Assessment of Kenya's montane forest ecosystems: A case study on the Cherangani Hills in Western Kenya.

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Abstract:

The study in the Cherangani Hills, Western Kenya aimed at developing a historical vegetation and altitudinal references for the Cherangani survey sites to help evaluate the current forest state in terms of species composition, species distributions and potential disturbance (natural or anthropogenic), and assess whether the vegetation changes can be ascribed to environmental, climatic or anthropogenic impacts. We laid 24 belt transects with plots and subplots following an altitudinal gradient to enable us create a sample/site presence/absence data matrix to be used in TWINSPAN plant community analyses. Simple linear regressions were performed on average annual temperature (°C) and precipitation (mm) for the year 1970-2010, and population pattern assessed for all areas near the forest ecosystem based on the last five national census exercises (1969-2009). A total of 163 plant species from 71 families and 133 genera were identified, including the endemic Seneciojohnstonii ssp. battiscombei var. cheranganiensis and an invasive yellow cestrum (Cestrum aurantiacum). TWINSPAN cluster analyses gave five interpretable floral groups and defined species distributions along the altitudinal gradient. Rainfall received and temperatures recorded in areas near the survey sites significantly increased in the last four decades, with a general increase in human population in all the neighbouring areas. Historical vegetation and altitudinal references aid in unravelling the past forest state, species composition and plant communities, and help in evaluation of the current forest state, which may be useful for conservation and protection purposes. Based on our scientific predictions; climate, population growth and anthropogenic factors are potential factors that could affect montane forest ecosystems in Kenya. However, there is need for the acquisition of site-specific climatic, environmental, palynological, and additional forest data to help explain changes in critical montane forest ecosystems.

Introduction

Montane forest ecosystems face a real challenge of biodiversity loss due to a complex and more often a conglomerate of interconnected factors. Ecological predictions have shown an upward shift of tree lines and decline in white spruce density due to rise in temperature affecting the boreal forests of Canada, Alaska and Siberia, which also increased insect infestation (spruce beetle), occurrence and spread of wild fires (Soja *et al.*, **2007**). Similarly, a vast area of the Eastern Arc Mountains of Africa have been affected (Newmark, **1998**). Species shifts takes a longer time and can be predicted using vegetation references of sites under investigation (Walther *et al.*, **2005**). A comparative study of "pristine" forests, coffee plantations and cultivated grasslands conducted in Mexican tropical montane cloud forests showed a similarity in species richness but glaring differences in species composition to about 90%. However, a study in the eastern Andean slopes of Bolivia, show a decline in species richness. Forest fragmentation hastens biodiversity loss by making montane forests vulnerable to introduction of alien species, a single successful invasion of a montane forest by *Pittosporum undulatum* Vent was reported in Jamaica (Whitmore, **1991**; Turner, **1996**; Kessler, **2001**). *Psidium*, *Ligustrum* and *Ardisia* species have almost replaced indigenous wet forests of Mauritius (Phillips, **1997**). Endemic species being at the core of montane forest biodiversity are dependent on natural habitats and are threatened by increased frequency of disturbance, mainly climate-induced or anthropogenic. This susceptibility is attributed to their taxa 'inferiority' to preclude species exclusion in tampered ecosystems as seen in the case of Bolivian Montane forests (Kessler, **2001**). Selective logging in South American tropical forests have nearly driven the highly targeted mahogany tree species (*Swietenia macrophylla*) and the South American cedar (*Cedrela odorata* on the brink of extinction in their usual natural habitats (Phillips, **1997**). Main ecological processes affected by climate change and human population increase include land transformation, biogeochemical cycles and potential species loss (Vitousek *et al.*, **1997**; Wang *et al.*,**2001**). Population increase in areas near major forest ecosystems were mainly attributed to a growing demand for land for settlement and agriculture (Kenya N.E.N.I, **2014**).Natural processes like forest maturation and stand dynamics also affect vegetation composition and structure (Bodin *et al.*, **2013**). There are five major montane forests in Kenya namely; Mau Forest Complex (400,000 ha), Aberdare Range (250,000 ha), Mt. Kenya (220,000 ha), Cherangani Hills (120,000 ha), and Mt. Elgon (73,706 ha), and they constitute an important water catchment resource (Akotsi & Gachanja, **2004**; Lambrechts *et al.*, **2005**; Kipkore *et al.*, **2014**). Mt. Kenya, Aberdares Range and Mt. Elgon demonstrate clear floristic zonations and transitions unlike the low lying Mau Forest Complex (MFC) and the Cherangani Hills (Bussmann, **1996**; Mathooko & Kariuki, **2000**; Bussmann, **2006**; Kinyanjui, **2011**; Gehrke & Linder, 2014; Kinyanjui *et al.*, **2014**; Rhino Ark, **2015**). Several floristic associations have been identified in the MFC which include *Tabernaemontana-Allophylus-Ekebergia-Albizzia*, *Juniperus-Dombeya-Casaeria-Prunus*, *Acokanthera-Cussonia-Olea-Vepris* and finally *Tabernaemontana-Syzygium-Podocarpus-Neoboutonia* (Kinyanjui *et al.*, **2014**). *Neoboutonia macrocalyx* and *Macaranga kilimandscharica* were identified as a leading pair of coloniser species for disturbed montane and submontane areas. The coniferous *Juniperus procera* and *Podocarpus latifolius* were recorded on the drier slopes of the MFC (Kinyanjui, **2011**). Riparian community analyses showed that the principal montane formations were mainly characterised by *Juniperus procera-Olea europaea* ssp. *africana* forests (2300-2600 m asl), with *Erica arborea* found as low as 2500m asl while *Acacia abyssinica* dominating the lower elevation areas. The upper montane stretch composed of *Rapanea-Dombeya-Nuxia* forests. *Achyranthes aspera* was regarded as an indicator of anthropogenic disturbance, whereas *Hypoestes forskaolii* dominated the herbaceous layer (Mathooko & Kariuki, **2000**). Recent land satellite images of the

MFC showed a reduction in forest cover changes in 22 forest locations studied (Ayuyo & Sweta, **2014**). Mt. Kenya forest is contiguous with the Aberdares Range and has two main peaks, Batian (5198 m) and Nelion (5188 m). The upper tree line was found to have been influenced by wild fires, whereas the lower tree line was due to previous forest cutting and agricultural encroachment. Species composition varied according to slope aspect and demonstrates a typical floristic zonation. Common species found in the montane and submontane areas (up to 3300 m) include *Syzygium guineense, Juniperus procera, Pouteria adolfi-friedericii, Hagenia abyssinica* (an altitudinal co-dominant species), *Olea europaea, Nuxia congesta, Rapanea melanophloeos,* and *Podocarpus falcatus* (Bussmann, **2006**). *Macaranga kilimandscharica* and *Neoboutonia macrocalyx* were considered indicators of disturbance and characteristic of a secondary forest formation. Aggressive moorland species of *Stoebe kilimandscharica, Euryops brownei* and *Erica arborea* have also spread into the *Hagenia* forests (Bussmann, **1996**). In areas affected by high altitude fires, *Protea kilimandscharica* and *Stoebe kilimandscharica* were found to be dominant (Bussmann, **2006**).

The Aberdare Range highest peak is Oldonyo Lesatima which measures up to 3998 m asl. The most dominant species include *Neoboutonia macrocalyx, Macaranga capensis, Tabernaemontana stapfiana, Psychotria fractinervata, Podocarpus latifolius, Nuxia congesta, Clausena anisata* and *Dombeya torrida*(Rhino Ark, **2015**).The transboundary Mt. Elgon in the Western Kenya had a volcanic orogeny and is located near the Cherangani Hills which had crystalline orogeny but to a large extent share floristic similarity (Bussmann, **2006**; Gehrke & Linder, **2014**).

Common degradative activities facing Kenya's montane forests include deforestation, cattle grazing, infrastructural development (Ayuyo & Sweta, **2014**), selective logging, charcoal burning, *Cannabis sativa* fields, landslides, quarries and human encroachment (Lambrechts *et al*., **2005**), sand harvesting (Olang' & Kundu, **2011**).

The aim of this study was to conduct a vegetation survey in the Cherangani Hills mainly on five forest reserve sites with a view to evaluate the current forest state using historical vegetation and altitudinal references with respect to species composition, species distributions and draw comparison with the other four major forest ecosystems in Kenya. And also to determine whether changes in species composition can be ascribed to the two potential factors namely climate (temperature and precipitation) and anthropogenic activities as a result of increase in human population growth. We therefore hypothesised (*a prior*i assumptions)that historical vegetation and altitudinal references predict potential species shifts or compositional shifts in the Cherangani Hills, and that ecological indicator plant species for wet, dry and/or disturbed environments reflects changes in climate and increase in anthropogenic activities.

Materials and methods

The Cherangani Hills study area is located in Elgeyo Marakwet County and managed by Kenya Forest Service (Cherangani Forest Station, 1°16'N, 35°26'E) with community contribution through registered Community Forest Association (CFA). The five sites surveyed measure up to 20,215.3 ha; Kipteber (12,886 ha), Kerrer (2,160 ha), Koisungur (1,085.8 ha), Toropket (117.4 ha) and the Tenden forest site (no size specifications)

(Kenya Forest Service, **2010**; BirdLife, **2015**). Having no meteorological data recorded on the survey sites, the rainfall received in the Cherangani Hills was estimated to be between 60-80 inches (approx. 1500-2000) per year (Cotton & Blakelock, **1937**).

Historical vegetation reference

An account of historical vegetation and altitudinal references of the Cherangani Hills forest ecosystem were compiled through literature review and overview, with a special emphasis put on finding out ecological plant indicator species of wet, dry and/or disturbed conditions. The indicators for disturbance were included since it covers both natural and anthropogenic causes that affects forest ecosystems, where disturbed areas referred to forest clearings, open areas, forest edges and pathsides (Beentje, **1994**; Agnew, **2013**). The derived ecological plant indicator species were also monitored for potential species shifts or compositional shifts based on our field observations from the survey sites.

Vegetation sampling, clustering and data analyses

The vegetation sampling was conducted in the month of July **2014**, following an altitudinal gradient (Odland & Birks, **1999**) where the site coordinates and altitude were determined using a GARMIN **2010** GPS. A total of 24 belt transects measuring 5m × 20m were laid, with subplots measuring 5m × 10m, (5 × 5) m^2 and (1 × 1) m^2. The sampling followed the requirements of homogeneity with regard to sampled life-forms (lianas, epiphytes) and growth habits; tree layer, shrub layer and the herbaceous layer (Mueller-Dombois & Ellenberg, **1974**). Most of the plant species were identified in the field by taxonomic experts, and voucher specimens collected for herbarium verification and determination with the aid of the following taxonomic literature. From the derived species lists in each transect, a comprehensive species list was compiled. Sample/sites clustering for Kipteber (KI), Koisungur (KO), Toropket (TO), Tenden (TE), and Kerrer (KE) was carried out on the recorded data comprising presence/absence scores using Jaccard distance to produce a two way cluster dendrogram and help determine maximum possible number of interpretable floral groups and generate a floristic table that illustrate site/species presences (using dummy variable 1), species distributions, altitudinal ranges and species richness per transect. All analyses were performed using TWINSPAN, where the minimum group size for division was set at five and maximum levels of divisions set at six (Hill, **1979**; Roleček *et al.*, **2009**; Čarni *et al.*, **2009**).

Climate and population data

The mean annual temperature (°C) and precipitation (mm) ranges were computed and used to determine the variations in the last four decades, where simple linear regressions were performed to determine the climate trend (Schmidt, **1991**; Hemp, **2005**). For assessment of human population growth of the communities living near the forest reserve sites, the population data drawn from the last five national censuses (1969-2009) were downloaded from the Kenya National Bureau of Statistics (KNBS) official website (http://www.knbs.or.ke) and was used to assess the pattern of population increase for the Kapcherop, Lelan, Kaptalamwa, Koisungur and Tenden administrative regions.

Results

Species composition, relative 'completeness' and 'natural' state of the Cherangani Hills

A total of 163 plant species from 71 families and 133 genera were recorded in the Cherangani study sites, including the endemic *Senecio johnstonii* ssp. *battiscombei* var. *cheranganiensis* and potentially invasive *Cestrum aurantiacum*The five floral groups interpreted from TWINSPAN clustering illustrated the potential species distributions based on frequency of occurrence in the Cherangani Hills following an altitudinal gradient. The **first group** composed of *Hypoestes forskaolii*, *Stephania abyssinica*, and *Pentas longiflora* herbaceous layer; **second group** had *Scutia myrtina, Dovyalis abyssinica*, *Achyrospermum schimperi*, *Cyphostemma kilimandscharica* and *Achyranthes aspera* (weed). The **third group** included a tree layer of *Neoboutonia macrocalyx* (pioneer species), *Vepris nobilis*, *Allophylus abyssinicus*, *Urera hypselodendron* (liana) and an undergrowth of *Acanthus eminens.* And the **fourth group** composed of a tree layer of *Rapanea melanophloeos*, *Podocarpus latifolius*, *Maytenus undata*, *Hagenia abyssinica* and *Olea europaea* ssp. *africana* and the **fifth group** composed of *Juniperus procera*, *Prunus africana*, herbaceous *Kalanchoe densiflora* and *Carduus afromontanus*. The species composition and distribution in the Cherangani Hills demonstrated a rather mixed secondary forest formation consisting mostly of a *Podocarpus latifolius* forest, an altitudinal codominant *Hagenia abyssinica*, and indicators of forest edge effects/disturbance (e.g. *Achyranthes aspera*, *Acanthus eminens*), lianas/woody climbers (e.g. *Urera hypselodendron*, *Simirestis goetzei*) and a fast growing pioneer species (e.g. *Neoboutonia macrocalyx*).

The climatic data (temperature and precipitation) for the period 1970-2010

Rainfall received in the areas near the Cherangani forests significantly increased during the last forty years (Figure **1**,**2**), with the lowest average annual rainfall levels received in the early 1980s and the highest average rainfall levels received in the late 1990s and 2000s. The annual average rainfall for the period was 1274 mm.

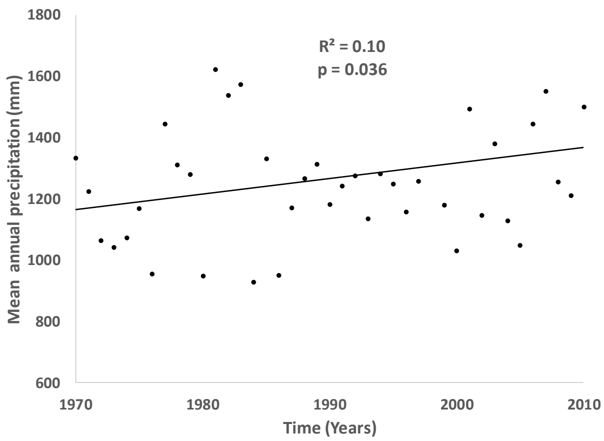

Figure 1: The mean annual precipitation (1970-2010), with a significant increase (p = 0.036) in the amounts of rainfall received in the areas near the Cherangani forest survey sites. Climatic data drawn from Kitale Meteorological Station).

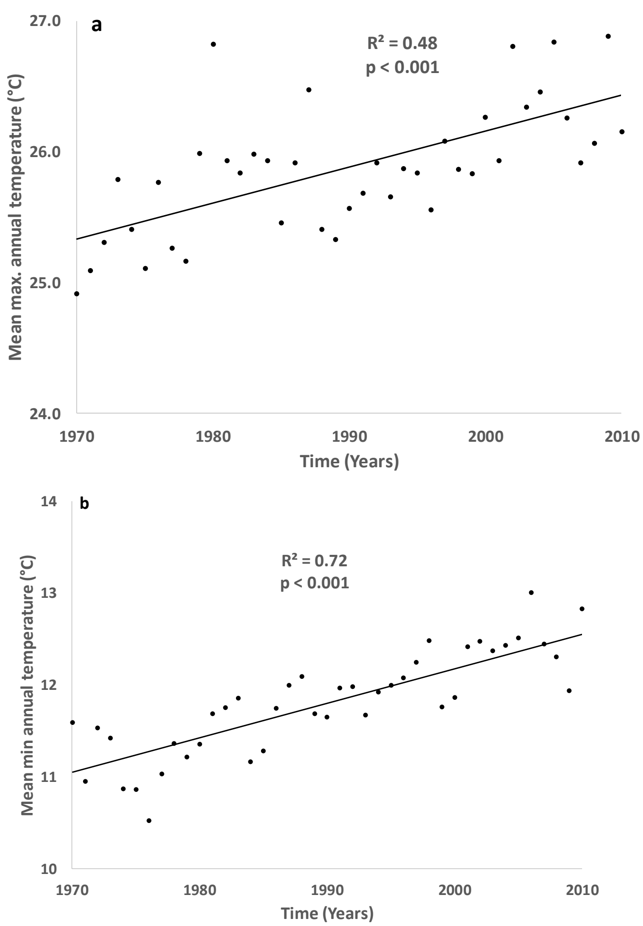

Figure 2: (a) The mean minimum annual temperature and (b) maximum annual temperature (1970-2010) recorded in areas near the Cherangani forest survey sites, indicating a very high significant increase (p< 0.001). Climatic data drawn from Kitale Meteorological Station.

Both the lowest average annual minimum temperature and lowest average annual maximum temperature were recorded in the early 1970s and the highest average annual minimum temperature and highest annual maximum temperature were recorded in the late 2000s.

Human population growth

There was an increase in human population in the areas near the study sites in the last forty years (Figure **3**). Lelan had the highest population density whereas Kaptalamwa had the lowest. Missing data was due to the changing administrative sites in the respective census period.

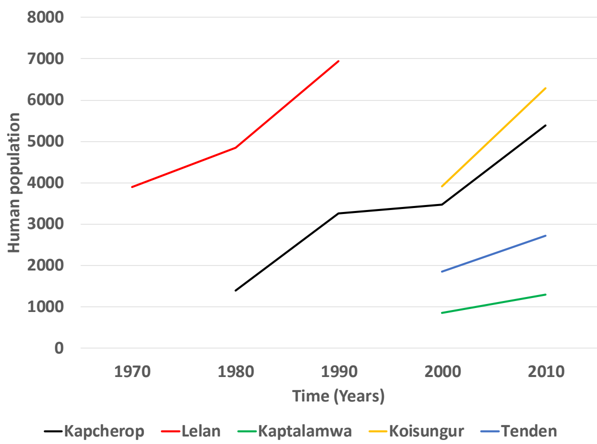

Figure 3: The increase in human population of Kapcherop, Lelan, Kaptalamwa, Koisungur and Tenden. Population data drawn from Kenya National Bureau of Statistics (KNBS).

Discussion

Species composition, relative 'completeness' and 'natural' state of the Cherangani Hills

Ecological indicators have been established as an effective tool for assessing change in an ecosystem (Noss, **1999**). With limited data on the Cherangani Hills, a broad based comparison of our field observations with the entire Kenyan flora explains the range of species altitudinal coverage and whether they can be found higher or lower than their "usual" elevation and their indicator purpose as derived from literature sources.

Table 1: Ecological indicator plant species of dry, wet and/or disturbance observed in the five sampled sites; Kipteber (KI), Tenden (TE), Toropket (TO), Koisungur (KO) and Kerrer (KE) of the Cherangani Hills, species indicated in bold lettering were found in relatively higher positions relative to published historical altitudinal references.

				Cherangani field observations				
Species	**Growth habit**	**Altitudinal reference (m) according to Beentje (1994) and Agnew (2013)**	**Indicator purpose as reported by Beentje (1994) and Agnew (2013).**	**KI**	**TE**	**TO**	**KO**	**KE**
Acacia abyssinica	Tree	1200-2300	Dry	2590	-	-	-	-
Acanthus eminens	Shrub	1500-2650	Disturbance	2365-2518	2548	-	-	-
Achyranthes aspera	Herb	0-3080	Disturbance	2518	2548	-	-	-
Achyrospermum schimperi	Herb	1600-3000	Wet	2498-2578	2548	2690-2733	-	-
Aerva lanata	Herb	0-2200	Dry	-	-	-	-	3029
Ageratina adenophora	Herb	1950-2300	Wet	2580	-	2733	-	-
Apodytes dimidiata	Tree	1450-2400	Dry	2470	-	-	-	-
Arundinaria alpina	Grass	2150-3300	Wet	-	-	-	2911-2940	-
Asparagus flagellaris	Shrub	800-2140	Dry	-	2548	-	-	-
Asparagus racemosus	Shrub	1160-2800	Dry, Disturbance	-	-	2733	-	-
Barleria submollis	Herb	50-1750	Dry	2518	-	-	-	-
Boerhavia erecta	Herb	1600-2500	Dry, Disturbance	2574	-	-	-	-
Canthium keniense	Tree	1400-1800	Dry	2470	-	-	-	-
Carduus afromontanus	Herb	2350-3430	Disturbance		2538		2923	3029-3082
Casaeria battiscombei	Tree	1350-2400	Wet	2470	-	-	-	-
Cassipourea malosana	Tree	750-2550	Dry	-	2543	-	-	-
Cestrum aurantiacum	Shrub	-	Disturbance	-	-	2690	-	-
Clematis simensis	Shrub	1600-3250	Disturbance	2578	-	-	-	-
Cupressus lusitanica	Tree	-	Disturbance	-	-	-	-	2895
Cussonia holstii	Tree	1050-2550	Dry	2558	-	-	-	-
Cyathea manniana	Fern	1350-2500	Wet	2470	-	-	-	-
Cyathula polycephala	Herb	1600-3000	Disturbance	2518	-	-	-	-
Desmodium repandum	Herb	1450-2800	Wet	2518	-	-	-	-
Dichondra repens	Herb	1650-2520	Wet & Disturbance	2593	-	-	2923	2984
Discopodium penninervum	Shrub	2100-2850	Disturbance	-	-	-	-	3029-3082
Ekebergia capensis	Tree	1300-2600	Dry	2574	-	-	-	-
Eleusine jaegeri	Grass	1800-3300	Disturbance	-	-	-	-	2895
Ensete ventricosum	Shrub	1400-2100	Wet	2498	-	-	-	-
Galinsoga parviflora	Herb	300-2300	Disturbance	-	-	2733	-	-
Hagenia abyssinica	Tree	2300-3300	Wet	2498-2580	2543		2911-2940	2895-3029
Halleria lucida	Tree	1550-2750	Dry	2558	-	-	2911	-
Hypoestes forskaolii	Herb	0-2820	Dry, Disturbance	2498-2593	2548	2733	-	-
Juniperus procera	Tree	1050-2950	Dry	2593	2543	2733	2911-2940	2984-3082
Kalanchoe densiflora	Herb	1500-3000	Disturbance	2470	2538	2690-2733	2911-2940	2895-3082
Keetia gueinzii	Climber	1300-2500	Wet	2498-2578	-	-	-	-
Laggera brevipes	Herb	1050-2400	Disturbance	2580	2548	-	-	-
Laportea alatipes	Herb	1560-3010	Wet & Disturbance	2470	-	-	-	-
Leucas calostachys	Shrub	1600-2575	Disturbance	2558-2593	-	-	-	-
Macaranga kilimandscharica	Tree	1650-2400	Wet	2365	-	2733	-	-
Maesa lanceoata	Tree	1300-2800	Disturbance	2558	2548	-	-	-
Microglossa pyrifolia	Shrub	1200-2900	Disturbance	2518-2574	2548	2733	2940	
Mikaniopsis bambuseti	Climber	2100-3000	Dry	2574	-	-	-	-
Myrsine africana	Shrub	1500-3000	Dry	2580	-	-	-	-
Neoboutonia macrocalyx	Tree	1600-2700	Wet, Disturbance	2365-2470	-	-	-	-
Olea europaea	Tree	950-2400	Dry	2558	2548		2923	2984-3082
Olinia rochetiana	Tree	1700-3050	Dry	2469-2558	-	-	-	-

Oxalis corniculata	Herb	0-3600	Disturbance	-	2548	-	-	3089
Pentas longiflora	Herb	1590-2400	Dry	2593	2548			
Pilea johnstonii	Herb	1680-2910	Wet, Disturbance	2365	-	-	2911	-
Plantago major	Herb	-	Disturbance	2518	-	-	-	-
Plectranthus punctatus	Herb	1950-3350	Disturbance	2498	-	-	-	2895
Podocarpus falcatus	Tree	1250-2700	Dry	2558-2578	2548	2733	-	-
Podocarpus latifolius	Tree	1500-3350	Wet	2365-2578	2548	2690-2733	2911-2940	2984-3082
Polyscias fulva	Tree	1400-2300	Wet	2578	2538	-	-	-
Rhus natalensis	Shrub	1050-2700	Dry	-	2543	2733	-	-
Rubus pinnatus	Shrub	2700-3400	Disturbance	2574	-	-	-	-
Senecio johnstonii ssp. *battiscombei* var. *cheranganiensis*	Shrub	2450-3300	Wet	-	-	-	-	2984
Senecio hadiensis	Climber	1000-2600	Dry	-	2548	-	2940	
Senna didymobotrya	Shrub	-	Disturbance	-	-	2733	-	-
Simirestis goetzei	Liana	1450-2350	Wet	-	2538	-	-	-
Solanecio manii	Shrub	700-2650	Dry, Disturbance	-	-	2733	-	-
Solanum aculeastrum	Shrub	1800-2650	Disturbance	2518	-	-	-	-
Solanum sessilistellatum	Herb	2130-2990	Disturbance	2498	-	2733	-	-
Sphaeranthus bullatus	Herb	1000-2100	Disturbance	2498	-	-	-	-
Urtica massaica	Herb	2000-3400	Disturbance	2590	-	-	2923	2895
Vernonia auriculifera	Shrub	1600-2650	Disturbance	2365-2580	2548	2690-2733		2984

Comparison of the Cherangani study sites with other montane forest ecosystems and implications.

The Cherangani study sites registered several weed species (*Solanum* species, *Achyranthes aspera, and Galinsoga parviflora*), colonizer species (*Neoboutonia macrocalyx* and *Macaranga kilimandscharica*) and a potentially invasive yellow cestrum (*Cestrum aurantiacum*) in the Toropket forest site. Other potential weed species recorded include *Sennadidymobotrya*, *Commelina africana*, *Boerhavia erecta*, *Oxalis corniculata*, *Rubus* species, *Triumfetta tomentosa* and *Urtica massaica* (Table **1**). The presence of alien species, weeds and colonizer species are mostly connected to disturbance (Turner, **1996**; Fox *etal*., **1997**), forest edge effects and agricultural encroachment (Young & Mitchell, **1994**). Comparing our work with published altitudinal ranges for the entire country according to Beentje (**1994**) and Agnew (**2013**), it was evident in our fieldwork observations that 'moorland' or 'subalpine species', for instance, *Stoebe kilimandscharica* could befound as low as 2593 m asl in the Kipteber forest site. However, there was no sufficient historical evidence for the Cherangani study sites to explain whether this was a species shift or rather normal species distributions. In both Mt. Kenya and Cherangani Hills, *Hagenia abyssinica* was expressed as a codominant canopy species and could cover a wide altitudinal range (Table **1**). However, palynological studies have revealed a down slope species shifts in the Mt. Kenya montane forest where *Erica spp.* and *Stoebekilimandscharica* were found in lower elevations (Rucina *et al*., **2009**). In the Cherangani Hills study sites, *Juniperus procera* was present as low as 2538 m asl in the Tenden forest site and as high as 3082 in the Kerrer forest site (Table **1**). Based on our field observations and the five floral groups derived from TWINSPAN analyses, the two initial floristic associations recorded in the late 1960s (*Juniperus-Maytenus undata-Rapanea-Hagenia* and *Juniperus-Nuxia-Podocarpus latifolius*) were notably still present and could potentially serve as serve as characteristic plant communities for the Cherangani study sites. These potential natural vegetation types (PNVTs) composed of original species as seen in Mt. Kenya also represent ecological suitability where any distortion of the original floral formations may imply a change in forest ecosystems (Kindt *et al*., **2007**). With a significant increase in temperature and precipitation in the last forty years (Figure **2**, **3**), these two meteorological parameters may be considered as main factors that may potentially effect change in species composition, alter forest formations and structure with time and a global ecosystem change. As seen in our forest survey, the endemic species *Senecio johnstonii* ssp. *battiscombei* var. *cheranganiensis* was only found in the wetter Kerrer forest site as indicated by its habitat, local requirements and ecological indicator plant species (Kindt *et al*., **2007**). The two related species of Podocarpaceae, *Podocarpus falcatus* and Podocarpus latifolius thrive in dry and wet conditions respectively (Table **1**). It has been shown that different montane species have different response to changing climatic conditions, for instance, *Olea capensis* showed preference to slightly drier conditions and *Podocarpus latifolius* showed preference for wetter conditions, as also confirmed by our established indicator plant species (Maley & Brenac, **1998**).Most species of the Cherangani Hills show floristic similarity with those of the neighbouring Mt. Elgon despite having different orogenic formations as seen in the resemblance of the endemic *Senecio johnstonii* ssp. *battiscombei* var. *cheranganiensis* to Mt. Elgon's *Senecio johnstonii* ssp. *elgonensis* var. *elgonensis* (3200-3300 m asl) (Cotton & Blakelock, **1937**). With respect, both Cherangani Hills and MFC are dominated by Compositae and Rubiaceae, except for the invasion of shrub/small tree *Trichocladum ellipticus*(Eckl. & Zeyh)and a shrubby *Solanum mauritianum* Scop.which negatively altered species diversity and richness of the MFC (Mutiso *et al*., **2015**). The Cherangani Hills and Mau Forest Complex show 'weak' forest transitions as compared to Mt. Kenya, Aberdare Range and Mt. Elgon, most probably due to their relative lower elevations, and are largely composed of a montane and submontane plant communities with few 'alpine' and 'subalpine' as observed from our field recordings in recording presences of *Stoebe kilimandscharica*, *Carduus chamaecephalus, Droguertia iners, Kniphofia thomsonii,* and *Clinopodium uhligii* which often occur in higher areas exceeding 3000m asl (Table **1**) (Hedberg, **1951**; Schmidt, **1991**; UNEP, **2003**; Bussmann, **2006**).

Conclusion

Historical vegetation reference help explain species composition, species distributions and habitat changes over a long period of time with the use of ecological plant indicators. However, the Cherangani historical vegetation and altitudinal references was not authoritatively sufficient to support our *a priori* assumptions of species shifts and compositional shifts or rather a case of having recordings of 'unpublished' references for the actual study sites in the Cherangani Hills forest ecosystem. Long term monitoring of ecological indicator plant species for dry, wet and disturbance help predict changes in climatic and anthropogenic impacts. However, these indicator plant species require timely revision, tests and validation. However, there is need for acquisition of more site-specific climatic, environmental, palynological and additional forest data to help explain spatio-temporal changes and conduct empirical determination of the species shifts phenomenon with respect to the Cherangani montane forest ecosystem. The data collected in this study can serve as a reference material for future studies.

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References

Agnew, A.D.Q. (**2013**). Upland Kenya wild flowers and ferns. A flora of the flowers, ferns, grasses and sedges of Highland Kenya. Third completely revised edition. Nature Kenya-The East Africa Natural History Society.

Akotsi E. & Gachanja M. (**2004**). Changes in forest cover in Kenya's five "Water Towers" 2000-2003.

Ayuyo, I. O. A., & Sweta, L. (**2014**). Land Cover and Land Use Mapping and Change Detection of Mau Complex in Kenya Using Geospatial Technology. International Journal.

Beentje, H. (**1994**). Kenya trees, shrubs and lianas. National Museums of Kenya.

BirdLife International (**2015**). Important Bird Areas factsheet: Cherangani Hills. Downloaded from http://www.birdlife.org on 20/08/2014 at 4.50pm.

Bodin, J., Badeau, V., Bruno, E., Cluzeau, C., Moisselin, J. M., Walther, G. R., & Dupouey, J. L. (**2013**). Shifts of forest species along an elevational gradient in Southeast France: climate change or stand maturation? Journal of Vegetation Science, 24(2), 269-283.

Bussmann, R. W. (**1996**). Destruction and Management of Mount Kenya's Forests. Royal Swedish Academy of Sciences, Ambio, 25(5), 314-317.

Bussmann, R. W. (**2006**). Vegetation zonation and nomenclature of African mountains—an overview. Lyonia, 11(1), 41-66.

Čarni, A., Košir, P., Karadžić, B., Matevski, V., Redžić, S., & Škvorc, Ž. (**2009**). Thermophilous deciduous forests in Southeastern Europe. Plant Biosystems, 143(1), 1-13.

Cotton, A. D., & Blakelock, R. A. (**1937**). The arborescent Senecios of the Cherangani Range, with supplementary notes on Mt. Elgon species. Bulletin of Miscellaneous Information (Royal Botanic Gardens, Kew), 361-371.

Feeley, K. J., Hurtado, J., Saatchi, S., Silman, M. R., & Clark, D. B. (**2013**). Compositional shifts in Costa Rican forests due to climate-driven species migrations. Global change biology, 19(11), 3472-3480.

Feeley, K. J., Silman, M. R., Bush, M. B., Farfan, W., Cabrera, K. G., Malhi, Y., & Saatchi, S. (**2011**). Upslope migration of Andean trees. Journal of Biogeography, 38(4), 783-791.

Fox, B. J., Taylor, J. E., Fox, M. D., & Williams, C. (**1997**). Vegetation changes across edges of rainforest remnants. Biological Conservation, 82(1), 1-13.

Gehrke, B., & Linder, H. P. (**2014**). Species richness, endemism and species composition in the tropical Afroalpine flora. Alpine Botany, 124(2), 165-177.

Hedberg, O. (**1951**). Vegetation belts of the East African mountains. Svensk Bot. Tidsk, 45, 140-202.

Hemp, A. (**2005**). Climate change-driven forest fires marginalize the impact of ice cap wasting on Kilimanjaro. Global Change Biology, 11(7), 1013-1023.

Hill, M. O. (**1979**). TWINSPAN: a FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes. Section of Ecology and Systematics, Cornell University.
Kenya Forest Service (**2010**). Participatory Forest Management Plan, Cherangani Forest Station, 2011-2015.
Kenya National Bureau of Statistics (**2014**). Population and Housing Censuses. Downloaded from http://www.knbs.or.ke on 24/08/2014.
Kenya, N. E. N. I. (**2014**). Interpretation of High Value Ecosystems and Natural Ecosystems for Kenya.
Kessler, M. (**2001**). Maximum Plant-Community Endemism at Intermediate Intensities of Anthropogenic Disturbance in Bolivian Montane Forests. Conservation Biology, 15(3), 634-641.
Kindt, R., Lillesø, J. P. B., & Van Breugel, P. (**2007**). Comparisons between original and current composition of indigenous tree species around Mount Kenya. African Journal of Ecology, 45(4), 633-644.
Kinyanjui, M. J. (**2011**). NDVI-based vegetation monitoring in Mau forest complex, Kenya. African Journal of Ecology, 49(2), 165-174.
Kinyanjui, M. J., Shisanya, C. A., Nyabuti, O. K., Waqo, W. P., & Ojwala, M. A. (**2014**). Assessing tree species dominance along an agro ecological gradient in the Mau Forest Complex, Kenya. Open Journal of Ecology, 2014.
Kipkore W., Wanjohi B., Rono H. & Kigen G., (**2014**). A study of the medicinal plants used by the Marakwet community in Kenya. Journal of ethnobiology and medicine, 10(1) 24.
Lambrechts C., Gachanja M., & Woodley B., (**2005**). Maasai Mau Forest Status Report.
Mabberley, D. J. (**1971**). The Dendrosenecios of the Cherangani Hills. Kew Bulletin, 33-36.
Maley, J., & Brenac, P. (**1998**). Vegetation dynamics, palaeoenvironments and climatic changes in the forests of western Cameroon during the last 28,000 years BP. Review of Palaeobotany and Palynology, 99(2), 157-187.
Mathooko, J. M., & Kariuki, S. T. (**2000**). Disturbances and species distribution of the riparian vegetation of a Rift Valley stream. African Journal of Ecology, 38(2), 123-129.
Mueller-Dombois, D., & Ellenberg, H. (**1974**). Aims and methods of vegetation analysis. John Wiley & Sons, Inc. New York, London, Sydney, Toronto.
Mutiso F. M. *et al.* (**2015**). Floristic composition, affinities and plant formations in tropical forests: A case study of Mau Forests in Kenya.
Newmark, W. D. (**1998**). Forest area, fragmentation, and loss in the Eastern Arc Mountains: implications for the conservation of biological diversity. Journal of East African Natural History, 87(1), 29-36.
Noss, R. F. (**1999**). Assessing and monitoring forest biodiversity: a suggested framework and indicators. Forest ecology and management, 115(2), 135-146.
Odland A., Birks H.J.B. (**1999**). The altitudinal gradient of vascular plant richness in Aurland, Western Norway. Ecography, 22(5), 548-566.
Olang, L. O., & Kundu, P. M. (**2011**). Land degradation of the Mau forest complex in Eastern Africa: a review for management and restoration planning. Environmental Monitoring. Rijeka (Croatia): InTech Europe.
Oxford University Expedition to the Cherangani Hills (**1969**) .National Museums of Kenya Herbarium Library Ecology file records, Kenya Ecology.
Phillips, O. L. (**1997**). The changing ecology of tropical forests. Biodiversity & Conservation, 6(2), 291-311.
RhinoArk (**2015**). Humans in harmony with habitat and wildlife. Downloaded from http://www.rhinoark.org on 22/01/2015 at 8.15pm.

Roleček, J., Tichý, L., Zelený, D., & Chytrý, M. (**2009**). Modified TWINSPAN classification in which the hierarchy respects cluster heterogeneity. Journal of Vegetation Science, 20(4), 596-602.

Rucina, S. M., Muiruri, V. M., Kinyanjui, R. N., McGuiness, K., & Marchant, R. (**2009**). Late Quaternary vegetation and fire dynamics on Mount Kenya. Palaeogeography, Palaeoclimatology, Palaeoecology, 283(1), 1-14.

Schmidt, K. (**1991**). The vegetation of the Aberdare National Park.

Soja, A. J., Tchebakova, N. M., French, N. H., Flannigan, M. D., Shugart, H. H., Stocks, B. J., & Stackhouse, P. W. (**2007**). Climate-induced boreal forest change: predictions versus current observations. Global and Planetary Change, 56(3), 274-296.

Turner, I. M. (**1996**). Species loss in fragments of tropical rain forest: a review of the evidence. Journal of applied Ecology, 200-209.

UNEP (**2003**). Aerial survey of the destruction of the Aberdare Range forests. Downloaded from http://www.unep.org on 28/07/2015 at 7.15pm.

UNEP (**2003**).Changes in forest cover in Kenya's five "Water Towers" 2000-2003. Downloaded fromhttp://www.unep.orgon 26/1/2015 at 4.13 pm.

Vitousek, P. M., Aber, J. D., Howarth, R. W., Likens, G. E., Matson, P. A., Schindler, D. W., & Tilman, D. G. (**1997**). Human alteration of the global nitrogen cycle: sources and consequences. Ecological applications, 7(3), 737-750.

Walther, G. R., Beißner, S., & Pott, R. (**2005**). Climate change and high mountain vegetation shifts. In Mountain ecosystems (pp. 77-96). Springer Berlin Heidelberg.

Wang, X., Feng, Z., & Ouyang, Z. (**2001**). The impact of human disturbance on vegetative carbon storage in forest ecosystems in China. Forest ecology and management, 148(1), 117-123.

Whitmore, T.C. (**1991**) Invasive woody plants in perhumid tropical climates. Ecology of Biological Invasions in the Tropics (ed. P. S. Ramakrishnan), pp. 35-40. International Publications, New Delhi.

Young, A., & Mitchell, N. (**1994**). Microclimate and vegetation edge effects in a fragmented podocarp-broadleaf forest in New Zealand. Biological Conservation, 67(1), 63-72.