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SHORT COMMUNICATION

Local wind damage in Barito Ulu, Central Kalimantan: a rare but essential event in a lowland dipterocarp forest?

J. PROCTOR*, F.Q. BREARLEY*, H. DUNLOP*, K. PROCTOR*, SUPRAMONO† *and* D. TAYLOR*

**Department of Biological Sciences, University of Stirling, Stirling FK9 4LA, Scotland*
†Faculty of Education, University of Palangkaraya, Central Kalimantan, Indonesia
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The importance of disturbances for the dynamics of tropical forests has been described by Whitmore & Burslem (1998). Among the phenomena which they classify as large scale disturbances are those caused by wind. The most extensive of these occur within the hurricane (cyclone) belt (10–20° from the equator) but outside this belt large blowdowns of trees are known to occur, perhaps most spectacularly in the Brazilian Amazon (Nelson *et al.* 1994). There is evidence that rare wind storms influence the dipterocarp rain forests of Peninsular Malaysia, 2–6°N. One famous storm in November 1880 which devastated hundreds of square kilometres of forests in Kelantan, north-east Malaya, was probably an aberrant cyclone (Wyatt-Smith 1954). Smaller windstorms which have blown down several hectares of forests have been reported from Malaysia including Borneo (Ashton 1993) but their frequency and extent have not been well documented (Whitmore & Burslem 1998). At Barito Ulu, Central Kalimantan, one such storm occurred recently and the fortuitous combination of a well patrolled trail system and the localization of the storm has allowed a detailed assessment of the forest damage.

Barito Ulu is at 113°56′E and 0°06′S. It is *c.* 150 m above sea level and from 1989 to 1998 has had an annual rainfall of *c.* 3600 mm ranging from 2780 mm (1997) to 4005 mm (1990). There were substantial droughts in 1991 (24 June–21 September had 44 mm rain), 1994 (30 August–7 October had 11.5 mm) and 1997 (6 August–28 September had 102 mm). The terrain is hilly with

ridges up to *c.* 100 m high and is covered with primary lowland evergreen tropical rainforest, much smaller areas of shifting cultivation fallows (dating from *c.* 1944 to *c.*1980), and heath forest. The primary forest is high stature with trees up to about 60 m tall, and species rich with 108 tree species (> 10 cm dbh) having been recorded in a 50-m × 50-m plot. Some trees in the oldest secondary forests reach 60 m also but they are less species rich. The heath forest is much shorter and less species rich.

On 26 November 1997 there was a storm of an unprecedented ferocity (within the memories of local field assistants up to 45 y of age). The storm followed a dry summer. Only 438 mm of rain had fallen in the 20 wk before heavy rain (84 mm) on 22 November. This was followed by 2.0 mm the next day, and then 2 d without rain. The 26 November began cloudy and a storm broke at 1400 and lasted for *c.* 1 h. During the storm 30 mm of rain fell, there was simultaneous thunder and lightning, and a very strong wind which blew down thousands of large trees. Much of the damage was in the southern part (*c.* 1.6 km^2) of the Barito Ulu research site, which has a total forest area of about 4 km^2. The southern part includes *c.* 7 ha of secondary forest and *c.* 3 ha of heath forest. It is crossed by numerous small paths that are used for primate studies and in the present work as a means of accessing the new gaps. Since the paths are well patrolled by local field assistants it was possible to ascertain that the mapped gaps all resulted from the same event.

The site was visited from 14 July to 15 August 1999 (*c.* 20 mo after the storm). An area in the north-west of the site where there was extensive damage on the top and north-east slopes of a north-west/ south-east trending ridge was difficult to access and could not be surveyed accurately but certainly included some large (> 1 ha) felled areas. The southern part of the site was mapped in detail and places (gaps) where the canopy had been opened by tree damage were delimited using poles and a string placed under the edge of the intact canopy. The area of the gaps was calculated from measurements made of the string with a compass and tape. It was not possible with the time and equipment available to measure the gaps in any other way although it is accepted that the definition of a gap is complex. The prevailing direction of fall of the large trees was noted, the gaps were labelled and their edges marked by chainsawing peripheral dead trees which were lying horizontally across the gap boundary.

In all, 78 gaps (> 100 m^2) had been created in the southern part of the site mainly in the primary lowland evergreen rain forest with some in the secondary forest. The heath forest was virtually undamaged despite much of it being in an exposed position and adjacent to badly damaged lowland evergreen rain forest. The total gap area was 10.2 ha (*c.* 6% of the site). Sixty-five per cent of the gaps were between 100 and 1000 m^2, 23% were 1001–2500 m^2, and 12% > 2500 m^2. The largest gap was 12 000 m^2 (1.2 ha). Plot surveys (J. Proctor, unpubl. data) indicate that the forests have about 550 trees (> 10 cm dbh) ha^{-1} and therefore the storm felled *c.* 5500 of them. About 90% of the trees fell

in a S, SW or W direction. There was a tendency for the gaps to be associated with ridges because they are higher and more susceptible to the effects of winds and subsequent tree falls. There has been no opening up of the canopy along the ridge trail systems and hence no likelihood that they might have facilitated treefalls in the manner envisaged for existing gaps by Young & Hubbell (1991).

Recolonization was slow in the *c.* 20 mo since the storm and involved much sprouting of damaged trees and the germination and growth of pioneers. A preliminary survey made in March–June 2000 of areas of 20-m × 5-m in each of 32 sampled gaps showed numbers of *Macaranga* individuals ranging from 0–18 and ranging up to 8.0 m high. *Macaranga* species are well known pioneer trees but their pattern of colonization seems to be slower and more complex than that reported in detail for the neotropical pioneer *Cecropia schreberiana* Miq. after hurricane damage in Puerto Rico (Brokaw 1998).

In combination with the anecdotal information in Whitmore & Burslem (1998), it is suggested that the Barito Ulu storm was an example of a rare but widespread event that is vital in rain forest dynamics outside the hurricane belt. The effects of the storm also indicate that predictions of the effects of droughts on forests must take into account the timing of storms in relation to the depth and wetness of the soil. The lack of damage to the heath forest may be general in these situations and go to explain the absence of pioneer trees in this forest formation (Whitmore 1984).

The Barito Ulu storm is the basis for a large natural experiment in that it has provided numerous gaps of a range of sizes and of a known age in which recolonization is to be followed.

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