LARGE-SCALE FIRE: CREATOR AND DESTROYER OF SECONDARY FORESTS IN WESTERN INDONESIA

R. Dennis,

Center for International Forestry Research (CIFOR), P.O. Box 6596 JKPWB, Jakarta 10065, Indonesia

A. Hoffmann,

Integrated Forest Fire Management Project (IFFM) - Ministry of Forestry-GTZ, Samarinda, Indonesia

G. Applegate,

Center for International Forestry Research (CIFOR), P.O. Box 6596 JKPWB, Jakarta 10065, Indonesia

G. von Gemmingen

Promotion of Sustainable Forest Management in East Kalimantan (SFMP) – Ministry of Forestry-GTZ, Samarinda, Indonesia

&

K. Kartawinata

Center for International Forestry Research (CIFOR), P.O. Box 6596 JKPWB, Jakarta 10065, Indonesia

---

DENNIS, R., HOFFMANN, A., APPLEGATE, G.,VON GEMMINGEN, G. & KARTAWINATA, K. 2001. **Large-scale fire: creator and destroyer of secondary forests in Western Indonesia.** Large-scale, catastrophic fires have become a significant and visible part of the tropical forest landscape in the past two decades with increased commercial exploitation of forests, forest conversion and increased population pressure. Secondary forests are an increasingly prominent feature of tropical landscapes and fires play a significant role in both the creation and destruction of these forests. In the past two decades large-scale forest fires have become more frequent in the moist tropics. In addition to climatic factors, the nature of tropical forests appears to be changing and becoming, as a consequence, more predisposed to burning. Secondary forests arising from intensive logging, in particular those that are in a degraded condition, are particularly vulnerable to repeated burning and further degradation. There has been limited general success in fire prevention and rehabilitation of secondary forests affected by fire. In addition, forest policy is not yet sufficiently attuned to address the management needs of the ever-increasing area of secondary forests affected by or developing following fire. Little is known about the exact extent and economic value or potential of post-fire secondary forests in Asia. It is clear, however, based on the experience of the past two decades, that there has been a significant increase in secondary forest affected by fire, particularly in Indonesia.

Rough estimates for Indonesia infer that there could be as many as 5 million ha of post-fire secondary forests following the 1997–98 fires. Based on this knowledge alone, it would seem that post-fire secondary forest is already an important forest type that will provide important goods and services both to the environment, the state and local communities alike, as the area of primary forest diminishes through over-exploitation and conversion.

Key words: Fire - secondary forests - Indonesia - Kalimantan

DENNIS, R., HOFFMANN, A., APPLEGATE, G., VON GEMMINGEN, G. & KARTAWINATA, K. 2001. Kebakaran besar-besaran: pencipta dan pemusnah hutan sekunder di Indonesia Barat. Bencana kebakaran secara besar-besaran menjadi penting dan ketara di landskap hutan tropika dalam dua abad yang lalu dengan meningkatnya eksploitasi komersial terhadap hutan, penukaran hutan dan tekanan pertambahan penduduk. Hutan sekunder merupakan ciri yang semakin menonjol dalam landskap tropika dan kebakaran memainkan peranan penting dalam penciptaan dan pemusnahan hutan. Sepanjang dua dekad yang lalu, kebakaran hutan besar-besaran berlaku lebih kerap di kawasan tropika lembap. Selain faktor cuaca, keadaan hutan tropika yang berubah menyebabkannya lebih mudah terbakar. Hutan sekunder yang tumbuh akibat pembalakan secara intensif, terutamanya hutan di tanah usang, lebih mudah terdedah kepada bahaya kebakaran berulang kali dan pendegradan seterusnya. Terdapat sedikit kejayaan dalam mengelakkan kebakaran dan pemulihan hutan sekunder yang terjejas akibat kebakaran. Selain itu, polisi hutan belum dapat disesuaikan untuk memenuhi keperluan pengurusan kawasan hutan sekunder yang kian bertambah dan terjejas ataupun tumbuh akibat kebakaran. Sedikit sahaja diketahui mengenai keluasan sebenar dan nilai ekonomi atau potensi hutan sekunder selepas kebakaran. Bagaimanapun, berdasarkan pengalaman dua dekad yang lalu, jelas terdapat pertambahan yang signifikan dalam hutan sekunder yang terjejas oleh kebakaran, terutamanya di Indonesia. Anggaran kasar bagi Indonesia menunjukkan bahawa mungkin terdapat sebanyak 5 juta ha hutan sekunder selepas kebakaran berikutan kebakaran tahun 1997-1998. Berdasarkan pengetahuan ini sahaja, nampaknya hutan sekunder selepas kebakaran merupakan jenis hutan yang penting untuk menyediakan barangan dan perkhidmatan penting kepada alam sekitar, negara dan penduduk tempatan, sementara kawasan hutan primer berkurangan akibat eksploitasi berlebihan dan pengalihan.

Introduction

Secondary forests are increasingly prominent features of tropical rain forest landscapes. Fire plays a significant role in both the creation and the destruction of secondary forests and this influence can be seen at two scales. For centuries, at a relatively small scale, people have deliberately used fire in clearing forest for swidden cultivation. Where these areas are left to regenerate, or abandoned, secondary forest results. In the past two decades, at a much larger scale, human-induced, uncontrolled fires have occurred in dry or drought years, burning large areas of secondary forest, and to a much lesser extent, primary forest. Depending on the degree of damage, the ultimate result of the natural regeneration of these fire-affected forests will be secondary forest. The implications of fire for secondary forests are enormous when one considers the spatial extent of the area affected and the impact on people, ecosystems and nations.

In 1982–83, intense drought and accompanying fires damaged or destroyed up to 5 million ha of land, including large tracts of secondary forest and some primary forest in Borneo (Lennertz & Panzer 1983, Malingreau *et al.* 1985, Leighton & Wirawan 1986, Woods 1987, 1989). More recently, in 1997–98, up to 10 million ha of forest and non-forest land were affected by fire in Indonesia (Asian Development Bank 1999). Other tropical regions also experienced fires at this time, with as many as 3 million ha burnt in the Amazon, including 1 million ha of rainforest (Nepstad *et al.* 1999a). However, it must be noted that not all forest fires in the tropics have a negative impact on forest ecosystems. Fire occurs regularly in the monsoon forest ecosystem of Indonesia and in most cases leads to the formation of different types of savannas and grasslands. Monsoon forests include the evergreen and semi-deciduous forests (Kartawinata 1993) of South and Southeast Sulawesi, East Java, East and West Nusa Tenggara, and southeast Papua (Van Steenis 1935, 1957). The focus of this paper will be restricted to the lowland dipterocarp and swamp forests of Kalimantan.

Now, it is generally thought that fire regimes in tropical rainforests, even those that are undisturbed or unlogged, have changed from those characterised by low-intensity, very infrequent surface fires to those in which fires are relatively frequent and of potentially high severity (Kauffmann *et al.* 1988; Kauffmann & Uhl 1990; Holdsworth & Uhl 1997, Cochrane *et al.* 1999, Nepstad *et al.* 1999a, b). In addition to climatic factors, it is believed that increased logging in tropical rainforests and an increase in degraded and secondary forest in general has led to an increased fire risk and incidence (Kauffmann *et al.* 1988, Schindele *et al.* 1989, Kauffmann & Uhl 1990, Holdsworth & Uhl 1997, Cochrane and Schulze 1999). Repeated burning, further exploitation and degradation, especially, threaten post-fire secondary forests, initiating a positive feedback loop in which forests are gradually replaced by fire-prone vegetation (Cochrane *et al.* 1999, Nepstad *et al.* 1999b). Existing secondary forests, in particular those that are poorly managed, are particularly vulnerable to damage from fire. This has led to an increased area of post-fire secondary forest and forest policy is not yet sufficiently attuned to address the specific management requirements of the ever-increasing area of post-fire secondary forests (Hoffmann *et al.* 1999). Post-fire secondary forest is defined as "forests regenerating largely through natural processes after significant reduction in the original forest vegetation due to a catastrophic human-induced fire or succession of fires, and displaying a major difference in forest structure and/or canopy species composition with respect to nearby primary forests on similar sites" (Chokkalingam *et al.* 2000).

This paper focuses on describing secondary forests impacted by or resulting from large-scale fires in the moister regions of Indonesia, with a special focus on Kalimantan. It discusses the current and future socio-economic importance of post-fire secondary forests. It outlines how secondary forest can be an asset to both local communities and the country as a whole in terms of maintaining biodiversity and providing tangible benefits, from which income can be derived. Finally, the paper discusses the management implications for post-fire secondary forests.

The impact of fires on secondary forests

Assessing the impact of large-scale fires on secondary forests is not an easy task because few reliable spatial estimates exist. Anecdotal evidence reveals that as far back as the 15th century, explorers in Borneo gave reports of large areas of forest fires and smoke. Careful historical analysis and cross-referencing show that large-scale catastrophic fires and drought occurred only in particular years that we now know as El Niño Southern Oscillation (ENSO)[1] years (Leighton 1984, Brookfield *et al.* 1995, Potter 1997). Despite the long history of ENSO-related large-scale fire in Indonesia, the extent and damage caused by the fires of the past two decades is historically unrivalled.

A series of large-scale fires occurred in fairly rapid succession in 1982–83, 1987, 1991, and 1994, and most recently in 1997–98 (SKEPHI 1992, Brookfield *et al.* 1995, Dennis 1999, Goldammer *et al.* 1999, Barber & Schweithelm 2000). This time period also coincides with a particularly intensive period of commercial logging and forest conversion. Spatial estimates of forests affected by fire are available for some years during this period but unfortunately the reliability of the estimates is variable. Official government forest fire estimates can vary widely from non-official sources. This is well exemplified by the burnt area estimates for the Indonesian fires of 1997–98. The Ministry of Forestry stated that 263 000 ha of forestland burnt in 1997 and 550 000 ha in 1998 (State Ministry of the Environment 1998). Based on satellite image analysis, and in some cases field checks, a combined group of non-government organisations came up with different estimates, the most widely cited of which is 4.7 million ha of forest impacted by fire (Asian Development Bank 1999).

In addition to confusion over area estimates, a lack of consistent terminology makes it difficult to compare and contrast forest fire statistics. 'Forest fires' was commonly used to describe the Indonesian and Amazonian fires but a large percentage of these fires were not in forests. Media reports, in particular, did not distinguish between fires in forests and fires in non-forest areas, nor between fires in primary forest and fires in secondary forest. Another confusing term is "forestland" fires: in many countries the state designates land as forestland but it does not always mean that the area is forested. Apart from the need for increased clarity on the type of vegetation burnt, there is also a need for improved information on the degree of the fire damage to forests. Keeping these distinctions clear makes a great difference in assessing the damage and the prospects for recovery, the social and economic cost of the fires, and in understanding the causes.

---

[1] The El Niño Southern Oscillation is the result of a cyclic warming and cooling of the surface of the eastern Pacific. This region of the ocean is normally cooler than its equatorial location would suggest, mainly due to the influence of north-easterly trade winds, a cold ocean current flowing up the coast of Chile, and the upwelling of cold deep water off Peru. At times, the influence of these cold waters wanes, causing the surface of the eastern and central Pacific to warm up. This is called an El Niño event. ENSOs also affect the Earth's trade wind patterns, which in turn influence sea surface temperatures over vast areas of the Pacific. These changes can produce extreme weather throughout the tropics and have been linked to severe droughts in Indonesia and Australia, and heavy rainfall in South America.

The impact of the 1982–83 fires

Following the 1982–83 fires, a number of assessments found that fire intensity and damage was significantly higher in secondary forests, with the degree of damage related to the degree of prior disturbance (Wirawan 1983, Leighton 1984, Mackie 1984, Malingreau *et al.* 1985, Schindele *et al.* 1989, Wirawan 1993). In East Kalimantan, Schindele *et al.* (1989) concluded that during the 1982–83 fires 4 million ha of area were burnt to varying degrees, of which 2.7 million ha were classified as forest (Schindele *et al.* 1989). Breaking this figure down into its constituent parts shows that only 7577 ha of primary or undisturbed forest were affected by fire. Most of the fire damage in the primary lowland and swamp forest was confined to understorey vegetation and small trees, with very few large trees killed. For the remaining forest areas affected by fire Schindele *et al.* (1989) used the term 'disturbed forest'. According to definitions presented by Chokkalingam *et al.* (2000), some of the disturbed forest class could be classified as secondary forest. Chokkalingam *et al.* (2000) define secondary forests as 'forests regenerating largely through natural processes after significant human disturbance of the original forest vegetation at a single point in time or over an extended period, and displaying a major difference in forest structure and/or canopy species composition with respect to nearby primary forests on similar sites'.

The total area of lightly disturbed lowland forest affected by fire was 635 680 ha, with the fire mainly affecting the lower and middle storeys (Schindele *et al.* 1989). Fire damage was particularly bad in moderately disturbed lowland forest with as many as 826 560 ha badly affected by fire. These forests showed significant disturbance in structure; the lower and middle storeys were seriously damaged and the upper storey was opened to a limited extent. Much of the heavily disturbed lowland forest in the area was destroyed by fire, with an estimate of 639 760 ha (Schindele *et al.* 1989). In addition to the lowland forest, as many as 373 450 ha of disturbed swamp forest were destroyed.

In Sabah, an estimated 1 million ha of forest were affected by fire (Beaman *et al.* 1985), of which 85% were post-extraction secondary forest and 15% were primary forest. Post-extraction secondary forests are defined here as "forests regenerating largely through natural processes after significant reduction in the original forest vegetation through tree extraction at a single point in time or over an extended period, and displaying a major difference in forest structure and/or canopy species composition with respect to nearby primary forests on similar sites" (Chokkalingam *et al.* 2000). Beaman *et al.* (1985) and Woods (1987, 1989) partly attributed the extent and severity of the fires of 1983 to the increased density of man-made ignition sources, and increased commercial exploitation of forests. In Sabah, rates of tree mortality after drought and fire ranged from 38 to 94% in post-extraction secondary forests and from 19 to 71% in unlogged forest (Woods 1987, 1989). For saplings, rates of mortality of original species exceeded 80% in both forest types. In the same site, the research also noted that the fires had a significant negative impact on the seed-bank and seedlings in burnt post-extraction secondary forest, which did little to assist the recovery of the original species (Woods 1987, 1989).

Impact of the 1997–98 fires

There is wide variation in the figures cited for the total area burnt in 1997–98 in Indonesia. A number of projects, organisations and institutes both in Indonesia and overseas produced burnt area estimates (Legg 1997, EUFREG 1998, Liew *et al.* 1998, Ramon & Wall 1998, Antikidis *et al.* 1999, Asian Development Bank 1999, Hoffmann *et al.* 1999, Barber & Schweithelm 2000). The Asian Development Bank Project (Asian Development Bank 1999) estimated the area burnt by island and land cover type to be 9.7 million ha, as shown in Table 1. For East Kalimantan alone, Hoffmann *et al.* (1999) estimated that 5.2 million ha of forest and agricultural land burnt in 1997–98 (see Table 2). Much of the area of East Kalimantan that burnt in 1982–83 burnt again in 1997–98 (Hoffmann *et al.* 1999). From Tables 1 and 2 it can be seen that much of the forest areas burnt could be classified as secondary forest. Post-extraction secondary forest, especially the most recently logged, suffered the most burning: 1.4 million ha in 1982–83 and 2.3 million ha in 1997–98.

Table 1 Estimated extent of burnt area in Indonesia 1997–98 (after Asian Development Bank 1999)

Land use/cover Island	Lowland forest	Peat and swamp forest	Dry scrub and grass	Timber plantations	Agriculture	Estate crops	Total (ha)
Kalimantan	2 375 000	750 000	375 000	116 000	2 829 000	55 000	6 500 000
Sumatra	383 000	308 000	263 000	72 000	669 000	60 000	1 755 000
Java	25 000		25 000		50 000		100 000
Sulawesi	200 000				199 000	1 000	400 000
Irian Jaya	300 000	400 000	100 000		97 000	3 000	900 000
Total (ha)	3 283 000	1 458 000	763 000	188 000	3 844 000	119 000	9 655 000

Table 2 Estimated extent of burnt area in East Kalimantan 1997–98 (after Hoffmann *et al.* 1999)

Land status	Total area (ha) E. Kalimantan	Burnt area (ha)	% burnt	Damage 25–50%	Damage 50–80%	Damage >80%, biomass still intact	>80%, biomass mostly destroyed
Natural forest Concession	9 771 384	2 347 717	24	767 629	1 234 413	237 719	107 956
Forest plantation	1 393 074	883 987	64	209 498	429 623	111 935	132 931
Estate crops	746 603	382 509	51	83 731	198 151	11 966	88 661
Protection forest	4 562 059	440 381	10	84 146	263 656	23 656	68 923
Undefined land use (cultivation)	3 275 441	1 161 174	36	106 684	69 650	233 088	753 876
Total (ha)	19 748 561	5 215 768		1 249 564	2 195 493	618 364	1 152 347

Development and characteristics of post-fire secondary forests

Fires that burn secondary forests destroy most of the aboveground biomass, releasing smoke and gasses to the atmosphere and setting back the process of forest recovery (Nepstad *et al.* 1999a). Since the trees of secondary forests are small in stature and generally require many years to develop bark sufficiently thick to protect against fire damage, the mortality of stems is high. Most studies of the recovery of fire-affected areas in East Kalimantan reported a vigorous re-growth of pioneer species following the rain after the fires (Leighton 1984, Malingreau *et al.* 1985, Leighton & Wirawan 1986, Wirawan 1993). Many authors remark that there is still a lack of knowledge and understanding of natural recovery of the tropical rainforest after fire (Leighton & Wirawan 1986, Toma *et al.* 2000).

There are many factors that influence the recovery of a tropical forest ecosystem. The availability of seed is particularly important for the development of post-fire secondary forests. The impact of fire differs from other natural gap forming processes (cyclones) in that most pre-existing seedlings and saplings may be killed by fire and the soil laid bare. Thus post-fire secondary forests are often poor in species diversity and in upper-canopy species.

The prospects for recovery of forest structure appear good in burnt primary forest although species composition may be permanently altered. In forests logged before the fire, the prospects for recovery of forest structure are not good, especially if further burning occurs (Fox 1976, Woods 1987, Applegate & Bragg 1992). The vigorous secondary tree species can shade out the pervasive grass *Imperata cylindrica*. However, repeated burning and the continued presence of this grass may herald the conversion of the forest to grassland, as has occurred widely (Woods 1989, Nepstad *et al.* 1999a, b). The degradation towards grasslands is very quick; for example an area burnt three times in two years can become grassland (Kartawinata 1993). Rehabilitation methods, such as enrichment planting of indigenous species and associated maintenance for a number of years, and protection from further fires and grazing, may be required.

Toma *et al.* (1999, 2000) observed secondary forest regeneration in an area that was logged selectively in the early 1970s and burnt once in 1982–83. After the first fires (1982–83), large canopy gaps caused by the fire were filled with pioneer tree species, especially *Macaranga gigantea* and *M. triloba*. By 1997, as a result of selective logging and forest fire, the area had become a mosaic of forest stands dominated by surviving dipterocarps and pioneer *Macaranga* sp. established after 1982–83. Succession was proceeding from pioneer to primary species such as dipterocarps. However, the fire in 1998 destroyed the forest and because the secondary forest consisted of a more open canopy with dense undergrowth, the damage was more severe than in 1983 (Toma *et al.* 1999, 2000).

Hess and Tangketasik (1994) described how in heavily burnt forest in Semboja, East Kalimantan, the vegetation 10 years later is dominated by *Mallotus* sp., *Macaranga* sp. and widespread *Imperata* grassland. In medium and lightly burnt forests, pioneer trees and regeneration of commercial dipterocarp trees occur.

In particular, former swidden agricultural fields burnt in 1982/83 showed very distinct succession types dominated by one or few main pioneer species such as *I. cylindrica, Trema orientalis, Eupatorium* sp. and *Piper aduncum.*

Socio-economic importance of post-fire secondary forests

The socio-economic importance of post-fire secondary forests is potentially high. These forests should be considered important to both the state and local communities, and not considered a 'lost cause' because they are no longer primary forests. In East Kalimantan alone, at least 2.3 million ha of potential post-fire secondary forest exist after the 1997–98 fires (Hoffmann *et al.* 1999). This figure represents 24% of all lowland forest allocated to logging concessions in East Kalimantan (Hoffmann *et al.* 1999), and shows the relative importance of post-fire secondary forests to the socio-economy of East Kalimantan. These forests, if allowed to recover, provide an important resource for the future in terms of timber and non-timber forest products both to local communities and commercial companies.

The literature contains few examples stressing the importance of post-fire secondary forests to local communities and commercial stakeholders. However, the following two examples describe instances where post-fire regeneration is particularly important to local communities. Twenty-five percent of all forests in the 80 000 ha Danau Sentarum Wildlife Reserve in West Kalimantan have been affected by fire over the past decades (Giesen 1996, Dennis *et al.* 1998). Burnt areas located on slightly higher ground have been densely colonised by *Fagraea fragrans*, the most important timber species in the area for both commercial and subsistence use (Luttrell 1994). This species grows naturally in a wide variety of different habitats ranging from primary to secondary forests, burnt areas, and fields of *I. cylindrica* (Peters 1995). *Fagrea fragrans* produces strong and durable timber (Peters 1995). Fishermen use the wood for building houses, honey-boards, and for constructing boardwalks linking stilted houses together in a village. In addition, those who have chain saws and live near forests with workable volumes of the species sell the timber commercially (Peters 1995). Local demand for *F. fragrans* is outstripping the supply. A 40-cm-dbh tree, which is the minimum size that can be used for house construction, is around 50–60 years old (Peters 1995). If the *F. fragrans* forest areas at Danau Sentarum Wildlife Reserve are not protected and managed properly they will be at risk from repeated burning during very dry years. Peters (1995) suggested monitoring, enrichment planting and silvicultural treatment of young poled-sized stands to maintain the *F. fragrans* forests.

In the provinces of South Sumatra and Lampung in Indonesia, many of the swamplands are used for rice production using a technique referred to as "sonor". This involves burning the swamp in very dry years and sowing the rice directly into the burnt debris. The rice grows together with the rising water during the wet season and often has to be harvested by boat, six months after sowing. Very little tending or maintenance is undertaken after the rice is sown. This burning has also promoted the development of *Melaleuca cajuputi*, which is native to the area (see

Box 1). Sonor is not practised annually but only during very dry or El Nino years, allowing *Melaleuca* trees to establish well prior to the next burning year. This has resulted in a mosaic of small patches of even-aged *Melaleuca*. Many of the stands are very young, many less than four years old, but already communities are harvesting the timber as poles for building construction and the larger sizes for sawn timber in makeshift mills located beside the small rivers that are scattered throughout the area (Suyanto *et al.* 2000). Charcoal is produced from the sawmill off-cuts and waste and sent to Jakarta or to the ports for export (Suyanto *et al.* 2000). The stands of *Melaleuca* are not managed for timber by the communities, but are seen as public goods to be used in an opportunistic manner, so there is no effort to protect the young stands from fire when burning the swamp during dry years for sonor rice production. It is likely that these forests will take on a high economic importance if the current utilisation trends continue and the species continues to expand at the current rates into cleared and burnt swamp forests.

Box 1 Post-fire *Melaleuca* forests in Sumatra

Post-fire secondary forests dominated by *Melaleuca leucadendra* occur in some of the low-lying saline marsh and fresh water swamp areas in eastern Indonesia. *Melaleuca cajuputi* is more prominent in the same environment in southern Sumatra. *Melaleuca cajuputi* is a fast growing, highlight-demanding tree species that has a tolerance of low intensity fires and acid soils (Turnbull 1986). It also survives inundation for a number of months through the development of adventitious root systems (Turnbull 1986) and survives in brackish water (Boland 1989). It can readily regenerate from seed or through coppicing following a fire. These characteristics enable the species to establish in relatively pure stands of similar age classes and expand rapidly into swampy areas in parts of southern Sumatra, which have been heavily logged and burnt. In areas in southern Papua, burning patterns have enabled stands of *Melaleuca* spp. to grow to 40 m in height with diameters up to 1 m dbh.

Management of post-fire secondary forests

Post-fire secondary forests are particularly vulnerable to recurrent fires and consequently good management, and in particular good fire management, is extremely important if the environmental and socio-economic values of the forests are to be maintained. Present land tenure insecurity, lack of funding for rehabilitation and the lack of will to protect forests from fire are important factors affecting the regeneration of post-fire secondary forests. SFMP (1999) emphasises the importance of natural regeneration and mixed planting of native species, protection from further disturbance, and community participation for successful rehabilitation and management of post-fire secondary forests. Mayer (1989) found that local communities had strong interest in forest rehabilitation close to the village, and less interest in areas farther away or managed by logging companies. Although keen on forest rehabilitation measures, many village leaders were worried

that the schemes would not directly, quickly and concretely benefit the community. The idea of community forests on village lands was generally well received.

In East Kalimantan, much of the area burnt in 1982–83 continued to regenerate up until the devastating fire of 1997–98. Since 1982–83, intensive logging has taken place in the former burnt area and large-scale rehabilitation only took place in the Bukit Soeharto Recreation Forest (Hoffmann *et al.* 1999). In other areas of East Kalimantan, plantation development companies converted severely burnt degraded forests to plantations. The majority of the literature concerning the management of secondary forest resulting from large-scale fires in Indonesia focuses on areas such as logging concessions and not on areas used by local communities.

The Ministry of Forestry and Estate Crops (MOFEC) introduced salvage logging as a management and financing tool in forest areas burnt in 1997–98 (Ministry of Forestry and Estate Crops 1999a, b). Salvage logging gives companies the right to remove dead timber from severely burnt post-extraction secondary forest or burnt primary forest. There is, however, some concern that salvage logging activities may adversely affect the course of vegetation succession.

Following the 1982–83 fires, Schindele *et al.* (1989) proposed a number of rehabilitation measures for post-fire secondary forests such as enrichment planting, timber stand improvement and encouragement of natural succession. They recommended enrichment planting with dipterocarps in areas with a low number of seed trees and less natural regeneration. They also recommended afforestation for areas that were heavily burnt with few remaining trees (Schindele *et al.* 1989). However, there has been little success or commitment to the rehabilitation of post-fire secondary forests in East Kalimantan. ITTO supported a project experimenting with a wide variety of species and silvicultural treatments to rehabilitate fire-affected forests (Hess & Tangketasik 1994), but the demonstration plot was almost completely destroyed during the 1997–98 fires.

There is a strong need to promote commercial interest in the rehabilitation of severely affected post-fire secondary forests on a large scale. The Government of Indonesia is therefore about to launch a large rehabilitation programme focusing on degraded former concession areas and on the participation of local people. Plywood mills have started investing in peeling machines, which can take smaller tree diameters. This provides opportunities for selected pioneer species to be utilised and therefore managed in the forests, thus contributing to an increase in the value of post-fire secondary forests.

Conclusion

Large-scale fires have contributed greatly to the creation and destruction of secondary forests in Indonesia. The moist ecosystems of Indonesia are now much more susceptible to burning even during normal dry seasons due to the degraded forest condition and the accumulation and alteration of native fuel complexes. Secondary forests are very prone to fires because they dry more quickly and therefore burn more easily than primary, mixed-lowland dipterocarp forests that are heavily shaded and have sparse ground fuels. Of all the forest types affected by

fire in Indonesia, secondary forests are impacted most. Post-extraction secondary forest, especially the most recently logged, has suffered the most burning in the past two decades: 1.4 million ha in 1982–83 and 2.3 million ha in 1997–98 in East Kalimantan alone, and perhaps as many as 5 million ha in Indonesia as a whole. The result of these forest fires is the creation of vast areas of post-fire secondary forest, which, if managed judiciously, are of great importance to both the state and local communities.

In order to maintain or encourage the development of post-fire secondary forests there is a need for improved rehabilitation and management of these forests either by the government, private sector companies and/or local communities. However, in cases where the forests are lightly burnt, logging often continues, thus extending the recovery time of the forest, and where forests are badly burnt, the tendency seems to be conversion to alternative land use such as plantations (Potter & Lee 1998). Improved fire management and implementation of fire prevention systems in post-fire secondary forests is of the utmost importance to prevent future fires and allow recovery to take place. Despite many recommendations, there are still very few examples of rehabilitation and forest fire management measures being implemented on a large scale (Fatawi & Mori 2000).

As the area of primary forest is decreasing in Indonesia, secondary forests should be assuming a much more important role. However, if the environmental and socio-economic importance of secondary forests is not recognised, and large-scale fires are allowed to continue, these forests will continue to degrade until they are reduced to grassland or shrubland.

Acknowledgement

The authors would like to thank P. Moore for his comments on this paper.

References

ANTIKIDIS, E., ARINO, O., JANODET, E. & ACHARD, F. 1999. Development of a new method for burned forest area assessment in Borneo during the 1997 exceptional fire event. Pp. 241–249 in *Proceedings of the FIMP-INTAG International Conference: Data Management and Modelling Using Remote Sensing and GIS for Tropical Forest Land Inventory.* 1998. October 26–29 Jakarta, Indonesia.

APPLEGATE, G. B. & BRAGG, A. 1992. Recovery of coastal lowland rainforest damaged by cyclone 'Winifred' : a photographic record. *Queensland Forest Service Technical Paper* (51):18.

ASIAN DEVELOPMENT BANK. 1999. *Causes, Extent, Impact and Costs of 1997/1998 Fires and Drought.* Final report, Annex 2. Planning for Fire Prevention and Drought Management Project. Asian Development Bank TA 2999-INO. Jakarta, Indonesia, Fortech, Pusat Pengembangan Agribisnis, Margules Jaako Pöyry Consulting.

BARBER, C. V. & SCHWEITHELM, J. 2000. *Trial by Fire. Forest Fires and Forestry Policy in Indonesia's Era of Crisis and Reform.* Forest Frontiers Initiative, World Resources Institute (WRI), Washington D.C. U.S.A. In collaboration with WWF-Indonesia and Telapak Indonesia Foundation. 76 pp.

BEAMAN, R. S., BEAMAN, J. H., MARSH C., and WOODS, P. 1985. Drought and forest fires in Sabah 1983. *Sabah Society Journal* 8:10–30.

BOLAND, D.J. (Ed.) 1989. *Trees for the Tropics. Growing Australian Multipurpose Trees and Shrubs in Developing Countries.* Australian Centre for International Agricultural Research, Canberra.

BROOKFIELD, H., POTTER, L. & BYRON, Y. 1995. *In Place of the Forest: Environmental and Socio-Economic Transformation in Borneo and the Eastern Malay Peninsula.* United Nations University Press, Tokyo. 310 pp.

CHOKKALINGAM, U., DE JONG, W., SMITH, J. & SABOGAL, C. 2000. Tropical secondary forests in Asia: introduction and synthesis. Paper prepared for the "Tropical secondary forests in Asia: Reality and perspectives' workshop". 10–14 April 2000. Samarinda, Indonesia. Center for International Forestry Research, Bogor, Indonesia.

COCHRANE, M. & SCHULZE, M. 1999. Fire as a recurrent event of the Eastern Amazon: effects on forest structure, biomass, species composition. *Biotropica* 31(1): 2–16.

COCHRANE, M. A., ALENCAR, A., SCHULZE, M. D., SOUZA, C. M., NEPSTAD, D. C., LEFEBVRE, P. & DAVIDSON, E. A. 1999. Positive feedbacks in the fire dynamic of closed canopy tropical forests. *Science* 284(5421): 1832–1835.

DENNIS, R. A. 1999. *A Review of Fire Projects in Indonesia 1982–1998.* Center for International Forestry Research, Bogor. 112 pp.

DENNIS, R. A., PUNTODEWO, A. & COLFER, C. J. P. 1998. Fishermen, farmers, forest change and fire. *GIS Asia Pacific* February/March: 26–30.

EUFREG (European Union Fire Response Group). 1998. *Assessment of the 1997 Fires in Indonesia.* European Union, Ministry of Forestry and Estate Crops, Jakarta, Indonesia. 15 pp.

FATAWI, M. & MORI, T. 2000. Description of Forests and Forestry in East Kalimantan. In Guhardja, *et al.* (Eds.) *Rain Forest Ecosystems of East-Kalimantan: El Nino, Drought, Fire and Human Impacts.* Ecological Studies Volume 40. Springer-Verlag, Tokyo. 330 pp.

FOX, J. E. D. 1976. Environmental constraints on the possibility of natural regeneration after logging in tropical moist forest. *Forest Ecology and Management* 1: 512–536.

GIESEN, W. G. 1996. *Habitat Types and their Management: Danau Sentarum Wildlife Reserve, West Kalimantan, Indonesia.* Wetlands International-Indonesia Programme/PHPA, Bogor, Indonesia. 90 pp.

GOLDAMMER, J. G., SCHINDELE, W., SIEBERT, B., HOFFMAN, A.J. & ABBERGER, H. 1999. Impacts of fire on dipterocarp forest ecosystems in Southeast Asia. Pp 15–39 in Suharyoyo, H. & Toma, T. (Eds.) *Proceedings of the Third International Symposium on Asean Tropical Forest Management.* Samarinda, Indonesia. Pusrehut Special Publication No. 8. Tropical Forest Research Center, Mulawarman University and JICA.

HESS, P. & TANGKETASIK, J. 1994. *The Establishment of a Demonstration Plot for Rehabilitation of Forest Affected by Fire in East Kalimantan,* FRIS, DFS, Ministry of Forestry ROI, ITTO. 97 + 85 pp.)

HOFFMANN, A. A., HINRICHS, A. & SIEGERT, F. 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.* IFFM-SFMP Report No.1a. MOFEC, GTZ and KfW. Samarinda, East Kalimantan. 26 pp.

HOLDSWORTH, A. R. & UHL, C. 1997. Fire in Amazonian selectively logged rainforest and the potential for fire reduction. *Ecological Applications* 7(2): 713–725.

KARTAWINATA, K. 1993. A wider view of the fire hazard. Pp. 261–266 in Brookfield, H. & Byron, Y. (Eds.) *Southeast Asia's Environmental Future: The Search for Sustainability.* United Nations University Press, Tokyo.

KAUFFMANN, J. B. & UHL, C. 1990. Interactions of anthropogenic activities, fire and rainforests in the Amazon Basin. Pp. 84: 117–134 in J. G. Goldammer (Ed.) *Fire in the Tropical Biota: Ecosystem Processes and Global Challenges.* Springer-Verlag, Berlin, Germany.

KAUFFMANN, J. B., UHL, C. & CUMMINGS, D. L. 1988. Fire in the Venezuelan Amazon 1: fuel biomass and fire chemistry in the evergreen rainforest of Venezuela. *Oikos* 53: 167–175.

LEGG, C. A. 1997. *A Preliminary Report on Fires in Sumatra, Kalimantan, Sulawesi and Irian Jaya During September 1997.* EU Forest Inventory and Management Project. Jakarta. 5 PP.

LEIGHTON, M. 1984. *The El Nino Southern Oscillation Event in Southeast Asia: Effects of Drought and Fire in Tropical Forest in Eastern Borneo.* WWF-US. Washington, D. C. 32 pp.

LEIGHTON, M. & WIRAWAN, N. 1986. Catastrophic drought and fire in Borneo tropical rainforest associated with the 1982–83 El Niño Southern Oscillations event. Pp. 75–102 in Prance, G. *Tropical Rain Forests and the World Atmosphere.* American Association for the Advancement of Science, Washington, D. C.

LENNERTZ, R. & PANZER, K. F. 1983. *Preliminary Assessment of the Drought and Forest Fire Damage in Kalimantan Timur.* Report of the Fact-Finding Mission, Transmigration Area Development Project PN 76.2010.7, DFS German Forestry Service Ltd. for GTZ. 45 pp.

LIEW, S. C., LIM, O. K., KWOH, L. K. & LIM, H. 1998. *A Study of the 1997 Forest Fires in South East Asia Using SPOT Quicklook Mosaics.* 1998 International Geoscience and Remote Sensing Symposium. 6–10 July 1998. Seattle, USA.

LUTTRELL, C. 1994. *Forest Burning in Danau Sentarum.* Preliminary report for AWB/PHPA. UK-Indonesia Tropical Forest Management Project, Sub-Project 5 Conservation. Bogor, Indonesia. 26 pp.

MACKIE, C. 1984. The lessons behind East Kalimantan's forest fires. *Borneo Research Bulletin* 16:63–74.

MALINGREAU, J. P., STEPHENS, G. & FELLOWS, L. 1985. Remote sensing of forest fires: Kalimantan and North Borneo in 1982–83. *Ambio* 14: 314–321.

MAYER, J. H. 1989. *Socio-Economic Aspects of the Forest Fire 1982/83 and the Relation of Local Communities Towards Forestry and Forest Management in East Kalimantan.* FR-Report No. 9. FR-Project, ITTO, Balai Penelitian Kehutanan, DFS and GTZ. GTZ-PN: 38.3021.3-11.000. ITTO: PD 17.18 (F).

MINISTRY OF FORESTRY AND ESTATE CROPS. 1999a. Circular about salvage logging in burnt forest areas. Ministry of Forestry and Estate Crops.

MINISTRY OF FORESTRY AND ESTATE CROPS. 1999b. Revision of Circular No. 259/IV–BPH/1999 regarding salvage felling in burnt forest areas. Ministry of Forestry and Estate Crops, Jakarta.

NEPSTAD, D. C., MOREIRA, A. G. & ALENCAR, A. A. 1999a. *Flames in the Rain Forest: Origins, Impacts and Alternatives to Amazonian Fires.* Pilot Program to Conserve the Brazilian Rain Forest. Brasilia, Brazil. 161 pp.

NEPSTAD, D. C., VERISSIMO, A., ALENCAR, A., NOBRE, C., LIMA, E. *et al.* 1999b. Large-scale impoverishment of Amazonian forests by logging and fire. *Nature* 398: 505–508.

PETERS, C. M. 1995. *Tembesu* (Fagraea fragrans *Roxb.*): *Utilization and Management in the Danau Sentarum Wildlife Reserve.* Bureau-Indonesia, Bogor. 27 pp.

POTTER, L. 1997. Where there's smoke there's fire. *Search* 26: 307–311.

POTTER, L. & LEE, J. 1998. *Oil Palm in Indonesia: Its Role in Forest Conversion and the Fires of 1997/98.* WWF - Indonesia Programme, Jakarta. 38 pp.

RAMON, J. & WALL, D. 1998. *Fire and Smoke Occurrence in Relation to Vegetation and Land Use in South Sumatra Province, Indonesia with Particular Reference to 1997.* European Commission Forest Fire Prevention and Control Project, Jakarta, Indonesia. 5 pp.

SCHINDELE, W., THOMA, W. & PANZER, K. 1989. Investigation of the steps needed to rehabilitate the areas of East Kalimantan seriously affected by fire. *The Forest Fire 1982/83 in East Kalimantan. Part I: The Fire, the Effects, the Damage and the Technical Solutions.* GTZ-PN:38.3021.3–11.000, ITTO:PD 17/87 (F).

SKEPHI. 1992. Special Report on Forest Fire. *Setiakawan* 7: 27–59.

SFMP. 1999. *Technical Guidelines for Rehabilitation of Fire-Affected Forests in Concession Areas.* SFMP Document No. 6/99 (Indonesia).

STATE MINISTRY OF THE ENVIRONMENT. 1998. *Analisis Kebijakan Penanggulangan Kebakaran Hutan dan Lahan.* Tahun 1997. Jakarta.

SUYANTO, S., DENNIS, R. A., RUCHIAT, Y., KURNIAWAN, I., STOLLE, F., MAUS P. & APPLEGATE G. 2000. *The Underlying Causes and Impacts of Fires in Southeast Asia. Site 2. Menggala, Lampung Province, Indonesia.* CIFOR, ICRAF and USFS, Bogor. 53 pp.

TOMA, T., MATIUS P., HASTANIAH, KIYONO, Y., WATANABE, R. & OKIMORI, Y. 2000. Dymanics of burned lowland dipterocarp forest stands at Bukit Soeharto, East Kalimantan. Pp.107–119 in Guhardja *et al.* (Eds.) *Rain Forest Ecosystems of East Kalimantan: El Nino, Drought, Fire and Human Impacts.* Ecological Studies, Volume 40. Springer–Verlag, Tokyo.

TOMA, T., P. MATIUS & SUTISNA, M. 1999. Fire and human impacts on aboveground biomass of lowland dipterocarp forests in East Kalimantan. Pp. 297–305 in Suharyoyo, H. & Toma, T. (Eds.) *Proceedings of the Third International Symposium on Asian Tropical Forest Management.* Samarinda, Indonesia.

TURNBULL, J.W. 1986. *Multipurpose Australian Trees and Shrubs; Lesser Known Species for Fuelwood and Agroforestry.* ACIAR Monograph No. 1. Australian Centre for International Agricultural Research, Canberra.

VAN STEENIS, C. G. G. J. 1935. Maleische Vegetatieschetsen. *Tijdschrift van het Koninklijk Nederlandsch Aardrijskundig Genootschaap* Series 2 (52): 26–67, 171–203, 303–198.

VAN STEENIS, C. G. G. J. 1957. Outline of vegetation types in indonesia and some adjacent regions. Pp. 61–97 in *Proceedings of the Pacific Science Congress 8 (4).* Manila, Philippines. Pacific Science Association.

WIRAWAN, N. 1983. *Progress in Management of Protected Areas in Kalimantan and Consequences for Recent Forest Fires.* IUCN/FAO Project 1687 Report. 12 pp.

WIRAWAN, N. 1993. The hazard of fire. Pp. 242–260 in Brookfield, H. & Byron, Y. (Eds.) *The Search for Sustainability.* United Nations University Press, Tokyo.

WOODS, P. 1987. Drought and fire in tropical forests in Sabah: an analysis of rainfall patterns and some ecological effects. Pp 367–387 in Kostermans, A. J. G. H. (Ed.) *Proceedings of the Third Round Table Conference on Dipterocarps.* 1985 April 16–20. Samarinda, Indonesia. UNESCO, Jakarta.

WOODS, P. 1989. Effects of logging, drought and fire on structure and composition of tropical forests in Sabah, Malaysia. *Biotropica* 21(4): 290–298.