

Vegetation Composition and Natural Regeneration in a Tropical Montane Forest Following Anthropogenic Disturbances

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Abstract

The Mau complex in Kenya is a range of highlands covered by natural forests known as South -West Mau, Eastern Mau, Ol'donyo Purro, Transmara, Maasai Mau, Southern Mau and Western Mau. The Western Mau Forest is located at an altitude between 2,000 and 2,600 m and between latitude $0^{\circ} 10' 46''$ S to $0^{\circ} 17' 42''$ S and longitude of $35^{\circ} 27' 05''$ E to $35^{\circ} 39' 42''$ E. The Mau complex is an important source of many rivers that flow into Lake Victoria basin, yet it has been under pressure for conversion into farmland. A study was carried out on the vegetation composition, regeneration and anthropogenic disturbances. The study was conducted using 500 m long and 2 m wide belt transects in forest zone, 30 m long, 5 m wide transects both in transition zone and grasslands. The forest zone transects were subdivided into 50 m by 2 m subplots, transition and grassland zone transects were subdivided into 5 m by 5 m subplots. In all subplots, a 1 m by 1 m quadrat was placed at the centre. Data were collected on occurrence of fern, liana, shrub, seedling (< 1 cm), sapling (DBH 1 -9.9 cm) and tree (DBH ≥ 10 cm) species. The data were used to calculate abundance, diversity and regeneration. The data were analyzed using analysis of variance and chi-square statistic. Shannon-Weiner index was used to quantify species diversity. Two hundred and twenty three (223) vascular plant species belonging to eighty three (83) families were identified. The Asteraceae had the highest number of species (18) followed by Fabaceae (17). Forty (40) families had a single species each. There were more plant species in the transition zone than forest and grassland zone. The forest was dominated by seedlings and saplings (DBH ≤ 3 cm); the diameter size distribution was reverse J-shaped, indicating that the forest has a good regeneration potential. Species diversity was significantly higher in the forest (3.5 to 4.5) than transition zone (2.0 to 3.5) or grassland (1.5 to 3.0). There was a significant human disturbance, and this affected the species composition, diversity and forest regeneration.

Keywords: Western Mau Forest, Vegetation Composition, Conservation, Natural Regeneration

Introduction

Conservation of natural vegetation is currently one of the leading agenda for a number of world conservation organizations, authorities and interest groups (UNDESA, 2004). The concern over vegetation conservation generally stems from the anthropogenic activities that lead to depletion of forest resources (Ramirez *et al.*, 2001; Reyers, 2004). In the face of these problems, ecologists and conservation biologists have proposed the protection of forest vegetation using several strategies that range from strict protection in the national parks to suitable management and other integrated conservation and development programs (Borgerhoff & Coppolillo, 2005).

The Western Mau Forest, which is one of the blocks in Mau complex, provides critical ecological services to the country, in terms of water source; river flow regulation; flood mitigation; recharging groundwater; reduction of soil erosion and siltation; conservation of plant biodiversity and micro-climate regulation. Through these ecological services, the Western Mau Forest supports major economic sectors in Rift Valley, Western and Nyanza provinces of Kenya, including energy, tourism, agriculture and industries (DRSRS & KFWG, 2006). In spite of multiple uses, values and functions associated with the forest it has been a subject of encroachment and unregulated resource extraction. Similar destruction has been noted for other natural forests throughout the world, such that many of them might disappear before some of the species are properly studied, catalogued, used or domesticated (Hitimana, 2000). This could lead to instability of ecosystems and reduced availability of various forest products and services (Alemu & Bluffstone, 2007).

Materials and Methods

The research was carried out in Western Mau Forest block in the south Rift region in Kericho County (Figure 1). It is located at an altitude between 2000 and 2600 m; and between latitude $0^{\circ} 10' 46''$ S to $0^{\circ} 17' 42''$ S and longitude of $35^{\circ} 27' 05''$ E to $35^{\circ} 39' 42''$ E. It is managed by Kenya Forest Service and covers about 22,712 hectares of indigenous forest.

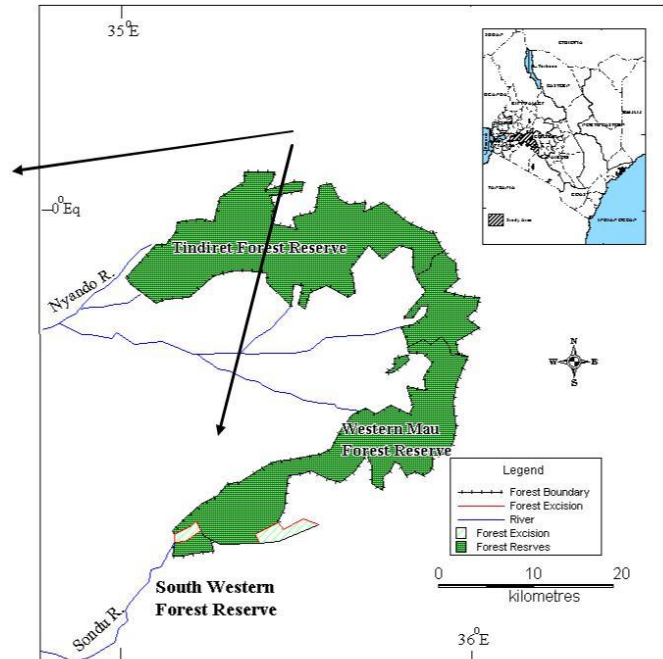


Figure 1. Map of Western Mau Forest, Kenya

The forest was divided into three study sites; Site 1 (Masaita and Mt. Blackett blocks), Site 2 (Kerisoi and Londiani blocks), Site 3 (Kedowa and Kericho blocks). Stratified sampling method was used in each site, where the study area was subdivided into relatively homogenous parts of grassland, transition and forest zones.

Sampling Procedures

Forest, Transition and Grassland Zone Sampling

The belt transect method was used in the forest zone. Transects were randomly established using a table of random numbers. The belt transects were 2 m wide and 500 m long (Kent & Coker, 1992) and each transect was subdivided into ten subplots of 2 m by 50 m and in each subplot a 1 m by 1 m quadrat was set at the center. In the transition and grassland zone, belt transect method was applied. Transects were randomly established using a table of random numbers. The transects of 5 m wide and 30 m long, were then subdivided into six 5 m by 5 m subplots; each having 1 m by 1 m quadrat positioned at the center. All non-herbaceous plant species in the subplots were identified by scientific name and counted. The count of each individual species was used to calculate the density and relative density of the species. In every quadrat within each subplot all ferns and herbs were identified by scientific names and subjective percent cover recorded. The percent cover was used to calculate the abundance of species.

Assessment of Plant Species Composition and Diversity

All the plant species from the forest, transition and grassland community were identified to the species level. Nomenclature followed Agnew and Agnew (1994) and Beentje (1994). Unstructured sampling was used to record additional species not represented in the sample plots. The total number of each species in the various forest sites was used to calculate Shannon -Weiner diversity index (Pielou, 1975).

Assessment of Regeneration

Regeneration and recruitment trends were determined by taking measurements on diameter at breast height (DBH) of mature trees, saplings at 1.45 m above ground level (Mueller and Ellenberge, 1974) and the count of seedlings along the belt transect from the forest community, transition zone and plots from grassland community. It was being categories as;

1. Seedlings (height < 1.3 m)
2. Saplings (DBH 1 – 9.9 cm and height > 1.3 m)
3. Mature trees, diameter classes (DBH >10 cm)

The DBH for mature trees and saplings were measured using a diameter tape. Densities and relative densities of seedlings, saplings and mature trees were calculated and regeneration and recruitment trends inferred.

Assessment of Human Impact

The human impact was determined by recording the following anthropogenic disturbances signs; footpath, charcoal burning, tree cutting, fire, grazing, and debarking as described by Silori, (2001) and Silori and Mishra (2001). The intensity of these human activities was determined by Likert's scores ranging from 1-5 where 1 represented least disturbance while 5 represented high disturbance (Likert, 1932). The scores were summed up and overall disturbance index calculated using the formula;

$$\text{Disturbance Index} = \frac{\text{Disturbance score}}{\text{Total maximum score}} \times 100$$

Total maximum score was obtained by multiplying number of disturbances with maximum score.

Data Analysis

All statistical analyses were performed using STATISTICA 6.0 (StatSoft, 2001). Normality and homoscedasticity of data distribution was checked by means of the skewness and kurtosis (Zar, 2001). Spatial variation in plants abundance was analyzed using one-way analysis of variance, and plant abundance among sites in different zones was analyzed by two-way analysis of variance. Differences in plant species composition was analyzed using Chi-Square test. All statistical analyses were done at 95% level of confidence.

Results

Plant Species Composition

A total of 223 vascular plant species belonging to 83 families were identified and documented from the study area (Appendix). The number of species per family differed significantly in the forest ($\chi^2 = 154.618$, $df = 82$, $P < 0.05$). The major families were Asteraceae with 18 species, Fabaceae with 16 species, Euphorbiaceae with 11 species and Rubiaceae with 10 species. Some 41 Families were represented by a single species each.

Plant Species Abundance

The abundance of non-herbaceous plant species sampled in Western Mau Forest is shown in Figure 2. There were highly significant differences in the plant forms encountered during sampling ($\chi^2 = 1259.589$, $df = 4$, $P < 0.05$). The most abundant plant form was shrubs followed by seedlings and saplings and palms were the least in species composition.

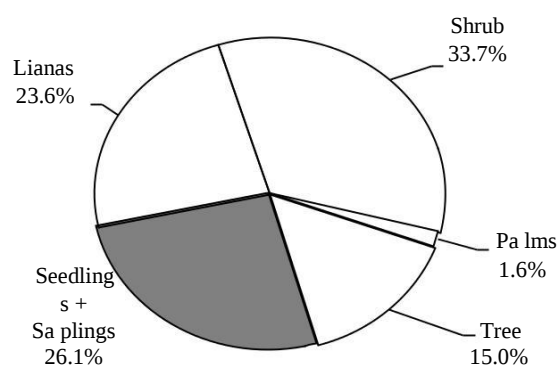


Figure 2. Non-herbaceous Plant form Abundance of Species Sampled in Western Mau Forest

The overall abundance of non-herbaceous plant species among sites and at different sampling zones is presented in Figure 3. There were significant differences in plant species abundance among sites and zones ($P < 0.05$). In Site 1, the highest species abundance was recorded for the forest, whilst in Site 3 the transition zone had the highest plant species abundance. On the other hand, Site 2 had no significant differences in the plant species abundance among sampling zones.

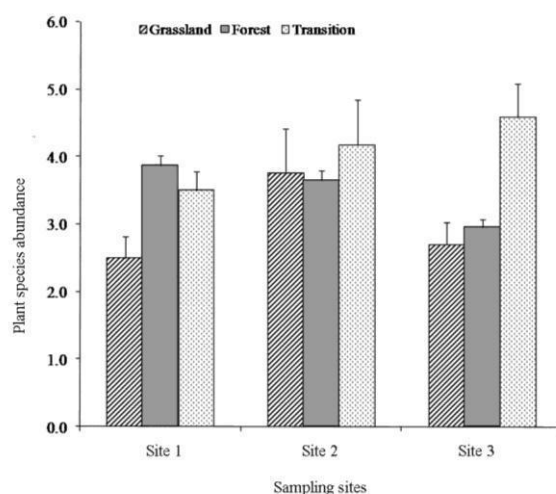


Figure 3. Overall Plant Abundance in the Three Sampling Sites

Species Diversity

Species diversity in the three sampling sites is presented in Table 1. The highest species diversity occurred at the forest zone in Site 1 ($H' = 4.05$), Site 2 ($H' = 3.98$) and Site 3 ($H' = 3.90$) with the lowest species diversity being grassland zone at Site 1 ($H' = 1.77$).

Table 1. Shannon-Weiner Diversity Index for Plant Species in the Western Mau Forest

Sites	Zones	Shannon-Weiner Diversity indices
Site 1	Grassland	1.77
	Forest	4.05
	Transition	3.10
Site 2	Grassland	2.29
	Forest	3.98
	Transition	2.47
Site 3	Grassland	2.62
	Forest	3.90
	Transition	3.30

Forest Regeneration

The diameter breast height of the forest is shown in Figure 4. There were significant differences in the DBH in the three sites ($P < 0.05$). DBH was dominated by trees of < 3 cm and decreased thereafter in the forest. The diameter distribution followed the reverse J-curve.

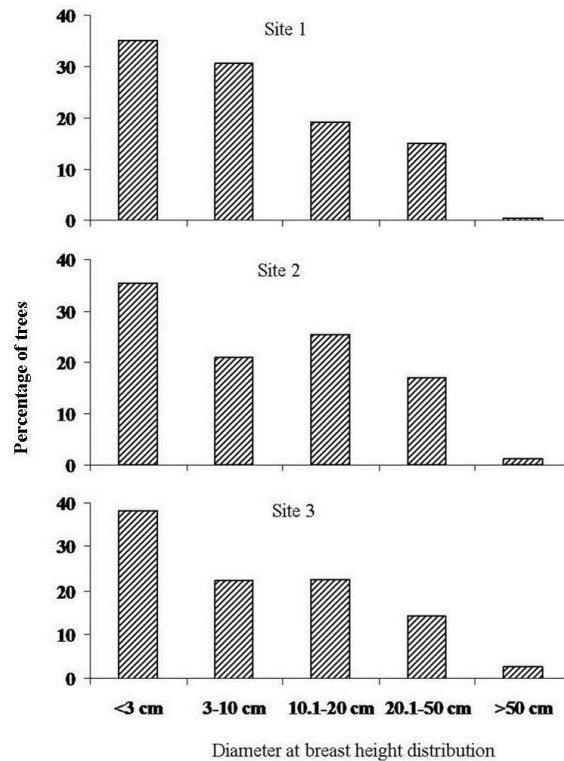


Figure 4. Diameter at Breast Height (DBH) of Trees in the Forest of Western Mau

Anthropogenic Disturbances

The various types of human disturbances in the forest habitats are presented in Table 2. The most common form of disturbance was grazing, followed by footpaths and tree cutting. The event that had the least disturbance in the forest was charcoal burning. Site 3 was the most disturbed in the forest zone followed by Site 2. Site 3 was the most disturbed site in the transition zone whilst Site 1 and 2 had the same disturbance index. Site 3 was the most disturbed site in the grassland zone followed by Site 2, whilst Site 1 was the least disturbed.

Table 2. The Scores of the Various Types of Human Activity in Western Mau Forest

	Site 1			Site 2			Site 3			Disturbance intensity	Disturbance index
	Grassland	Forest	Transition	Grassland	Forest	Transition	Grassland	Forest	Transition		
Charcoal making	0	0	0	0	0	0	0	3	0	3	10
Tree cutting	0	4	2	0	4	0	0	5	4	19	63.33
Footpath	1	3	1	3	1	1	5	1	5	21	70.00
Fire	0	1	0	0	0	0	0	1	0	2	6.67
Grazing	4	0	2	3	2	4	5	4	5	29	96.67
Debarking	0	2	0	0	4	0	0	5	0	11	36.67
Disturbance intensity	5	10	5	6	11	5	11	20	14		
Disturbance index	16.67	33.33	16.67	20.00	36.67	16.67	36.67	66.67	46.67		

Discussion

Species Composition, Abundance and Diversity

In this study, the species composition of Western Mau Forest was determined; it was established that there were 223 vascular plant species. The high number of species could be due to disturbance in the forest. Forest disturbance has been observed to stimulate establishment of varied species (Franklin *et al.*,

2002). It could also possibly indicate that the forest has an ideal habitat for floral growth and reproduction. This is because of high humidity witnessed in the forest during sampling; vegetative growth is more likely to be encouraged (Odum, 2008). Asteraceae was the most dominant plant family in the forest. The presence of Asteraceae in the forest can be attributed to their successful wind and animal dispersal (Franssen *et al.*, 2006). Members of the Asteraceae are typical indicators of disturbance (Umberto *et al.*, 2010).

Plant species richness, abundance and composition differed substantially among the zones in the Western Mau Forest. The species composition of the different functional groups was fairly well-separated among zones, mainly because several species were strictly associated with the different ecological zones. This supports previous findings that after establishment, species form distinct combinations, depending on the suitability of small-scale environmental conditions (Myer, 2004). The results also showed that there were significant differences in sapling richness and abundance between the grassland, transition zone and forest zone. However, species richness and abundance of adult trees were high in the transition zone and forest zone, suggesting that previously disturbed areas transitioned towards forest type structure and composition. The transition zone and forest zone had higher plant dominance than the grassland zone, probably due to more intense grazing pressure in the grassland zone (Ostertag & Verville, 2002).

The highest species diversity occurred in the forest zone followed by transition zone whilst grassland had the lowest species diversity. The differences in the species diversity in Western Mau Forest can be attributed to differences in anthropogenic effects. In the grassland zone there was intense grazing which may have led to loss of some species. Plant diversity is enhanced through periodic disturbance of plant communities (Rogers & Ryel, 2008).

Forest Regeneration

The study showed gradual increase in species richness and abundance of tree seedlings, saplings and adult trees from the grassland zone towards the forest zone. This could indicate recovery in degraded natural forest (Duarte *et al.*, 2006). The analysis showed that, there were high frequency values in the lower DBH classes and progressively decreased to higher DBH class in all the three sites. The pattern had more individuals at seedling stage and decreasing number of individual successively at sapling and adult stages. This exhibited reverse J-shape curves but not perfectly in Site 2 and Site 3, typical of uneven-aged mixed forests. The reverse J-shape pattern signifies that the forest has a good regeneration potential (Meyer, 1952).

There was a higher density of trees at lower diameter classes compared to larger diameter classes. These results are similar to many previously reported findings. Sherma and Kumar (1992) and Geldenhuy and Murray (1993) reported that logging reduced the density of larger diameter class trees. This could result from slow recruitment of the residual trees in the lower diameter classes into higher ones after logging, because indigenous trees grow slowly (KFMP, 1994). Uncontrolled and continuous exploitation of the forest trees for timber and fuel wood by the surrounding settlements could also cause slow recovery of the forest. Extensive logging in the forest could therefore be increasing the diameter distributions in favour of the tree species with lower diameter at breast height (DBH) (Campos, 2001).

Human Disturbance

Although Western Mau Forest is under Kenya Forest Service (KFS), currently, the conservation status of the forest is at a very low status. Forest conservation has never been a concern for the local communities as the local people view a forest as a source of fuel wood, and a hindrance to cultivation. At the present, the largest proportion of this forest has been cleared for cultivation.

In this study, six factors were found to be the key agents of disturbance within the forest ecosystem. These include; tree cutting, charcoal making, footpaths, fire, grazing and debarking. The expanding rural population in the area which utilizes plant material from the forest for construction, fuel and charcoal, threatens the forest. One of the major activities of the local people being livestock production, the forest provides grazing area to the local communities. Grazing is likely to influence soil and above ground vegetation, which may significantly impede forest regeneration, particularly recovery of species composition. As an example, Haggard *et al.*, (1997) and Posada *et al.*, (2000) reported that severe reduction in regeneration of trees and shrubs in pastures were due to intensive browsing by livestock.

The footpaths and animal trails were evidence of easy human access in the forest, and usually bring about the trampling of seedlings and soil thus affecting forest regeneration (Serna, 1986). Disturbance levels seemed to decrease with distance from villages, indicating that the pressures of illegal logging, harvesting and other human impact were closely connected to accessibility and transport cost.

Conclusion

Western Mau Forest had high species diversity, that is, 223 species of vascular plants belonging to 83 families were recognized. Species diversity and richness varied among the zone types. The density of tree species in the forest decreases with increasing DBH, which implied the predominance of small sized individuals in the lower classes than in higher classes indicating good recruitment of the forest. Protection of the Western Mau Forest seems nominal; there is no proper management plan in place and no enforcement of the rules. There is a high rate of destruction because of the frequent visits of the people from nearby villages for fuel, fodder, wood for construction and other forest products. This has resulted in the depletion of the forest, thereby causing damage to plant diversity in the area.

Recommendations

The forest requires more strict protection if continuous forest regeneration are to be maintained. Relying on forest guards to protect the forest is not adequate if not ineffective. There is therefore a need to revise or improve the system currently being used to protect the forest. This may include involving the local people in efforts to conserve the forest.

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