THE SECONDARY FOREST SITUATION IN SRI LANKA: A REVIEW

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PERERA, G. A. D. 2001. The secondary forest situation in Sri Lanka: a review. Most forests in Sri Lanka are secondary, are mostly confined to the dry and intermediate zones of the country, and arise out of swidden agriculture. The majority of secondary forests which regenerate after swidden farming in the dry parts of Sri Lanka are grown from vegetative parts, that is from remaining roots and stumps. Secondary forests provide numerous products of importance to local people. They also help to bridge seasonal gaps in livelihoods. Secondary forests of Sri Lanka are being disturbed or transformed by intensive cultivation, fire, the implementation of development projects, the establishment of plantations and by the construction of houses by the local people. Secondary forests in the dry parts of Sri Lanka could be managed as conservation areas for timber production or for multiple use. Regional climate, the ecology of secondary forests and anthropogenic pressures need to be considered when selecting suitable management options for a given site. Most of the secondary forests are heavily degraded and need to be rehabilitated. Intensification towards improved fallow systems or plantations is inhibited by poor site conditions, the threat of destruction by elephants, and insecure tenure.

Key words: Sri Lanka - secondary forests - swidden agriculture - dry zone - vegetative reproduction - degraded forests

PERERA, G. A. D. 2001. Situasi hutan sekunder di Sri Lanka: satu tinjauan. Kebanyakan hutan di Sri Lanka adalah sekunder, terhad di zon kering dan sederhana negara tersebut, dan wujud akibat pertanian ladang. Majoriti hutan sekunder yang pulih selepas pertanian ladang di bahagian kering Sri Lanka tumbuh daripada bahagian vegetatif, iaitu akar dan tunggul yang masih tinggal. Hutan sekunder menyediakan banyak hasil keluaran yang penting kepada penduduk tempatan. Ia juga membantu sebagai mata pencarian antara musim. Hutan sekunder di Sri Lanka telah rosak atau diubah akibat penanaman intensif, kebakaran, pelaksanaan projek pembangunan, penubuhan ladang dan juga pembinaan rumah oleh penduduk tempatan. Hutan sekunder di kawasan kering di Sri Lanka dapat diuruskan sebagai kawasan pemuliharaan untuk pengeluaran balak atau untuk pelbagai kegunaan. Iklim, ekologi hutan sekunder dan tekanan antropogen perlu dipertimbangkan apabila memilih pengurusan yang sesuai untuk tapak yang diberikan. Kebanyakan hutan sekunder berkeadaan teruk dan perlu dipulihkan. Pengintensifan ke arah memperbaik sistem tanah bekas ladang terhalang oleh keadaan tapak yang teruk, ancaman pemusnahan oleh gajah, serta pemegangan yang tidak pasti.

Introduction

Sri Lanka, a country situated in the Indian Ocean with a warm and tropical climate and a total land area of 6.6 million ha (Legg & Jewell 1995), has three different ecological zones (Figure 1). The distinction between zones depends mainly on the amount of rainfall they receive. The dry zone has an average annual rainfall of less than 1900 mm, the intermediate zone of about 1900–2540 mm, while the wet zone has an average annual rainfall of about 2540–5686 mm (Anonymous 1991). Closed natural forest covers 23.8% of the total island area (Legg & Jewell 1995), and most (85%) of it is situated in the dry zone (Perera 1994).

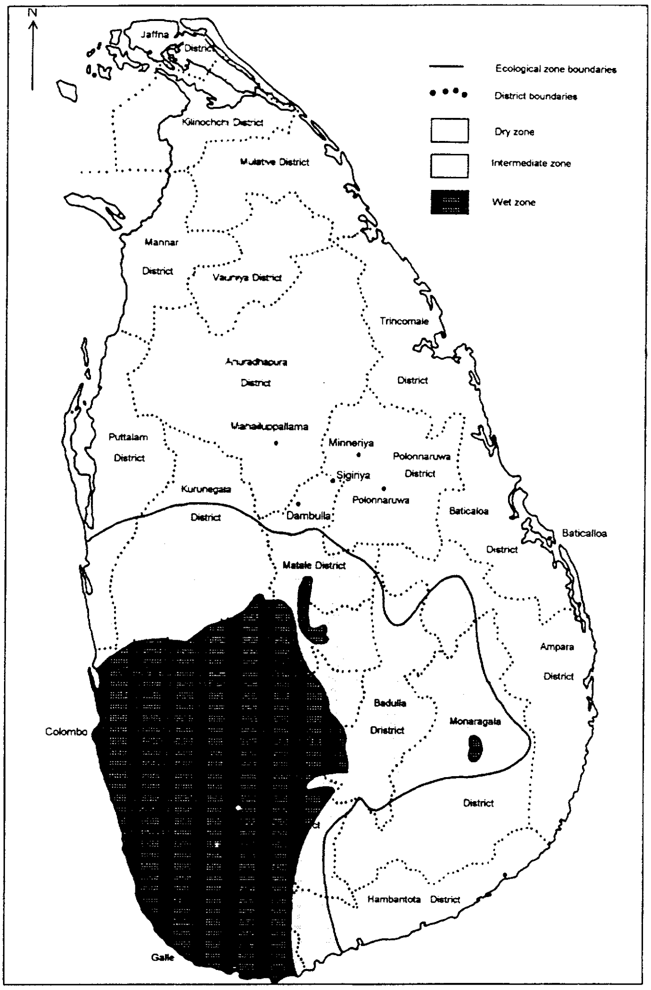

Figure 1 Major ecological zones and districts of Sri Lanka (Source: Survey Department 1988)

Sri Lanka contains a considerable amount of secondary forest. However, information on secondary forests is limited. A few researchers have studied the regeneration of forests after large-scale disturbance or described the ecology of secondary forests (e.g. Holmes 1954, 1956, 1957, de Rosayro 1961, Dittus 1977, Perera 1998). Secondary forests are defined here 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" (Chokkalingam *et al.* 2000).

Most of the secondary forests are situated in the dry zone of Sri Lanka and arise from swidden agriculture (Liyanage 1996, personal observation). In areas where the rainfall is high and well distributed throughout the year, all the land previously used for swidden agriculture has already been converted to permanent agriculture or tree crops such as tea, rubber and coconut. There are also alternative job options and people do not have to rely on swidden farming. As a result, the wet zone of Sri Lanka has a negligible area of secondary forests (Table 1, Figure 1). In areas with high population density and intermediate rainfall, the length of the fallow period of swidden agriculture is between one and three years. Farmers in these areas may use chemical fertilisers to enhance their crop production.

Table 1 Extent of natural and sparse forests in different districts of Sri Lanka in 1992. (See also Figure 1)

District	Total area of district (ha)	Closed canopy natural forests (ha)	Sparse forests (ha)	% of sparse forests to the total forest cover
Ampara	450 031	124 908	41 760	25.1
Anuradhapura	722 178	180 083	116 693	39.3
Badulla	285 673	26 428	27 843	51.3
Baticaloa	263 983	36 493	16 325	30.9
Colombo	68 469	1832	36	1.9
Galle	161 256	19 089	1699	8.2
Gampaha	141 890	409	20	4.7
Hambantota	262 307	24 377	55 077	69.3
Jaffna	107 848	1081	298	21.6
Kalutara	164 391	20 310	1266	5.9
Kandy	192 808	27 241	5980	18.0
Kegalle	168 328	15 446	492	3.1
Kilinochchiya	132 499	32 686	6042	15.6
Kurunegala	489 787	9980	14 766	59.7
Mannar	200 148	113 445	11 762	9.4
Matale	206 050	74 809	9207	11.0
Matara	130 829	19 901	2076	9.4
Moneragala	576 763	182 601	52 569	22.4
Mulativu	260 946	154 332	17 987	10.4
Nuwara-Eliya	174 109	39 646	3273	7.6
Polonnaruwa	344 988	115 881	22 949	16.5
Puttalam	315 485	82 529	17 104	17.2
Ratnapura	327 034	62 357	4491	6.7
Trincomalee	267 991	113 812	17 629	13.4
Vavniyawa	200 835	103 182	16 504	13.8
TOTAL	6 616 627	1 582 858 (23.9% of the total land area)	463 848 (7% of the total land area)	22.7

(Source: Legg & Jewell 1995)

Farmers commonly practise swidden farming in the areas where the rainfall is low and seasonal, and there is much forest cover (Anonymous 1991). Also in this dry zone, there is rapid population increase (Survey Department 1988), lack of alternative job opportunities and inadequate facilities for sedentary agriculture. Most of the rural people in the dry parts of Sri Lanka continue to subsist below the poverty level (Navarathne 1985). Swidden fallow secondary forest regeneration and succession and the related restoration of soil fertility in these areas is slow, and farmers have to wait for at least 10–12 years for the next cultivation cycle. Swidden fallow secondary forests are defined here as "forests regenerating largely through natural processes in woody fallows of swidden agriculture for the purposes of restoring the land for cultivation again" (Chokkalingam *et al.* 2000). The status and condition of these secondary forests depends on intensity of cultivation, length of the fallow period, and intensity of fire, grazing as well as product extraction pressures. These secondary forests may contain some valuable timber species but the regeneration may need to be assisted and managed.

Intensive selective logging of Sri Lanka's natural forests has been taking place since colonial times. Although the government has prohibited logging since 1990, local people continue to practise illegal logging. In these logged-over areas, early and late seral species regenerate on patches, sometimes in combination with a few mature primary forest trees, forming post-extraction secondary forests. Post-extraction secondary forests are defined 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). Remote sensing techniques do not allow for accurate distinction between closed canopy post-extraction secondary forests and mature high forests.

The Forest Department of Sri Lanka considers secondary forests together with other types of open canopy forests and describes all these areas as "sparse forests". These sparse forests include the following subcategories:

(1) Swidden fallow secondary forests.
(2) Post-abandonment secondary forests following abandonment of permanent cultivation. Post-abandonment secondary forests are defined here as "forests regenerating largely through natural processes after total abandonment of alternative land use (plantations, agriculture, pasture, etc.) on formerly forested lands" (Chokkalingam *et al.* 2000).
(3) Post-extraction secondary forests.
(4) Young weed-ridden or fire-damaged plantations.
(5) A few natural scrub forests in very dry areas.

Satellite images showed that Sri Lanka has 463 847 ha of such sparse forests in 1992, amounting to 22.7% of the total area of natural forest (Legg & Jewell 1995). Remote sensing also does not allow for the distinction of different types of secondary forests based on underlying cause of origin. There are no statistics to show the extent of forest cover of each of the above subcategories. The Department of Wildlife Conservation protects 93 748 ha of the area under sparse forests, and the Forest Department protects 942 ha (Forestry Planning Unit 1995). Farmers still practise swidden farming in some of these protected areas as the institutions responsible for protection do not have adequate resources to stop the practice (personal observation).

This paper reviews the secondary forest situation in Sri Lanka and proposes options for managing this resource. The second section of the paper provides a historical perspective on secondary forests. The third section outlines current practices that give rise to secondary forests, their importance and the pressures they face. The last sections describe the ecology and management options for secondary forests.

Origin and management of secondary forests in Sri Lanka: a historical perspective

It is believed that in ancient Sri Lanka before the arrival of the Aryans in 585 B.C., farmers practised swidden agriculture (Anonymous 1991). The Aryans mainly engaged in sedentary agriculture using irrigation techniques and to a minor extent practised swidden farming in remote areas (Anonymous 1991, Nanayakkara 1996). At that time, most of the Sinhalese kingdoms occupied the northern dry zone of the country. The king of Sri Lanka exclusively owned the forest land (Tisseverasinghe 1956, Nanayakkara 1996).

The ancient hydraulic civilisation of the dry zone disappeared after the 12th century as a result of climatic change, malaria, invasions from south India and a famine (Paranavithana 1960, Anonymous 1991). The decline of irrigated agriculture caused demographic shifts from the dry zone to the wet zone. Forests grew back on many of the abandoned irrigated lands (de Rosayro 1961). It is believed that most of the present closed canopy mature forests in the dry zone of Sri Lanka are thus post-abandonment secondary forests regenerated on abandoned irrigated cultivation land. With the passing of time, the irrigation infrastructure decayed because of the lack of proper management and maintenance. Therefore, people who remained in the dry zone turned to swidden farming. Consequently, swidden fallow secondary forests were formed in the dry zone of Sri Lanka (Anonymous 1991).

In ancient times, only a few local people practised swidden farming and the demand for cultivation was not very high. Most of the time, farmers used mature secondary forest or primary forest patches for swidden agriculture and kept the land under long fallow periods (Gunawardena 1993). The long rotations helped maintain the ecological sustainability of the system.

During the British colonial period, the government considered those secondary forests, especially young swidden fallow secondary forests, to be degraded and poor quality forests. As of 1840, the Crown Land Encroachment Ordinance turned swidden agricultural land into crown property. The government took the decision to make them productive by planting timber or plantation crops (Tables 2 and 3). In the dry and intermediate zones it planted exotic timber species (e.g. teak,

Table 2 The extent of plantation forest land in Sri Lanka

Year	Total extent (ha)
1890	365
1952	10 522
1962	21 044
1992	125 000**

**estimated through satellite image analysis
Source: Nanayakkara 1996

Table 3 The extent of major plantation crops in Sri Lanka

Year	Total extent (ha)		
	Tea	Rubber	Coconut
1948	225 000	256 000	433 000
1952	231 000	266 000	433 000
1962	239 000	273 000	466 000
1972	242 000	230 000	416 000
1982	242 000	206 000	416 000[a]
1992	222 000	199 000	416 000[a]
1999	195 000	159 000	416 000[a]

[a]the accuracy of the data has not been confirmed.
Data supplied by the Central Bank, Colombo, Sri Lanka

Honduras mahogany, *Eucalyptus* species) as well as few indigenous tree species. The government also tried the Burmese taungya cultivation system on these fallow lands, especially to grow teak (Perera 1962, Nanayakkara 1996). In the wet zone entrepreneurs established tea, coffee, coconut and rubber plantations on secondary forest lands. Some of these plantations failed and were abandoned and evolved into post-abandonment secondary forests. However, very often, especially in the wet zone, failed plantations were replanted with tea or with exotic fast growing timber species such as *Pinus caribeae*.

After independence, the Forestry Department continued to establish teak plantations on "bare land" under the Co-operative Reforestation Scheme, especially in the dry and intermediate zones of the country. The local people were allowed to cultivate vegetables and cash crops in the plantations for the first three years while looking after young teak seedlings. However, "bare land" to a forester's eye was most probably a young swidden fallow secondary forest to local people. In 1981, the Forestry Department abandoned the Co-operative Reforestation Scheme because of continuous agitation by environmental groups (Nanayakkara 1996) and lack of support from local villagers.

At present there is increased interest from the government, academics and NGOs in forest conservation. Since 1990, the government has imposed a logging ban on timber from natural forests (Nanayakkara 1996). The new forest policy introduced in 1995 emphasises the protection of natural forests for biodiversity conservation and for the perpetuation of environmental benefits. The Sri Lanka Forestry Sector Master Plan (Forestry Planning Unit 1995) has identified six types of degraded lands and it emphasises the necessity of rehabilitating them. The degraded lands include all *patana* grasslands, abandoned and degraded tea estates that were handed over to the Forest Department, degraded rubber plantations, catchments and watersheds devoid of trees, sandy tracts on the coastline and highly degraded scrubland in the dry zone. This last land category may involve both young healthy swidden fallow secondary forests as well as secondary forests disturbed by repeated cultivation, fire or grazing. The perception of secondary forests as highly degraded, unproductive land has not changed and at present government agencies continue to establish new forest plantations on very young fallow forests with many indigenous species such as *Chloroxylon swietenia* (Satin wood), *Chukrassia tabularis* (Hulan Hik), *Azadirachta indica* (Kohomba) and *Berrya cordifolia* (Halmilla). In the wet zone, the private sector continues to cultivate tea, rubber and coconut (Table 3).

Table 3 shows that there is a slight reduction of the land area under tea, rubber and coconut plantations, a result of occupation as living space. Plantation owners have abandoned some tea plantations in the wet zone, especially on steep slopes, because of low soil fertility and resulting low productivity. These areas either remain as grasslands or become occupied by local people for the cultivation of spices (personal communication with the officers of the Central Bank, Sri Lanka). Thus, there has been no silvicultural or other type of management on secondary forest lands of Sri Lanka apart from swidden agriculture or conversion to other land use.

Formation, importance and causes of change of secondary forest

Swidden farming in the dry zone of Sri Lanka and secondary forest

Traditional swidden farmers in the dry zone of Sri Lanka clear a forest area of 8–10 ha in the main dry season (July or August). Usually, 10–12 families cultivate a single site. They allow the vegetation to dry and then burn it prior to the rains of August or September. Farmers sow seeds at the onset of the rains around September–October. The most important crops they grow are *Brassica juncia* (mustard), *Eleusine coracana* (elucine), maize and vegetables. Farmers will harvest their fields towards the end of the rainy season, around January, and then abandon the land for several years. Agricultural weeds (de Rosayro 1961) and the lack of water during the dry season are the major factors that limit continuous cultivation. Wild elephants and other grazing animals often visit abandoned swiddens. At present, in the rural dry zone of Sri Lanka, the fallow period is 12–15 years, but shorter in more densely populated areas.

In addition to swiddens, households independently grow mustard in 0.5–1 ha plots. Farmers also prepare the land for this crop by clearing and burning the vegetation, and they will abandon such lots after cultivating once. In addition to swidden land, most of the farmers have permanent cultivation fields near water reservoirs and streams. They live in separate permanent settlements and do not settle inside their swidden land.

To regulate swidden farming in Sri Lanka the District Government Agent used to issue cultivation permits. Since 1981, this agency has stopped handing out these permits (Ranasinghe 1996), but this has not stopped local people from continuing to practise swidden farming. The government does not collect official statistics on the area under swidden agriculture, while local people are reluctant to give information. The present extent of land occupied by swidden agriculture is therefore unknown.

The importance of secondary forests

Like any natural forest ecosystem, secondary forests provide both tangible and intangible goods and services. Secondary forests contribute to carbon sequestration, the protection of soil and the conservation of biodiversity. They help recover the fertility of soils exhausted by cultivation. Secondary forests also provide many products such as construction timber, small poles, fuelwood, bush meat, honey, medicinal plants, yams and other food (personal observation, Table 4). The use of these products from secondary forests reduces the pressure on high forests. Changing weather patterns, particularly prolonged droughts, make dry zone rain-fed agriculture risk-prone, and often lead to crop failures. In addition, lack of water for irrigated cultivation, threats to permanent crops from wild elephants and inability to afford fertilisers limit crop yields. Then, secondary forests help to bridge seasonal gaps in local peoples' livelihoods. Young fallow secondary forests are also used as grazing grounds for domestic cattle and goats as well as many wild herbivores.

Threats to secondary forests

Activities that reduce the cover of secondary forest are clearance for sedentary or short-rotation swidden agriculture, the implementation of government development projects, intensive cattle grazing and conversion into plantations and other land use types. Fire and the related invasion of grasses, ferns or exotic plant species (e.g. *Prosopis juliflora* in the southern dry forests of Sri Lanka) and cyclones, to a lesser extent, also reduce the area of secondary forests. However, some of the anthropogenic activities are more common in certain areas of the country and may be related to both the ecological environment and the social and cultural background of the local people.

Cultivation of tea, rubber, coffee, coconut or other permanent crops together with intensive timber harvesting resulted in a dramatic reduction of the area of natural high forest cover between 1900 and 1983 (Table 5). The government implemented many development projects in the 1980s and as a result, the destruction of both natural high forests and secondary forests has continued. One of these projects, the Accelerated Mahaweli Development Project, resulted in a loss of 242 820 ha of natural forests, including some secondary forests, within

Table 4 Some forest products harvested from swidden fallow secondary forests of Sri Lanka

Category of secondary forest product	Some examples	Approximate age (in years) of forest	Scale of harvesting
Food	Fruits of *Momordica* sp.	< 3	Semi-commercial
	Leaves of *Wattakaka volubilis*	< 3	Subsistence
	Yams of *Dioscorea pentaphylla*	8–18	Subsistence
	Edible fungi	1–25	Subsistence
Poles	*Pleurostylia opposita*	25–35	Subsistence
	Pterospermum suberifolium	25–35	Subsistence
Construction timber	*Pterospermum suberifolium*	25–35	Semi-commercial
Fuelwood	Many different species depending on availability	forests of all ages	Semi-commercial/ Subsistence
Medicine	*Salacia reticulata*	20–35	Semi-commercial/ Commercial
	Azadirachta indica	10–35	Subsistence
	Cassia fistula	4–15	Subsistence
	Allophylus cobbe	4–30	Subsistence
	Streblus asper	4–30	Subsistence
Others: to make baskets	Canes and rattans	20–30	Semi-commercial/ Commercial
for binding	*Ichnocarpus frutescens*	< 25	Subsistence
to make handles for agricultural tools	*Diplodiscus verrucosus*	20–30	Subsistence

Table 5 Decline in forest cover in Sri Lanka (Nanayakkara 1996)

Year	Area of closed forests (ha)	Area of sparse forests (ha)
1884	5 540 000	*
1900	4 610 000	*
1953	3 295 000	*
1956	2 900 000	*
1983	1 760 000	625 000
1992	1 582 756	463 000

*Data not available

a period of eight years. At present, however, the government has stopped the planning and implementation of such major development projects.

The high population growth in the rural areas of the dry zone of Sri Lanka increased the need for agricultural lands. As more and more people practise swidden farming, the length of the fallow period generally decreases with land scarcity. This may lead to soil deterioration (Bayliss-Smith 1982) resulting in a regressive succession to vegetation dominated by grasses and ferns (Leburn 1936, Riswan & Hartanti 1995). In the dry zone of Sri Lanka, grasses such as *Imperata cylindrica* invade land that has been cultivated continuously for long periods, whereas in the wet zone *Pteridium* sp. and *Imperata cylindrica* invade such lands.

Fire, used with the preparation of agricultural land, very often escapes and spreads into adjacent secondary forests. Due to the frequent burning of the vegetation, deflected succession of secondary forests takes place. Grasses such as *Imperata cylindrica* and *Cymbopogon nardus* and ferns like *Pteridium* sp. thrive on such land. Although cyclones are not very common in Sri Lanka, in 1964 and 1979 cyclones damaged many secondary forests, especially in the dry zone of the country. However, while destroying some secondary forest these cyclones also created new secondary forests with subsequent regeneration.

The ecology of secondary forests in the dry zone of Sri Lanka

Very little research has been performed on the ecology of Sri Lanka's dry deciduous secondary forests. Most of the information on the ecology comes from the author's own research findings. Immediately after the abandonment of the swidden field, the forest regenerates almost entirely by vegetative re-growth rather than from seeds (Perera 1998). The vegetation is therefore very similar to that which existed prior to cultivation (Table 6). All the tree seedlings burn when preparing the swidden. The vegetation in young secondary forests consists mostly of pioneer species that can reproduce from root suckers. A study done at Sigiriya, Sri Lanka reveals that 67% of the species and 57% of the individuals that sprouted immediately after swidden farming are early and late seral species (Perera 1998). Possibly, this secondary forest vegetation has undergone a selection to establish itself by vegetative means as a result of repeated cycles of cutting and burning throughout the recent history.

Typical swidden fallow secondary forest vegetation includes many forest patches at different stages of succession. The structure of swidden fallow secondary forests changes rapidly at the young stages. The principal structural changes include increased canopy height and tree diameter, a stratification of the tree vegetation and a reduction in the number of stems per individual. One can identify several plant associations in secondary forests at different ages of succession (Table 7). However, even within a given age category, the composition of these plant associations may change slightly depending on available soil moisture content (Dittus 1977) and on human or animal disturbances (personal observation).

It is difficult to distinguish a definite plant association in swidden fallow secondary forest younger then three years. The vegetation of such forests depends on the plant species that existed prior to cultivation (i.e. on their light tolerance and sprouting abilities), the nature of the disturbance and the microclimate of the site. After four to five years, *Phyllanthus polyphyllus*, *Croton laccifer* and *Securinega leucopyrus* dominate the vegetation, occurring in dense stands (Table 7). After about 12 to 15 years, thorny climbers such as *Ziziphus oenoplia*, *Lantana camara* and *Catunaregam spinosa* grow luxuriantly and compete with tree species for light, space and water. After about 17 years, many light-demanding shrub species die, leaving behind the trees and shade-tolerating shrubs stratified into two layers.

Table 6 Similarity of species before and immediately after shifting cultivation at Sigiriya area in the dry zone of Sri Lanka. Dominant species and families in the vegetation which composed 75% of the vegetation are given in descending order of abundance. Species and families common to both vegetation types (i.e. the vegetation before and after shifting cultivation) are underlined

Value of Sorenson coefficient		Before shifting cultivation (12–15-year-old secondary forest)	After shifting cultivation (1-month-old fallow forest)
0.759 ± 0.106	Dominant species	<u>*Chromolaena odorata*</u> <u>*Pterospermum suberifolium*</u> <u>*Securinega leucopyrus*</u> <u>*Catunaregam spinosa*</u> <u>*Toddalia asiatica*</u> *Lantana camara* <u>*Grewia damine*</u> <u>*Mallotus philippensis*</u> *Ziziphus oenoplia* *Salacia oblonga*	<u>*Pterospermum suberifolium*</u> <u>*Securinega leucopyrus*</u> <u>*Chromolaena odorata*</u> *Grewia orientalis* <u>*Mallotus philippensis*</u> <u>*Grewia damine*</u> <u>*Catunaregam spinosa*</u> <u>*Toddalia asiatica*</u>
	Dominant families	<u>Euphorbiaceae</u> <u>Asteraceae</u> <u>Sterculiaceae</u> Rutaceae Verbenaceae Rubiaceae Leguminosae	<u>Euphorbiaceae</u> <u>Sterculiaceae</u> Tiliaceae <u>Asteraceae</u>

Source: Perera 1998

Table 7 Common plant associations in dry deciduous secondary forests

Age of forest	Plant associations	Other characteristics
> 3 years	Many resprouted individuals	Many agricultural weed and grass species grow. The soil is exposed to direct sunlight
4–11 years	*Phyllanthus polyphyllus* - *Croton laccifer* - *Catunaregam spinosa** - *Securinega leucopyrus**	Pseudo-canopy appears. Individuals have many stems. *Croton laccifer* grows well in somewhat shady/moist places (Dittus 1977).
12–17 years	*Ziziphus oenoplia** - *Lantana camara** - *Catunaregam spinosa**- *Securinega leucopyrus**	Thorny shrub species dominate the land.
~18 years to old growth forest	*Grewia* spp. - *Pterospermum suberifolium* - *Premna* spp. - *Walsura trifoliolata*	Tree species dominate the forest.

*Shrubs with thorns or prickles

The species (Alpha) diversity in dry deciduous regenerating forests initially increases with succession but decreases slightly at a later stage. It is high in 20- to 25-year-old forests, but low in old growth forests (Perera 1998). Habitat (Beta) diversity increases with time and is high in both 20- to 25-year-old forests and in high forests (Perera 1998). This demonstrates that forests in mid-successional stages have high species and habitat diversities in agreement with Connell's (1978) and Swaine and Hall's (1983) findings for the humid tropics. The higher diversity is partly due to the survival of secondary forest species and partly due to the invasion of new primary forest species, which arrive from seeds brought in by frugivorous animals.

The diversity of plant families is low in young fallow forests but comparatively higher in mature swidden fallow secondary forests. Table 8 shows the dominant families estimated by counting the families of common species which represent 75% of all individuals in a secondary forest area at Sigiriya, Sri Lanka.

Table 8 Dominant families estimated by counting the families of common species which comprised 75% of all individuals. (Families are arranged in descending order of abundance.)

1-month-old	1 year	4–7 years	12–15 years	20–25 years
Once-disturbed	*Once-disturbed*	*Once-disturbed*	*Once-disturbed*	*Once-disturbed*
Euphorbiaceae	Asteraceae	Euphorbiaceae	Euphorbiaceae	Rutaceae
Sterculiaceae	Euphorbiaceae	Asteraceae	Asteraceae	Euphorbiaceae
Tiliaceae	Sterculiaceae	Myrtaceae	Rubiaceae	Annonaceae
Asteraceae	Leguminosae	Sterculiaceae	Sterculiaceae	Rubiaceae
			Verbenaceae	Asteraceae
			Tiliaceae	Sapindaceae
				Sterculiaceae
				Tiliaceae
			Repeatedly disturbed	*Repeatedly disturbed*
			Asteraceae	Euphorbiaceae
			Verbenaceae	Rubiaceae
			Euphorbiaceae	Sterculiaceae
			Leguminosae	Rutaceae
			Rubiaceae	Verbenaceae

Source: Perera 1998

Seed production, dispersal and storage in dry deciduous swidden fallow secondary forests

In recently abandoned swidden agricultural land, many grass and agricultural weed species produce seeds in very large numbers that are mainly dispersed by the wind. Seeds of these grass and agricultural weed species, especially the seeds of the shrub *Chromolaena odorata,* cause a high seed density in young fallow forest soil. Many pioneer species which grow in young fallow forest also produce seeds in large quantities but individuals of late seral and climax forest tree species in such forests may not be mature enough to produce fruits. In contrast, mature secondary forests have some mature individuals of late seral and primary forest species that are able to produce seeds *in situ*. Therefore, mature secondary forests attract many animals and this facilitates the arrival of seeds from outside sources (Perera 1998).

The composition and abundance of the seed rain vary with the age of the secondary forest, and also with the time of the year (Perera 1998). In general, the diversity and density of the seed rain is high in rainy seasons. The soil seed bank also varies seasonally and with the age of the secondary forest (Perera 1998). Spatial variability in seed source, seed dispersal patterns, seed predation, seed germination, loss of viability as a result of the microclimatic conditions, and variable intensity and duration of fire cause clumping of seeds.

The number of seedlings in young secondary forests in the dry zone of Sri Lanka is low, and they consist of few species. Many of them are agricultural weed species with a few individuals of pioneer species. When farmers prepare land for agriculture, they destroy tree and shrub seedlings. In addition, lack of sufficient seed dispersal, unfavourable climatic conditions for seed germination and seedling establishment, high post-dispersal seed and seedling predation explain the low numbers of seedlings. In contrast, some climax forest tree and shrub seedlings grow in mature secondary forests.

Recovery and resilience of swidden fallow secondary forests in the dry zone of Sri Lanka

Studies done in secondary forests suggest that the forest recovers within a 10–12 year period and that secondary dry forests have a high resilience (Perera 1998). Possibly the selection for centuries of species that re-grow after burning and cultivation have resulted in this adaptation to anthropogenic disturbances. This supports Denslow's (1980) hypothesis of disturbance-derived regeneration.

Minor disturbances superimposed on those caused by swidden farming may have different impacts on differently aged forests. The time since last disturbance is the principal factor that affects the forest structure, microclimate, species composition and plant diversity (Perera 1998). Annual burning in young fallow forests may encourage the growth of many agricultural weeds such as *Chromolaena odorata* and grasses such as *Imperata cylindrica* (personal observation). However, minor disturbances of older secondary forests may not result in such a deflected succession.

Management options for dry deciduous swidden fallow secondary forests

The term "forest management" has a broad meaning, ranging from strict forest protection at one extreme to nearly complete forest conversion at the other (Bawa & Krugman 1991). In Sri Lanka, some of the secondary forests are situated within protected areas (e.g. Wasgomuwa National Park) and continue to grow with minimum disturbances. However, most of the secondary forests are still liable to be disturbed by human activities. When considering management options for secondary forests, it is important to remember that the term "secondary forests" is an umbrella term for successional forests at different ages that have been disturbed in different degrees and in different ways. Therefore, secondary forest managers should select management options depending on the age and ecology of the forest, the soil type of the site, the degree of disturbance, as well as impact of present and past human activities. Also, in dry seasonal environments, it is essential to consider the season of the year and the microclimate of the site when implementing management practices.

Some secondary forest management options that are possible in other regions of Asia are not applicable to the dry zone of Sri Lanka. For instance, there are many difficulties with applying improved fallow management. First, farmers abandon swidden land at the beginning of the dry season. It is, therefore, difficult to grow mulch or nitrogen-fixing species due to lack of water. Even when one plants these species at the onset of the rainy season, there is still the risk of unpredictable weather patterns. Second, the resprouting roots and stumps may compete with introduced mulch or nitrogen-fixing species. Finally, the growing of mulch or nitrogen-fixing species will attract large herbivores, including elephants and wild buffaloes. These large herbivores not only destroy mulch or nitrogen-fixing species but are also a danger to local people who collect firewood or other forest products from secondary forests, or they may invade and destroy nearby rice fields. Also, community participation in such activities is low because of insecure tenure rights. Potential options available for secondary forest management in the dry zone of Sri Lanka include managing for conservation, timber production or multiple use.

Conservation management

Secondary forests situated on river banks, on steep slopes and those situated adjacent to natural high forests may need to be conserved for soil and watershed protection. Secondary forests situated adjacent to mature high forests could be conserved as buffer zones. Local people however, would still need rights to extract some fuelwood, medicinal plants and other products for subsistence.

Having some secondary forests near high forests may help in maintaining high wildlife diversity because high forests provide most of the required habitats for wildlife, but secondary forests contain more foods for animals. As Whitmore (1990) stated, pioneer species which are common in secondary forests do have little or no mechanical or chemical protection against herbivores and this may be one reason that most herbivores feed in secondary forests. Also, many early and late seral tree species in secondary forests produce edible fruits in large quantities (personal observation). This leads to the conclusion that conservation management of the forest ecosystem could include some swidden farming to maintain some secondary forests (including 20- to 25-year-old forests) to maximise biodiversity. Areas of secondary forest under such a regime need not necessarily be very large as the species diversity in 20- to 25-year-old forests is high.

Management of forests for multiple uses

Local people use and manage dry deciduous secondary forests. Improving current management practices could increase the value of secondary forests and reduce pressure on primary forests. The Forestry Department could support the management of secondary forest at the village level to achieve an increased supply of multiple products, especially timber, construction poles, fuelwood and medicinal plants. Suitable policies and rules for equitable tenure and cost-benefit sharing are required. Timber and construction poles could be harvested from swidden fallow secondary forests in rotations of 25–30 years, and the sites used for swidden farming after each cycle.

Management of secondary forests for timber production

The forestry community has a growing interest in the production of timber from the long-lived pioneers (late seral species) in secondary forests despite the fact that the timbers are relatively light and lack natural durability (Finegan 1992). There is a high local demand for light timber in the dry areas of Sri Lanka. Many individuals of fast growing light timber species such as *Pterospermum suberifolium* are abundant in swidden fallow secondary forests and applying suitable silvicultural treatments can support their growth. Also, *Chloroxylon swietenia* (Satin wood), which provides class one timber, easily coppices in abandoned swiddens. However, the silviculture of this species needs further study.

As many coppiced individuals have several stems (Perera 1998), timber production in these stands could include removing additional stems, and leaving only the best one. Self-thinning of forest stands takes place after five to seven years. After self-thinning, the stand density of trees of desirable species is not high (Perera 1998). If forest managers carry out artificial thinning after five to six years, a high stand density of desirable timber species could be maintained. Removal of thorny scrub species (*Ziziphus oenoplia, Catunaregam spinosa*) avoids the suppression of trees that normally takes place in 10- to 15-year-old forests. Thinning at the beginning of the long dry period may suppress the re-growth of thorny climbers.

Cleaning as well as protection from fire and from grazing may support the growth of timber species. However, cleaning after self-thinning results in more sunlight reaching the forest floor. Then fire-prone grasses (e.g. *Imperata cylindrica*) increase their presence on the forest floor. This type of stand will need protection from fire for the natural regeneration to survive but this is very costly (Popham, pers. comm.).

Rehabilitation of degraded lands and degraded forests

Secondary regeneration is limited on land subject to continuous or frequent cultivation with short rotations, especially when these forests occur on sloping land (personal observation). Where logging of natural forests has taken place on slopes, pioneer shrub (e.g. *Croton laccifer* and *Ziziphus oenoplia*) and grass species fill the gaps. Such areas will burn easily in the dry season and need some sort of assistance to promote natural regeneration of forest species while protecting them from fire. Most of the native primary forest species would not develop in these open places, even when seeds are provided, as the conditions for seed germination and establishment are not favourable on such sites. In such instances, a mixture of seeds of both pioneer and climax forest species can be used. Pioneer seeds will germinate and establish themselves easily and the seedlings of pioneer species will protect climax forest tree seedlings from strong sunlight.

Degraded secondary forests could be enriched by planting seedlings or sowing seeds of desirable species during the long rainy period. A 20- to 25-year-old secondary forest has a high soil moisture content and low root competition, which are appropriate conditions for enrichment efforts (Perera 1998). When valuable timber species such as *Chloroxylon swietenia* (Satin wood) and *Berrya cordifolia* (Halmilla) are planted or sown in such forests they will most likely do well.

In the dry environment, planting has to be carried out at the beginning of the long rainy period and other measures such as trenching need to be implemented to retain soil moisture and reduce root competition on the site (Holmes 1956). Also, soil erosion has to be reduced on slopes, and the sites protected from fire, grazing and trampling by wild elephants.

However, it must be emphasised that the above-mentioned management options can only be implemented after a thorough survey of the area because, within the dry zone of Sri Lanka, the geography, regional climate patterns, population density and human activities vary from place to place. Consequently, the ecology of secondary forests (e.g. microclimate, species composition and abundance as well as density of healthy parent timber trees) and the patterns of forest regeneration and succession vary. Depending on these variations, suitable management options need to be selected. For instance, secondary forests situated in remote, less populated areas are less disturbed and may have many climax forest species which provide valuable timber. These secondary forests can be improved for timber production. If the secondary forests are situated close to densely populated areas and the people need to use these forests, it is advisable to manage them with the participation of local people to get multiple forest products.

Conclusion and recommendations

Most secondary forests are situated in the dry zone of Sri Lanka and arise from swidden agriculture. There are also some secondary forests arising from intensive logging and the abandonment of permanent agriculture and plantations. Since the colonial time, government officers have considered the young secondary forests of Sri Lanka as bare, unproductive or waste land. Policy makers and scientists tend to undervalue the potential of secondary forests. Such a perception of secondary forests as unproductive land contributes to their destruction and degradation. Secondary forests could be managed for the conservation of biodiversity, or to obtain timber or multiple forest products. Regional climate, the ecology of secondary forests and anthropogenic pressures need to be considered when selecting suitable management options for a given site. However, as almost all of these forests are highly degraded, they need to be restored first to receive productive or protective benefits. New secondary forests could also be developed on degraded lands with assistance. Local participation may be crucial for the success of such efforts and the local knowledge of the rural farmers could be favourably used in formulating necessary policies, and in planning and implementing management practices.

At the same time, it is vital to take actions to prevent the destruction of secondary forests. These include:

(1) Increasing the awareness of the importance of swidden fallow secondary forests.
(2) Policy formulation and implementation for the protection and sustainable management of secondary forests. Measures are required to facilitate income generation from secondary forests and improve the tenure situation for secondary forests.
(3) Exploring alternative livelihood options to reduce local pressures on secondary forests.
(4) Increasing information on the ecology and silviculture of secondary forests.

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

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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.

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