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Floristic Similarity and Diversity Gradients in the Eastern Arc and Coastal Forests of Tanzania

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Abstract
The Eastern Arc and Coastal forests of Tanzania are biodiversity hotspots, centres of endemism, and highest priority ecosystems for biodiversity conservation worldwide. But, their floristic similarity and species diversity gradients over geographical distances and longitudinal locations, respectively, are poorly understood. Thus, this study investigates the relationship between floristic similarity and geographical distances, as well as species diversity and longitudinal locations among the forests. A total of 37 inventories from the Eastern Arc and Coastal forests of Tanzania were selected based on inventories with minimum diameter at breast height (DBH) $\geq$ 10cm), and identification of trees done at species level. The floristic similarity was determined using the Sørensen's similarity coefficient. The Pearson correlation test was used to study differences between floristic similarities and geographical distances, as well as species diversity and longitudinal location. The findings revealed three clusters of forests assembled due to their geographical proximity. The correlation between geographical distances and floristic similarities revealed a significant negative association ($n = 528$, $R^2 = 0.1821$, $p < 0.001$), while species diversity and longitudinal location of forests had a significant positive correlation ($n = 37$, $R^2 = 0.5401$, $P < 0.05$). The results suggest that high environmental heterogeneity across the forests should be well thought-out in their management plans to uphold their values.

Keywords*: biodiversity, cluster analysis, conservation, longitude, similarity*

1. Introduction

The Eastern Arc and Coastal forests of Tanzania run along the coastline region of the country, including Zanzibar (Myers et al., 2000). Generally, the term 'Eastern Arc' describes the forest-capped prehistoric crystalline mountains of south-east Kenya and eastern Tanzania (Lovett, 1985), while 'Coastal forests' refer to a chain of forests and thicket patches set within savannah, woodland and agricultural land, which stretch from Southern Somalia to Southern Mozambique (White, 1983). The two ecosystems are under the influence of the Indian Ocean climatic regime, and thus comprise foreseeable local climate (Lovett, 1985). The Eastern Arc and Coastal forests are known to be biodiversity hotspots for conservation priorities as they harbor at least 1,500 endemic plant species found nowhere else in the globe, and about 121 endemic vertebrates and over 333 globally threatened species (ICBP, 1992; Strattersfield et al., 1998; Mittermeier et al., 1998; 2004; Myers et al., 2000). All this information shows the extreme biological importance of the Eastern Arc and Coastal forests in global terms. Despite of their

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importance, the Eastern Arc and Coastal forests are among the world ecosystems that face most urgent threat in terms of potential species extinction (Ricketts et al., 2005). The utmost threats to habitat in the region include fragmentation, agricultural encroachment, timber extraction and charcoal production (Newmark, 2002). Increased anthropogenic activities threaten the biodiversity value of the ecosystems and their existence, and thus a prioritization for conservation.

Globally, floristic analyses are valuable for recognizing spatial patterns in plant diversity and composition, and when pooled with environmental variables such as soil fertility and geographical gradients, can offer significant data on the processes that uphold the high levels of tree species diversity in tropical forests. In that outlook, floristic analyses have just received substantial attention in forest studies (Terborgh & Abdresen, 1998; Ter Steege et al., 2000; Wittman et al., 2006; Silva et al., 2011). Many studies done in the Amazonian forests describe the geographical variation in floristic composition and tree species diversity based on associations among floristic parameters at diverse sites, and on environmental variables like soil fertility and precipitation (Gentry, 1988; Leigh, 1999; Ter Steege et al., 2000; Pitman et al., 2002). Other studies use ancient and evolutionary expositions to clarify variations in tree species composition (Mori, 1991; Prance 1994; Oliveira & Daly, 1999). The use of relations between environmental factors and floristic diversity patterns is challenging due to variations of precipitations (Junk et al., 1989) and soil fertility (Furch & Klinge, 1989).

Some efforts to determine patterns of tree species composition and diversity in various forest ecosystems in the globe have emphasized on the determination of floristic similarity and diversity gradients (Ter Steege et al., 2000; Condit et al., 2000, 2002; Pitman et al., 2001; Tuomisto et al., 2003; Wittmann et al., 2006; Silva et al., 2011). In Eastern Africa, particularly in the Eastern Arc and Coastal forests, no such kind of study has been undertaken. Instead, many studies undertaken in the Eastern Arc and Coastal forests of Tanzania have focused on assessing floristic composition, diversity, and anthropogenic activities on biodiversity (Burgess & Clarke, 2000; Ahrends, 2005; Temu & Andrew, 2008; Burgess et al., 2007; Kacholi et al., 2015). Therefore, this study aims to investigate: (1) how floristic similarity changes over geographical distance; and (2) whether species diversity gradient exists along longitudinal variations of the selected forests within the region. The study hypothesizes that floristic similarity and geographical distance are inversely related, while species diversity and longitudinal location are directly related. To achieve the two goals, this study uses tree species inventory data collected from 37 locations within the Eastern Arc and Coastal forests of Tanzania to investigate the patterns.

2. Materials and Methods

2.1 Study Sites and Climate

This study used secondary data from a total of 37 forest inventories compiled by different authors across the Eastern arc and Coastal forests of Tanzania (Table 1). The selected inventories cover an area of 188,411ha, which are distributed over 2 regions (Morogoro and Tanga) along the coastline of Tanzania (Fig. 1). 74.3% of the selected inventories are from Morogoro region, while the remaining 25.7% are from Tanga region.

Table 1: References and site features of tree inventories

Reference	Forest Reserve	Region	Latitude /Longitude	Richness	Diversity
Beharrell et al., 2002	Nilo	Tanga	04°50'S/38°37'E	126	4.83
Bracebridge and Sallu, 2004	Mahenge Scarp	Morogoro	08°37'S/36°42'E	78	4.15
Cunneywothy & Stublefield, 1996	Mlungui	Tanga	05°00'S/38°42'E	51	3.92
Doggart et al., 1999	Kwamgumi	Tanga	04°55'S/38°44'E	129	4.86
Doody et al., 2001a	Mpanga	Tanga	04°47'S/38°47'E	60	4.09
Doody et al., 2001b	Amani	Tanga	05°04'S/38°30'E	124	4.82
Hall et al., 2002	Mlinga	Tanga	05°04'S/38°44'E	106	4.66
Jenkins&Roettcher,2001	Nambinga	Morogoro	08°44'S/36°27'E	74	3.94
Kacholi et al., 2015	Kimboza	Morogoro	07°00'S/37°48'E	93	3.40
Kacholi et al., 2015	Kilengwe	Morogoro	07°29'S/37°32'E	52	4.02
Kacholi et al., 2015	Kisego	Morogoro	06°59'S/37°47'E	21	2.50
Kacholi et al., 2015	Milawilila	Morogoro	06°58'S/37°45'E	20	2.62
Kacholi et al., 2015	Nemele	Morogoro	07°11'S/37°46'E	19	2.76
Kacholi et al., 2015	Ngambaula	Morogoro	06°58'S/37°45'E	17	2.60
Kacholi et al., 2015	Gunauye	Morogoro	06°58'S/37°50'E	22	2.80
Malimbwi et al., 2005	Dindili	Morogoro	06°42'S/37°37'E	21	2.78
Malimbwi et al., 2005	Dunduma	Morogoro	06°10'S/37°37'E	13	2.16
Malimbwi et al., 2005	Mindu	Morogoro	06°50'S/37°35'E	8	1.70
Malimbwi et al., 2005	Kanga	Morogoro	05°33'S/37°40' E	28	2.99
Malimbwi et al., 2005	Kilengwe	Morogoro	07°30'S/37°28'E	25	4.01
Malimbwi et al., 2005	Kimboza	Morogoro	06°59'S/37°47'E	28	3.40
Malimbwi et al., 2005	Kitulangalo	Morogoro	06°39'S/37°57'E	18	2.17
Malimbwi et al., 2005	Lubalanzi	Morogoro	07°17'S/37°40' E	33	3.09
Malimbwi et al., 2005	Pangawe East	Morogoro	06°49'S/37°48'E	21	2.68
Malimbwi et al., 2005	Pangawe West	Morogoro	06°49'S/37°46'E	12	1.79
Malimbwi et al., 2005	Ruvu	Morogoro	06°53'S/37°49'E	28	3.06
Malimbwi et al., 2005	Mkulanzi	Morogoro	06°57'S/38°05'E	66	3.51
Malimbwi et al., 2005	Mkindo	Morogoro	06°12'S/37°28'E	29	2.99
Malimbwi et al., 2005	Mlilingwa (N)	Morogoro	06°40'S/37°50'E	40	3.24
Malimbwi et al., 2005	Mvuha	Morogoro	07°13'S/37°51'E	27	2.73
Malimbwi et al., 2005	Nongeni	Morogoro	06°49'S/37°43'E	27	1.88
Malimbwi et al., 2005	Vigoregore	Morogoro	07°60'S/37°52'E	22	2.64
Malimbwi et al., 2005	Nguru South (L)	Morogoro	06°09'S/37°28'E	26	2.96
Malimbwi et al., 2005	Nguru ya Ndege	Morogoro	06°41'S/37°35'E	27	2.92
Marshall, 2008	Magombera	Morogoro	07°55'S/37°03'E	83	4.42
Salter et al., 2002a	Bombo East (I)	Tanga	04°48'S/38°42'E	59	4.82
Salter et al., 2002b	Bombo East (II)	Tanga	04°43'S/38°39'E	47	3.52

Both regions experience oceanic climate due to proximity to the Indian Ocean; with bimodal rainfall regime: the long and short rainy seasons lasting from March to May and October to December, respectively. The study chose only inventories that met the benchmarks of a minimum DBH of 10cm, list of trees present in the forests, and identification of trees at species level.

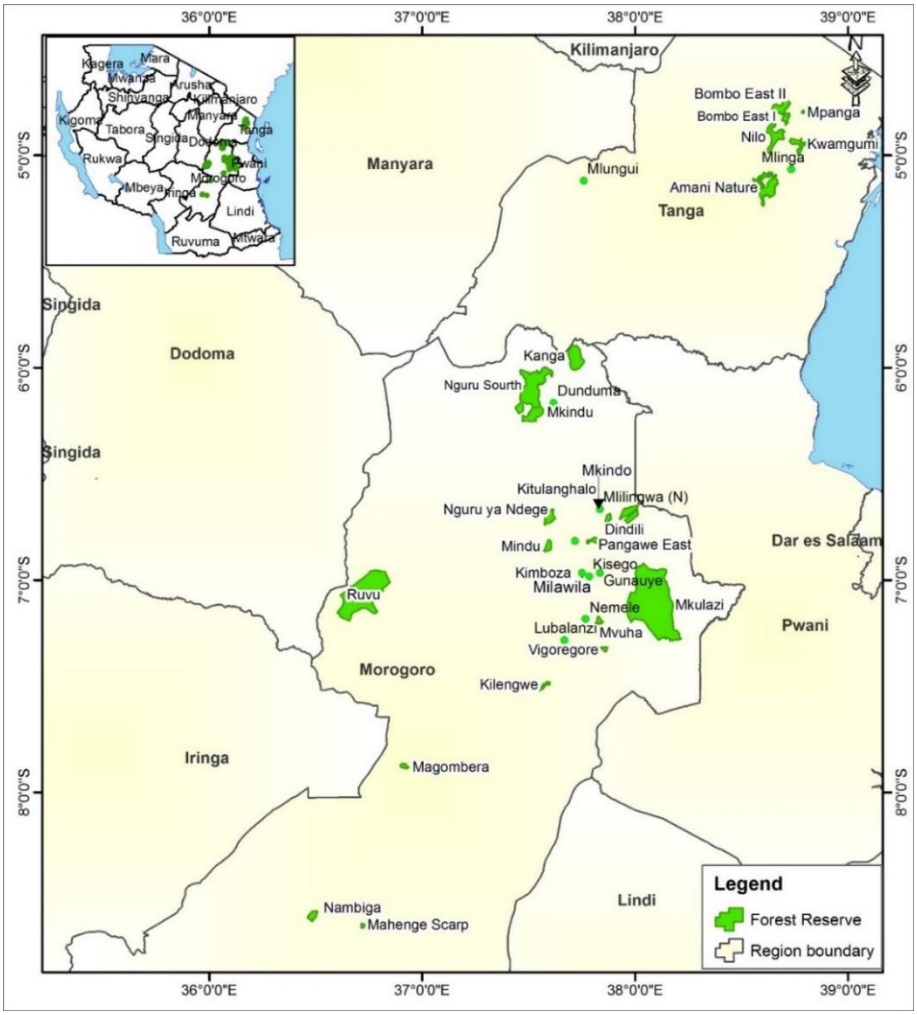


Figure 1: ***Map Showing the Location of the Forest Reserves***

2.2 Data Analysis

The floristic similarity between forest pairs was determined using Sørensen's similarity coefficient (equation 1), whereby a multivariate agglomerative clustering technique using the Ward's linkage was carried out using the Community Analysis Package version IV (CAP IV) software (Seaby & Henderson, 2006). The geographical distance between forest pairs was obtained by means of the online distance calculator (available at http://www.movable-type.co.uk/scripts/latlong.html), using latitude and longitude points. The species diversity was calculated using the Shannon-Wiener diversity index (equation 2). The Pearson correlation test was used to determine the influence of geographical distance on floristic similarity and longitudinal location on species diversity among the forests.

$$\text{Similarity coefficient} = \frac{2C}{S_a + S_b} \quad (1)$$

Whereby C refers to the number of common species among the forest pair; while S_a *and* S_b represent the number of species present in forest 'a' and 'b', respectively.

$$H' = -\sum_{i=1}^{S} P_i \, InP_i \quad (2)$$

Where, H' is the Shannon-Wiener index, S is the species richness, and P_i is proportional individuals in the ith species in a forest.

3. Results

3.1 Floristic Similarity and Geographical Distance

The Sørensen coefficients of species similarity ranged from 0.00 to 0.59 (Fig. 2). The higher coefficient was between Nilo and Amani (0.59), followed by Bombo East (I) and Bombo East (II) (0.58), Nemele and Milawilila (0.55), Kimboza and Kilengwe (0.54), Kitulangalo and Pangawe West (0.53), Mlilingwa and Mkulanzi (0.53), Amani and Mlinga (0.51), Mlilingwa and Nguru ya Ndege (0.51), while the remaining forest pairs had floristic similarity coefficients of less than 0.50.

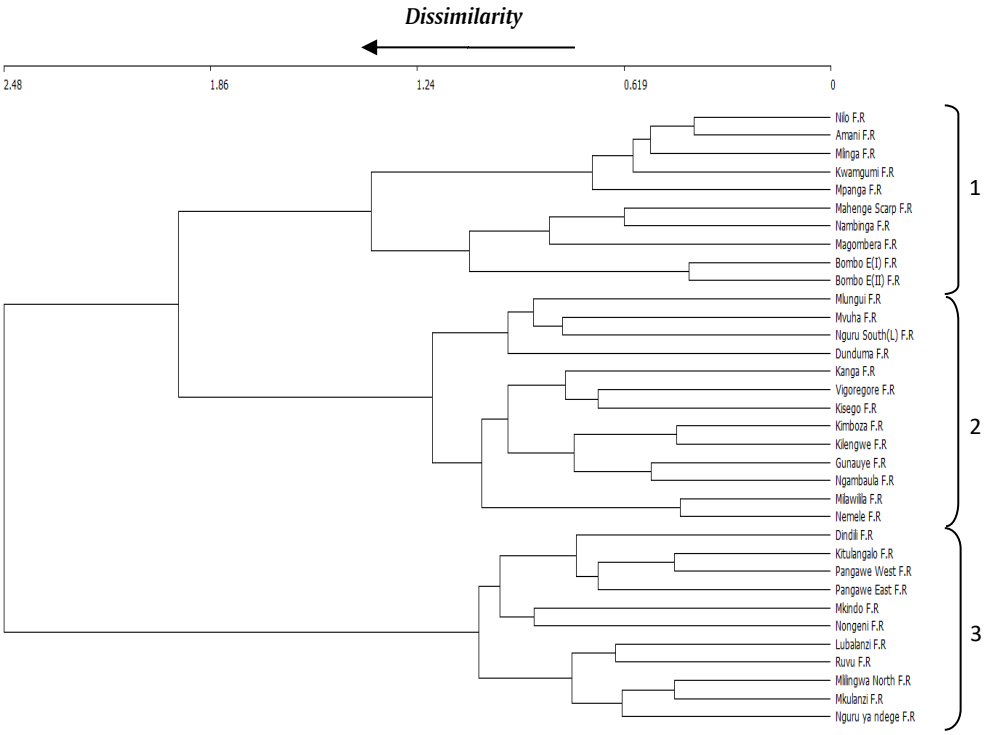


Figure 2: ***Dendrogram Constructed from Sørensen Coefficients of Similarity Based on Species Composition in the Selected Eastern Arc and Coastal Forests.***

The distance between forest pairs varied widely from a minimum of 3.7km between Pangawe East and Pangawe West, to a maximum of 509.2km between Nambinga and Mpanga forest. Basically, the cluster analysis grouped the 37 inventories into three major clusters. The distance between forest pairs in cluster one varied from a minimum of 10.8km between Bombo East (I) and Bombo East (II), to a maximum of 508.4km between Nambinga and Bombo East (II). The distance variation in cluster two ranged from a minimum of 5.1km between Milawilila and Ngambaula, to a maximum of 346.1km between Mlungui and Vigoregore forest; while in cluster three the distance ranged from a minimum of 3.7km between Pangawe East and Pangawe West, to a maximum of 117.1km between Dindili and Kitulangalo forest reserve.

The Pearson correlation test (Fig. 3) revealed a significant negative association ($n = 528$, $R^2 = 0.1821$, $p < 0.001$) between geographical distance and floristic similarity.

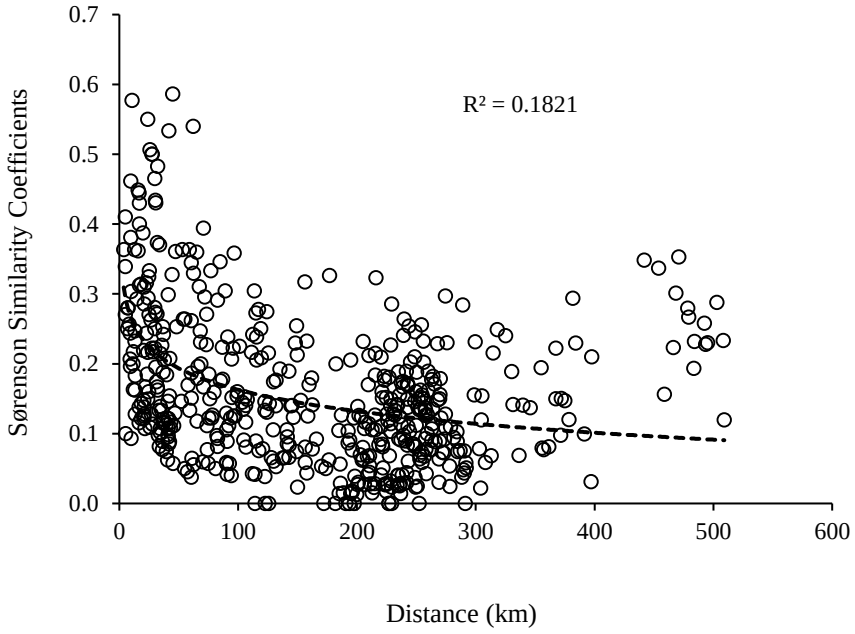


Figure 3: Relationship between Floristic Similarity and Geographical Distance among Forest Pairs

3.2 Species Diversity and Longitudinal Location of Forests

The Shannon-Wiener diversity indices (Table 1) of the studied forests ranged from 1.70 at Mindu forest reserve to 4.86 at Kwamgumi forest reserve. The relationship between the Shannon-Wiener diversity indices and longitudinal locations of the forests revealed a significant positive association ($n = 37$, $R^2 = 0.5401$, $P < 0.05$), signifying a trend of increasing species diversity from western to eastern (Fig. 4).

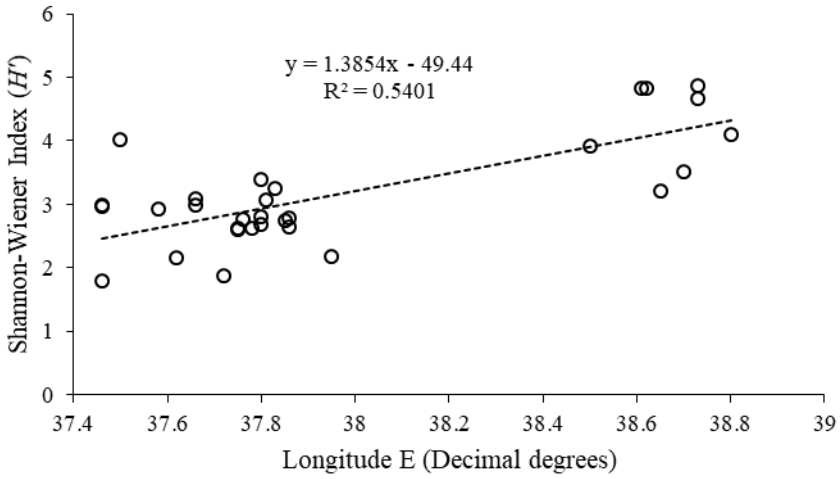


Figure 4: ***Shannon-Wiener Diversity Index and Longitudinal Location of the Forests***

4. Discussion

The cluster analysis informs that the forests are basically grouped into three clusters based on geographical proximity. For instance, in cluster one, Bombo East (I) and Bombo East (II) located 10.8km apart, shared 58%; Nilo and Amani forest located 45.2km shared 59%; and Amani and Mlinga located 25.8km shared 51% of their species. In cluster two, among the closer located forest pairs are Nemele and Milawilila (located 24km), which shared 55% of their species; and Kilengwe and Kimboza forests located 62km apart, which shared 54%. In cluster three, Kitulangalo and Pangawe West forests located 27.5km shared 53%, Mlilingwa and Mkulanzi forests located 42km shared 53%, and Mlilingwa and Nguru ya Ndege forests located 28km shared 51% of their species. These findings are lower when compared with Silva et al. (2011), who found closer forests sharing more than 70% of their species in Central Amazon, Brazil.

The observed trend in the cluster analysis was confirmed by the Pearson correlation test, which showed a significant negative exponential relationship between geographical distances and floristic similarities. This relationship signifies that the shorter the geographical distance between forest pairs, the more similar the forest pairs are in terms of floristic composition. The observed pattern confirms the study hypothesis that floristic similarity is inversely proportional with geographical distance. This study finding also conforms to the neutral theory: that between-site floristic similarity decreases with increasing geographical distance due to spatially limited dispersal (Condit et al., 2002). Other studies such as Coronado et al. (2009), Terborgh and Andersen (1998), Tuomisto et al. (2003) and Phillips et al. (2003): all offer evidence that floristic variation is well explained by environmental heterogeneity and geographical distance. The observed inverse relationship has also been reported by Tuomisto et al. (2003), Slik et al. (2003) and Silva et al. (2011) in their studies. Though environmental factors were not studied

in the present work, they could be the possible factors for the observed trend as different studies (e.g., Slik et al., 2003; Bohlman et al., 2008) reported that edaphic factors, especially soil type and nutrient availability, are the most important variables for species distribution and abundance patterns among forests. When forest pairs are adjacent, the more comparable are environmental factors, hence similar floristic composition as compared to distant forest pairs (Barrantes & Sandoval, 2009). The variations in species adaptation abilities to different edaphic factors (Gentry, 1988), dispersal limitation (Hubbell, 2001; Condit et al., 2002), herbivory and competition (Tuomisto & Ruokolainen, 2005), play a significant role in influencing spatial variation in floristic composition too.

However, it was also noticed that some forests were clustered together regardless of their geographical proximity. For instance, the Nambinga and Bombo East (II) forest pair, though assembled together in cluster 2, are spatially distant (508.4km) as compared to the remaining forest pairs in the same cluster. Also, the Milawilila and Ngambaula forests are geographically close, just about 5.1km apart, but had low similarity of 27%. These reversals from the observed general trend correspond to the forests with dissimilar/ similar environmental factors regardless of their distances (Philips et al., 2003; Tuomisto et al., 2003). Consequently, local environmental heterogeneity could explain well the observed low similarities within and between the formed groups (Gilbert & Lechowicz 2004; Tuomisto & Ruokolainen, 2005).

Tree species diversity in the studied forests increased from western to eastern. The opposite of this was observed in Brazil, whereby diversity increased with longitude from eastern to western Amazonia (Wittman et al., 2006). This observation supports the finding on geographical distance explained before, because when longitude increases the geographical distance increases too, which in one way or another creates increased environmental heterogeneity (Conorado et al., 2009) that consequently increases species diversity. This result concludes the study hypothesis that species diversity is directly proportional to longitudinal locations.

5. Conclusion and Recommendation

The study revealed that floristic similarity among forest pairs and geographical distance are inversely associated, which infers that the more closely forest pairs are, the higher floristic similarity among the pairs. Also, the study observed species diversity and longitudinal locations to be directly related, whereby the gradient of increasing species diversity was from west-to-east. The findings suggest that geographical distance and longitudinal distance were the contributing factors for floristic similarity and species diversity differences between the studied forests, respectively. Therefore, the study recommends that future floristic studies should focus on other environmental factors such as soil type and fertility across forests for the purpose of understanding mechanisms that bring about and uphold species composition in forests.

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References

Ahrends, A. 2005. Patterns of Degradation in Lowland Coastal Forests in Coastal Region Tanzania. MSc. thesis, Ernst-Moritz-Arndt University of Greifswald, Germany.

Barrantes, G. & L. Sandoval. 2009. Conceptual and Statistical Problems Associated with the Use of Diversity Indices in Ecology. *International Journal of Tropical Biology,* 57(3): 451–460.

Beharrell, N.K., S.M. Hall & S.A. Ntemi. 2002. Vegetation in Nilo Forest Reserve: A Biodiversity Survey. pp. 12-74. East Usambara Conservation Area Management Programme, Technical Paper 53. Frontier Tanzania; Forestry and Beekeeping Divison and Metsahallitus Consulting, Dar es Salaam, Tanzania and Vantaa, Finland.

Bohlman, A.S., W.F. Laurance, S.G. Laurancce, H.E.M. Nascimento., P.M. Fearnsie & A. Andrade. 2008. Importance of Soils, Topography and Geographic Distance in Structuring Central Amazonian Tree Communities. *Journal of Vegetation Science,* 19: 863–874.

Bracebridge C. & A.N. Sallu. 2004. Results of Flora. A Biodiversity Survey in Mahenge Scarp Forest Reserve: pp. 12–13. Frontier Tanzania Environmental Research Report 107. Society for Environmental Exploration UK, University of Dar es Salaam, Forestry and Beekeeping Division, Dar es Salaam, Tanzania. ISSN 1479–1161.

Burgess, N.D. & G.P. Clarke. 2000. *The Coastal Forests of Eastern Africa*. IUCN: Cambridge and Gland.

Burgess, N.D., T.M. Butynski, N.J. Cordeiro, N.H. Doggart, J. Fjeldsa, K.M. Howell, F.B. Kilahama, S.P. Loader, J.C. Lovett, B. Mbilinyi, M. Menegon, D.C. Moyer, E. Nashanda, A. Perkin, F. Rovero, W.T. Stanley & S.N. Stuart. 2007. The Biological Importance of the Eastern African Mountains of Tanzania and Kenya. *Biological Conservation,* 134: 209–231

Condit, R., N. Pitman, E.G. Leigh, Jr, J. Chave, J. Terborgh, R.B. Foster, V. Percy Nunez, S. Aguilar, R. Valencia, G. Villa, H.C. Muller-Landau, E. Losos & S.P. Hubbell. 2002. Beta-Diversity in Tropical Forest Trees. *Science*, 295: 666–669.

Condit, R., P.S. Ashton, P. Baker, S.Bunyavejchewin, S. Gunatilleke, N. Gunatilleke, S.P. Hubbell, R.B. Foster, A. Itoh, J.V. LaFrankie, H.S. Lee, E. Losos, N. Manokaran, R. Sukumar & T. Yamakura. 2000. Spatial Patterns in the Distribution of Tropical Tree Species. *Science*, 288: 1414–1418.

Coronado, E.N.H., T.R. Baker, O.L. Phillips, N.C.A. Pitman, R.T. Pennington, R.V. Martinez, A. Monteagudo, H. Mogollon, N.D. Cardozo, M. Rios, R. Garcia-Villacorta, E. Valderrama, M. Ahuite, I. Huamantupa, D.A. Neil, W.F. Laurance, H.E.M. Nascimento, S.S. de Almeida, T.J. Killeen, L. Arroyo, P. Nunez & L.F. Alvarado. 2009. Integrating Regional and Continental Scale Comparisons of Tree Composition in Amazonian Terra Firme Forests. *Biogeosciences Discuss,* 6: 1421–1451.

Cunneyworth, P. & L. Stubblefield. 1996. Mlungui Proposed Forest Reserve: A Biodiversity Survey. East Usambara Catchment Forest Project Technical Paper No. 32. Forestry and Beekeeping Division & Finnish Forest and Park Service & Society for Environmental Exploration, Dar es Salaam, Vantaa & London.

Oliveira, A.A. & D. Daly. 1999. Geographic Distribution of Tree Species in the Region of Manaus, Brazil: Implications for Regional Diversity and Conservation. *Biodiversity and Conservation*, 8: 1245–1259.

Doggart, N., M.S. Dilger, P. Cunneyworth & E. Fanning. 1999. Vegetation in Kwamgumi Forest Reserve: A Biodiversity Survey. In East Usambara Conservation Area Management Programme Technical Paper No. 40. Frontier Tanzania: Forestry and Beekeeping Division and Metsähallitus Consulting, Dar es Salaam, Tanzania and Vantaa, Finland.

Doody, K.Z., A. Ntemi, R. Killenga & N.K. Beharrell. 2001a. Vegetation in Mpanga Village Forest Reserve: A Biodiversity Survey. In East Usambara Conservation Area Management Programme Technical Paper No. 51. Frontier Tanzania: Forestry and Beekeeping Division and Metsähallitus Consulting, Dar es Salaam, Tanzania and Vantaa, Finland.

Doody, K.Z., K.M. Howell & E. Fanning. 2001b. Amani Nature Reserve: A Biodiversity Survey. East Usambara Conservation Area Management Programme Technical Paper No. 52. Frontier Tanzania; Forestry and Beekeeping Division and Metsähallitus Consulting, Dar es Salaam, Tanzania and Vantaa, Finland.

Furch, B. & H. Klinge. 1989. Chemical Relationships between Vegetation, Soil and Water in Contrasting Inundation Areas of Amazonia. In J. Proctor (ed.). *Mineral Nutrients in Tropical Forest and Savanna Ecosystems.* Oxford: Blackwell Scientific Publications, pp. 189–204.

Gentry, A. 1988. Changes in Plant Community Diversity and Floristic Composition on Environmental and Geographical Gradients. *Annals of Missouri Botanical Garden,* 75(1): 1–34.

Gilbert, B. & M.J. Lechowicz. 2004. Neutrality, Niches, and Dispersal in a Temperate Forest Understory. *Proceedings of the National Academy of Sciences,* 101: 7651–7656.

Hall, S.M., S.A. Ntemi, S. Oliver, J. Smith & A. Murphy. 2002. Vegetation in Mlinga Forest Reserve: A Biodiversity Survey. In: East Usambara Conservation Area Management Programme, Technical Paper 56. Frontier Tanzania; Forestry and Beekeeping Division, Dar es Salaam, Tanzania and Indufor / Metsähallitus Group, Vantaa, Finland.

Hubbell, S.P., J.A. Ahumada., R. Condit & R.B. Foster. 2001. Local Neighborhood Effects on Long-Term Survival of Individual Trees in a Neotropical Forest. *Ecological Research,* 16: 859–875.

International Council of Bird Preservation (ICBP). 1992. Putting Biodiversity on the Map: Priority Areas for Global Conservation. International Council for Bird Preservation, Cambridge.

Jenkins, R.K. & K. Roettcher. 2001. *Forest Composition and Structure*. In: Nambiga Forest Reserve Biodiversity and Resource Use Survey. Frontier Tanzania Savanna Research Programme. The Society for Environmental Exploration, UK and the University of Dar es Salaam.

Junk, W.J., P.B. Bayley & R.E. Sparks. 1989. The Flood Pulse Concept in River-Floodplain Systems. Proceedings of the International Large River Symposium, Ottawa. In D. Dodge (ed). *Canadian Special Publications of Fisheries and Aquatic Sciences,* 106: 110–127.

Kacholi, D.S., A.M. Whitbread & M. Worbes. 2015. Diversity, Abundance, and Structure of Tree Communities in the Uluguru Forests in the Morogoro Region, Tanzania. *Journal of Forestry Research,* 26(3): 557–569.

Leigh, E.G. 1999. Tropical Forest Ecology: A View from the Barro Colorado Island. Oxford: Oxford University Press.

Lovett, J.C. 1985. Moist Forests of Tanzania. *Swara,* 8(5): 8–9.

Malimbwi, R.E., D.T.K. Shemweta., E. Zahabu., S.P. Kingazi., J.Z. Katani., & D.A. Silayo. 2005. Forest Inventory for Mvomero District, Morogoro-Tanzania. FORCONSULT. Unpublished Report.

Marshall, A.R. 2008. Assessing and Restoring Biodiversity in Tanzania's Forests. The Case of Magombera. Proceedings of the 6th TAWIRI Scientific conference, December 2007.

Mittermeier, R.A., N. Myers, J.B. Thompsen, G.A.B. da Fonesca & S. Olivieri. 1998. Global Biodiversity Hotspots and Major Tropical Wilderness Areas. *Conservation Biology,* 12: 516–520.

Mittermeier, R.A., P. Robles Gil, M. Hoffman, J. Pilgrim, T. Brooks, C.G. Mittermeier, J. Lamoreux & G.A.B. da Fonseca. 2004. Hotspots Revisited. CEMEX, Mexico City.

Mori, S.A. 1991. The Guyana Lowland Floristic Province. *Compte-rendu de la Societe de Biogeographie,* 67: 67–75.

Myers, N., R.A. Mittermeier, C.G. Mittermeier, G.A.B. da Fonseca & J. Kent. 2000. Biodiversity Hotspots for Conservation Priorities. *Nature,* 403: 853–858.

Newmark, W.D. 2002. *Conserving Biodiversity in East African Forests. A Study of the Eastern Arc Mountains*. New York: Springer.

Phillips O.L., P.N. Vargas, A.L. Monteagudo, A.P. Cruz, M.E.C. Zans, W.G. Sanchez, M. Yli-Halla & S. Rose. 2003. Habitat Association among Amazonian Tree Species: A Landscape-Scale Approach. *Journal of Ecology,* 91: 757–775.

Pitman, N.C.A., J. Terborgh, M.R. Silman, P.V. Nu´n˜ez, D.A. Neill C.E. Cero´n, W.A. Palacios & M. Aulestia. 2001. Dominance and Distribution of Tree Species in Upper Amazonian Terra Firme forests. *Ecology*, 82: 2101–2117.

—. 2002. A Comparison of Tree Species Diversity in Two Upper Amazonian Forests. *Ecology*, 83: 3210–3224.

Prance, G.T. 1979. Notes on the Vegetation of Amazonia III. The Terminology of Amazonian Forest Types Subject to Inundation. *Brittonia*, 3, 26–38.

—. 1994. The Use of Phytogeographic Data for Conservation Planning. Systematics and Conservation Evaluation. In P.L. Forey, C.J. Humphries & R.I. Vane-Wright (eds.). *Systematic Association Special, Vol. 50*. Oxford: Clarendon Press, pp. 145–163.

Ricketts, T.H., E. Dinerstein, T. Boucher, T.M. Brooks, S.H. Butchart, M. Hoffmann, J.F. Lamoreux, J. Morrison, M. Parr & J.D. Pilgrim. 2005. Pinpointing and Preventing Imminent Extinctions. *Proceedings of the National Academy of Sciences, USA*, 102 (51): 18497–18501.

Salter, R.F., A.S. Ntemi, N.S. Svoboda, S. Staddon & C. Bracebridge, 2002a. Vegetation in Bombo East I Forest Reserve: A Biodiversity Survey. In: East Usambara Conservation Area Management Programme Technical Paper No. 57. Frontier Tanzania; Forestry and Beekeeping Division, Dar es Salaam, Tanzania; and Indufor / Metsähallitus Group, Vantaa, Finland.

—. 2002b. Vegetation in Bombo East II Forest Reserve: A Biodiversity Survey. In: East Usambara Conservation Area Management Programme Technical Paper No. 58. Frontier Tanzania; Forestry and Beekeeping Division, Dar es Salaam, Tanzania; and Indufor / Metsähallitus Group, Vantaa, Finland.

Seaby, R.M. & P.A. Henderson. 2006. Community Analysis Package Version 4 (CAP IV). Pisces Conservation Ltd., Lymington, England.

Silva, K.E., S.V. Martins., C.A.A.S. Ribeiro., N.T. Santos., C.P. de Azevedo, L. Matos., & I.L. do Amaral. 2011. Floristic Composition and Similarity of 15 Hectares in Central Amazon, Brazil. *International Journal of Tropical Biology,* 59(4): 1927–1938.

Slik, J.W.F., A.D. Poulsen, P.S. Ashton, C.H. Cannon, K.A.O. Eichhorn, K. Kartawinata, I. Lanniari, H. Nagamasu, M. Nakagawa, M.G.L. van Nieustadt, J. Payne, Purwaningsih, A. Saridan, K. Sidiyasa, R. W. Verburg, C. O. Webb & P. Wilkie. 2003. A Floristic Analysis of the Lowland Dipterocarp Forests of Borneo. *Journal of Biogeography,* 30: 1517–1531.

Stattersfield, A.J., M.J. Crosby, A.J. Long & D.C. Wege. 1998. Endemic Bird Areas of the World: Priorities for Biodiversity Conservation. BirdLife Conservation Series No 7. BirdLife International, Cambridge, UK.

Temu, R.P.C. & S.M. Andrew. 2008. Endemism of Plants in the Uluguru Mountains, Morogoro, Tanzania. *Forest Ecology and Management,* 255(7): 2858–2869.

Ter Steege, H., D. Sabatier, H. Castellanos, T. van Andel, J. Duivenvoorden, A.A. de Oliveira, R. Ek, R. Lilwah, P. Maas, & S. Mori. 2000. An Analysis of the Floristic Composition and Diversity of Amazonian Forests including those of the Guiana Shield. *Journal of tropical Ecology,* 16: 801–828.

Terborgh, J. & E. Andresen. 1998. The Local Compositions of Amazonian Forests: Patterns at Local and Regional Scales. *Journal of Tropical Ecology,* 14: 645–664.

Tuomisto, H. & K. Ruokolainen. 2005. Environmental Heterogeneity and the Diversity of Pteridophytes and Melastomataceae in Western Amazonia. *Biol. Skr.,* 55: 37–56. ISSN 0366-3612. ISBN 87-7304-304-4.

Tuomisto, H., K. Ruokolainen & M. Yli-Halla. 2003. Dispersal, Environment and Floristic Variation of Western Amazonian Forests. *Science,* 299: 241–244.

White, F. 1983. *The Vegetation of Africa.* UNESCO, Paris.

Wittmann, F., J. Schöngart, J.C. Montero, T. Motzer, W.J. Junk, M.T.F. Pieadade, H.L. Queiroz & M. Worbes. 2006. Tree Species Composition and Diversity Gradients in the White-Water Forests across the Amazon Basin. *Journal of Biogeography,* 33(8): 1334–1347.