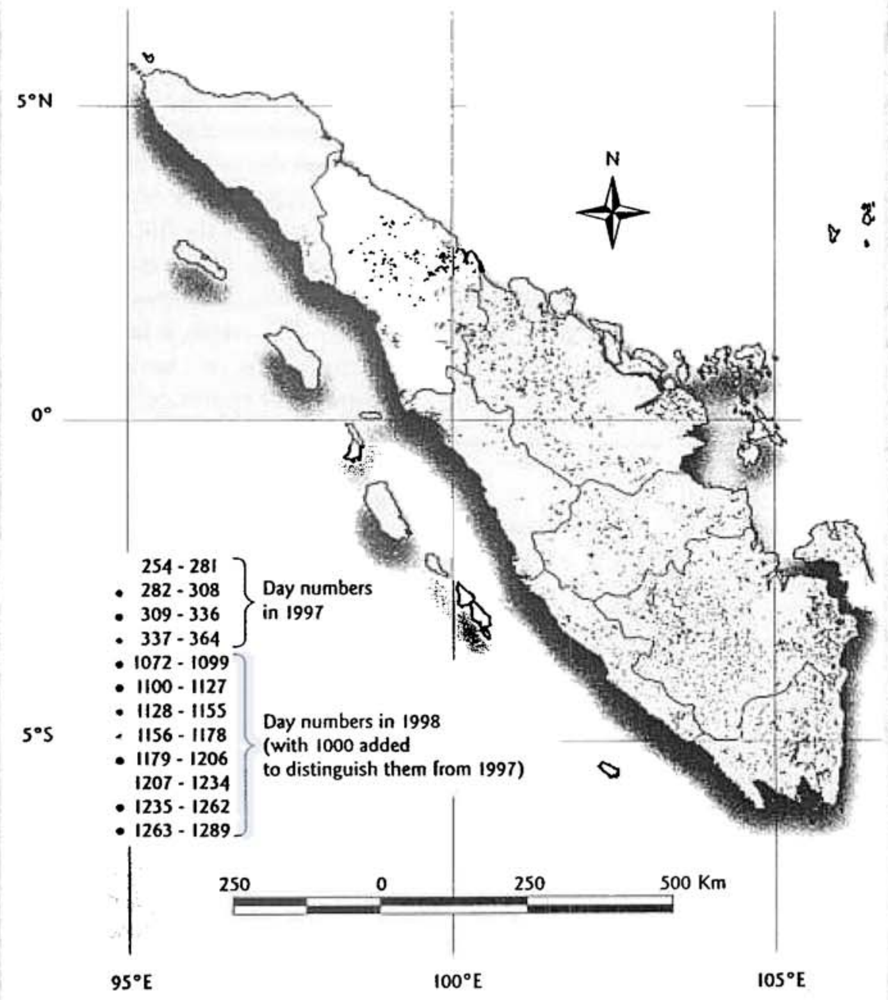
Figure 4. Hot spots in different time periods in 1997-1998.



32,000 hot spots were recorded in Sumatra. Of particular note, the hot spots were very densely concentrated in time (Figure 3). From the 31,500 hot spots recorded from 11 September 1997 onwards, 50% of the total hot spots were recorded in September and October 1997 with more than one-third being recorded in a period of a single week (12-18 October 1997). Rain started in late October in Sumatra, which put out most of the fires. A short drought at the end of 1997 gave rise only to a few fires, since the area was mostly wet and unlikely to burn. In 1998, the normal fire season started again in March until early May (20% of hot spots) and continued from early June onwards (13% of total hot spots). In short, though the El Niño event started in early 1997 and ended in mid-1998 (i.e. it lasted about 18 months), the fires had their major impact in a very short time span of less than a month.

Fires affected different parts of Sumatra at different times (Figure 4). The initial hot spots in September-October 1997 were concentrated in the southern Sumatra provinces of Lampung, Sumatra Selatan and Jambi. In these southern provinces, a total of 11,000 hot spots occurred at the beginning of the drought, representing 35% of the total hot spots recorded in Sumatra in 1997-1998.

In 1998, the hot spots were mainly recorded in the central and northern Sumatra provinces of Riau and Sumatra Utara. For example, the province of Riau (8,000 hot spots in 1997-1998, 25% of the total recorded in Sumatra) contributed much more importantly to hot spot densities in the later stages of the drought (when 60% of the hot spots in Riau were recorded in the period February-May 1998).

The rainfall figures for Palembang (Sumatra Selatar) showed that the drought started in southern Sumatra around June 1997. During the El Niño event, only three rainy days were recorded in the Sumatra Selatan station (Palembang) from mid-June until early November. The fires actually started around mid-August: that is, there were two months of drought before the main fire episode happened. Studies in the Amazon region and in Kalimantan Timur showed that two weeks without rain in logged and secondary forest is enough to dry the vegetation to a point where it is highly susceptible to fire. Unfortunately, this indicative figure is not known for swamp vegetation. But from the data presented here it would seem that about two months is required before the same point is reached in swamp vegetation. The drought caused by El Niño was sufficiently severe to dry all vegetation types to an extent that they were highly susceptible to fire.

For the whole island of Sumatra, the average density of hot spots per unit area of 1 km^2 was 0.064, or 6.4% (i.e. 29,987 hot spots recorded over a total land area of 465,000 km^2). Taking this figure as a reference point, the areas with higher hot spots than average were wetlands, inland swamp, and the eastern coastal strip, each with more than double the average density (Table 2). These are all different land use terms from different data sources referring to the same area, the eastern lowlands of Sumatra.

Areas with lower-than-average fire densities were mountain forest (with different names in different data sources), protected areas (this category includes almost all primary forest areas left in Sumatra), lowland rain forest, and alang-alang (*Imperata cylindrica*) fields. The fire density data for rain forest (lowland as well as mountain) indicate a low susceptibility for fires, even though the lowland rain forest still suffered considerably and contributed significantly to the overall hot spots. Further it is somewhat surprising that the alang-alang fields, a degraded system known to be very susceptible to fire, had such a low fire density. The reason for this is not known. Transmigration sites gave mixed results. In some zones, the transmigration sites had a higher-than-average fire density, in others a lower.

The concessions and timber land use categories had a higher hot spot density, and were clearly a main contributor to the total number of hot spots. In most ecological zones, 'other land use' was the main contributor of hot spots, except in the eastern lowlands. In this zone, 30% of the total hot spots detected during the 1997-1998 fire event were detected in concessions and timber areas.

Table 2. Hot spots in different zones and cover types in Sumatra, from September 1997 to January 1998.

Land use/cover	Number of hot spots	Area (km^2)	Hot spot density Hot spots/Area	Contribution Hot spots/Total hot spots
Montane rain forest	284	31,551	0.9	1
Mountainous area	2,252	151,521	1.5	8
Protected area	1,844	59,606	3.1	6
Lowland rain forest	4,805	122,047	3.9	16
Piedmont	2,956	63,966	4.6	10
Alang-alang	1,297	27,225	4.8	4
Sumatra	29,987	465,000	6.4	100
Mangrove	682	10,031	6.8	2
Western coastal strip	1,515	22,246	6.8	5
Transmigration	2,433	25,943	9.4	8
Peneplain	9,795	103,473	9.5	33
HPH & HTI[a]	13,779	140,481	9.8	46
Wetlands	17,620	112,138	15.7	59
Eastern coastal strip	12,930	81,865	15.8	43
Inland swamp	11,911	64,183	18.7	40

a. HPH – Commercial Forest Concession. HTI – Industrial Forest Plantation

CONCLUSIONS

Analysis of the fire event of 1997-1998 in terms of the spatial distribution and timing of the fires highlights some interesting facts, and enables the event to be placed in a broader perspective of what happened where and when.

Most hot spots were detected in a very brief span of time, with more than 30% of all hot spots of 1997-1998 being registered in a single week. This indicates that the fires must have had numerous ignition points. Given the unlikeliness of numerous ignition points arising from natural causes, it seems probable that the fires were largely human-induced. The question then arises on whether the fires were indeed forest fires – as the term most frequently used during the fire event of 1997-1998 – or whether other cover types burned. The results of the analyses reported here indicate that the fires were not principally located in natural forest areas: protected forest, and lowland and mountain forest, were areas with the lowest fire densities and lowest contribution of hot spots.

If the fires were not natural and not in forested areas, where and why were they set? The cover type with the heaviest burning was in the wetland zone, accounting for more than 50% of the total fires in Sumatra. Within this zone, more than 60% of the fires were in forest-concession and timber-estate areas. Many of these areas would already have been logged by concessionaires and probably consisted of secondary vegetation or smallholder uses like rubber or fruit gardens. Logged forest is well known to be very susceptible to fire since it contains much dead material that easily ignites[20]. This may explain how the fires could burn over such extensive areas, but it does not explain why the vegetation was set on fire, since this happened at so many places at the same time.

Two explanations might be considered. As mentioned earlier, recent years have seen an increased pressure on land and resources in Indonesia, particularly in terms of conversion to oil palm plantations. This demand is still increasing. The change of land use from smallholdings to large estates has also sharpened conflicts between the parties concerned. In this vein, one perception is that although many fires were found on forest-concessions and timber estates, large landholders did not set these fires themselves, but rather that these fires were set by others to settle a land use conflict[21].

The second explanation is that after logging, concessionaires cleared the land by fire in order to start plantations. This is generalized practice in Indonesia, where rapid increase in oil palm plantations in particular has been fuelled by the high profit margins in this sector. More than 2.4 million ha of land have already been converted to oil palm, and the target for the year 2000 has been set at 4 million ha. If one assumes (a) that all the hot spots were a sign of total land clearance for conversion to oil palm, (b) that the fire extent was half the pixel size for each pixel and (c) that no pixel was double counted, then this would account for about 1.5 million ha of land being converted. Such figures underline the enormous extent of the land use change that is happening today in Indonesia.

Transmigration areas have a higher fire density than other land uses or concession and timber estates. However, the transmigration fires were few compared to fires in other land use categories, and contributed less than 10% of the total hot spots in 1997-1998. Though transmigration can indeed be a driving factor of land use change and land use conflicts, its importance in terms of haze and greenhouse gases is limited.

Analysis by ecological regions indicates that the fire situation was very variable in different provinces and in different ecological zones, and it would seem logical that the underlying driving forces were also different in different provinces and zones. In this respect – and also because at least 50% of the fires took place elsewhere than in forested areas – the term 'forest fire' does not describe adequately the area under fire. The other widely used term ('wild fire') would also seem inappropriate, since it would suggest that the fires happened accidently, which seems highly unlikely.

The Indonesian economy is on the move, which brings with it many changes in itself. Among the changes in land use is that associated with the replacement of smallholdings by large plantations. Although the profits go mainly to a few large investors, it is not yet clear if these plantations also contribute to an increase in wealth of the area itself. With the targets of land conversion to oil palm set, it would seem that the El Niño drought was not the 'reason' for the extreme fire situation, but rather presented a convenient opportunity to convert in a single season what would have been converted anyhow in the seasons to come. Within such a perspective, the term 'development' fires might be a more adequate term than the term 'forest' or 'wild fires' to describe the extensive fires of 1997-1998.[22]

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