# Regeneration of indigenous trees in Mgahinga Gorilla National Park, Uganda

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## Abstract

This study examines the regeneration of indigenous tree species in the formerly encroached area in Mgahinga Gorilla National Park (MGNP), south-western Uganda. Before gazetting in 1992, MGNP had basically been agricultural land for well over 50 years. The distribution of exotic vegetation was established using a Geographical Positioning System receiver and indigenous vegetation was sampled by establishment of quadrats along transect lines.

Observations indicated that approximately 2% of the old cropland was covered by exotic woodlots. Black wattle (*Acacia mearnsii*) and *Eucalyptus* trees were found to be the most widely distributed and *Pinus patula* the least distributed species in the park. Species numbers of indigenous trees ($n = 26$) were high in the old cropland, compared with twelve species observed in exotic woodlots. The natural forest supported the highest (75%) stem density and the lowest (4%) stem density was recorded in exotic woodlots. Seedling class ( < 2 cm, d.b.h.) accounted for the majority of juveniles, with the lowest stem density (1350 seedlings $ha^{-1}$) recorded in exotic woodlots compared with 6609 seedlings $ha^{-1}$ in the old cropland and 24,625 seedlings $ha^{-1}$ in the natural forest. The levels of tree diversity and stocking characteristics recorded under the exotic species suggest that a low diverse community of native species may exploit this environment.

*Key words:* afromontane, encroachment, exotic, Mgahinga, nutrients, woodlot

## Résumé

Cette étude examine la régénération des espèces indigènes d'arbres dans la zone précédemment empiétée du Mgahinga Gorilla National Park (MGNP), au sud-ouest de l'Ouganda. Avant son enregistrement en 1992, le MGNP avait été une zone principalement agricole pendant bien plus de 50 ans. On a établi la distribution de végétation exotique au moyen d'un système GPS (Geographical Positioning System) et on a récolté de la végétation indigène en créant des quadrats le long de lignes de transects.

Les observations ont montré que près de 2% des anciennes cultures étaient couverts de parcelles de bois exotiques. On a trouvé que les *Acacia mearnsii* et les *Eucalyptus* étaient les plus largement distribués et que les *Pinus patula* constituaient l'espéce la moins distribuée dans le parc. Le nombre d'espèces d'arbres indigènes ($n$ = 26) était élevé dans les anciennes cultures, comparé aux 12 espèces observées dans les parcelles de bois exotiques. C'est dans la forêt naturelle que l'on trouvait la plus forte densité de repousse (75%) et dans les parcelles de bois exotiques qu'elle était la plus faible (4%). La classe des jeunes plants ( < 2 cm de diamètre à 1 m de haut) comptait la majorité des juvéniles, et la densité la plus faible de jeunes pousses (1350 jeunes plants/ha) se retrouvait dans les parcelles de bois exotiques, comparée aux 6.609 jeunes plants/ha dans les anciennes terres de culture et aux 24.625 jeunes plants/ha de la forêt naturelle. Le taux de diversité des arbres et les caractéristiques de réserve relevés parmi les espèces exotiques suggèrent que seule une faible diversité d'espèces natives est à même d'exploiter cet environnement.

## Introduction

Lands that have been degraded by previous land use practices such as agriculture and logging are generally

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difficult to re-vegetate with desirable species because degraded soils and competition from undesirable species arrest successional process (Lieth & Lohmann, 1993). Enrichment plantings have been used to solve the problem of ecological succession (Fimbel & Fimbel, 1994), as well as encouraging the development of rich forests. Establishment of exotic species on these sites has often been preferred because of their adaptability to such conditions (Thompson *et al.*, 1986; Turnbull, 1987; Evans, 1992).

In recent years, the potential for exotic plantations or woodlots to serve as nurse crops for the establishment of native forest species has been gaining recognition (Jordan & Farnworth, 1982; Hughes & Styles, 1986; Parotta, 1992; Lugo *et al.*, 1993). However, limited work has been done to establish treatments designed to maximize the native forest restoration capabilities of these plantings (Lugo, 1992; Brown & Lugo, 1994). In Uganda, forest resource has been reduced from a rich variety of hundreds of indigenous species in favour of a few exotic tree species. Nevertheless, plantations of exotic species pose a threat to natural habitat (Poore & Fries, 1985; Strushsaker, 1987; Evans, 1992; Sawyer, 1993; Groove, 1995). The exotic plantations are incompatible with wildlife and in the case of *Eucalyptus*, they are detrimental to soil nutrients and water catchment (Poore & Fries, 1985; Evans, 1992). The incompatibility not only leads to loss of a natural heritage, but also represents a serious loss of ecological benefits and genetic diversity (Strushsaker, 1987).

MGNP is characterized by a diversity of habitat types associated with its wide altitudinal range. The reserve has been subjected to serious abuse and intensive illegal activities such as bamboo and pole wood harvesting, which have led to forest degradation (Cunningham *et al.*, 1993; Reynolds & Pomeroy, 1993). The original forest was cleared for agriculture and part of the degraded land was planted with exotic plant species (Kalina, 1993). In 1992, the old cropland was gazetted and left to naturally regenerate (Cunningham *et al.*, 1993).

### *Study area*

MGNP is part of an Afromontane Forest Region situated in south-west Uganda on the slopes of the Virunga volcanoes (Fig. 1). The park is roughly 33.7 $km^2$ in area and forms part of the Virunga Conservation Area (Butynski, 1984; Sayer *et al.*, 1992; UNP, 1996). The three volcanoes of MGNP form part of the Virunga Volcanic Range in East and Central Africa, expanding to the Albertine Rift on the Congo, Rwanda and Uganda border (Spinage, 1972). The terrain ranges from gentle slopes at lower elevation to steep slopes at high altitudes. The soils are classified as Sabinyo complex (Harrop, 1960), derived from volcanic activity. The rainfall pattern over MGNP is characterized by two wet seasons (March–April and September–December) and two dry seasons (January–February and May–August).

As stated above the area is characterized by a great diversity of habitat types. The vegetation comprises both montane and afroalpine flora (Werikhe, 1991). The montane forest belt consists of the woodland zones, bamboo and *Hagenia–Hypericum* zones. The subalpine/ericaceous belt is made up of ericaceous and moorland zones. The alpine belt, which is characterized by giant *Senecio* and *Lobelia*, occurs above the ericaceous belt. The park area is also a unique area for biodiversity and endemism in Africa (Kalina, 1993). It is a part of the Albertine Rift Afromontane Region, which is today believed to hold the richest montane fauna in Africa (Kingdon, 1990). For example the park is a habitat for the rare mountain gorilla (*Gorilla gorilla beringei*) and golden monkey (*Cercopithecus mitis kandti*), known only to occur in the Virungas and two other forests in Central Africa (Kingdon, 1971).

This study identified the dominant exotic plant species of the park and investigated their distribution and effect on the regeneration of indigenous tree species in the park.

## Materials and methods

### *Vegetation mapping*

Areas formerly cultivated (old croplands) were surveyed to establish species type, composition and locations of exotic woodlots. Each exotic woodlot was identified and its location established using a Global Positioning System (GPS) receiver (Haines-Young *et al.*, 1990). Area coverage of each woodlot was determined by measuring the length and width of the woodlot using a tape measure. The recorded points and areas were transformed into a database at the Remote Sensing (RS) and Geographical Information System (GIS) laboratory, Institute of Environment and Natural

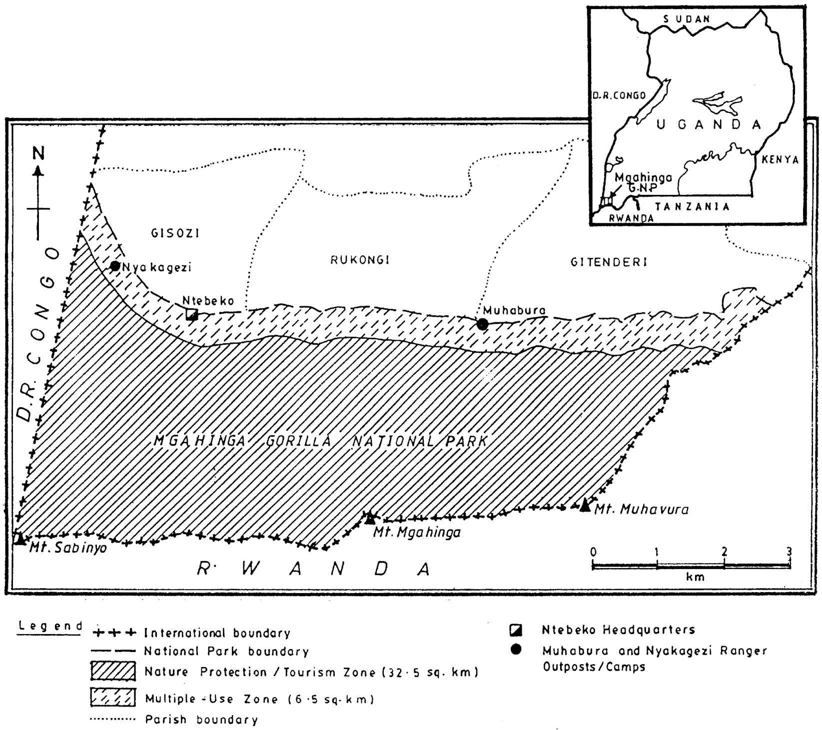


**Fig 1** Location (inset) and map of Mgahinga Gorilla National Park (UNP, 1996)

Resources (MUIENR), Makerere University. Point locations were then marked on the map of MGNP to show the distribution of the exotic species.

### *Vegetation sampling*

Transect lines were randomly established in the exotic woodlots, old croplands and natural forest habitat. All transects, which ran from north to south, were positioned using a compass and marked with stakes and flagging tapes. The transect lines were positioned so because the terrain rises gently towards the south and as such, vegetation from transition zones could be sampled. Lengths of transect lines were strictly established in the natural forest and the degraded area. In some instances, however, lengths of old croplands were affected by the narrow width of some parts of the area.

Systematic sampling was used, which involved location of sampling points at regular intervals as employed by Kent & Coker (1996). Along each transect, $20 \times 25$ m plots were established at regular intervals, 50 m apart. Successive sample plots were positioned on alternating sides of the transect line. Three nested quadrats measuring $2 \times 4$, $5 \times 10$ and $10 \times 15$ m were established within each of the $20 \times 25$ m plots to identify and enumerate tree species that occupied different vegetation strata. All trees that measured $\geq 15$ cm and 10 to $< 15$ cm at 1.3 m height (diameter at breast height, d.b.h.), were enumerated in the $20 \times 25$ m plots. Poles with a diameter range of 5 to $< 10$ cm d.b.h. were enumerated in a $10 \times 15$ m quadrat. Tree saplings with a diameter range of 2 to $< 5$ cm d.b.h. within a nested quadrat size of $5 \times 10$ m were counted. Tree seedlings with $< 2$ cm d.b.h. were carefully searched for in the under-storey vegetation and recorded in a quadrat size of $2 \times 4$ m.

### *Soil sampling*

A total of ten plots of $10 \times 10$ m were established within each habitat type, i.e. exotic woodlots, old croplands and natural forest. In the natural forest the plots were located along the four transects used earlier for vegetation sampling at 50 m intervals, while in the exotic woodlots, the plots were located in randomly selected woodlots (six in black wattle and four in *Eucalyptus* woodlots). In the degraded area, similar plots of 10 × 10 m were randomly established at 20 m away from each exotic woodlot.

Three sub-plots were randomly located in each sample plot within each habitat type. Composite soil samples were taken from each sub-plot to a depth of 20 cm, using a shovel (Soedarsono & Kuswata, 1991). In all three habitats, the soil samples were collected in polythene bags and sun-dried to halt biological activities. The dry soil samples were sieved through a 2 mm screen and sub-samples from the same plots were combined. The samples were then packed in plastic bags and transported to the soil testing facilities at the Department of Soil Science, Faculty of Agriculture and Forestry, Makerere University. Soil chemical analyses of pH, organic matter content and exchangeable cations were carried out based on methods by Okalebo *et al.* (1993).

## Results

### *Distribution and abundance of exotic tree species*

Figure 2 shows the distribution of major exotic tree species in the park. *Acacia mearnsii* and *Eucalyptus* sp. were the most widely distributed species in MGNP. High densities of *A. mearnsii* were observed in areas between Mgahinga and Muhavura, whereas, woodlots of *Eucalyptus* sp. were highly concentrated along the Nyabirerema river and areas of Nyakigezi and Ntebeko. However, few woodlots of *Eucalyptus* sp. were recorded between Mgahinga and Muhavura camp. *Cupressus lusitanica* were encountered in a few areas of old homestead sites and only one woodlot of *Pinus patula* was observed in the natural forest.

Approximately 19.94 ha (2.14%) of the old croplands were planted with exotic tree species (Table 1). This average makes up 0.59% of the total area of the park. *Acacia mearnsii* was the most widely distributed exotic species observed in the park, covering an area of about 12.80 ha (1.38%) of old croplands (Table 1). Woodlots of *A. mearnsii* varied in size, with a mean total area of 0.15 ha, which is more than five times the mean area occupied by *Eucalyptus* sp. (Table 1). Mixed species stands of black wattle and *Eucalyptus* sp. occupied an area of 4.62 ha, with a mean area of 0.06 ha. This was followed by *C. lusitanica*, which occupied an area of 0.47 ha. *Pinus patula* had the least proportion of area coverage (0.02 ha), which is about 0.10% of the total area covered by exotic species.

### *Soil chemical characteristics*

Table 2 shows the mean values of the nutrients for the three habitat types. The mean pH values of the soils ranged from 4.8 in the natural forest to 5.2 in old croplands. There was significant variation between the mean pH values of natural forest compared to that of old cropland or exotic woodlots ($P < 0.05$, LSD). However, no significant variation in pH value was found between exotic woodlots versus old cropland ($P > 0.05$, LSD), as shown in Table 2.

The mean soil organic content ranged from 18.5% in exotic woodlots to 26.1% in natural forest ($P < 0.05$,

**Table 1** Total area and percentage contribution of exotic woodlots identified in Mgahinga Gorilla National Park

| Exotic species | No. of woodlots | Total area (ha) | Mean area (ha) | % coverage of old croplands | % coverage of park area |
|---|---|---|---|---|---|
| *Acacia mearnsii* | 87 | 12.80 | 0.15 | 1.38 | 0.38 |
| *Eucalyptus* sp. | 86 | 2.03 | 0.02 | 0.22 | 0.06 |
| *Cupressus lusitanica* | 15 | 0.47 | 0.03 | 0.05 | 0.01 |
| *Pinus patula* | 1 | 0.02 | 0.02 | 0.00 | 0.00 |
| Mixed spp. stands | 75 | 4.62 | 0.06 | 0.50 | 0.14 |
| Total | 264 | 19.94 | 0.28 | 2.14 | 0.59 |

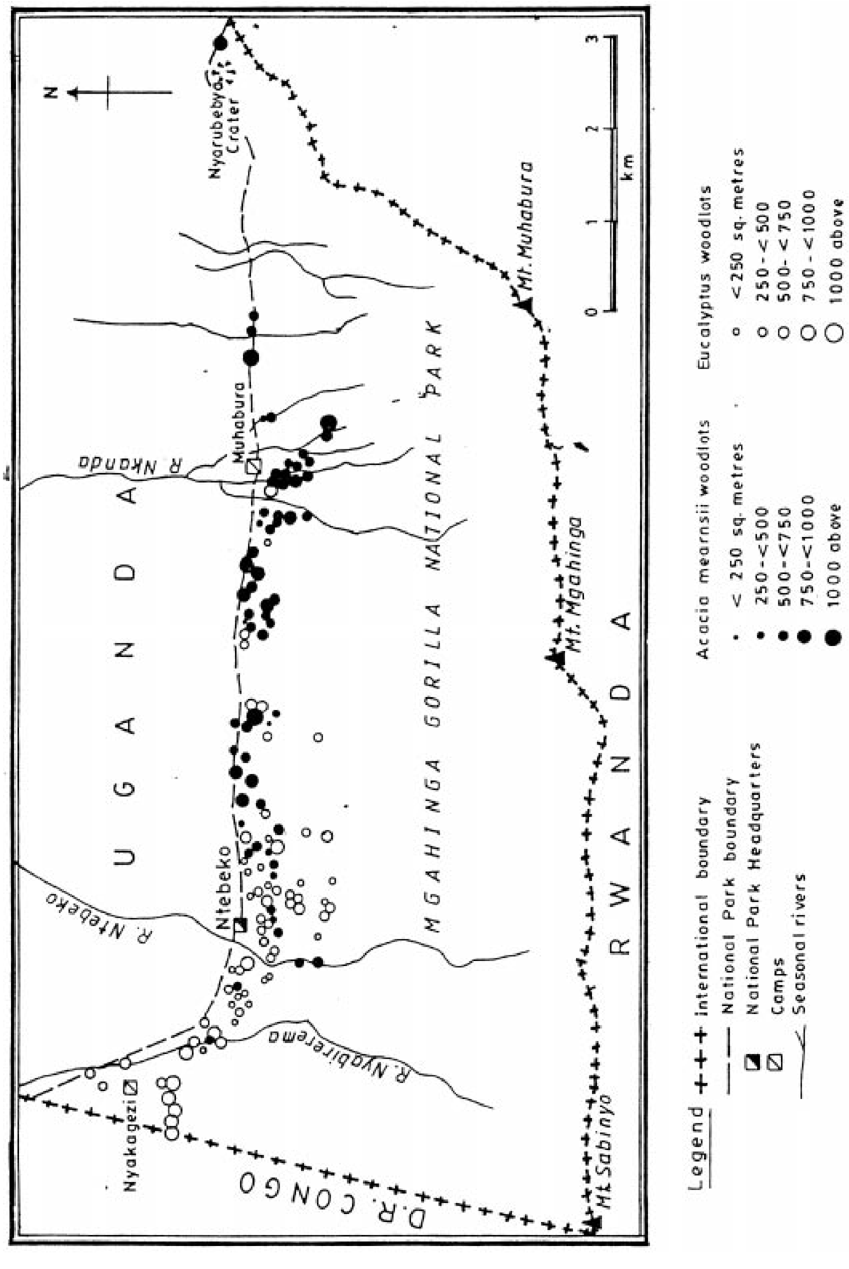


**Fig 2** Distribution of *Acacia mearnsii* and *Eucalyptus* woodlots in Mgahinga Gorilla National Park

**Table 2** Soil nutrient concentrations (mean values ± SE) recorded in natural forest, old croplands and exotic woodlots

| Habitat type | Soil pH | % organic matter | P (p.p.m.) | Ca (me/100 g) | K (me/100 g) | Mg (me/100 g) | Na (me/100 g) | % N |
|---|---|---|---|---|---|---|---|---|
| Exotic woodlots | 5.1 ± 0.0ab | 18.5 ± 1.4b | 5.3 ± 0.7b | 8.3 ± 1.7a | 2.8 ± 0.4b | 2.7 ± 0.4a | 0.2 ± 0.0a | 1.1 ± 0.1b |
| Natural forest | 4.8 ± 0.9b | 26.1 ± 1.4a | 14.8 ± 3.6a | 12.2 ± 1.2a | 3.4 ± 0.6a | 3.3 ± 0.6a | 0.2 ± 0.0b | 1.4 ± 0.1a |
| Old croplands | 5.2 ± 0.1a | 21.3 ± 1.7b | 5.7 ± 0.6b | 8.7 ± 1.7a | 2.1 ± 0.4b | 2.7 ± 0.5a | 0.2 ± 0.0ab | 1.1 ± 0.0b |
| Significance | ns | s | s | ns | ns | ns | ns | s |
| *P** | ** | * | * | ** | ** | ** | ** | * |
| LSD ($P < 0.05$) | 0.30 | 3.33 | 6.07 | ns | 1.13 | ns | 0.03 | 0.13 |
| CV (%) | 6.4 | 16.1 | 75.4 | 46.1 | 44.0 | 37.4 | 19.2 | 11.9 |

Comparison was by one factor analysis of variance. *$P < 0.05$, **$P > 0.05$, LSD, least significant difference; CV, coefficient of variation; s, significant; ns, not significant; a and b, ranks; means with same ranks are not significantly different.

LSD). Analysis of variance showed a highly significant variation in organic contents for the three habitats ($F = 11.68$; df = 2, 18; $P < 0.05$). However, there was no significant difference between the mean values in old croplands and exotic woodlots ($P > 0.05$, LSD). The available phosphorus, which ranged from 5.3 p.p.m. in exotic woodlots to 14.8 p.p.m. in the natural forest (Table 2) varied significantly in the three habitat types ($F = 6.89$; df = 2, 18; $P < 0.05$). Similar to organic content, there was no significant difference between the mean values of phosphorus in the old croplands and exotic woodlots ($P > 0.05$, LSD). Total nitrogen content ranged from 1.1% in the woodlots and formerly cultivated area to 1.4% in the natural forest. Analysis of variance showed a significant variation in soil nitrogen content in the three habitat types ($P < 0.05$, ANOVA).

Chemical analysis indicated that calcium, potassium and magnesium had the highest cation exchange capacity values recorded in the natural forest, except for sodium which had the same mean values of 0.2 me/100 g for the three habitat types (Table 2). The mean values of calcium, potassium, magnesium and sodium exchange capacity for the three habitat types were significantly similar ($P > 0.05$, LSD). A significant difference was observed for the mean values of potassium and sodium recorded in the natural forest ($P < 0.05$, LSD).

### *Recruitment of indigenous trees*

Table 3 shows the density of indigenous tree species of different size classes observed in each habitat type. Seedling recruitment was high in all habitat types, but varied significantly ($F = 74.79$, df = 2, 12; $P < 0.01$) in intensity (Table 3). Similarly, the highest recruitments of other size classes were recorded in the natural forest while in the exotic woodlots recruitments were lowest (Table 3). Again these species recruitment variations were also significantly different ($P < 0.05$, ANOVA).

**Table 3** Distribution of indigenous trees of different size classes in natural forest, old croplands and exotic woodlots

| Diameter size class (d.b.h.) | Natural forest | Old croplands | Exotic woodlot |
|---|---|---|---|
| Seedlings (< 2 cm) | 24,625 | 6608 | 1,350 |
| Saplings (2 to < 5 cm) | 2015 | 713 | 62 |
| Poles (5 to < 10 cm) | 338 | 104 | 12 |
| Smaller trees (10 to < 15 cm) | 43 | 5 | 1 |
| Larger trees (≥ 15 cm) | 96 | 16 | 3 |

Overall vegetative recruitment was superior in the natural forest, followed by old croplands and then exotic woodlots (Table 3). All three habitats showed a significant decrease in stem density from seedlings to the smaller tree size-class ($P < 0.05$, ANOVA).

*Establishment of canopy species in the three habitat types*

Table 4 shows the frequency and dominance of canopy tree species recorded in the natural forest, old croplands and exotic woodlots. Most of the canopy tree species were well represented in the old croplands, except *Lepidotrichilia volkensii*, which was not observed in this area. Species such as *Dombeya goetzenii*, *D. kirkii*, *Hagenia abyssinica* and *Faurea saligna* were not recorded in the natural forest. The exotic woodlot habitat was the least represented, with only seven canopy species. Among the canopy tree species, *Hypericum revolutum* had the highest frequency (104%) of occurrence recorded in the old croplands.

The dominance values shown in Table 4 were generally higher in the natural forest and lowest in the exotic woodlots. *Nuxia congesta* was the most dominant tree species recorded in both the natural forest (2.14) and old croplands (0.31), while, *H. revolutum* was the most dominant canopy species in exotic woodlots.

## Discussion

MGNP was greatly affected by human influence through mass settlement in the 1950s (Cunningham *et al.*, 1993). Forest clearance for agriculture totally transformed the landscape through terracing and replacement of most woody vegetation by exotic tree species. The patterns of distribution of exotic species in MGNP implied the relative values of these plant species and the settlement patterns of the local community before MGNP was gazetted. Exotic tree species such as cypress and pines were rarely encountered in the park because they were apparently not much used by the local people. Indeed, because cypress was only planted as a hedge its presence provided direct evidence of an old homestead site in the old cropland area. Pines were rarely encountered, except in a demonstration plot planted by the Forest Department near Nyakigezi. Areas of intense human activity had abundant distribution of black wattle (*A. mearnsii*) and *Eucalyptus* sp. Hence in Byagizo and Nyarubebya, where there was less human activity, few woodlots of exotic species were

**Table 4** Frequency and dominance of canopy tree species recorded in the natural forest (A), old croplands (B) and exotic woodlots (C)

| | % frequency | | | Dominance (basal area/total area) | | |
|---|---|---|---|---|---|---|
| Tree species | A | B | C | A | B | C |
| *Hypericum revolutum* | 104 | 33 | 4 | 0.03 | 0.31 | 0.80 |
| *Bersama abysinica* | 40 | 9 | 2 | 0.26 | 0.07 | 0.02 |
| *Maesa lanceolata* | 58 | 12 | 0 | 0.35 | 0.07 | 0.00 |
| *Nuxia congesta* | 13 | 40 | 6 | 2.14 | 0.38 | 0.05 |
| *Ilex mitis* | 33 | 1 | 0 | 0.15 | 0.01 | 0.00 |
| *Agauria salicifolia* | 13 | 10 | 2 | 0.39 | 0.02 | 0.01 |
| *Dombeya goetzenii* | 0 | 1 | 0 | 0.00 | 0.01 | 0.00 |
| *Erica arborea* | 37 | 28 | 4 | 0.00 | 0.17 | 0.01 |
| *Myrica salicifolia* | 35 | 16 | 12 | 0.00 | 0.15 | 0.02 |
| *Xymalos monospora* | 36 | 3 | 0 | 0.78 | 0.02 | 0.00 |
| *Neoboutonia macrocalyx* | 36 | 2 | 0 | 0.26 | 0.01 | 0.00 |
| *Dombeya kirkii* | 0 | 1 | 0 | 0.02 | 0.03 | 0.00 |
| *Hagenia abyssinica* | 0 | 3 | 6 | 0.00 | 0.01 | 0.03 |
| *Faurea saligna* | 0 | 2 | 0 | 0.00 | 0.01 | 0.00 |
| *Lepidotrichilia volkensii* | 108 | 0 | 0 | 0.43 | 0.00 | 0.00 |

established. *Acacia mearnsii* was spreading to many parts of old cropland through natural dispersal of large amounts of viable seeds, which implies that it is an invasive species.

The pH values recorded in the area were generally below 5.5, an indication of strongly acidic soils. Higher pH values in soils under exotic woodlots compared to those recorded in the natural forest (Table 2) contradicts results obtained in studies carried out in India and South Africa (Poore & Fries, 1985). This could be due to the high organic content recorded under exotic woodlots. The mean values of organic content (Table 2) were generally high, more than three times that of an average soil (5%) (Brook, 1983). This was encouraged by conditions of poor drainage resulting from the effect of relief on the climate (Brook, 1983) which in turn led to conditions favouring the development of thick organic horizons. Low temperatures retard biological activities in the breakdown of organic matter (Brook, 1983). Significantly lower values of organic matter observed in the old cropland are due to previous human activity which occurred in this area. Forest clearing exposes the land to solar radiation, resulting in increased temperatures and rapid decomposition of organic matter.

The phosphorus content of soil is a useful index of fertility status (Brook, 1983). The Bray 2 method (Moukam & Nyakanou, 1997) assumes values greater than 35 p.p.m. to be high, between 15 and 35 p.p.m. as medium and those below 15 p.p.m. as low. Generally, available phosphorus in topsoil decreases with increasing intensity of soil formation. Low mean values of phosphorus recorded in the exotic woodlots and old croplands reflected high intensity of past land use in the area. Total nitrogen (Table 2) was very high according to the ratings of Brook (1983) and Landon (1984), where values below 0.2% are considered to be low, between 0.2 and 0.5% medium, above 0.5% high. These high values of nitrogen indicate that the soils are very rich.

Regeneration of indigenous species under exotic woodlots was generally low compared to that recorded in old croplands and natural forest. This agrees with the findings of Poore & Fries (1985) and Evans (1992). Evans (1992) stated that exotic species usually create competition for nutrients and water, which affects indigenous plant species. Similarly, the exotic plantations or woodlots that replace the natural forest community usually have fewer indigenous species and contain different species from the natural forest they replace (Poore & Fries, 1985). Large-scale disturbance due to agricultural practices encouraged the regeneration of secondary tree species in the old cropland.

There were higher densities of seedlings and saplings than of poles and larger trees (Table 3). This is because of higher initial seedling and sapling recruitment and frequent deaths, which decline with time. This permits the natural forests to be self-maintaining (Swaine & Lieberman, 1987). Campbell (1988) also pointed out that a reverse J-shaped distribution is an indication of a growing cohort of trees that may have experienced a past disturbance. High densities of seedlings in all the habitat types highlight the importance of propagules in determining the composition of early successional communities and their establishment. This also gives an idea of the recovery potential of each habitat type.

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