Tropical forest
can rates of natural

Joseph P. Skorupa and John M. Kasenene

Only a small percentage of tropical forests are legally protected and so, if we are to conserve tropical forest species we must encourage sustainable exploitation of unprotected forest areas. Selective timber harvesting is frequently cited as a sustainable use of tropical forests and the authors studied the effects of this kind of exploitation on natural treefall rates, an important regulative process, in the Kibale Forest, Uganda. Their results indicate that levels of destruction typical of capital intensive mechanised timber harvesting seriously disrupt the dynamic balance of the forest. They discuss alternative methods for selective timber harvesting that would be less disruptive and present an objective method which may help rain forest managers determine which multiple-use options are compatible with rain forest conservation.

Recent estimates of tropical forest destruction rates portend alarming implications for the conservation of tropical fauna and flora. Only 3.6 per cent of all closed canopy broadleaved tropical forests are legally protected from exploitation (Steinlin, 1982) and thus the conservation of tropical species is substantially dependent on sustainable use of unprotected forest lands; a goal which is also compatible with the long-term economic interests of tropical countries. In this regard, perhaps the most promising of past management options has been the attempt to manage native forests for sustained timber production as, for example, is a stated goal of forest management in Uganda (Dawkins, 1958). While most foresters would agree that sustainable selective logging is feasible, its failure in practice is often due to inadequate control of damage. Thus, many observers emphasise the distinction between moderate, sustainable timber production and non-sustainable over-exploitation (Gomez-Pompa *et al.*, 1972). However, there is still almost no information on just how much damage is too much.

The structure and persistence of rain forests is now generally recognised to be dependent upon a dynamic balance of many regulative processes, and, if their sustainable use is to be achieved, we require knowledge of the effects of exploitation on the regulative processes. One regulative process that has been identified as an integral component of the dynamic balance is the rate of natural treefalls (Bazzaz and Pickett, 1980; Hartshorn, 1978); they control canopy gap dynamics, which in turn largely determine the mosaic structure of rain forests. Consequently, we might expect treefall rates to be a potential key to answering our question of how much damage is too much.

Surprisingly, there is very little information about the effects of selective timber harvesting on natural treefall rates. We would expect natural treefalls from old age to decrease after timber harvest since the older trees are harvested. On the other hand, the experience of tropical plantation forestry has shown that more trees are blown down in heavily thinned plots. Moreover, due to the differential effects of many other sources of natural mortality (i.e. diseases, insects, etc.) it is

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management: treefalls help guide us?

impossible to predict what the net effect of selective harvesting might be. One long-term study found higher treefall rates in severely logged plots but provides no information on the effects of moderate exploitation (Briscoe and Wadsworth, 1970). Our studies were conducted in three similar forest plots of different management histories in the Kibale Forest, Uganda, our aim being to examine the effects of logging disturbance on natural treefall rates and to consider the implications for rain forest conservation.

The forest

Kibale Forest, in western Uganda, has been described as a medium-altitude moist evergreen forest, being distinguished from true lowland

A tree being harvested by the pit-sawing method, where logs are hand-sawn into boards at the site of harvest*(Joseph P. Skorupa)*.

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tropical rain forest by its higher altitude, lower temperature, and lower rainfall, but otherwise possessing most of the same typical features (Langdale-Brown *et al.*, 1964). Our study area is in the central part of the forest near the Kanyawara Forest Station, where the altitude varies between approximately 1350 and 1550 m. The mean annual rainfall is approximately 1700 mm, and is well dispersed although there are two distinct wet seasons per year. Winds are generally mild, being strongest immediately prior to and during convectional rainstorms. The topography is gently undulating with forest in some instances being replaced by swamps in low-lying areas and by grasslands on hilltops. Under the administration of the Uganda Forests Department, Kibale Forest has been managed as a timber reserve with a planned felling cycle of 70 years. Approximately the northern third of the forest has been selectively harvested to date. Detailed descriptions of the forest flora, fauna, and general history are available (Kingston, 1967; Wing and Buss, 1970). In addition, the Kanyawara study site has been described in detail (Struhsaker, 1975).

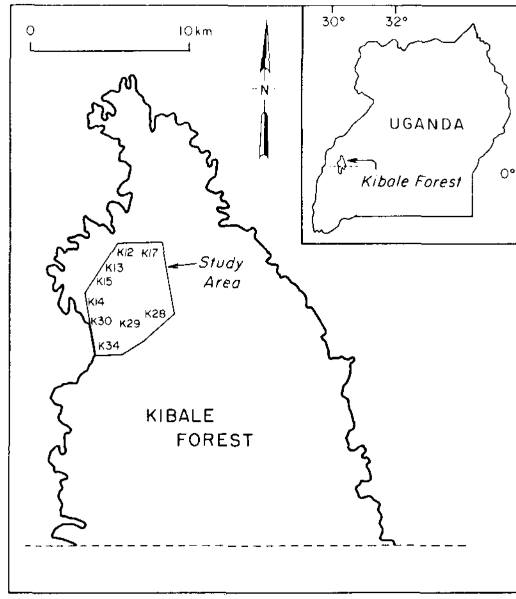

Figure 1. Map showing location of Kibale Forest in Uganda, and the location of study compartments in Kibale Forest and their relation to neighbouring compartments.

We studied natural treefall rates in portions of three timber management areas (known as compartments) with the following histories:

Compartment 30 (K-30): K-30 includes approximately 300 ha of relatively undisturbed mature forest. In the past, a few large trees (totalling 3–4 stems/sq km) were felled by pit-sawyers but this made relatively little impact on the compartment as a whole. Since 1970, K-30 has been protected from additional pit-sawing, and has been the site of extensive research on primate socioecology and various other aspects of rain forest biology.

Compartment 14 (K-14): K-14 includes approximately 390 ha of forest that were selectively harvested between May and December 1969. Total harvest averaged 14 cu m/ha (saleable volume; Uganda Forests Department records). Although mean harvest values are useful for broad comparison, disturbance in harvested compartments is patchy, and the 65 ha of K-14 that served as our study plot were only lightly to moderately disturbed as indicated by several parameters of post-harvest forest structure (Table 1).

Compartment 15 (K-15): K-15 includes approximately 360 ha of forest that were selectively harvested between September 1968 and April 1969. Total harvest averaged 21 cu m/ha (saleable volume; Uganda Forests Department records). The 100 ha of K-15 that we studied were heavily disturbed as indicated by the structure of the remnant forest (Table 1).

Table 1. Parameters of forest structure in the study plots

	K-30	K-14	K-15
Stems per hectare	256	267	125
Basal area (sq m/ha)	35.5	26.7	19.0
Per cent canopy cover at 15 m	72	50	32
Diversity index (*H'*)	3.00	2.60	2.41

Based on plot enumeration of all trees 9 m or more tall (approximately 35 cm circumference) at a sampling intensity of 1.5–7.0 per cent depending on the site.

The compartments are located adjacent to one another with K-14 lying between K-15 and K-30. The maximum linear distance across the three compartments is approximately 5 km, and they have all been classified as *Parinari* forest, a forest type in which the crowns of grey plum *Parinari excelsa* trees are the dominant feature on aerial photographs. Timber stock enumerations showed there was prominent local variation in densities of individual tree species but that composite parameters of forest structure such as those listed in Table 1 were relatively constant ($\pm$5 per cent) across all subtypes of *Parinari* forest prior to logging (Kingston, 1967). In summary, these compartments are well matched in their vegetative affinities, topography, and climate.

Study methods

We collected our data on treefall rates in conjunction with separate studies of rain-forest rodents and rain-forest primates and therefore our methods varied. In K-30 and K-14 JMK re-established several 900$\times$900 m rodent trapline plots (with transects at 10-m intervals) at locations that had been randomly selected for a previous study. From January to June 1979 (three wet and three dry months) six plots in K-30 and five plots in K-14 were monitored for treefalls, each treefall being enumerated during regular trapline visits. Only fallen trees whose stems had originally been rooted inside plot boundaries were counted. As this method is a direct count over a prescribed area, it provides information on both the absolute and the relative treefall rates.

JPS established several routes along pre-cut trail grid networks in K-30 and K-15 for enumerating primates and collecting tree phenology data. From December 1980 to December 1981, 8.7 km of trail in K-30 and 13.6 km of trail in K-15 were monitored for trees falling across the trail. Not all routes were monitored for this entire time span; for instance 2.1 km of the routes in K-30 were monitored from May to December only. Overall, 51 per cent of 2843 and 54 per cent of 4570 km-days monitored in K-30 and K-15 respectively occurred during the rainy seasons (monitoring 1 km of trail for new treefalls over a period of one week would be equivalent to 7 km-days). All trails were approximately 1 m wide, and the proximity of a tree stem to the trail did not appear in any way to influence the probability of that stem falling. This method only provides information on relative treefall rates as the data are merely an index of treefalls. However, since JMK's data provide an estimate of the absolute treefall rate in K-30, and the rate in K-15 relative to K-30 is provided by JPS's data, an absolute rate for K-15 can also be estimated.

Results

The mean annual rate of natural treefalls in K-30 (undisturbed forest), expressed as a percentage of all stems 9 m or more tall, was estimated at 1.4 per cent (Table 2). This result is consistent with mean rates for mature forest reported from Malaysia (1.1 per cent), Ivory Coast (1.4 per cent), and Puerto Rico (1.2 per cent) (Leigh, 1975). The estimated rate of natural treefalls in K-14 (1.3 per cent), a lightly to moderately disturbed plot, is not statistically different from the K-30 rate (details of all statistical analyses available from JPS upon request). However, the estimated rate of natural treefalls in K-15 (6.2 per cent), a heavily disturbed plot, differs significantly from the rate in K-30 and other mature forests.

Table 2. Treefall rates in the Kibale Forest, Uganda

	K-30	K-14	K-15
Treefalls/(ha yr)	3.70	3.46	—
Treefalls/(km yr[a])	0.38	—	0.80
Treefalls/(sq km yr)	370	346	778[b]
Treefall rate[c] (per cent)	1.4	1.3	6.2

[a] One km yr = 365 km days.
[b] Estimated by multiplying value for K-30 by (0.80/0.38).
[c] Per cent of all stems 9 m or more tall.

It is unlikely that the increased rate of treefalls in K-15 is due to the residual deaths of trees which were damaged or otherwise weakened during logging operations, since logging occurred 12 years prior to this study and since none of the trees which fell in K-15 were dead. It also does not appear to be attributable to increased insect or pathogen weakening of tree stems, since the incidence of treefalls via stem break, as opposed to the tree being uprooted, was lower in K-15 (40 per cent) than in K-30 (67 per cent). Similarly, the high rate of treefalls in K-15 is not due to a greater presence of high-risk size classes since the density of stems in all size classes of fallen trees is greater in K-30 than in K-15.

Most of the fallen trees counted in K-15 appeared to be healthy individuals that were simply uprooted by wind. Therefore, the high treefall rate in K-15 seems most likely related to changes in forest structure that affect factors such as aerodynamic roughness, windbreak protection provided by neighbouring trees, and soil cohesion (Fons, 1940).

Our results suggest that light to moderate disturbance (about 25 per cent destruction) in the K-14 plot only disrupted the regulative process of natural treefalls temporarily, if at all, as the rate was equivalent to that for comparable mature forest 11 years after initial disturbance. However, heavy disturbance (about 50 per cent destruction) in the K-15 plot seriously disrupted the rate of natural treefalls which is an integral component of the forest's dynamic balance. This kind of disruption is particularly hazardous as it is known that once the dynamic balance of the forest is seriously disrupted it is very difficult or even impossible to re-establish (UNESCO, 1978).

How much damage is too much?

Rates of natural treefalls seem to show promise for answering our question. For example, we illustrate in Figure 2 a method by which our treefall data could be used to estimate the maximum allowable destruction compatible with maintaining a healthy forest mosaic. Using our information on treefall rates in K-30 we can calculate what range of percentages is typical of mature, undisturbed forest at Kibale and in doing this we find that treefall rates up to 2.3 per cent can be considered normal. Using 2.3 per cent as an upper limit we find that about 35 per cent destruction is the maximum allowable disturbance in Kibale.

Capital-intensive, mechanised timber harvesting in the tropics generally destroys about half the original forest stand (Ewel and Conde, 1976). This level of disturbance is dictated by the need for adequate short-term cash return typical of capital-intensive forestry. Consequently, our results provide evidence that mechanised selective timber harvesting may not be a sustainable method of exploiting Kibale Forest. Our results also bring into question the wisdom of allowing mechanised selective timber harvesting as a multiple-use option in tropical rain forest conservation areas as, for example, is allowed at present in the game production reserves of Ghana (Gartlan, 1982).

Our results by no means rule out all forms of selective harvesting as a sustainable use of unprotected rain forest, and/or multiple-use of forest reserves, where economic pressures absolutely require it. For example, a programme of pit-sawing conceivably could be managed in ways compatible with maintaining the dynamic balance of the forest (but would have to be effectively regulated). Pit-sawing greatly reduces the incidental (i.e. non-marketable) destruction associated with logging and in many cases may therefore result in a non-disruptive level of disturbance. Pit-sawing would also be more beneficial to the local economy as it would be labour intensive, and likely to be oriented toward domestic rather than export markets. Likewise, mechanised timber harvesting conceivably could be conducted in such a manner as to limit disturbance to non-disruptive levels (less than 35 per cent in the case of Kibale), but this would be economically viable only if world prices for timber increased sufficiently.

Some caveats

To determine if the concept we have illustrated here for Kibale Forest can truly be developed into a general management aid requires further study.

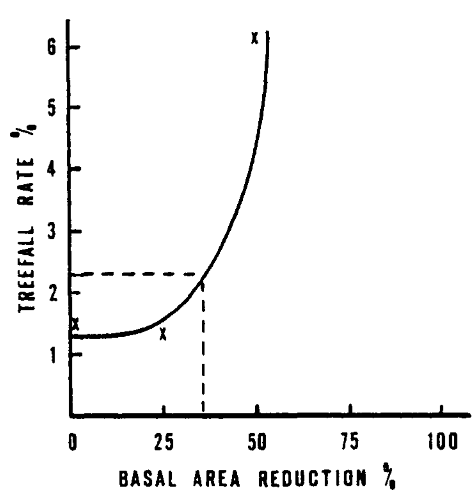

Figure 2. Relation between intensity of disturbance and the rate of natural treefalls in Kibale Forest, Uganda. The dashed line indicates the cutoff point at which higher intensities of disturbance will result in a rate of natural treefalls significantly higher than in undisturbed forest.

The facts we present here come from only one vegetative association of one forest. In addition, the time interval over which we collected our data was relatively short and does not allow us to assess the influence of rare events (such as severe storms). Nonetheless, we are encouraged by how closely our results for mature forest agree with previously reported values. In conclusion, we feel that we have outlined an objective approach that could potentially prove most useful to tropical rain forest managers as they attempt to evaluate which land management options are compatible with rain forest conservation.

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Round Island in 1982

Due to an unfortunate oversight the credits for the photographs used to illustrate Round Island in 1982 on pages 36–41 of the January 1984 issue of *Oryx* were omitted. They should have read: Ben Osborne/Round Island Expedition 1982. The Editor apologises for the error.

Focus on Wildlife

An international competition to find the Wildlife Photographer of the Year, 1984, has been organised by: BBC WILDLIFE Magazine, ffPS and the British Museum (Natural History). Details in April issue of BBC WILDLIFE Magazine. There will be an exhibition of prizewinning entries at the British Museum (Natural History) in London in the late autumn of 1984.

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