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Human impacts on forest structure and species richness on the edges of a protected mountain forest in Uganda

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ABSTRACT

We investigated how local scale variation in human impacts influenced forest structure and tree species richness within Mt Elgon National Park, Uganda. We assessed basal area (BA), stem density, diameter at breast height (dbh) and indicators of human activity in 343 plots in four study sites, on transects running inwards from the boundary of the park. Mt Elgon hosts the only remaining natural forest in a densely populated region (150–1000 p/km^2). All study sites suffered past encroachment for agriculture and were in various stages of recovery or renewed-clearing at the time of the study. Areas recovering from encroachment had lower mean BA (BA = 3–11 m^2/ha), dbh and often also lower stem densities than forest that had never been cleared (BA = 21–43 m^2/ha), even 35 years after abandonment and with restoration planting. Human impacts were found beyond 2 km into the park. Although most activities decreased with distance inside the boundary, their prevalence varied among sites. High coefficients of variation in BA (Cv = 0.8–1.1) and stem density (Cv = 1.0–2.2) within sites, together with the evidence of sustained human activities, suggest that forest use histories strongly influenced local forest structure. Mean BA increased with distance inside the boundary in all sites, but stem densities reflected more complex patterns. Large trees (dbh $\geqslant$ 20 cm) were most affected by former clearing for agriculture. The collection of stems used as crop-supports reduced regeneration and the density of smaller stems at one site. In another site, charcoal making was associated with the smallest mean BA and marked variability in forest structure. Grazed forest consisted of large trees with very little regeneration. On forest margins in two sites grazing, generally together with fire and tree-cutting, had eroded the forest edge and prevented regeneration. Human impacts as well as natural gradients had major impacts on species richness patterns. Several areas in intermediate states of disturbance showed higher tree species richness than either old-growth forest or more severely degraded areas. This study illustrates the fine scale variation due to local impacts within one forest.

1. Introduction

Most tropical forests, even those in protected areas, are influenced by human activity (MacKenzie et al., 2012; Olupot et al., 2009). Harvesting of forest resources to meet livelihood needs can impact forest regeneration, structure and diversity (Fashing et al., 2004; Olupot, 2009), but there is scope for considerable variation with location, human activities and histories. To better manage forests for multiple local, regional and global values we need to understand human impacts and their variation at local scales. Such understanding is pertinent for forests managed for biodiversity conservation, catchment values and tourism that are increasingly considered in terms of their carbon stocks and the various benefits that they can provide to local people.

Different types and intensities of local resource extraction can lead to varying outcomes even within one forest (Thapa and Chapman, 2010). For example, forest grazing leads to different impacts than cutting timber or gathering other forest products (Fashing et al., 2004; Vadjunec and Rocheleau, 2009), and intensive extraction of certain highly valued species may have a greater impact on diversity than less intense forest uses (Ndangalasi et al., 2007).

Distance from settlements is often considered as a proxy for the extent of human impacts on forest (Boudreau et al., 2005), but preferred forest resources may not be evenly distributed and differ among groups of people. Environmental gradients like elevation, slope, substrate and moisture can confound results based on distance. For example elevation is known to affect tree size and species diversity (Ghazoul and Sheil, 2010), but human activities are

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also likely to be more intensive in lower elevation forest that is easier to access than on more remote, higher elevation sites.

In densely populated landscapes remaining natural forests have generally been subjected to multiple human impacts. The resulting complexity and the challenge of defining simple cause and effect relationships may explain why these patterns have seldom been studied in detail. Yet the diversity in human activities and their impacts call for different interventions. For instance, different approaches may be required where people have long used forest as a source of medicinal products or foods, or as a location for cultural activities, than in areas where people claim forest-land for agriculture. Historical factors such as conflicts over boundaries may also influence attitudes and behaviours towards forest management (Cernea and Schmidt-Soltau, 2006).

In this paper we investigate how use of the forest by communities on the edge of the Mt Elgon National Park (Uganda) has affected local forest structure and tree species richness. This is part of a linked series of studies that examine these forests and their relationship with local people. In a previous paper we have described the processes, contexts and drivers that led to localised episodes of forest loss and recovery over recent decades (Sassen et al., 2013). Here we look more closely at the nature of the resulting forests. We conducted a detailed comparative analysis of four study sites that vary in terms of the local land-use and the history of forest clearing and regeneration. We studied the variation of local activity and their ensuing impacts. We addressed the following questions: (1) How do indicators and measures of human activity vary within and among sites? and (2) How do forest structure and diversity vary with these indicators?

2. Site and methods

2.1. Mt Elgon

Mt Elgon (4321 m) is an extinct solitary shield volcano from the Miocene on the border between Uganda and Kenya. The top is an 8 km wide crater. The slopes are generally gentle until 2800–3000 m, with characteristic steep cliffs dropping down to the plains in the north, and some steeper slopes in the south-west. The mountain's slopes are cut by river and stream valleys that run down the mountain from the caldera (Fig. 1). A 20 km long ridge extends towards the west (Fig. 1). Dry north-easterly and moist south-westerly winds determine the climate. Rain falls year-round but peaks in April–May and September–November. Annual precipitation is between 1500 and 2000 mm. Rainfall is higher on the southern and western slopes than on the northern and eastern slopes and most rain falls at between 2000 and 3000 m above sea level (Dale, 1940; IUCN, 2005).

Mt Elgon is an important water catchment area for several million people in the surrounding districts, for the Nile and Victoria basins as well as Lake Rudolf through the Turkwell River (IUCN, 2005). A belt of bamboo and afromontane forest is found at on average between 2000 and 3000 m, followed by heathers and high elevation moorland (Dale, 1940; van Heist, 1994). Mt Elgon is valued for its global biodiversity values (Howard, 1991). It hosts 39 endemic higher plant species as well as many species with limited distributions (for details see Davenport et al., 1996; IUCN, 2005). Wildlife consists mainly of various monkeys, small ungulates and bush pig (*Potamochoerus larvatus*); rodents and birds are abundant (Davenport et al., 1996), but larger wildlife, in particular elephant (*Loxodonta africana*) and buffalo (*Syncerus caffer*), are found mainly on the Kenyan side of the mountain (van Heist, 1994).

Mt Elgon National Park in Uganda (1120 km^2) has a long history of human influence. As long as people remember, its forests provided a broad range of products and services such as fuelwood, medicine, food, materials for construction, grazing for cattle, cultural sites (e.g. circumcision rituals, burial) and shelter against cattle raiding (Katto, 2004; Scott, 1994).

The slopes of Mt Elgon in Uganda are inhabited by two ethnic groups. The Bagisu, of Bantu origin, dominate the south and south-west since around 1500 AD. Their population density reaches over 1000 people/km^2 in places (UBOS, 2002c). They practice an intensive mixed agriculture dominated by coffee and banana (Kayiso, 1993; McMaster, 1962). Important forest products for the Bagisu include construction materials, bamboo stems and shoots and crop-supports (called "crop-stakes" from here-on) for bananas and for climbing beans (Sassen, unpublished data; Scott, 1994).

The second group is the Sabiny, a Nilo-Cushtic group of pastoralists, settled in the north and north-east from the 17th century. They lived on the edges of open grassy areas inside the forest (called "glades") on the higher slopes of Mt Elgon, until they were resettled down the mountain in the 1980s. Land for resettlement was allocated in an excision from the protected area, which was then still a forest reserve (van Heist, 1994). The forest in the excised area was rapidly converted to agricultural land (Scott, 1998) where people cultivate maize, potatoes, wheat and maintain pastures as cattle remain important. The Sabiny still use the forest and the glades (up to 3 km inside the park boundary) for (illegal) grazing, timber, medicine and wild foods (Norgrove, 2002; Scott, 1994).

Communities living near the park are poor and suffer land shortages; nearly all land directly surrounding the park is cultivated (IUCN, 2005; van Heist, 1994). There are no remnant forests within 20 km around the park and people are settled up to right next to the park boundary (Sassen et al., 2013). On the western and southern slopes trees are part of the agricultural system. They are found in combination with coffee and bananas, around homesteads and in valleys planted with *Eucalyptus* woodlots. In the north, where people are more recently settled, trees outside the park are scarce, particularly nearer to the park boundary. A few isolated former forest-canopy trees remain scattered amongst the fields (Sassen et al., 2013).

Political instability from 1971 until 1986 was associated with widespread encroachment of Uganda's forest reserves (Hamilton, 1985; Turyahabwe and Banana, 2008) and around 30% of Mt Elgon was cleared for agriculture (Sassen et al., 2013). From 1987, forest boundaries were reinstated and restoration activities were started on the western slopes (UWA, 2000). The forest on Mt Elgon was first gazetted as a reserve in 1938 and became a national park in 1993 (Scott, 1998). Since the late 1990s, Uganda Wildlife Authority (UWA), which manages the park, has initiated agreements with local people that allow regulated collection of non-timber products, fuelwood and crop-stakes from restricted non-tree species (*Mimulopsis arborea* and *Vernonia* spp.) (Scott, 1998; UWA, 2000). Although activities such as pit-sawing declined after the establishment of the national park (Scott, 1998), illegal resource extraction remained common at the time of our study. Law enforcement efforts were understaffed and overstretched but also felt that they could not always stop people from harvesting essential resources such as firewood (A. Bintoora, Conservation Area Manager, personal communication; personal observations).

2.2. Data collection

Four locations were selected to represent different elevation ranges and forest change histories. These locations are subsequently referred to as Sites 2, 9, 11 and 14 (see Table 1 for site codes and corresponding villages) – these numbers are the same as those used in Sassen et al. (2013). The communities near Sites 2 and 9 practise intensive coffee–banana based agriculture, while