

# Fires In Tropical Forests – Throwing Good Money After Bad?

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## Abstract

In recent decades, the spectre of fires has loomed large and created surges of concern, of interest, and of alarm. This has been particularly evident in parts of South East Asia and the Amazon, but fires have drawn attention worldwide not least in the recent summers in Australia, Europe, and the United States.

In the tropics, concern about forest fires, and related air pollution and biodiversity impacts, has lead international organizations and Northern countries – such as the Asian Development Bank, the European Union, FAO, UNEP, The World Bank, and Germany – to prepare global, regional, and national fire assessments and to provide technical assistance. NGOs, such as IUCN and WWF, have also been devoting increased attention to fires.

Lack of clarity about “fire problems” have at times lead to the adoption of policies that could have negative impacts on livelihoods, the environment and the economy.

Two ‘simple’ changes in the way fires are considered would improve significantly fire-related policies and initiatives:

- fires should be seen as a component of land management processes – and at times as part of land use changes – that can have positive and/or negative impacts, rather than as a “problem” to be prevented, suppressed, or mitigated;
- not all fires are the same! Fires in ENSO (El Niño Southern Oscillation) years often have different causes and impacts of fires in non-ENSO years; forest fires often have different impacts (and sometimes causes) of peat fires.

These two points are discussed in the context of South East Asia, and particularly Indonesia, as a practical example of the problems and questions faced by tropical countries. Aiming to prevent future fires, 40 fire projects and missions costing well over US\$ 30 million have worked in Indonesia over the last 20 years. Despite the money and effort spent on them, fires continue to burn every year. It may appear to some that efforts to address the “fire problem” have not been effective as fires still occur. We argue that those efforts have generated increased knowledge of the “fire problem”; now, we need to capitalize on that knowledge to avoid wasting money in the future.

The forest-fire exploitation cycle and its relevance to South East Asia is recalled. What are (and are not) fire related problems is discussed with the focus on the impacts caused by fires and land use changes. Whether the impacts should and could be tackled is helped by a clarification of the causes of the fires. Despite an improved understanding of the problems, there is still a need for further information and data gathering as well as research. However, several possible initiatives to address fire-related issues are identified on the basis of existing knowledge.

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In recent decades, the spectre of fires has loomed large and created surges of concern, of interest, and of alarm. This has been particularly evident in parts of South East Asia and the Amazon, but fires have drawn attention worldwide not least in the recent summers in Australia, Europe, and the United States.

In the tropics, concern about forest fires, and related air pollution and biodiversity impacts, has led international organizations and Northern countries – such as the Asian Development Bank, the European Union, FAO, UNEP, The World Bank, and Germany – to prepare global, regional, and national fire assessments (eg Qadri, 2001; FAO, 2000; Cochrane, 2002) and to provide technical assistance. NGOs, such as IUCN and WWF, have also been devoting increased attention to fires.

This increased interest in, and funding for, fire-related initiatives has generated improved knowledge about fires. However, there is still a lack of understanding of “fire problems” and what should be done to address them. This lack of clarity and the “heat and hype” (Sierra Club 2002) generated by large-scale fire events have at times led to the adoption of policies (such as legal bans on all fires in some Asian and African countries) that could have negative impacts on livelihoods, the environment and the economy (eg Laris 2002).

Two ‘simple’ changes in the way fires are considered would improve significantly fire-related policies and initiatives:

- fires should be seen as a component of land management processes – and at times as part of land use changes – that can have positive and/or negative impacts, rather than just as a “problem” to be prevented, suppressed, or mitigated;
- not all fires are the same! Fires in ENSO (El Niño Southern Oscillation) years often have different causes and impacts of fires in non-ENSO years; forest fires often have different impacts (and sometimes causes) of peat fires.

We discuss these two points in the context of South East Asia, and particularly Indonesia, as a practical example of the problems and questions faced by tropical countries. We do not imply that the situation in other countries will be the same as that discussed below. The analysis of the situation in Indonesia is presented as an example of the work that needs to be done in other countries to understand their own specific conditions and problems.

Aiming to prevent future fires, 40 fire projects and missions costing well over US\$ 30 million have worked in Indonesia over the last 20 years. Despite the money and effort spent on them, fires continue to burn every year. Therefore, it may appear to some that efforts to address the “fire problem” have not been effective. Those efforts, however, have improved the knowledge basis about “fire problems”. Now, we need to capitalize on that knowledge to avoid wasting money in the future.

The scene is set by providing an overview of recent investments in fire activities in Indonesia. Then, the thousand year old cycle of forest-fire exploitation and its relevance to South East Asia is recalled. Within in this cycle, communities, states and companies have used forests in the process of development, sometimes changing their ecological structure, other times clearing them. We then discuss what are (and are not) fire related problems. The focus in addressing them should be on the impacts caused by fires and land use changes. As the impacts are better understood, whether they should and could be tackled is helped by a clarification of the causes of the fires. Despite an improved understanding of the problems, there is still a need for further information and data gathering as well as research. This is discussed before concluding with the identification of several initiatives to address fire-related issues on the basis of existing knowledge.

## **Investment patterns in fire management**

The 'Great Fire of Borneo' in 1982-83, and those in 1987, 1991, 1994 and then 1997-98, sometime referred to as 'mega-fire events', stimulated a wide range of responses. Assistance to Indonesia consisted of assessment and investigation missions, emergency support, technical aid and equipment and training as well as expertise and management assistance (Dennis 1999). The range of efforts constitutes a logical response incorporating the advantages and focus of those undertaking it.

Dennis (1999) identifies that projects on fires are generally in response to significant fire events. The trans-boundary smoke, widespread fires and large economic costs combined with local and regional scale impacts 'strongly suggest a problem'. Before 1994 there was a sense that the fires were a one-time event and related to weather and climate conditions. Following 1994 there was a recognition that the fire related issues were more complex than shifting agriculture and weather and involved commercial companies, land use changes and perhaps climate. Consequently projects began to include these wider issues as well as the basic needs of firefighting. This change reflects a shift from a mainly fire fighting response to one especially focused on determining the underlying causes of fires and their impacts. Of the 35 projects listed, 19 focussed on fire fighting capacity, reflecting the initial thinking that inadequate technical knowledge and resources were the problem while 6 focused on improved understanding of underlying causes only. Ten projects of 35 sought to improve understanding as well as deal with the practicality of fire fighting. This range of projects covered the full spectrum of fire management.

Despite the international efforts, very little of the analysis undertaken resulted in governments taking clear steps to manage future fires (Byron and Shepherd 1998). A series of apparently sound recommendations generated by some of these efforts have remained largely unimplemented. We suggest this is similar to the circumstances in other tropical parts of the world. The following discussion of "fire problems", their impacts and causes will shed light on this apparent lack of action, as well as providing guidance for future activities.

## **The forest-fire exploitation cycle**

For some ecosystems fire is very important. In the wet tropics, however, fire is almost always an ecological disaster. Tropical rain forests in their undisturbed state are nearly 'fire proof'. The vegetation layers keep moisture in and wind and heat out. Conditions for destructive fires do not develop. However, when the canopy is opened up (for example due to logging or roads) sun and heat enter the forest, moisture escapes and the forest dries out. As tropical forests are opened up for logging and road construction, they not only lose their natural defence against fire, but logging residues and dead wood is left behind in the forest, providing fuel for future fires. After a forest is burnt, more light and space is available for grasses and other vegetation to grow on the forest floor. This vegetation dries out more quickly and easily burns, creating a cycle rendering the forest ever more inflammable. If this cycle is not interrupted, the forest may completely disappear and grasslands or other vegetation replace it (Nepstad 1999; Byron and Shepherd 1998).

While pristine rainforests may be almost fire proof, 'it is increasingly difficult to think that any forests, from the tundra margins to the tropics, were ever pristine and untouched' (Williams 2003, p. 14). For millennia until today humans have used, burnt and cleared forests for subsistence and commercial activities. Williams (2003) notes that fire was the force that allowed humans to accomplish the first great ecological transformation of the Earth; only the development of agriculture and animal husbandry 10,000 years ago, and the industrial revolution 200 years ago caused ecological changes of a similar magnitude. Globally, the area of forest cleared before 1950 still exceeds the area cleared since then (Williams, 2003). This applies particularly to areas such as Europe and North America, but in areas experiencing recent and rapid economic growth, such as South East Asia, the pace of forest clearance has

picked up since 1950. In Indonesia, forests covered some 162.3 million hectares or 84% of the land in 1950, and had decreased to about 95.6 million hectares or 50% of the land by 1997 (FWI, WRI, GFW 2002). Other countries, such as the Philippines and Malaysia, went through a rapid deforestation phase with associated smoke and haze emissions earlier than Indonesia, with historical records showing that Peninsular Malaysia saw wide-scale forest burning in the two rubber-plantation booms of 1905-6 and 1909-10 (Potter, 2001).

Fire in tropical countries such as Indonesia is best seen as a component of land management processes – and at times as part of land use changes – rather than as a problem to be prevented, suppressed, or mitigated. The obvious implication is that when fires are used intentionally to change the land use, fire fighting is irrelevant unless there are unwanted fires, eg unintentionally escaped fires. Of course, as discussed below, drought conditions contribute at times to unwanted fires.

### **Fire problems in Indonesia**

It is misleading to think about ‘fires’ as the policy problem. The impacts of fires are the problem. Not recognizing this has two significant implications:

1. There is a risk that all fires are perceived as problematic rather than considering in what circumstances fire may be an appropriate land management tool;
2. We might lose sight of the fact that fires may have differentiated impacts (eg according to the location and impacted areas) that require different policies to be addressed.

In Indonesia there are two major fire-related policy problems:

- smoke haze pollution, including carbon emissions, and related impacts;
- forest degradation and deforestation, including the loss of products and services, including timber, non-timber forest products, biodiversity, soil erosion and flood control.

### ***Smoke haze pollution***

Smoke haze pollution from fires has affected Indonesia and South East Asia since at least the late 1800s (Potter 2001). In recent years peat land fires have been identified as the major source of smoke haze pollution. In Indonesia, peat land fires may have contributed between 60% and 90% of the emissions resulting in smoke haze in 1997/98 and were also the major source of carbon emissions (BAPPENAS-ADB 1999). In 1997, the main contributors to smoke haze pollution were fires in the peat lands areas of the degraded South Sumatran wetlands and in the peat lands of the “One Million Hectare Rice Project”, Central Kalimantan, initiated by the government in 1996. Fires in the peat lands of Jambi, Riau, and West Kalimantan (linked to plantation and small-holder activities) also contributed to the smoke haze, but to a lesser degree. The total area of peat and swamp forest burnt amounted at least to 624,000 ha in Sumatra, 1,100,000 ha in Kalimantan, and 400,000 ha in West Papua (Table 1).

Peat land fires in plantations of oil palm and timber occurred in 1997, but they also recur regularly in non-ENSO years, when they are probably the main source of smoke haze in Riau and Jambi provinces. Unfortunately, no data is yet available on the average areas burnt on an annual basis for plantation purposes and their potential impacts.

Other problematic peat land fires are found in peri-urban areas. They are lit on an annual basis for agricultural purposes on shallow peat land that has already been converted to agriculture. These fires cause local smoke haze problems that can negatively affect health and disrupt transportation, business and schooling. Fires typical of this group are annual fires around Pontianak, and other towns in Kalimantan and Sumatra. In this case as well there is no data on their extent and impact.

Smoke haze pollution has significant impacts on human health and the environment. During the 1997/98 ENSO event, an estimated 35 million people were affected by higher than

normal pollution levels (Glover and Jessup, 1999), with hospitalization estimates ranging from 19,000 patients (BAPPENAS-ADB 1999) to 267,000 cases (Glover and Jessup 1999). Carbon emissions from peat fires have been estimated in the range of 442 million tonnes (Tacconi 2003) to 810 million tonnes (Page et al. 2002). The lower bound estimate is equivalent to about 27% of the average annual global emissions from land-use change over the period 1989-1995. Health costs for the region were estimated at US\$ 147-289 million, and carbon emission costs at US\$ 2.8 billion for the lower end estimate (Tacconi 2003). These impacts occurred during one of the most significant ENSO events of the 20<sup>th</sup> century. The impacts of smoke haze in non-ENSO years have yet to be assessed.

Table 1. Fire affected areas in 1997/98 (hectares)

| Vegetation type       | Sumatra        | Java          | Kalimantan     | Sulawesi      | West Papua     | Total           |
|-----------------------|----------------|---------------|----------------|---------------|----------------|-----------------|
| Montane forest        |                |               | 213194         |               | 100000         | 313194          |
| Lowland forest        | 383000         | 25000         | 2690880        | 200000        | 300000         | 3598880         |
| Peat and swamp forest | 624000         |               | 1100000        |               | 400000         | 2124000         |
| Dry scrub and grass   | 263000         | 25000         | 375000         |               | 100000         | 763000          |
| Timber plantation     | 72000          |               | 883988         |               |                | 955988          |
| Estate crops          | 60000          |               | 382509         | 1000          | 3000           | 446509          |
| Agriculture           | 669000         | 50000         | 2481808        | 199000        | 97000          | 3496808         |
| <b>Total</b>          | <b>2071000</b> | <b>100000</b> | <b>8127379</b> | <b>400000</b> | <b>1000000</b> | <b>11698379</b> |

Source: Tacconi (2003).

### *Forest degradation and deforestation*

The Indonesian fires of 1997/98 generated considerable international attention. This was not only because of the smoke haze generated but also because it was perceived the fire caused the economic and ecological losses associated with degradation or deforestation of the areas affected. Little attention was paid to the fact that fires were mainly affecting secondary logged-over forest rather than 'pristine' forest. Land clearing fires in plantation areas were also criticized as perceived to be contributing to forest loss.

In relation to problematic wildfires, those of East Kalimantan in 1997/98 are the most glaring example. The over 2 million hectares of forest burnt in East Kalimantan (about 60% of the total lowland fire-affected forest in Indonesia) were all categorized as degraded lowland forest.<sup>1</sup> East Kalimantan was also the area most severely affected by the ENSO related drought at the national level, and indeed one of the most affected on a global scale.<sup>2</sup>

Arson fires are obviously considered a problem. While they are at times described also as 'conflict fires', they should perhaps be considered as 'livelihood induced fires', as these deliberately lit fires are an attempt to reacquire, or access for the first time, land resources needed for livelihood purposes. While they may be problematic from the perspective of the party controlling the resources affected, they are beneficial to those who ignite them. In 1997/98, fires from arson affected established plantation areas and national parks. The data available are scarce and we are unable to say if these fires affect more than a few thousand

<sup>1</sup> Spatial data from the Integrated Forest Fire Management Project (GTZ).

<sup>2</sup> Let us note that in this paper wildfires means anthropogenic fires, possibly started for a specific purpose or accidentally, that burn out of control, hence unwanted on that scale. Accidental ignition, hence accidental fire, refers to ignitions that are not deliberate acts.

hectares as recorded for plantations (Gouyon 1999) and national parks (Suyanto et al. 2000) in Sumatra.

There are also fires that should not be regarded to be problematic. Land clearing fires to establish plantations are in this category, unless they generate significant smoke haze, ie are on peat land. Plantation fires represent the most obvious example of the need to consider fire issues in the context of land use processes. These fires are used to clear land allocated to a land use alternative to natural forest. Therefore, the fires themselves are not the cause of deforestation. The 1997/98 fires in Sumatra, Sulawesi, West and Central Kalimantan, and West Papua appear to have been largely in land clearing areas (Tacconi 2003).

The net impacts on forests of wildfires that occur in ENSO years are difficult to assess, because statistics of areas of fire-affected forest in non-ENSO years are not available. However, it is possible to make a rough assessment by considering the annual deforestation rate as a benchmark. This is estimated in the range of 1.7-2 million ha (FWI, WRI, GFW 2002). Given that about 6 million hectares of forest were burnt in 1997/98 (Table 1), some 4 million hectares of forest above the annual average were burnt during that ENSO event. The economic losses relating to burnt timber, loss of future timber growth, and non-timber forest products have been estimated in the range of US\$ 1.25-1.93 billion, and the losses relating to flood protection, soil erosion and siltation, and biodiversity in the range of US\$ 0-340 million (Tacconi 2003).

### **The causes of fire-related problems in Indonesia**

The causes of problematic fires are often complex and interlinked. They can be summarized in five main categories:

- i) Environmental conditions;
- ii) Livelihood, financial, and economic interests;
- iii) Bad governance;
- iv) Lack of knowledge; and
- v) Accidental ignitions.

The fire events of 1972, 1982-83, 1987, 1991, 1994 and 1997/98 occurred in ENSO years. The contribution of environmental conditions to wildfires is therefore obvious. Of course, this does not imply that just environmental conditions in themselves caused the fires. Rather they represent a necessary but not sufficient cause of large-scale fire events.

Livelihood activities in swamp and peat areas, such as agriculture, fishing and turtle hunting, appear to be responsible for deforestation and smoke haze in 1997/98 in the Mahakam area in East Kalimantan (Chokkalingam et al. 2001), and in the Danau Sentarum area in West Kalimantan (Dennis et al. 2000a). Smoke haze in the Mahakam area is also reported in the historical records dealing with the droughts of the late 1800s (Potter 2001) showing how ENSO and livelihood combined to generate smoke haze pollution well before the establishment of modern commercial activities in Kalimantan.

A combination of lack of knowledge, financial and economic interests, and more recently livelihood activities created the worst peat and swamp fires of South Sumatra in 1997/98. They were responsible for a significant share of the smoke haze pollution over Sumatra and Peninsular Malaysia. Logging concessions were first allocated starting in the 1970s. The concessionaires exploited the forest, and people started moving in. Most of them moved voluntarily, but some also arrived under the transmigration program. To ensure the long-term prevention of fires would, at that time, have required the capacity to foresee that logging operations were not going to operate sustainably, although this should have been a straightforward conclusion given the standards of logging operations in Indonesia. Long-term prevention of fires would have also required recognizing that once people had moved in after logging, they were going to adopt livelihood practices in drought years that result in large-

scale escaped fires in peat lands.<sup>3</sup> It is obvious that this would have required a great deal of foresight.

Bad governance, environmental and livelihood causes have been at the root of the worst case of peat land fires in Indonesia and probably globally, the “One Million Hectare Rice Project” in Central Kalimantan. The Indonesian Government had environmental impact assessments showing that the scheme was not feasible. However, former president Suharto personally supported it. The decision to implement the project was deeply rooted in the political economy of the forest sector rather than based on rational-technical reasons. Bad governance dominated this land use decision that led to the unsustainable development of a peat land area that made it prone to fires. In more recent years, the area has come under increasing settlement pressure and small-holder land clearing fires. There are also fires apparently associated with illegal logging. All these generate smoke haze on an annual basis, which becomes particularly critical during ENSO years.

Financial interests drive peat land fires for land clearing in plantations of oil palm and timber that reoccur on an annual basis, even in non-ENSO years, when they are probably the main source of smoke haze in Riau and Jambi provinces, often drifting to Singapore and Peninsular Malaysia. In ENSO years, the smoke haze problem is aggravated by the increased dryness of the peat. In Indonesia, forest clearing to establish timber plantations on peat soil is estimated to cost \$US/ha 180 with burning, whereas “zero-burning” methods (ie mechanical clearing) may cost up to \$US/ha 817 (Gouyon and Simorangkir, 2002). Bad governance, ie lack of law enforcement, could also be said to cause clearing fires on peat land. The Indonesian legislation bans all land clearing fires but it is not enforced even in regards to peat areas that clearly generate significant pollution.

The economic interests possibly driving the actions of the Government of Indonesia can be discussed in the context of the estimated costs of the 1997/98 fires. If preventing the fires in East Kalimantan implied maintaining the forest in its ‘pristine’ state, this would have required forgoing decades of log production. Official log production in East Kalimantan over the period 1969-97 was about 172.7 million cubic metres (data from Hinrichs and Solichin 1999). The net present value<sup>4</sup> of those logs in 1997 was roughly US\$ 25.4 billion. To err on the conservative side, it may be assumed that the value of the timber produced in the area burnt is equivalent to one quarter (ie about US\$ 6.3 billion) of the total production, which is the ratio of the area burnt to total forest in logging concessions. Comparing the net value of log production with the costs of the fires in East Kalimantan, estimated at a maximum of about US\$ 1.7 billion (Tacconi 2003), shows that it may not be desirable from a national economic point of view to maintain ‘pristine’ forests in order to avoid the costs of fires.<sup>5</sup>

Accidental causes are said to contribute to fires particularly during ENSO years, but their potential contribution is difficult to assess due to lack of data. Only BAPPENAS-ADB (1999) reports data showing that community members in Riau (46% of respondents) and East Kalimantan (15%) thought that dry peat areas were vulnerable to discarded cigarette bats during the long drought. Byron and Shepherd (1998) dismiss accidental sources of ignitions, but Vayda (1998) cautions against that, at least until more information is available.

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<sup>3</sup> See Dennis et al. (2000b) for a description of the area and some of the fire issues.

<sup>4</sup> The net present value at 1997 was calculated by multiplying the volume of logs produced in year ‘t’ by the net value of logs (US\$ 28, the minimum net value used in the estimates of timber loss by ADB study) and compounded at a rate of 10%.

<sup>5</sup> It has been noted above that bad governance has affected forest management during the Suharto period. This example does not imply that forest management decisions were made on a rational economic basis. It shows what the incentive structure would be, ‘if’ a rational economic approach were adopted.

The preceding analysis has considered the situation in Indonesia to clarify some of the perceived problems, impacts and causes, thus exemplifying the analysis needed to understand “fire problems”.

To summarize, fires are a component of land management processes. In tropical countries, fire is often used to carry out land use changes. There are also situations in which fire affects land use, but not in a planned, or rational way, rather it has impacts distributed over long periods of time, in an unregulated fashion, linked to multiple causes. Fire can have positive and/or negative impacts, and it is not just a “problem” to be prevented, suppressed, or mitigated. It is obvious that not all fires are the same. Wildfires in ENSO years can be expected to have more significant negative impacts of wildfire in non-ENSO years, and forest fires often have different impacts (and sometimes causes) of peat fires.

## **Improving knowledge about fire problems**

### ***Country studies***

Country level studies are required to improve the understanding of fire issues in most tropical countries. Global and regional reviews (eg FAO, 2000; Cochrane, 2002) have improved existing information about individual countries, but more in depth studies are needed to understand whether fires are problematic and what should be done in each country. These studies would seek answers to questions such as the following:

- ❖ Is people’s health negatively affected?
- ❖ Is biodiversity threatened, protected or even stimulated?
- ❖ Do fires save or cost money, at the individual, company and national level?
- ❖ Who benefits and who loses? And who has power to affect change?

### ***Fire data***

Consistently collected data over time will help in improving comprehension of “fire problems”. Nepstad (2002) notes that the need is first to quantify and systematize field observations to understand why fires are lit and which fires are fought. This is a critical effort that with some exceptions is yet to be undertaken. Reliable data on the numbers of fires, area burnt and the averages across the years are infrequently available for most countries in the tropical forested regions of the world.

The data needed include information such as: When did the fire start? Where did the fire start? When did the fire finish? How large is the area burnt? What ignited the fire? Well-collected data can identify the geographic focus, the major land uses, the key fire users and the timing of fires. Supported by this basic data, a stronger delineation between fires that are wanted and those unwanted can be made.

### ***Ecological, economic, and social research***

To develop policies aimed at reducing future risks and negative impacts of fires during ENSO events, it is necessary to assess both the ecological and socio-economic factors contributing to increased fire risk in the relevant forest ecosystems, particularly in areas that are identified as protected or production forests.

There needs to be systematic assessments of the characteristics of fuels, weather and ignition sources, and the fire behaviour they generate. Researchers, institutions and organisations with land management responsibilities should collect the data necessary, analyse it and work through the implications for fire fighting structures and arrangements from the local level to the national and perhaps trans-boundary scales.

## **What should be done to address fire problems?**

It is always ideal to have as much information and knowledge as possible. However, perfect information and knowledge are never available. Therefore, after having indicated above areas for further research, we discuss some practical initiatives aimed at addressing “fire problems”.



### ***The role of fire fighting***

The visible symptoms of fires readily reported are the flames and smoke. External actors, and often local and national actors, assume that the extensive and persistent nature of the fires arises from the lack of equipment, training, infrastructure and organisation for fire suppression. The response by donors and national governments, consistent with this understanding, is then to supply, suggest or seek additional fire fighting capacity. In many cases this suits donors, organisations and the private sector. The response is simple, demonstrable and involves supply of highly visible support for which there is often a domestic source of willing expertise readily available.

Currently, fire management in South East Asia, as in other parts of the world, is almost exclusively a government effort and focuses more on fire suppression than on fire management strategies that balance preventing fires, preparing for fires, fighting fires and restoring damage. Much of this emphasis is based on the perceptions of fire from outside the tropics. The assumption that the fires are uncontrolled wildfires that threaten lives and destroy infrastructure in dramatic circumstances appears generally unfounded. Additionally, firefighting is strongly limited in its effectiveness, is expensive, difficult to implement and addresses only the symptoms. Further investments in fire fighting should therefore be considered carefully. Such investments are likely to be appropriate in situations and locations where fires are mainly accidental and not linked to the forest-fire exploitation cycle.

### ***Supporting research capacity***

In developing countries, forest fire scientists are few, mainly un-supported and a relatively recent addition to the research fraternity (Nepstad 2002). Their research is in the very early stages of its evolution and represents a very small proportion of the fire research being published. For the International Wildland Fire Conference, Sydney 2003 papers from developing country scientists and practitioners number 47 (from 17 countries) with 234 from 14 developed nations (International Wildland Fire, 2003). Supporting the improvement of fire research capacity in tropical countries should be a priority. This investment would itself pay off handsomely, as increased research capacity would contribute to on going identification and monitoring of fire problems and it would save a great deal of investment in fire management activities focused on the wrong problems.

### ***Reducing smoke and haze pollution***

Smoke haze pollution is a significant problem in South East Asia, and Indonesia is the major source of that pollution. It deserves therefore special attention. Peat lands cover 11-16% of Indonesia's landmass (Bellamy 1997), but when they burn, produce about 60-90% of smoke and haze, including carbon emissions. This knowledge suggests focusing efforts on the peatlands, where it will be most effective in reducing or preventing smoke haze pollution.

In ENSO years, degraded peat lands are probably the most significant risk factor for the generation of smoke haze. Their management and eventually their regeneration and restoration may be required to avoid significant events of air pollution. The costs and the viability of this policy need to be ascertained, and compared with the expected benefits (ie improved economic production, positive environmental benefits, and avoided environmental costs). In non-ENSO years, a reduction in peat fires from land clearing in plantations would reduce considerably smoke haze pollution. A decision to introduce policies aimed at effecting that reduction requires an assessment of its health, environmental, and economic implications. It was noted above that the use of "zero-burning" methods on peat lands might not be financially attractive to companies and an incentive system would have to be designed if a reduction in smoke haze pollution was warranted.

### ***Improved logging practices***

Ecological studies show a positive feedback between logging, forest fires, fuel loading, and future fire susceptibility. Therefore, forest management practices such as reduced-impact logging minimize fire susceptibility in areas prone to droughts. However, it needs to be understood that improved management practices reduce fire risk to a greater extent in areas completely controlled by the concessionaires, ie with limited human presence. Also, reduced-impact logging results at times in “reduced-income logging” (Putz et al. 2000), thus financial incentives and enforcement activities would have to be put in place.

### ***Improving governance***

Improving governance may seem an issue far removed from fire management. We have seen that in some cases livelihood, financial, and economic interests might be favouring fires. Bad governance means that fire prevention and suppression may not eventuate even in situations where these interests would favour them. Forest management, including fire management, is above all affected by the governance system. Efforts directed at improving forest governance, and which embrace the whole forest sector and integrated fire management approaches, are the initiatives best placed to have real and lasting impacts on “fire problems”.

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