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Research Article

Influence Buffer Zone Regimes Area on the Protected Tree Species Richness and Density in Kakamega Forest, Kakamega County, Kenya

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Abstract: Buffer zone regimes (BZRs) enhance protection of forests in the world. For instance, they influence protection of about 50% in Latin America 30% in Sub-Saharan Africa and 63% in temperate countries. In Kenya, Nyayo Tea Zone (NTZ) was established as a BZR around all gazetted forests in early 1980's. In areas where soils were not ideal for tea, Exotic Tree Plantations (ETP) was established. In spite of BZR in Kakamega forest, some section of BZR remains Open Edge (OE) probably because TEA and ETP did not thrive or as a result of poor management. In the past the trees that were abundant in Kakamega forest currently, remained threatened and some species rare possibly due to exploitation. However, studies on the influence of BZR (OE, ETP, and NTZ) area on tree species richness remain unknown in Kakamega forest. Therefore, the objective of this study is to examine the influence of BZRs area on tree species richness. Study population was unknown. Cross- sectional descriptive research design was employed. Saturated sampling was used to sample at least 40 humanly accessible along a string placed 100m from forest edge area interior gradient as it was assumed to be most disturbed area. OE acted as a control site assuming all the forest conditions were similar. A tape measure was adjusted along the string for identified plots. Study sites were located using hand held GPS. Trees were identified visually and counted. There was assumption of sources of errors for failure to come up with regular squares. Simple linear regression was used to assess the influence of BZRs (OE, ETP, and NTZ) area and the protected tree species richness. Results showed that NTZ 93% (r^2=0.93, p = 0.000), ETP 82% (r^2=0.82, p = 0.000) as compared to those in OE 68 % (r^2 = 0.68, p = 0.000). The results implied that both NTZ and ETP were better supporting protection of the higher number of tree species richness as compared to OE.The study concluded that BZRs (OE, ETP and NTZ) area influenced tree species richness as opposed to OE. The study recommends the investigation onto the impact of NTZ and ETP on the health of trees in order to compare the health condition of the forest or its deterioration.
Keywords: Buffer Zone Regimes, Tree Species Richness, species relative abundance.

1. INTRODUCTION

Species richness refers to the total number of different species represented in an ecological community regardless of their abundance in a given area (IUCN, 2007). Worldwide studies have shown the total number of species richness in earth possibly lie between 10 to 30 million ranges with only three quarter of the species found in tropical forest whose biodiversity is greatly threatened (MEA, 2007). Buffer zones regimes are therefore established to enhance the protection of the IUCN red listed as critically endangered vulnerable and diverse species richness of plants and animals (IUCN ,2010). Early studies, demonstrated that the overall plant species richness was higher in forest with cash crop farming in the buffer zones than open edge (Thorel & Gotmark, 2005). Other study by (Rie, 2004) noted that increased erosion in the OE, minimize the chances of plants survival, and hence low number of tree species richness (Derlaeminek *et al.*, 2005; Porter *et al.*, 2012; Norman *et al.*, 2016).Moreover, Malvado *et al.*, 2014 & Norman *et al.*, 2016) reported that plants in the OE forests are coupled with exposed roots and low nutrients hence low species richness. These global studies have shown plants species richness being low in the open edge forests. However, there's need to assess the tree species richness protected by BZR and compare with open edge that is unknown.

Moreover, world species habitat are threatened by fragmentation that accounts for reduced size and lack of connectivity limit their capacity to

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fulfill their aim of biodiversity protection (Worboys, 2006). For instance, in Latin America 50% of protected forests with soya farming as a cash crop create a sub canopy at the forest edge against erosion disturbance (Soule & Sandajan, 2007). However, following the planting of ETP in the BZR, some indigenous plant species have disappeared due to competition for water, nutrients, spread of diseases that undermine growth and development of the plants hence low tree species richness expected (Jaquetet, 2005; Soule & Sandajan, 2007). Although, according to another, study in Chitwan districts established that ETP species in BZR attributed to high plant and animal species richness in forest (Radha, 2009; Nepal, 2010). This may have resulted due to ETP in the BZR enhanced edaphic factors in particular soil moisture, nitrogen, ph, suitable for high plant species survival (Govenne *et al* 2007; Lasgorceix *et al.,* 2010; Dalling *et al.,* 2016). In addition exotic trees and cash crops in the BZR ameliorate the harsh microclimatic condition, leading to high species richness (Martino 2001; CBD, 2012). For instance cocoa plantation create a sub canopy climate, thus improves drainage, aeration and constant moisture for increased plant species growth and development (Dhakal, 2012). These, studies have illustrated the contributions of cash crop farming and ETP on the plants species richness, however, there's need to specifically assess the influence of Nyayo Tea Zone on tree species richness that is unknown.

In Africa protection areas include Forest, Mountainous regions and the savanna grassland areas with estimated 200000 species of plants regionally recognized (Azami, 2004,). For instance Madagascar had about 4.22% or 25 percent plant species richness in forest adjacent to clove plantation in the buffer zone (Synott, 2007; Moe 2009). Further examples in Africa, Atlas Mountain has 151 species of different types of mammals and plants species, 15, are currently threatened in the open edge forest (Lovech, 2008). Since, the indigenous wood species are known for their quality wood and non-wood products such as timber, for furniture, medicinal herbs for curing diseases hence, the trees like Mahogany, teak, Prunus africanus among other species have become extinct (Wilson *et al.,* 1996 & Naido *et al.,* 2006. In fact, a large area of forest land is located in adjacent communities who continue struggling over forest resources (Mondal& Southworth, 2010; Kearn, 2011). Thus as a result of forest are clearance to pay way for, crop cultivation and harvesting of wood has led to low number of indigenous species richness (Dinnerstein, 2014). These studies have generally demonstrated human threats on the forest resources without specifically assessing buffer zone regimes and tree species richness.

Gilbert *et al.,* (2010), in a comparative assessment of the south and western Africa forest the study on BZR revealed that the presence of ETP in the BZR provide a taller structure, that creates a sub canopy microclimate hence increased biodiversity in adjacent forests areas (Dhakal, 2010). For instance, in the tropical rainforest of South Africa, the trees density was found to be four times higher than in the open edge protected reserves (Vollan, 2008). However, a study across Nigeria coast showed that almost 70% ---80% of the country's population use charcoal, firewood collection supplemented by ETP planted in BZR (Kasolo & Temu, 2008; UNESCO, 2011).This means that buffer zone regimes have protected easy human access, invasion by exotic plants, storm and erosion exposure of roots on surface within the 100m margin to the forest (Laurace 1997; Karanth *et al.,* 2013) and hence enhance increased growths and development of some indiginious trees species from extinction (Gascon *et al.,* 2010; Cambi *et al.,* 2015). Thus, it's clear from the discussions that buffer zone regimes are shown not only being suitable to protect reserves resources, but, also sites rich to provide alternative wood for human basic needs (Bennet & Saudine 2011). There is however, need to show how tree species richness protected by BZR would compare with those in the open edge.

In the tropical forest of Benin, studies have shown that ETP in BZR mitigates forest against external disturbance due to human and strong winds breakages than those in the open edge (Allisop *et al.,* 2007; CBD, 2008 &). Furthermore, (Colley *et al.,* 2009; USAID, 2000; Pinto *et al.,* 2010) acquitted increased large trees supported by ETP sub canopy microclimate and the restrictions from forest reliability by local communities and thus increased plants species richness were realized in the recent past. According to (MEA, 2008; Joseph *et al.,* 2011), this enhances establishment of increased woody species richness. For instance in Ghana FAO, (2012) study revealed a steady higher increase by 60 of higher plant species richness in the forest adjacent to cocoa Plantation in buffer zone regimes. Similarly, Nyungwe national park in Rwanda and in Budongo forest in Uganda over 550 different plants species richness reported in adjacent tea plantation as compared to those adjacent to ETP (Adhikari, 2012). The presence of tea plantation has been associated with improved aeration, drainage, favorable for rich woody species richness (Govenne *et al.,* 2007; Dalling *et al.,* 2016). From these studies, buffer zone regimes have been demonstrated to influence the general plant species richness; however, there is need to assess buffer zone regime area and tree species richness that is unknown.

In Kenya, just like other parts of Eastern Africa, the policy for forest protection is thus highly challenging in nature reserves and national parks conservation (Republic of Kenya, 2010). There are about 60 parks and reserves in the country endowed with approximately 35000 known species of plants and animals (Mitchel, 2004; Mars Group Kenya, 2010). However, challenges of high population densities and dependence on forests for livelihood needs to focus on types of land use activities in the buffer zone regimes to enhance increased protection of plant species richness density and diversity (Klop, 2012). Later studies revealed that in early 1980s' NTZ and ETP was established as BZR around all forest ecosystems (NEMA, 2009; Pokharel & Otsuka, 2014;) although, in some forests there's existence of an OE to date probably tea or exotic tree species did not thrive or probably as a result of resistance of land owners to manage (Mbuvi *et al.,* 2015). Recent studies in Taita hills have reported improved soil nutrients and moderate constant moisture conditions for increased number of plant species richness in forest adjacent to agro forestry in the buffer zone (Cognalo *et al* 2006; Wekesa *et al.,* 2018). In addition cash crop farming has contributed to significantly high plant biomass during decomposition, leading to increased soil nutrients for species growth and development (Cognalo *et al* 2006; Wekesa *et al.,* 2018).. These studies have shown that both reserves and parks are protected however, a clear focus on the types of BZR used could be important to create an in depths understanding on how specific BZRs have contributed to protection of tree species richness that is unknown.

Given constraints on land availability and increased human disturbance, OE forest resources remain currently threatened due to logging and the number of trees are limited and endangered (Nambiro, 2000;,& Harper *et al.,* 2005). For instance, in Mau and Masaai Mara national park harvesting of ETP at BZR contributed to disappearance of grasses, sedges and higher plant species richness (Ottichilo, 2000;, Collins, 2006 & NEMA,2009). This currently was witnessed by both the local and regional decline of wood species that has severely disrupted wood species richness and diversity (Okello & Kiringe, 2004; KNBS, 2011; KEFRI, 2016). A recent study in Busia County showed the effects of anthropogenic activities on terrestrial biodiversity conservation (Mutavi, 2012). Even though the studies investigated the effect of human activities on the plant species, there is no fully empirical investigation on how BZR would influence tree species richness. Therefore, there is potential need for investigation of BZR as a possible reason for protected tree species richness and density in the tropical ecosystem.

Assessment of tree species richness from the forest edge has been achieved by different scholars for example, Murcia 1995; & Olsen 1988 they used a distance of 10m away from the forest edge. Samson, (2000) used a random distance between 20m to 100m away to enumerate all trees and shrubs and on the other hand (Thorel & Gotmark, 2005) used a distance of at least 15m away from forest edge and plots of 15m x15m. Later Dhakal *et al.,* 2010 & Ojoyi *et al.,* 2012 relied on the sample sites above 20m away and area of 20m x 20m from the forest edge. Recently (Andreas *et al.,* 2015) used at least a distance of sample sites as 3m away whereas Mbuvi *et al.,* 2015 opted for a distance between 20m and area of large plot as 80mx 80m from the forest edge to be adequate for plots to assess edge effects. There is evident in variation of sample plots of BZR appropriate in examination of the tree species richness protected, the studies distance being more than 20m and about area of 100mx100m. This study therefore relied on saturated sampling of accessible 40 plots in adjacent BZR to the interior of the forest at least 80m away transect with large plot of 80mx 80m as adequate sampling size for the protected tree species richness in the study area.

At the study area, Kakamega Forest in the recent decades the forests has witnessed accelerated rates of clearing and degradation (Bleher, & Gegory, 2012). The forest plants and animal species currently are threatened by high population densities, high levels of poverty, rapid economic growths industrialization and urbanization (Klop, 2012). This has been evidenced by the Adjacent land types that degrade tree resources as considerable logged trail densities and unknown number of individual tree species still poached in some parts of the forest (Gregory- KESSA, 2013). Thus along with the increased policy in protection of forest resources the increasing number of large population around the forest has added pressure on the limited resources (Forest report, 2014). Thus, the established Nyayo Tea zone and Exotic Tree Plantation comprising of (eucalyptus, cypress and pine) aimed to supplement socio-economic and biological benefits (Mbuvi *et al.,* 2015). Studies have explained that the increased threats have contributed to unknown number of quite unique plants species that were most abundant in the recent past decreased and become rare(KFE Management Plan, 2012—2022).Recent study, revealed that human activities have negative influence on the kakamega forest (Vuyiya *et al.,* 2014). Most recent satellite image captured showed that the forest cover has been heavily affected (Urthecast, 2016). These studies have demonstrated that human threats have contributed to decreased plants species; however, it would be appropriate to specifically assess the contribution of BZR on protected tree species richness and density & compare with open edge.

2. MATERIALS AND METHODS

2.1. Study Area and Data

2.1.1. Study Area

3.2.1 Location of study area

Kakamega forest is located in Kakamega East in Kakamega county western Kenya. It lies between latitudes 0^0 09' N and 0^0 25' N and longitudes 34^0 49'E, and 34^0 57 '26.5'E at an altitude of about 1500 to 1700m above sea level (Tsingalia, 1988) (Fig.1).

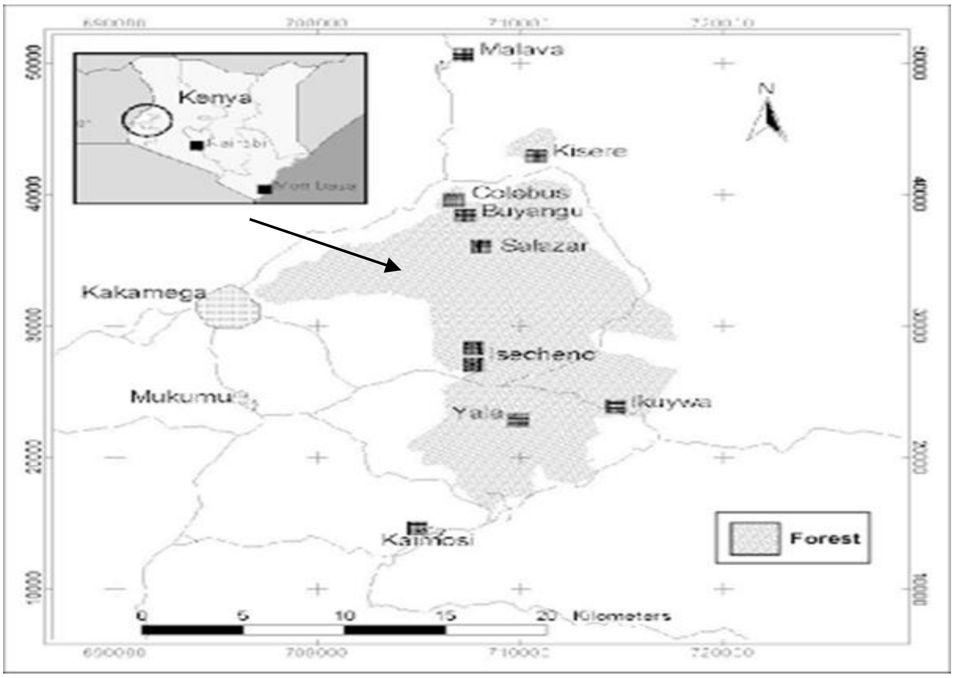

Figure 2. Showing the location of Kakamega forest
Source: Kakamega Education Environmental Programme

The Kakamega forest has high biodiversity and host indigenous tree species such as *Elgon teak, Prunus africanus, Croton megalocarpus, Albinzia gummifera, Bosquie aphoberos, Fantuma elastic, Annigera altisima* the rest being shrubs, grassland or cultivated areas(Genday, 2006 & KFE Management Plan, 2012- 2022). Currently ,the trees remain threatened .Higher point like Buyangu and Lirhanda hill, the forest appear as a strike green beautiful landscape with fewer forest structure , gaps in the forest canopy which allow for succession and maintenance of species diversity(KEFRI, 2010).

The socioeconomic of the study area include the support of the densely rural and urban population of 600 people per square Kilometers (KNBS 2009). The settlers practice mixed crop system (maize, beans, vegetables, corns, beans and potatoes) (KF Survey 2008) and also rear livestock such as (sheep, goats, cattle, pigs). Majority of the population are living at poverty levels with continued extraction of forest resources to meet their daily family basic needs (medicinal ,herbs, fuels animal grazing, land for settlement , timber among others) has undermined the economic growths and deterioration of the biodiversity in the forest(Vuyiya *et al.*, 2014). In the recent past, parts of the forest look heavily degraded zone dominated by grasses, shrubs here termed as grass zone or glades (ICIPE, 2014; KEEP, 2016). Outside this zone there is less disturbed zone consisting of early colonizing shrubs and few tree seedlings. Due to the past selective logging the forest is dominated by pioneer species (gap species) like *tabernaenontanas uregadaprocera (Euphobiaceae, xymalos monospora (momimiaceae*) (Kohler, 2004). Being a tropical rainforest many studies in the area have focused on the effect of human activities on the tree species , another recent studies have shown the forest still experience severe degradation in the past decades, (ICIPE, 2014, ; KEEP, 2016). However, the buffer zone regimes have been integrated as a forest management to reduce the direct independent on the forest resource by supplementing the local community with alternative source of their basic needs so as to protect the rich biodiversity from disturbance. Yet, the influence of Buffer Zone Regimes on the protected tree species richness, and density is unknown.

The climate is related to Lake Victoria which is an important source of precipitation. Annual average between 1500-2000 mm rainfalls is sufficiently high and well distributed throughout the year to support rainforest (Nambiro 2000). However, data from meteorological station at Isecheno shows the forest has warm and wet climate and experience two rainy seasons. April-May and August-Sept with peak in August and has mean daily temperature of 11degrees with range of 5-26’0c (Tsingalia, 1988).it has a varied topography with altitudes ranging from 1250 to 2000m above sea level (Vuyiya *et al.,* 2014).

The geology of the study area Kakamega Forest consists of a wide variety of underlying rocks which include basalt, phenollites and ancient gneiss which are nerved with gold bearing quartz vein (KIFCON, 1994).Soils are fertile clay-loam soils belong to latosols more precisely to the frivols (schiultka, 1995).Soils are well drained, very deep, reddish brown to yellowish red with humic top soil that support large numbers of forest plant species (Tsingalia, 1988). Tea does well in acidic volcanic soils. Habitats within the forest include indigenous forest, swamp and riverine forest, colonizing forest forestry plantations area (Mitchell, 2004) and are dominated by evergreen hardwoods trees and natural grass glades. Closed canopy of indigenous forest cover 30% of the forest. Planted exotic trees such as eucalyptus have also been planted in areas where soils were not ideal for tea survival (Mbuvi *et al.*, 2015).

2.1.2 Sampling and Data

The study population of the buffer zone regimes area was known whereas the study population of the trees was unknown. Cross sectional descriptive research design was used. The design was employed because it allowed for studying trees in their natural state. The design allowed for future detailed investigation on key variable studied and gave an opportunity to gather in-depth information about the variables. This was an appropriate method for this study since the units of analysis; the trees and buffer zone regimes were already in the study area and could be studied within the shortest time possible. The actual data about the buffer zone regimes area and number of tree species richness and density was not inexistence. Saturated sampling was used to sample at least 40 accessible plots as appropriate area after reviewing literature on appropriate sample sizes that have been used by other researchers elsewhere. The distance and area studied was regarded adequate following the studies by (Andreas *et al.*, 2015) used at least a distance of sample sites as 30m and plots of 30m x30m away whereas (Mbuvi *et al.*, 2015) opted for a distance between of 20m away and minimal sample plot of 20m x 20m and maximum plot of 80mx80m from the forest edge to be adequate for plots to assess edge effects. There is evident in variation of sample plots of BZR appropriate in examination of the tree species richness protected, the studies distance and area being more than 20mx 20m and about 100mx 100m. This study therefore relied on saturated sampling of accessible 40 plots in adjacent BZR to the interior of the forest at least a distance of 80m away and highest quadrant area as 80m x80m area as adequate sampling size for the tree species richness and density in the study area.

The measurement tape was used to estimate the regular square plots of based on their location and researcher's convenience with the starting plot of 2mx2m which increased at an interval distance of 2m from the previous plot along the transect to get the adequate sample of 40 plots for analysis of trees within the study area. Global Positioning System (GPS) coordinates helped in avoiding repetitive sampling of the area studied.

Data used in this study were obtained between 20th March to 20th April 2017. Primary data collection methods adopted were observation, measurement, counting and recording. These methods were appropriate for the data collection because the data to be collected could be obtained by measurement (area of plots from edge of BZR into forest interior), counting of tree species richness within the plots and observation of the buffer zone regimes (open edge, exotic tree plantation, Nyayo tea zone) and trees.

Buffer zone regimes area was estimated from the regular square plots which increased at an interval distance of 2m from the previous plot along the 100m transect placed vertically from adjacent BZR to forest interior, to get the adequate sample of 40 plots for analysis of trees within the study area. To find out the plot following the formula adopted by (Scott, 2000) for calculation of square plot obtained as follows:

$$A = sxs$$

The trees in the forest were regarded as woody perennial plant having a single stem or trunk growing to a considerable height of 5m above the ground determined by inclinometer an applied by (Moe *et al.*, 2009). The trees species richness within the plots were identified and counted by the two research assistant where one was a local Para taxonomist and the other one from the Kenya Forest Service staff. The plot method followed the works of (Beaudrot *et al.*, 2011 & (Kaspari *et al.*, (2014) and the nomenclature followed the works of Agnew and Agnew (1995) and Beenjte *et al* (1994) and the sampling approach applied.

The plots area method was settled by the study as appropriate for estimation of tree species richness in each of 40 plots area established and counting of trees that was labor intensive. The plots area applied had been used elsewhere by (Thorell & Gotmark, 2005) 10, 15, 20, 25, 30, 35, 40, 45, 50. Mbuvi *et al.*, (2015) opted for a distance between of 20m away and minimal sample plot of 20m x 20m and maximum plot of 80mx80m from the forest edge. Andreas *et al.*, (2015) used at least 24 plot of variable length along 30m x30m transect. The current study therefore relied on saturated sampling of accessible 40 plots in adjacent BZR to the interior of the forest along string of 100m away and highest quadrant area as 80m x80m area. The individual tree species were counted in each plot. This was done at least twice on each plot to obtain the average number of trees per plot after then taking a total of all average number of trees per plot area for all the 40 plots and dividing by the whole plots area to get tree density.

2.2 Analytical Methods

The total numbers of tree species richness from the 40 plots accessed in each BZR area adjacent to the forest were recorded in the frequency table. With all the BZR area (OE, ETP, NTZ) as independent variable and the protected tree species as dependent variable were subjected to simple linear regression which was developed in statistical package for social sciences (spss, version 16.0, Microsoft inc.) programmed. To determine the best regime that had the highest tree density of protected tree species richness. The data of tree species richness was divided by the total area from the plots adjacent BZR area surveyed. This gave a set of 3 densities that were subjected to anova analysis of variance and the significant means were separated by Kruskal wallis test to show the significant difference at p≤ 0.05.

3. RESULTS AND DISCUSSION

The influence of buffer zone regimes area on the protected tree species was analyzed. The results are in Figure 4.1

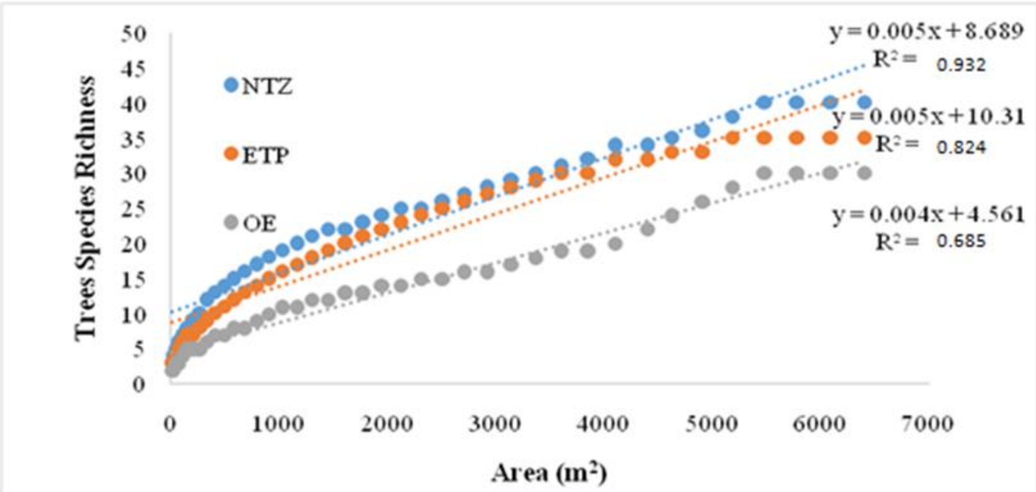

Figure 4.1. Scatter plot showing the line for linear regression results betweeen BZR area on tree species richness. OE stands for Open Edge ; ETP, Exotic Tree Plantation; NTZ, Nyayo Tea Zone.

There was a positive linear regression relationship between OE area and tree species richness (OE 68 % (r^2 = 0.68, p = 0.000), (Figure 4.5). The results demonstrated that in the OE 68 % of the variation of tree species richness could be accounted for by BZR area and 32 % of the variation of tree species can be explained by other factors which were not considered in the study (Figure 4.5). There was also a positive linear regression relationship between ETP area and tree species richness (ETP 82% **(**r^2=0.82, p = 0.000) (Figure 4.5). The results revealed that 82% of the variation of tree species richness can be accounted for by BZR area and the 18 % of the variation can be explained by other factors not considered in the study (Figure 4.5). There was also a positive linear regression relationship between NTZ area and tree species richness (NTZ 93% **(**r^2=0.93, p = 0.000) (Figure 4.5). This indicated that NTZ seems to be dominant factor with 93% explaining the variation of tree species richness and only 7% of the variation can be accounted for by other factors not considered in this study (Figure 4.5).

Variation of buffer zone regime area and the number of tree species richness as demonstrated by slope of the regression lines figure 4.5 implied that as the BZR area increases, the number of tree species richness increases in the OE, ETP, and NTZ. Probably in the OE area was exposed to erosion disturbance and hence minimal chance of trees survival in the forest. Seemingly, this explains why only 68 % variation could be accounted for by area. In the ETP, the 82% variation of tree species could be attributed to the fact that despite the less exposure to erosion disturbance, the ETP supported the large taller trees that formed a sub canopy microclimate which enhanced more tree species richness as compared to OE. In NTZ area seems to be dominant factor 93 % explaining the variation could be attributed to despite controlled erosion disturbance, NTZ created a sub canopy microclimate which enhances establishment of more trees. In addition NTZ improved on the aeration, drainage and increased plant biomass hence increased survival of more tree species richness.

The study findings in Figure 4.5 are in accordance to that of (Rie, 2004) who reported that increased erosion disturbance in the forest adjacent to OE. Deerlaeminek *et al.*, 2005 & Porter *et al.*, 2012 noted that increased erosion disturbance minimizes chances of trees survival and therefore reduced number of tree species richness. Bernitez & Malvado *et al.*, 2014 & Norman *et al.*, 2016 further asserted that despite of increased erosion in the OE, other factors coupled with erosion such as seed dispersal to far distance contributes to less establishment and growth of woody species in the OE (Norman *et al.*, 2016). Further findings by (Laurence 1997 & Karanth *et al.*, 2013) reported that increased erosion disturbance contribute to lose soil nutrients that are important for tree growths. However, in contradicting findings (Moe, 2009) who reported increased number of tree species richness in the sampled OE introduced with crop farming at the

BZR as compared to completely disappearance of some tree species in OE. Thus, presence of low species richness in the OE is hinted by increased erosion due to increased soil disturbance, poor aeration, drainage and loses of soil nutrients.

USAID 2000; Colley *et al.*, 2009; Pinto *et al.*, 2009, noted that trees growing in forest adjacent to ETP, were less exposed to erosion disturbance than those in the OE. Gilbert *et al.*, 2010 further revealed that establishment of ETP in the BZR supported larger trees with taller structure that minimized chances of erosion disturbance (Colley *et al.*, 2007; Vollan 2008; Pinto *et al.*, 2010) and that created sub canopy microclimate that enhanced improved growth of tree species richness than those in the OE (Allisop *et al.*, 2007, CBD 2008; Bennet & Saudine 2011; Joseph *et al.*, 2011). The reduced erosion disturbance by ETP has been coupled with improved aeration and drainage. However, in a contradicting findings by (Otichillo 2000; Collins 2006; NEMA 2009) reported complete disappearance of predominant tree species following the harvesting of ETP at the BZR in Mau forest. Moreover other studies (Gosling *et al* 2012; Saijo & Tundis 2012; Ali *et al.*, 2013) have argued that some huge uptake of water by blue gums deprives moisture for some indigenous trees species hence low species richness as compared to NTZ. Further findings (Gascon *et al.*, 2010; Cambi *et al.*, 2015) noted that some indigenous species are intolerant to shade due to dense canopy closure by ETP species leads to complete disappearance of some species and hence the 16 % of the tree variation that could be explained by other factors. Thus the ETP ensures protection of soil against soil erosion thus ensuring more tree species richness as compared to OE.

Tea plantation has been advocated by other study (Adhikari 2012) in Nyungwe national park , who revealed that NTZ protect soil erosion leading to increased soil nutrient hence improved growth of tree species richness. Similarly other study in Ghana (Laurence *et al.*, 2002; Kraus *et al.*, 2004) postulated that cocoa farming in the BZR creates sub canopy microclimate favorable for controlled erosion disturbance, improved drainage and aeration hence high tree species richness (Govenne *et al.*, 2007; Dalling *et al.*, 2016). Moreover, other related studies in Taita hills Kenya (Cagnalo *et al.*, 2006; Wekesa *et al.*, 2018) further asserted that cash crop farming in adjacent forest edge contributes to significantly high plant biomass on decomposition due to constant available moisture leading to improved soil nutrients hence high tree species richness. According to (Bennet &Saudine 2011; Joseph *et al.*, 2012; Fieschman 2014) the improved nutrients implied that better aerated and drained soil offer favorable and moderate moisture conditions for growing trees compared to OE, hence (Wekesa *et al.*, 2016) thus high tree species richness in the region under study. Therefore the presence of tea plantation plays an important role in enhancing tree species richness growths and development.

Therefore, there is enough evidence to reject the null hypothesis that buffer zone regimes area (OE, ETP, NTZ) areas do not influence the number of protected tree species richness. As buffer zone regimes area of both NTZ and ETP significantly ($p \leq 0.05$) influence the higher number of tree species richness than open edge area in Kakamega forest the study area. This study finding suggested that NTZ is the better in supporting tree species richness within Kakamega forest as compared to ETP. However, for better protection of high tree species richness the study suggested the enhancement of either NTZ or ETP in the OE.

4. Conclusion and Recommendation

The study also concluded that BZR area have influenced the number of the protected tree species richness. It was found out that both NTZ and ETP gave significantly higher protected tree species richness as opposed to OE. This implied that both NTZ and ETP protected the trees against extractive activities on trees. It was evident that both NTZ and ETP prevented soil erosion, increased soil moisture content and prevented seeds dispersal to far distance. These supported the highest number of tree species richness protected. Thus, for the purpose of protecting tree species richness, NTZ and ETP should be enhanced in the OE area for better protection of tree species richness in the study area Kakamega forest.

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