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Assessment of Tree Species Richness, Diversity, Population Structure and Natural Regeneration in Nongeni Forest Reserve in Morogoro Region, Tanzania

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Abstract

This study examined tree species richness, diversity, population structure and regeneration in Nongeni forest reserve, Morogoro, Tanzania. The study deployed plot sampling technique whereby a total of 20 plots of 0.05 ha each were randomly established in the forest. All species and individuals encountered in each plot were counted, identified and DBH measured. A total of 751 individuals/ha representing 24 species belonging to 11 families were recorded. Family Fabaceae was dominant with 9 species. The Shannon-Wiener, Margalef, Simpson's and Pielou J index were calculated as 2.667, 3.474, 10.58 and 0.839, respectively. The *Diplorhynchus condylocarpon* (52.18) was the dominant species in terms of species importance value index (IVI) followed by *Antidesma venosum* (27.40) and *Stereospermum kunthianum* (21.16). The forest mean basal area was 10.80 m^2/ha whereby *D. condylocarpon* (2.26 m^2/ha) had highest value followed by *Julbernardia globiflora* (1.36 m^2/ha). Of the observed species, 12.5% exhibited good regeneration, 45.8% poor regeneration, 29.2% new regeneration and 12.5% displayed fair/hampered regeneration pattern. Also, 29.1% of the species displayed both poor regeneration pattern and low IVI. The study concludes that the forest was rich in tree species and had good regeneration. However, conservation attention and proper management strategies for the species that exhibited poor regeneration and low IVI is imperative.

Keywords: Diversity, Forest health, Importance value index, Regeneration, Species richness

Introduction

Tropical forests are biodiversity rich communities on the earth because they harbor substantial amount of global life forms (Phillips and Gentry 1993, Myers et al. 2000, Baraloto et al. 2013). The forests offer numerous products such as food, medicines, energy and timber (Phillips and Gentry 1993, Huang et al. 2003) and they provide ecosystem services such as nutrient cycling, soil formation, soil erosion prevention, water supply, soil formation, habitats for plants and animals, species conservation and climate regulation (Armenteras et al. 2009, Kumar et al. 2011). However, overexploitation of the forest resources is among the major environmental and economic evils that have resulted in the hasty loss of the forests (Mani and Parthasarathy 2006). Worldwide, tropical forests are declining at disquieting rates, whereby 1 - 4% of their area is reduced annually (Laurance 1999). The disappearance of forest areas is well connected to increased anthropogenic pressures that have led to agricultural expansion, firewood/charcoal demand increase, overgrazing and illegal timber logging due to increased human population living nearby the forests (Anitha et al. 2010, FAO 2010). The loss of forest area endangers not only livelihood of people who depend on the forests for socio-cultural, ecological and economic services, but also it affects the forest composition, structure and regeneration of trees as well as existing biodiversity (Blasco et al. 2000, Kacholi 2013).

According to the Tanzania National Carbon Monitoring Centre report of 2018, the country annual forest loss is estimated to be 469,420 ha, which is 20.7% increase from the state of the environment report of 2014. This loss is growing at an alarming rate and is highly influenced by four drivers, which are energy demand, poverty, population growth and unsustainable farming practices. It is reported that a good number of the rural and urban inhabitants cannot afford to pay for other sources of energy such as electricity and gas due to their low purchasing power, hence, depend solely on firewood and charcoal for their domestic purposes (URT 2018). The economic activities of the majority of the rural people are directly linked to deforestation and forest degradation (Kacholi 2013) while growth of human population close to forest areas exerts more pressure to the forest resources due to increased demands for more land for agricultural activities. Due to poverty, the locals engage in unsustainable farming practices, like uncontrolled burning and forest clearance and shifting cultivation, which all together contribute to deforestation and degradation of forests (FBD 2000).

As part of the forest management strategies, the government of Tanzania through the National Forest Policy has transferred power over the forest resources back to community level whereby citizens are involved in forest conservation and management (URT 2018). This strategy of involving local communities and other stakeholders in forest management is referred to Participatory Forest Management (PFM). The PFM is part and parcel of the rural development strategies with an intention of improving rural livelihoods and reducing poverty, while at the same time protecting the forest resources and stimulating equitable distribution of benefits (FBD 2000). Irrespective of the PFM, protection of forests in some parts of the country faces challenges that put the forests and associated biodiversity in great threat of deforestation and extinction, respectively.

The forest ecosystem composition and functions are determined by plants, especially tree components, which are fundamental components than any other living component of the system (Richards 1996, Ssegawa and Nkuutu 2006). Forest tree species must be regularly monitored and managed for directing successional processes towards upholding species and habitats varieties (Turner 1987, Attua and Pabi 2013). Forest tree diversity is a useful tool in plant ecology and forestry for comparing the compositions (Mani and Parthasarathy 2006, Magurran 2004). The tree species diversity is influenced by the distribution and abundance of species (Debnath et al. 2012) while species richness is influenced by a range of biotic and abiotic factors (Huston 1994). For instance, factors like topography, climate, soil and geographical settings of a place influence species diversity of forest ecosystems (Ram et al. 2004). The species diversity is an essential characteristic of any forest ecosystem (Tchouto et al. 2006) and the index provides information on the stability and sustainability of the forest communities (Sakar and Devi 2014). Information obtained from studies on forest species richness and diversity is a very important component in management in terms of economic value, regeneration potential and for biodiversity conservation value (Wyatt-Smith 1987, Kacholi et al. 2015). Natural regeneration is expressed by the number of individuals present in each of the defined diameter size classes (Zegeye et al. 2006) where an effective regeneration is indicated by the existence of the abundant number of young trees in a population while the reverse indicates poor regeneration (Pokhriyal et al. 2010). Therefore, natural regeneration in any forest is an essential element for forest ecosystem dynamics, and protection and maintenance of biological diversity (Tesfaye et al. 2010, Rahman et al. 2011).

The Nongeni forest reserve is one of the forests in the region that are known to be rich in biodiversity, including flora and fauna (Myers et al. 2000). Like many other tropical forests, the Nongeni forest reserve is facing anthropogenic pressures due to its proximity to the Morogoro urban and Dar es Salaam city whose people depend on forest products for timber, firewood and charcoal. Also, apart from the mentioned uses, the locals from the surrounding villages depend on the forest for traditional medicines, hunting, grazing and beekeeping. Forest encroachment has been observed due to increased demand for agricultural land by the population living nearby the forest. Thus, with all these burdens to the forest, this study aimed to analyze the status of the forest in-terms of species richness, diversity, stand structure and regeneration patterns of tree species in the forest. The findings presented in this work are absolutely adding records on the health status of Nongeni forest reserve in particular, but also in the region and Tanzania in general.

Materials and Methods

Study area description

Nongeni forest reserve (latitude 06°49'S and longitude 37°43'E and altitude ranging from 400 to 1000 m.a.s.l) is located in the Bigwa ward in Morogoro urban district, Morogoro region (Figure 1). The forest covers an area of about 231.5 ha and is surrounded by two villages namely, Bigwa and Bong'ola. The forest is accessible through the old Dar es Salaam road, which is located about 2 km from Bigwa village. The topography of the forest area is hilly and undulating. The forest is owned and managed by the central government of Tanzania through the Forest and Beekeeping Division Regional Office. The forest has mixed lowland-woodland vegetation types. Streamlets/Rivers such as Bigwa and Nongeni, originate from this forest while Lukuyu and Mkangazi pass through the forest. Water from these streamlets/rivers is mainly used for irrigation and domestic purposes by the villagers. Trees of timber values, such as *Khaya anthotheca, Pterocarpus angolensis, Albizia gummifera* and *Brachystegia* species are present in the forest. In terms of anthropogenic impacts, the forest is highly disturbed by human activities like grazing, pit sawing, hunting (traps), charcoaling, wildfire, beekeeping, medicinal activities and encroachment for cultivation.

The climate of the region is tropical sub-humid with bimodal rainfall regime. The mean annual rainfall in the region is 740 mm with the mean monthly minimum and maximum of 440 and 1094 mm of rainfall, respectively. The mean annual temperature is 25.1 °C with the mean monthly minimum and maximum temperature of 19.7 °C and 30.6 °C, respectively (Figure 2).

Data collection

The assessment of tree species richness, diversity, stand structure and natural regeneration of the Nongeni forest reserve was conducted between April and June 2017 deploying the random sampling technique. A comprehensive field work was conducted during phytosociological study period whereby twenty (20) plots of 0.05 ha (20 m x 25 m) covering an area of 1 ha were randomly placed in the forest. From each plot, all species and individuals encountered were counted, identified and DBH measured. Individuals with DBH > 10 cm were considered mature tree/adult (overstory layer) and those with DBH ≤ 10 cm were considered young (understory layer). The identification of trees was done to species level by forest taxonomist from the regional forest department.

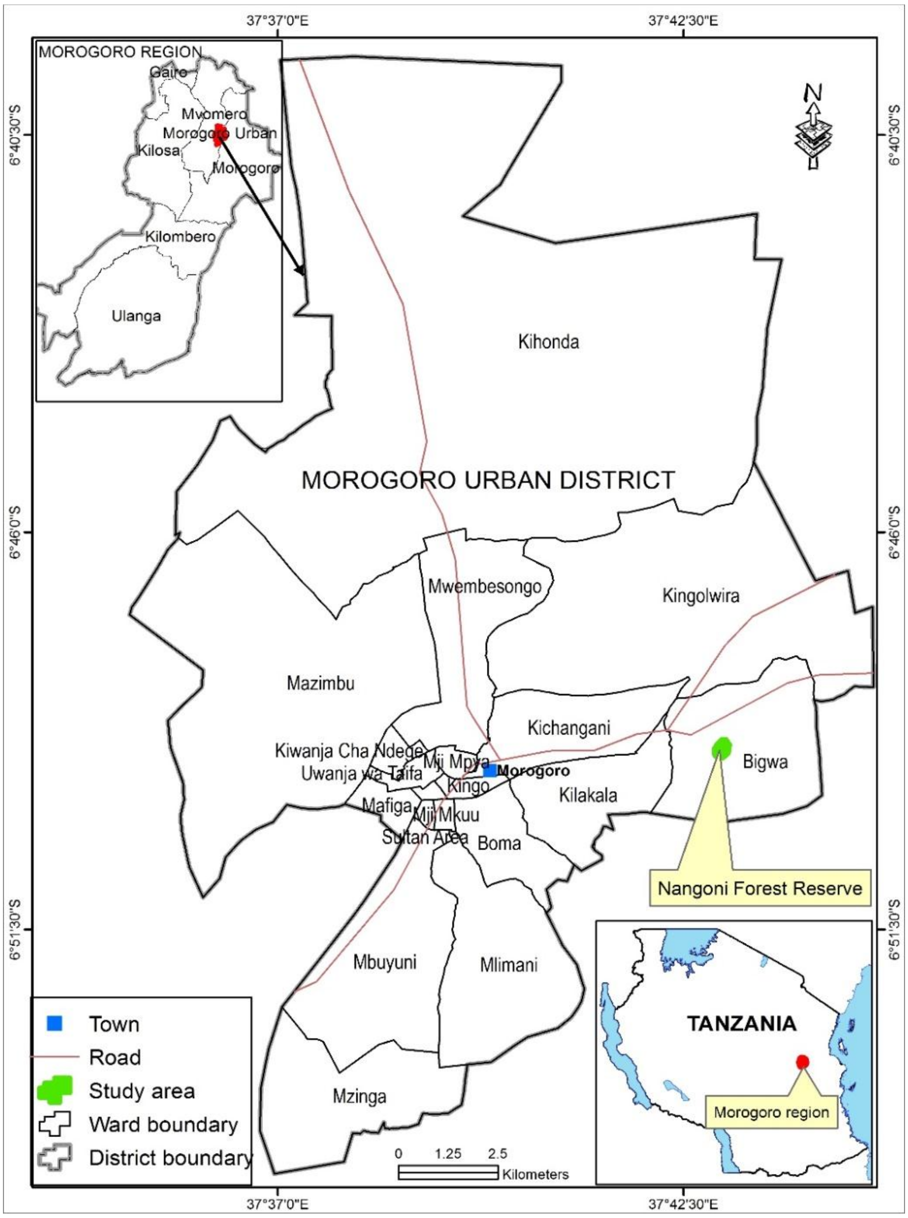

Figure 1: Map showing the location of the study area in the Morogoro urban district and the location of the district in Morogoro region, Tanzania.

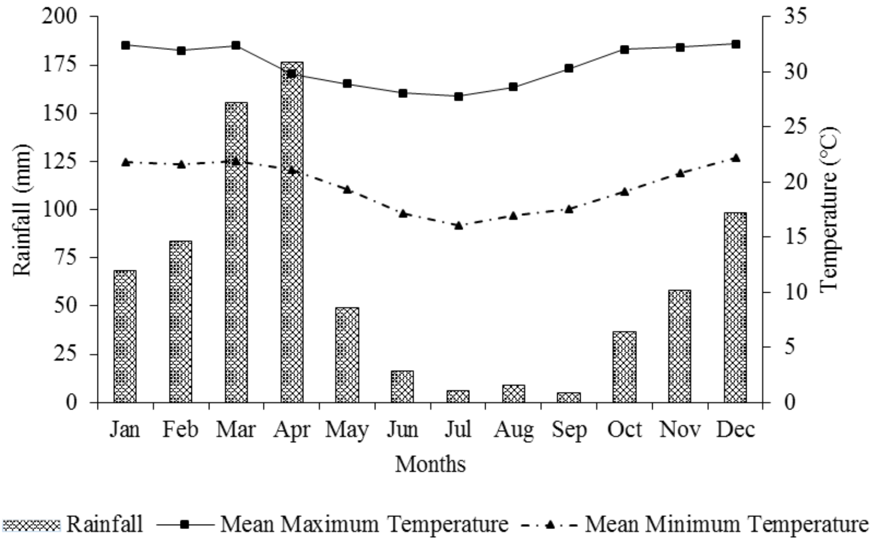

Figure 2: Monthly mean rainfall, mean maximum and mean minimum temperature of Morogoro region (*Source:* Kacholi 2013).

Data analysis

Depending on the data of the individuals recorded in each plot, tree data were quantitatively analyzed for species richness, stem density, basal area, relative frequency, relative dominance and relative density. Species richness was determined by the number of observed species in the forest and two species richness estimators, first-order Jackknife (Jackknife 1) and Michaelis Menten Means (MMMeans) were used to approximate possible number of species in the forest (Magurran 2004). The mean density of the tree species was determined by converting the total number of individual tree species encountered in all the plots to equivalent number per hectare as per Mueller-Dombois and Hellenberg (1974). The species-area curve was constructed based on number of individuals and total sampled area (Magurran 2004). The species importance value index (IVI) was calculated as the sum of relative density (RDe), relative frequency (Rf) and relative dominance (RDo) (Curtis and McIntosh 1950) as shown in equation 1 below. Basal area (BA) was also computed based on equation 2 below (DBH in cm).

$$\mathrm{IVI} = \mathrm{Rf} + \mathrm{RDe} + \mathrm{RDo} \quad (1)$$

$$BA = 0.00007854\ x\ DBH^2 \quad (2)$$

Obtained field information were also used to determine community indices like species diversity using Shannon-Wiener Index (Shannon and Wiener 1963) and Margalef index (Margalef 1968) while species dominance was computed following the Simpson index (Simpson 1949) and species equitability was calculated using the Pielou J index (Pielou 1966). The formula for the above mentioned indices are presented below (equation 3 to 6) and all these were calculated using the Species Diversity and Richness IV (SDR IV) software.

$$H' = -\sum_{i=1}^{S} P_i\ InP_i \quad (3)$$

Where: H' is Shannon-Wiener index, S is species richness encountered, P_i is a number of individuals of one species in relation to a number of individuals in a population and In is natural logarithm.

$$D_{mg} = \frac{S-1}{In\ N} \quad (4)$$

Where: D_{mg} is Margalef diversity index, S is the number of species encountered, N is a number of individuals in a population and In is natural logarithm.

$$D = 1/\sum_{i=1}^{s} P_i^2 \quad (5)$$

Where: D is Simpson's diversity index, S is species richness encountered, P_i is a number of individuals of one species in relation to a number of individuals in a population.

$$J' = H'/\ln S \quad (6)$$

Where: J' is evenness, H' is Shannon-Wiener index, S is species richness and In is natural logarithm.

The regeneration status of each encountered tree species was determined using the histograms constructed using the density of individuals present in the six categorized diameter size classes, *i.e.*, 0.0-10, 11-20, 21-30, 31-40, 41-50 and > 50 cm. Individuals were considered as adults (overstory layer) when DBH > 10 cm and young ones (understory layer) when DBH ≤ 10 cm. The status of a species was determined based on the density of the young and adult trees. A species displayed, (a) good regeneration when exhibited purely inverse J-curve, (b) poor regeneration when survived only on adults and lacking young trees, (c) new regeneration when no adults, but young ones present and (d) fair/interrupted regeneration when young ones were present but lacking individuals in some adult diameter size classes.

Results

Species richness, diversity and importance value index

A total of 24 species were enumerated in Nongeni forest reserve. The Shannon-Wiener index, Margalef index, Simpson's index and Pielou's evenness index were calculated as 2.667, 3.474, 10.58 and 0.839, respectively (Table 1). The observed species belong to 20 genera and 11 families. Among the families, Fabaceae was the dominant with 9 species followed by Combretaceae with 3 species, Anacardiaceae, Sterculiaceae and Bignoniaceae recorded 2 species each. Within the family Fabaceae, genus *Acacia, Albizia* and *Brachystegia* contributed two species each (Table 2). The species-area curve revealed an increasing trend as sampling efforts increased (Figure 3) and the species richness estimators such as Jackknife 1 and Michaelis-Menten Means projected higher species richness than the observed (Table 1). The top five species with highest IVI values contributed by 46% to the total IVI (Table 2). The *Diplorhynchus condylocarpon* was the dominant tree species with 52.18 IVI value, followed by *Antidesma venosum* (27.40), *Stereospermum kunthianum* (21.16), *Julbernardia globiflora* (19.44) and *Combretum molle* (17.75). Six species (*Sterculia quinqueloba, Acacia nilotica, Lepidoctrichilia volkensii, Acacia nigrescens, Sclerocarya birrea* and *Lannea welwitschii*) had IVI value less than 5.0 (Table 2).

Table 1: Density, basal area, diversity measures and species richness of the studied forest

Parameter	Mean value ± SE
Species richness	24.00 ± 1.556
Shannon-Wiener index	2.667 ± 0.066
Margalef index	3.474 ± 0.249
Simpson's index	10.58 ± 0.689
Pielou's evenness index	0.839 ± 0.021
Jackknife 1	26.85 ± 1.556
Michaelis-Menten Means	27.14 ± 0.000
Density (Individuals ha^{-1})	751.0 ± 178.4
Basal area (m^2 ha^{-1})	10.80 ± 2.640

Table 2: Family, species name, basal area, density, importance value index and regeneration status of tree species in the forest reserve

Family	Species Name	BA	D	IVI	RS
Anacardiaceae	*Sclerocarya birrea* (A. Rich.) Hochst.	0.20	3	2.97	Poor
	Lannea welwitschii (Hiern) Engl.	0.13	3	2.32	Poor
Apiaceae	*Steganotaenia araliaceae* Hochest.	0.07	25	11.17	New
Apocynaceae	*Diplorhynchus condylocarpon* (Muell.Arg.) Pichon	2.26	154	52.18	Good
Bignoniaceae	*Kigelia africana* (Lam.) Benth.	0.48	27	12.35	Fair
	Stereospermum kunthianum Cham.	0.26	76	21.16	New
Combretaceae	*Combretum adenogonium* Steud. ex A. Rich.	0.13	25	11.72	New
	Combretum molle R.Br. ex G.Don.	0.35	55	17.75	Good
	Terminalia sericea Burch. ex DC.	0.14	13	7.34	Poor
Fabaceae	*Acacia nigrescens* Oliv.	0.21	3	3.06	Poor
	Acacia nilotica Linn.	0.16	6	4.44	Poor
	Albizia gummifera (J.F. Gmel.) C. A. Sm.	1.33	6	14.53	Poor
	Albizia petersiana (Bolle) Oliv.	0.94	6	10.93	Poor
	Brachestegia boehmii Taub.	0.90	26	16.10	Poor
	Brachestegia speciformis Benth.	0.03	25	7.20	New
	Julbernardia globiflora (Benth.) Troupin	1.36	30	19.44	Fair
	Pterocarpus angolensis DC.	0.10	25	10.01	New
	Xeroderris stuhlmanii (Taub.) Mendonca & Sousa	0.20	8	5.07	Poor
Meliaceae	*Lepidotrichilia volkensii* Gürke	0.20	3	3.69	Poor
Myrtaceae	*Syzygium guineense* Wall.	0.10	25	7.13	New
Phyllanthaceae	*Antidesma venosum* E. Mey. ex Tul.	0.44	105	27.40	Fair
Salicaceae	*Oncoba spinosa* Forssk.	0.36	45	12.92	Good
Sterculiaceae	*Dombeya rotundifolia* (Hochst.) Planch.	0.20	51	14.39	New
	Sterculia quinqueloba (Garcke) K. Schum.	0.27	6	4.73	Poor

Note: BA = basal area (m^2/ha), D = density (Individuals/ha), IVI = species importance value index and RS = regeneration status.

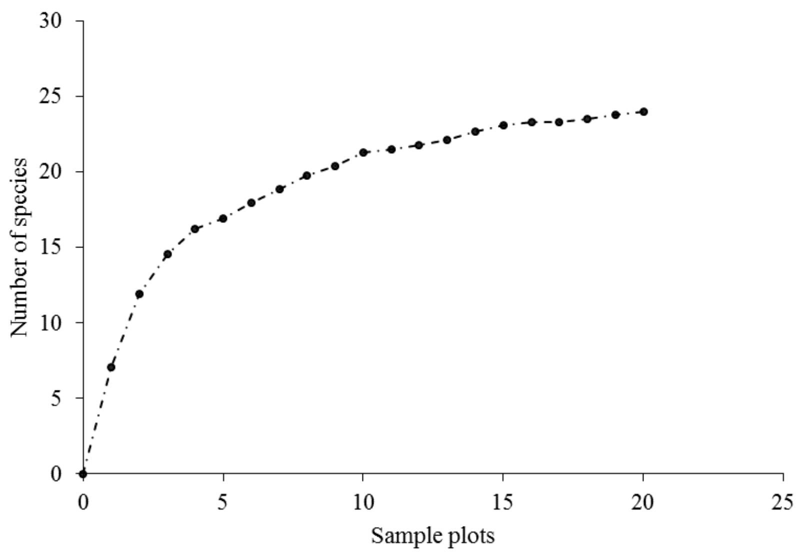

Figure 3: Species-area curve.

Density and basal area

The mean tree density of the forest was 751.0 individuals/ha (Table 1). The density of the overstory layer (mature trees, DBH > 10 cm) contributed by 18.2% (137 individuals/ha) while the understory layer (young trees, DBH ≤ 10 cm) contributed by 81.8% (614 individuals/ha) of the overall density. Tree species with highest abundance was *D. condylocarpon*, which contributed 20.5% of the total density (Table 2). Other species with highest density were *A. venosum* contributing 14.0% of the total density, *S. kunthianum* (10.1%), *C. molle* (7.3%), *D. rotundifolia* (6.8%) and *Oncoba. spinosa* (6.0%) while the remaining species contributed less than 6.0% each to the total density. Tree species with lowest abundance were *Lepidotrichilia volkensii*, *Acacia nigrescens*, *Sclerocarya birrea*, and *Lannea welwitschii*, each had 3 individuals/ha (Table 2). In terms of basal area, the forest recorded the mean of 10.80 m^2/ha (Table 1) whereby the overstory and understory layers contributed 79.8% and 20.2% of the recorded basal area, respectively. The species with higher basal area were *D. condylocarpon* (2.26 m^2/ha) followed by *Julbernardia globiflora* (1.36 m^2/ha) and *A. gummifera* (1.33 m^2/ha), which contributed 45.7% of the total basal area in the forest (Table 2). The species with lower basal area value were *Brachystegia speciformis* (0.03 m^2/ha), *Steganotaenia araliaceae* (0.07 m^2/ha), *Syzygium guineense* (1.0 m^2/ha) and *P. angolensis* (1.0 m^2/ha).

Population structure and regeneration status

The broad-spectrum population structure of all the observed tree species based on diameter size-class distribution generated the reverse J-shaped curve (Figure 4). About 81.8% of the observed individuals belonged to the first size class (i.e., 0.0 – 10.0 cm) and the number gradually decreased with increasing size class. 54.2% of the total species richness was observed in the first DBH class followed by the 21.0 – 30.0 cm DBH class with 29.2% of the species. The highest basal area of 2.6 m^2/ha was observed in the 41.0 – 50.0 DBH class, followed by 0.0 – 10.0 cm with 2.18 m^2/ha and the lowest value was 0.94 m^2/ha in the > 50 cm DBH class (Figure 4). Population structures of a few species (*D. condylocarpon, A. gummifera, J. globiflora* and *S. guineense)* that denoted categorically the regeneration status of other observed species in Nongeni forests are presented in Figure 5. The *D. condylocarpon* represented reverse J-shaped curve, which signifies good regeneration, *A. gummifera* represented poor regeneration as it lacked young trees on the lower DBH classes, *J. globiflora* represented fair, but interrupted/hampered regeneration as some DBH classes (≥ 11 cm) lacked individuals and *S. guineense* represented a new regeneration pattern as it possessed young trees in the first DBH class only. In this study, 12.5% (3 species) of the species exhibited ‘good’ regeneration, 45.8% (11 species) showed ‘poor’ regeneration status, 29.2% (7 species) revealed ‘new’ regeneration and 12.5% (3 species) displayed ‘fair/interrupted’ regeneration status (Table 2). The species that displayed good regeneration patterns were *D. condylocarpon, C. molle* and *Oncoba spinosa*, while poor regeneration pattern was exhibited by *B. boehmii, S. quinqueloba, A. nilotica, L. volkensii, A. nigrescens, S. birrea, L. welwitschii, A. petersiana, T. sericea, X. stuhlmanii* and *J. globiflora.* The species that revealed new regeneration patterns were *S. kunthianum, D. rotundifolia, C. adenogonium, S. araliaceae, P. angolensis, B. speciformis* and *S. guineense*, while *A. venosum, J. globiflora* and *Kigelia africana* revealed fair/hampered regeneration patterns.

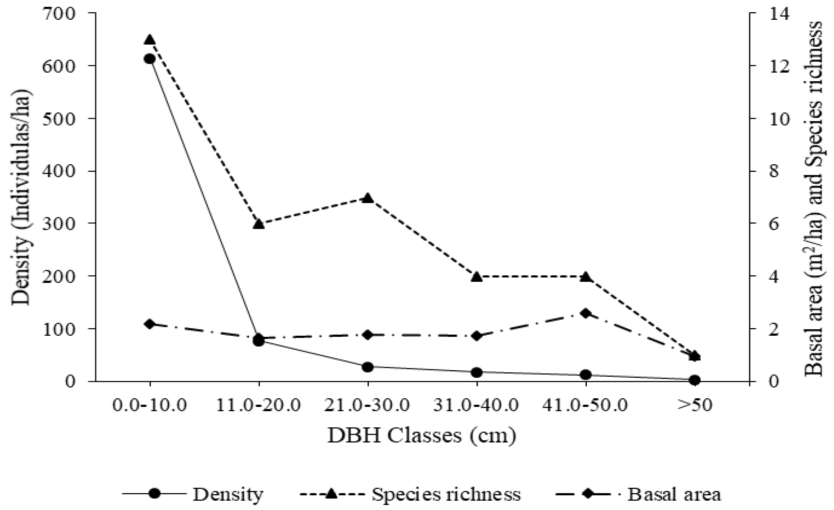

Figure 4: Stem density, basal area and species richness in different size (DBH) classes.

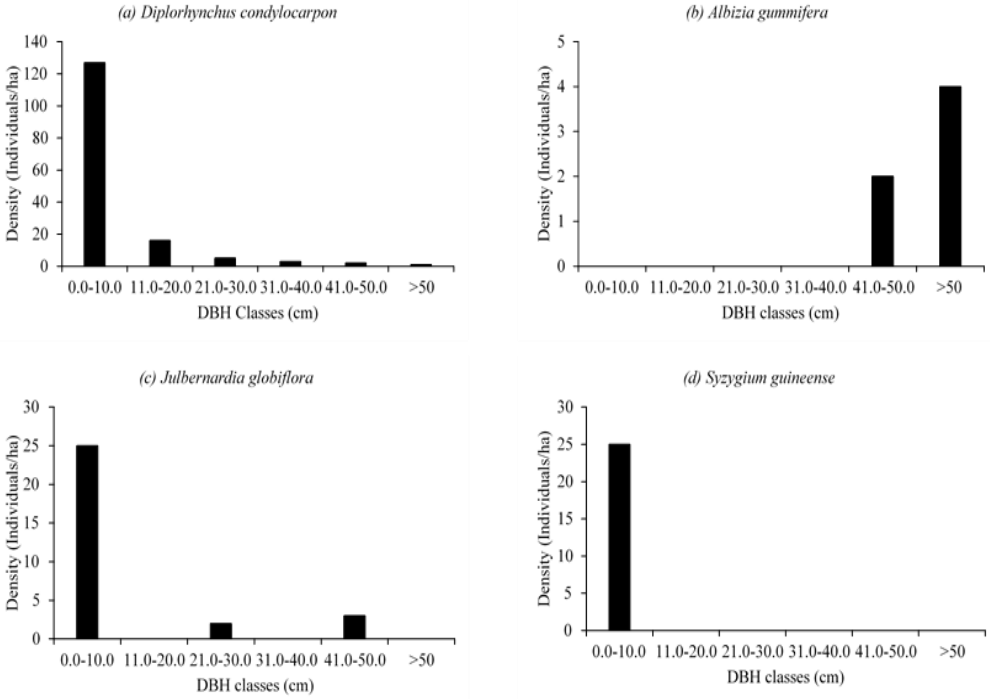

Figure 5: Population structure of (a) *D. condylocarpon, (b) A. gummifera, (c) J. globiflora* and *(d) Syzygium guineense* species representing good, poor, fair/interrupted and new regeneration patterns recorded in the studied forest, respectively.

Discussion

The species richness and diversity differ significantly from place to place due to variations in habitats, biogeography, competition and disturbances (Gentry 1988, Whitmore 1998, Neumann and Starlinger 2001, Padalia et al. 2004). The species richness of 24 species/ha recorded in the forest is within the range of global tropical rainforests of 20 to 223 species/ha (Whitmore 1984). Yet, the observed species richness value is lower in comparison with other forests in the Morogoro region (Kacholi et al. 2015). The species diversity is generally higher in the tropical forests (Magurran 2004). The Shannon-Wiener diversity index usually ranges from 1.5 to 3.5 and seldom exceed 4.5 (Kent and Coker 1992). The recorded Shannon-Wiener index (2.66) in this study lies within the tropical forest range and is within the range of 2.50 to 4.02 recorded in Uluguru forests (Kacholi et al. 2015) and 0.81 to 4.1 recorded in other tropical forests (Visalakshi 1995, Sundarapandian and Swamy 2000, Sahu et al. 2012). The Simpson's index (10.58) is within the range of 9.4 – 63.1 recorded in Uluguru forests (Kacholi 2013). As the Simpson index increases, diversity decreases and the index is heavily weighted towards the most abundant species in the sample, while being less sensitive to species richness (Magurran 2004). The recorded Margalef index (3.474) is lower the range of 4.54 – 23.41 recorded in other tropical forests (Mishra et al. 2005, Kumar et al. 2010, Sathish et al. 2013). The evenness (0.839) is comparable with those recorded in Uluguru forests (Kacholi 2013), tropical evergreen forests (Tynsong and Tiwari 2010) and wet evergreen forests (Nath et al. 2005). The higher the evenness value indicates more consistency in species distribution (Magurran 2004). The species-area curve illustrated an increasing trend as the number of sample plots increased. The findings correspond with the estimated value given in Table 1 where the species richness estimator anticipated more species in the forest than the observed. The curve did not show asymptotic behavior due to the existence of several rare species and/or species with constricted habitat ranges (Gotelli and Colwell 2011). The cumulative trend in the number of species with increasing forest size implies that more sampling effort could have resulted to more species. Thus, more sample plots are needed during further research in the forest for the purpose of earning more species.

The dominance of the Fabaceae family was due to the high species richness as it had 37.5% of the recorded total species. Different authors have reported the family to dominate lowland tropical forests (Gentry 1988, Valencia et al. 1994, Addo-Fordjour et al. 2009, Kacholi et al. 2015) and the family is reported to dominate by up to 50% of the total species richness in the coastal forests of Tanzania (Burgess and Clarke 2000). In Uluguru forests, Fabaceae was found to dominate by 33% of the total species (Kacholi et al. 2015); the observation which is a bit lower than of the present study. In forest ecological studies, importance value index (IVI) indicates the ecological importance of a species in a community and provides an overview of the social structure of a species (Sakar and Devi 2014). The IVI is used for prioritizing conservation of species, species with low IVI index value are given higher priority than those with high value due to rarity (Zegeye et al. 2006, Kacholi 2013). In the present study, seven species (*X. stuhlmanii, S. quinqueloba, A. nilotica, L. volkensii, A. nigrescens, S. birrea* and *L. welwitschii*) had low IVI values and were poorly regenerating (Table 2). The low IVI value was due to the fact that the species were occasional and less abundant in the forest, hence the need for conservation arise in order to protect them from extinction. Unlike other species, the high IVI value for *D. condylocarpon* was mainly contributed by combination of high relative density, basal area and frequency in the forest and the species revealed a good regeneration pattern (Figure 5). Also, the high frequency displayed by *D. condylocarpon* indicates that the species has wider range of ecological adaptations compared to other species.

The observed density of overstory layer in the forests (137 individuals/ha) is within the range of 85 – 390 individuals/ha recorded in Uluguru forests (Kacholi et al. 2015) and 61 – 317 individuals/ha recorded in Mvomero district forests (Malimbwi et al. 2005). On the other hand, the obtained value was lower compared to 512 individuals/ha observed in Zaraninge (Mligo et al. 2009), 436 individuals/ha at Kwamgumi forest (Doggart et al. 1999) and 837 individuals/ha at Mpanga forest (Doody et al. 2001). The mean density of 614 individuals/ha in the understory layer was lower compared to the values obtained by Mligo et al. (2009) and Kacholi (2013) in their studies in Zaraninge and Uluguru forests, respectively. The differences in stand density in forests may be attributed by natural and anthropogenic disturbances as well as soil properties and micro-climatic factors. A study carried-out in other Eastern Arc forests revealed human population to be negatively associated with tree density and forest size (Kacholi 2014) while forest disturbances have been reported to be strongly positively associated with increasing human population (Wang et al. 2001, Chittibabu and Parthasarathy 2000, Top et al. 2009). Observed human activities that seem to affect tree community density in Nongeni forest reserve include, but not limited to, illegal logging, charcoaling, pit sawing, encroachment, uncontrolled fire, grazing, and uprooting of young trees for medicinal purposes.

The observed basal area of 10.8 m^2/ha is within the range of 3.0 – 24.0 m^2/ha obtained in Uluguru forests (Kacholi et al. 2015), 1.7 – 32.3 m^2/ha in Mvomero District (Malimbwi et al. 2005) and 3.9 – 16.7 m^2/ha obtained in Moimbo woodland (Backéus et al. 2006). The difference in the basal area between the overstory and understory layer may be attributed to disparity in species composition, degree of disturbances, age of trees and succession strategies of the stands (Sahu et al. 2010, Bhadra et al. 2010). The distribution of trees through dissimilar DBH classes shows how well the growing forest is utilizing the functional and structural resources (Whitmore 1989).

The size class distribution is commonly used to characterize the population structure and regeneration of forest or a species (Whitmore 1989, Lykke 1998). The overall size class distribution of the forest (Figure 4) revealed a reverse J-shaped population curve, which signifies superb recruitment, stable and healthy population in the forest ecosystem. (Lykke 1998, Mishra et al. 2005, Mwavu and Witkowski 2009, Sahu et al. 2012). Though the regeneration of the forest is good at community level, 11 species revealed poor regeneration, the condition that can affect forest population size in future (Condit et al. 1996, Hadi et al. 2009, Sakar and Devi 2014). Normally, the regeneration of species is influenced by various natural and anthropogenic factors (Whitmore 1989, Khan and Tripathi 1989, Iqbal et al. 2012). Some of the observed anthropogenic disturbances that might have contributed to poor/hampered regeneration of the species include clearing of vegetation for cultivation of crops, grazing pressure, fuel wood collection, cutting of stems and chopping off branches of woody species for fencing farms and houses, wildfire and charcoaling (Sukumar et al. 1998, Iqbal et al. 2012, Kacholi 2013) while natural factors include poor abiotic potential of tree species, which either affects seed germination and fruiting or development of seedling to sapling (Welden et al. 1991, Iqbal et al. 2012, Sarkar and Devi 2014). Moreover, lack of seedlings from poor regenerating tree species could be associated with environmental stress caused by change in micro-environmental factors (Benitez-Malvido 1998, Tabarelli et al. 2004). The variation of micro-environmental factors can affect seedling and sapling growth, which consequently affect population structure (Murcia 1995). Also, poor regeneration of some tree species can be affected by forest canopy cover as good canopy cover always reduce penetration of sunlight to reach forest floor community (Whitmore 1989, Pokhriyal et al. 2010).

The species that revealed good regeneration *(D. condylocarpon, C. molle* and *O. spinosa)* signified that they had great ability of producing many seedlings and ability of the seedlings and saplings to survive and grow (West et al. 2000, Kacholi et al. 2015). The new regenerating category signifies newly colonizing species to the study area, which were represented by the presence of seedling and/or saplings only. The species may have colonized the area by seed dispersal through dispersal agents like birds and animals and find favorable micro-climatic factors for them to germinate and establish (Richards 1996, Whitmore 1989). Moreover, another reason for the presence of the newly regenerating species could be that the mature trees were very poor and perhaps have been chopped by locals, but seeds remain as seed bank which germinate during favorable conditions (Iqbal et al. 2012). The fair or interrupted regeneration is due to under representation in some size classes, especially the middle size classes, which is associated with illegal logging or selective exploitation for charcoal, poles and timber (Kacholi et al. 2015). Species like *P. angolensis, K. africana* and *J. globiflora* observed to be illegally logged for timber uses by the locals. Elsewhere, 87% and 25% of *P. angolensis* and *J. globiflora* stumps, respectively, are reported to be logged below the minimum harvestable diameter (MHD) prescribed by the Tanzanian 2004 Forest regulations (45 cm and 40 cm MHD for the two species, respectively) (Ahrends 2005).

Conclusion and recommendation

Detailed valuation and understanding of the forest resource dynamics is imperative for sustainable management, utilization and conservation. The findings show that Nongeni forest houses 24 species that represent 11 families and 20 genera, which offer local community with several goods and services. In spite of apparent anthropogenic disturbances, grazing pressure and recurring annual fires, the overall size class distribution of the forest exhibited good regeneration; however, some species displayed poor regeneration patterns and low IVI values, which suggest the need for conservation and appropriate management strategies by the relevant authorities towards the species. Thus, the study recommends the following; first, reduction of anthropogenic pressure towards the reserve by prohibiting or planning for controlled harvest and grazing. Second, the regional forest and bee keeping division should introduce management plans and appropriate technology that will stabilize and/or promote the type, diameter and height classes and density of individuals of the existing species to be harvested for the known needs of the communities. Third, the provision of environmental awareness in the local communities on the importance of forests and build-up a “we feel” for the communities, which will actually promote responsible management, protection, utilization and conservation of species. Lastly, this study would like to suggest for further research on the effects of anthropogenic activities, especially cutting diameter and height on re-sprouting and/coppicing ability of the species, which will help to establish ideal cutting diameter and height for maximum re-sprouting ability of the species.

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Conflict of Interest Statement

The author declares that there is no potential conflict of interests on publication of this article.

References

Addo-Fordjour P, Obeng S, Anning K and Addo MG 2009 Floristic composition, structure and natural regeneration in a moist-semi deciduous forest following anthropogenic disturbances and plant invasion. *Int. J. Biodivers. Conserv.* 1: 21-37.

Ahrends A 2005 *Patterns of degradation in lowland coastal forests in coastal region Tanzania.* PhD Dissertation, Ernst-Moritz-Arndt University of Greifswald, Germany.

Anitha K, Shijo J, Robert JC, Ramasamy EV and Prasad SN 2010 Tree species diversity and community composition in a human-dominated tropical forest of Western Ghats biodiversity hotspot, India. *Ecol. Compl.* 7: 217-224.

Armenteras D, Rodríguez N and Retana J 2009 Are conservation strategies effective in avoiding the deforestation of the Colombian Guyana Shield? *Biol. Conserv.* 142: 1411-1419.

Attua EM and Pabi O 2013 Tree species composition, richness and diversity in the northern forest-sananna ecotone of Ghana. *J. Appl. Biosci.* 69: 5437-5448.

Backéus I, Pettersson B, Strömquist L and Ruffo C 2006 Tree communities and structural dynamics in Miombo (*Brachystegia julbernardia*) woodland, Tanzania. *For. Ecol. Manage.* 230: 171-178.

Baraloto C, Molto Q, Rabaud S, Hérault B, Valencia R, Blanc L, Fine PVA and Thompson J 2013 Rapid simultaneous estimation of above ground biomass and tree diversity across Neotropical forests: A comparison of field inventory methods. *Biotropica* 45: 288-298.

Benitez-Malvido J 1998 Impact of forest fragmentation on seedling abundance in a tropical rain forest. *Conserv. Biol.* 12: 380-389.

Bhadra AK, Dhal NK, Rout NC and Raja V 2010 Phytosociology of the tree community of Gandhamardan hill ranges. *The Ind. Forester* 136: 610-620.

Blasco F, Whitmore TC and Gers C 2000 A framework for the worldwide comparison of tropical woody vegetation types. *Biol. Conserv.* 95: 175-189.

Burgess ND and Clarke GP 2000 The coastal forests of Eastern Africa. IUCN forest conservation programme, Gland, Switzerland and Cambridge, UK.

Chittibabu CV and Parthasarathy N 2000 Attenuated tree species diversity in human-impacted tropical evergreen forest sites at Kolli Hills, Eastern Ghats, India. *Biodivers. Conserv.* 9: 1493-1519.

Condit R, Hubbell SP, LaFrankie, JV, Sukumar R, Manokaran N, Foster RB and Ashton PS 1996 Species-area and species-individual relationships for tropical trees: A comparison of three 50 ha plots. *J. Ecol.* 84: 549-564.

Curtis JT and McIntosh RP 1950 The interrelations of certain analytic and synthetic phytosociological characters. *Ecol.* 31: 434-455.

Debnath P, Sudin P and Soma C 2012 Diversity and richness of plants in Darjeeling Himalaya with an eye on Gaddikhana forest beat, Senchal East zone forest range, Darjeeling. *Ind. J. For.* 35: 39-44.

Doggart N, Dilger MS, Cunneyworth P and Fanning E 1999 Vegetation in Kwamgumi Forest Reserve: A Biodiversity Survey. pp. 13-45 from East Usambara Conservation Area Management Programme Technical Paper No. 40. Frontier Tanzania: Forestry and Beekeeping Division, Dar es Salaam, Tanzania and Metsähallitus Consulting Vantaa, Finland.

Doody KZ, Ntemi A, Killenga R and Beharrell NK 2001 Vegetation in Mpanga Village Forest Reserve: A biodiversity survey. pp. 9-39 from East Usambara Conservation Area Management Programme Technical Paper No. 51. Frontier Tanzania: Forestry and Beekeeping Division, Dar es Salaam, Tanzania and Metsähallitus Consulting Vantaa, Finland.

FAO 2010 *Global forest resources assessment 2010: Main report FAO paper 163.* Rome, Italy.

FBD (Forest and Bee keeping Division) 2000 *Forestry for poverty reduction and economic growth: National forest programme formulation in Tanzania.* Forestry and Beekeeping Division, Tanzania.

Gentry A 1988 Changes in plant community diversity and floristic composition on environmental and geographical gradients. *Ann. Miss. Bot. Gard.* 75: 1-34.

Gotelli NJ and Colwell RK 2011 Estimating species richness. In: Magurran AE, McGill BJ, (eds), *Biological Diversity: Frontiers and Measurement and Assessment.* Oxford University Press, New York, pp. 39-54.

Hadi S, Ziegler T, Waltert M and Hodges K 2009 Tree diversity and forest structure in northern Siberut, Mentawai islands, Indonesia. *Trop. Ecol.* 50: 315-327.

Huang W, Pohjonen V, Johansson S, Nashanda M, Katigula MIL and Luukkanen O 2003 Species diversity, forest structure and species composition in Tanzanian tropical forests. *For. Ecol. Manage.* 173: 11-24.

Huston MA 1994 Biological Diversity: The coexisting of species in changing landscapes. Cambridge University Press, Cambridge, UK.

Iqbal K, Pala NA, Bhat JA and Negi AK 2012 Regeneration status of trees around Khoh River in Garhwal Himalaya. *Ind. J. For.* 35: 471-476.

Kacholi DS 2013 *Effects of habitat fragmentation on biodiversity of Uluguru Mountain forests in Morogoro region, Tanzania.* PhD Dissertation, Georg-August University Göttingen, Germany.

Kacholi DS 2014 Indigenous tree uses, use-values and impact of human population on forest size, structure and species richness in Uluguru Morogoro Tanzania. *Tanz. J. Sci.* 40: 34-50.

Kacholi DS, Worbes M and Whitbread AM 2015 Diversity, abundance, and structure of tree communities in the Uluguru forests in the Morogoro Region, Tanzania. *J. For. Res.* 26: 557 - 569.

Kent M and Coker P 1992 *Vegetation description and analysis.* Belhaven Press. London, UK.

Khan ML and Tripathi RS 1989 Effects of stump diameter, stump height and sprout density on the sprout growth of four tree species in burnt and unburnt forest plots. *Acta Oecol.* 10: 303-316.

Kumar J, Patel K, Kumar R and Kumar R 2011 Forest structure, diversity and soil properties in a dry tropical forest in Rajasthan, Western India. *Ann. For. Res.* 54: 89-98.

Kumar JIN, Kumar RN, Bhoi RK and Sajish PR 2010 Tree species diversity and soil nutrient status in three sites of tropical dry deciduous forest of western India. *Trop. Ecol.* 51: 273-279.

Laurance WF 1999 Reflections on the tropical deforestation crisis. *Biol. Conserv.* 91: 109-117.

Lykke AM 1998 Assessment of species composition change in savanna vegetation by means of woody plants' size class distributions and local information. *Biodivers. Conserv.* 7: 1261-1275.

Magurran AN 2004 Measuring Biological Diversity. Blackwell Science Ltd, Melden, USA.

Malimbwi RE, Shemweta DTK, Zahabu E, Kingazi SP, Katani JZ and Silayo DA 2005 *Forest inventory for Mvomero district, Morogoro-Tanzania.* FORCONSULT Report.

Mani S and Parthasarathy N 2006 Tree diversity and stand structure in inland and coastal tropical dry evergreen forests of peninsular India. *Curr. Sci.* 90: 1238-1246.

Margalef R 1968 Perspectives in Ecological Theory. University of Chicago Press, USA.

Mishra BP, Tripathi OP and Laloo RC 2005 Community characteristics of a climax subtropical humid forest of Meghalaya and population structure of ten important tree species. *Trop. Ecol.* 46: 241-251.

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

Mueller-Dombois and Hellenberg H 1974 Aims and methods of vegetation ecology. John Wiley and Sons, New York.

Murcia C 1995 Edge effects in fragmented forests: implications for conservation. *Trends Ecol. Evol.* 10: 58-62.

Mwavu EN and Witkowski EDTF 2009 Population structure and regeneration of multiple-use tree species in a semi-deciduous African tropical rainforest: implications for primate conservation. *For. Ecol. Manage.* 258: 840-849.

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

Nath PC, Arunachalam A, Khan ML, Arunachalam K and Barbhuiya AR 2005 Vegetation analysis and tree population structure of tropical wet evergreen forests in and around Namdapha National Park, Northeast India. *Biodivers. Conserv.* 14: 2109-2136.

Neumann M and Starlinger F 2001 The significance of different indices for stand structure and diversity in forests. *For. Ecol. Manage.* 145: 91-106.

Padalia H, Chauhan N, Porwal MC and Roy PS 2004 Phytosociological observations on tree species diversity of Andaman Islands, India. *Curr. Sci.* 87: 799-806.

Phillips OL and Gentry AH 1993 The useful plants of Tambopata, Peru. II: Additional hypothesis testing in quantitative ethnobotany. *Econ. Bot.* 47: 33-43.

Pielou EC 1966 The measurement of diversity in different types of biological collections. *J. Theor. Biol.* 13: 131 - 144.

Pokhriyal P, Uniyal P, Chauhan DS and Todaria NP 2010 Regeneration status of tree species in forest of Phakot and Pathri Rao watersheds in Garhwal Himalaya. *Curr. Sc.* 98: 171-175.

Rahman MH, Khan MASA, Roy B and Fardusi MJ 2011 Assessment of natural regeneration status and diversity of tree species in the biodiversity conservation areas of Northeastern Bangladesh. *J. For. Res.* 22: 551-559.

Ram J, Kumar A and Bhatt J 2004 Plant diversity in six forest types of Uttaranchal, central Himalaya, India. *Curr. Sc.* 86: 975-978.

Richards PW 1996 The tropical rain forest: an ecological study. 2nd ed, Cambridge University Press, Cambridge, UK.

Sahu SC, Dhal NK and Bhadra AK 2010 Arboreal taxa diversity of tropical forests of Gandhamardan hill range, Eastern Ghats, India: an approach to sustainable biodiversity conservation. *Taiwania* 55: 208-215.

Sahu SC, Dhal NK and Mohanty RC 2012 Tree species diversity, distribution and population structure in a tropical dry deciduous forest of Malyagiri hill ranges, Eastern Ghats, India. *Trop. Ecol.* 53: 163-168.

Sakar M and Devi A 2014 Assessment of diversity, population structure and regeneration status of tree species in Hollongapar Gibbon Wildlife Sanctuary, Assam, Northeast India. *Trop. Plant Res.* 1: 26-36.

Sathish BN, Viswanath S, Kushalappa CG, Jagadish MR and Ganeshaiah KN 2013 Comparative assessment of floristic structure, diversity and regeneration status of tropical rain forests of Western Ghats of Karnataka, India. *J. Appl. Nat. Sci.* 5: 157-164.

Shannon CE and Wiener W 1963 The mathematical theory of communication. University of Illinois Press, USA.

Simpson EH 1949 Measurement of Diversity. *Nature* 163: 688.

Ssegawa P and Nkuutu DN 2006 Diversity of vascular plants on Ssese islands in Lake Victoria, Central Uganda. *Afr. J. Ecol.* 44: 22-29.

Sukumar R, Suresh HS, Dattaraja HS and Joshi NV 1998 Dynamics of a tropical deciduous forest: Population changes (1988 - 1993) in a 50-hectare plot at Mudumalai, southern India. In: Dallmeier F and Comisky JA (eds) *Forest Biodiversity Research, Monitoring and Modeling: Conceptual background to old world case studies*. Parthenon publishing, pp. 495 - 506.

Sundarapandian SM and Swamy PS 2000 Forest ecosystem structure and composition along an altitudinal gradient in the Western Ghats, South India. *J. Trop. For. Sci.* 12: 104-123.

Tabarelli M, Da Silva JMC and Gascon C 2004 Forest fragmentation, synergisms and the impoverishment of neotropical forests. *Biodivers. Conserv.* 13: 1419-1425.

Tchouto MGP, De Boer WF, De Wilde J and Van der Maesen LJG 2006 Diversity patterns in the flora of the Campo-Ma'an rain forest, Cameroon: Do tree species tell it all? *Biodivers. Conserv.* 15: 1353-1374.

Tesfaye G, Teketay D, Fetene M and Beck E 2010 Regeneration of seven indigenous tree species in a dry Afromontane forest, Southern Ethiopia. *Flora* 205: 135-143.

Top N, Mizoue N, Ito S, Kai S, Nakao T and Ty S 2009 Effects of population density on tree structure and species richness and diversity of trees in Kampong Thom Province, Cambodia. *Biodivers. Conserv.* 18: 717-738.

Turner MG 1987 Landscape heterogeneity and disturbance. Springer-Verlag, New York, USA.

Tynsong H and Tiwari BK 2010 Diversity of plant species in arecanut agro forests of south Meghalaya, north-east India. *J. For. Res.* 21: 281-286.

URT (United Republic of Tanzania) 2018 *Study on the status of environment with a focus on land degradation. forest degrdation and deforestation.* A report of the Controller and Auditor General of Tanzania. pp. 93.

Valencia R, Balslev H and Miño GPY 1994 High tree alpha-diversity in Amazonian Ecuador. *Biodivers. Conserv.* 3: 21 - 28.

Visalakshi N 1995 Vegetation analysis of two tropical dry evergreen forests in southern India. *Trop. Ecol.* 36: 117-127.

Wang X, Feng Z and Ouyang Z 2001 The impact of human disturbance on vegetative carbon storage in forest ecosystems in China. *For. Ecol. Manage.* 148: 117-123.

Welden CW, Hewett SW, Hubbell SP and Foster RB 1991 Sapling survival, growth and recruitment: relationship to canopy height in a neotropical forest. *Ecol.* 72: 35-50.

West AG, Midgley JJ and Bond WJ 2000 Regeneration failure and the potential importance of human disturbance in a subtropical forest. *Appl. Veg. Sci.* 3: 223-232.

Whitmore TC 1984 Tropical rain forest of the Far East. 2nd ed, Oxford, Clarendon Press.

Whitmore TC 1989 Southeast Asia tropical forests. In: Lieth H and Werger MJA (eds) Ecosystems of the World. Tropical rainforest ecosystems: Biogeographical and ecological studies. Elsevier: Amsterdam, pp. 195-218.

Wyatt-Smith J 1987 The management of moist forest for the sustained production of timber: some issues. IUCN/IIED Tropical Forest Policy Paper No. 4.

Zegeye H, Teketay D and Kelbessa E 2006 Diversity, regeneration status and socio-economic importance of vegetation in the islands of lake Ziway, South-Central Ethiopia. *Flora* 201: 483-498.