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EXOTIC TREE PLANTATIONS AND THE REGENERATION OF NATURAL FORESTS IN KIBALE NATIONAL PARK, UGANDA

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Abstract

Exotic tree plantations have been considered as a management strategy for the rehabilitation of indigenous tree communities in situations that require human intervention to assure forest ecosystem rehabilitation. This study evaluated the value of pine Pinus caribaea *and* Pinus patula *and cypress* Cupressus lusitanica *plantations as a means of permitting indigenous trees to become established on derelict land in the Kibale National Park (766 km²) of western Uganda. We present data on the size and density of indigenous trees >2 m tall growing in 80 (10 m × 10 m) quadrats in plantation areas before and after plantation harvest. Species richness for indigenous trees was high in the plantation areas; 47 species of indigenous trees were found in the 0·8 ha sampled, as compared to 78 species in a 5·4 ha area of intact forest. The number of indigenous trees in the quadrats varied from five to 38. There was no significant difference in species richness or density between areas of logged and unlogged* P. patula. *However, damage resulting from the logging operation was evident and may affect longer term regeneration patterns. Recommendations and cautionary remarks are made with respect to using plantations as a management scheme to rehabilitate indigenous tree communities in derelict areas. Copyright © 1996 Elsevier Science Limited.*

Keywords: conifers, restoration, rehabilitation, regeneration, Kibale Forest.

INTRODUCTION

Tropical forests are increasingly threatened by accelerating rates of forest conversion and degradation (Lanly, 1982; Brown & Lugo, 1990). In an ever-changing political world, it is often infeasible to protect areas from such conversion until political and economic systems change. By the time the political environment is suitable to pursue conservation or management goals, the forests have often been converted to other uses. In Africa, forest conversion is primarily to agricultural land, while Latin American forests are typically cleared for ranching. However, in both ecosystems, the converted land is generally agriculturally non-productive, biologically impoverished, and far more flammable than the forests that were replaced. The need to increase the intrinsic or economic value of degraded forests has led to a growing area of ecological research in forest rehabilitation (e.g. Jordan *et al.*, 1987; Cairns, 1988*a*,*b*). However, there are still few quantitative data available for tropical forest managers regarding the potential of various management options.

Although forest succession in the lowland tropics can be rapid (Ewel, 1980; Lugo, 1988, 1992; Brown & Lugo, 1990), there are a number of situations where succession can be extremely slow, or not proceed at all. The area may be too dry or have soil with poor fertility (Ewel, 1980), there may be extensive skid damage and erosion following logging or bulldozer activity (Uhl *et al.*, 1982), reforestation may be inhibited by extensive herb layer growth (Fitzgerald & Selden, 1975; Brokaw, 1983; Kasenene, 1987), or fires set by neighboring agriculturalists may inhibit regeneration in the flammable degraded land (Uhl *et al.*, 1981, 1988*a*,*b*,*c*; Uhl & Buschbacher, 1985; Janzen, 1988; Uhl & Kauffman, 1990; Nepstad *et al.*, 1991). When attempting to manage lands that require human intervention to assure forest ecosystem rehabilitation, Lugo (1992) suggested that tree plantations should be considered as a means of restoring the productivity of the land. However, for plantations to be a component of a management strategy that has the goal of rehabilitating an indigenous community, it must be demonstrated that indigenous tree species can become established under plantations and that plantation harvest will not destroy the potential for the establishment of indigenous trees.

In this paper we evaluate the value of pine *Pinus caribaea* and *Pinus patula* and cypress *Cupressus lusitanica* plantations as a means of permitting indigenous trees to become established on derelict land in the Kibale National Park (766 km²) of western Uganda. We present data on the indigenous trees >2 m tall growing in plantation areas before and after logging.

Planting of softwoods (at 2·7 m × 2·7 m spacing) near the study site at Kanyawara was started in 1963 in areas dominated by elephant grass *Pennisetum purpureum* and continued through 1965 (Kingston, 1967). These grassland areas in Kibale are the result of past human clearing and are maintained by fires which inhibit natural colonization by tree species (Kasenene, 1987). Areas of elephant grass not converted to plantations in the

1960s are still dominated by elephant grass today (although some areas near the Ngogo Research Camp that were protected from fire have become forested, T.T. Struhsaker, pers. comm.). Plantation areas were initially clean-slashed or selectively slashed to minimize the effects of grass growth on tree growth. Initially, there were doubts as to whether the *P. patula* or *P. caribaea* could suppress the elephant grass (Osmaston, 1959; Kingston, 1967); however, subsequent observations belie this doubt. These plantations were part of the management plan for the area, designed to maximize sustainable harvest of timber, written at a time when the area was a Forest Reserve (gazetted a crown forest in 1932) administered by the Forestry Department. However, in 1993 the area became a National Park, and new management objectives reflect this change in status.

METHODS

Study site

The Kibale National Park (766 km^2), located in western Uganda (0°13'–0°41'N and 30°19'–30°32'E) near the base of the Ruwenzori Mountains, is a moist, evergreen forest (Struhsaker, 1975; Skorupa, 1988). The study site, known as Kanyawara, is situated at an elevation of 1500 m. Mean annual rainfall averaged 161 cm from 1977 to 1993 and annual mean daily maximum temperature from 1977 to 1986 averaged 23·1 ± 0·6°C. The rainfall tends to be well-dispersed, falling on an average of 166 days per year; however, there are distinct wet and dry seasons (Kingston, 1967).

Three plantations near the Makerere University Biological Field Station (Kanyawara), Butanzi, Nyakajojo and Nyamusika, planted between 1963 and 1965, were selected for study. Logging operations involving either portable sawmills and/or pitsawing have been ongoing at Butanzi and Nyakajojo since the fall of 1993, and the timber is sold either locally or in the capital city. Only areas where pitsawing was the principal extraction technique were sampled. To obtain a baseline level of indigenous tree richness to contrast with the richness found in the plantations, we used data collected for phenological sampling of the area (Chapman *et al.*, 1995). Twenty-six vegetation transects were established in the Kibale Forest near Kanyawara. Each transect was 200 m × 10 m, providing a total sampling area of 5·2 ha. Each tree >10 cm DBH (diameter at breast height) within 5 m of each side of the trail was individually marked with a numbered aluminum tag and measured (DBH).

Sampling procedure

The objective was to sample 20 10 m × 10 m quadrats in each of six areas (logged and unlogged for the three exotic species), but it was difficult to find areas of *C. lusitanica* that had not already been logged, and no areas of logged *P. caribaea* were available. Thus, the sample consisted of 20 quadrats of unlogged *P. patula*, 20 unlogged *P. caribaea*, 20 logged *P. patula*, and 20 logged *C. lusitanica*, all planted approximately 30 years ago.

The location of each quadrat was randomly selected within the plantation, and a series of parameters characterizing the quadrat was measured (slope, distance to the natural forest, estimated percentage of the ground covered by herbaceous vegetation, dominant type of herbaceous vegetation, second most dominant herbaceous vegetation). Subsequently, all trees >2 m were identified (we were not able to identify 0·4% of the individual trees) and their height measured (using a series of interlocking poles of known height). To eliminate possible biases created by the logging practices, only the unlogged quadrats were considered in analyses of factors relating to rehabilitation. The adjacent natural forest is not uniform in nature; some areas were selectively logged to differing intensities in the late 1960s and early 1970s (Skorupa, 1988). Plant taxonomic nomenclature follows Hamilton (1991).

RESULTS

Species richness, tree number and indigenous tree height

In total 47 species were found in the combined sample of quadrats, occupying 0·8 ha. This represents 60% of the 78 species of trees that were identified in the 5·4 ha of natural forest in Kanyawara. The average number of species found in a quadrat differed between treatments (unlogged *P. patula* mean = 7·5, unlogged *P. caribaea* mean = 9·85, logged *P. patula* mean = 6·45, logged *C. lusitanica* mean = 6·25; $F = 9{\cdot}34$, $p < 0{\cdot}001$; Table 1). Scheffe tests ($p < 0{\cdot}05$) indicate that areas of unlogged *P. caribaea* had significantly higher species richness than the other areas. In general, logged areas had fewer species than unlogged areas, but the differences were not significant when only logged and unlogged *P. patula* quadrats were contrasted (Table 1).

There were 1341 individual trees >2 m tall in the combined sample of quadrats or an average of 17 indigenous trees in each quadrat (range = 5–38). The mean number of trees per quadrat varied between treatments (unlogged *P. patula* mean = 18·5, unlogged *P. caribaea* mean = 20·1, logged *P. patula* mean = 17·5, logged *C. lusitanica* mean = 13·3; $F = 3{\cdot}38$, $p = 0{\cdot}01$). Scheffe tests ($p < 0{\cdot}05$) indicate that areas of unlogged *P. caribaea* had significantly more trees than areas where *C. lusitanica* had been logged. Other paired contrasts were not significant. In general, logged quadrats were characterized by fewer trees; however, the magnitude of the reduction was not significant in the paired comparison of *P. patula* (logged mean = 17·5 trees vs unlogged = 18·5 trees). Since these trees have a maximum of 30 years of growth, the average height of the indigenous trees was not tall (approximately 5 m, Table 2); however, trees over 10 m in height were not uncommon (Table 2). There was no significant difference between treatments in the height of the trees ($F = 0{\cdot}859$, $p = 0{\cdot}47$).

Table 1. Characteristics of 10 m × 10 m quadrats sampled in logged and unlogged plantations of exotic tree species in the Kibale National Park, Uganda

	Unlogged *P. caribaea* 1	Unlogged *P. patula* 2	Logged *P. patula* 3	Logged *C. lusitanica* 4	Scheffe contrasts[c]
Mean no. of indigenous trees[a]	20	18·5	17·5	13·3	1 2 3 4
Mean height	5·0	5·0	4·7	4·5	
Max height[b]	23	24	12	25	
Mean no. of indigenous species	9·9	7·5	6·5	6·3	1 2 3 4
Mean no. of wind dispersed	1·0	0·2	0·1	0·4	1 2 3 4
Mean no. of animal dispersed	18·0	18·4	17·2	13·0	

[a] The mean represents the average of the number of indigenous trees found in each of the 10 m × 10 m quadrats.
[b] The height of the tallest individual tree in any of the 20 quadrats of that type of plantation.
[c] Underlined species in Scheffe contrasts are not significantly different.

Factors relating to rehabilitation

Neither the number of individual trees ($r = 0·071$, $p = 0·66$, $n = 40$ unlogged quadrats), nor the number of species in a quadrat ($r = -0·228$, $p = 0·16$) was related to the distance from intact forest. This may reflect the fact that very few of the species found in the quadrats rely on wind dispersal. On average, only 3·2% of the trees had seeds with a morphology indicative of wind dispersal. This finding supports data from an extensive series of fruit traps which indicated that wind-dispersed seeds make up a relatively small proportion of the seeds falling to the ground in Kibale Forest relative to other tropical forests (Chapman *et al.*, unpublished data).

It was estimated that the herb layer covered an average of 60% of the ground surface and had an average height of 1·3 m. None of the quadrats was dominated by elephant grass or *Acanthus pubescens*, despite early fears of the forest managers at the time of planting (Osmaston, 1959; Kingston, 1967).

DISCUSSION

A number of animals routinely use the exotic conifer plantations in Kibale Forest. It was not uncommon to see redtail monkeys *Cercopithecus ascanius* and chimpanzees *Pan troglodytes* in the plantations, and evidence from tracking stations (B. Keith, pers. comm.) suggests that duiker *Cephalophus harveyi* and *C. moniticola*, bushbuck *Tragelaphus scriptus*, bushpig *Potomochoerus porcus*, civets *Viverra civetta* and *Nandinia binotata*, and genet *Genetta* sp. frequently use the plantations. Use of these areas by frugivores may account for the high level of regeneration observed. It is unlikely that the indigenous trees in the plantations came from a seedbank, since the planted areas had been grasslands for a number of years before they were converted to plantations; and during this time they were repeatedly burnt. In addition, many of the tree species found in the plantation have large seeds (e.g. *Mimusops bagshawei* an oval seed, with the longest axis averaging 11·0 mm, SD = 1·8, $n = 25$), with a morphology suggesting that they require animal dispersal. Thus, it is likely that most trees established from seeds dispersed by frugivores or secondary dispersers. For example, we found seven *Mimusops bagshawei* trees in the areas sampled in the plantation, and evidence suggests that this tree is very reliant on chimpanzees for much of its seed dispersal (Wrangham *et al.*, 1994).

Table 2. Mean and maximum heights of the 10 most common indigenous trees found in the plantations of exotic conifers in Kibale National Park, Uganda

Density in the natural forest was determined from 26 transects (200 m × 10 m = 5·4 ha) established throughout the area, where each tree >10 cm DBH within 5 m of each side was identified.

	Density in natural forest	Unlogged *P. caribaea*	Unlogged *P. patula*	Logged *P. patula*	Logged *C. lusitanica*
Diospyros abyssinica	44·6	3·5/6·5	5·4/16·7	3·6/5·1	3·7/6·3
Celtis africana	8·1	6·2/9·8	5·3/7·5	4·0/6·5	4·7/7·8
Celtis durandii	38·0	5·3/6·9	4·6/7·3	2·7/3·5	4·8/5·5
Albizzia sp.[a]	3·0	6·4/15·0	7·8/24·0	5·6/10·9	11·1/25
Teclea nobilis	14·1	4·8/7·5	4·8/6·6	4·9/7·6	3·3/4·0
Olea welwitschii	2·6	6·1/10·1	6·3/12·0	Not present	5·5/11·0
Trema orientalis	3·5	5·0/5·0	5·5/5·5	4·1/5·0	4·5/6·3
Lindackeria mildbraedii	0·4	3·0/3·0	4·1/5·5	4·4/8·0	4·0/5·0
Fagaropsis angolensis	2·8	4·3/8·0	5·1/9·1	6·4/8·0	3·5/6·0
Clausena anisata	0·2	3·5/5·0	3·7/5·0	5·6/7·0	2·6/3·2

[a] Includes individuals of *Albizia gummifera* and *A. grandibracteata*; *A. gummifera* can be distinguished by more numerous leaflets, but since hybridization is known to occur (Hamilton, 1991), we considered them as a complex.

From focal tree observations, and counts of the fruits eaten by all diurnal frugivores attending *M. bagshawei* trees, we have estimated that 34·5% of the fruits processed at *M. bagshawei* trees are eaten by chimpanzees (Chapman & Chapman, in press).

Although our study reports high levels of natural regeneration under pine plantations, Struhsaker *et al.* (1989) report a dieback of three species of rainforest trees in Kibale which were downslope from conifer plantations. Over a 9-year period they reported mortality rates of 45%, 90% and 100% for *Aningeria altissima*, *Lovoa swynertonii* and *Newtonia buchannii*, respectively. Based on these findings, Struhsaker *et al.* (1989) suggest that conifer plantations should not be planted near natural forests in the tropics, but rather be restricted to areas far from natural forests. This would obviously not serve the purpose proposed here of having plantations aid in the regeneration of natural forest, since the majority of the tree species recruiting under the pines are animal-dispersed and it is unlikely that many animals would visit isolated plantations.

Clearly more research is needed. For example, it would be desirable to have a longer duration over which indigenous trees in plantations are monitored, particularly post-logging, and we must identify possible pathogenic agents or environmental changes associated with conifer plantations. Considering the potential dangers of species introductions, it would also be desirable to examine the feasibility and problems associated with plantations of indigenous tree species. Finally, plantations are only one means to rehabilitate indigenous forests, but these plantations are attractive from an economic perspective, since the costs of planting can be recovered when the plantations are harvested. If an economic incentive is not essential, an investigation of the rehabilitation that would result from simply the control of fire should be quantified. Similarly, simple manipulations, such as the broadcasting of seeds of indigenous trees, or the planting of cuttings to act as perches to attract avian seed dispersers should be evaluated.

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