures increasing from 21.7^{0}C in July to 38.5^{0}C in November through December (White 1983).

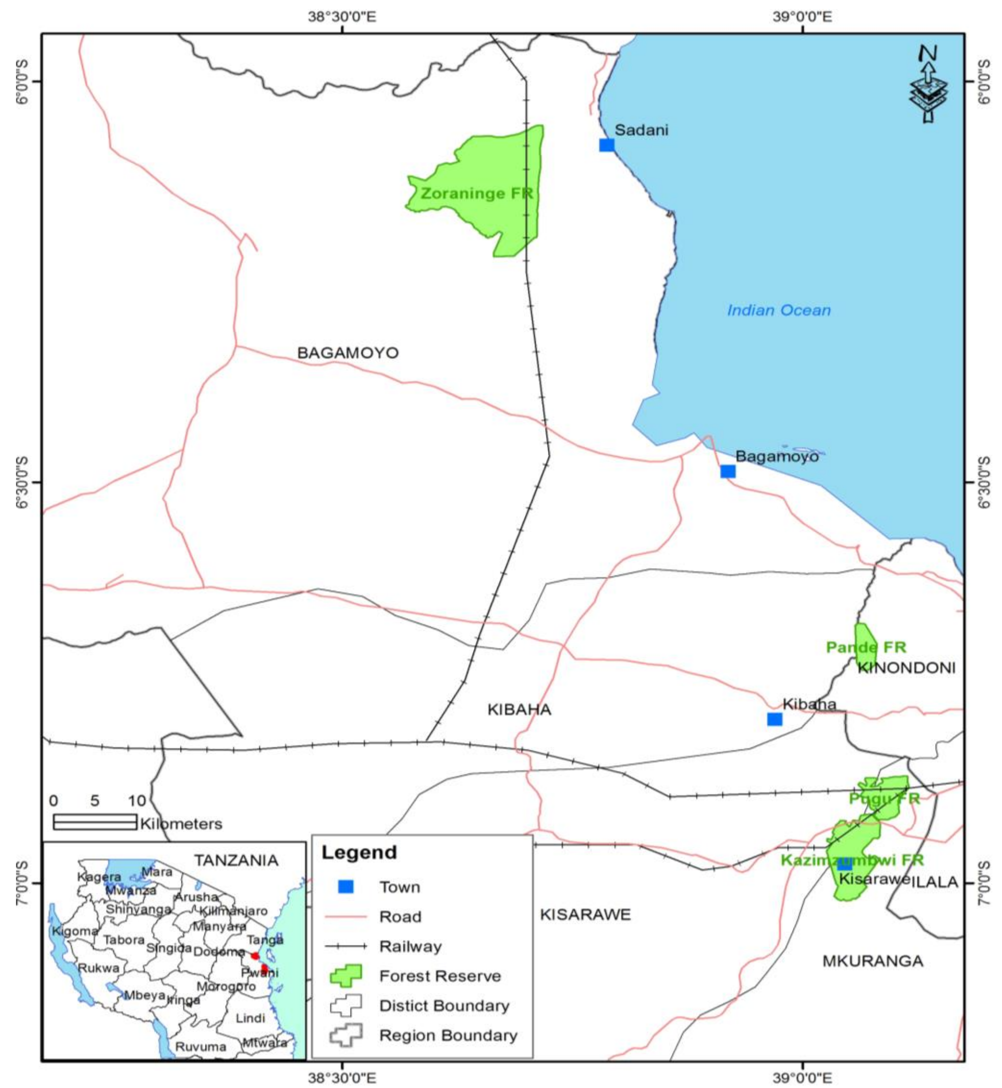

Figure 1: Location of Zaraninge, Pande and Kazimzumbwi Forests in Tanzania

Vegetation sampling procedures in the study forests

After a comprehensive preliminary survey to identify the existing habitats in each of the three selected coastal forests, sampling of plant species was carried out. Transects were laid out from the boundary towards the forest interior to determine the gradient of change in plant communities. Six transects of 0.65 km long each were established in each forests, making a total of 18 transects that covered an area of 1.8 ha in each forest. A total of 36 nested plots as recommended by Stohlgren *et al*. (1995) were systematically established after every 100 m along a given transect. The sampling plots were positioned on alternating sides of transects following the method of Kasenene (1987). Three levels of sampling were employed in the field: (a) A plot of size 25 m × 20 m was used measuring trees with $\geq$30 cm circumference at the height of 1.3 m from the ground level; (b) 5 m × 2 m subplots nested in the major plot for assessment of shrubs and saplings; and (c) 2 m × 0.5 m subplots nested in the 5 m × 2 m subplots for herbs and grasses. A composite data was generated by including all taxonomic specifications. All plants were identified to species level in the field and for plants that were difficult to identify in the field voucher specimens were collected by matching with preserved herbarium specimens of the Department of Botany, University of Dar Es Salaam.

Determination of species diversity and evenness indices

Plant species diversity was determined in terms of Shannon diversity index (Shannon and Wiener 1948) according to the following formula below:

$$Diversity\,Index\,(H') = -\sum_{i}^{\infty} pi \ln pi ...(1)$$

Where pi = ni/N and is the proportion of the total number of all species in a quadrat and ln = natural logarithm to base *e*.

Evenness (E) was calculated using the formula by Alatalo (1981):

$$Evenness\ (E) = \frac{H^{i}}{\ln S} .....(eq2)$$

Where H' is the Shannon-Weaver diversity index and S is the total number of species at a site. These indices were then compared among forests using Analysis of Variance (GraphpadInstat 2003).

Algorithmic establishment of linear regression model

The model established from the ecological parameters determined from vegetation raw data set of 108 samples from the three coastal forests. The parameters (diversity, richness and evenness indices) determined from raw data were fit in the observed data to obtain a linear regression model. The model was optimized step by step until the best fit for the linear relationships among parameters was obtained.

The linear model had only one dependent variable (Y) and two independent variables (Xk^{th}). The dependent variable (*Y*) (i.e. species diversity) was assumed to have values above zero from multiple independent variables. The parameters that had an apparent influence on the species diversity index were regarded as independent variables (*x*). The regression model was fit to multiple responses of *Y* from vegetation parameters (evenness and richness) that could indicate the change in plant species diversity of coastal forests. For each possible set of values of the independent variables there was a probability that a variable significantly influences change in species diversity within a plant community. However, the k^{th} coefficient was also estimated to show changes in explanatory variables within vegetation data. It was considered internal variation within vegetation data among sampling points that made it possible to report all the parameters as mean and standard error. The weighted aggregate variation computed delineated the magnitude of coefficients between explanatory variables to identified variables that correctly defined plant species diversity in the coastal forests of Tanzania. The species diversity was considered to be direct proportional to the number of plant species (richness) $H^{!} \propto r$ and the extent to which individuals of the species are distributed (evenness) i.e. $H^{!} \propto e$. Therefore $H^{!} = \beta_2 * r$ and $H^{!} = \beta_1 * e$ but $\beta_1 > 0$ and $\beta_2 > 0$. The species richness (r) was replaced by variable $X_{2\ \text{and}}$ evenness index (e) was replaced by X_1. The decision to predict y = 0 when x_2 is less than one ($x_2 < 1$) or y>0 when $x_2 > 1$ and $x_1 > 0$ was based on the linear equation 3.

$$y = b_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots \beta_n x^{kth} \ldots \text{ (Equ. 3)}$$

Where Y is the logistic transformation of species data, which is equivalent to the predictive Shannon's diversity index (H!)

x = Vegetation parameters (Evenness -x_1 and Richness-x_2)

β_1 = coefficients of the species evenness (Slope 1)

β_2 =coefficients of the species richness (Slope 2)

b_0 = Regression constant

The algorithmic development of the regression model was done by using the Graphpad-Instat statistical software, version 3.06 (GraphpadInstat 2003). The critical values were computed as normal F-ratio to determine whether or not pairs of parameters were significantly related. The coefficients of the regression models indicated the magnitude of impact of an independent variable to the dependent variable. The coefficient of determination of multicollinearity was estimated at $r^2 = 0.75$. The graphic patterns of vegetation parameters were developed based on the same software (Graphpad Instat 2003).

RESULTS

The plant species composition, diversity, evenness and richness

The difference in plant species composition exists among selected coastal forests was because of different levels of management regimes. A total of 75 plant species recorded in Zaraninge forest where *Brachylaena huillensis, Croton macrostachyus, Rinorea arborea, Haplocoelum mombasense, Panicum heterostachys* and *Combretum harrisii* were highly represented in woodlands, the closed canopy plant community was represented by *Cynometra webberi, Cynometra brachyrrhachis, Landolphia kirkii, Scorodophloeus fischeri, Dalium holztii* and *Rothmania fischeri.* It was recorded a total of 120 plant species in Pande Forest where *Afzelia quanzense, Trema orientalis, Mimusopsis fruitcosa, Dalbergia melanoxylon, Spirostachys africana, Vitex doniana, Colla clavata* and *Panicum trichocladum* dominated in the woodlands. *Scorodophloeus fischeri, Salacia madagascariensis, Cynometra webberi, Albizia gumifera, Milletia usambarensis* and *Uvaria kirkii* were common in the closed canopy plant community. Also a total of 146 plant species were recorded in Kazimzumbwi Forest which was represent by *Canthium mombazense, Manilkara sulcata, Grewia platyclada, Strychnos panganiense, Cussonia zimmermannii, Mimosa pigra, Albizia petersiana, Milletia impressa, Antiaria toxicaria* and *Trema orientalis.*

A significant difference in species diversity exists among studied forests ($P<0.05$) (Table 1), and a significantly lower diversity was observed in Zaraninge Forest than Pande Forest (LSD = 0.520, $P<0.01$) and Kazimzumbwi Forest (LSD = 0.35, $P<0.05$). Similarly, the plant species richness was significantly lower in Zaraninge Forest than in Kazimzumbwi Forest (LSD= 6.86, P = 0.0010) and Pande Forest (LSD = 5.44, P

<0.01). However, no significant difference was observed in plant species evenness among these forests (P>0.05) (Table 1).

Table 1: The plant species diversity, evenness and richness within the studied forests (Mean ± SE) and the probability at 5% critical value

Parameters	**Pande**	**Kazimzumbwi**	**Zaraninge**	**Probability value**
Shannon-Wiener diversity index	[a]2.415 ± 0.022	[b]2.578 ± 0.092	[c]2.057 ± 0.112	P<0.05
Evenness index	[a] 0.488 ± 0.004	[a] 0.452 ± 0.016	[a] 0.457 ± 0.025	P>0.05
Simpson index	[a] 9.677 ± 0.305	[b] 16.75 ± 2.18	[c] 6.54 ± 0.83	P<0.05
Richness	[a] 19 ± 1	[b] 20 ± 2	[c] 14 ± 1	P<0.05

Different letters (*a*, *b*, *c*) means significant difference and same letters (*a*, *a*, *a*) mean no significant difference

Application of regression model to predict change in species diversity

The generated linear regression model was a sufficient predictor of species diversity (y) in the coastal forests with varying explanatory variables (x^{Kth}) (Table 2). The evenness (X_1) contributed more to the change in plant species diversity bearing the higher gradient in first part of the regression model, than richness that had insignificant influence. The goodness of fit of the regression showed that species evenness significantly influenced change of species diversity in Kazimzumbwi ($F = 3.839 \times 10^9$, DF = 33, P<0.0001), Zaraninge ($F = 2.21 \times 10^9$, DF = 33, P<0.0001) and Pande Forest (F = 2.619 x 109, DF = 33, P<0.0001). The influence of evenness was consistent and informative on both full and simple regression models. Within the linear models (Table 2), the signs of the estimated gradients give the direction of effects of the explanatory variable on the probability of change in diversity index at any one particular observation. Positive gradients in evenness (x_1) and the richness (x_2) suggest that the increase in coefficient of an independent variable gives a high probability of its contribution to the species diversity in the forests. The negative estimated gradient on the species richness in Zaraninge Forest showed that species diversity was determined by species evenness alone and the dominance by a few species is the cause on low richness and diversity indices.

Table 2: The linear models that best fit between diversity (Y) and the determining variables (x_1-Evenness and x_2-Richness)

Forest	**N**	**Regression model**	**P**	**Conclusion**
Zaraninge	36	$y = 4.50\,x_1 - 2.572 \times 10^{-7}\,x_2 + 2.076 \times 10^{-5}$	<0.0001	Significant
Pande	36	$y = 4.94\,x_1 + 0.004 \times 10^{-6}\,x_2 + 2.633 \times 10^{-5}$	<0.0001	Significant
Kazimz.	36	$y = 5.69\,x_1 + 4.489 \times 10^{-7}\,x_2 + 5.398 \times 10^{-6}$	<0.0001	Significant

Based on the linear models, the basic multicolinearity test generated produced problems with data from Zaraninge and Pande Forests because of low level of disturbance such that richness measures contributed redundant information. The direct multicolinearity exists between predictors (either richness or evenness) and diversity in Kazimzumbwi Forest because of being in a heavily disturbed condition (Table 3). The goodness of fit of the model shows that, evenness explained 100% of the variation in species diversity among selected coastal forests, whereas richness explained 79.01% in Zaraninge Forest, 83.16 % in Pande Forest and 62.79% in Kazimzumbwi Forest which is less than the minimum percentage coefficient of determination (75%) for the entire vegetation data set (Table 3). The species diversity was perfect positive correlated with evenness ($r = 1$), but somewhat lower with richness in Zaraninge ($r = 0.88$) and Pande ($r = 0.91$), decreasing to 0.79 for Kazimzumbwi forest (Figure 3). Since the same correlation coefficient values obtained when both diversity and evenness were compared with richness, it implies that the two ecological parameters (richness and evenness) conveyed different ecological interpretation and cannot be used interchangeably to describe the biodiversity value of the coastal forests ecosystem. The trend line on the graphs generated from among parameters for data from Zaraninge Forest begins as polygonal sharp peaks and valleys where plots 1-13 showed similar pattern (Figure 3). However the pattern changed between plot 8-10 and between 14-24 as well plots 29-36. The trend line for the diversity curve had similar pattern with that of the species evenness but deviated from the species richness curve (Figure 3).

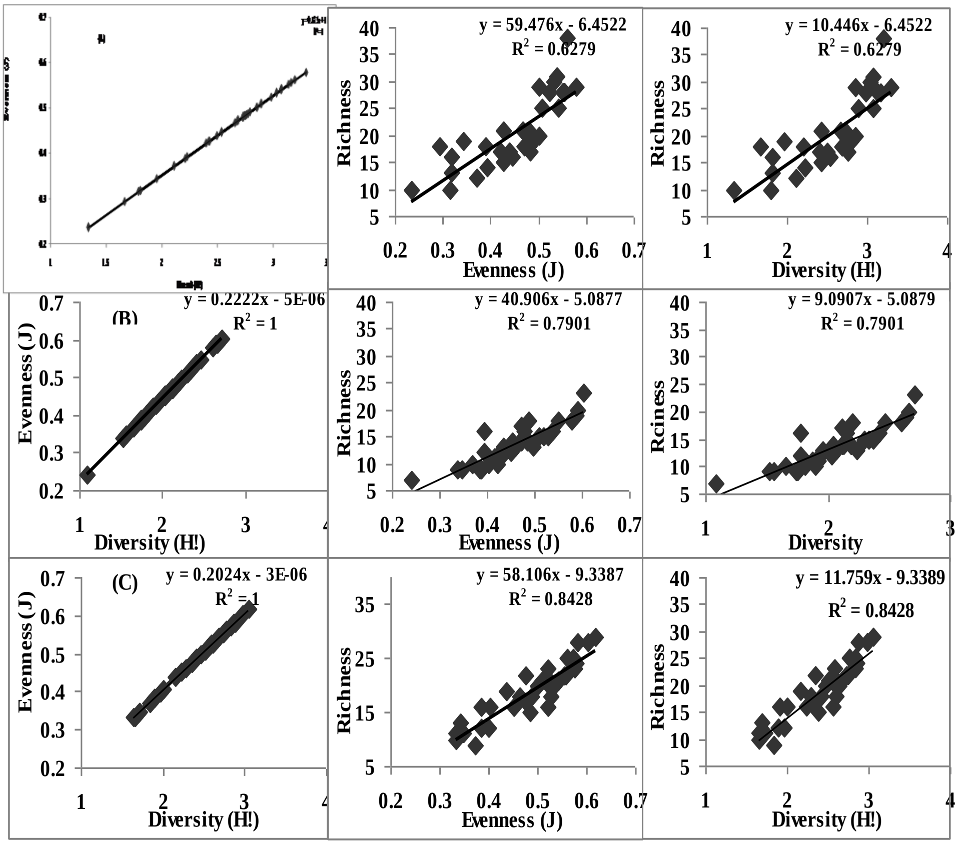

Figure 2: Correlation among ecological parameters (species diversity, richness and Evenness) determined from vegetation data from coastal forests in Tanzania (A) Kazimzumbwi forest (B) Zaraninge Forest and C) Pande Forest.

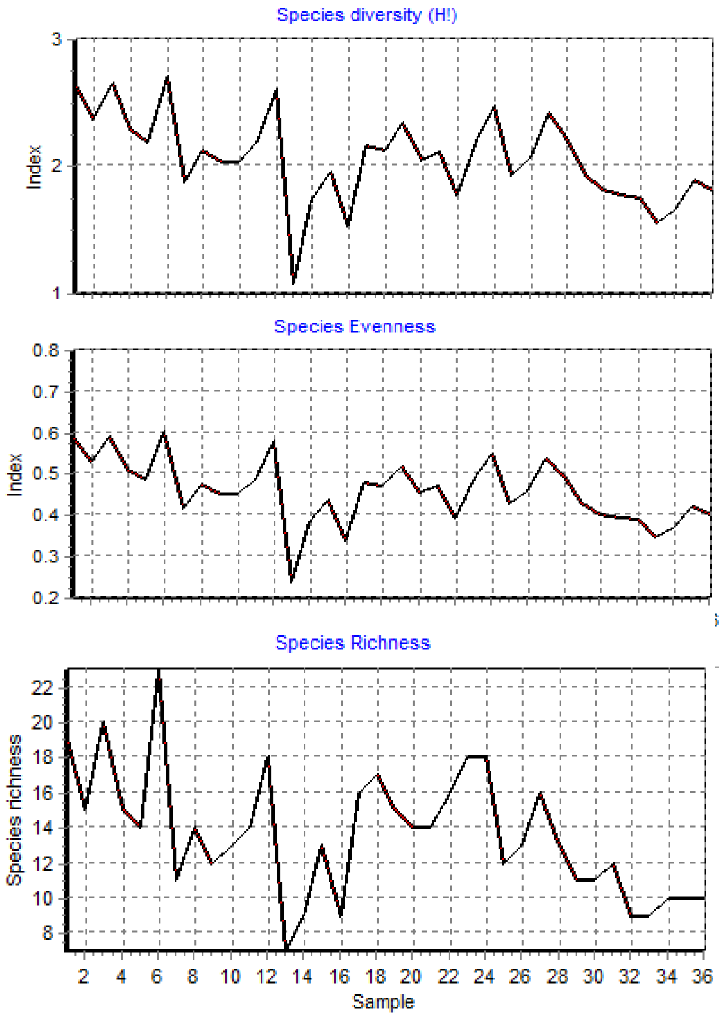

Figure 3: The similarities among trend lines for evenness, richness and diversity indices on vegetation data from Zaraninge Forest Reserve. The evenness trend line is equal to the pattern of species diversity whereas that of richness deviates from the other two. This pattern shows that evenness is an important parameter that provides the best interpretation of species diversity in coastal forests of Tanzania**.**

Table 3: t-test for multicollinearity of the variables (richness and evenness) against variation in species diversity in forests

Site	Statistic	Evenness	Richness	Y-intercept
Zaraninge	t-ratio	3047	0.08	0.06
	p-value	<0.0001	0.93	0.56
	r^2	1	0.7901	
	Remarks	Significant	not significant	not significant
Pande	t-ratio	28693	0.37	0.62
	p-value	<0.0001	0.71	0.54
	r^2	1	0.8316	
	Remarks	Significant	not significant	not significant
Kazimzumbwi	t-ratio	53450	0.31	0.17
	p-value	<0.0001	0.75	0.86
	r^2	1	0.6279	
	Remarks	Significant	not significant	not significant

DISCUSSION

Plant species diversity in the coastal forests of Tanzania

It was observed the highest diversity in Kazimzumbwi followed by Pande and Zaraninge Forests and the difference was significant among forests studied ($P<0.05$), (Table 3). Kent and Coker (1992) pointed out that most Shannon's diversity indices in forest ecosystems ranges between 1.5 and 3.5. Studies in Taita Hill Forests using Point Centered Quarter method (Wilder *et al*. 1998) reported species diversity in a ranged between 1.68 and 2.75 from heavily and least disturbed parts respectively. The diversity indices (with a range between 2.05 and 2.58), obtained in the studied forests indicate that they are moderately rich in plant species. The diversity indices above were determined from data that covered different levels of taxonomic specifications because some plant species in forests exists as herbs, grass, lianas and shrubs that never grow into trees. When a single life form such as tree or herb is considered separately, species diversity becomes lower than a composite data with all life forms inclusive (Mligo 2010). Heyer (1994) pointed out that some tropical forests are species poorer than others when only dominant life form is considered. Using such data will result into high values of diversity indices, which can mislead the prioritization of biodiversity sanctuary for conservation. Similarly, when data from one coastal forest fragment is considered, species diversity can be lower than data from two or more patches or multiple forest fragments provided they have been collected by using the same sampling techniques. This is because of variation in species composition among coastal forests that have high proportion of plant species with limited distribution pattern (endemism). Variations in environmental variables that determine species diversity provide room to compare the same among forests. The habitats in coastal forest ecosystem are fragmented, heterogeneous with soils are predominantly sandy and infertile because of potential leaching (Koné *et al*. 2014). Also the climatic conditions in coastal areas are different from other ecosystems due to the influence of the Indian Ocean of which these forests are in close proximity (Burgess and Clarke 2000). So comparing diversity from the coastal forest ecosystem with other ecosystems should be done cautiously.

Among the three forests studied, Kazimzumbwi and Pande Forests are anthropogenically disturbed due to illegal exploitation pressure that has been there over the years than the intensively protected Zaraninge Forest that had stable plant communities. Selective exploitation of woody species creates large canopy gaps for light to reach the forest floor, a condition that favored establishment of pioneer species (Ndangalasi 1997). *Trema orientalis* and *Panicum trichocladum* are among species benefited from the gaps created through disturbance within these forests (Mligo 2010). The aforementioned two species have invaded the exposed soil and can perform well in soils with poor fertility.

Variation in plant species richness among selected forests

Regardless of being the least disturbed, Zaraninge Forest had low species richness than the disturbed Kazimzumbwi and Pande Forests (Table 1). Disturbance in the later forests were of different forms, while some parts within the forest have been selectively exploited of large canopy plant species, some parts were heavily affected. The response of species to disturbance resulted into difference in richness among forests. If the frequency and magnitude of disturbance increase beyond the irreparable level, only the colonizing species with high growth rates and dispersal rates are able to exist in a plant community (Moshi 2000). However, the decrease in plant species richness may constitute a temporary ecosystem change (Halpern and Spies 1995). That means plant communities in the affected coastal forests may recover through natural regeneration of indigenous plant species provided that there is an improved conservation management (Mligo *et al*. 2011). This is true in the disturbed Pande and Kazimzumbwi Forests that were dominated by colonizers following selective removal of woody species that gave room to understorey and ground layer species to regenerate successfully that contributed to high species richness. A few small plant populations disperse seeds that successfully germinates in a new environment (disturbed area) predict plant community distribution and this agrees with neutral diversity theory of species dispersion (Hubbel 2001). Disturbance triggered the recovery in favour of opportunistic plant species in Kazimzumbwi and Pande forests that increased richness than low species richness in the pristine conditions of Zaraninge Forest. The undisturbed condition in Zaraninge forest made a few plant species including *Scorodophloeus fischeri, Cynometra webberi, Cynometra brachyrrachis, Brachystegia spiciformis* and *Tessmannia burtii* to forms a climax community (Mligo *et al.* 2009). The aforementioned species are better adapted under pristine conditions and have outcompeted other species because of their ability to exploit large amount of environmental resources and consequently low in species richness as pointed out by Luoga (2000).

Variation in plant species evenness among selected forests

The role of species evenness in biological conservation is very important, although it is rarely examined (Mattingly *et al*. 2007). It was recorded higher plant species evenness in Pande Forest than Zaraninge and Kazimzumbwi Forests with no significant difference among them. However, evenness in the study forests was generally lower than in savanna ecosystems (Mligo 2006). Low evenness indices are indications of inequitable distribution pattern among individuals of species within plant communities in the forests studied. Terazaki (1999) pointed out that plant community with evenness indices less than 0.588 is unstable and communities with evenness indices above 0.851 are indications of high ecosystem stability. The evenness indices from this study implies that vegetation communities in the coastal forests are less stable and can change rapidly through any form of disturbance. The lack of significant discrepancy of the overall species evenness among forests studied is because of being exposed to similar environmental conditions influenced by the Indian Ocean. However, habitat fragmentation has contributed to uneven species distribution and consequently low evenness among individuals of plant species within these forests. Some species have individuals widely distributed among habitats or restricted to only one or two habitats and a number of species in coastal forests fall under later category. For example *Scorodophloeus fischeri, Cynometra webberi, Cynometra brachyrrachis* and *Tessmannia burttii* are the dominant canopy tree species in Zaraninge forest (Mligo *et al*. 2009, 2010), whereas a pronounced dominancy of *Spirostachys africana* exists in Pande Forest. Only a few pure stands of *Manilkara sulcata* were found in the southern and western parts in Kazimzumbwi forest with a well identifiable zonation of plant communities in this forest such as the hilltops (*Manilkara sulcata),* hill slopes (*Millettia puguensis* and *Scorodophloeus fischeri*) and or valley bottoms (*Antiaris toxicaria* and *Milicia excelsa*). Therefore, low species evenness in this forest can be contributed by complex habitat zonation existing in the forest.

The definition of plant species diversity based on linear model

Data from coastal forests of Tanzania (Burgess and Clarke 2000, Howell et al. 2009, 2011), are usually presented in terms of number of species (richness) in a particular fragment excluding other forms of species assemblages. Stirling and Wilsey (2001), Purvis and Hector (2000) pointed out that using species richness alone is insufficient parameter to describe plant community characteristics without putting into consideration of species evenness. However the established definition of species diversity by Kent and Coker (1992) and Magurran (2004) included both richness and evenness of species and this ecologically sounds. The established species diversity curve displayed similar pattern with that of species evenness, but deviated substantially from that of richness because the two parameters have no significant relationship (Figure 3). Hill (1973) pointed out that richness regulates variation in both evenness and diversity, however scaled down by Wisley and Stirling (2007) that, species evenness predicts large proportions of covariations among the three ecological parameters which is in agreement with the current observation. The weak positive correlation between species richness and evenness in each forest implies that the two parameters provide different interpretation on the coastal forests' biodiversity.

The examined balance between the two ecological parameters (richness and evenness) using the linear model indicated that evenness parameter significantly determines change in species diversity than richness. The species evenness therefore provides adequate interpretation of change in plant biodiversity within coastal forests with characteristic higher gradients than richness that had insignificant influence. This observation can be strongly supported by Triin et al. (2009), that evenness accounts for the major variation in the species diversity on composite vegetation data from different study areas whereas species richness contributes less. It is therefore rejected the assumption that both evenness and richness have equal influence on species diversity and this gives justification that species evenness can be used as an adequate measure of plant biodiversity characteristics of the coastal forest ecosystem.

However, the application of evenness concept to determine the plant biodiversity conservation value is likely to vary from one ecosystem to another. This is because the Eastern African coastal forest ecosystem is composed of large number of plant species with habitat restrictions (endemism) that may have contributed to low evenness indices. Low evenness indices influenced the sensitivity of the regression model to identify its commanding power on variation in species diversity within these forests. It was predicted that species habitat fragmentation and local endemism are a function of evenness since many individuals of plant species restricted within one or a few plant communities within coastal forests. It is therefore, the evenness component that commands the strongest measure of diversity because of being associated with the level of management and habitat conditions than richness measures which is associated with natural regeneration potentials of the indigenous plant species. Therefore the model is suitable to predict the trend of change in plant species diversity indirectly when anthropogenic or other forms of disturbance affect species evenness within a forest. This tells that plant species evenness is more sensitive and responds faster under different forms of disturbance than richness. The model usually is consistent in vegetation data collected from the same phytogeographical region. Also the sampling technique should not be based on a frequency measures because the widespread species can be underestimated and rare species can be overestimated which may not reflect the importance of the evenness parameter as a measure of the conservation value of an ecosystem.

CONCLUSION

It was found significant difference in plant species diversity among coastal forests because of differences in conservation management regimes. The linear model showed plant species diversity was influenced by richness and evenness at different levels and this implies that the two parameters provide two different ecological interpretations of the conservation value of an ecosystem. The trend line for species diversity curve follows a similar pattern as the trend line of species evenness, means that, in any case species evenness is an ecological parameter that adequately provides a true picture of the ecological characteristics of the coastal forests in Tanzania. The way individuals of species are distributed within any particular plant community determines the means through which an ecosystem is defined. Therefore, plant species evenness usually was an adequate predictor of the coastal forests' conservation value because coastal forests have a large number of plant species with limited distribution patterns. Designing and implementation of forest biodiversity conservation strategies should be regional specific and should consider fragments that are in close proximity within an ecological landscape. This will guarantee conservation of many species that are localized within coastal forest fragments in Tanzania.

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REFERENCES

Alatalo RV 1981"Problems in the measurements of evenness in ecology". *Oikos* **37**: 199-204.

Bock CE, Jones ZF and Bock JH 2007 Relationships between species richness, evenness, and abundance in a southwestern savanna. *Ecol*. **88**:1322–1327.

Burgess ND and Clarke GP 2000 *Coastal Forest of Eastern Africa*. IUCN-The World Conservation Union. Gland, Switzerland and Cambridge, U.K.

Burgess ND, Clarke GP, Madgewick J, Robertson S A and Dickinson A 2000. Distribution and Status. *In.* Burgess ND and GP Clarke, (eds).*The Coastal Forests of Eastern Africa,* IUCN.

Clarke G P and Burgess ND 2000 Geology and geomorphology, *In*: Burgess ND and Clarke GP (eds). *Coastal Forests of Eastern Africa*, pp.29-39. Norwich Ltd UK.

Clarke G P and Dickinson A 1995 *Status report for 11 coastal forests in the coast region of Tanzania.* Frontier-Tanzania Technical Report No.17. The Society for Environmental Exploration, UK/ University of Dare es Salaam, Tanzania.

Frazier J G 1993 Dry coastal ecosystems in Kenya and Tanzania. In Van der Maarel, E (ed.) *Ecosystems of the World 2B- Dry Coastal Ecosystem: Africa, America, Asia,* and *Oceania.* Elsevier, Amsterdam.

Gaston K J and Spicer J I 1998 Biodiversity: An introduction. Blackwell Science, Oxford, pp.420.

Graphpad Instat 2003. GraphpadInstat software Inc, 3.06.

Halpern CB and Spies TA 1995 Plant species diversity in natural and managed forests of the Pacific Northwest. *Ecol. Appl.* **5**: 913-934.

Hamilton AJ 2005 Species diversity or biodiversity? *J. Env. Manag*. **75**: 89-92.

Heyer WR Donnelly MA, McDiarmid RW, Hayer LC and Foster S eds. 1994 Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institute Press, Washington D.C.

Howell KM, Msuya CA, Mligo C, Werema C, Kihaule P, Honorati NK and Suleiman HO 2012 Biodiversity surveys of poorly Known Coastal Forests of Southern, Eastern Tanzania and Zanzibar.

Hill MO 1973 Diversity and Evenness: A unifying notation and its consequences. *Ecol*. **54**: 427-432.

Hubbel SP 2001 The unified neutral theory of biodiversity and biogeography. Princeton University Press.

Kasenene JM 1987 The influence of the mechanized, selective logging, felling intensity and gap size on the regeneration of tropical moist forest in Kibale Forest Reserve, Uganda. Unpublished PhD Thesis, Michigan State University, Eat Lansing, USA.

Kent M and Coker P 1992 *Vegetation Description and Analysis*. *A practical Approach. John* Willey and Sons, New York, pp. 319.

Koné B, Bognompke JP, Cherif M, Oikeh S, Konan F and Traoré M J 2014 Characterization of Soil Nutrients Leaching in Perched Groundwater as Occurring in Bush Fallow of Forest Zone. *1nt. J. Ecol. Env. Sci.* **40 (2-3)**: 165-174.

Luoga EJ 2000 The effects of Human disturbance on diversity and dynamics of the Eastern Tanzania miombo arborescent species, PhD. Thesis. Witwatersrand University. Johannesburg, South Africa.

Ma M 2005 "Species richness vs evenness: independent relationship and different responses to edaphic factors". *Oikos* **111**: 192–198.

Magurran A E 2004 Measuring biological diversity. Blackwell Science, Oxford.

Mattingly WB, Hewlate R and Reynolds HL2007 "Species evenness and invasion resistance of experimental grassland communities". *Oikos* **116:**1164–1170.

Mligo C, Lyaruu HVM and Ndangalasi H J 2011 The Effect of Anthropogenic disturbances on Population structure and regeneration potentials of *Scorodophloeus fischeri* and *Manilkara sulcata* in coastal forests of Tanzania. *J. For. Sci.* **73(1)**: 33–40.

Mligo C, Lyaruu HVM, Ndangalasi H J and Marchant R 2009 Vegetation community structure, composition and distribution pattern in the Zaraninge Forest, Bagamoyo District, Tanzania. *J. East Afr. Nat. Hist.* **98** (2)**:** 223–239.

Mligo C 2006 Effects of Grazing Pressure on Plant Species composition and Diversity in the Semi-Arid Rangelands of Mbulu District, Tanzania. *Agr. J.* **1 (4):** 277-283.

Mligo C 2010 *Composition gradient in species distribution and genetic diversity of Scorophloeus fischeri* Taub. *In coastal forests*, *Tanzania*. PhD thesis, University of Dar es Salaam.

Mligo C 2015 Plant Species Composition and Distribution in Relation to Land Use Patterns in Serengeti ecosystem Tanzania. *Op. J. For.* **5:** 607-620.

Moshi GY 2000 *The influence of Disturbance on the status and Regeneration rate of selected Forests in the Udzungwa Mountains, Tanzania*. M.Sc. Thesis, University of Dar es Salaam.

Myers N, Mittermeier RA, Mittermeier CG da Fonseca GAB and Kent J 2000 "Biodiversity hotspots for conservation priorities" *Nat.* **403**: 853-858.

Ndangalasi HJ 1997 *Canopy gap characteristics and regenerating species in Pugu Forests Reserve, Tanzania.* M.Sc. Thesis, University of Dar es Salaam.

Purvis A and Hector A 2000 "Getting the measure of biodiversity". *Nat.* **405**: 212–219.

Shannon CF and Weiner W 1948 The Mathematical Theory of Communication. University of Illinois Press, Urbana. pp150.

Stirling G and Wilsey B 2001 "Empirical relationships between species richness, evenness and proportional diversity". *Am. Nat.* **158**:286–299.

Stohlgren TJ, Falkner MB and Schell LD 1995 "A Modified-Whittaker nested vegetation sampling method". *Vegetatio* **17:** 113-121.

Terazaki M 1999 "Mass Occurrence of Bathypelagic Chaetognath *Eukrohnia fowleri* from the Arabian Sea and Bay of Bengal". *Ind. J. Mar. Sci.* **28**: 163-168.

Triin R, MartinT S, Lotten JJ, Mikael L, Karin H, Marie V and Honor CP 2009 "Small-scale plant species richness and evenness in semi-natural grasslands respond differently to habitat fragmentation" *Biol. Cons.* **142**: 899-908.

Watanabe NM and Suzuki E 2008 Species diversity, abundance, and vertical size structure of rattans in Borneo and Java. *Biod. Cons.* **17**: 523–538.

White F 1983 The vegetation of Africa. Natural Resource Research, No. 20. Report to accompany UNESCO/AETFAT/UNSO Vegetation Map of Africa, UNESCO, Paris.

Wilder C, Brooks T and Lens L 1998 "Vegetation structure and composition of the Tahita Hills Forests". *J. East Afr. Nat. Hist.* **87**: 181-187.

Wilsey B and Stirling G 2007 Species richness and evenness respond in a different manner to propagule density in developing prairie microcosm communities. *Plant Ecol.* **190**:259–273.

WWF 2002 "Ecoregion Profile: Eastern Arc Forests. Tropical & Subtropical Moist Broadleaf Forests". *Cons.* **5**: 431-433.