The Ecological Consequences of Logging in the Burned Forests of East Kalimantan, Indonesia

MARK G. L. VAN NIEUWSTADT,*† DOUGLAS SHEIL,†
AND KUSWATA KARTAWINATA†

*Section Plant Ecology, Utrecht University, P.O. Box 800.84, 3508 TB Utrecht, The Netherlands,
email m.g.l.vannieuwstadt@bio.uu.nl
†CIFOR, P.O. Box 6596 JKPWB, Jakarta 10065, Indonesia

Introduction

In 1997–1998 over 50,000 km^2 of East Kalimantan burned, affecting some 23,000 km^2 of natural forest concessions. This is nearly one-quarter (24%) of the area of all natural forest concessions in the province (Hoffmann et al. 1999). The biomass of the trees living at the time of the burn was little reduced by the fire, which tended to be restricted to the litter and understory, and although many trees died, most stems remained standing. These dead stems in the burned forest represent a significant timber resource. A government regulation was issued (Directorate of Forest Utilization 1999) indicating that in concessions where fires had occurred, "salvage felling"—harvesting of the remnant commercial dead timber by conventional methods—should precede any continuation of regular harvesting operations in unburned forest areas. The reason for this regulation was that the dead stems could still provide valuable timber if removed before serious deterioration occurred (Ulbricht et al. 1999). It was apparently assumed that such salvage activities would have little additional effect on the already degraded forest. There are good reasons, however, to be concerned about the ecological effects of salvage felling after fire.

Forest areas can recover after fire, but they remain in a very sensitive state in which additional disturbances, such as salvage felling, will cause significantly increased levels of forest deterioration and loss. The results from our 2-year study on post-fire vegetation dynamics in the unlogged dipterocarp rainforest of Sungai Wain near Balikpapan East Kalimantan, (lat 1.16°S, long 116.54°E; elevation 40–140 m above sea level; average yearly rainfall 2790 m) (Vose et al. 1992), compel us to warn against the implications of salvage felling. We intend to publish a more detailed account of our study, but the urgency of the situation makes it important that we disseminate our main conclusions as soon as possible.

Paper submitted July 24, 2000; revised manuscript accepted March 14, 2001.

Vegetation Processes after Single and Repeated Disturbance

The recovery capacity of forest vegetation after fire and other disturbances involves four main processes: tree survival, the resprouting of damaged trees, germination of seeds in the seed bank, and seed rain. To study the relative contribution of these processes to vegetation development, we established permanent sample plots of 1.8 ha each in unburned forest and in forest that burned accidentally in March 1998 after several months of drought. Nine pairs of burned and unburned plots were established adjacent to one another over a human-made edge (a successful fire break that usually does not correspond to any topographical feature) between burned and unburned forest. The plots were spread over a total area of about 20 km^2. Each pair of plots formed one contiguous transect of 60 × 600 m, half in burned and half in unburned forest. In these plots, we measured and labeled more than 3000 (both dead and living) stems larger than 28 cm diameter at breast height (dbh; diameter measured at 1.3 m height). In subplots of 0.4 ha, we measured and labeled an additional 4700 trees between 8 cm and 28 cm dbh. A total of 2190 (dead and living) seedlings and saplings (<8 cm dbh) and 445 living resprouts on stems smaller than 8 cm dbh were measured and labeled in 10-m^2 burned subplots. Living trees and sprouts and dead trees larger than 28 cm dbh belonging to 10 common species were identified by local experts.

Directly after the low-intensity ground fire, most of the trees remained standing, although a high proportion of the stems appeared to be dead. One year after burning, <1% of trees smaller than 8 cm dbh survived, but larger sizes generally fared better. Survival of trees larger than 30 cm dbh was about 45%, with a range of 20–95% among species. Comparable levels of survival for trees larger than 10 cm dbh 1 month after fire have been found in a recently logged forest in Sabah (Woods 1988), whereas survival 6 months after fire was about 25% higher in an unlogged forest in Kutai National Park, East Kalimantan (Leighton & Wirawan 1986) and in Sumatra (Kinnaird & O'Brien 1998). The surviving trees in the Sungai Wain forest appeared sensitive to wind. Of the 35% of living stems that died in the second year, one-fifth had fallen. The remaining trees provided a sparse matrix, with a considerably impoverished species composition.

After the fire, some trees that were killed above ground sprouted from basal parts. This is a common phenomenon after slash-and-burn practices (Stocker 1981; Riswan & Kartawinata 1991; Kammesheidt 1998) and has been observed after fire in other tropical forests (Leighton & Wirawan 1986; Riswan & Yusuf 1986; Pinard et al. 1999). With a proportion of about 17%, sprouting frequency was highest for above-ground-killed seedlings and saplings smaller than 8 cm dbh. This was enough to provide densities of 0.2–0.4 sprouting trees per square meter. Trees larger than 10 cm dbh that were killed above ground had a sprouting frequency below 10% and added little to the density of sprouting individuals.

In an experiment in the unburned forest we assessed the sprouting vigor of young trees of six primary-forest species (*Dipterocarpus confertus* Sloot, *Durio acutifolius* [Mast.] Kosterm., *Gironniera nervosa* Planch., *Macaranga lowii* King ex Hook.f., *Madhuca kingiana* [Brace] H.J.Lam, *Shorea laevis* Ridl.) after clipping the main stem. Two hundred individuals from each species were checked monthly over 6 months for the number of sprouts produced, sprout length, and number of leaves. Sprouting occurred quickly, with more than 90% of the individuals sprouted after 3 months in four of the six species. Several species were affected negatively by repeated disturbance. Plants that were clipped for a second time 2 months after the initial clipping showed a reduction in sprouting frequency ranging from 0–40% when the top of the remaining stem was removed to 64–100% when the plants were clipped at ground level. Thus, where the heavy machinery used for salvage felling damages resprouts, their survival is reduced.

Sprouts of primary tree species competed with ferns and secondary seedlings of pioneer trees and shrubs in the young vegetation and were often overgrown by these within 1 year. Most of the sprouts nevertheless survived for the first 2 years. After 2 years, 25% of the sprouts had outgrown the layers of ferns and shrubs and appeared to play an important role in the persistence of many primary-forest species.

Stratified soil samples, taken in six replicates from unburned and burned areas in the Sungai Wain forest were placed in the nursery under high light conditions, which triggered abundant germination of seeds. The experiment revealed that the fire killed 85% of the seeds lying dormant in the litter layer and more than 60% of the seeds in the upper 1.5 cm of the soil. No reduced seed density was found in deeper soil layers. In the burned forest, the gap-like environmental circumstances induced frequent germination of seeds from the seed bank (Vázquez-Yanes & Orozco-Segovia 1993). Notwithstanding the high seed mortality in the upper soil layers, a dense carpet of pioneer seedlings had established 4 months after the fire in those places where high densities of pioneer trees had been present prior to the burning. Because of this high mortality and high germination incidence soon after the fire, the density of viable seeds remaining in the soil is greatly reduced (Hopkins & Graham 1984; Young et al. 1987; Saulei & Swaine 1988). Under these circumstances the local seed bank has little potential for further regrowth. These areas, if further damaged, risk invasion by wind-dispersed species, including *Imperata cylindrica* [L.] Beauv. (alang-alang, grass), *Pteridium caudatum* [L.] Maxon (bracken fern), and *Dinochloa sp.* (bamboo). It has previously been shown in East Kalimantan that complete conversion of a primary forest to *Imperata* grassland can take place rapidly after clearfelling and repeated burning (Kartawinata 1993). Substantial local seed production for rapidly maturing shrubby species takes 1 year or more (e.g., *Homalanthus populneus* [Geiseler] Pax, *Macaranga trichocarpa* ([Reichb.f. & Zoll.] Müll.Arg., some *Ficus* spp.) and at least 4 years for the larger secondary tree species (e.g., *Dillenia* spp., *Mallotus paniculatus* [Lam.] Müll.Arg.) (Saulei & Swaine 1988).

Seed production by trees that survive either as individuals in the burned area or in pockets of unburned forest ultimately will be the main source of regeneration of many primary-forest tree species. Initially the density and diversity of the seed rain will be impoverished by the low availability of seed sources. Because the seed-dispersal distance of many tree species is limited (Howe & Smallwood 1982; Whitmore 1984), the proximity and composition of relic unburned patches is anticipated to have a large effect on the persistence of fire-sensitive species in the burned forest.

Many species in the Sungai Wain forest fruited in 1997 during the long pre-fire drought and did not seed again during the first 2 years after the fire. As we described above, the burned forest by that time was densely covered by ferns, pioneer seedlings, sprouts, and grasses. Seedling establishment from the post-fire seed rain under these circumstances remains to be assessed, but it is evident that it will take a long time before seedlings of primary species will have become established from the seed rain in densities comparable to those of post-fire resprouts. For that reason the presence and performance of resprouts is a more important factor in the initial restoration of the forest than is the density of tree seed sources.

Conclusions and Recommendations

Fire does not in itself cause complete loss of forest cover. The survival and sprouting capacity of primary-forest trees and the seedling establishment of pioneer trees and shrubs suppress the establishment of nonforest species. But, post-fire vegetation is certainly less resilient than might be assumed by anyone witnessing the vigorous post-fire regrowth. The post-fire undergrowth cannot withstand repeated disturbance: previously sprouted individuals show reduced sprouting potential and survival after being damaged a second time, the seedbank is largely reduced after the initial post-fire burst of germination, and the density of vital seed trees is low. The open areas created in the understory by the conventional heavy logging machinery used for salvage felling encourage the rapid development of nonforest vegetation and seriously reduce the potential for recovery.

The genuine regenerative potential of burned tropical rainforest and the potential consequences of further disturbance caused by salvage felling need to be recognized. Our evidence implies that the maintenance of a productive permanent forest estate is likely to be served best by avoiding logging activities in burned areas. Further studies should be made in areas already harvested to further clarify the effects of salvage felling, but until such information is available, caution is the only environmentally defensible option.

We have presented only ecological concerns, but there are other reasons to review current practices of salvage harvesting. In Indonesia, concession holders cannot normally recut harvested forest areas without waiting the statutory period (a 20-year cutting cycle is the norm). If fire occurs in a concession, however, this restriction is lifted and further cutting is allowed. Such incentives must be avoided.

Acknowledgments

This research was performed at the International Ministry of Forestry (MOF)–TROPENBOS–Kalimantan research station, East Kalimantan. We thank the many staff members working there for their support, especially M. de Kam, K. Sidiyasa, Ambriansyah, Z. Arifin, and A. K. Pakala. The field work benefited greatly from the dedication of N. Syah, F. Udin, and S. Laysa Putra. We are grateful to J. A. Sayer, M. J. A. Werger, M. van Noordwijk, D. W. Dijkman, G. M. Fredriksson, J. W. F. Slik, and A. Hoffmann for their support and fruitful discussions. M. J. A. Werger, H. ter Steege, A. Hinrichs, and three anonymous reviewers made valuable comments on earlier versions of the manuscript. The research was supported by the Netherlands Foundation for the Advancement of Tropical Research (WOTRO) with grant 84–408 to M.v.N.

Literature Cited

Directorate of Forest Utilization. 1999. Penyempurnaan surat edaran direktur jenderal pengusahaan hutan produksi nomor 259/IV-BPH/1999 tentang tebang penyelamatan di areal HPH bekas kebakaran. Departemen Kehutanan dan Perkebunan, Direktorat Jenderal Pengusahaan Hutan Produksi, Republik Indonesia, Jakarta.

Hoffmann, A. A., A. Hinrichs, and F. Siegert. 1999. Fire damage in East Kalimantan in 1997/98 related to land use and vegetation classes: satellite radar inventory results and proposal for further actions. Report 1 of the integrated forest fire management project and sustainable forest management project. Samarinda, Indonesia.

Hopkins, M. S., and A. W. Graham. 1984. The role of soil seed banks in regeneration in canopy gaps in Australian tropical lowland rainforest: preliminary field experiments. The Malayan Forester **47(2):** 146–158.

Howe, H. F., and J. Smallwood. 1982. Ecology of seed dispersal. Annual Review of Ecology and Systematics **13:**201-228.

Kammesheidt, L. 1998. The role of tree sprouts in the restoration of stand structure and species diversity in tropical moist forest after slash-and-burn agriculture in Eastern Paraguay. Plant Ecology **139:** 155–156.

Kartawinata, K. 1993. A wider view of the fire hazard. Pages 261–266 in H. Brookfield and Y. Byron, editors. South-East Asia's environmental future: the search for sustainability. United Nations University Press, Tokyo.

Kinnaird, M. F., and T. G. O'Brien. 1998. Ecological effects of wildfire on lowland rainforest in Sumatra. Conservation Biology **12:**954–956.

Leighton, M., and N. Wirawan. 1986. Catastrophic drought and fire in Borneo tropical rain forest associated with the 1982–1983 El Niño Southern Oscillation Event. Pages 75–102 in G. T. Prance, editor. Tropical rain forests and the world atmosphere. American Association for the Advancement of Science selected symposium 101. Westview, Boulder, Colorado.

Pinard, M. A., F. E. Putz, and J. C. Licona. 1999. Tree mortality and vine proliferation following a wildfire in a subhumid tropical forest in eastern Bolivia. Forest Ecology and Management **116:**247–252.

Riswan, S., and K. Kartawinata. 1991. Regeneration after disturbance in a lowland mixed dipterocarp forest in East Kalimantan, Indonesia. Pages 295–301 in A. Gomez-Pompa, T. C. Whitmore, and M. Hadley, editors. Rainforest regeneration and management. Man and the biosphere series. Volume 6. United Nations Educational, Scientific, and Cultural Organization, Paris.

Riswan, S., and R. Yusuf. 1986. Effects of forest fires on trees in the lowland dipterocarp forest of East Kalimantan, Indonesia. Pages 155–163 in Proceedings of symposium on forest regeneration in Southeast Asia. Special publication 25. Southeast Asian Regional Center for Tropical Biology, Bogor, Indonesia.

Saulei, S. M., and M. D. Swaine. 1988. Rain forest seed dynamics during succession at Gogol, Papua New Guinea. Journal of Ecology **76:** 1133–1152.

Stocker, G. C. 1981. Regeneration of a North Queensland rain forest following felling and burning. Biotropica **13:**86–92.

Ulbricht, R., A. Hinrichs, and Y. Ruslim. 1999. Technical guideline for salvage felling in rehabilitation areas after forest fires. Report 1 of the sustainable forest management project. Samarinda, Indonesia.

Vázquez-Yanes, C., and A. Orozco-Segovia. 1993. Patterns of seed longevity and germination in the tropical rainforest. Annual Review of Ecology and Systematics **24:**69–87.

Vose, R. S., R. L. Schmoyer, P. M. Steurer, T. C. Peterson, R. Heim, T. R. Karl, and J. K. Eischeid. 1992. The global historical climatology network: long-term monthly temperature, precipitation, sea level pressure, and station pressure data. Carbon Dioxide Information Analysis Center, Oak Ridge, Tennessee. Available from ftp://cdiac.esd.ornl.gov/pub/ndp041/ (accessed 8 November 2000).

Whitmore, T. C. 1984. Tropical rain forests of the Far East. Oxford University Press, Oxford, United Kingdom.

Woods, P. 1988. Effects of logging, drought, and fire on structure and composition of tropical forests in Sabah, Malaysia. Biotropica **21:** 290–298.

Young, K. R., J. J. Ewel, and B. J. Brown. 1987. Seed dynamics during forest succession in Costa Rica. Vegetatio **71:**157–173.