WORKING PAPER 225

Trends in forest conditions and implications for resilience to climate change under differing forest governance regimes

The case of Mount Elgon, East Africa

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Photo: Daniel Waiswa

1 Introduction

The importance of forests in protecting biodiversity and providing a range of ecosystem services to society is well established (Millennium Ecosystem Assessment 2003). The latter include an array of provisioning services (food, fuel, fibers, etc.), regulating services (regulations for water, local microclimates, soil erosion, etc.), cultural services (religious, recreational, etc.) and supporting services (nutrient cycling, soil formation, etc.) A number of studies have documented the variety of ways in which forests contribute to increasing human quality of life (Levy et al. 2005; Colfer et al. 2006; Colfer ed. 2008; Russell et al. 2013). Additionally, forests play a dual role with regard to climate change: first as carbon sinks that help global societies reduce the rates of carbon accumulation in the atmosphere (climate mitigation); and secondly as a source of societal adaptation to climate change and to increases in climate variability that are certain to occur (IUFRO 2009).

To a very large extent, the management of natural resources in Africa through the mid-1980s was based on a “fortress conservation approach” that aimed to preserve “climax” ecosystems through the exclusion of all human influences (with the exception of tourism and in some cases Eurocentric forms of hunting – Vedeld 2002). The numerous conservation failures and ethical dilemmas of this top-down resource governance approach raised awareness of the need for a more inclusive conservation approach (Scott 1994). At the same time, ecologists were increasingly appreciating the dynamic, rather than linear, nature of forest successional stages in ecosystems that are liable to pass over “thresholds” and transition abruptly to new “climax” ecotypes when exposed to certain environmental, climatic and/or societal pressures; and the fact that previous efforts to maintain forests in any specific form of stasis risked reducing the resilience of those forests to major shocks.

Today, most natural resource managers are adopting “adaptive management” approaches that allow for greater variability and disturbances, maintaining diversity in structure, rather than optimizing or maximizing any specific type of production (Holling 1973; Holling ed. 1978; Holling and Meffe 1996; Holling and Sanderson 1996). This coincides with societal demands for greater equity and justice for those stakeholders living around forest resources and depending on them for their livelihoods. National resource management agencies across Africa currently employ a range of participatory to centralized protected area (forest) management approaches with varying degrees of success in terms of achieving societal and conservation objectives.

Conservation and development objectives were previously regarded in opposition to each other, but there is increasing awareness of interlinkages between societal and ecological resilience (Gunderson and Holling 2002; Walker et al. 2006). Furthermore, the importance of the ecosystem services forests provide to society in coping with climate change is generating some momentum for recasting the politically opposing priorities related to climate-change mitigation (highly overlapping with traditional conservation priorities) and climate-change adaptation (overwhelmingly a societal development priority) as part of a unified ecosystem-based adaptation approach to climate change (TEEB 2009; Russell et al. 2012).

2 Literature Review

2.1 Critical roles of sky islands like Mount Elgon

The African Eastern Arc Mountains harbor high levels of biodiversity and endemism as significant flora and fauna populations are remnants from previous cooler climatic periods (Birdlife International 2012; Mazel et al. 2014; Mittermeier et al. 2004; Howard 1991). Mount Elgon is the oldest of the East African volcanoes, has an average annual precipitation of 1280 mm and minimum and maximum temperatures of 9 °C and 22 °C, and lies at latitude 1° 08' N and longitude 34° 45' E. (Davies 1952). In contrast with many other montane forest ecosystems in East Africa, Mount Elgon also remained connected to lowland forests until very recently, thereby prolonging the period and opportunities for the exchange of (and competition among) biodiversity across what in East Africa are frequently found to be strictly altitude-delineated floristic communities (Hamilton 1975; Hamilton and Perrott 1981). Given its relative isolation from other so-called "sky islands," several studies have documented Mount Elgon's importance as a particularly stable ecological refuge in the Kenyan highlands (Demos et al. 2015; Davenport et al. 1996; Wagner et al. 2014).

Mount Elgon's vegetation is grouped into four altitudinal zones (Howard 1991): mixed montane forest up to an elevation of 2500 m; bamboo and low canopy montane forest from 2400–3000 m; high montane heath from 3000–3500 m; and moorlands above 3500 m. The majority of the plant species are found between 2000 and 3500 meters above sea level (masl) (Vedeld et al. 2005), with changes in topography, slope, aspect, rainfall and soil causing variations in vegetation composition. Common resources from Mount Elgon include firewood, timber, ropes, poles, bamboo shoots, vegetables, honey, bush meat, fruits, medicinal herbs and grass (Scott 1994; Sassen and Sheil 2013). Out of a total area of approximately 772,000 ha, 221,000 ha has been set aside as reserves and national parks (IUCN 2007).

In addition to harboring unique biological diversity, the forests and wetlands of Mount Elgon provide a range of goods and services to surrounding human populations. The mountain's slopes are among the most densely populated areas in Uganda and produce large volumes of food crops (e.g. maize, plantains, beans) and cash crops (e.g. coffee, tea). Furthermore, this transboundary montane ecosystem is referred to as one of the key "water towers" and regulates critical hydrological flows across large watersheds in Uganda and Kenya (and onward to the Nile River basin) (van Heist 1994; IUCN 2005).

2.2 The impacts of climate change on societal and forest resilience

The mean annual temperatures across East Africa are expected to rise over the course of the century, and while there is uncertainty regarding average annual precipitation, there is some confidence in the predictions of increased rainfall during the short dry season (Shongwe et al. 2009 Few et al. 2015; Christensen et al. 2014; Boelee et al. 2013). The impacts of increasing climate variability and droughts on societal health (Alonso et al. 2011; Roncoli et al. 2010), agricultural productivity (Russell et al. 2013; Okonya et al. 2013; Jaramillo et al. 2011; Mubiru et al. 2012), food security (Kristjanson et al. 2012; Webber et al. 2014), livestock (Ngugi 2002) and landslide risk (Knapen et al. 2006) in East Africa's highlands are already being documented.

These anthropogenic disturbances of the forest are likely to interact with changing weather patterns to increase demand for forest products directly, as well as facilitating the introduction of exotic species and increased disease prevalence (Millennium Ecosystem Assessment 2003; Binggeli 1998). Both forest loss and conversion to plantations impact mycorrhizal fungal diversity, which is known to play a role in enabling a range of tree and flora species to recover from shocks (Johnson et al. 2013;

Grilli et al. 2012). The abilities of different trees and plant species to adapt and respond to changes in temperature and precipitation, as well as associated changes in atmospheric and subsoil nutrient levels, are highly complex and do not allow generalizations to be drawn. However, there is clear evidence of impacts from increasing atmospheric CO_2 on soil biota and carbon fixation by plants (Rillig et al. 2002; Drigo et al. 2010; Singh et al. 2010). Furthermore, there is mounting evidence of various species' phenological mistiming of seasonal activities (such as flowering) and the growing risk of mismatches between the phenology of organisms at different trophic levels that may rely on each other (i.e. soil biota, trees, insects, birds) (Visser and Both 2005; Voigt et al. 2003; Walther et al. 2002; Hughes 2000).

A key to ensuring the future resilience of relatively isolated islands of biodiversity such as Mount Elgon (and the wealth of ecosystem services they provide to society) will be efforts to maximize the diversity at various spatial scales (i.e. with respect to both species diversity within forest stands and the diversity of different ecological niche types themselves) (Peterson et al. 1998; Ives and Carpenter 2007; Thompson et al. 2009).

2.3 Forest governance and climate-change policy approaches in Uganda and Kenya

Mount Elgon forest is an important transboundary resource shared by Kenya and Uganda, and each side has witnessed a range of population and forest governance policies. Both the Kenyan and Ugandan parts of the mountain were under a certain level of protection during the colonial period as forest reserves.

On the Ugandan side, Mount Elgon Crown Forest was gazetted by the Forest Department in 1937, 1948 (as a Forest Reserve) and 1951 (as a Demarcated Protection Reserve) (Synott 1968). From the 1930s to the 1960s, the colonial protectorate administration faced conflicts with local Sabiny and Bagisu communities, leading it to excise portions or grant use rights to certain areas (Wiley 1993). During the 1970s and 1980s, the post-independence Forestry Department was unable to fulfil its mandate due to political instability, violence and lawlessness, leading to large losses of forest cover within the forest reserve margins and the resettlement of large populations around them (Sassen et al. 2013; Onyango 1996; Turyahabwe and Banana 2008). During the late 1980s to the early 1990s, the forest reserve's boundaries were redrawn several times (fostering further conflicts with communities), and the management of Mount Elgon National Park was taken over by the Uganda Wildlife Authority (UWA) (Himmelfarb 2006; Norgrove and Hulme 2006). Since the 1990s, UWA has attempted to improve relations by entering into formal collaborative forest management agreements with a number of communities. However, these have had mixed success in terms of addressing either the livelihood or conservation objectives (Hinchley 1999; Norgrove and Hulme 2006; Sassen and Sheil 2013; Sassen et al. 2013).

The history of the protected area and land-use policies on the Kenyan side of Mount Elgon was quite different, as large portions of the surrounding agricultural lands were alienated by the colonial administration for settlement and large-scale agricultural development by Europeans, and later by East African army veterans (Soini 2007). Parts of Mount Elgon were first gazetted as a government forest reserve in 1932 (Ongugo et al. 2011). These gazettements and displacements have similarly resulted in long-standing claims by displaced peoples, and the post-independence government implemented several poorly-managed and corrupted land re-allocation schemes in the 1970s, the 1990s and 2005 (Soini 2007; Ongugo et al. 2011). Today, parts of the forest on the Kenyan side are managed by the Kenya Wildlife Service (KWS) and Kenya Forest Service (KFS), employing a strict exclusionary approach, and a "participatory" management approach, respectively.

The existing and growing societal demand for forest resources ranges from urban demand for charcoal and timber, to encroachment by local communities for farmland and livestock fodder, and wood pulp extraction by private industries (Sassen and Sheil 2013; Sassen et al. 2015; Nakakaawa et al. 2015). As shown above, the policies used by the government have an impact on managing these socioeconomic drivers of land use and ecological change on Mount Elgon, that in turn will have a great influence on forest resilience to climate change. However, forest conservation cannot be accomplished in isolation from the range of overlapping agricultural, land-use, conservation and energy policies that impact how society and other agencies interact with the forest. Reviews of these overlapping, and at times conflicting, policies and programs implemented by an array of national and decentralized government agencies and departments (and NGOs) highlight an overwhelming lack of coordination among them, reflecting the maintenance of highly sector-specific traditional ministerial intervention silos (Ongugo et al. 2014; Banana et al. 2014). Despite the rising global urgency to address drivers of climate change through carbon sequestration and the adaptation of vulnerable societies to the impacts of climate change, the current Ugandan and Kenyan climate-change strategies seem to be designed according to these same silos (Russell et al. 2016a; Russell et al. 2016b).

Incomplete understanding of many natural forests in Sub-Saharan Africa in terms of their structure, composition and regeneration, and of their provision of tangible and intangible benefits, severely limits evidence-based forest governance capacities (Godoy 1992). The objective of this study was to assess the impact of different forest governance regimes on forest structure and biodiversity in four study sites (Kimothon, Chorlem, Kapkwai and Bufuma) in the Mount Elgon ecosystem over time, reflecting both the policies and the way in which they have been implemented. This would then be used as a means for assessing which model is most likely to enhance the long-term climate resilience of Mount Elgon's forests.


Photo: Daniel Waiswa

3 Study Area

Mount Elgon is an old volcanic remnant straddling the border of Uganda and Kenya (Figure 1) that forms part of the East African Arc Mountains. It is referred to as a “water tower” due to the important ecosystem services it provides for large watersheds (and human populations) in Kenya and Uganda, and as a “sky island” or “refugium” due to its large amount of endemic flora and fauna. As a result of its fertile soils, agreeable climate and low insect-borne disease burden, the slopes of this mountain have attracted and supported high population levels and significant exports of food crops (especially maize, plantains and beans) and cash crops (especially tea and coffee).

This study includes two sites on the Ugandan side – Kapkwai in Kapchorwa district and Bufuma in Bududa district – and two on the Kenyan side – Chorlem and Kimothon (Figure 1). These sites were established by Makerere University and the Kenya Forestry Research Institute (KEFRI) in 1997 for long-term research activities to monitor forest resources and institutions under the International Forestry Resources and Institutions (IFRI) research program (Wollenberg et al. 2007). The sites in Uganda have been revisited in 2001, 2008 and 2012, while those in Kenya were revisited in 2001/2 and 2012/13. This is therefore one of the longest time-series data collections integrating both the forests’ conditions and the associated community-based uses, institutions and perceptions in Africa (though it should be mentioned that there are much older datasets monitoring forest conditions, such as Budongo, Uganda – see Eggeling 1947 *in* Sheil 1995).

Figure 1. The transboundary Mount Elgon containing the four study sites: the Kapkwai and Bufuma forest sites in Uganda and the Chorlem and Kimothon forest sites in Kenya.

Source: Muhweezi et al. 2007

3.1 Uganda: The Kapkwai and Bufuma sites

A number of forest patches on the Ugandan slopes of Mount Elgon were protected during British Protectorate times as "forest reserves," a status that continued even after Uganda gained independence in 1962 under Forest Department management. However, due to the Forest Department's inability to stem forest degradation, these patches were gazetted as a National Park in 1993, putting them under the management of the Uganda Wildlife Authority. Both the Kapkwai and Bufuma forest units lie within Mount Elgon National Park and officially enjoy high levels of legal protection for conservation purposes (Scott 1998; Norgrove and Hulme 2006). However, communities around the park area continue to rely significantly on trees inside the park for fuelwood and for high-value species as a source of commercial timber (Sassen et al. 2015; Nakakaawa et al. 2015). Even the integrity of the park boundaries remains heavily contested, and UWA has been forced to degazette certain portions of the park to allow for the livelihoods of forest-dwelling Sabot communities. It has also established memorandums of understanding (MOUs) granting certain communities access rights to the park to harvest selected resources in exchange for their participation in buffer zone afforestation activities; and encouraged others to engage in *taungya*-style agroforestry practices in degraded areas of the park currently under cultivation (Lang and Byakola 2006; Norgrove and Hulme 2006; Russell et al. 2013; Nakakaawa et al. 2015).

3.2 Kapkwai Forest

The Kapkwai Forest Unit lies on the northwestern flank of Mount Elgon in Kapchorwa District. The IFRI team has collected four sets of forest condition data there (1997, 2001, 2008 and 2013). The forest unit covers 354.6 km^2 and lies adjacent to (and upslope from) a district with a population density of 294.9 persons/km^2 (UBOS 2014). The Kapkwai Forest Unit is located at an average altitude of 2091 masl, with slopes averaging 13.35%.

The communities of Kapchorwa have signed a total of 24 participatory forest management agreements with UWA, which is the largest number of all the Ugandan districts on the western slopes of Mount Elgon (Nakakaawa et al. 2015). Since UWA signed an MOU establishing collaborative forest management (CFM) with the Kapkwai community in 2001, the community has enjoyed legalized access to the park to harvest non-timber forest products on a regulated basis in exchange for their participation in a buffer-zone afforestation program.

3.3 Bufuma Forest

The Bufuma Forest Unit lies on a southwestern flank of Mount Elgon in Bududa District. The IFRI team has collected three sets of forest condition data there (1997, 2001 and 2008). Due to challenges related to accessibility and fears of landslides, no further forest condition data collection was possible during the 2012-2013 research period. The forest unit covers 250.8 km^2 and has a population density of 844 persons/km^2 (UBOS 2014a). The Bufuma Forest Unit is located at an average altitude of 2969 masl, with slopes averaging 19.55%.

In contrast with Kapchorwa District, Bududa District has benefitted from the signing of just one MOU with UWA (Nakakaawa et al. 2015). Due to the remoteness of the Bufuma Forest Unit and poor relations between the community and UWA, there is no MOU in place allowing the community to access Bufuma Forest Unit. Given that, it is a punishable offence for this community to access or harvest forest resources, relationships between the community and UWA have been particularly acrimonious, with accusations of physical violence and arrests. It should also be mentioned that this community and the district in general are particularly vulnerable to landslides, which have killed hundreds of people, with large landslide events occurring in 2010, 2012 and 2013.

3.4 Kenya: The Chorlem and Kimothon sites

Mount Elgon was part of Kenya's “white highlands,” where the allocation of land to settlers often resulted in the displacement of local people, who were mainly pastoralists (Waweru 1974). The Kenyan part of the park was gazetted in 1968. It covers 1,279 km^2, with cypress and pine plantations accounting for an estimated area of 4,500 ha (Ongugo et al. 2011). Nevertheless the forest remains significant to the livelihoods of the Sabaot and Ogiek indigenous peoples and other local communities in terms of food, subsistence hunting, wild fruits, honey, thatching materials, medicine, and traditional and religious ceremonies. There were several contentious land reallocations in 1974 when the area was originally excised for a forest-dwelling community of the Sabaot (Ndorobo, Kony, Sabiny, etc.) in exchange for their original homeland within the gazetted forest reserve, with additional reallocations in the 1990s and as late as 2005 (Soini 2007). Population resettlements and locally growing populations have contributed to forest degradation through encroachment for charcoal production and agricultural cultivation, while private sector elites have circumvented logging bans, resulting in the over-exploitation of Mount Elgon teak (*Olea welwstchii*) (Ongugo et al. 2011). In 2000, there was a further large-scale population eviction from the Mount Elgon forest when it was declared a game reserve.

3.5 Chorlem Forest

Chorlem Forest Unit lies within Mount Elgon National Park, which is managed by the Kenya Wildlife Service (KWS) and was created in 1990 under the auspices of chapter 376 of the Wildlife Act of 1975 (Nield et al. 2000). It is a conservation and protection forest area for flora and fauna, with an average altitude of 2297 masl and slopes averaging 10.95%. It covers 169 hectares of mainly indigenous tree species.

Chorlem Forest is strictly managed for conservation and ecotourism purposes, with only limited non-extractive access permitted for the local community, although there is evidence of illegal harvesting of both flora and fauna. All tourism is managed and operated by the KWS management, although it does offer some employment (as guides, guards, tree planters and hospitality staff) to community members registered with the local community-based organizations. The forest has been protected by an electric perimeter fence since 1994, both to control unmonitored access to the park and to reduce human-wildlife conflicts (particularly crop raiding by elephants and baboons).

3.6 Kimothon Forest

Kimothon Forest is a forest reserve located on a northeastern slope of Mount Elgon. It is managed by the Kenya Forest Service as a production/protection forest and therefore contains a mixture of indigenous and planted exotic tree species. This forest covers 10,243 ha with an average altitude of 2313 masl and slopes averaging 12.32%.

The communities living adjacent to the forest are primarily farmers of maize, beans and vegetables (kales, tomatoes) and they depend on the forest for timber, poles, herbal medicine, food, fuelwood and livestock grazing. These products are both for subsistence and commercial purposes.

Prior to 1986, this forest underwent a period of significant harvesting and, despite government bans on logging, certain politically-connected private companies where able to gain access up to the mid-1990s. This contributed to a deterioration in relations with local communities leading to further small-holder encroachment of the park and livestock herding. Recognizing its inability to impose strict closures, the passage of the 2005 Forest Policy permitted the Kenya Forest Service to enter into forest management agreements with community forest associations (CFA). Access to the forest for the harvesting of certain products is governed by a set of rules that include paying some levies (Soini 2007). The rules are deemed to be clear, fair, easy to understand and legitimate and are flexible when it comes to dealing with unusual problems (Kiragu 2002), although observance of the rules is far from universal.

4 Methods

4.1 Data collection

Forest degradation can be assessed through characterization of changes in the vertical and horizontal forest structure and through its consequences within the ecosystem, including its effects on and changes in floristic composition, species diversity, soil fertility and forest regeneration characteristics (Hitimana et al. 2004). A forest's vertical structure includes its differentiation into layers between the ground and canopy (vegetation layers of different heights and species occupying different canopy levels at maturity – Bourgeron 1983). The horizontal structure of a forest is composed of the diameter-size distribution of tree species and their stocking (density or basal area) (Philip 1994). This reflects both the spatial distribution of individual trees within the forest and the distribution of different species in relation to one another. Diameter distributions are used to assess disturbance effect within forests and to detect trends in regeneration patterns.

Data on these phenomena was collected using the IFRI methodology (Wollenberg et al. 2007) based on the Institutional Analysis and Development framework (IAD). Thirty plots were randomly established in each of the sites in 1997. In order to avoid biasing assessments of forest over time, subsequent forest unit revisits in 2001/2, 2008 and 2012/13 employed new randomized selections of sample plots.

Each plot consisted of three concentric circular plots of 1-m radius (3.14 m^2), 3 m radius (28.26 m^2) and 10 m radius (314 m^2) (Figure 2). Within the inner 1-m radius subplot, all woody seedlings of young trees, shrubs and woody climbers with a diameter at breast height (DBH) of <2.5cm or a height of less than 1 m were recorded, along with the herbaceous plants (percent ground cover). In the 3-m radius subplot, the DBH and height of all shrubs and saplings of 2.5cm<DBH<10cm were recorded. And finally, the DBH and heights of all trees with a diameter at breast height of >10 cm were recorded in the 10-m radius subplot. All plant species (shrubs, saplings and trees) were taxonomically identified.

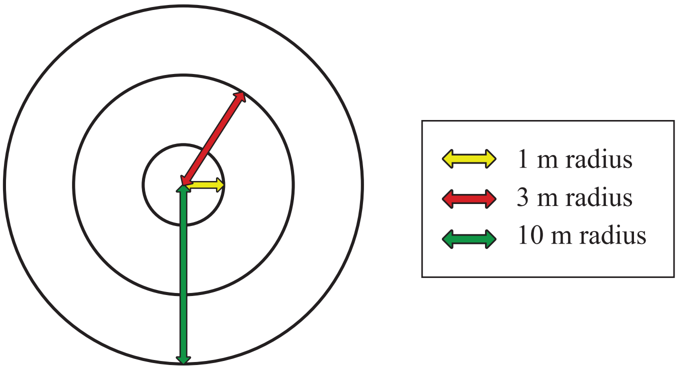

Figure 2. IFRI concentric circle forest plot sampling methodology.

4.2 Data analysis

The analysis focused on woody plant species (saplings, shrubs and trees) and provides comparative stand-level analyses of trends in forest/tree cover, species richness and diversity, and forest successional stage, using the following formulae:

Stem density: To compare the density of the plant types for each of the visits, the area of each plot was calculated using the formula Area (hectares) = $(\frac{\pi r^2}{10{,}000})$. Meanwhile, the plot area covered by saplings and shrubs was calculated using $(\frac{\pi * 3^2}{10{,}000}) = 0.002826$ ha and the plot area covered by trees using $(\frac{\pi * 10^2}{10{,}000}) = 0.0314$ ha, where π is 3.14 and "r" refers to the sample plot radius.

The density (number of stems per hectare) for each plant type was therefore calculated using $\left((\frac{\text{Number of plants}}{\text{Plot size}}) \big/ \text{Sample size (30)}\right)$.

Basal area: The size distribution was determined for saplings, shrubs and trees in the four sites, based on the basal area per hectare (m^2/ha) for each visit. Having recorded the diameters at breast height (DBH), the basal areas were calculated using the formula $\left(\frac{\pi}{4} * 10{,}000\right) * \text{DBH}^2$ for each tree or sapling.

The total basal area for each plot was obtained by summing the values for the individual trees, while the total basal area of the forest unit was determined by adding the values for the 30 plots. The average basal area was calculated by dividing the total basal area by the sample size (30), and divided by the plot size of 0.002826 hectares for saplings and shrubs and 0.0314 hectares for trees. The standard deviation and standard error were also calculated for both plot density and basal areas. Box plots were generated to show the distribution of the stem density and basal areas of trees and saplings/shrubs over time across study sites and also to provide an impression of the extent to which the diversity of ecological niches has widened or narrowed. Analysis of variance (ANOVA) and post hoc comparisons using the Tukey HSD test were conducted to ascertain any significant differences in the sites over time.

Biodiversity was expressed in terms of species richness and species diversity, the former determined by counting the number of distinct woody species encountered during each site visit and the latter based on the Shannon index (H). The Shannon index was calculated using the formula $H = -\sum_{i=1}^{s} \text{Pi} \ln \text{Pi}$, in which "p" is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N); "ln" is the natural log; Σ is the sum of the calculations and "s" is the number of species. The Shannon index is the most commonly used indicator to describe species diversity, and from a conservation stand-point it should be noted that it attributes a greater value to the presence and evenness of distribution of rare species than to those of the dominant species (Heip and Engels 1974).

The dominant species (with the highest frequencies of occurrence) in the four sites were identified. In order to get their relative percentage over the years, the frequency per species was divided by the cumulative frequency of the dominant species and multiplied by 100% (Relative percentage $= \frac{\text{species frequency}}{\text{cumulative frequency}} * 100\%$). The succession stages of the most dominant species were also identified to illustrate how changing forest structure and species diversity may be interpreted with regard to the levels of disturbance of the forest.

5 Results

5.1 Chorlem Forest – A Kenyan “no-access forest” case study

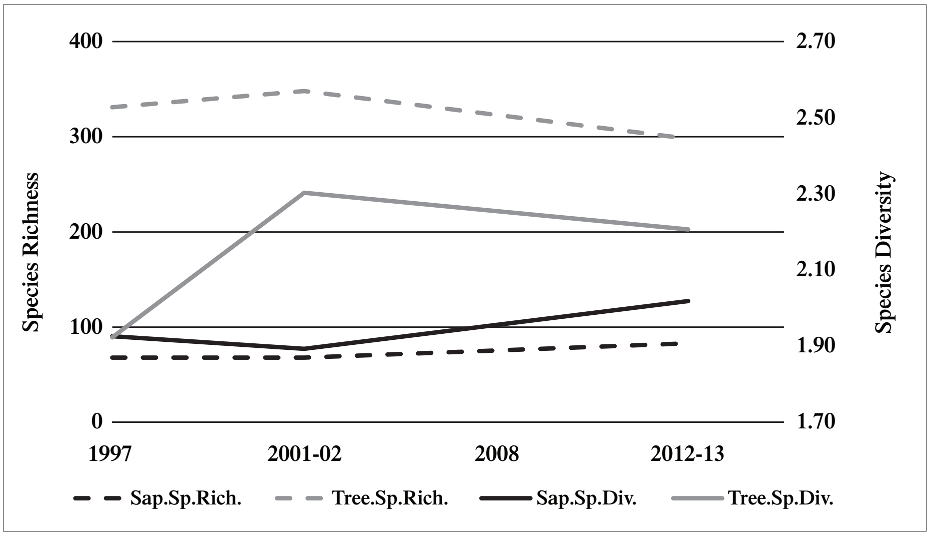

Figure 3. Chorlem (KE) trends in species richness and diversity (1997–2013).

Table 1. Chorlem (KE) trends in forest structure and composition (1997–2013).

Avg. % change		1997–2001	2001–2012	1997–2012
Tree	Stem dens.	Avg: +5.12% [p=0.741]	Avg: -14.36% [p=0.310]	Avg: -9.97% [p=0.425]
	Basal area	***Avg: +17.69% [p=0.380]***	***Avg: -14.98% [p=0.384]***	Avg: +0.06% [p=0.998]
	Sp. rich.	+1.3%/yr	-1.2%/yr	-0.6%/yr
	Sp. div.	***+4.9%/yr***	-0.3%/yr	+0.9%/yr
Sapling/shrub	Stem dens.	Stable [ns, p=1]	***Avg: +22.1% [p=0.570]***	***Avg: +22.1% [p=0.570]***
	Basal area	Avg: -6.92% [p=0.861]	***Avg: +17.77% [p=0.693]***	Avg: +9.62% [p=0.776]
	Sp. rich.	+0.0%/yr	+1.8%/yr	+1.4%/yr
	Sp. div.	-0.4%/yr	+0.6%/yr	+0.3%/yr

The overwhelming dominance of pioneer-class tree species (*Euclea divinorum*, *Croton macrostachyus*, *Brachylaena huillensis*) in the first data collection confirms that this forest had been heavily disturbed two to three decades previously, although some climax trees were also present (*Olea africana*, *Diospyros abyssinica*) (Table 5). During the first monitoring period (1997–2001), this forest witnessed a 17.69% increase in average tree basal area that was mirrored by a 6.92% decline in average sapling and shrub basal area (though neither change is statistically significant). During this same period, tree species diversity increased by an estimated 4.9%/year, consistent with a forest recovering from an earlier period of heavy selective harvesting of certain valuable tree species.

Over the course of the second (longer) monitoring period, trends in average forest structure appeared to reverse themselves, with a 14.98% decline in tree basal area, again mirrored by a 17.77% increase in average sapling/shrub basal area, and a 22.10% increase in average stem density (though neither change is statistically significant). During this time, species richness and the diversity of saplings and shrubs also increased somewhat. These trends are consistent with a period of harvesting, prompting a surge in recruitment.

Over the 15-year study timeframe (1997–2013), the dominance of pioneer tree species has gradually been supplanted to a significant extent by "climax" tree species (*O. africana, D. abyssinica)*, which would be consistent with the KWS's emphasis on protecting and conducting enrichment planting for key indigenous species. The sudden decline of *E. divinorum* as a dominant species suggests it was harvested (for small-scale construction, fuelwood or medicinal uses). Overall, tree and sapling/shrub indicators of forest structure and species diversity show minor, but consistently positive, trends of change since the first data collection point (1997). As the colonizing tree species are all quite fire sensitive, their presence confirms that fires have not been a significant influence on the forest vegetation assemblages.

Despite the overall improvements over the last 15 years, the negative recent monitoring phase (which is a reversal of the first data collection) suggests that despite being labelled a "no-access" forest, societal acceptance of these regulations cannot be taken for granted (as confirmed by team observations of illegal harvesting). In terms of forest niche diversity, the boxplots (see Figure 7) of basal area and stem density median and the quartile distributions indicate that this forest has in most regards maintained a wide range of ecological niches.

5.2 Kimothon Forest – A Kenyan "participatory forestry" case study

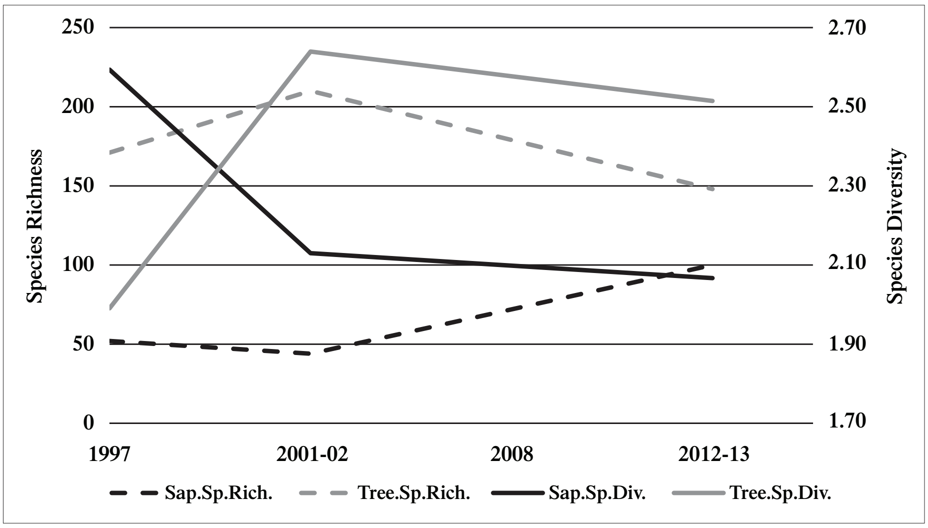

Figure 4. Kimothon (KE) trends in species richness and diversity (1997–2013).

Table 2. Kimothon (KE) trends in forest structure and composition (1997–2013).

Avg. % change		1997–2001	2001–2012	1997–2012
Tree	Stem dens.	***Avg: +22.81% [p=0.300]***	***Avg: -29.52% [p=0.094]***	***Avg: -29.52% [p=0.455]***
	Basal area	Avg: +0.32% [p=0.993]	***Avg: -54.28% [p=0.094]***	***Avg: -54.13% [p=0.005]*****
	Sp. rich.	***+4.6%/yr***	***-3.0%/yr***	-0.9%/yr
	Sp. div.	***+6.5%/yr***	-0.5%/yr	+1.8%/yr
Sapling/shrub	Stem dens.	Avg: -15.33% [p=0.661]	***Avg: +127.36% [p=0.048]****	***Avg: +92.50% [p=0.123]***
	Basal area	***Avg: +145.22% [p=0.495]***	***Avg: -74.25% [p=0.374]***	***Avg: +36.85% [p=0.574]***
	Sp. rich.	***-3.1%/yr***	***+12.7%/yr***	***+6.2%/yr***
	Sp. div.	***-3.6%/yr***	-0.3%/yr	-1.4%/yr

Note: p-value <0.05 is statistically significant (*); p-value <0.001 is highly statistically significant (**)

During the first monitoring phase (1997–2001), both the average stem density of trees and the basal area of shrubs increased, by 21.81% and 145.22%, respectively. However, these increases are not statistically significant. Indeed, despite the overall average increase in basal area, the box plots (see Figure 7) demonstrate a significant narrowing of tree size ranges. During this time, the richness and diversity of tree species increased sharply (4.6%/year and 6.5%/year, respectively), while those of shrubs and saplings decreased (-3.1%/year and -3.6%/year, respectively). This would be consistent with efforts to reduce both overall harvesting pressure and selective harvesting of key valuable species. The effects on the sapling/shrub layer are more difficult to explain, though it can be noted that there was a particularly high reporting of livestock browsing in the forest during that period.

During the second phase (2001–2012), the trends in forest conditions have been reversed and amplified. Average tree density and basal area declined by 29.52% and 54.28% respectively (both highly suggestive of overall trends, though not conclusive: p=>0.1), while for saplings and shrubs the mean density increased by 127.36% (p=0.048) and the basal area declined by 74.25%. These trends were matched by declining tree species richness (-3.0%/year) and sharply increased sapling/shrub species richness (12.7%/year). These trends would be consistent with a large increase in logging activities. The significant increase in sapling/shrub density but with a smaller basal area is consistent with a recent regrowth of the understory due to the opening up of the canopy. The declining shrub/sapling basal area and increasing species richness may suggest continuing disturbance regimes in different portions of the forest creating a range of forest conditions in which different species have an advantage. This would be consistent with continued noticeable livestock grazing (and/or the growth in ungulate wildlife populations) within the forest and the occurrence of significant forest fires in 2005, 2012 and 2013.

With regard to the dominant tree species, *O. africana* (a “climax” species) was the overwhelmingly dominant tree species at the beginning and end of this study. Two planted species had the second largest proportion of trees counted at the beginning (*P. radiata*) and the end (*P. patula*) of the study, confirming the KFS’s continued practice of planting exotics in degraded forest patches. At the mid-point of the study, pioneer species (*E. divinorum*, *Olinia rochetiana*) were highly present, consistent with a recovering forest, though their sharp decline towards the end of the study suggests continued harvesting of wood by local communities for subsistence use and sale (as firewood or charcoal).

Over the longer timeframe, trends in Kimothon Forest show highly significant losses of forest cover (-54.13%, p=0.005), a 29.52% decline in average tree stem density and a 92.50% increase in understory stem density. These trends are reflected in the medians and quartile distributions (see Figure 7) that demonstrate a severe loss in forest sample sites hosting larger individuals, while the number of sites with high densities of saplings has increased greatly.

5.3 Bufuma Forest – A Ugandan “no-access forest” case study

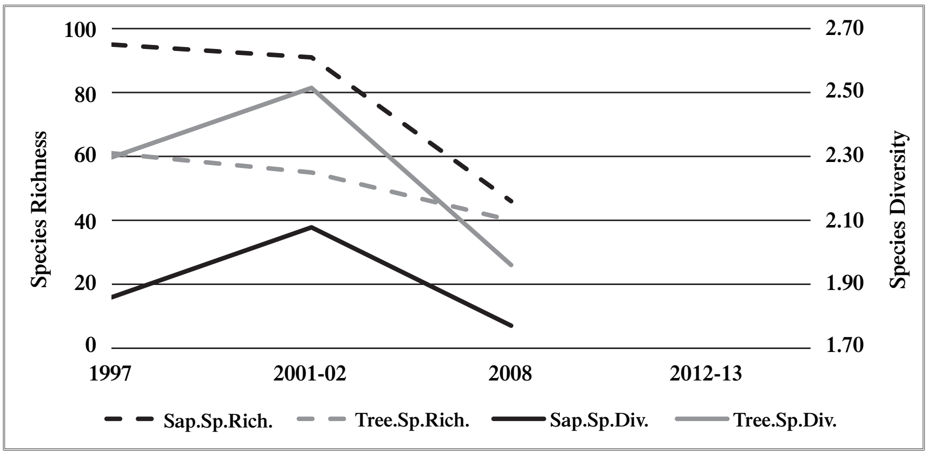

Figure 5. Bufuma (UG) trends in species richness and diversity (1997–2013).

Table 3. Bufuma (UG) trends in forest structure and composition (1997–2013).

Avg. % change		1997–2001	2001–2008	1997–2008
Tree	Stem dens.	Avg: -9.72% [p=0.744]	***Avg: -27.35% [p=0.402]***	***Avg: -34.41% [p=0.300]***
	Basal area	***Avg: -56.46% [p=0.079]****	Avg: -6.25% [p=0.928]	***Avg: -59.18% [p=0.113]***
	Sp. rich.	***-2.5%/yr***	***-3.9%/yr***	***-3.1%/yr***
	Sp. div.	***-2.4%/yr***	***-3.1%/yr***	-1.3%/yr
Sapling/shrub	Stem dens.	Avg: -3.21% [p=0.918]	***Avg: -49.95% [p=0.045]****	***Avg: -51.56% [p=0.088]***
	Basal area	Avg: -13.25% [p=0.755]	***Avg: -58.62% [p=0.020]****	***Avg: -64.10% [p=0.113]***
	Sp. rich.	-1.1%/yr	***-7.1%/yr***	***-4.7%/yr***
	Sp. div.	***+2.9%/yr***	***-2.1%/yr***	-0.4%/yr

Note: p-value <0.05 is statistically significant (*); p-value <0.001 is highly statistically significant (**)

This forest was heavily disturbed prior to commencement of the study with an overwhelming dominance of pioneer species such as *Podocarpus milanjianus* (Table 6). During the first monitoring phase (1997–2001), there was a significant decline in tree basal area (-56.46%, p=0.079), and a lesser decline in average stem densities and decreases in both tree species richness and diversity. These trends are consistent with harvesting biased toward larger-sized valuable trees. In contrast with other sites, this was not paralleled by an increase in sapling and shrub density or basal area, suggesting that in many locations clearance of large trees was coupled with clearance of the understory for agricultural purposes.

During the second monitoring period, the negative overall trends in mature tree harvesting continued (though on a less consistent basis) with a 27.35% decline in average stem density, while the sapling and shrub understory saw significant declines in both stem density (-49.95%, p=0.045*) and basal area (-58.62%, p=0.020*). Trends in the species diversity and species richness of trees and saplings/shrubs were consistently negative. This combination of trends could be attributed to the harvesting of the remnant ‘less valuable’ larger-sized trees, ultimately opening up land for agricultural production manifested through subsequent understory clearance.

Over the period of this study, the continued dominance of pioneer species is consistent with observations of the establishment of informal agricultural plots within the national park, where certain species are able/permitted to endure at the margins (*Maesa lanceolata*, *Neoboutonia macrocalyx*) and in wetter areas less suited to agriculture (*Macaranga sp*.).

The above conclusions are amplified by the boxplots of tree and sapling/shrub density and basal area (see Figure 7), which consistently reflect both declining medians and significant narrowing of ranges. This confirms that the range of ecological niches to support the flora and fauna communities is severely limited, offering doubtful contributions to fostering ecological community adaptation to climate warming.

5.4 Kapkwai Forest – A Ugandan "participatory forestry" case study

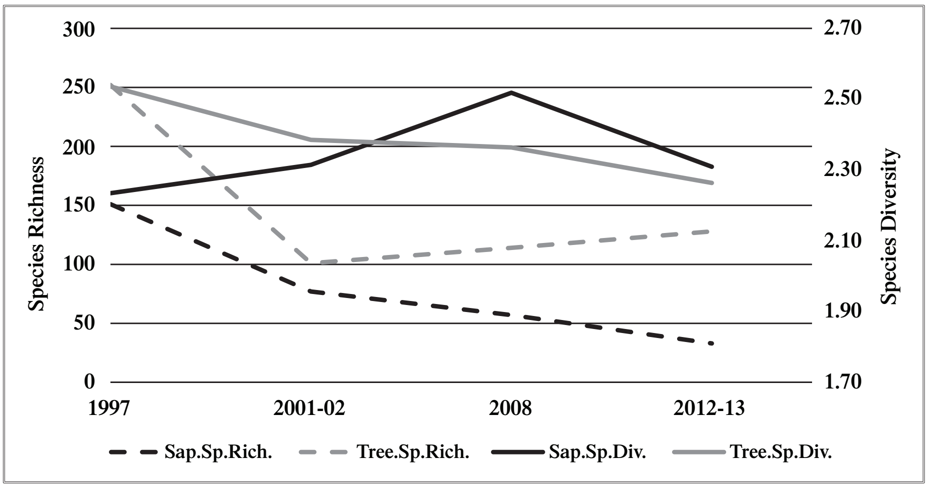

Figure 6. Kapkwai (UG) trends in species richness and diversity (1997–2013).

Table 4. Kapkwai (UG) trends in forest structure and composition (1997–2013).

Avg. % change		1997–2001	2001–08	2008–12	1997–2012
Tree	Stem dens.	***Avg: -64.10% [p=0.000]*****	Avg: +13.08% [p=0.604]	Avg: +12.40% [p=0.555]	***Avg: -49.25% [p=0.001]*****
	Basal area	***Avg: -73.50% [p=0.000]*****	***Avg: +50.67% [p=0.310]***	***Avg: -33.89% [p=0.237]***	***Avg: -73.60% [p=0.000]*****
	Sp. rich.	***-15.0%/yr***	+1.8%/yr	+*3.1%/yr*	*-3.3%/yr*
	Sp. div.	***-1.5%/yr***	-0.1%/yr	-1.1%/yr	-0.7%/yr
Sapling/shrub	Stem dens.	***Avg: -49.02% [p=0.001]*****	***Avg: -25.99% [p=0.227]***	***Avg: -36.76% [p=0.149]***	***Avg: -76.14% [p=0.000]*****
	Basal area	***Avg: -60.76% [p=0.001]*****	***Avg: -30.29% [p=0.238]***	Avg: +0.82% [p=0.979]	***Avg: -72.42% [p=0.000]*****
	Sp. rich.	***-12.3%/yr***	***-3.7%/yr***	***-10.5%/yr***	***-5.2%/yr***
	Sp. div.	+0.9%	+1.3%/yr	***-2.1%/yr***	+0.2%/yr

Note: p-value <0.05 is statistically significant (*); p-value <0.001 is highly statistically significant (**)

This forest unit was quite degraded at the start of the data collection, as indicated by the overwhelming dominance of pioneer tree species such as *Vernonia auriculifera, Neoboutonia macrocalyx* and *Croton macrostachyus* (Table 6). The first monitoring phase witnessed further severe and significant decreases in most key indicators. Tree density and basal area declined by 64.10% (p=.0000**) and 73.50% (p=0.000**), respectively, while species richness declined by 15%. The understory was similarly heavily degraded with highly significant reductions in stem density (-49.02%, p=0.001**) and basal area (60.76%, p=0.001**), as well as a 12.3% decline in species richness. This period corresponds with a regulatory vacuum during an administrative transition as the forest had been gazetted as a national park, but was still technically under the management of the Forest Department. During this time, there was a large-scale scramble by communities to gain whatever profits remained and to stake claims to land in the hope that it might be degazetted.

During the second monitoring phase (2001–2008), following the signing of an MOU between UWA and the local community giving inhabitants certain rights to access the park, most of these declining indicators look to have largely stabilized. An increase in tree species was recorded, although the understory looks to have continued to face pressure. The increasing number of trees could also be attributed to an UWA-FACE Project that involved enrichment planting using indigenous species with the involvement of the local communities. However, the declining understory could be attributed to the observation of continuing harvesting of fodder for livestock and the increasing harvesting of saplings and poles to support banana plants.

During the third monitoring period (2008–2012), some of the previous improvements may have been eroded with reductions in mean tree basal area and continued reductions in sapling/shrub stem density. These declines are consistent with the observed re-occurrence of illegal activities such as pole harvesting in the forest. The erosion of early improvements in deforestation trends may suggest a decline in collaboration between UWA and the local communities following the end of previous externally funded bufferzone afforestation project interventions.

Over the course of this 15-year study, Kapkwai Forest witnessed significant declines in the basal area, stem densities and species richness of both trees and understory saplings/shrubs, despite moderate improvements in recent times. It is also noteworthy that none of the dominant tree species are regarded as “climax” species, indicating that the forest still has some way to go to recover from the earlier period of forest degradation and reach pre-harvesting conditions. However, it should be noted that species diversity has remained remarkably stable over time, suggesting that while some species may have disappeared (i.e. a reduction in species richness), the distribution of species and threats to their survival are relatively homogeneous across the forest unit.

The tree basal area and stem density boxplots (see Figure 7) provide some encouragement, as medians and quartile distributions indicate that greater numbers of sample plots are increasingly populated by more and larger trees than was previously the case. However, the medians and quartile distributions also highlight a greater concentration of lower-density and smaller saplings and shrubs over time, indicating that recruitment is significantly repressed in some areas (which is consistent with the harvesting of poles for house construction and agricultural support stakes).

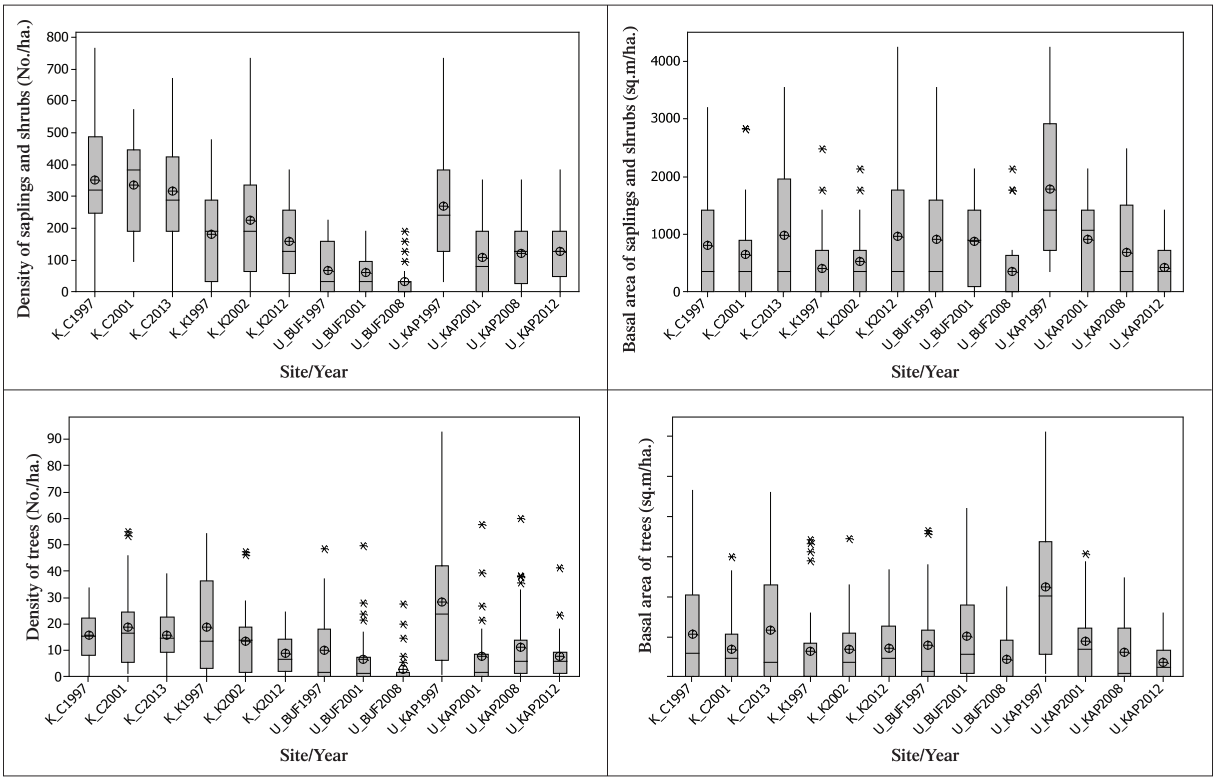

Figure 7 (a-d). Comparative boxplots of tree density and basal area (1997–2013).

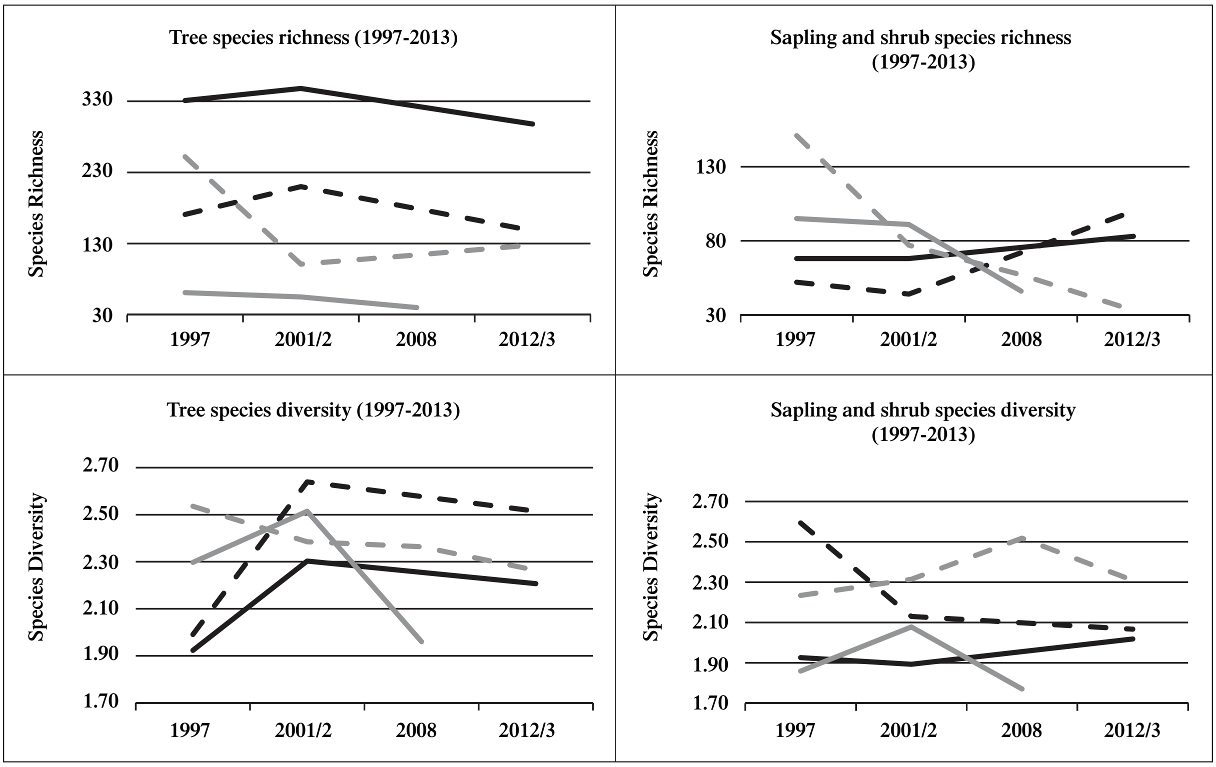

Figure 8 (a-d). Comparative trends in species richness and diversity (1997–2013).

Legend: Chorlem (KE) = dark solid; Kimothon (KE) = dark dash; Bududa (UG) = light solid; Kapkwai (UG) = light dash

6 Discussion

The four forest units under study are located on different slopes of Mount Elgon, with unique physical conditions (e.g. soil type, steepness) and different exposures to climatic conditions (precipitation, fog, sun, wind, etc.). These conditions shaped the establishment of diverse ecological niches around the mountain over many millennia, and subsequently influenced the types of human pressures on the ecosystem during the last centuries. While the comparison of single data collections from different sites around the mountain cannot hope to provide much useful information when it comes to drawing conclusions regarding the impacts of different forest governance regimes, the availability of forest data spanning a 15-year period provides very clear evidence of the impacts of different government policies and practices on forest resilience over very short periods of time. Additionally, by analyzing the successes and failures across the different policy contexts prevailing on the Kenyan and Ugandan sides of this mountain, this study is able to draw conclusions that defy dogmatic perceptions of the desireability of either protected area and participatory forest management governance approaches.

Nield et al. (2000), Matiru (1999) and a range of press sources documented the impacts of controversial, unsustainable pulpwood and hardwood harvesting operations of questionable legal standing on the Kenyan side of Mount Elgon during the 1990s, culminating in a number of legal and illegal protest actions by local county councils and communities up to the year 2000. This study's initial forest assessments (in 1997) confirmed the degraded state of these forests. However, while Chorlem, under Kenya Wildlife Service management, showed clear signs of stabilizing in the late 1990s, the severe narrowing of the tree size range depicted by the basal area of trees confirms that logging of both large trees and poles in Kimothon (under Kenya Forest Service management) continued through to the end of this period. The 2000s saw continued gradual declines in the indicators for average forest tree size (stem density, basal area, species diversity and species richness) though this was certainly greater in Kimothon.

In Uganda, the Forest Department's failure to manage forest reserves sustainably was the rationale for creating the Mount Elgon National Park under the Uganda Wildlife Authority in 1993 (though this did not truly come into force until 2000). Corresponding to findings by Sassen et al. (2013), the first project monitoring phase (1997–2002) confirmed the impacts of this short period of institutional uncertainty, with very large decreases in tree cover across both Ugandan sites. However, this analysis of forest conditions confirms that while deforestation rates quickly levelled off following the signing of an MOU between the Kapkwai Local Community and UWA, they have continued to deplete the resource base in Bufuma (see also Sassen et al. 2013; Nakakaawa et al. 2015).

When we compare the two partial-access forest units, Kimothon (KE) had been more heavily logged prior to the start of the study than Kapkwai (UG) and had less diversity or richness of larger tree size species. Both of these forests then suffered severe and statistically significant reductions in tree basal area in the 1990s due to lack of enforcement by the Kenya Forest Service and an institutional transition on the Ugandan side that left an enforcement vacuum. This short period of logging appears to have had inverse impacts on tree species diversity (very negative on the Ugandan side, positive on the Kenyan), which may be consistent with the fact that Kimothon is a much larger forest unit and that the logging activities, while severe, were more patchy, allowing sufficient recruitment to take place. As both of these sites allow some access to communities for the collection of non-timber forest products and dead wood (undoubtedly providing cover for some elicit logging), the continued disturbance regimes maintain a range of habitats supporting intermediate to high levels of species diversity and species richness. Alarmingly though, while Kimothon's (KE) forest conditions are still better overall than Kapkwai's (UG), the negative trends over the last 10 years suggest that its participatory forest management regime is not as sustainable as Kapkwai's, where the initially negative deforestation trends have largely levelled off.

When we compare the two no-access sites, Bufuma (UG) and Chorlem (KE) had quite similar levels of tree cover at the start of the study, but the contrasts between weak and strong governmental enforcement capacities (in those sites respectively) resulted in dramatically different outcomes over this 15-year period. Today, Chorlem (KE) has high species richness and low diversity. This is to be expected in a forest that has successfully transitioned from its post-disturbance recovery period, when more generalist pioneer species dominated, to an assemblage of more differentiated (though less well-evenly spread) and maturing ecological niches. In comparison, the complete failure of governance in Bufuma (UG) resulted in continued high levels of deforestation and land clearing that have severely reduced indicators of both species richness and diversity.

Photo: Daniel Waiswa

7 Conclusions

An analysis of either the Ugandan or the Kenyan sites for trends data in isolation would support two ideologically opposing and very dogmatic interpretations of the sustainability of participatory versus centralized (fences and fines) forest governance approaches. The Ugandan case studies would support the contention that participatory forest management is inherently more sustainable, while the Kenyan side would support the contention that parks are more effective than participatory regimes in ensuring forest resilience.

By comparing these four case studies, we see that fences-and-fines work reasonably well when there is significant investment in enforcement and where the government addresses community livelihood concerns, as in Chorlem (KE). In this case electric fences keep people out of the forest and prevent wildlife from raiding crops; and local people generate income from a tree nursery used by the government to conduct enrichment planting within the park and are provided employment in tree planting. However, fences-and-fines approaches have failed when they only focus on enforcement, ignoring peoples' livelihood concerns, as in Bufuma (UG). It should also be mentioned that short periods of inconsistency in UWA's engagement with different communities and the lack of clear communication between UWA and the decentralized government fostered an atmosphere in which local government representatives (who see themselves as representing the needs of the community) and UWA ended up working at cross-purposes.

Similarly, the two participatory case studies demonstrate that not all "participation" is equal. While both UWA and KFS have supported different livelihood diversification activities and allowed communities access to the forests for certain extractive uses, UWA's engagement on the Ugandan side appears to be much closer. The stakeholders in the Kimothon community feel relatively poorly supported by the Kenya Forest Service, with participation in livelihood diversification activities that may not be representative of the community as a whole, meaning that the benefits deriving from it, and therefore adherence to forest regulations, may be inconsistent as well. It should also be acknowledged that a majority of the community members in Kimothon were not original inhabitants of this area and may therefore take the resources they gain from the forest for granted. In contrast Kapkwai (UG) members have lived in this area for several generations.

Mount Elgon's range of flora and fauna is vulnerable to a range of human activities including timber extraction, charcoal production, non-timber forest product harvesting, livestock grazing, fires spreading from adjacent farmlands, and outright encroachment/land-use conversion. For a natural resource manager mandated with ensuring the resilience of Mount Elgon's flora and fauna, these types of activities may represent a zero-sum trade-off between conservation and development objectives. However, the growing exposure of local communities to climate variability (which is already making its effects felt in surrounding communities through the loss of morning fog, increased hail storm incidence, wind gusts, peak temperatures and alterations to precipitation patterns) has the potential to increase both anthropogenic and phenological pressures on Mount Elgon's forest resources.

Where forested areas are truly critical for conservation, a strong enforcement approach is needed (coupled with strong livelihood interventions), as in Chorlem, but this is not replicable everywhere due to resource limitations. In all other areas, the government will need to focus its investments more actively on building collaborations with agencies and decentralized governments that can support livelihood development in order to gain both their and the communities' active support for participatory management regimes.

The central agencies managing these protected areas need to recognize the importance of their role in reforestation and afforestation activities beyond the borders of the protected areas to enhance communities' food and fodder supplies and their energy (fuelwood and charcoal) needs; and to provide better protection from flash-flooding and landslides, among other effects. Conversely, both natural resource and agricultural agencies need to recognize the values of patches of biodiversity in on-farm tree niches (hedgerows, wetlands, woodlots, windbreaks, orchards, silvopastures) and that these synergies represent opportunities for furthering common mandates.

In mountain resource contexts, the interactions between rural communities (responding to socioeconomic drivers and supported by agricultural policies) and forest resources (that are impacted by those communities and provide a range of ecosystem services) require integrated policy approaches. In order to enhance the resilience of these mountain ecosystems in the face of climate change, both to protect biodiversity and to provide ecosystem services to local communities and downstream users, natural resource conservation and agricultural ministries from different central agencies and the decentralized local governments need to consider the impacts they have on each other more strategically.

Unfortunately, as evidenced by Kenya's and Uganda's recently developed climate-change adaptation strategies and respective flagship and NAPA projects, policy makers have approached climate-change strategy implementation in largely sectoral/ministerial silos (Banana et al. 2014 Ongugo et al. 2014), which is likely to perpetuate the no-sum game between adaptation and mitigation objectives. In line with project conclusions elaborated in Russell et al. (2016a, 2016b), a key recommendation from this analysis would be to propose more active integration of climate-change adaptation and mitigation activities through an ecosystem-based adaptation planning approach, and more active engagement by protected area enforcement agencies with decentralized government authorities and local communities.

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Annexes

Table A1. Dominant species – Kenya (representing >15% of total stems counted).

Kenya	Trees					Saplings and shrubs					
						Chorlem					
Species	**1997**	**2001-2002**	**2012-2013**	**Succ. stage**	**Prim. use**	**Species**	**1997**	**2001-2002**	**2012-2013**	**Succ. stage**	**Prim. use**
Euclea divinorum	62.9	4.1	9.9	b	a, c, d, k	*Brachylaena huillensis*	31.1	0	0	Coloniz.	b, c, d
Croton macrostachyus	13.7	10.9	13.2	b	a, c, d, e, f, m	*Euclea divinorum*	51.1	25	38.6	Coloniz.	a, c, d, k
Brachylaena huillensis	11.7	10.9	13.2	b	b, c, d	*Cassipourea malosana*	4.4	43.8	7	Coloniz.	c, d, f
Olea africana	11.3	32.1	33.5	a	a, c, d, e, l, m	*Teclea nobilis*	13.3	31.3	29.8	Under-story tree species	b, c, d, g, m
Diospyros abyssinica	0.4	42.0	30.1	a	a, d, g, f	*Dombeya torrida*	0	0	24.6	Pioneer	a, c, j,
						Kimothon					
Olea africana	59.8	24.4	68.9	a	a, c, d, e, l, m	*Cestrum aurantiacum*	0.0	0.0	80.4	Climax	l
Olinia rochetiana	0.0	35.6	6.6	b	d, e, h	*Hesperocyparis lusitanica*	32	59	0	Coloniz.	a, d, g, n
Pinus radiata	32.1	0.0	0.0	c	a, n	*Croton macrostachyus*	5.3	0	19.6	Coloniz.	a, c, d, e, f, m
Euclea divinorum	0.0	35.6	4.9	c	a, c, d, k	*Teclea nobilis*	10.5	40.9	0	Under-story tree species	b, c, d, g, m
Pinus patula	8.0	4.4	19.7	c	a, c, n	*Solanum indicum*	52.6	0	0	Climax	m

Ecological successional stages: a. climax overstory tree; b. pioneer overstory tree; c. plantation overstory tree; d. climax understory tree; e. climax understory tree saplings; f. climax understory shrubs; g. pioneer understory tree saplings; h. pioneer understory shrubs.

Primary uses: a. timber; b. handicraft; c. fuelwood; d. construction; e. charcoal; f. tool handles; g. furniture; h. posts; i. planting stakes; j. rope making; k. fodder and forage; l. ceremonial/cultural; m. medicinal; n. pulpwood.

Table A2. Dominant species – Uganda (representing >15% of total stems counted).

Uganda	Trees						Saplings and shrubs						
							Kapkwai						
Species	**1997**	**2001**	**2008**	**2012**	**Succ. stage**	**Prim. use**	**Species**	**1997**	**2001**	**2008**	**2012**	**Succ. stage**	**Prim. use**
Vernonia auriculifera	42.2	0	0	0	b	c	*Vernonia auriculifera*	53	40.0	28.6	100.0	Pioneer	c
Neoboutonia macrocalyx	35.4	54.7	40.7	30.9	b	c	*Neoboutonia macrocalyx*	32	48.9	38.1	0.0	Pioneer	c
Croton macrostachyus	22.4	22.6	0	0	b	a, c, d, e, f, m	*Arundinaria alpina*	15	0.0	0.0	0.0	Climax	i
Maesa lanceolata	0	22.6	22	60.5	d	c	*Maesa lanceolata*	0	0.0	33.3	0.0	Pioneer	c
Acacia senegalensis	0	0	37.3	8.6	b	c, k							
							Bufuma						
Podocarpus milanjianus	100.0	0.0	0.0	N/A	b	a	*Arundinaria alpina*	59.7	56.1	45	N/A	Climax	i
Dombeya mukole	0.0	52.4	0.0	N/A	b	h	*Dracaena fragrans*	27.8	35.1	0	N/A	Understory	d, h
Maesa lanceolata	0.0	23.8	33.3	N/A	d	c	*Vernonia auriculifera*	12.5	0	0	N/A	Pioneer	c
Macaranga sp.	0.0	23.8	25.9	N/A	b	c	*Rumex abyssinicus*	0	0	40	N/A	Pioneer	m
Neoboutonia macrocalyx	0.0	0.0	40.7	N/A	b	c	*Macaranga sp.*	0	8.8	15	N/A	Pioneer	c

Ecological successional stages: a. climax overstory tree; b. pioneer overstory tree; c. plantation overstory tree; d. climax understory tree; e. climax understory tree saplings; f. climax understory shrubs; g. pioneer understory tree saplings; h. pioneer understory shrubs.

Primary uses: a. timber; b. handicraft; c. fuelwood; d. construction; e. charcoal; f. tool handles; g. furniture; h. posts; i. planting stakes; j. rope making; k. fodder and forage; l. ceremonial/cultural; m. medicinal; n. pulpwood.

Table A3. Documented uses of dominant tree and shrub species on Mount Elgon.

Tree species	Documented uses
Acacia hockii	Medicinal
Alangium chinense	Fuelwood
Albizia coriaria	Timber, construction
Allophylus abyssinica	Fuelwood
Brachylaena huillensis	Construction, handicraft, firewood
Cassipourea malosana	Construction, tool handles, firewood
Croton macrostachyus	Construction, medicinal, fuelwood, charcoal, tool handles, timber
Diospyros abyssinica	Construction, tool handles, timber, furniture
Dombeya mukole	Posts
Dombeya torrida	Fuelwood, medicinal, rope making, timber
Dracaena steudneri	Posts, construction
Ekebergia capensis	Timber
Euclea divinorum	Fuelwood, medicinal, timber, construction, fodder and forage
Hagenia abyssinica	Timber
Hesperocyparis lusitanica	Timber, construction, pulpwood, furniture
Holoptelea grandis	Timber, construction
Macaranga monandra	Fuelwood
Maesa lanceolata	Fuelwood
Neoboutonia macrocalyx	Fuelwood
Olea africana	Charcoal, construction, medicinal, ceremonial, fuelwood, timber
Olinia rochetiana	Posts, charcoal, construction
Pinus patula	Fuelwood, timber, pulpwood
Pinus radiata	Pulpwood, timber
Podocarpus milanjianus	Timber
Rumex abyssinicus	Unknown
Shefflera abyssinica	Unknown
Solanum indicum	Medicinal
Syzygium giuneense	Fuelwood
Teclea nobilis	Construction, medicinal, furniture, handicraft, fuelwood
Triumfetta macrophylla	Construction
Vernonia auriculifera	Fuelwood, planting stakes
Vernonia duammeri	Fuelwood

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Mount Elgon is a transboundary East African montane ecosystem that harbors unique biological diversity and provides critical goods and services to the surrounding densely populated communities. As a key water tower, the effectiveness of forest- and land-management policies has direct impacts on agriculture, hydropower, fisheries and other sectors across large watersheds in Uganda and Kenya (and onward to the whole Nile River basin). The Uganda Wildlife Authority (UWA), the Kenya Wildlife Service (KWS) and the Kenya Forest Service (KFS) have developed a range of exclusionary protected area and partial-access participatory forest management approaches to enforce national conservation mandates in different portions of the Mount Elgon. The future resilience of forest assemblages will be challenged as climate change and increased variability in weather patterns interact that with societal interventions that may enable the introduction of exotic species, the expansion of diseases. The objective of this study was to assess the impact of different forest governance regimes on forest structure and composition over time (1997–2014). Two study sites in Uganda (Kapkwai and Bufuma) and Kenya (Chorlem and Kimothon) under differing forest governance arrangements were monitored from 1997 to 2014 using the International Forestry Resources and Institutions (IFRI) methodology. Each forest unit was sampled three to four times (1997, 2001/2, 2008, 2013/14), at 30 randomly established sample plots. Data was collected on seedlings (counts), saplings and shrubs (diameter at breast height [DBH] and height), trees (DBH and height) and forest use. This analysis of forest structure and composition included density, basal area, dominant species, species richness and the Shannon-Wiener species diversity index. When comparing the outcomes for participatory forest management and centralized forest management in Uganda versus Kenya, the results defy dogmatic generalizations as the outcomes differed in the two countries. Furthermore, this study highlighted the fragility of certain improvements in forest resilience. In this respect, recent declines in forest cover mean that these forest management regimes will need to continue improving their engagement with local communities in order to address both internal socioeconomic and urban-/private sector-driven deterioration of Mount Elgon's forests. This study also highlights the need for greater integration of development (climate-change adaptation) and conservation (climate-change mitigation) policies.

This research is carried out by CIFOR as part of the CGIAR Research Program on Forests, Trees and Agroforestry (FTA). This collaborative program aims to enhance the management and use of forests, agroforestry and tree genetic resources across the landscape from forests to farms. CIFOR leads FTA in partnership with Bioversity International, CATIE, CIRAD, INBAR, Tropenbos International and the World Agroforestry Centre.

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