

STAND COMPOSITION, FLORISTIC AFFINITIES AND PLANT FORMATIONS IN MAU FORESTS

**Festus M. Mutiso¹, Mware J. Mugo², Joshua Cheboiwo³, Francis Sang⁴ & George K. Tarus⁵*

¹South Eastern Kenya University, School of Environment & Natural Resources Management, P.O. Box 170-90200, Kitui

²Karatina University, School of Environmental Studies and Natural Resources Management, *P.O. Box 1125, Karatina*

³Kenya Forestry Research Institute, P.O. Box 8, Londiani

⁴University of Eldoret, School of Natural Resources Management, P.O. Box 1125, Eldoret

⁵Kenya Forest Service, P.O Box *823-0006, Nairobi*

ABSTRACT

The Mau ecosystem post-disturbance recovery process, integrity retention and resilience to future disturbances and sustainability remain unknown. In this paper, the ecosystem floristic composition, richness, diversity and affinities are evaluated. Diameter at breast height (dbh) of mature trees was measured and disturbances recorded in plots, dbh of saplings measured in subplots and seedlings count in microplots. To obtain the floristic composition and richness, we categorized species based on their families, development stages and life forms. Species density and quantity-measured diversity index (H') were used to evaluate the species diversity. Jaccard (JIA) and Sorensen(S) similarity indices were used to calculate the species similarity between survey sites. Trees, Shrubs and climbers recorded belonged to 52 species, 45 genera and 31 families for seedlings; 43 species, 38 genera and 29 families for saplings and 55 species, 48 genera and 31 families for mature stems. The most species-rich family was rutaceae with six species followed by moraceae and flacourtiaceae with five. Anacardiaceae had 4 while rubiaceae and euphorbiaceae had 3 species each. Western Kedowa had the highest species diversity. Eastern Mt. Blackett had the lowest species diversity. Northern and Western Kedowa were the most similar pairs followed by Eastern and Western Mt Blackett and Western Kedowa and Southern Mt. Blackett. Past and present disturbance are the main cause of low number of species per family. We attribute the low diversity observed in Mt Blackett sites to aggressive proliferation of the invasive; *Trichocladus ellipticus*, which has modified natural regeneration patterns resulting close to an individualistic successional pathway. In conclusion, the sites represent different plant formations and thus floristically, they are dissimilar but at varying degrees. The post-disturbance recovery on different sites is following different trajectory successional pathways. There is lack of species co-existence under natural environment due to the presence of invasive species. We recommend that the on-going disturbances should be curtailed to promote regeneration and successful

recruitment of non-pioneer species. Rehabilitation efforts should be based on the understanding of post disturbance floristic affinities and species mosaics.

Authors' Keywords: Mau Ecosystem, Floristic Composition, Species Richness, Diversity and Similarity indices

INTRODUCTION

The disappearance of tropical forests at an estimated rate of 1 - 2 % per year comes at a time when our knowledge of their structure, composition, dynamics, diversity and taxonomy has been not fully unraveled (Krishnamurthy *et al.* 2010). Kharkwal *et al.* (2005) opine that accelerated species loss could lead to collapse of some ecosystems. Successful implementation of ecosystem management requires strategic forest management planning, including the ability to forecast future forest composition (Taylor *et al.* 2009). Predicting plant community compositional change is a key challenge for ecologists and resource managers (Ibanez *et al.* 2009; Taylor *et al.* 2010).

Understanding post-disturbance stand composition and plant formations give insights into the future ecosystem integrity, resilience and sustainability. Gaaf (1986), Finegan and Camacho (1999) and Kumar (2001) caution that post-disturbance departure from natural regeneration patterns is detrimental to future ecosystem sustainability.

Mutiso *et al.* (2011) cite alteration of cyclic and parallel configuration processes of the Mau ecosystem by disturbances and its implication on future stand resilience. It is important for forest managers to identify and understand post-disturbance stand successional trajectory pathways. This enables the managers to isolate different plant formations representing different management units with botanical uniqueness (UNO, 1994). Management should take action against large-scale post-disturbance departure from natural successional pathways. It is, however, worth to note that any action taken to aid in rehabilitation should mimic the natural processes (Gaaf *et al.* 1999, Finegan and

Camacho, 1999, Gendreau-Berthiaume *et al.* 2012). Further, Bergeron *et al.* 1999 stress the importance of forest management based on natural disturbances to cushion ecosystems against collapse. Post-disturbance lack of species co-existence under natural regimes (Armesto *et al.* 2009) and individualistic successional pathways (Taylor *et al.* 2009, Mutiso *et al.* 2011) should be identified. Management need to understand the ecosystem threshold responses after disturbances. Note that Kumar (2001) and Mutiso (2009) and Burton *et al.* (2010) caution that if disturbances are beyond a certain critical limit, the ecosystem can “flip” off into an alternative state to the detriment of all the biota inhabitation.

Regaining pre-disturbance stand composition and diversity gives the ecosystem the much needed high redundancy and resilience to future disturbances. High ecosystem redundancy cushions ecosystem against species collapse in case of perturbation. Mutangah *et al.* (1993) state that Mau ecosystem may take many years to regain its pre-disturbance stand structure. Similar sediments are shared by Mwangi *et al.* (1991) who described the Mau ecosystem as a sea of *Neoboutonia macrocalyx* with isolated stands of *Juniperus procera* several years after disturbances. UNEP (2009) observed dominance of *Cassipourea malosana*, *Juniperus procera* and *Podocarpus* spp in Mt Kenya forest. Similar observations were made in the upper amazonian forest where species appeared to be restricted to a single forest type (Huang *et al.* 2003). Mwangi (2008) document that though the Mau ecosystem showed signs of recovery after evictions of the “Ndorobos”, it will take along time to regain its pre-disturbance stand structure. Further, there is concern over the recovery process after recent studies; (Mutiso *et al.* 2011) revealed individualistic successional pathway in Mau characterized by invasive species such as *Trichlodus ellipticus*. The study also questioned the aggressiveness and persistent existence of pioneers and invasives 30 years after disturbances. Mutiso *et al.* (2013) document similar invasion of Kakamega and Mt Elgon tropical forests by invasive species after disturbances.

For the ecosystem to regain its pre-disturbance stand structure and diversity, the early successional species should give way to late successional non-pioneers. Managers should understand responses of pioneers and non-pioneers after disturbances (Mesquita *et al.* 2001). Mutiso *et al.* (2011) quote post-disturbance modification of natural regeneration patterns in the Mau ecosystem. It is important for management to understand that the success of non-pioneers life history entirely relies on survivorship of the juveniles and their subsequent recruitment to upper age cohorts. Previous studies in Mau have shown poor recruitment patterns (Mwangi *et al.* 1991 and Mutangah *et al.* 1993). This puts the future ecosystem integrity, resilience and sustainability at stake. The gradients in revegetation and pulses in regeneration as observed in Mau (Mutiso *et al.* 2011) are worth investigating. Rydgren *et al.* (2009) stress the importance of understanding the full complexity of revegetation and processes following disturbances. Further, Frelich *et al.* (1998); Taylor *et al.* (2009) and Krishnamurthy *et al.* (2010) and Beaudet *et al.* 2011, point at the need of developing conceptual models of forest response to changes in disturbance severity. Such models will show equilibrium attractors and give insights on how a given landform will support a successional complex of species after disturbance and whether the expected change will be continuous, discontinuous or cusp.

METHODOLOGY

Description of the Study Sites

The study was conducted in Mt Blackett and Kedowa forest blocks, on the western dip slope of the Mau escarpment, within the larger Western Mau block. The two study sites (Figure 1) lie between 2000 and 2600 m above sea level. Soils are mainly mollic and andosols derived from tertiary volcanic parent materials (Jeatzold and Schmidt, 1983). Within the andosols, inclusions of cambisols occur on the steeper slopes and humic nitrosols. Soils are well drained, shallow to moderately deep clays and well drained, shallow to moderately deep friable clays. Rainfall is high and continuous with

moderately high peaks in April. The mean annual rainfall is 2000 mm. Temperatures vary very little throughout the year, but are closely related to altitude, aspect and sunshine. Mean annual temperatures range from 11 to 16⁰c, with greatest diurnal variation during the dry season.

Figure 1:

Sampling Design and Data Collection Techniques

The two study sites (Mt Blackett and Kedowa) were selected subjectively to represent the disturbed and intact sites of the Western Mau block. In Mt Blackett, four transects were established on the Eastern, Western, Northern and Southern parts of the hill while in Kedowa two transects were established on the western and Northern sides of Kedowa forest (Figure 1). Each transect, measuring 20 m by 250 m was subdivided into 10 m by 10 m plots. A GPS receiver was used to collect UTM coordinates of the corners of transects and the plot centres to aid in future monitoring. The plots were further subdivided into 2 m by 5 m subplots and the subplots subdivided into 1 m by 2 m microplots. Complete enumeration was done on these data collection units.

In each plot, the dbh of all individual stems (dbh \geq 5 cm) in the plot was measured. Subplots were used to capture dbh of all saplings (\geq 1- <5 cm) while microplots were used to facilitate seedlings (dbh <1cm) count. The recorded individual stems were categorized into various life forms: shrubs (< 5cm height at maturity), small trees (5-20m height at maturity), large trees (>20m height at maturity) and climbers. All the data collected were recorded in prescribed field data collection forms.

Methods of Data Analysis

The field data was summarised and organised in tabular form ready for further processing. The scientific names, families and development stages of trees, shrubs and climbers in the two study sites were identified to capture floristic composition. Species were grouped into respective families to

capture species richness. The quantity weighted diversity index (H') was used to compute the species diversity in each transect by application of the **Shannon-Wiener information index (H')**:

$$H' = [N * \ln N - \sum(n_i * \ln n_i)] / N,$$

Where, n_i is the number of individual of species i ; and $N = \sum n_i$

Jaccard and Sorensen similarity indices were calculated to examine the species similarity across the six transects by application of:

Jaccard's index

$$JIA = a / (a+b+c),$$

Where, a = the total number of species in common between site 1 and site 2

b = the total number of species in site 1 but not site 2

c = the total number of species in site 2 but not site 1

Sørensen's similarity coefficient

$$QS = \frac{2C}{A + B}$$

Where, A and B are the number of species in samples A and B , respectively, and C is the number of species shared by the two samples.

RESULTS

Floristic Composition

Table 1:

Trees, Shrubs and climbers recorded in sampled sections of Mau ecosystem (2.8 Ha) belonged to 52 species, 45 genera and 31 families for seedlings; 43 species, 38 genera and 29 families for saplings and 55 species, 48 genera and 31 families for mature stems (Table 1). The table also shows the life form of each recorded species according to Beentje (1994) categorization based on maximum height reached at maturity. In terms of life form, we found that large trees (>20m height at maturity) dominated the forest based on the number of species (40%) followed by small trees 39%: (5-20m height at maturity) while woody shrubs and climbers had 19% and 2% respectively. Species, genera and families were well represented at mature stems stage compared to seedlings and saplings stages. As such 11 species (18%), 8 genera (15%) and 1 family (3%) were missing at seedlings stage; 19 species (31%), 15 genera (28%) and 3 families (9%) were missing at sapling stage and 7 species (11%) 5 genera (9%) and 1 family (3%) were missing at mature stem stages (Table 1).

Species Richness

Table 2:

Majority (53%) of the families and genera were represented by one species while 31% of the families had two species. The most species-rich family was rutaceae with six species followed by moraceae and flacourtiaceae with five. Anacardiaceae had 4 while rubiaceae and euphorbiaceae had 3 species each (Table 2).

Species Diversity

Table 3:

Table 3 shows the area sampled, species number, species diversity (H') and density in sections of Mt. Blackett and Kedowa forests. In terms of the actual number of the species per sample site, Western Kedowa was the most species rich site followed by Northern Kedowa, Eastern Mt. Blackett and Northern Mt. Blackett. Southern Mt. Blackett was the poorest site. Based on the quantity weighted diversity index (H'), Western Kedowa had the highest species diversity while Eastern Mt. Blackett had the lowest. Despite the high diversity in Western Kedowa, the site had the lowest number of stems while Southern Mt. Blackett had the highest (Table 3). Mt. Blackett sites recorded relatively high density compared to Kedowa.

Species Similarity between Survey Sites

Table 4:

According to Jaccard and Sorensen similarity indices, Northern and Western Kedowa were the most similar pairs followed by Eastern and Western Mt Blackett and Western Kedowa and Southern Mt. Blackett.

DISCUSSION

Floristic Composition

The observed low floristic composition at the seedling and sapling stages is an indication of poor establishment and recruitment. Mutiso *et al.* (2011) record ongoing disturbances on the sites that impacted negatively on the regeneration and recruitment processes. Keating (2000) document similar effects on recruitment and floristic composition. A different study in Mau forests, documents a post-disturbance modification of natural regeneration regimes to a more individualistic successional

pathway (Mutiso *et al.* 2011). Such regeneration patterns promote mono-dominant forests with low redundancy (Gaaf, 1986; Gaaf *et al.* 1999 and Taylor *et al.* 2009) and characterized by lack of species co-existence under natural disturbance regimes (Armesto *et al.* 2009). Invasive such as *T. ellipticus*, might have reshaped the stable pre-disturbance regeneration regimes leading to low floristic composition at seedling and sapling stages. Elsewhere in Kakamega and Mt. Elgon forests, Mutiso *et al.* (2013) recorded similar invasion by invasives such as *Solanum mauritianum*. Further, post-disturbance gradients in revegetation and pulses in regeneration are likely to have played a major role in the decline. To regain the pre-disturbance floristic composition in Mau, it is important for management to understand the post-disturbance ecosystem threshold responses. Such information will give insights on whether the successional pathway taken is continuous, discontinuous or cusp. Frelich *et al.* (1998) stresses the importance of understanding post-disturbance successional trajectory of stands and take action to oscillations in composition that may lead to individualistic and irregular regimes rather than any stable cycle.

Post-disturbance establishment is a complex process driven by a series of factors interacting to determine emergence and net recruitment and the achievement of pre-disturbance floristic composition. These include mechanisms such as stochastic processes, neighbour plant interactions (Maestro and Reynolds, 2007; Huang *et al.* 2003; Frelich *et al.* 1999) and abiotic constraints determined by resources such as light, water and nutrients (Cayuela *et al.* 2008 and Taylor *et al.* 2010). Though these factors might have played nominal role, anthropogenic disturbances played a critical role in the observed post-disturbance revegetation process. In a different study in Mau ecosystem, Mwangi *et al.* (1991) singled out the case of grazing and tree poaching as the major disturbances that were greatly affecting recruitment of species. Disturbances have also been known to promote regeneration (Mutangah *et al.* 1993; Fausto and Sarmiento, 1997) but suppress recruitment (Mutiso *et al.* 2011). In all the sites, small trees were mainly targeted for charcoal making as opposed

to large trees. This is likely to have reduced the richness of such lifeform. It is, however, important to note that small trees subdivide habitats more finely than larger trees (Hitimana, 2000) hence expected to be many but disturbances could have altered this trend.

Species Richness

Past and present disturbance are the main cause of low number of species per family. Such alteration of species composition affects the future ecosystem integrity, resilience and sustainability. It is worth to note that in the current study, the most species-rich family (*rutaceae*) had only six species while Mutangah *et al.* (1993), in a study in Mau forests (Kipsangon, Timbili and Nairotia) in early 1990s recorded a higher number of species per family. For instance, in the 1990s study, the most species-rich families were *rubiaceae* (20 species), *compositaceae* (17 species), *acanthaceae* (14 species) and *aspleniaceae* with 14 species. Though the two studies are not authoritatively comparable because they were undertaken in different sites, they can give a general insight on species number decline over time. Having majority of the families and genera represented by one species raises a lot of concerns. High species richness cushions collapse/extinction of a given family/Genera and ensures ecosystem's parallel and cyclic configuration processes are taken over by other species in the family/genera incase of disappearance of a member.

Gaaf (1986) and Finegan & Camacho (1999) stress the importance of maintaining species richness as a strategy against ecosystem collapse following disturbances. Similar sentiments are expressed by Huang *et al.* (2003) who asserts that the species richness-abundance relationship suggests that large populations are less prone to extinction than small ones. There is need to understand the post-disturbance succession process of various plant formations and relate them to forest dynamics. We also suggest that the aggressive proliferation of invasive species such as *T. ellipticus* and wide spread charcoal making (Mutiso *et al.* 2011) could be playing a critical role in curtailing species richness.

Olea species regenerates under shaded conditions but this was not the case under the canopy of the invasive. Further studies could establish whether the species has any allelopathic effects preventing regeneration and co-existence with other native species. It is possible that the invasive may be reshaping the micro-conditions of the sites in favour of its competitive ability under natural conditions.

Elsewhere in Kakamega and Mt. Elgon forests, Mutiso (2009) and Mutiso *et al* (2013) attributed proliferation of invasive species that modified regeneration patterns to charcoal making. Mutangah *et al.* (1993) and Omoro *et al.* (2007) stress the need for management to document these “indicator” species of disturbance. Clumping and uniform dispersion of the invasive in Mt Blackett is an indicator of widespread disturbances. Similar sediments are expressed by Goparaju & Jha (2009) and Krishnamurthy *et al.* (2010) who assert that clumping or aggregation of individuals in the tropical forests is common and may be due to the inefficient mode of seed dispersal or due to the large gap formation in the forest that occurs on account of either natural or anthropogenic disturbances. Further, UNO (1994) asserts that it is the role of forest managers to recognize these potentially harmful invasives at an early stage and take actions. Hitimana *et al.* (2006), in a study in Kakamega and Mt. Elgon, document similar case of post-disturbance invasive (*Solanum mauritianum*). The weed not only had aggressive proliferation strategies but also out-competed natural regeneration of other native species thereby reducing species richness and diversity drastically.

Species Diversity

The 52 species captured in the study sites reflects a relatively species-diverse forest typical in tropical forests. Omoro *et al.* (2007) captured 58 species in Taita hills forests while in Kakamega forest, Fashing *et al.* (2003) and Mutiso (2009) recorded 64 and 45 species respectively. The observed differences in actual number of species between N. Kedowa and other sites is likely to have been

caused by sample size. It is probable that if the sample size in N. Kedowa was increased to 0.5 Ha, the diversity could be high. This is consistent with Fashing *et al.* (2003) and Mutiso (2009) who, in a study in Kakamega forest, observed increase in diversity with increase in sample size. The poor diversity but high density in Southern Mt. Blackett implies that the site is at an early stage of succession than the other studied sites. At such stage, pioneer species have high density and luxuriant growth (Fashing *et al.* 2003; Asselin *et al.* 2001 and Arun *et al.* 2013). The diversity in such sites may also be curtailed by the ongoing disturbances such as grazing and charcoal making. Our findings are also echoed by Fashing *et al.* (2003) who found out that recurrently browsing and trampling undergrowth by cattle was responsible for creating persistent light gaps which facilitated the success of pioneer species and prevented the emergence of shade-tolerant later successional species. Similar sediments on the negative impact of grazing on regeneration in South American forests are shared by Glenn-Lewin *et al.* (1992). *Olea capensis*, *olea Africana* among others are key later seral species in Mau ecosystem that only germinate and establish under shade.

We also attribute the low diversity but high density observed in Mt Blackett sites to aggressive proliferation of *T. ellipticus*. Mutiso *et al.* (2011) record its aggressive regeneration through root suckering and successful recruitment of the invasive into sapling and mature stages. The invasive, whose individuals are at the lower age cohorts, contributed the high density observed in Mt Blackett. Under normal circumstances and based on the relationship between abundance and diversity, habitats supporting larger numbers of individuals can support more populations and more species than habitats supporting small numbers of individuals (Huang, *et al.* 2003). The invasive has altered this completely. Further, it will be prudent for management to monitor the tree population dynamics on these sites since some of the pioneers and invasives have persisted for over 30 years after disturbance. This persistence is likely to interfere with the with initial floristic composition successional pathway whereby selective elimination of some elements of the flora can produce new and often stable plant

communities (Egler, 2007). To regain pre-disturbance stand structure and species diversity, early successional species should give way to late non-pioneer successional species (Emery 2012; Arun *et al.* 2013). There is need to investigate why non-pioneers cannot germinate successfully under the canopy of the invasive; *T. ellipticus*. Note that pioneers maintain a seed bank and seeds are physiologically tuned to respond to increased light levels produced by canopy disturbance while those of non-pioneers germinate in shade and maintain a seedling bank ready to respond to any disturbance to the canopy (Emery 2012; Arun *et al.* 2013). Further, disturbance may lead to the loss or severe alteration of three critical forest recovery mechanisms; seed dispersal, seed banks and sprouting (Mesquita *et al.* 2001).

Rehabilitation strategies should be geared towards suppression of invasives and promotion of regeneration and successful recruitment of non-pioneers. Management need to understand that the most important transition in a pioneer life history is the survival of seeds in the seed bank and the growth rate of juveniles while it is the survivorship of juveniles that is the most critical to the life histories of non-pioneers. Such survivorship is largely lacking in Mt. Blackett hence low diversity. It is important to note that future re-measurement of the plots will give authoritative insights on the diversity of the study sites. Similarly, how high diversity in tropical forests is maintained and how they change over time require long-term monitoring using permanent plots (Krishnamurthy *et al.* 2010). It is, however, difficult to authoritatively state when species diversity is expected to peak in Mau ecosystem. Generally, species diversity is believed to be low in extreme conditions and high in optimum conditions. In relation to succession, diversity is either highest in a climax forest or peak in mid-succession towards forest (Mcqueen, 2009).

Species Similarity between Survey Sites

Based on the results of Jaccard and Sorensen similarity indices, it is very clear that the six study sites represent different plant formations. We attribute plant formation homogeneity observed in Northern and Western Kedowa sites to low level of disturbances as opposed to other sites. It is important to note that disturbance plays a critical role in plant succession. Depending on the severity of the disturbance, different stands take different trajectory successional pathways (Mesquita *et al.* 2001; Taylor and Chen, 2010). Studied sites were subjected to varying degrees of disturbance severity. Mutiso *et al.* (2011) document post-disturbance succession in Mt Blackett characterized by aggressive regeneration and recruitment of colonizer species and in some sites, individualistic successional pathway. This explains the observed floristic dissimilarities in Mt. Blackett.

It is important to note that, in all sites there is a certain degree of species sharing that we greatly attribute to endemism and neighborhood effects. Huang *et al.* (2003) and Maestre and Reynolds (2007) quote neighbor plant interactions as a determinant of post-disturbance plant formations. Further, plant propagules from the neighborhood plays a critical role in post-disturbance plant mosaics (Hazarika *et al.* 2006).

Understanding post-disturbance floristic affinities and species mosaics form a powerful management tool in rehabilitation of degraded areas. Our sediments are also shared by Mutangah *et al.* (1993) who in a study in the Mau ecosystem, state that the observed floristic affinities could act as a tool when considering and formulating conservation strategies of Mau forests. It is important to note that relatively high heterogeneity of habitats we observed leads to creation of vegetation mosaics. Such mosaics have their own species and should be treated as different management units. Since species groupings represent botanical uniqueness (UNO, 1994), it is important for forest managers to identify such formations in the rehabilitation of degraded ecosystems.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

We strongly concluded that the floristic composition is low as evidenced by majority of the families having only one species. Species richness per family cushions an ecosystem against collapse in case of disturbances. Loss of such a species not only implies the local extinction of the family and genera but also complete interference with the ecosystem parallel and cyclic configuration processes undertaken by such a species.

The study sites represent different plant formations and thus floristically, they are dissimilar but at varying degrees. It is evident that depending on the degree of disturbance severity, the post-disturbance recovery in Mt Blackett and Kedowa forests is following different trajectory successional pathways.

Past and present disturbances were found to impact negatively on small tree life form. Though disturbance promoted regeneration, it suppressed recruitment. This has affected floristic composition by promoting mono-dominant forest successional pathway and thus reducing the required ecosystem redundancy.

Compared to the other previous studies in Mau and elsewhere, species diversity was found to be low and invasives such as *T. ellipticus* were found to play a critical role in modification of regeneration regimes, recruitment and species co-existence under natural environment. Such low richness is detrimental to ecosystem integrity, resilience, parallel and cyclic configuration processes.

We concluded that the on-going disturbances were, by creating persistent light gaps, promoting successful regeneration and recruitment of invasives such as *T. ellipticus* and *S. mauritanum* while preventing the emergence of shade-tolerant later successional native species.

Recommendations

We strongly recommend that formulation of conservation strategies for Mau should be bench-marked on understanding of post disturbance floristic affinities and species mosaics. Such vegetation mosaics form different management units identifiable by their botanical uniqueness and thus should be treated individually in rehabilitation efforts.

The on-going disturbances should be curtailed to promote regeneration and successful recruitment of non-pioneer species. This will ensure the ecosystem regains its pre-disturbance stand composition and diversity that are critical for future ecosystem resilience, sustainability and redundancy.

We recommend a research on proliferation strategies of *T. ellipticus* and its role in the modification of natural regeneration and recruitment regimes of other native species in the Mau ecosystem.

Acknowledgement

We are highly indebted to KEFRI (Londiani) and the World Bank through Kenya Forest Service for logistical support. The authors acknowledge the inputs of the field crew. Review of the paper by professionals from KEFRI, South Eastern Kenya University, Karatina University and University of Eldoret is highly appreciated.

References

- Asselin H, Fortin J, Bergeron Y. 2001. Spatial distribution of late-successional coniferous species regeneration following disturbance in Southwestern Québec boreal forest. *For. Ecol. Manag.* 140(1):29-37.
- Armesto J, Pickett S. 2009. Experiments on disturbance in old-field plant communities: impact on species and abundance. *Ecology*: Vol. 66, No. 1, Pp. 230-240.
- Arun K, Brian D, Suzanne B, Marilou B, Alain L. 2013. Constraints to partial cutting in the boreal forest of Canada in the context of natural disturbance-based management: a Review. *Forestry an International Journal of Forest Research.* 86(5) doi: 10.1093/forestry/cpt047
- Beaudet M, Messier C, Harvey D, Coates D, Poulin J, Kneeshaw D. 2011. Managing understory light conditions in boreal mixedwoods through variation in the intensity and spatial pattern of harvest: a modelling approach. *For. Ecol. Manag.* 261(1):84-94.
- Beentje J. 1994. Kenya Trees, Shrubs and Lianas. National Museums of Kenya, 772p.
- Burton P, Bergeron Y, Bogdanski B, Juday G, Kuuluvainen T, McAfee B, et al. 2010. Sustainability of boreal forests and forestry in a changing environment. *IUFRO World Series.* 25:249-282.
- Bergeron Y, Harvey B, Leduc A, Gauthier S. 1999. Forest management guidelines based on natural disturbance dynamics: stand- and forest-level considerations. *For. Chron.* 1999;75(1):49-54.
- Cayuela L, Benayasa J, Maestreb F, Escudero A. 2008. Early environments drive diversity and floristic composition in Mediterranean old fields: insights from a long-term experiment. *Acta oecologica* 34:311 – 321.

-
- Egler F. 2007. Vegetation science concepts i. initial floristic composition, a factor in old-field vegetation development with 2 figs. *Plant Ecology* Volume 4, Number 6, 412-417.
- Emery S. 2012. Succession: A closer look. *Nature education knowledge* 3(10):45
- Gaaf R. 1986. A silvicultural system for natural regeneration of tropical rain forest in suriname. (Ecology and management of tropical rain forests in Suriname 1). Wageningen Agricultural University Press, Wageningen, the Netherlands.
- Gaaf N, Poels H, Rompaey R. 1999. Effect of silvicultural treatment on growth and mortality of rainforest in suriname over long periods. *Forest Ecology and Management*. Volume 124, Issues 2-3, Pages 123-135. Elsevier Science B.V.
- Gendreau-Berthiaume B, Kneeshaw D, Harvey D. 2012. Effects of partial cutting and partial disturbance by wind and insects on stand composition, structure and growth in boreal mixedwoods. *Forestry*. 2012;85(4):551-565.
- Glenn-Lewin C, Peet K, Veblen T. 1992. Plant succession: theory and prediction. Chapman & Hall, London,UK. 352 p.
- Goparaju L & Jha C. 2009. Spatial dynamics of species diversity in fragmented plant communities of a Vindhyan dry tropical forest in India. *Tropical Ecology* (In Press).
- Fashing P, Forrestel A, Scully C. and Cords M. 2003. Long-term tree population dynamics and their implications for the conservation of the Kakamega Forest, Kenya. *Biodiversity and Conservation* 00: 1-0, 2003.
- Fausto O. 1997. Landscape regeneration by seeds and successional pathways to restore fragile Tropandean Slopelands *Mountain Research and Development*, Vol. 17, No. 3, The United Nations University. Managing Fragile Ecosystems in the Andes. (Aug., 1997), pp. 239-252.
- Finegan B and Camacho M. 1999. Stand dynamics in a logged and silviculturally treated Costa Rican rain forest, 1988-1996. *Forest ecology and management* 121: 177-189.

- Frelich L and Reich P. 1998. Disturbance severity and threshold responses in the boreal forest. *Conservation Ecology (Online)* 2(2):7.
- Frelich L and Reich P. 1999. Neighbourhood effects, disturbance severity, and community stability in forests. *Ecosystems* 2:151-166.
- Huang W, Pohjonen V, Johansson S, Nashanda M, Katigula M, Luukkanen O. 2003. Species diversity and species composition in Tanzanian tropical forests. *Forest ecology and management* 173 11-24. Elsevier science B.V.
- Hitimana J. (2000) Structure, composition and regeneration of Mt Elgon moist lower montane forest Kenya with particular interest in *Olea capensis* subsp *welwitschii*. MPhil thesis, Moi University, Eldoret
- Hitimana J, Mutiso F, Kiyiapi, J and Sang F. 2006. Ecology, impact and potential control of *S. mauritianum* in Kenya. In: Muchiri, M., Kamondo, B., Ochieng, D., Tuwei, P., Wanjiku, J (Eds.) Proceedings of the 3rd KEFRI Scientific Conference on Forestry Research in Environmental Conservation, Improved Livelihoods and Economic Development, 6-9 November 2006, KEFRI Headquarters, Muguga, Nairobi. Pg. 106-114.
- Hazarika P, Talukdar N, Singh P. 2006. Natural colonization of plant species on coal mine spoils at Tikak Colliery, Assam *Tropical Ecology* 47(1): 37-46
- Krishnamurthy Y, Prakasha H, Nanda A, Krishnappa M, Dattaraja H, Suresh H. 2010. Vegetation structure and floristic composition of a tropical dry deciduous forest in Bhadra Wildlife Sanctuary, Karnataka, India *Tropical Ecology* 51(2): 235-246.
- Kharkwal G, Mehrotra P, Pangtey Y. 2005. Comparative studies on species richness, diversity and composition of oak forests in Nainital District, Uttarachal. *Current Science* 89: 668-672.
- Keating L. 2000. Chronically disturbed tropical alpine vegetation at a site in Southern Ecuador. *J. Torrey Bot. Soc* 127:162–171.

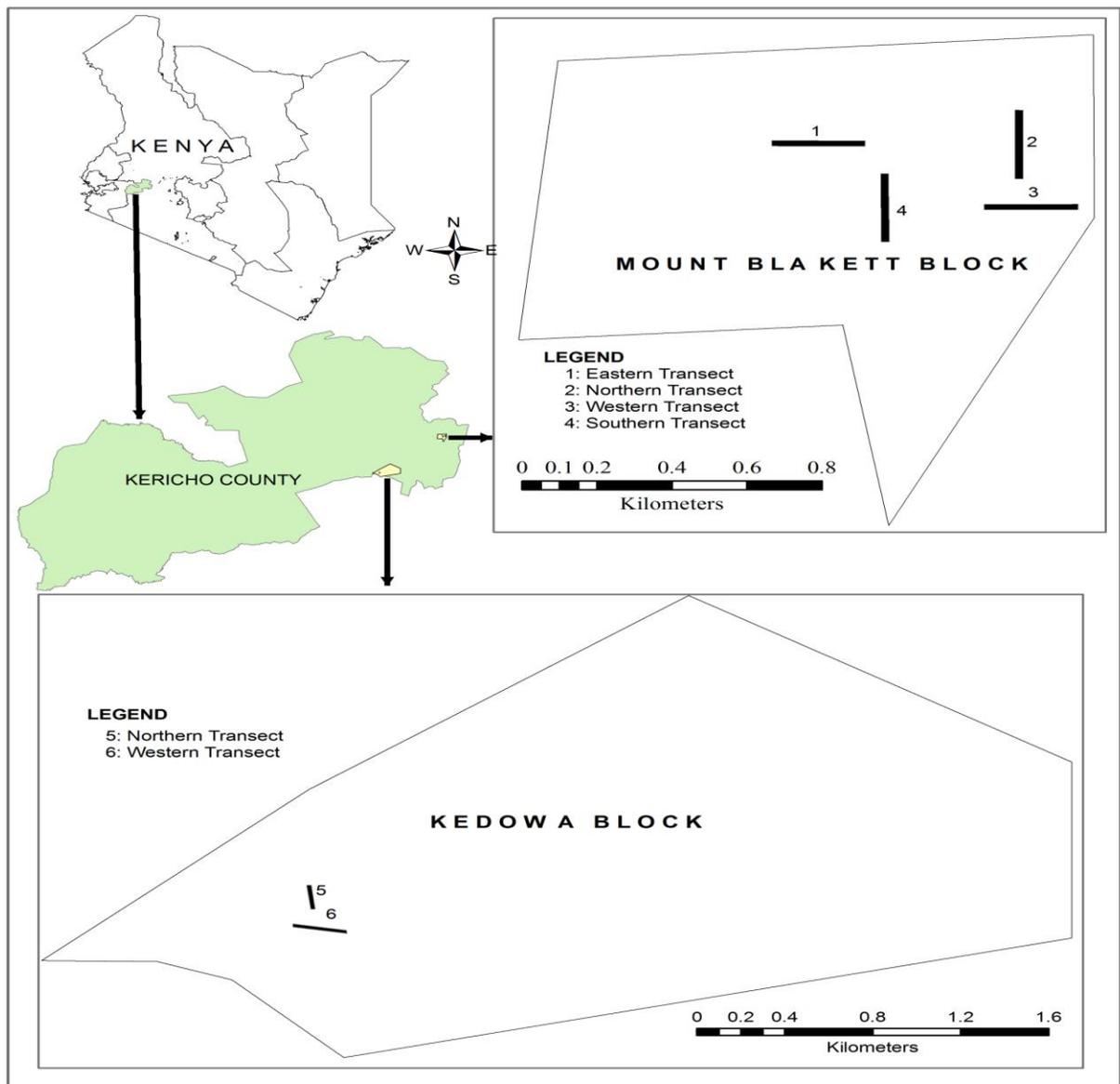
-
- Taylor A, Chen H, VanDamme A. 2009. A review of forest succession models and their suitability for forest management planning. *FOR. SCI.* 55(1):23–36.
- Taylor A, Chen H. 2010. Multiple successional pathways of boreal forest stands in central Canada *Ecography* 000: 000_000, 2010
- Ibanez I. 2009. Estimating colonization potential of migrant tree species. *Global Change Biol.* 15: 1173-1188.
- Jaetzold R and Schmidt H. 1983. Farm management handbook (Vol. II): Natural conditions and farm management information. Ministry of Agriculture, Nairobi, Kenya.
- Kumar H. 2001. Forest Resource and Management. Replika Press Private Ltd, New Delhi.
- Maestre T and Reynolds F. 2007. Amount or pattern? grassland responses to the heterogeneity and availability of two key resources. *Ecology* 88, 501–511.
- Mcqueen D. 2009. Plant succession and species diversity in vegetation around Lake Pounui Southern North Island, New Zealand. Victoria University of Wellington.
- Mesquita R, Ickes K, Ganade G, Williamson G. 2001. Alternative successional pathways in the Amazon Basin. *Journal of Ecology* 89, 5 28-537.
- Mutiso F, Hitimana J, Kiyiapi J, Sang F. & Eboh E. 2013. Recovery of Kakamega tropical rainforest from anthropogenic disturbances. *Journal of Tropical Forest Science* 25(4): 566–576, Forest Research Institute Malaysia.
- Mutiso F, Mugo M & Cheboiwo J. 2011. Post-disturbance tree species regeneration and successional pathways in Blakett and Kedowa forest blocks, Mau ecosystem. *Research Journal of Environmental and Earth Sciences* 3: 745–753.
- Mutiso F. 2009. Applicability of Selected Sampling Designs to Forest Health Assessment: The Case of Kakamega Moist Tropical and Mt Elgon Montane Forests. M.Phil Thesis, Department of Forestry and Wood Science, Moi University, Eldoret, Kenya

- Mutangah J, Mwangangi O and Mwaura P. 1993. Mau forest complex vegetation survey. KIFICON Report. Natural Resources Institute, Chatham Maritime, UK. National Museums of Kenya, Nairobi.
- Mwangi J. 2008. Monitoring forest cover changes using supervised vegetation classification in the western blocks of Mau forests complex, Kenya. Proceedings of Moi University 4th annual international conference: In: Imo M, Ipara H, Etiegni L, Mulewa C, Muisu F, Njiru, J and Balazi, B (Eds): Resource utilization for sustainable growth and development in the 21st Century. 29th July – 1st August 2008, Eldoret, Kenya.
- Mwangi J and Nahama E. 1991. Licensed management of the Mau Forest Complex: Kericho District. KIFICON Report. Natural Resources Institute, Chatham Maritime, UK
- Omoro P, Pellikka , Rogers C. 2007. Tree species diversity, richness, and similarity between exotic and indigenous forests in the cloud forests of Eastern Arc Mountains, Taita Hills, Kenya Journal of Forestry Research, Volume 21, Number 3, 255-264.
- United Nations Environmental Programme – World Conservation Monitoring Centre (UNEP-WCMC). 2009. Mount Kenya National park and national forest, Kenya. <http://www.eoearth.org/view/article/154706>
- United Nations Organization (UNO). 1994. Conservation and management of closed forest: A manual of field techniques for students and trainees. UNO/RAF/006/GEF. 1994, Uganda.
- Rydren K, Okland R, Hestmark G. 2009. Disturbance severity and community resilience in a boreal forest. <Http://Www.Consecol.Org/Vol 2/Iss2/Art7/>.

List of figures

Figure 1: A map showing the study sites

Figure 1:



List of tables

Table 1: Scientific names, families and development stages of trees, shrubs and climbers recorded in sampled sections of Mau ecosystem

Table 2: Species richness in Sampled Sections of Mau ecosystem

Table 3: Species diversity in sampled sections of Mau ecosystem

Table 4: Species composition similarity between six transects in sampled sections of Mau forests

Table 1:

Genera, species and authority	Family	Development stage			
		SE	SP	MS	LF
<i>Albizia gummifera</i> (JFG mel)CA.SM.Var gymm	Mimosaceae	X	X	X	LT
<i>Bersama abyssinica</i> fres.ssp.Abyssinica	melianthacea	X	X	X	LT
<i>Bischovia japonica</i>	Euphorbiaceae	X	0	X	LT
<i>Cassipourea malosana</i> (Bak) Alston	Rhizophoraceae	X	0	X	LT
<i>Chionanthus battiscombei</i> (Hutch)	Oleaceae	X	X	X	LT
<i>Celtis africana</i> Burm.f.	Ulmaceae	X	X	X	LT
<i>Cussonia holstii</i> Engl. Var	Araliaceae	0	0	X	LT
<i>Cussonia Spicata</i> Thumb	Araliaceae	X	X	X	ST
<i>Clausena anisata</i> (Wild) Benth	Rutaceae	X	X	X	ST
<i>Croton macrostychus</i> Del.	Euphorbiaceae	X	X	X	LT
<i>Claredendron johnstonii</i> Oliv.	Verbenaceae	X	X	0	S
<i>Cotoneaster Pannosa</i>	Rosaceae	X	0	X	S
<i>Cartha edulis</i> (Vahl.) Endl	Celastraceae	X	X	X	ST
<i>Cathium Keniensis</i> Bullock	Rubiaceae	0	0	X	S
<i>Calodendrum Capensis</i>	Rutaceae	0	0	X	LT
<i>Drypettes gerrardii</i> Hutch	Euphorbiaceae	X	X	X	ST
<i>Dovyalis abyssinica</i> (A.Rich) Warb	Flacourtiaceae	X	X	X	ST
<i>Dolyalis macrocalyx</i> (Oliv.) Warb	Flacourtiaceae	X	X	X	ST
<i>Diospyros abyssinica</i> (Hiem.) F.White ssp.abysi	Ebenaceae	X	0	X	LT
<i>Dombeya goetzenii</i> K. Schum.	Sterculiaceae	X	X	X	LT
<i>Dodonaea augustifolia</i> L.F.(D.Viscosa sensu kts.	Sapindaceae	X	X	X	S
<i>Euclea divinorum</i> Hiern	Ebenaceae	X	X	X	ST
<i>Ekerbegia capensis</i> Sparm. (E.meppeliana)	Meliaceae	X	X	X	LT
<i>Ehretia cynamosa</i> Thonn.	Boraginaceae	X	X	X	ST
<i>Erica arborea</i> L.	Ericaceae	X	X	X	S
<i>Fagaropsis angolensis</i> (Engl.) Dale	Rutaceae	X	X	X	LT
<i>Ficus natalensis</i> Hochst	moraceae	X	X	X	LT
<i>Flacortia indica</i> (Burm.f.) merril	Flacourtiaceae	0	X	0	ST
<i>Juniperus procera</i> Endl.	Cupressaceae	X	X	X	LT
<i>Manilkara discolor</i> (Sond)J.H. Hemsl	Sapotaceae	0	0	X	ST
<i>Meyna tetraphylla</i> (Hiern) Robyns	Rubiaceae	0	0	X	C
<i>Maytenus senegalensis</i> (Lam.) Exell	Celastraceae	X	0	X	S
<i>Nuxia cogesta</i> Fres.	Loganiaceae	X	X	X	LT
<i>Olea welwitschii</i> (knob.L) Gilg and schellemb)	Oleaceae	X	X	X	LT
<i>Olea africana</i> (mill) P.Green	Oleaceae	X	X	X	LT
<i>Olea hochesterri</i> (Bak.)	Oleaceae	X	X	X	LT
<i>Ochna ovata</i> F. Hoffm	Ochnaceae	X	X	X	ST
<i>Ochna holstii</i> (Engl)	Ochnaceae	X	0	0	ST
<i>Prunus africana</i> (Hook.f.) Kalkm.	Rosaceae	X	0	X	LT
<i>Polyscias kikuyuensis</i> Summerh	Araliaceae	X	0	X	LT
<i>Polyscias fulva</i> (Hiern) Harms	Araliaceae	X	0	0	LT
<i>Podocarpus falcatus</i> mirb (P.graciliar pilger)	Podocarpaceae	X	X	X	LT
<i>Osyris lanceolata</i> Hochst and steudeh	Santalaceae	X	X	X	ST
<i>Rhus natalensis</i> Krauss	Anacardiaceae	X	X	X	ST

<i>Rhus vulgaris</i> meikle	Anacardiaceae	X	X	X	ST
<i>Scolopia zeyheri</i> (Nees) Harv.	Flacourtiaceae	X	X	X	ST
<i>Solanum mauritianum</i> Scop.	Solanaceae	X	X	X	S
<i>Syzygium afromontana</i> F. white	Myrtaceae	X	0	X	ST
<i>Strychnos usambarensis</i> Gilg	Loganiaceae	0	X	X	S
<i>Scherebia alata</i> (Hochst) Welw.	Oleaceae	0	0	X	LT
<i>Trichilia emetica</i> Vahl.	meliaceae	0	X	0	ST
<i>Trichocladus ellipticus</i> Eckl. And Zeyh.	Hamamelidiceae	X	X	X	S
<i>Teclea nobilis</i> Del.	Rutaceae	X	X	X	ST
<i>Teclea simplifolia</i> (Engl.) Veerdoorn	Rutaceae	X	X	X	ST
<i>Tarconanthus camphoratus</i> L.	Compositae	X	X	X	S
<i>Trimelia grandifolia</i> (Hochst)	Flacourtiaceae	X	X	X	ST
<i>Toddalia asiatica</i> (L) Lam.	Rutaceae	X	0	0	S
Unidentified	-	X	X	X	ST
<i>Vangueria madagascarensis</i> Gmel.	Rubiaceae	X	X	X	ST
<i>Vernonia auriculifera</i> Hiern.	Compositae	X	0	0	ST
<i>Warbugia ugandensis</i> Sprague ssp. Ugandensis	Canellaceae	X	X	X	LT

*Development stages: SE =Seedlings (< 1cm dbh), Sp=Saplings (1-5cm dbh), MS=mature stems (> 5cm dbh).

X=found and recorded 0=absent.

Life form (LF) categories: S=shrub (< 5cm height), C=climber, ST=small trees (5-20m height at maturity), LT=large trees (>20m height at maturity)

Table 2:

Family	Species.
<i>Anacardiaceae</i>	<i>Rhus natalensis</i> <i>Rhus vulgaris</i>
<i>Araliaceae</i>	<i>Cussonia Spicata</i> <i>Cussonia holstii</i> <i>Polyscias fulva</i> <i>Polyscias kikuyuensis</i>
<i>Boraginaceae</i>	<i>Ehretia cynamosa</i>
<i>Canellaceae</i>	<i>Warbugia ugandensis</i>
<i>Celastraceae</i>	<i>Catha edulis</i> <i>Maytenus senegalensis</i>
<i>Compositae</i>	<i>Tarconanthus camphoratus</i> <i>Vernonia auriculifera</i>
<i>Cupressaceae</i>	<i>Juniperus procera</i>
<i>Ebenaceae</i>	<i>Diospyros abyssinica</i> <i>Euclea divinorum</i>
<i>Ericaceae</i>	<i>Erica arborea</i>
<i>Euphorbiaceae</i>	<i>Croton macrostychus</i> <i>Drypettes gerrardii</i> <i>Bischofia japonica</i>
<i>Flacourtiaceae</i>	<i>Dovyalis abyssinica</i> <i>Dovyalis macrocalyx</i> <i>Flacortia Indica</i> <i>Scolopia zeyheri</i> <i>Trimelia grandifolia</i>
<i>Hamamelidiceae</i>	<i>Trichocladus ellipticus</i>
<i>Loganiaceae</i>	<i>Nuxia cogesta</i> <i>Strychnos usambarensis</i>
<i>Meliaceae</i>	<i>Ekerbegia capensis</i> <i>Trichilia emetica</i>
<i>Melanthaceae</i>	<i>Bersama abyssinica</i>
<i>Mimosaceae</i>	<i>Albizia gummifera</i>
<i>Moraceae</i>	<i>Ficus natalensis</i>
<i>Myrtaceae</i>	<i>Syzygium afromontana</i>
<i>Oleaceae</i>	<i>Chionanthus battiscombei</i> <i>Olea welwitchii</i> <i>Olea africana</i> <i>Olea hochesterri</i> <i>Scherebia alata</i>
<i>Ochnaceae</i>	<i>Ochna ovata</i> <i>Ochna holstii</i>
<i>Podocarpaceae</i>	<i>Podocarpus falcatus</i>
<i>Rhizophoraceae</i>	<i>Cassipourea malosana</i>
<i>Rutaceae</i>	<i>Clausena anisata</i> <i>Fagaropsis angolensis</i>

	<i>Teclea nobilis</i>
	<i>Teclea simplifolia</i>
	<i>Toddalia asiatica</i>
	<i>Caledendrum capensis</i>
Rosaceae	<i>Cotoneaster pannosa</i>
	<i>Prunus africana</i>
Rubiaceae	<i>Cathium keniensis</i>
	<i>Meyna tetraphylla</i>
	<i>Vangueria madagascarensis</i>
Santalaceae	<i>Osyris lanceolata</i>
Sapotaceae	<i>Manilkara discolor</i>
Sapindaceae	<i>Dodonea augustifolia</i>
Solana ceae	<i>Solanum mauritianum</i>
Sterculiaceae	<i>Dombeya goetzenii</i>
Ulmaceae	<i>Celtis africana</i>
Verbenaceae	<i>Claredendron johnstonii.</i>

Table 3:

Site	Area sampled (Ha)	No. of species	H'	Density (No./Ha)
E. Mt	0.5	22	1.080	1564
W. Mt	0.5	21	1.466	1770
S. Mt	0.5	19	1.805	1962
N. Mt	0.5	22	1.984	1360
W. ked	0.5	33	2.535	752
N. ked	0.3	22	1.983	856

*E. Mt = Eastern Mt. Blackett, W. Mt. = Western Mt. Blackett, S. Mt. = Southern Mt Blackett, N. Mt = Northern Mt. Blackett, W. ked =Western Kedowa, N. ked=Northern Kedowa, H'= Diversity index

Table 4:

	W. Mt	S. Mt	N. Mt	W. ked	N. ked
E. Mt	0.62 (76.5)	0.22 (34.5)	0.34 (50.0)	0.22 (35.8)	0.30 (45.9)
W. Mt		0.38 (58.1)	0.35 (53.1)	0.30 (45.1)	0.35 (52.3)
S. Mt			0.51 (70.4)	0.22 (36.1)	0.26 (40.0)
N Mt				0.26 (41.3)	0.33 (49.1)
W. ked.					0.68 (81.3)

*Index outside brackets was calculated using Jaccard index (JIA) while the index inside brackets was calculated using Sorensen similarity index (S).