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**EARLY DETECTION OF TROPICAL FOREST DEGRADATION:
AN IFRI PILOT STUDY IN UGANDA**

by

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Tropical deforestation and ever wider forest degradation are global environmental problems of which is replete of international treaties and conventions (Borner & Woodwell, 1993). Land use changes followed by changes in ecosystem structure (Mooney, 1993) are two probable outcomes of deforestation that may curtail important ecosystem services provided by tropical and other forests. Erosion, siltation, flood control, availability of local foods and medicines, and a sustainable supply of wood products are some of the services we depend on most at home. Tropical deforestation and degradation are cumulative processes and the primary consequences of use by people living in or around the forest, and partly the result of exploitation by other people who are not local. In central Africa, the Congo basin region, and lowlands, some 1.25 million square miles of lowland forest are estimated to be cleared every year (Harvey, 1993).

The issue of deforestation or forest degradation demands local level perceptions, individual interests, and management arrangements guiding the stewardship of forests (see Gombya-Ssembajjwe et al., 1991; Larson et al., 1992a; Ostrom, 1990; Thomson, 1992), and Arnold (1991) emphasizes the need, and provides approaches, for a strong human component at the local level in order to understand and prevent or limit the negative environmental and social impacts of deforestation. They found that sustainability of forest depends on local rules, user behavior, and incentives created by international, regional, national, and local institutions. Indeed, if ecological consequences are the same, make a local and a global

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Forest. In this International Forest Resources and Institutions (IFRI) pilot study, we explore this hypothesis in two Ugandan tropical forests held under different management regimes.

The IFRI research programme aims to understand the physical and social conditions over time under

forests that are under the stewardship of these national (Ostrom et al., 1992a). The phrase 'economically and ecologically sustainable' can simply be taken to mean social arrangements that support a natural system with applied renewable resources such as water and forests, ecological and economic sustainability refers to the study of a forest's present consumption as a non-consumptive resource for many generations of people with no major change in forest structure, dominant plant and animal species, species diversity, and ecological functions.

During an IFRI training session in Uganda in December 1993, we studied the local rules, use patterns, a local condition, of Namungo Forest, a natural, private owned tropical forest. We also learned that a government owned and managed forest, Lwamunda Forest Reserve, was adjacent to Namungo Forest. Although both forests were in the same watershed and ecological, they appeared to differ markedly in governance, incentives, and local use patterns. We expanded the goal to compare the two forests, and prepared some of the general working hypotheses of our IFRI research programme. We asked two broad questions:

- 1) Do Namungo Forest and Lwamunda Forest differ significantly in 10 ecological measures of institutional sustainability posed by Ostrom et al. (1992a) such as what ways?
- 2) Do ecological measures of the physical stream biodiversity, and signs of human encroachment, at the forest patches correspond in any predictable way to institutional sustainability?

The physical conditions of Namungo Forest and Lwamunda Forest Reserve should reflect the local rules, incentives, and day-to-day actions of local people, and forest under the two different institutional arrangements.

Ostrom et al. (1992a) suggest that sustainable stewardship of forests is most likely to result when:

1. Markets for forest products are distant.
2. Population growth rate is low.
3. Population pressure is concentrated away from the forest.
4. The institutions that govern the forest are strong and



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Early Detection of Tropical Forest Degradation: an IFRI* Pilot Study in Uganda

by

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INTRODUCTION

Tropical deforestation and even wider forest degradation are global environmental problems the tackling of which is needful of international treaties, commissions, and conventions (Brown *et al.*, 1992; Ramakrishna & Woodwell, 1993). Loss of biodiversity (Wilson, 1988) followed by changes in ecosystem function (Schultze & Mooney, 1993) are two probable outcomes of deforestation that may curtail important ecosystem services provided by tropical and other forests. Erosion control, flood control, availability of local foods and medicines, and a sustainable supply of wood products, are some of the services to humans that are most at stake. Tropical deforestation and degradation are cumulative processes and are partly due to patterns of use by people living in or around the forest, and partly the result of exploitation by markets that are not local. In equatorial Africa, the Amazon region, and Indonesia, some 55,000 square miles (143,000 sq. km) of rain-forest are estimated to be cleared each year (Lewis, 1990).

The extent of deforestation or forest degradation depends on local needs, perceptions, commercial interests, and institutional arrangements guiding the stewardship of forested areas (Dorm-Adzobu *et al.*, 1991; Ostrom *et al.*, 1993a). Ostrom (1990), Thomson (1992), and Arnold (1993), emphasize the need, and provide approaches, for analysing human institutions at the local level in order to understand, and possibly reduce the negative environmental and societal costs of, deforestation. They contend that sustainability of forests depends on local rules, use-patterns, and incentives created by international, regional, national, and local, institutions. Indeed, if ecological conditions are the same, major structural and biological differences between local patches of forests may be almost completely the consequence of human rules and use-patterns. In this International Forest Resources and Institutions (IFRI) pilot study, we explore this hypothesis in two Ugandan tropical forests held under different property-rights and rules.

The IFRI research programme aims to gather a large and representative array of data on rules, use-patterns, and the physical conditions of local forests over time, in order to test a broad set of hypotheses regarding local institutions and the economic and ecological sustainability of

forests that are under the stewardship of these institutions (Ostrom *et al.*, 1993a). The phrase 'economically and ecologically sustainable' can simply be taken to mean social arrangements that exploit a natural system without destroying it. As a working hypothesis in the context of this paper, applied to renewable resources such as natural tropical forests, ecological and economic sustainability refers to the ability of a forest to provide consumptive and non-consumptive benefits for many generations of local users with no major change in forest structure, dominant plant and animal species, species diversity, and ecological functions.

During an IFRI training session in Uganda in September 1993, we studied the local rules, use-patterns, and forest condition, of Namungo Forest, a natural, privately-owned tropical forest. We next learned that a government-owned and -managed forest reserve, Lwamunda Forest Reserve, was adjacent to Namungo Forest. Although both forests were in the same watershed and ecological zone, they appeared to differ mainly in governance, rules, incentives, and local use-patterns. We expanded the project to compare the two forests, and explored some of the central working hypotheses of the IFRI research programme. We asked two broad questions:

1) Do Namungo Forest and Lwamunda Forest Reserve differ significantly in 10 hypothetical sources of institutional sustainability posed by Ostrom *et al.* (1993a)? If so, in what ways?

2) Do ecological measures of the physical structure, biodiversity, and signs of human exploitation, in these forest patches correspond in any predictable way to the institutional sustainability?

The physical conditions of Namungo Forest and the Lwamunda Forest Reserve should reflect the local rules, incentives, and day-to-day actions of local people, on the forests under the two different institutional settings.

Ostrom *et al.* (1993a) suggest that sustainable stewardship of forests is more likely to result when:

1. Markets for forest products are distant;
2. Population growth-rate is low;
3. Population pressure in surrounding areas is low;
4. The institutions that govern the forest system have been stable for a long period of time and are understood by forest users;
5. Monitoring, sanctions, conflict resolution, and governance, are organized in multiple layers of nested enterprises;

* International Forest Resources and Institutions.

ungo's family, and officials involved in governing Lwamunda Forest Reserve. The team, including the Authors of this paper, visited Mbazzi daily during weeks in September 1993. Data about the users of the forests, the products which they removed, what rules they themselves imposed, and what rules were imposed upon them, were obtained during the meetings with the men, women, and children, of Mbazzi. More details about official rules, sanctions, and the level of enforcement of rules regarding use of the two forests, were obtained through meetings with the District Forest Office, the District Administrator, and the owner of Namungo Forest, as well as by discussion with forest guards and users (Gombya-Ssembajjwe *et al.*, 1993).

Data Collection on the Forest's Condition

After mapping the boundaries of the forests, 30 randomly-selected plots were mapped in each forest (Ostrom *et al.*, 1993b). Namungo Forest consisted of 100 acres (40 hectares). To provide an *in situ* comparison, an equivalent area of the Lwamunda Forest Reserve, adjacent to Namungo Forest, was demarcated and randomly sampled. Two teams, each composed of three or four people, located the randomly-selected plots in the forests. Before collecting botanical data, the team recorded soil texture, position, and the presence or absence of indication of recent forest exploitation (such as firewood- or pole-cutting, charcoal-making, and pit-sawing or chain-sawing, etc.) on each plot (Gombya-Ssembajjwe *et al.*, 1993). At least two people skilled at identification of local flora were on each team, to assist with identification of plants.

When the centre of a plot has been located, three concentric circles were established around it at radial distances of one, three, and ten, metres. Species of herbs and woody seedlings were identified in the smallest circle, and the percentage of ground covered by each species was recorded. In the circle with a three-metres' radius, tree saplings and shrubs were identified, and details of each individual's maximum stem-diameter (cm) and height (m), were recorded on IFRI coding-sheets. Trees were classed as saplings when their stem diameters were greater than 2.5 cm but less than 10 cm. Trees with at least a 10 cm diameter at breast-height (DBH) were enumerated in the largest circle. The DBHs of the trees were measured with calipers, while heights of trees were estimated after determining the heights of several reference-trees with the help of a clinometer.

Data Analysis

The information provided by residents of Mbazzi, the Namungo family, and local forest management authorities, was used to generate a set of sustainability factors for each forest. In addition, these data provided an idea of incentives that currently structure the use-patterns in the two forests.

Data collected about the trees in the sample plots, and the types of open-access commercial exploitation on the plots, were compiled to assess the physical and biological condition of the two forests. Exploitation reflects current use, while age-class structure, biomass per unit area, and biological diversity of the forests, reflect both past and present use-patterns. Biological diversity in the two forests was estimated by ds , an inversion of the Simpson's

dominance index (Equation 1) and by the Shannon diversity index, H' (Equation 2). The inversion of the Simpson's dominance index is defined as:

$$ds = N(N-1) / \sum n_i (n_i - 1) \dots \dots \dots \text{(Equation 1)}$$

where N is the total number of individual trees in the sample, and n_i is the abundance of each species in the sample. Regarding diversity indices see Cox (1990).

The Shannon diversity index is defined as:

$$H' = (N \ln N - \sum n_i \ln n_i) / N \dots \dots \dots \text{(Equation 2)}$$

where \ln refers to the natural log (base e).

The distribution of size classes (by DBH) of trees, total basal area in wood, and importance values of trees, were also calculated. Importance value (Curtis & McIntosh, 1950) was calculated by summing relative density (number of trees of each species per hectare), relative dominance (basal area of each species as a percentage of all species), and relative frequency (percentage of sample plots containing each species) for each species, and then dividing by three to obtain a value between 0 and 100. Tree species were ranked by importance value and compared to see if any species differed greatly in rank in the two forests, or if certain species were missing in one forest but were present in the other.

RESULTS

No significant differences in the soil types, slopes, or drainage patterns by plot, were found between the two forests ($P > 0.10$). Both Namungo Forest and the Lwamunda Forest Reserve shared similar topography as forested areas in the drainage of a wide, gently-sloping watershed. Dark-brown sandy-loam topsoils, covered by 2–3 cm of humus, were found to be the representative soil condition in both forests. Both forests were crossed by roads and foot-trails, and were bordered by agricultural fields, pastures, and family dwellings.

Rules

Many of the official rules applying to local use are currently similar in the two forests and have probably been so for the last five years, though adherence to the rules differed. For example, local residents are authorized to harvest water, dead wood for fuel-subsistence, wild foods, and plants for medicines and crafts, in both forests. On the other hand commercial timber-harvesting, charcoal-burning, and harvesting of commercial fuel-wood by local residents, is prohibited in the two forests. The District Forest Office controls the permitting for harvesting of large timber trees in both forests. While Mr Namungo retains the right to harvest trees from his private property, he must first obtain permits from the District Forest Office to do so.

Some wildlife, such as 'giant forest hogs', may be harvested on Namungo's property, but not on the government Reserve. However, the local men informed us that they were unsuccessful at hunting Boars and did not hunt other species in these forests, where accordingly wildlife utilization was probably very low in both cases.

In the recent past, both forests were somewhat abandoned due to the civil war from 1981–85. Prior to 1981, selective harvesting of trees over 80 cm in diameter by timber companies had been permitted and carried out in both forests. During Amin's rule (1971–86), the govern-

ment forests were declared 'open access', and remained so until 1986, when the current government of Prime Minister Museveni placed them under central government control again. Since 1986, Lwamunda Forest has been managed by the Mpigi District Forest Office, under the direction of the central government authority, while Mr Namungo has been the steward of his and his family's forest.

Sustainability of Institutions of Forest Governance

Factors predicted to affect institutional sustainability differed for the two forests — especially the monitoring and sanctioning of prohibited activities, and the ability of local users to make rules affecting the use of the forest (Table I). Namungo Forest had six factors that are hypothesized to affect sustainability positively, while the Lwamunda Forest Reserve had only two.

Population growth, local population pressure, and distance to markets, were the same for both forests and thus can be eliminated from the comparison. Population growth in Uganda is above 3%, local population is increasing, and demand for firewood and charcoal was high in Kampala, only 25 kilometres away by paved road, giving negative sustainability values for these factors in both forests (*cf.* Table I).

TABLE I

Factors Hypothesized to Influence the Sustainability of Forests with Qualitative Values Determined for Namungo and Lwamunda Forests, Uganda, in 1993. A minus sign denotes that the factor was found to reduce the probability of sustainability of the forest. A plus sign indicates that the factor increased the probability that the forest would be sustained in its current condition.

SUSTAINABILITY FACTORS	FORESTS	
	Namungo versus Lwamunda	
Economic and Population factors:		
1. Distance to markets for forest products	-	-
2. Population growth-rate	-	-
3. Population pressure in surrounding area	-	-
Institutional Design and Rule factors:		
4. Institutional stability and understanding of users	+	-
5. Monitoring, sanctions, conflict resolution, and governance, are organized in multiple layers of nested enterprises	+	+
6. Rapid access to low-cost conflict resolution	+	+
7. Graduated sanctions on violations enforced	+	-
8. Quality of monitoring	+	-
9. Local users can participate in modification of rules	+	-
10. Local users design institutions governing use of forest	-	-
SUM OF SUSTAINABILITY FACTORS	6	2

Council system creates an institutional structure by which local people could influence the rules regulating forest use. However, local users were not using collective choice to design institutions governing the use of the forests. Thus this factor (number 10 on the list) was scored as negative for both forests.

Only four of the factors that were hypothesized to influence sustainability were qualitatively different in the two forests: institutional stability and understanding of rules by the users, enforcement of sanctions, quality of monitoring, and participation by locals in rule-making, were all ranked as positive for Namungo Forest but negative for Lwamunda Forest Reserve.

Over the past 30 years, Namungo Forest has been in private stewardship and has had well-defined rules except during the period of the civil war. When residents of Mbazzi drew a map of the forested areas around their settlement, they clearly illustrated that Namungo Forest was a separate property from the governmental forest Reserve. They claimed that they knew what resources they could take from Namungo Forest, and what they could not take. For example, several women mentioned that they knew they were free to collect fallen and dead wood for firewood, but that they should not cut down or mutilate any living trees. In contrast, the governmental forest reserve changed from a regional forest reserve used for commercial revenue to a central governmental reserve after independence from Britain, next to an open-access resource during the Amin regime and the civil war years, and then back to a central government reserve after the civil war — as a result, the rules applying to Lwamunda Forest were less well-known and were clearly not followed by local users.

Graduated sanctions for rule-breaking appeared more likely to exist and be enforced by Mr Namungo in his forest than by forest guards in the Reserve. Mr Namungo reported that he has reduced illegal harvesting of poles from his property by informing local residents that they must purchase such rights to harvest poles, or in some cases simply seek permission. As the chairman of a sub-county Resistance Council (RC3), Mr Namungo is clearly in a position to enforce his guidelines. Local residents knew he was involved in litigation against a timber company that 'accidentally' cut trees in his forest. The company claimed they thought they were in the Lwamunda Forest Reserve.

In the Forest Reserve, sanctions on rule-breaking do not appear to be applied, much less graduated. Illegal charcoal-making, commercial fuel-wood harvesting, and pole cutting, appeared to be 'helplessly' ignored by the Forest Reserve guards. Thus, Namungo Forest was given a positive sustainability value, and Lwamunda Forest Reserve a negative one, for the existence and enforcement of graduated sanctions.

The quality of monitoring was distinctly different in the two forests. While Namungo employed local workers to demarcate his forest and to patrol it occasionally, forest guards rarely patrolled the patch of Lwamunda Forest Reserve neighbouring Namungo Forest. The different sizes of the two forests are an obvious factor: the whole of Lwamunda Forest Reserve is about 10 times that of Namungo Forest, and is reported to be under only one or two guards who patrol on foot. Behaviour of the local people suggests that unrestricted and unplanned charcoal-making

Local governing bodies at the village level (Resistance Council 1 [RC1]) and sub-county level (RC3) provide access to low-cost conflict resolution at the local level. Also in principle, monitoring, sanctions, conflict resolution, and governance, are organized in multiple layers of nested enterprises. For these factors, both forests were given positive scores because the Resistance

is not always ignored by the guards, nor are the rules against it unknown. When we met men transporting charcoal in Lwamunda Forest Reserve, they took care to tell us that they had made the charcoal on private land and were simply taking a short cut through the reserve to the local market.

Modification of rules by day-to-day users is an option that is not currently formalized in the Lwamunda Forest Reserve, where the unwritten rules could be paraphrased as 'until you are made to believe otherwise, this forest is open-access'. As a result, Mbazzi residents and others living adjacent to the Reserve were making charcoal and harvesting firewood to sell to merchants who truck these goods to Kampala. Local residents were earning 10 to 30% of the final market price on fuel-wood products.

In Namungo Forest, Mr Namungo and his family have a substantial voice in determining local operational rules, and local residents could participate in this process by communicating with Mr Namungo himself. We were told that on several occasions, after being asked by members of the local community, Mr Namungo had given special permission to harvest building-poles. We found no evidence that local users had made any attempt to modify official rules for Lwamunda Forest Reserve.

Degradation, Structure, and Diversity, Indices in the Forests

Evidence of recent exploitation of trees for commercial purposes was more frequently recorded in the Lwamunda Forest Reserve plots than in plots in Namungo Forest (Chi-square = 17.4, DF = 3, p < .001). Indications of commercial firewood-cutting, pit-sawing, and/or charcoal-making; were noted on more than half of the plots in the Lwamunda Forest Reserve, while only 4 out of 30 plots in Namungo Forest revealed evidence of such exploitation (Fig. 3).

The number of trees in Namungo Forest was greater than in Lwamunda Forest Reserve, but only by about 15 trees per hectare. Basal area, an index of the amount of timber in the forest, was somewhat greater in Namungo Forest than in Lwamunda Forest (Table II), though mean values for the number of trees per plot were not significantly different between the two forests. Likewise, the mean of the DBHs for all the trees were not significantly different between the two forests (t = 1.2, DF = 130, P = 0.24).

The distribution of different-sized trees was similar in the two forests. As shown in Fig. 4, both forests were

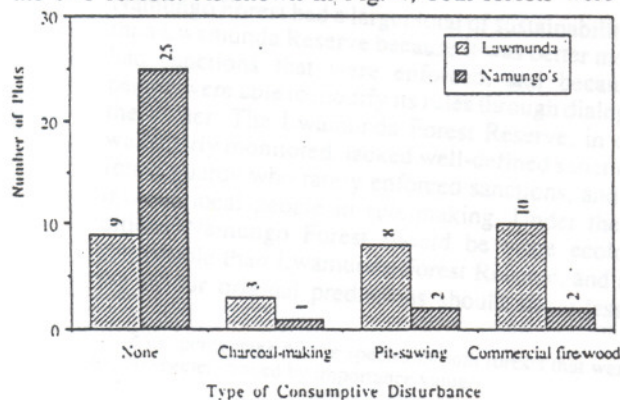


FIG. 3. Types and frequency of commercial exploitation in plots sampled in Namungo Forest and the Lwamunda Forest Reserve, Mpigi District, Uganda, 1993.

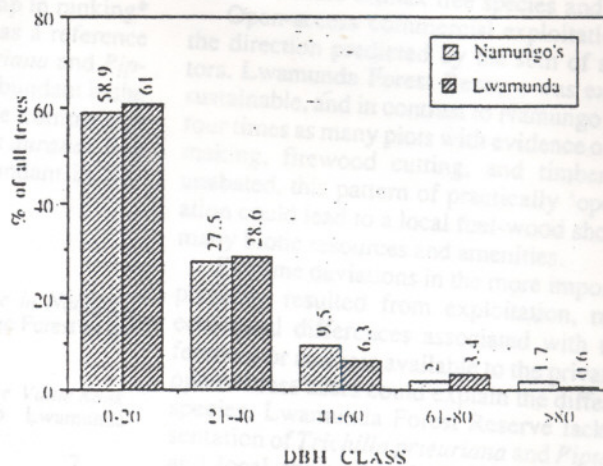


FIG. 4. Percentage of trees belonging to size-classes defined by the standard forestry measure of diameter at breast height (DBH) in centimetres. Data are from IFRI project in Uganda, 1993.

dominated by trees having DBHs in the range of 10 to 40 cm. Very large trees, such as those with DBHs greater than 80 cm, were rare in both the forests, representing less than 2% of the number of trees.

The forest with the lower sustainability index, Lwamunda Forest Reserve, had at least 5 more species of trees in it than the forest with the higher sustainability index. The Simpson and Shannon's diversity indices suggest that Namungo Forest has a slightly more equitable distribution of different species, resulting in higher values (Table II).

TABLE II

Summary of Data Collected for Trees in Plot Samples from Namungo Forest (N = 30) and the Lwamunda Forest Reserve (N = 30), Mpigi District, Uganda, 1993. (Standard deviations are shown with means.)

Trait	Namungo (private forest)	Lwamunda Forest Reserve (governmental)
Species Richness	64	69
Shannon Diversity	3.69	3.67
Simpson's Diversity	30.2	27.8
Trees in 30 plots	339	325
Trees / ha	360	345
Mean Nr trees / plot (density)	11.3 ± 4.5	10.8 ± 6.2
Mean DBHs (cm)	23.9 ± 18	23.1 ± 17.1
Basal Area	23.9 ± 0.4	21.9 ± 0.4

The Shannon index is particularly sensitive to the presence and absence of rare species, and indicates that both forests are very similar in their content of rare species. The Simpson's diversity index, which is sensitive to evenness of distribution, was higher in the Namungo Forest samples than in those of the Lwamunda Forest Reserve.

Even though the two forest areas were adjacent to each other and were in similar physical locations, 30% of the tree species recorded in the study plots were found in only one of the forests. There were 13 tree species recorded in the Namungo Forest plots that were absent in the Lwamunda plots, and 30 species in the opposite comparison. With the exception of *Bridelia micrantha* in Namungo Forest and *Staudtia kamerunensis* and *Myrianthus arboreus* in the Lwamunda Forest Reserve, all of the non-

overlapping species were recorded only once or twice in the plots (*i.e.* were rare species).

In a comparison of the 10 most important tree species in each forest, there was a 50 to 60% overlap in ranking* (Tables III & IV). With Namungo Forest as a reference (*cf.* Table III), two species, *Trichilia prieuriana* and *Piptadenia africana*, were conspicuously less abundant in the Lwamunda Forest Reserve. In the opposite comparison (*cf.* Table IV), *Staudtia kamerunensis*, *Celtis durandi*, and *Ficus capensis*, were significantly less abundant in Namungo Forest.

TABLE III

Comparison of Tree Species by Importance Value in Namungo Forest and the Lwamunda Forest Reserve. (Namungo Forest as the reference.)

Species	Use*	Importance Namungo	Value Rank Lwamunda
<i>Pseudospondias microcarpa</i>	tb	1	7
<i>Trichilia prieuriana</i>	fc/tb	2	40
<i>Bosqueia phoberus</i>	tb	3	10
<i>Tabernaemontana holsti</i>	fc	4	2
<i>Macaranga monandra</i>	fc	5	1
<i>Antiaris toxicaria</i>	tb	6	5
<i>Funtumia elastica</i>	tb	7	12
<i>Piptadenia africana</i>	tb	8	43
<i>Celtis mildbreadii</i>	tb	9	3
<i>Blighia unijugata</i>	tb	10	14

* fc = firewood and charcoal, tb = timber and building

TABLE IV

Comparison of Tree Species by Importance Value in Namungo Forest and the Lwamunda Forest Reserve. (Lwamunda Forest as the reference.)

Species	Use*	Importance Lwamunda	Value Rank Namungo
<i>Macaranga monandra</i>	fc	1	5
<i>Tabernaemontana holsti</i>	fc	2	4
<i>Celtis mildbreadii</i>	tb	3	9
<i>C. durandi</i>	tb	4	24
<i>Antiaris toxicaria</i>	tb	5	6
<i>Pseudospondias microcarpa</i>	tb	6	1
<i>Staudtia kamerunensis</i>	tb	7	**
<i>Ficus capensis</i>	fc	8	20
<i>Bosqueia phoberus</i>	tb	9	3
<i>F. exasperata</i>	fc	10	15

* fc = firewood and charcoal, tb = timber and building

** not recorded in Namungo Forest

DISCUSSION

Namungo Forest had a larger total of sustainability factors than Lwamunda Reserve because it was better monitored, had sanctions that were enforced, and because local people were able to modify its rules through dialogue with the owner. The Lwamunda Forest Reserve, in contrast, was poorly monitored, lacked well-defined sanctions, had forest guards who rarely enforced sanctions, and did not involve local people in rule-making. Under these conditions Namungo Forest should be more ecologically sustainable than Lwamunda Forest Reserve, and according to our original predictions should show less open-

access exploitation, have greater species evenness and diversity, have greater measures of basal area and density, and have more climax tree species and large-DBH trees.

Open-access commercial exploitation was clearly in the direction predicted by the sum of sustainability factors. Lwamunda Forest Reserve was expected to be less sustainable, and in contrast to Namungo Forest had nearly four times as many plots with evidence of illegal charcoal-making, firewood cutting, and timber sawing. If left unabated, this pattern of practically 'open-access' utilization could lead to a local fuel-wood shortage and loss of many biotic resources and amenities.

Extreme deviations in the more important tree species probably resulted from exploitation, rather than from ecological differences associated with the forests. Preferences or markets available to the private owner and the open-access users could explain the differences in timber species. Lwamunda Forest Reserve lacked much representation of *Trichilia prieuriana* and *Piptadenia africana*, and local charcoal-makers reported these species to be preferred by them. Most charcoal pits were located near cut stems of *T. prieuriana*. The lack of *Celtis durandi* and *Ficus capensis* in Namungo forest corresponds with traditional preferences for their wood for drums, canoe-making, and building, rather than for commercial exploitation. Mr Namungo related to us that he had cut and sold *Staudtia kamerunensis* to a veneer company. While one cannot totally rule out biological and physical explanations for other differences in species composition between the two forests, the major differences in importance values of the trees can be clearly related to historical and current use.

Only minor differences were noted in indices of species diversity. Contrary to predictions, the Lwamunda Forest Reserve had more species of trees per unit area than had Namungo Forest. While this could be a chance sampling difference, there are biological processes that could play a role. Gap formation associated with repeated selective harvesting when the reserve was managed as a regional commercial forest, could generate high species-diversity. When large trees are harvested, they leave openings in the forest where a wide variety of seeds may become established and compete, leading to increase⁴ species-richness (Denslow, 1987). As was predicted, tree species evenness was higher in Namungo Forest. The slightly lower density of trees and sum of their basal area in Lwamunda Forest Reserve probably reflects greater harvesting in the past and a decline in forest biomass due to current open-access exploitation. However, subtle biological or physical reasons cannot be ruled out with regard to these relatively minute differences in the two forests.

The conflicting measures of species richness *versus* diversity in the two forests call attention to the care that must be taken in interpreting different indices of diversity as response-variables. In this case, both forests were as high as, or higher than, 12 protected forest reserves in Uganda in tree species-richness (Howard, 1991). This result suggests that small-scale, selective harvesting and utilization may facilitate high tree-species diversity in tropical forests, and is consistent with the paradigm of 'intermediate disturbance', in which some perturbation opens new niches and allows more species to function in a community (Krebs, 1993). However, if current patterns of

* *i.e.* percentage of tree species in both forests that were in the top 10 species ranked by importance value.

'open-access' exploitation of trees for firewood and charcoal-burning continue, a serious decline in species evenness, diversity, and richness, and a change in forest structure, would be expected to take place in the Lwamunda Forest Reserve in this decade. It is not at all clear whether this would tip the balance to some new botanical community that might not regenerate into a forest. The IFRI Collaborating Research Centre in Uganda intends to repeat this study every 3 years, to monitor the social and ecological trends in these two forests.

CONCLUSIONS

Most human enterprises in sub-Saharan Africa rely on wood for energy, and Uganda is no exception. From small households to large commercial bakeries and university kitchens in Kampala, Uganda is about 94% powered by wood. In 1993, the Ugandan Government increased the price of hydro-generated electricity with the goal of raising revenue to repay World Bank loans. As a result, many private users of hydroelectric power were forced back to their reliance on wood-burning for energy, which led to further increases in the destruction of natural forests (Gombya-Ssembajjwe *et al.*, 1993). With the exception of Nature reserves, all government forests within 50 kilometres of Kampala were accordingly greatly exploited for timber, firewood, and charcoal production, suggesting that our pilot study is representative of these public goods.

As a private owner, Mr Namungo has ultimate control over his forest, and its sustainability depends greatly upon his personal ethics, values, knowledge, and the local respect for his rights as an owner. As incentives for exploitation of forests increase, private owners are more likely to utilize their natural forests or transform them according to market demand. While we did not carefully inventory other private forests in the general study-area, we did note that a neighbour of Mr. Namungo was converting some of his trees to charcoal. The aggregate effect of such personal decisions in terms of their impact on forests needs more study.

During our study, Mr Namungo was partitioning his forest into two management units, one of them being kept natural, and the other cleared and planted with an exotic *Eucalyptus* species. While this may be a wise short-term investment strategy, planting an exotic monoculture where a natural forest has been sustainably harvested and chronically regenerating, is certainly not ecologically sustainable by our definition. In this context, privatization is clearly no guarantee of sustainable use or conservation of natural tropical forest. Privatization has actually favoured expansion of open-access exploitation on to poorly-protected government-owned forests that typically lack rules and institutional arrangements designed by and for local users (Bromley & Cernea, 1989).

The economic incentives associated with the forest exploitation that is occurring in the Lwamunda Forest Reserve are clear, but the exact mechanisms in terms of possible corruption and rent-seeking are obscure. Our preliminary analysis clearly suggests that the present rate of forest destruction in Lwamunda Forest Reserve can be partially explained by the lack of monitoring by guards, reluctance to enforce sanctions, lack of well-defined rules concerning local use, and lack of participation by local users in making any rules.

Uganda is currently in the position to affect popular decision-making for local resource management. The RC system of administration is well-established, and provides clear mechanisms for local and regional government, NGOs, and grassroots organizations, to establish sustainable systems for the use and conservation of forest resources at a local level. Realizing such goals in the face of an ever-expanding population and limited forest resources will remain a substantial challenge for Uganda in the 21st century.

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SUMMARY

Early detection of forest degradation may help to compensate for the time-lag that often exists between recognition of poor stewardship and the policy-changes required to mitigate such negative impacts. We report here on an International Forestry Resources and Institutions (IFRI) pilot study in Uganda.

We pose and explore a set of hypotheses about the sustainability of natural forests under two different institutional settings. Namungo Forest and Lwamunda Forest Reserve are in the same watershed, at the same altitude, and on similar soils, but the institutional environments structuring their use over the past 20 years have differed greatly. A scoring system for sustainability suggests that Lwamunda should be subjected to more 'open-access' utilization, and therefore should be more degraded than Namungo Forest. In 30 random plots each of 300 m² made in each forest, evidence of degradation caused by commercial and open-access exploitation is significantly greater in Lwamunda than in Namungo forest. A different set of tree species dominates each forest area, depleted species clearly reflecting utilization patterns.

These results suggest that IFRI methodologies are sensitive to initial patterns of degradation in forest ecosystems, and are useful for characterizing changes in tropical forest plant communities in conjunction with societal and institutional behaviour. While the IFRI

approach for testing robust hypotheses depends greatly on repeating this study and comparing it with other longitudinal data-sets, the preliminary study illustrates that even in a cross-sectional comparison, the IFRI method captures many details of the societal and ecological aspects of deforestation.

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