Ecological recovery of an afromontane forest in south-western Uganda

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Abstract

A study of the regeneration of an afromontane forest was carried out in Mgahinga Gorilla National Park (MGNP), south-western Uganda. The area landscape has been subjected to agricultural encroachment for the last 50 years. The landscape was changed by terracing and removing the indigenous vegetation and replacing it with exotic tree species. Stratified random sampling was employed in sampling the vegetation. There was a significant difference in species richness and density in the three habitat types. The natural forest supported the highest stem density (75%) and the lowest stem density (4%) was recorded under exotic woodlots. Seedlings (<2 cm, diameter at breast height) accounted for the majority of juveniles in the three habitats. The natural forest had the highest density (24,625 seedlings ha^{-1}) and exotic woodlots supported the lowest stem density (1350 seedlings ha^{-1}). The level of regeneration in the encroachment area is influenced by the intensity of cultivation and soil nutrients. The advanced growth beneath the exotic woodlots, especially black wattle (*Acacia mearnsii*) and *Eucalyptus* sp. stands is relatively impoverished. This condition beneath the exotic species suggests that a low diverse community of native species is able to exploit this environment.

Key words: cultivated area, encroachment, Mgahinga, recruitment, woodlots

Introduction

One of the major factors controlling the distribution of vegetation types is the effect of human activities such as burning and cultivation (Grove, 1995). In south-west Uganda, radio-carbon dating suggests that forest clearing began as early as 4800 years ago (Hamilton, Taylor & Volgel, 1986; Cunningham *et al.*, 1993). In the early 1900s, the tropical moist forests covered more than 6% of Uganda's land area (Butynski, 1984), but due to agricultural expansion these forests have been reduced by more than half (Struhsaker, 1987). FAO (1988) estimated that in the 1980s, there were 7500 km^2 of closed forest in Uganda, and about 5900 km^2 of these are tropical high forests and 1500 km^2 are montane catchment forests. The remaining forests, however, are now widely separated from one another forming ecological islands surrounded by other vegetation types (Hamilton, 1984).

The main cause of forest destruction is agricultural encroachment and increased demand for fuelwood (Struhsaker, 1987). Howard (1991) estimated that 12% of the forested land within Uganda's principal reserves had been affected by agricultural encroachment. The increased demand for agricultural land and forest products is attributed primarily to the high population growth rate of more than 3%, which has led to the doubling of the population since 1960 (Hamilton, 1984). Extensive transformation of the Kigezi highlands landscape has occurred since the 1900s as a result of natural population increase and migration from Rwanda (Cunningham *et al.*, 1993).

Mgahinga afromontane forest was subjected to serious abuse and intensive illegal activities that led to forest degradation (Cunningham *et al.*, 1993; Reynolds & Pomeroy, 1993). The forest reserve was cleared for agriculture and part of the degraded land was replaced by exotic plant species with the aim of reducing the transformed land (Kalina, 1993). In the early 1990s, however, the forest reserve was gazetted as a national park and the area was left to natural regeneration (Cunningham *et al.*, 1993). This study examines the effect of agricultural encroachment on soil nutrient status and the extent of vegetation recovery in the formerly encroached areas.

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 Afr. J. Ecol., **42** (Suppl. 1), 64–69

Study area

Mgahinga Gorilla National Park (MGNP) is an afro-montane forest region situated in south-west Uganda on the slopes of the Virunga volcanoes. It is located at the edge of the Western Rift Valley (Fig. 1). The terrain ranges from a gentle slope at lower elevations [2227 m above sea level (a.s.l.)] to steep slopes at high altitudes (4127 m a.s.l.). MGNP is characterized by a great diversity of habitat types associated with its wide altitudinal range. The vegetation comprises both montane and afroalpine flora (Werikhe, 1991). The montane forest belt consists of the montane woodland zones, the bamboo zone and the *Hagenia–Hypericum* zone. The montane woodland zone is the lowest zone of primary vegetation. It consists of open forest with dense ground flora, herbs and vines. The bamboo zone extends into a belt between 2500 m and 2800 m. The subalpine/ericaceous belt comprises of ericaceous and moorland zones. The ericaceous zone is dominated by *Phillipia johnstonii* (tree heath) and the alpine belt is characterized by giant *Senecio* and *Lobelia*, which occurs above the ericaceous belt (Kalina, 1993).

MGNP is also a unique area for biodiversity and endemism in Africa. It is a part of the Albertine Rift Afromontane region that is currently believed to hold the richest montane fauna in Africa (Kingdon, 1990). The area is a habitat for the rare mountain gorilla (*Gorilla gorilla beringei*) and the rare golden monkey (*Cercopithecus mitis kanditi*), known only to occur in the Virungas and two other forests in Central Africa (Kingdon, 1971). The park also supports a unique avifauna. Seventy-nine bird species have been recorded within the park, including several species endemic to the East Congo montane region (Kalina, 1993). Grauer's rush warbler (*Bradypterus graueri*), listed in the IUCN/ICBP Red Data book as vulnerable to extinction, occurs in MGNP (UNP, 1996).

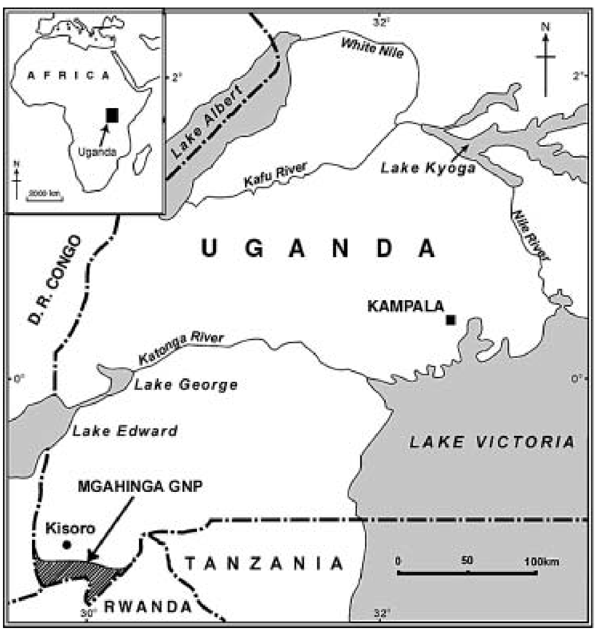

Fig 1 Map of Uganda showing the location of Mgahinga.

Materials and methods

Vegetation sampling

Transect lines were established in the exotic woodlots, degraded area and less disturbed natural forest habitat. Four transect lines each 1000 m long were established in the natural forest and 12 were established in the formerly cultivated area. The transect lines established in the formerly cultivated area ran from one edge to the other because the width of the formerly cultivated area was narrow in some parts, ranging from 700 m to 1300 m. The transects were positioned using a compass and marked with stakes and flagging tapes.

Sampling points were systematically established at regular intervals following the method of Kent & Coker (1996). In each transect, a series of 20 m × 25 m (0.05 ha) plots were established 50 m apart. The sample plots were positioned on alternating sides of the transect line following the method of Kasenene (1987). A series of nested quadrats were established within the 20 m × 25 m plots. The size-classes of tree species that occupy different vegetation strata within the habitat were identified and enumerated. All larger and smaller trees with a diameter range of >15 cm diameter at breast height (d.b.h.) and 10–15 cm d.b.h. were measured at 1.3 m height, identified and enumerated. Poles with diameter range of 5–10 cm d.b.h. were enumerated in a 10 m × 15 m quadrat. Tree saplings with diameter range of 2–5 cm d.b.h. were sampled in a nested quadrat size of 5 m × 10 m, whereas tree seedlings with <2 cm d.b.h. were recorded in a quadrat size of 2 m × 4 m. Tree seedlings in 2 m × 4 m plots were carefully searched in the under storey vegetation and counted. The data were subjected to statistical analysis using Shannon diversity index and Analysis of Variance (ANOVA).

Soil sampling

Within the exotic woodlots, degraded area and natural forest, 10 plots of 10 m × 10 m were randomly established. In the natural forest the plots were established along transects used in earlier vegetation sampling. In the degraded area, the plots were also randomly established 20 m away from each exotic woodlot. Three subplots were randomly located in each plot. Composite soil samples were systematically excavated from each quadrat to a depth of 20 cm using a shovel, following the method of Soedarson & Kuswata (1991). The soil samples were put in polythene bags and were later sun dried to halt biological transformation. The dry soil samples were sieved through a 2-mm screen and subsamples from the same plots were combined. Soil chemical analyses of pH, organic content and exchangeable cations were carried out. Analyses of the nutrients were all based on methods of Okalebo, Gathma & Woomer (1993). Data were analysed by the Mstact computer package.

Results

Soil chemical characteristics

Table 1 shows the mean values of nutrients for the three habitat types. The mean pH values of these soils ranged from 4.8 in the natural forest to 5.2 in the formerly cultivated area. The mean pH values of all the three habitats were less than 5.5, an indication that these soils were strongly acidic. Generally, the mean pH values were not significantly different in the three habitat types ($F = 3.39$; df = 2, 18; $P > 0.05$, ANOVA); however, there was significant variation between the mean pH values of the natural forest compared with that of the degraded area ($P < 0.05$, LSD). No significant difference was found between the exotic woodlots and natural forest or the formerly cultivated area ($P > 0.05$, LSD).

The mean soil organic content ranged from 18.5% in exotic woodlots to 26.1% in mature forest. These mean values of organic content were more than three times that of an average soil of 5% (Brook, 1983). Analysis of variance showed that there was a highly significant variation in organic content among the three habitats ($F = 11.68$; df = 2, 18; $P < 0.01$, ANOVA); however, there was no significant difference between the mean values in the formerly cultivated area and the exotic woodlots ($P > 0.05$, LSD).

The available phosphorus ranged from 5.3 p.p.m. in the exotic woodlots to 14.8 p.p.m. in the natural forest (Table 1). Two-way analysis of variance showed a highly significant variation in mean values of phosphorus in the three habitat types ($F = 6.89$; df = 2, 18; $P < 0.01$, ANOVA); however, there was no significant difference between the mean values of the formerly cultivated area and the woodlots ($P > 0.05$, LSD). Total nitrogen content ranged from 1.1% in the woodlots to 1.4% in the natural forest. These values are higher than the average values (0.2%–0.5%) (Brook, 1983) and are indicators of a very rich soil. Analysis of variance showed a very highly significant variation of soil nitrogen in the three habitat types ($P < 0.001$, ANOVA).

Vegetation recruitment

Table 2 shows the density distribution of different size-classes observed in each habitat type. From the observations, higher densities of seedlings were recorded in each habitat type. This ranged from 1350 seedlings ha^{-1} under exotic woodlots to 24,625 seedlings ha^{-1} in the natural

Table 1 Soil nutrient concentrations (mean values + S.E.) recorded in natural forest, formerly cultivated area and exotic woodlots

Habitat type	Soil pH	% Org. matter	P (p.p.m.)	% N
Exotic woodlots	5.1 ± 00^{a}	18.5 ± 1.4^{b}	5.3 ± 0.7^{b}	1.1 ± 0.1^{b}
Natural forest	4.8 ± 0.9^{b}	26.1 ± 1.4^{a}	14.8 ± 3.6^{a}	1.4 ± 0.1^{a}
Formerly cultivated area	5.2 ± 0.1^{a}	21.3 ± 1.7^{b}	5.7 ± 0.6^{b}	1.1 ± 0.0^{b}
Significance	ns	s	s	s
P	>0.05	<0.05	<0.05	<0.05
LSD ($P < 0.05$)	0.30	3.33	6.07	0.13
CV (%)	6.4	16.1	75.4	11.90

Comparition was by one-factor analysis of variance. LSD, least significant difference; CV, coefficient of variation; s, significant; ns, not significant; ^{a}, ^{b} & ^{ab} area ranks. Means with same ranks are not significantly different.

Table 2 Density of various size-classes recorded in the natural forest, formerly degraded area and exotic woodlots

Habitat type	Seedlings	Sapplings	Poles	Smaller trees	Larger trees
Natural forest	24,625	2015	338	43	96
Formerly cultivated area	6608	713	104	5	16
Exotic woodlot	1350	62	12	1	3

forest. This variation was highly significant ($F = 74.79$, df $= 2, 12$; $P < 0.01$, ANOVA). Similarly, the highest recruitment of other size-classes recorded in the formerly cultivated area had the lowest densities observed under the exotic woodlots. These variations in plant recruitment were also significantly different ($P < 0.05$, ANOVA). All the three habitats showed a sharp decline in the number of seedlings surviving to the smaller tree size-class with a slight increase in stem density in the larger tree size-class ($P < 0.05$, ANOVA).

Regeneration of native tree species

Table 3 shows the density and dominance of canopy tree species recorded in three forest types. From the observations, most of the canopy species were well represented in the formerly cultivated area, only *Faurea saligna* and *Lepidotrichilia volkensii* were not observed in this area. However, *Lepidotrichilia volkensii* was only recorded in the natural forest. *Hypericum revolutum, Bersama abysinica, Nuxia congesta, Agaurea salicifolia* and *Myrica salicifolia* do occur in all three habitats. Among these canopy tree species, *Hypericum revolutum* had the highest density of recruitment (2220 stems ha^{-1}) recorded in the formerly cultivated area ($P < 0.05$, ANOVA). This was followed by *Erica arborea*, with a density of 1025 stems ha^{-1}.

Among the species recorded in the natural forest, *Nuxia congesta* was the most dominant species recorded in both the natural forest and the formerly cultivated area, with a value of 2.14 and 0.05, respectively. While *Hypericum revolutum* was the most dominant species observed in exotic woodlots.

Table 3 Density and dominance of canopy tree species recorded in the natural forest, formerly cultivated area and exotic woodlot

	Density (no. ha^{-1})			Dominance (m^2 ha^{-1})		
Tree species	A	B	C	A	B	C
Hypericum revolutum	76	2220	644	0.03	0.31	0.8
Bersama abyssinica	188	167	0	0.26	0.07	0.02
Maesa lanceolata	43	167	0	0.35	0.07	0.00
Nuxia congesta	62	567	1	2.14	0.38	0.05
Ilex mitis	398	36	0	0.15	0.01	0.00
Agauria salicifolia	14	626	12	0.39	0.02	0.01
Dombeya goetzenii	0	75	26	0.00	0.01	0.00
Erica arborea	0	1025	12	0.00	0.17	0.01
Myrica salicifolia	0	708	26	0.00	0.15	0.02
Xymalos monospora	881	5	0	0.78	0.02	0.00
Neoboutonia macrocalyx	43	5	0	0.26	0.01	0.00
Dombeya kirkii	2	17	0	0.02	0.03	0.00
Hagenia abyssinica	0	5	6	0.00	0.01	0.03
Faurea saligna	0	0	0	0.00	0.01	0.00
Lepidotrichilia volkensii	453	0	0	0.43	0.00	0.00

A, natural forest; B, formerly cultivated area; C, exotic wood.

Discussion

Mgahinga forest was greatly affected by human influence and agricultural clearing after mass settlement in the 1950s (Cunningham *et al.*, 1993). This influence totally transformed the landscape of the formerly encroached area through terracing, and removal as well as replacement of most woody vegetation by crops and exotic tree species such as *Acacia mearnsii* and *Eucalyptus* sp. The levels of vegetation regeneration and patterns of distribution of exotic tree species in Mgahinga suggest the intensity of cultivation and effects of these plant species in the now gazetted area.

Results from this study indicate higher pH value in soils under exotic woodlots compared with that recorded in the natural forest. This contradicts results obtained in studies carried out in India and South Africa (Poore & Fries, 1985). This therefore suggests that the lower pH value observed in the natural forest could be due to the presence of high organic matter recorded in this study site. Peat soil found in this area was encouraged by conditions of very poor soil drainage. This is due to the effect of relief upon the climate, which is well known for its depression of temperature and increase in rainfall (Brook, 1983). This leads to conditions favouring the development of thick organic horizons as a result of low temperatures retarding biological activities in the breakdown of organic matter. The significantly lower values of organic matter observed in the formerly cultivated area suggests high incidences of past human activities that occurred in this area. Forest clearing exposes the land to solar radiation, resulting in increased temperatures and rapid decomposition of organic matter (Sawyer, 1993).

Phosphorus content of the soil has often been used as a soil degradation index. Available phosphorus in top soil decreases with increasing intensity of soil formation. This is generally true according to the results obtained in this study. Low mean values of phosphorus recorded in the exotic woodlots and formerly cultivated area, indicate a high intensity of past land use in this area. The Bray 2 method of phosphorus determination (Moukam & Nyakanou, 1997) rates values greater than 35 p.p.m. as high, between 15 and 35 p.p.m. as medium and those lower than 15 p.p.m. as low. Therefore the intensive use of land in this area could be the cause of extremely low values of phosphorus in these soils. Results obtained for total nitrogen were very high based on the ratings of Brook (1983) and Landon (1984). Landon (1984) also considers total nitrogen values to be low when below 0.2%, medium when between 0.2% and 0.5% and high when above 0.5%. So the high values of total nitrogen obtained in MGNP indicates a very rich soil.

The regeneration of indigenous species under exotic woodlots was generally low compared with that recorded in the formerly cultivated area and natural forest. This agrees with the findings of Evans (1992) and Poore & Fries (1985). Evans (1992) stated that exotic species usually cause competition for nutrients and water, which influence indigenous plant species. Similarly, human disturbance that results in the replacement of natural forest community with exotic plantations or woodlots are usually poorer in species and contain different species than the natural forest they replace (Poore & Fries, 1985). The colonizing characteristics of exotics species have on occasions enabled them to compete successfully against native vegetation for resources (Sawyer, 1993). Large-scale disturbance due to agricultural practice in the formerly cultivated area encouraged the regeneration of secondary tree species, which demand light for regrowth. A large proportion of the degraded area is, however, still covered by grasses and herbaceous plants.

The assessment of the size-class distribution of plant community provides knowledge about the population structure and function of a given population (Tsingalia, 1982). From the results of this study, heavy recruitment of juveniles into the population was obvious. However, the survival rate of these size classes into the larger size classes was low, leading to a decline in tree densities with increased size. High densities of seedlings in all the habitat types highlights the importance of propagules in determining the composition of early successional communities and indeed their establishment. This also indicates the recovery potential of each habitat type. For instance the natural forest had the highest potential of recovery, probably attributed to the presence of forest gaps created by dead trees.

Acknowledgements

I am grateful to Mgahinga and Bwindi Conservation Trust for their financial support. Sincere thanks goes to ITFC for providing the research facilities.

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