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The Impacts of Land Use and Forest Activities on Tree Species Composition and Structure on the Edges of Budongo Forest Reserve, Uganda

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Abstract: The impact of land use activities on tree species composition, structure and diversity in and around Budongo Forest Reserve was assessed in August and September 2000. Forty plots measuring 50×50 m were laid at 100 m intervals along 1,000 m transects originating from each land use type activity and the number, species, diameter at breast height (dbh) and height of trees ≥10 cm recorded. The land use/forest activities considered were farming, settlement, charcoal production and harvesting of timber, firewood and building poles. One way ANOVA, Kruskal-Wallis test and Shannon-Weaner diversity index were used to analyse the data. It was found that different land use activities have affected forest tree species abundance ($H = 24.77$, $p = 0.001$), composition ($F = 2.87$, $p = 0.047$) and structure (dbh: $F = 3.82$, $p = 0.018$ and height: $F = 1.63$, $p = 0.039$). Timber harvesting had the least negative effect on tree species diversity ($H' = 2.8016$) and the highest negative effect on forest structure (average dbh = 33.06 cm; average height = 22.06 m). Farming had the highest negative effect on tree species diversity ($H' = 2.57$) and the lowest negative effect on forest structure (average dbh = 39.11 cm; average height = 25.18 m). It is recommended that the effect of land use practices on the forest fringes should be monitored and a methodology for an integrated land use-forest management plan developed.

Key words: Budongo, land use, forest edge, tree species composition, structure, practice

INTRODUCTION

Growth in human population around natural forests, the demand for more agricultural land and increase in land use activities have exerted pressure on tropical forests whose tree cover, species composition and structure have changed over the past few decades. According to Moran and Krug (2000), there is a strong relationship between land use and land cover change. Understanding this relationship necessitates documentation of past and current alterations in land cover. Recent projected land use trends in the tropics indicate that land use activities are causing rapid changes in natural forest composition and structure. Extensive uncontrolled and unplanned land use accelerates forest fragmentation and results in substantial loss of forest cover and biomass. Such biomass losses from fragmented forests have been found to be a significant source of green house emissions (Keller *et al*., 2001). Growing concern about unsustainable forest resource management and utilization practices as well as the associated decline in forest quality have led to the realisation that the impacts of human activities on the forest cannot be addressed without analysing the land use activities on the forest edges. Although, the problem of multiple-use is recognised in natural forest management, relatively little attention has been paid to the impacts of such activities on Uganda's natural forests.

Forest management problems usually have a human dimension because decisions about land use and forest resource utilisation are driven by human needs. But when developing forest management plans, forest managers do not consider land use activities around the forest

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which remain a major challenge. According to Mohamed *et al.* (2000), land use plans should be integrated into the management plans of other natural resources because land use activities affect the management and conservation of such resources. The development of an integrated management plan requires combining data from forest and land use inventories. This study examined the land use types and activities around Budongo forest reserve, their impacts on the forest and the implications for forest management policy and planning. The aim was to assess the influence of land use activities on tree species structure and composition and how they vary from the forest edge into the forest.

Forest-edge tree species dynamics: Formal studies and state of knowledge of forest-edge tree species dynamics are limited. No definitive study in the tropics has been traced on the effects of land use activities on forest-edge tree species dynamics. Published information and comments in literature describing the changes in the structure and composition on the forest edge is scarce. Studies by Eggeling (1947), Richards (1979) and Synnott (1985) indicate that forest-edge tree species dynamics is complex. The forest edge is often dominated by fast colonising and light demanding pioneer species whose seed require light stimuli to germinate, e.g., *Cecropia obtusifolia*, *Harungana madagascariensis*, *Milicia excelsa*, *Musanga cecropioides*, *Mitragyna ciliata* and *Trema orientalis*. According to Richards (1979), there is poor regeneration of forest tree species in the heavily harvested forest edges due to suppression of young trees by dense shrubs and climber tangle. Synnott (1985) reported that colonising forests occur along the margins of the forest and is made up of a matrix of woodland species such as *Sapium ellipticum* and *Cordia africana* and wooded grassland invaded by *Acanthus* sp., *Maesopsis emini*, *Spathodea campanulata* and other colonising species. Older colonising forest at the edge usually has species such as *Cordia millenii*, *Diospyros abyssinica*, *Cola gigantica*, *Funtumia* sp., *Olea welwitschii* and other young trees of mixed forest species with intermediate shade tolerance.

Description of the study area: Budongo Forest Reserve is a medium altitude moist semi-deciduous forest. It is located between 1°35'-1°55'N and 31°18'-31°42'E on the edge of the western rift valley in western Uganda. Budongo forest reserve was gazetted as a central forest reserve in 1932. The reserve is a mixture of tropical high forest with a large population of mahoganies, woodlands and savanna grasslands thought to be capable of supporting forest. Budongo covers 825 km^2, making it Uganda's biggest forest reserve (Hamilton, 1984). It has one of the largest continuous research records of any tropical high forest in Africa (Langoya and Long, 1997), with Permanent Sample Plots (PSPs) dating back to the beginning of the last century. The forest contains two types of climax communities and three distinct seres. The climaxes are the ironwood (Cynometra) forest and the swamp forest which is an edaphic climax. The seres are the colonisers, Maesopsis and the drier woodland forest and the mixed forest (Paterson, 1991). Budongo forest is of exceptional biodiversity importance, ranking third in overall importance in the country (Howard *et al.*, 1996). There are about 465 species of trees and shrubs and about half of the forest reserve is dominated by *Celtis*, *Khaya* and *Cynometra* sp.

The forest is surrounded by several agro-pastoral ethnic groups of Sudanic and Congo origin. Crop production is the major economic activity. The main cash crop grown is tobacco and the major food crops are maize, beans, cassava, potatoes, millet, groundnuts and bananas. According to Langoya and Long (1997), the local population has changed in ethnic composition during the last century. The traditional inhabitants, the Banyoro pastoralists were joined by mainly crop farming peoples from other parts of Uganda, Sudan and Congo (now the Democratic Republic of Congo), who settled in the villages surrounding the forest. As a result, the local community today is very homogenous in terms of culture, language and nationality.

MATERIALS AND METHODS

Spatial analysis of topographic data and delineation of land uses around Budongo forest reserve: Arc/Info GIS was used to extract a layer of Budongo forest reserve and the surrounding land uses from a 1995 land use/land cover map of Masindi (scale 1:50,000). Spatial buffering at a distance of 10 km around the forest boundary was performed in Arc/Info and used to clip and produce the map shown in Fig. 1.

Field data collection procedure: The land use types/ activities considered in this study were farming, settlement, timber harvesting, charcoal production and harvesting of firewood and building poles. These were identified and delineated from the topographic map indicated above and confirmed with a field reconnaissance. Forty alternating plots measuring 50×50 m were located at intervals of 100 m along transects originating from each land use type on the forest edge and extending into the forest. In each plot, the tree species were identified, counted and recorded, their height estimated and diameter at breast height (dbh) measured.

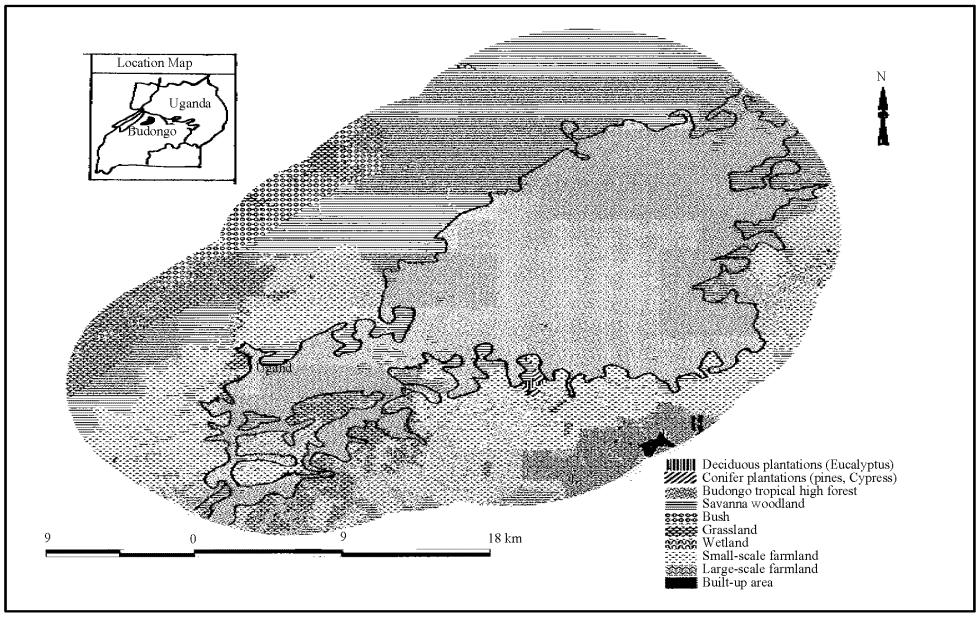

Fig. 1: Budongo forest reserve (with bold boundary) and the surrounding land uses

Data analysis: Tree species diversity was computed using the Shannon-Weaner diversity index (H') which indicates that the higher the index the higher the tree species diversity (Magurran, 1988; Kent and Coker, 1992). The index relates the proportional weight of the number of individuals per species to the total number of individuals for all the species. Tree species structure was analysed using a paired t-test and the composition analysed using Kruskal-Wallis test. The variation in tree species abundance and composition from the forest edge into the forest was analysed using a one way ANOVA (Kent and Coker, 1992).

RESULTS AND DISCUSSION

Budongo forest reserve and the surrounding land uses: The land use/land cover types around Budongo forest reserve are savanna woodlands, bush, grasslands, wetlands, farmlands and settlements (Fig. 1). The impacts of these land use/cover types, timber harvesting, charcoal production and harvesting of firewood and building poles are presented in the study.

Tree species composition and diversity: Table 1 shows the tree species that were least and most dominant in the forest areas affected by the land use activities. Table 2 shows the number, species diversity, average height and diameter at breast height (dbh) of trees with dbh ≥10 cm enumerated from the forest edge to 1 km into the forest. It was noted that where timber harvesting was taking place, the forest had the highest number of tree species. The areas that were adjacent to settlements and where there were charcoal burning and harvesting of fuelwood and building poles, follow this. The forest area that was close to the agricultural land had the lowest number of tree species. This observation is consistent with the data shown in Fig. 2 which shows that the number of tree species increases from each land use type/activity on the forest edge towards the forest interior and then declines.

Kelly and Walekr (1976) reported a similar observation in their study of the effects of different forms of land use on the ecology of a semi-arid forest in Southwestern Rhodesia. They found that uncontrolled land use activities negatively affect the population structure and natural regeneration of tree species. The

Table 1: The most and least dominant tree species recorded in the forest areas affected by the land use types/activities

Land use type/activity	Most dominant tree species	Least dominant tree species
Agriculture	*Cynometra alexandrii*, *Lasiodiscus mildbraedii*, *Rinorea ardisiaeflora*	*Dictyandra arborescens*, *Olea welwitschii*, *Sapium elipticum*, *Tabernaemontana holstii*, *Uvariopsis congolensis*
Timber harvesting	*Celtis brownii*, *Cynometra alexandrii*, *Lasiodiscus mildbraedii*, *Maesopsis eminii*	*Cleistopolis patens*, *Erythrina mildbraedii*, *Majidea fosteri*, *Musanga cecropioides*, *Piptadeniatrum africanum*, *Pycnanthus angolensis*
Settlement	*Cynometra alexandrii*, *Lasiodiscus mildbraedii*, *Lipidoturus laxiflorus*	*Cleistopolis patens*, *Dictyandra arborescens*, *Drypetes ugandensis*, *Mitragyna ciliata*, *Monodora angolensis*, *Tabernaemontana holstii*
Charcoal burning, firewood and pole collection	*Cynometra alexandrii*, *Lasiodiscus mildbraedii*, *Tapura fischeri*	*Albizia gradibracteata*, *Cleistopolis patens*, *Maesopsis eminii*, *Monodora angolensis*, *Pyllanthus discoideus*, *Pleiocapa pycnanthus*

Table 2: The average number, diameter at breast height (dbh), height and diversity of tree species recorded from the forest edge into the forest

Land use type/activity	No. of trees≥10 cm dbh	Number of tree species	Average height (m)	Average dbh (cm)	Diversity index (H')
Agriculture	524	73	39.11	25.18	2.57
Timber harvesting	637	82	33.06	22.06	2.80
Settlement	519	68	34.87	23.87	2.59
Charcoal burning, firewood and pole harvesting	527	78	34.52	24.73	2.69

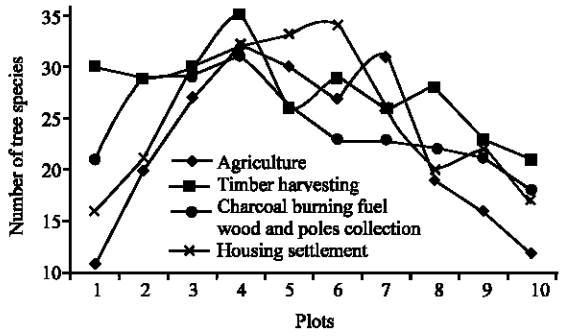

Fig. 2: Variation in the number of tree species from the forest edge towards the forest interior

variation in the number of tree species from the forest edge towards the forest interior shown in Fig. 2 is attributed to the effects of human activities which are more usually more intense on the forest edge than in the interior. This is because trees are cut for timber, fuelwood, building poles and the forest is cleared to open up more land for farming and settlement. As such the tree species on the forest edge are more vulnerable to over exploitation, destruction and extirpation than those found deeper in the forest.

One way analysis of variance of tree species diversity showed that there was a significant variation in the effect of the four land use types/activities on the abundance and composition of forest tree species ($F = 2.87$, $p = 0.047$). Timber harvesting had the least and farming had the highest effects on the number and composition of forest tree species. Results of the Kruskal-Wallis test shown in Table 3 indicate significant differences in the number of forest tree species affected by all the land use types ($H = 24.77$, $p = 0.001$).

It is clear from literature that low levels of timber harvest and incidental damage do not seriously reduce the regeneration and species richness of natural forests. According to Cannon *et al.* (1994), the level of harvest and incidental damage not exceeding 25% of the basal area/or canopy disturbance enhances natural forest regeneration and species abundance. A study by Kasenene (1987) found that moderately logged compartments of Kibale forest reserve in western Uganda had significantly more woody plant species than the unlogged forest. Furthermore, a report by Plumptre *et al.*

Table 3: Kruskal-Wallis test of the effects of land use type/activities on the number and composition of forest tree species on the edges of Budongo forest reserve

Land use type/activity	No. of tree species	Median	Z-value	H-value	p-value
Agriculture	524	35	1.43	24.77	0.001
Timber harvesting	637	31	-3.66	-	-
Charcoal burning, firewood and poles collection	519	31	-1.50	-	-
Settlement	527	40	3.96	-	-

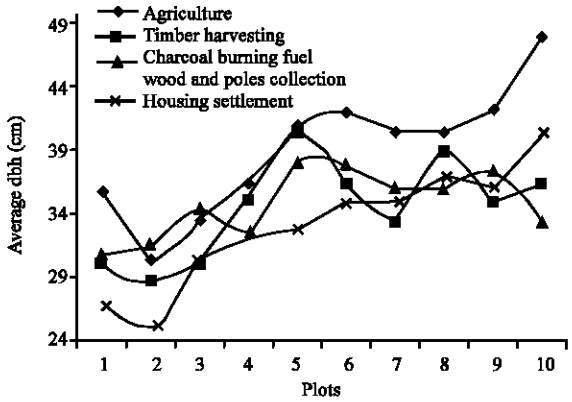

Fig. 3: Change in the average tree diameter from the forest edge towards the interior

(1997) indicated that the number of tree species increased in the compartments of Budongo forest reserve that were disturbed by logging. On this basis it can be concluded that land use practices that lightly disturb trees on the forest edge would not significantly reduce tree species richness and abundance.

Table 3 also shows that human settlement and farming adversely affected the number and diversity of tree species on the edges of Budongo Forest Reserve. Mather (1986) noted that agricultural practice such as the application of aboricides alters the habitat and reduces the number and diversity of tree species. Other management practices associated with agriculture such as firing also suppresses tree regeneration and reduces the number and diversity of tree species that regenerate (Uhl 1982; Saulei, 1984). In the case of Budongo forest, it can be said that the traditional slash and burn farming method practised by the agro-pastoral local communities living around the forest mainly affected the tree species richness.

Tree diameter and height: There was a gradual increase in the average diameter of the trees from the forest edge towards the forest interior from all the land use types (Fig. 3). This is also attributed to effects of intense utilisation of forest resources, farming activities and human settlement on the edges of Budongo forest reserve. It was noted that households living close to the forest edge had easier access to forest resources. Farming was concentrated on the outer fringes of the forest while

Table 4: Paired t-test of the means of diameters and heights of trees on the forest edge affected by the land use types/activities around Budongo forest reserve

	Differences in mean diameter		Differences in mean height	
Land use types	t-value	p-value	t-value	p-value
Agriculture and settlement	-4.11	0.003	-5.01	0.001
Agriculture and charcoal burning, firewood and building pole collection	3.13	0.012	7.09	0.000
Agriculture and timber harvesting	9.07	0.000	1.24	0.044
Settlement and timber harvesting	1.37	0.045	-4.46	0.002
Settlement/housing and charcoal burning, firewood and building pole collection	1.51	0.049	1.93	0.048
Timber harvesting and charcoal burning	-3.98	0.002	-3.62	0.006

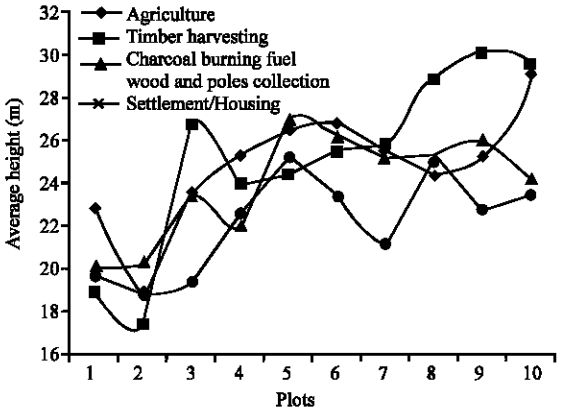

Fig. 4: Change in the average tree height from the forest edge towards the forest interior

the inner forest areas were left relatively intact. Clearance of tall trees to open forestland for farming and to reduce shading of agricultural crops was confined to the forest edges and did not significantly disturb the forest structure. Since access to forest resources in Budongo is restricted, local communities usually resort to illegal harvesting of trees especially for timber and select only the best trees for felling. One-way analysis of variance of tree diameters showed a significant variation ($F = 3.82$, $p = 0.018$) in the effects of the four land use types/activities on forest tree species. A paired t-test (Table 4) showed significant differences in the average diameters and heights of trees due to the impacts of the land uses/activities.

It is clear from Table 4 that farming activities had the least impacts on forest structure (mean diameter = 39.110 cm) whilst timber harvesting had the highest effect (mean diameter = 33.060 cm). This observation is not surprising because Budongo is a multiple-use/production forest and much of the forest interior has been harvested by licensed pit-sawyers and sawmillers. As would be expected, loggers select big trees whose diameters at breast height are ≥30 cm (Odd Lie, personal communication). This practice significantly reduces the number of trees with diameters that are ≥30 cm. In the process the forest structure is altered (Fig. 4) as large diameter trees are extracted and the remaining forest is dominated by trees of smaller diameters. One way ANOVA of the tree heights showed significant variations in the effects of the land use types/activities on forest structure ($F = 1.63$, $p = 0.039$). A paired t-test showed significant differences in the tree heights (Table 4). The mean height of trees shown in Fig. 4 indicate greater negative impacts of timber harvesting on the forest structure (mean height of 22.060 m) than the other land use activities. This is due to the fact that loggers/pit-sawyers usually select and cut trees with big straight boles in order to maximise the recovery per tree. Agriculture had the least negative impacts on the forest structure (mean height of 25.180 m).

Significance of the findings for forest management policy and planning: The results presented in this study attempt to explain the changes in tree species structure and composition on the forest edge. Knowledge of forest-edge tree species dynamics is essential for developing appropriate forest management plans. Moreover, understanding the impacts of human activities on natural forest ecosystems is a good basis for developing sustainable forest management and conservation strategies.

This study has revealed that forest edges affected by timber harvesting are characterised by a high diversity of tree species. This finding is consistent with Synnott's (1975) observation that logged areas of Budongo forest reserve were rich in tree species especially the mahoganies. Low impact timber harvesting appears to have minimum impacts on tree species diversity and structure. Since Budongo forest reserve is a multiple-use/production forest, there is a need to regulate extractive activities such as harvesting of timber, firewood and building poles and to confine them to clearly demarcated community use zones. Lessons learnt from Bwindi Impenetrable Forest National Park (Cunningham, 1996), indicate that limiting local community extraction of forest products to designated community use zones helps to regulate forest resource use. Furthermore, the local community becomes responsible for their activities and help to monitor changes in the forest ecosystem. By

controlling the exploitation of the forest, minimising the adverse effects and allowing the affected areas to regenerate, the managers of Budongo would be applying the fundamental principles of sustainable forest management.

The findings of this study are therefore significant in many ways. Firstly, as Uganda revises its land use policy, it would be appropriate to consider the integration of other land use plans into the forest management plans. A further challenge is to develop a methodology that integrates agro-ecological data into land use planning and policy analysis. According to Fresco *et al.* (1992) and Elizabeth (1994), the first step toward the development of such a methodology would be to integrate information from the various land use disciplines. However, efforts to develop such a methodology have been hampered by lack of adequate data from the different forms of land use (RAWOO, 1989) and yet the methodology would be essential if scientific research is to effectively contribute to sustainable forest management and conservation.

Secondly, for along time, the managers of Uganda's forests have relied on data collected by the traditional forest inventory methods to prepare forest management/working plans. In order for the forest managers to incorporate land use data into forest management plans, they need to have a good knowledge of the impacts of the surrounding land uses/activities on the forest ecosystem. A clear understanding of these impacts is an essential prerequisite for the development of an integrated land-use-forest management plan. For the foreseeable future, the management plans of Budongo and other natural forests in Uganda may continue to be based on traditional forest inventory data only. However, this will need to change as the Uganda Forest Department is transformed into the National Forest Authority and forest management is decentralised to the districts and lower levels of government.

A major lesson that can therefore be learnt from this study is that data on land use/activities around the forest and their impacts on the forest conditions can be generated and used for the development of an integrated land use-forest management plan.

CONCLUSION

The following conclusions can be drawn and recommendations made from this study. The most common land use types/activities on the edges of Budongo forest reserve were logging, agriculture, settlement, charcoal burning and harvesting of firewood and building poles. These activities affect forest tree species composition and structure. The number and diversity of tree species affected by the land use activities increased from the forest edge towards the interior and then declined. Timber harvesting had the least and farming had the most significant impacts on tree species abundance and composition.

RECOMMENDATIONS

There is a need to monitor the effects of land use activities on forest tree species composition and structure and to generate data that can be used develop an integrated land use-forest management plan for Budongo forest reserve.

There is a need to demarcate community use zones in Budongo forest reserve to control and regulate forest resource exploitation by the local communities living around the forest. In this way, the forest will be conserved, the biodiversity protected and the resources sustainably used.

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