Journal of Education, Humanities and Sciences, Volume 5 No. 2, 2016: 67-76

Changes in Forest Composition, Edaphic Factors and Exploitation Pressure Between Edge and Interior Habitats in The Kimboza Forest in Morogoro Region, Tanzania

David Sylvester Kacholi, PhD[*]

Abstract

Biodiversity loss is linked to the destruction and fragmentation of tropical forest ecosystems. This study was conducted at Kimboza forest located in Morogoro region, Tanzania. The main goal was to compare the forest edge and interior habitats in terms of tree species richness, stand structure, soil moisture, organic matter and exploitation pressure. All trees with DBH ≥ 10cm were sampled from 6 plots of 0.04ha placed in each habitat. A total of 217 individuals from 49 tree species and 21 families were recorded in both habitats. Of the total recorded species, 37% were common, while 22% and 41% occurred exclusively at the edge and interior, respectively. The species richness, tree density, basal area, soil organic matter and moisture were significantly higher in the forest interior than the edge. On the contrary, the number of stumps per hectare was significantly higher in the edge (3.8) than interior (1.8). The Sørensen coefficient of similarity among the two habitats was 0.54, signifying the presence of uniqueness among the habitats. In summary, the findings suggest that the two habitats are unique and different in terms of species composition, species richness, stand structure, soil moisture, organic matter and anthropogenic exploitation pressure.

Keywords: *basal area, biodiversity, fragmentation, forest edge, species richness, stand structure*

1. Introduction

Globally, tropical forests are facing great threat of deforestation and fragmentation, and some are already archipelagos of small remnants (Turner, 1996). The fragmentation of forests has increased in recent decades due to increased human population around the forests. It is estimated that 500m people are living in or near tropical forests, the majority of whom depend on the forests as their primary source of supply for food, firewood, medicines, building poles and other indispensable needs (FAO, 2003). The dependency towards forest resources has caused great loss in the global forest cover. For instance, the global annual loss in forest area from 1990 to 2000 and 2000 to 2010 was 8.327 × 106 ha/year and 5.211 × 106 ha/year, respectively (FAO, 2010). The loss due to fragmentation results to edge formation, area reduction and isolation of habitats (Murcia, 1995). The edge formation causes ecological change as it involves alteration of micro-environmental conditions, which negatively affect plant community (Saunders et al., 1991; Jose et al., 1996). Normally, edges are characterized by high light intensity and

[*] *Senior Lecturer,* Dar es Salaam University College of Education (DUCE): kacholi78@yahoo.com

duration, higher soil and air temperature, lower humidity, increased wind forces as well as lower soil and litter moisture than interior habitats (Jose et al., 1996; William-Linera 1990; Didham & Lawton, 1999). Various studies done elsewhere have revealed that edge effects can cause tree mortality (Laurence et al., 1998); change in forest vegetation structure (William-Linera, 1990; Didham & Lawton, 1999); reduce recruitment rate of woody seedlings (Benitez-Malvido, 1998); and in a long-run it can alter species composition, density of pollinators, dispersers and seed predators (Gascon et al., 1999).

In Tanzania, human population has increased nearly six times from 1948 to 2012, with 80% living in rural areas where forests are situated (Newmark, 2002; NBS, 2012). The high population concentration in rural areas has put much pressure on forest resources as a result of increased socio-economic demands (Newmark, 2002). Like other Eastern Arc and Coastal forests of Tanzania, the Kimboza forest is rich in biodiversity concentration and species endemism, but high anthropogenic pressure and encroachment threatens its conservation value (Temu & Andrew, 2008). Although few studies on floristic composition (Malimbwi, et al., 2005; Temu & Andrew, 2008; Kacholi, 2013a) have been done in the Kimboza forest, the variation between edge and interior habitats has not been assessed. Thus, the aim of this study is to compare forest edge and interior habitats in terms of tree species richness, species diversity, stand density, stand basal area, soil organic matter, moisture, anthropogenic exploitation and regeneration potential. This study hypothesizes that edge and interior habitats are different in terms of floristic composition, edaphic factors, and levels of anthropogenic activities.

2. Material and Methods

2.1 Study Site

The study was carried out at the Kimboza forest located on the eastern part of the Uluguru foothills in Morogoro Region (06° 59' and 07° 02' South and 37° 47' and 37° 49' East). The study site is a lowland forest (300-400m) with an area of 405ha. The forest is known to have about 226 vertebrates, which include 52 amphibians and 174 mammals; and it has several flora species. The climate of Morogoro region is oceanic due to its proximity to the Indian Ocean (about 200km), with bimodal rainfall regime. The long rains last from March to May, peaking in April; and the short rains last from October to December. The mean annual rainfall and temperature are 740mm and 25.1°C, respectively. Agriculture is the major socio-economic activity for the people living in the villages surrounding the forest. Livestock keeping, bee keeping, fishing, carpentry and small-scale mining are also done at a small scale.

2.2 Data Collection

Six plots of 20m × 20m each were randomly placed in the forest edge (100m from forest margin) and interior (> 200m from forest margin) habitats. This design was due to the fact that edge effects can penetrate to 100m into forest (Laurence et al., 1998). All trees with diameter at breast height (DBH) ≥ 10cm measured at 1.3m above the ground were counted, identified, and stem diameters recorded from each plot in both habitats. Trees with multiple stems at 1.3m height were treated as single individual, whereby the diameters of all stems were taken and averaged. If a tree had buttress at

1.3m height, the diameter was measured just above the buttress where the stem assumes near cylindrical shape. The identification was done to species level in the field with assistance from forest experts of the Forest and Beekeeping Department in Morogoro region using relevant flora identification monographs (Flora of Tropical East Africa and Flora of Zambeziaca). The number of stumps present in each plot in the habitats was counted for quantification of exploitation pressure. Soil samples were collected from each plot and taken to the Chemistry laboratory of the University of Dar es Salaam for determination of soil moisture and organic matter.

2.3 Data Analysis

Species richness was measured using the number of observed species, Chao 1 and the first order Jackknife estimator; while species diversity was calculated using the Shannon-Wiener diversity and Margalef index. The paired sample t-test was used to check for differences in species richness, species diversity, stand density, basal area, organic matter, moisture, and number of stumps ha^{-1} between edge and interior habitat. The Shapiro-Wilk test was used to test for normality of data before subjecting them to t-test. The species composition similarity among the two habitats was calculated using the Sørensen similarity formula, while species accumulation curves were constructed to compare the increase in species with an increasing sample size between the habitats. Seven size class distribution arranged in 10cm intervals were formed based on the recorded tree diameters from the two habitats. The species diversity, species richness and species accumulation curves were all computed using the Species Diversity and Richness IV software (SDR IV) (Seaby & Henderson, 2006).

3. Results

3.1 Floristic Diversity and Structural Composition

A total of 217 trees belonging to 49 species and 21 families were recorded. Fabaceae was the richest family with 15 species, followed by Moraceae with 5 species. Of the total observed species, 22% and 41% occurred exclusively to the forest edge and interior habitat, respectively; while 37% were common in the two habitats. The Sørensen coefficient of similarity between the two habitats was 0.54. The number of observed species per plot ranged from 5–8 and 7–14 for edge and interior plots, respectively. The tree density ranged from 225–250 stems ha^{-1} and 475–850 stems ha^{-1} while basal area ranged from 6.6–27.2m^2 h^{-1} and 22.4–70.8m^2 ha^{-1} for edge and interior, respectively. Statistically, the mean species richness, stem density, and basal area were significantly higher in the forest interior than edge plots (Table 1).

Table 1: Means (Standard Errors) of Measured Parameters in the Two Studied Forest Habitats

Parameter	Edge	Interior	t- statistic	p-value
Species richness	6.5 ± 0.3	11.3 ± 2.3	3.87	0.01
Shannon-Wiener diversity index	1.78 ± 0.1	2.00 ± 0.2	1.63	0.16
Margalef index (D)	2.45 ± 0.17	3.16 ± 0.37	1.98	0.10
Tree density (individual ha^{-1})	238 ± 16	667 ± 52	8.85	0.00
Basal area (m^2 ha^{-1})	14.9 ± 3.0	44.8 ± 8.1	4.60	0.01
Number of stumps ha^{-1}	3.8 ± 0.7	1.3 ± 0.3	3.48	0.02

The number of stumps ha^{-1} ranged from 2–6 stumps ha^{-1} and 0–2 stumps ha^{-1} for edge and interior habitat, respectively, whereas the mean was significantly higher in the forest edge than interior habitat. The Shannon-Wiener diversity indices ranged from 1.696–2.043 and 1.557–2.474, while the Margalef indices ranged from 2.17–3.19 and 1.80–4.09 for edge and interior habitat, respectively. Though the two species diversity indices did not differ appreciably among the two habitats, the interior habitat was diverse than the edge (Table 1).

3.2 Species Accumulation Curves

The species accumulation curves revealed an increasing trend as the number of sample area increase in both habitats (Fig. 1). The non-parametric species richness estimators (Jackknife 1 and Chao 1) revealed higher species richness in each habitat compared to the observed ones, and both estimators revealed interior to be the richest habitat (Table 2). Likewise, the rate of species increase per unit area (i.e., regression slope) was higher in the forest interior than edge. The species richness and forest size were strongly positively correlated (Table 2).

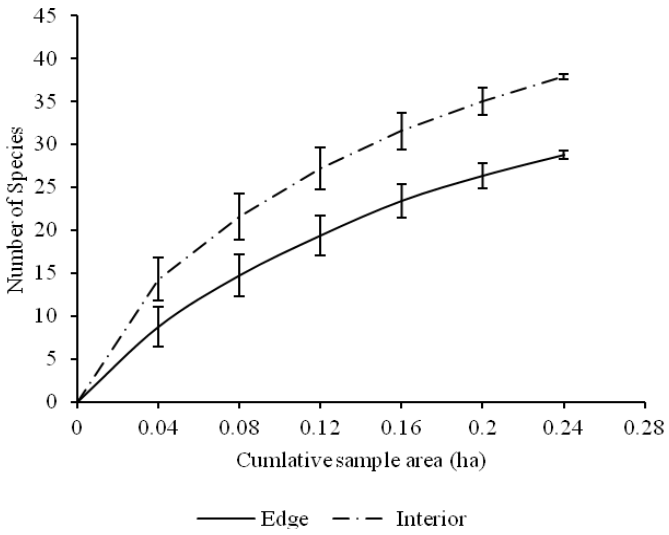


Figure 1: Species Accumulation Curves of Tree Species in the Two Forest Habitats

Table 2: Observed Species Richness, Estimated Richness and Relationship Between the Two Habitats

Parameter	Edge	Interior
Observed species	29 ± 2	38 ± 3
Jackknife 1(± SE)	47 ± 2	56 ± 3
Chao 1 (± SE)	43 ± 8	52 ± 8
Regression	Species richness = 15.0 ln area–0.9 (r^2 = 0.99)	Species richness = 19.4 ln area + 0.3 (r^2 = 0.99)

3.3 Comparison of Edaphic Conditions

The findings revealed the mean percentage soil moisture ($t = 14.5$, $d.f = 5$, p = 0.000) and organic matter ($t = 7.7$, $d.f = 5$, $p = 0.000$) to be significantly higher in the forest interior than edge plots (Fig. 2).

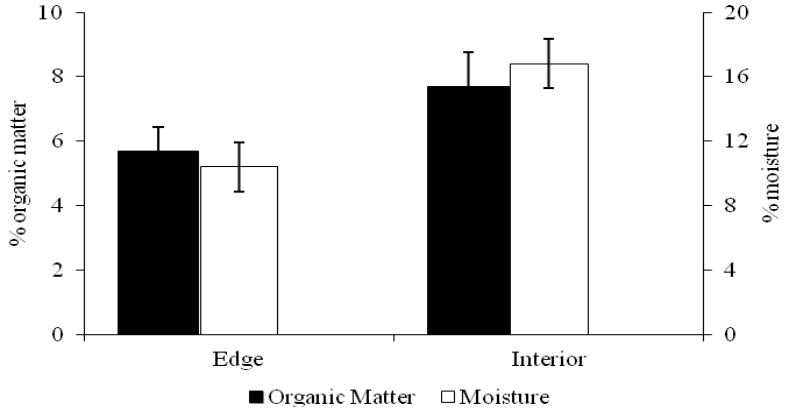


Figure 2: Percentage Soil Organic Matter and Moisture among the Studied Habitats in Kimboza Forest

3.4 Size Class Distribution among the Habitats

The interior habitat exhibited a purely hypothetical negative exponential curve and all the size classes were represented. About 81% of the trees in the interior habitat were in the first (59%) and second (22%) size classes (Fig. 3).

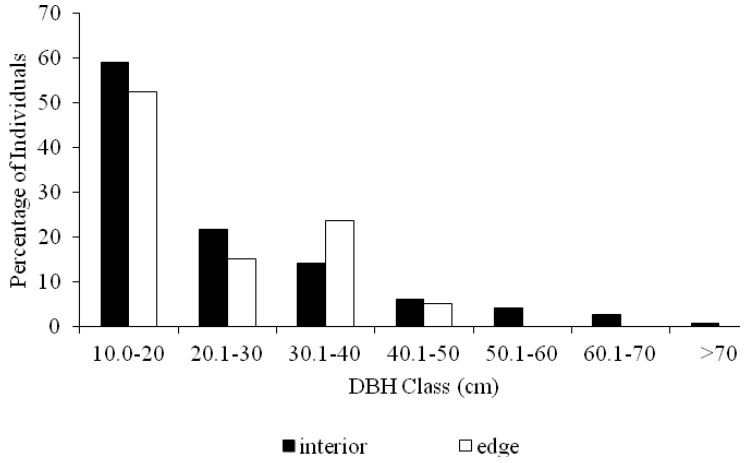


Figure 3: Diameter Class Distribution of Trees Recorded in the Studied Habitats in Kimboza Forest

The edge habitat represented an interrupted reverse J-curve at second class and had no individuals in the size classes greater than 50cm DBH. Of all the trees, 68% of the trees in the edge were in the first (53%) and second (13%) size classes. The maximum DBH value in the interior and edge habitat was 126cm and 60cm recorded for *K. anthotheca* and *Milicia excelsa*, respectively.

4. Discussion

4.1 Floristic Diversity and Structural Composition

The comparison has revealed that the edge and interior habitat are different in terms of species richness, stems density, basal area, soil moisture and organic matter. The significant differences in species richness, tree density and basal area could be caused by observed appreciable differences in soil organic matter and moisture as these two edaphic factors are well known to favour recruitment of some species over others (Murcia, 1995). Edges have less dense canopy cover, higher light intensity and duration, higher air and soil temperature, and increased wind shear forces (Jose et al., 1996; Didham & Lawton, 1999; Newmark, 2002), which directly affect soil moisture and relative humidity. This in turn affects the distribution of species as some of them require forest interior conditions, while others require edge related conditions (Saunders et al., 1991; Murcia, 1995).

The substantial low species richness, stem densities and basal areas at the edges could also be associated with high exploitation pressure, which was observed through the presence of a significant number of stumps as compared to interior habitat. The easy accessibility by locals to edges while fetching for their basic needs like firewood, charcoal, building poles, traditional medicines and timber has resulted into disturbances, and hence low observed values (Kacholi, 2013b). The grazing and cattle trampling could also contribute to the observed lower values at the edge as seedling get crushed by the livestock and the preferred plants are consumed, hence, less species richness and density (Wassie et al., 2010). Moreover, the occasional penetration of fire to forest edges from nearby farms could also be the causal factor for the observed findings as periodic fires reduce canopy cover and change significantly the vegetation composition and structure (Cochrane & Laurence, 2002; Fontoura et al., 2006). The proximity of surrounding villages to the forest provides a significant predictor of disturbance intensity (Sagar et al., 2003; Karanth et al., 2006). Elsewhere, the presence of high predation, low pollinators and seed dispersers at the edges tend to limit some seedlings establishment among the habitats (Benitez-Malvido, 1998). Thus, the observed low Sørensen similarity coefficient (0.54) confirms the two habitats to be unique and different in terms species composition.

The presence of significantly lower stem density at the edges may also result from interplay of factors of two kinds: first, those that reduce the possibility of seedling establishment; and second, those that increase seedling, sapling and adult tree mortality rate (Benitez-Malvido, 1998). In tree communities, seedling is the first size class to be affected by edge effect because it is the life stage that is more sensitive to environmental changes and biotic interactions (Saunders et al., 1991). Some processes related to edge effects that explain the observed pattern in tree density include:

reduction in seedling recruitment at edges due to habitat desiccation, and higher mortality rates of adult trees at edges caused by uprooting and breakage. These are caused by wind turbulence and seedling damage, which are results of increasing litter-fall and tree fall near forest edges; and sapling mortality by competition with lianas, vines and ruderal species (Laurence et al., 1998; Benitez-Malvido, 1998; Tabarelli et al., 2004). Moreover, the observed lower basal area values at the edges can be associated with illegal logging conducted by unfaithful locals. In line with this, the higher number of stumps ha^{-1} at the edge indicates that the habitat is greatly affected by anthropogenic activities, especially logging of big trees as compared to the interior habitat. The same information can be seen from Fig. 3, which shows edge habitat to lack individuals in the size classes greater than 50cm.

4.2 Species-area Relationship

Both species accumulation curves (Fig. 1) displayed an increasing trend, which indicates that more sampling efforts could have amplified the species richness in each habitat (Magurran, 2004). This is also supported by the first order Jackknife and Chao 1 species richness estimator, which gives higher species richness estimates than the observed ones in each habitat (Table 2). The information is basically telling us that the sample size was not enough to capture all the species in the studied forest habitats. Thus, it informs that more sample plots are required for future inventories in the studied habitats. Also, the comparison of regression slopes revealed the interior habitat to have higher value than edge, which indicates that the interior habitat is speciose and has higher recruitment rate per unit area than the edge.

4.3 Natural Regeneration

The size class distribution (Fig. 3) revealed the interior habitat to have good regeneration, while the edge habitat had poor and interrupted regeneration. The lack of individuals in the higher size classes (DBH $>$ 50cm) at edges is an indication that big trees have been removed through illegal harvesting. The lack of individuals in higher size classes at edges could also be attributed to the observed higher number of stumps in the habitat. The stumps of *Pterocarpus angolensis, Dalbergia melanoxylon, Khaya anthotheca, Milicia excelsa, Combretum spp. and Terminalia spp* were the most observed at edges. The first four mentioned species are known to be exploited for timber, and majorities are logged below the minimum harvestable diameter. Ahrends (2005), Modest et al. (2010) and Kacholi (2013b) have reported the same species to be illegally exploited for various purposes, including timber. The *Combretum* and *Terminalia* species are used for charcoal making, firewood, and building poles. Furthermore, various authors have indicated that the presence of harsh micro-environmental conditions such as high air and soil temperature, high light transmittance, lower relative humidity, increased wind forces, lower availability of soil carbon, total nitrogen and phosphorus, and lower soil and litter moisture near edges contributes to drastic changes in the abundance and distribution of trees in the forest (Jose et al., 1996; Laurence et al., 1998; Didham & Lawton 1999; Newmark, 2001; Yan et al., 2007). Structural-wise, the edge was characterized by thin/small trees with few big trees, hence, scarce overstory cover. In contrary, the forest interior habitat had well-developed canopy. This trend explains the differences observed in average basal area between the two habitats where vegetation concentrates in the lowest layer in at the

edges, and in the highest ones in the interior. These features are similar to those reported in other studies from tropical and temperate forest edges (Ranney et al., 1981; William-Linera, 1990; Caseneva et al., 1995).

5. Conclusion and Recommendation

In summary, the findings provide evidence that edge and interior of the forests are two different habitats in terms of number of species, stand structure, measured edaphic factors and anthropogenic disturbances. On the other hand, the results provide an emphasis that if fragmentation of this forest continues, the edge effects will be more pronounced and majority of the forest species will disappear leaving only an impoverished subset of trees from the original biota that can withstand edge conditions. Additionally, the study recommends for long-term research on microclimate and edaphic factors among the two forest habitats to determine their influence on the understory vegetation composition and structure.

Acknowledgement

The author deeply appreciates the Morogoro Forest Department for permission to access the forest and providing technical and transport logistics to and from the study sites. Thanks also go to Mr. Nobert Rugudagiza of the Chemistry Department, University of Dar es Salaam for technical assistance during the laboratory work. *Shukrani.*

References

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

Benitez-Malvido, J. 1998. Impact of Forest Fragmentation on Seedling Abundance in a Tropical Rain Forest. *Conservation Biology,* 12(2): 380–389.

Caseneva, J.L., J.P. Pelotto & J. Protomastro. 1995. Edge-Interior Differences in Vegetation Structure and Composition in a Chaco Semi-Arid Forest, Argentina. *Forest Ecology and Management,* 72: 61–69.

Cochrane, M.A & W.F Laurance. 2002. Fire as a Large-Scale Edge Effect in Amazonian Forests. *Journal of Tropical Ecology,* 18(3): 311–325.

Didham, R.K. & J.H. Lawton. 1999. Edge Structure Determines the Magnitude of Changes in Microclimate and Vegetation Structure in Tropical Forest Fragments. *Biotropica,* 31(1): 17–30.

Food and Agricultural Organisation (FAO). 2003 Forests. a Life–Giving Resources. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy.

—. 2010. Global Forest Resources Assessment 2010: Main Report FAO Paper 163. Rome, Italy.

Fontoura, S.B., G. Ganade & J. Larocca. 2006. Changes in Plant Community Diversity and Composition across an Edge between Araucaria Forest and Pasture in South Brazil. *Brazilian Journal of Botany,* 29(1): 79–91.

Gascon, C., T.E. Lovejoy., R.O. Bierregaard Jr,, J.R. Malcom., P.C. Stouffer., H.L. Vasconcelos., W.F. Laurance., B. Zimmerman., M. Tocher & S. Borges. 1999. Matrix Habitat and Species Richness in Tropical Forest Remnants. *Biological Conservation,* 91: 223–229.

Jose, S., A.R. Gillespie., S.J. George & B.M. Kumar .1996. Vegetation Responses Along Edge-To-Interior Gradients in a High Altitude Tropical Forest in Peninsular India. *Forest Ecology and Management,* 87(1-3): 51–62.

Kacholi, D.S. 2013a. Effects of Habitat Fragmentation on Biodiversity of Uluguru Mountain Forests in Morogoro Region, Tanzania. Phd Thesis Submitted at Georg-August University Goettingen, Published By Cuvillier Verlag Goettingen, Germany.

—. 2013b. Floristic Composition, Diversity and Structure of the Kimboza Forest in Morogoro Region, Tanzania. *Journal of Education Humanities and Sciences* 2(2): 84–95.

Kacholi, D.S., Whitbread, A.M. & Worbes, M. 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.

Karanth, K.K., L.M. Kurran & J.D. Reunig-Scherer. 2006. Village Size and Forest Disturbance in Bhadra Wildlife Sanctuary, Western Ghats, India. *Biological Conservation,* 128(2): 147–157.

Laurance, W.F., L.V. Ferreira, J.M. Rankin-Demerona & S.G. Laurance. 1998. Rain Forest Fragmentation and the Dynamics of Amazonian Tree Communities. *Ecology,* 79(6): 2032–2040.

Magurran, A.N. 2004. *Measuring Biological Diverisy*, Blackwell Science, Melden, Germany.

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.

Modest, R.B., S.L.S. Maganga, S.N. Hassan, S.B. Mariki & M. Muganda. 2010. Population Structure and Extraction of Three Commercial Trees in Nguru Ya Ndege Forest Reserve, Morogoro-Tanzania. *Ethiopian Journal of Environmental Studies and Management* 3(3): 41–48.

Murcia, C. 1995. Edge Effects in Fragmented Forests: Implications for Conservations. *Tree,* 10(2): 58–62.

National Bureau of Statistics (NBS). 2012. Basic Demographic and Socio-Economic Profile Report Tanzania Mainland. Dar Es Salaam, Tanzania.

Newmark, W.D. 2001. Tanzanian Forest Edge Microclimatic Gradient: Dynamic Patterns. *Biotropica,* 11(1): 2–11.

—. 2002. *Conserving Biodiversity in East African Forests. a Study of the Eastern Arc Mountains*, Springer, New York, NY, USA.

Ranney, J., M. Bruner & J. Levenson. 1981. The Importance of Edge in the Structure and Dynamics of Forest Island. In: R. Burgess and D. Sharpe (Eds). Forest Islands Dynamics in Man-Dominated Landscapes. Springer, New York.

Sagar, R., A.S. Raghubanshi & J.S. Sigh. 2003. Tree Composition, Dispersion and Diversity Along a Disturbance Gradient in a Dry Tropical Forest Region of India. *Forest Ecology and Management,* 186(1-3): 61–71.

Saunders, D. A., R.J. Hobbs & C.R. Margules. 1991. Biological Consequences of Ecosystem Fragmentation: a Review. *Conservation Biology,* 5(1): 18–32.

Seaby, R.M. & P.A. Henderson. 2006. *Species Diversity and Richness Version 4*, Pisces Conservation Ltd, Lymington, UK.

Tabarelli, M., J.M.C. Silva & C. Gascon, 2004. Forest Fragmentation, Synergisms and the Impoverishment of Neo-Tropical Forests. *Biodiversity Conservation,* 13(7): 1419–1425.

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.

Turner, I.M. 1996. Species Loss in Fragments of Tropical Rain Forest: a Review of the Evidence. *Journal of Applied Ecology,* 33(2): 200–209.

Wassie, A., F.J. Sterck & F. Bongers. 2010. Species and Structural Diversity of Church Forests in a Fragmented Ethiopian Highland Landscape. *Journal of Vegetation Science,* 21(5): 938–948.

Williams-Linera, G. 1990. Vegetation Structure and Environmental Conditions of Forest Edges in Panama. *Journal of Ecology,* 78(2): 356–373.

Yan, Y., Z. Zhong & J. Liu. 2007. Habitat Fragmentation Impacts on Biodiversity of Evergreen Broadleaved Forests in Jinyun Mountains, China. *Frontiers of Biology in China,* 2(1): 62–68.