CHAPTER 2

Forest Fires and Haze in the ASEAN Region

[This chapter focuses on forest fires and haze in the ASEAN region, and provides a detailed analysis of the causes and constraints that exacerbate these problems. Forestland conversion involving uncontrolled use of fire has been identified as a prime cause and source of forest fires. The social, economic, and environmental impacts of the recent forest fires and haze have been enormous, with the estimated total cost of the 1997-1998 occurrences alone amounting to $9.3 billion.]

The Background

Nearly half of the ASEAN[6] region is covered with tropical forest, accounting for about 6 percent of the forest area of the world. The region's forests have global significance in terms of biological diversity (FAO 1999a). ASEAN is an important timber producing region (particularly of tropical hardwoods), accounting for 6 percent of the world's industrial roundwood production. More than 85 percent of this comes from Indonesia and Malaysia. These two countries are major producers and exporters of wood-based panels (mainly plywood), together accounting for 34 percent (in value) of world export trade in panels. Three quarters of total wood production is used as fuelwood and charcoal. In addition, the region is rapidly developing a substantial pulp and paper industry. Many ASEAN member countries (AMCs) are also major exporters of nonwood forest products (NWFPs), in particular rubber, rattan, and bamboo.

Smoke emanating from plantation sites, as seen through satellite imaging, Indonesia, 1997.

Photo: ASEAN Specialized Meteorological Centre, Singapore

The amount of land under forest in the ASEAN region is 46.2 percent and forest area per capita is 0.4 ha. The rate of deforestation in the region has been substantial, at about –2.8 million ha during 1990-1995, representing an annual change of –1.3 percent.

Forests have supported overall economic development in AMCs by generating investment funds and providing land for the expansion of agriculture and estate crops. The need for increasing export earnings and other national economic development imperatives has prompted the conversion of forestlands into rubber, oil palm, and timber plantations. Fire has been used extensively in land preparation as a cost-effective process (see Box 6).

As a result of these and other factors, all AMCs are prone to wildfires, which are likely to remain a serious threat for some time. As a partnership for sharing experiences, information, responsibilities, and benefits, and

BOX 6 Land Conversion and Economic Development

Conversion of forest and wildlands to other productive uses is a prominent feature of the national economic development policy in a number of forest- and land-abundant ASEAN countries, just as it formed an important part of the economic development process of all countries that today enjoy a high level of income (i.e., the developed economies of Europe, North and South America, and Oceania). As in the case of these latter economies, the land conversion process is essentially complete in some AMCs (Brunei Darussalam, Philippines, Singapore, and Thailand).

In others (Indonesia and Malaysia), land conversion is taking place, and is seen by policymakers as an important and positive contribution to economic development. In yet other AMCs, land conversion is experiencing a hiatus as a result of previous political and economic dislocations (Cambodia and Viet Nam). Land conversion in these countries may, therefore, resume in the future when the pace of economic development quickens sufficiently. In still other AMCs (the Lao People's Democratic Republic [Lao PDR] and Myanmar), a significant amount of land remains in an undisturbed state, which means that national development policymakers in these countries have the option of using large-scale land conversion to help fuel future economic development.

Land conversion is undertaken in order to harness the wealth contained in land resources so that it directly and immediately enters into the flow of production and national income. Once brought into this flow, this wealth can easily be transformed into goods and services of all types. Some of this land wealth is transformed into investment in future productive capability, which stimulates employment and ultimately augments national income. Some of the remainder is used to purchase consumption goods, which in part increases the demand for home-produced goods, indirectly stimulating further domestic investment and employment.

But land conversion can support real development only if it can be carried out without damaging the environment. One of the major causes of Indonesia's 1997-1998 wildfires, identified by investigators, was the land clearing practices of oil palm plantations companies and smallholders, who used fire as a low-cost (or free) way of preparing land for cropping. More than 60,000 ha of forestland per year were converted into oil palm between 1995 and 1997. Most of the oil palm plantations were opened up through systematic burning of vegetation, primarily logged-over forest. In addition to the existing 2.4 million ha, the Indonesian Government intends to allocate another 3.1 million ha for future conversion into oil palm plantations.

Regulations allow for three kinds of land-clearing permits: open burning, controlled burning, and zero burning. However, landowners and companies are generally reluctant to adopt more expensive zero-burn land preparation systems. This is also true of forest plantations.

Source: ADB/ASEAN (1999). Final Report of RETA 5778: *Strengthening the Capacity of the ASEAN to Prevent and Mitigate Transboundary Atmospheric Pollution*.

working toward common good, ASEAN is in a strong position to address its fire problem at the regional level.

Similarities and Differences between AMCs

There are several differences and similarities between AMCs. The differences in geographic location, in terms of latitudes and longitudes, geological evolution, physiographic and topographic aspects, volcanism, wind direction, etc., are reflected in their climate, vegetational types, land categories, resource endowments, and capabilities. The diverse ethnic and historical background (including the history of colonization), coupled with the nature of resources available, has also resulted in differences in such aspects as religion, culture, political system, demographic features, level of economic development, and share of international trade.

Because of the proximity and contiguity of these countries, an underlying "unity in diversity" has developed in social and economic attitudes, resulting from migration, trade, and sociocultural interaction. Accordingly, there are considerable similarities in land-use practices, economic activities, social habits, commercial dealings, and international interests. In spite of the differences in the level of industrialization, agriculture continues to be important to all AMCs, with the exception of Brunei Darussalam and Singapore.

The entire ASEAN region generally falls within the tropical zone and follows comparable land management systems.

> ASEAN is in a strong position to address its fire problem at the regional level

Fire regimes are best understood as existing along a gradient of ecological and human factors

Shifting cultivation is prevalent in all the forested countries of the region.

The rapid land use changes taking place in the countries is reflected in the high rate of deforestation. For a comparison of population, income, land, and forests of AMCs, see Table 1.

Fire Regimes of the Region

The region has a number of distinct fire regimes, each with one or more associated vegetation formations. Fire regimes are best understood as existing along a gradient of ecological and human factors. The characteristics and features of the major fire regimes are briefly described in the following sections.

Tropical Rain Forests

Tropical rain forest is the natural vegetation over large areas of Southeast Asia and the Pacific. These forests require abundant rainfall and high temperatures all year round. If monthly rainfall drops below 100 millimeters (mm), drought will result. Insular Southeast Asia, Papua New Guinea, and the high islands of Melanesia were largely covered with species-rich forests until recent decades. Logging and agricultural expansion have now greatly decreased their quality and extent. Apart from Papua New Guinea and the protected or remote parts of Southeast Asia, the lowland rain forests of the region are a mosaic of disturbed stands, fire climax grasslands, secondary vegetation, and commercial crop plantations. Within this broad climate type, special vegetation types have their own fire regimes. The fire climax *Imperata cylindrica* grasslands are fired by humans annually to prevent invasion by woody pioneer species. Peat swamp forests are susceptible to continuous subsurface burning during severe

TABLE 1 **ASEAN Region: Country Information**

Country	Land Area ('000 ha)	Pop. Density (1997 pop/km^2)	GNP per Capita	Forest Area: Area ('000 ha)	Forest Area: % of Land Area	Forest Area: Per Capita (ha)	Annual Change in Forest Area: '000 ha	Annual Change in Forest Area: % Rate
Brunei Darussalam	527	56.9	25,160	434	82.4	1.5	-3	-0.6
Cambodia	17,652	59.5	270	9,830	55.7	1.0	-164	-1.6
Indonesia	181,157	112.3	980	109,791	60.6	0.6	-1,084	-1.0
Lao PDR	23,080	22.5	350	12,435	53.9	2.5	-148	-1.2
Malaysia	32,855	63.9	3,890	15,471	47.1	0.8	-400	-2.4
Myanmar	65,755	71.2	—	27,151	41.3	0.6	-387	-1.4
Philippines	29,817	237.1	1,050	6,766	22.7	0.1	-262	-3.5
Singapore	61	5,573.8	26,730	4	6.6	NS	0	0.0
Thailand	51,089	115.7	2,740	11,630	22.8	0.2	-329	-2.6
Viet Nam	52,797	34.7	260	9,117	28.0	0.1	-135	-1.4
Total	**454,790**	**96.5**	**1,594**	**202,629**	**44.6**	**0.5**	**-2,912**	**-1.4**

— = not available.
Source: *State of the World's Forests* (FAO 1999).

droughts, and heath and limestone forests are more fire-prone than other forest types due to the limited water-holding capacity of their soils.

Undisturbed lowland rain forest is highly resistant to burning, but scientific evidence indicates that Borneo's forests (and by inference, those elsewhere) have burned periodically over tens of millennia during extreme droughts. Humans have used fires as they settled in the forests over thousands of years to create swidden[7] plots and facilitate hunting. Traditional use of fire is thought to have had little long-term ecological effect on the forests, but increased human population density, shortened fallow periods, and cash-cropping have made shifting cultivation a major agent of deforestation. Careless commercial timber harvesting has greatly increased fire hazard, and logging roads have provided agricultural settlers with access to remote forest areas, thereby increasing the risk that their land-clearing activities will result in wildfires. Logged and otherwise disturbed forests are being cleared by "slash and burn" of waste wood, in preparation for conversion to palm oil or pulpwood plantations.

Severe ENSO-related droughts over the last two decades, combined with large-scale logging in the rain forests and indiscriminate use of fire for land clearance, have led to massive wildfires in Indonesia and, to a lesser degree in neighboring countries. These have dramatically changed the fire regime, and threaten the existence of lowland rain forest flora in many parts of Sumatra and Kalimantan in Indonesia, and Sabah and Sarawak in Malaysia. The rain forest fire regime has shifted to a much higher fire frequency; larger areas have burned and fire intensity has increased. But fire policy and fire management approaches for rain forests are at an early stage of development (Whitmore 1998a, Goldammer and Seibert 1990, Schweithelm 1998b).

Tropical Lowland Deciduous Forests

This regime includes monsoon and savannah forests, the latter having less tree cover and more grass. These forests occur in areas where the dry season is three to seven months long, total annual rainfall is usually less than 2,000 mm, and the mean temperature in the coldest month is rarely less than 20 degrees C. Monsoon teak (*Tectona grandis*) forests occur naturally in continental Southeast Asia and have been planted elsewhere. Dry Dipterocarp savannah forests are also found in continental Southeast Asia, and open grasslands and thorn forests are spread in patches across drier parts of the region. The relatively dry Lesser Sunda Islands of eastern Indonesia contain monsoon and savannah forests with affinities to Australian flora. These forests usually burn one or more times in a year with low level litter, ground-level fires being the norm. Levels of fire adaptation vary among formations. Fires are typically ignited purposely or accidentally by humans, and increased frequency of burning is putting stress on these fire-adapted ecosystems (Stott et al. 1990, Goldammer 1996).

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Fire Climax Pine Forests

Pine forests occur naturally on disturbed sites in the lower montane forests of tropical Asia, primarily in the Himalayan foothills, the mountains of continental Southeast Asia, Sumatra (Indonesia), and Luzon (Philippines). Human disturbance of forests at lower and higher elevations has caused the altitudinal range of fire climax pine forests to expand. Pine plantations have been established at lower elevations in many parts of the region. Tropical pine species have various levels of fire adaptation and are prone to burning due to the

Most fires are ignited by humans through carelessness, but may be started purposely to improve grazing or help with hunting

volume and flammability of their litter. These forests are productive if fire frequency and intensity are stable, but tend to become degraded if fire occurs too frequently or is combined with other disturbance factors. Most fires are ignited by humans through carelessness, but may be started purposely to improve grazing or help with hunting. Most pines will not regenerate if fire occurs annually, so it is necessary to reduce the fire frequency. Total fire exclusion usually results in broad-leaved species reclaiming the site (Goldammer and Penafiel 1990).

Forest Fire History

The Ancient Fires

Even though fire has been an integral part of tropical forest ecology in the Asian and Pacific region and wild forest fires have occurred in the region for centuries, they were much less prevalent in the tropical rain forests compared to the dry forests, savannahs, and grasslands.

The wildfires that have been a feature of Southeast Asia's ecology since the Pleistocene Age are made possible by periods of reduced rainfall, long enough for even rain forests to become dry enough to burn. During the Ice Age, extended periods of minimal rainfall occurred in Southeast Asia, making large areas of the region vulnerable to fire. More recently, the recurring *El Niño* phenomenon has created conditions that enable large-scale wildfires to reoccur in the ASEAN region (Qadri and Scarsborough 1998).

Scientific evidence based on dating charcoal deposits found in the soils of East Kalimantan indicates that forest fires have repeatedly burned areas of lowland rain forest since about 15500 BC. Goldammer and Siebert (1989, 1990) report that the radiocarbon dates of soil charcoal recovered in their study areas in East Kalimantan indicate that forest fires occurred between about 15510 BC and 1650 AD. They also report that the thermoluminescence analysis of burned clay collected on top of an extinguished coal seam near active coal fires has proven fires occurred between 11200 and 13300 BC. Charcoal residues suggesting ancient forest fires were also found in several places in Brunei Darussalam and Sabah.

Humans probably had a role in starting forest fires in recent millennia, and may have deliberately burned forests to improve hunting for thousands of years. As prehistoric human settlers of the Indonesian archipelago began to switch from hunting and gathering to growing crops, they used fire to clear agricultural plots in the forest. The cycle of forest clearing, cultivation, and abandonment is known as swidden, kaingin, or shifting cultivation, an agricultural system adopted throughout most of the region over a period of thousands of years. Swidden cultivation has continued into this century in locations where soils are too poor to support permanent cultivation of annual crops. Until recently, swidden agriculture was the dominant form of cultivation in Kalimantan, and is still practiced there as well as in Sumatra. Typically, swidden plots are cultivated for one to three years, then abandoned to allow natural vegetation to regrow, creating a mosaic of pioneer and secondary vegetation patches in the mature forest. In areas with growing populations of forest dwellers, the number of years between abandonment and the next clearance of a swidden plot has been shortened to a period that does not permit regeneration to progress beyond pioneer vegetation.

Recorded Fires of the Past

In the absence of droughts, undisturbed mature rain forest is resistant to burning due to high humidity below the forest canopy. There is also a scarcity of fuel such as ground vegetation, leaf litter, and fallen branches due to the rapid recycling of fallen vegetative material. Forests adapted to grow on sand and limestone-derived soils are more susceptible to fire than those growing on other soil types, and peat swamp forests are particularly vulnerable to above and below ground fires when water levels fall during droughts (Whitmore 1984). Tropical rain forests recover even after a severe fire, if left undisturbed and if seed sources are nearby. But hundreds of years may be required to reach a successional stage[8] that approximates the species composition that existed prior to the fire. High intensity fire, followed by frequent burning, leads to conversion of tropical rain forest to grasslands, unlike monsoon forest formations in seasonally dry areas that recover quickly from frequent fires.

The majority of forests on the islands of Borneo and Sumatra have been affected by human actions, and tens of millions of hectares have been converted to grasslands and various agricultural uses. An analysis of remote sensing data from the mid-1980s indicated that the Indonesian archipelago contained about 10 million ha of grasslands at that time (RePPProT 1990). Much of the remaining forest has been logged in recent years, and logged forests are frequently degraded or converted to agriculture. The present landscape is a mosaic of vegetation types and land uses, including some intact forest ecosystems, logged forests in various stages of regeneration, scrubland, grassland, annual crops, and tree plantations.

Forest fires have been reported a number of times over the past 150 years on the island of Borneo, and such fires probably also occurred in Sumatra. Records of forest fires were first made in the late 19th century when Michielsen (in 1882) conducted a survey of the region between the Kalanaman and Cempaka Rivers (now Sampit and Katingan Rivers) in Central Kalimantan. He reported that forest fires had damaged a number of sites in 1877. Soon after, Gerlach recorded evidence of forest fires in what is now the Sentarum Lake Wildlife Reserve in the southwestern region of West Kalimantan (Meijaarad and Dennis 1997). It can no longer be assumed that tropical forest fires are a recent phenomenon. But the frequency and intensity of tropical forest fires have increased in parallel with the frequency and intensity of human activities in the forests (Schindele et al. 1989).

Grasslands still cover the 80,000 ha Sook Plains in Sabah as the result of a drought-related forest fire in 1915 (Whitmore 1998a). Periodic fires have been reported in the Danau Sentarum Wildfire Reserve in West Kalimantan since the middle of the 19th century. Brunig (1971) reports that the relatively fire-prone *kerangas* or heath forests of Sabah and Sarawak burned spontaneously or by human action in the 1880s, the early 1930s, and the late 1950s. So while the burning of forests of Sumatra and Kalimantan is clearly not a recent or geographically unique phenomenon, the fact that these islands remained largely forested until recent decades indicates that neither naturally caused fire nor human use of fire led to significant deforestation in the past.

Earlier fires were undoubtedly smaller in area and probably more spread out over time than the fires of the past two decades. A 1924 forest map of what are now the provinces of Central, East, and South Kalimantan showed that this large portion of Borneo was still 94 percent forest covered at the time (RePPProT 1990).

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Fires in Recent Years

While the fires of 1997-1998 were severe, they were not the first such examples. Records in the region have shown that there have been at least nine instances of widespread fire and smoke in the region since the 1970s, occurring mostly during *El Niño* periods.

Indonesia

Areas in Indonesia that are prone to fire include forest areas whose canopies have been broken and opened, secondary forests, deciduous forests (particularly teak forests), and grasslands. Such areas are found in almost all provinces of Indonesia.

With the stepping up of economic activities in Indonesia's outer islands, forest fires have become commonplace, occurring every year. During pronounced *El Niño* years, when conditions are usually dry, fire and smoke problems tend to be much more serious. Serious fires occurred in 1982-1983, 1987, 1991-1992, 1994-1995, and 1997-1998. Less serious fires occurred in 1999. Again fires have been reported in March 2000, particularly from the Riau province. Media reports indicated that some 1,200 fires have been detected in Kalimantan and Sumatra. The economic cost of the fires has extended far beyond the destruction of large tracts of forestland. In addition to the direct damage these fires have caused to human and animal populations living in the affected areas, the resulting smoke has directly imperiled human health and economic well-being in adjacent AMCs.

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Fires of 1982-1983

One of the most serious of the recent fires was in East Kalimantan during 1982-1983, demonstrating the greater vulnerability of disturbed forests to blazes. In that fire season, ENSO caused large-scale wildfires, which ran out of control from several land clearings and slash-and-burn sites as well as from logging areas, *alang alang,* and camping sites. It has been estimated that the overall land area of Kalimantan affected by fire exceed 5 million ha. In East Kalimantan alone, about 3.5 million ha were affected by drought and fire. Of this, some 1.4 million ha were logged-over forest, 800,000 ha primary rain forest, 750,000 ha secondary forest, and 550,000 ha peat swamp forest. The fires resulted in the loss of timber values of about $8.3 billion, and a total of timber and nontimber values plus rehabilitation costs of about $9.1 billion (Goldammer et al. 1996). Undisturbed primary forests were less affected by fire, compared to the moderately and heavily disturbed forests. Logged-over forests are highly sensitive to drought and easily combustible (Malingreau et al. 1985, BAPPENAS 1999).

Fires between 1983 and 1997

Land and forest fires that occurred during the extended dry periods in 1987 (66,000 ha), 1991 (500,000 ha), and 1994 (4.87 million ha) were distributed over some 25 provinces, including Maluku and Sulawesi. These fires were larger than during years with normal rainfall. The smoke emitted from the Indonesian archipelago during these years was not primarily caused by forest fires alone, but also by the application of fire for converting forests into estate tree crops and forest plantations, as well as by slash-and-burn agriculture (Goldammer 1998b). Also, the burning of coal seams represents a permanent fire source from which wildfires spread whenever severe droughts occur and fuel conditions are suitable for carrying a fire.

Fires of 1997-1998 and Beyond

Noted by UNEP as one of the biggest environmental shocks since 1950, the 1997-1998 forest fires of Indonesia were among the most damaging in recorded history (UNEP 1999). The area affected by fire has been estimated as 9.76 million ha. Indonesia (and

Malaysia) experienced one of the worst recorded droughts in recent history during that period. It occurred in two spells. The dry conditions that started around April 1997 abated briefly by November 1997. But the *El Niño* persisted and drought resumed in early 1998, in a pattern reminiscent of the *El Niño* drought and fires of 1982-1983. The second spell lasted from January to May 1998, until the onset of rain.[9]

Less serious, sporadic fires occurred in the dry season of 1999. With the shock of 1997-1998 fires still strongly evident, the smaller outbreaks of 1999 did not attract much attention.

Two aspects of the fires that have affected Southeast Asia during the past two decades differentiate them from previous occurrences. First, the magnitude of the fires themselves surpassed all previous outbreaks of this type on record. Previous fires were much smaller, primarily because the scale of land clearances in the past was limited and consequently the fuel load for burning was also less. Second, the scale of the damage caused by transboundary haze pollution resulting from the fires has been without precedent.

The fires of the 1980s and 1990s were triggered by open burning for large-scale land preparation for commercial crops. This accounts for the exceptional magnitude of the fires themselves, and for the scale of the damage from the transboundary haze produced. All of the above factors have prompted much more swift responses from the AMC governments compared to their pre-1980 stance, that rains would eventually quell the fires, and at least in the long term, reverse any damage they may have caused.

Other ASEAN Countries

Even though the major centers of fires and haze during the last 20 years have been in Indonesia, other AMCs have also experienced forest fires, although on a smaller scale. Information available on the fire situation in these countries is scanty.

Some AMCs, apart from Indonesia, might experience significant forest fires and haze if conditions are created by land clearing for export-oriented commercial crops, socioeconomic evolution, and/or climatic variations.

Malaysia

The threat of forest fires in peninsular Malaysia has been relatively small and most of the recorded examples relate to plantation forests. Besides the documented fires in forest plantations, those in natural forests occur sporadically throughout the peninsula during dry spells of January-March and June-August. Such occurrences have been small in size and readily brought under control.

Fire appears to be a more serious problem in Sabah. The worst fires of recent years occurred in 1982-1983 when about 1 million ha of (mostly logged-over) forests were reported burned (Phillips 1987). The cause was attributed to a severe drought, which was also blamed in large part for the fires in Kalimantan during the same period.

In Sarawak, fires have been reported and documented to be confined to forest plantation areas, and to date have been relatively small (Mhd Saad et al. 1996). During 1997-1998, extensive fires did break out in Sabah, and to a lesser degree in Sarawak and in the peat and hill forests. Neighboring Brunei Darussalam also suffered small fires during the same period, extending over an area of about 6,500 ha of heath forests, peat swamp forests, and bushlands.

Thus, even though on a lower scale, forest fires in Malaysia remain a cause for concern, particularly since the country shares similar

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geographic, climatic, ecological, and land-use attributes with Indonesia.

Malaysia has a reasonably effective legal and institutional framework to control fires and haze, including: a system of fire permits and restrictions on open fires, a system for monitoring air pollution, forest management prescriptions in line with sustainability criteria, and a relatively advanced firefighting capability.

The Ministry of Science, Technology, and Environment has formulated a National Contingency Plan to Combat Forest and Plantation Fires in Malaysia. The Plan is executed by a National Forest and Plantation Fire Committee that is composed of various government agencies, with the mandate to develop guidelines and procedures to coordinate interagency fire response. The Fire and Rescue Services Department is the lead agency for fire suppression.

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Malaysia has pioneered the use of zero-burning techniques for forest clearance (Hashim et al. 1993) and is using persuasion, technical advice, and penalties to encourage plantation firms to adopt these techniques. Shifting cultivators in Sarawak are required to undertake prescribed burning to avoid wildfires. Many plantation units have their own fire detection and suppression systems. As part of routine forest management and as prescribed in the working plans, Malaysia maintains a system of firebreaks, and an adequate amount of firefighting equipment (BAPPENAS/JICA/ITTO 1999).

Philippines

As in the case of Indonesia, tropical rain forest is the dominant natural vegetation formation in the Philippines, but deforestation has progressed to the point that little intact lowland forest remains. Forest cover has diminished from more than half of the nation's land area in 1950 to 21 percent today. Population growth, commercial logging, and agricultural expansion are the main causes of deforestation. All fires are caused by human activity and often start from shifting cultivation. Meanwhile, fire preparedness planning and implementation has been more reactive than proactive (Castillo 1998). Forest fires occur in pure pine stands (*Pinus kesiya*) in the highlands of Northern Luzon, in broad-leaved forests adjoining shifting cultivation fields, and in grasslands (thereby complicating attempts at reforestation). The archipelago's 6 million ha of fire climax grassland are typically burned annually to enhance grazing. The pine forests are fire-prone and the broad-leaved forests are susceptible to burning during ENSO-related droughts. (Schweithelm 1998a). Laws forbidding swiddening and forest burning have been largely ineffective, resulting in a paradigm shift in the late 1980s toward community-based forest management.

The Philippines seems to have suffered from the second worst fires in 1982 and 1983 (after Indonesia). The total burned area was estimated at 8,063 ha in 1982 and 117,951 ha in 1983. In the years between 1984 and 1989, fires burned between 3,000 ha and 37,000 ha of forests per year. In the years 1990, 1992, and 1993, fires affected 12,473 ha, 36,906 ha, and 14,914 ha, respectively.

During 1997-1998, fires occurred in several provinces including Benguet, Bukidnon, Davao Oriental, Mountain Province, Negros Occidental, Nueva Vizcaya, Palawan, and Pangasinan. The fires consumed almost 50,000 ha of natural and plantation forests and 37,500 ha of grasslands.

Thailand

The forests of Thailand are categorized into two main groups: evergreen forests (45 percent) and deciduous forests (55 percent). Deciduous forests are further classified into three main subgroups: mixed deciduous forest, dry dipterocarp forest, and savannah. Since they shed their leaves during the dry season of December to April, creating high fuel loads, these forests are highly vulnerable to fire.

About 90 percent of the nation's land area was forested at the beginning of the 20th century but by 1999 this had reduced to about 23 percent, including areas under scrub and bamboo (FAO 1999a). The rapid rate of deforestation has been, and continues to be, the result of agricultural expansion to accommodate the growing human population, which has increased 10-fold since the beginning of the 20th century. Teak was always the main focus of commercial forestry, but output has fallen as deforestation has increased, leading to Thailand becoming a net timber importer in 1977. A total nationwide harvesting ban in natural forests has been imposed since 1989 (Mhd. Saad et al. 1996).

Fires occur annually in the dry season from December to May, typically in the form of ground fires in the drier forest formations, grasslands, and dryland agricultural areas, and mostly in the north and northeastern parts of the country.

Virtually all fires are started by humans in order to facilitate gathering of NWFPs, dispose of agricultural waste, convert forestland into agricultural fields, settle conflicts, help with hunting, and also due to carelessness. People have generally believed that fire is not harmful to forests.

Fire data are not regularly collected for the entire country, but an aerial survey in 1984-1986 indicated that 3.1 million ha of all vegetation types are burned annually, while a repeat survey in 1992 showed that the burned area was down to 2 million ha.

The National Forest Policy (1985) mandates that a plan for slowing deforestation must include forest fire prevention and suppression. Other laws set penalties for igniting open, unauthorized fires. Attempts at fire management began in 1971 with short-term technical assistance through a consultant, funded by the Canadian Government. This led to the training of some Thai forest officers abroad in forest fire control in the early 1970s and the establishment of a Forest Fire Control Section in the Forest Management Division of the Royal Forest Department (RFD). This section was upgraded to a Subdivision in 1981, and Office of Forest Fire Control and Rescue in 1991.

RFD has taken the following actions to prevent and control forest fires:

- established forest fire control units in fire-prone areas;
- cooperated with the Ministry of Interior to organize and train local government officials and volunteers in firefighting;
- organized a network of government agencies and commercial aviation firms to report fires;
- provided funds to purchase firefighting equipment;
- conducted a nationwide fire prevention campaign; and
- begun collecting fire data and conducting research.

RFD has had some success in reducing forest fires through public fire prevention campaigns and strengthening of local fire management brigades. Thailand is the first Southeast Asian country in which helicopters and fixed-wing aircraft have been used for aerial firefighting and personnel transport.

Further improvements in Thailand's equipment for fire management capability are constrained by budget and personnel limitations (Schweithelm 1998b).

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Viet Nam

The forests of Viet Nam, accounting for about 28 percent of the country's land area, have been considerably degraded due to shifting cultivation, fuelwood collection, overfelling, and fires. The unsettled situation in the country for the past several decades has accelerated the environmental degradation. Viet Nam is now in the process of rebuilding its resource management systems and related institutions.

The main problem areas with regard to forest fires in Viet Nam are the seasonally flammable deciduous forests, indigenous pine forests, degraded natural vegetation, shifting agriculture and deforestation complex, and intensively treated agricultural lands. The peak of burning activities in Viet Nam is during the mid to late dry season (January-April).

One major problem is the fires occurring in the economically valuable *Melaleuca leucadendron* forests. Available fire information is limited. In the mountainous pine forests in the highlands of Da Lat, northeast of Ho Chi Minh City, the annual area reported destroyed by fire usually does not exceed 100 ha, but many fires seem to be unreported (Goldammer 1992).

Causes

To start a forest fire requires inflammable matter (fuel load), a source and reason leading to actual ignition, and a favorable condition where the ignited fuel can spread the combustion. Climatic conditions, fuel source, and its nature define the fire-proneness of a situation; whereas the ignition source and condition of burning define the fire itself.

To start a forest fire requires inflammable matter (fuel load), a source and reason leading to actual ignition, and a favorable condition where the ignited fuel can spread the combustion

In the ASEAN region, various factors have been associated with the considerably increased incidence and intensity of fires of late. These include: (i) careless logging that has killed trees unnecessarily, left too much wastewood in the forest, opened the closed canopy exposing the forest floor to drying by sunlight and wind, and made the forest accessible to agricultural settlers; (ii) increasing numbers of people clearing land for farming in or near forests by burning; (iii) temporary forest conversion using traditional slash-and-burn methods; (iv) permanent conversion of forestland to agricultural uses (e.g., cultivation of food crops, estate crops, horticultural products, grazing of livestock); (v) conversion of natural forest (mainly exploited or otherwise degraded secondary forest) for the establishment of industrial timber plantations; (vi) drainage of peat swamps for agricultural or other purposes; and (vii) fires that have spread and turned wild from these interventions.

While the causes of forest fires are more or less common to all the AMCs affected by the recent fires and haze, discussions tend to focus on Indonesia because of its significance to the region and the availability of information from several studies on its forest fires. These suggest that the main causes of fires and haze are: (i) the imperatives of national economic development and related financing needs; (ii) land conversion using open fires, prompted by private profit maximization; and (iii) problems relating to land tenure and social equity. These causes are aggravated by factors such as ENSO-induced drought; technological and infrastructural limitations; and institutional inadequacies.

Land Conversion and Preparation

It is a common misconception that most land conversion in the ASEAN region involves the clearing of pristine forest. While this may be true in the case of peat swamp forestland, much land conversion in the region simply continues the process of human intervention that began with timber extraction from virgin forestland. According to a recent report, of the total area of about 4.8 million ha consumed by fire during 1994, 88 percent comprised logged-over forests, some of which were under cultivation by traditional dryland agricultural techniques. By contrast, shifting cultivation areas accounted for only 5.3 percent, transmigration farmland 4.5 percent, areas occupied by previously-established plantations only 0.8 percent, and natural protected forests a scant 0.2 percent. The corresponding figures for 1997 (which exclude information for calendar year 1998) tell a similar story. Of the total land area consumed by large-scale fires during that year, logged-over production forests accounted for 62 percent. The remainder comprised the following: national parks, 20.6 percent; protection forests, 8.4 percent; nature reserves, 6.5 percent; and recreation parks, 0.6 percent (MOE/UNDP 1998).

Observations made during the fires and haze of 1997-1998 and previous cases have indicated that the intensity of fire in logged areas was directly related to the intensity of logging.[10] Even severe fires did not completely destroy moderately logged stands where, after the fire, a few trees with green foliage could still be observed, although spaced and scattered. In heavily logged forest areas, where remaining trees were widely spaced, shrubs had formed a thick ground cover, providing an efficient biomass source for the fires after the extensive drought. Here, the fuel consumption was more complete (BAPPENAS 1999).

The main factors causing increased combustibility are wasteful logging; and forest clearance for agricultural crops, estate crops, and forest plantations leading to buildup of dry materials. The changing composition of vegetation due to mono-cropping, draining of peat swamps, and mining practices that expose coal deposits also contribute to altering the fuel characteristics.

Thus, land clearance and preparation activities influence the volume and condition of the fuel load, serve as the ignition source, and often cause the spread of fire. These activities, in effect, take advantage of drought conditions created by weather disturbances such as ENSO.

Drought Conditions

Indonesia's climate is shaped by the annual cycle of east and west monsoons, which affect rainfall and winds across the archipelago. The major islands and most smaller island groups are dominated by a humid tropical climate and rain forest vegetation, although the Lesser Sunda Islands, eastern Java, and small parts of other islands have mild to pronounced rainfall seasons. Drought in Indonesia is generally experienced between May and October.

There are two weather phenomenon considered to be crucial to the spread of forest fires and haze. The first is recurrent ENSO conditions, bringing extraordinarily dry weather to the region (and in the process, creating conditions ideal for disposing of biomass residue by open burning). Prolonged drought in Indonesia occurs at least once every 10 years. Data on rainfall in Bali, Java, Kalimantan, Sulawesi, and Sumatra since the early 1900s show that prolonged drought occurred 17 times during the century, of which 11 corresponded with an *El Niño*. When the dry season in Indonesia occurs at the same time as an *El Niño*, the result is a prolonged drought, which extends from June to November and can continue until May of the following year. The second weather factor is that in geographic areas that lie close to the equator, there is relatively little wind. This means that in the ASEAN areas where land conversion is in progress, the weather forces that mix (and dilute) the particulate matter from land conversion fires with unpolluted air are weak.

The intensity of fire in logged areas was directly related to the intensity of logging

> Compared with the previous *El Niño* years, the one in 1997 had the highest impact on drought and fires in Indonesia

In Indonesia, a prolonged drought as a consequence of an *El Niño* has occurred five times over the last 20 years. This had varying effects in different parts of the country, depending on the strength of the *El Niño* and the monsoon winds sweeping past Indonesia. Compared with the previous *El Niño* years, the one in 1997 had the highest impact on drought and fires in Indonesia. Forest and land fires in 1997 occurred in nearly all provinces.

Contributing Constraints

During the recent forest fires and haze, particularly in 1997-1998, several factors have aggravated the causes of fires.

Physiographic

The physical condition of the locality—difficult terrain, slope and accessibility, and inadequate availability of water—often makes fire management measures difficult to carry out. Fire crews often struggle to access forests in steep terrain and peatlands. Conditions such as low humidity, lack of clouds, and inaccessibility of natural water bodies affect fire suppression operations. Because of such constraints, performance of water bombing and cloud seeding operations in Indonesia during the 1997-1998 fires was unsatisfactory.

Sociocultural

Cultural and/or religious leanings of indigenous and rural communities, fire worship, and practice of slash-and-burn agriculture can become obstacles to adopting scientific fire management. Other sociocultural factors include land tenure issues, conflict of interest among different classes of people and communities, and use of fire as a weapon to inflict harm on the enemy. Such situations are common among indigenous communities and between the indigenous communities and transmigrants. Also, in some situations, rural people move into the forest to eke out a livelihood by illegally clearing and cultivating forestland.

Inadequate social awareness is, in several cases, reflected in eco-hostile and private profit-maximizing attitudes by private operators unwilling to invest in fire protection. Also, fire is often set deliberately for individual economic gain, through grazing, collection of honey, and other NWFPs, as well as hunting and gathering. In addition, villagers are also often reluctant to fight fire without attractive cash incentives.

Technological and Infrastructural

Technological constraints include lack of appropriate technology; inadequate knowledge and appreciation about technological possibilities as well as limitations; insufficient tools and equipment; inadequately trained personnel; lack of research support; inadequacies in forest fire management exemplified by lapses in monitoring, fire danger warning, fire protection measures, presuppression planning and preparedness, and firefighting; and reluctance to adopt zero-burn techniques of land preparation and low impact logging.

Lack of infrastructure such as access roads, fire corridors, fuelbreaks, observation towers, water reservoirs, communication and mapping facilities, satellite stations, etc., affect the efficiency of fire management.

For example, the total reported length of cleared fireline in Indonesia is only about 150 km, which appears grossly inadequate. Adequate infrastructure is found only in areas covered by some of the donor-funded projects.

Institutional

Most of the important constraints are institutional in nature. Lack of political will, inappropriate and poorly specified policies, weak legislation, ambiguous regulations, bureaucratic procedures, and inadequate resources for enforcement of laws and regulations have come up again and again as crucial and crippling constraints. Policy gaps and conflicts relating to land use, tenure security, and economic development add considerably to the forest fire danger.

Indonesia's economic policy, which allows for large-scale expansion of commercial crops, encourages land speculation and may lead to ecological disaster. The pace and manner of plantation development has been such that the Ministry of Forestry and Estate Crops (MOFEC) is little more than a hapless bystander (Anon 1997b). Unlike other countries in the region, Indonesia's policy on timber pricing subsidizes the concessionaire. In some other countries it is based on competitive bids. A study indicated that in 1990, Indonesia's timber subsidies cost the Government $2.5 billion in lost revenues (Constantino 1990); and this further leads to wasteful use of resources. For reasons related to tenure security, many forest dwelling communities do not yet acknowledge current forest boundaries.

An absence of properly designed plans relating to land use; inadequacies of forest management and fire management; and lack of updated land-use maps, fire maps, fire information management, and dissemination reflect institutional weaknesses. Lack of institutional ability to learn lessons from past mistakes and to follow up on recommendations is a matter to be addressed seriously. For example, there have been several recommendations to curtail the volume of timber production to ensure sustainable forest management (SFM) in Indonesia, including protection of forests from fire and other damaging agents. A national fire management plan was prepared by the Ministry of Forestry (predecessor of MOFEC) in the mid-1980s, in cooperation with FAO.

According to the plan, the forest area of the country was to be divided into firefighting control units of 40,000–50,000 ha in Java, and 100,000–150,000 ha outside Java, such that fires (even if they occur) can be prevented from spreading and confined to the control unit (GOI/FAO 1990b). But this plan has not been pursued. Again, after the Bandung Conference of 1992, a Long-Term Integrated Forest Fire Management Strategy for Indonesia was prepared, but this also was not seriously followed up.

Inadequate research, technology development, and knowledge about the different aspects and situations of fire (for example: in coal seams and peat swamps); and inadequacies of measures and means at all levels to improve fire management skills have been major constraints. There are relatively few personnel trained in fire science.

Recently, efforts have been made in Indonesia to strengthen training facilities. A report indicates that by the end of August 1998 there were 16,175 persons trained in fire protection and suppression, up from about 14,000 in 1997 (MOFEC 1998).

Some of the other constraints identified by analysts following the 1997-1998 fires and haze, particularly as applied to Indonesia, include the following.

- Increasing vulnerability of forestlands to fires resulting from unsustainable forest management and harvesting practices.
- Conflicting and inadequately identified roles and responsibilities of institutions concerned with managing forestlands and forest fires, especially with regard to mandate, authority, financial resources, and accountability.

Indonesia's economic policy, which allows for large-scale expansion of commercial crops, encourages land speculation and may lead to ecological disaster

The three biggest fires were those of 1982-1983, 1994, and 1997-1998, and the areas affected, respectively, were 5,000,000 ha; 4,865,000 ha, and 9,756,000 ha in Indonesia

- "Business as usual" attitude of government agencies.
- Indifference to the cyclical nature of fire and haze from institutions charged with managing forestlands and forest fires, including disregard for early warning announcements concerning the onset of ENSOs.
- Inadequate information and systems for communicating fire-related information.
- Vested interests that marginalize issues relating to fire and haze as a means of favoring a particular sector, corporate body, or individual(s).
- Neglect by government and entrepreneurs to local customary rights, livelihood strategies, and traditions, which result in erosion of customary law, social cohesiveness among indigenous groups, and traditional knowledge relating to the prevention and control of fires.
- Lack of incentives for promoting logging techniques that lead to sustainable output of production forests and mechanical land clearing; inadequate use of logging residues as productive inputs and development of products made from them; and absence of an incentive system to involve local people.
- Insufficiency or nonexistence of committed funding at national, subregional, provincial, and local levels to adequately address the issue of forest and land fires.[11]
- Lack of a proactive quick action approach.[12]
- Delay or inaction, often due to lack of funds, in rehabilitating the badly burned areas. Apart from harboring pests and diseases, the dead and charred materials remaining in the area can cause future fires by providing a highly combustible fuel load.
- Poor coordination of fire management (including fire suppression). Inadequate coordination among sectors, between central and provincial levels and/or among the donors has been reported.[13]

The Dimensions of the Impact

Area Affected

The size of the area affected by fires over the years has varied considerably. The three biggest fires were those of 1982-1983, 1994, and 1997-1998, and the areas affected, respectively, were 5,000,000 ha; 4,865,000 ha, and 9,756,000 ha in Indonesia. Distribution of the fires differs depending on the interpretational and definitional differences, and also on how the estimates were made.

1994 Fires

In 1994, fires (of varying intensities) occurred in 24 provinces of Indonesia. Distribution by land-use type is given in Table 2.

Table 2 suggests that the incidence of fire in primary forests is relatively low (8,000 ha), far less, for example, than the extent of fire in reforestation areas. Based on this data, fires appear to be closely associated with other land-use activities and hence fire control should not be the sole responsibility of MOFEC (MOE-UNDP 1998).

1997–1998 Fires

The 1997-1998 fires occurred in 27 provinces of Indonesia, falling within the five large islands. Nearly 70 percent of the fires were in Kalimantan. Irian Jaya, Sulawesi, and Sumatra were also significantly affected (BAPPENAS 1999). Fires also occurred on a smaller scale in Brunei Darussalam, Malaysia, Philippines, and Thailand. Details of their impacts are not available.

TABLE 2 Spatial Distribution of Areas Affected by 1994 Fires in Indonesia

Land-Use Type Affected by Fire	Area Burned ('000 ha)
Traditional Dry Land Farming	2,800
Shifting Cultivation	1,500
Transmigration Farming	260
Plantations	221
Transmigrant Settlements	39.5
Reforestation Areas	20.5
Timber Estates	17
Natural Forests	8
Total	**4,866**

Source: Goldammer 1997.

TABLE 3 Spatial Distribution of Areas Affected by 1997–1998 Fires in Indonesia

Land-Use Type Affected by Fire	Area Burned ('000 ha)
Agriculture	3,843
Estate Crops	119
Timber Plantations	188
Lowland Forest	3,100
Peat and Swamp Forest	1,450
Dry Scrub and Grass	700
Montane Forest	100
Total	**9,500**

Source: ADTA INO 2999: *Planning for Fire Prevention and Drought Management* (BAPPENAS 1999).

ADB under its advisory technical assistance[14] (ADTA) used a variety of techniques, depending on availability of data, to obtain spatial estimates. For estimates of the area burned in Irian Jaya, a combination of aerial and ground surveys was used; along with a comparison of Total Ozone Mapping Spectrometer (TOMS) imagery for Irian Jaya, Kalimantan, and Sumatra. The rest of the estimates were obtained from analysis of SPOT images by the Center for Remote Imaging, Sensing and Processing (CRISP) at the National University of Singapore.

In addition to computation of the area burned, CRISP (Liew et al. 1998) undertook a manual classification of fire scars for both Kalimantan and Sumatra, concluding that about half of the affected area consisted of plantations and/or agricultural lands, 20 percent was peat swamp forests, and the remainder secondary forests and bushes. CRISP has also performed preliminary estimates of areas burned in Java and Sulawesi through a visual assessment of SPOT Quicklook Mosaics. In the absence of detailed analyses of satellite imagery for all the affected provinces, a lack of up-to-date landcover maps, and ability to overlay all fire areas on land-use or land classification systems, assessments of fire location by functional land-use categories were achieved by extrapolation of findings by CRISP. Distribution by land-use type so assessed is given in Table 3.

The extent of the forest area burned and the share of peat and swamp forest in it are particularly noteworthy, because of the transboundary implications (see Box 7).

Transboundary Haze Pollution

The transboundary dimension of fires can manifest itself in various ways: fires crossing national boundaries cause direct damage, mass migration of wildlife (and also of humans)

BOX 7 Tropical Peatlands

Peat forests are waterlogged forests growing on a layer of dead leaves and plant material of up to 20 meters deep. These are a biologically diverse resource and a recognized component of the world's biological heritage.

The countries of Southeast Asia, in particular Indonesia and Malaysia, have more than 20 million ha, or 60 percent, of the world's tropical peatlands. In the event of a prolonged spell without rain, and a lowering of the water table in the peatswamp, the organic layers progressively dry out. Subsequent fires have spread to forests covering thousands of hectares of peatlands. Fires in these peatlands create much more smoke per hectare than other types of forest fires and are difficult to extinguish. The fires go deep underground and can burn uncontrolled and unseen in the peat deposits for several months.

While the spread of surface and ground fires in this type of organic terrain may not be severe, deep burning of organic matter leads to the toppling of trees and a complete removal of standing biomass. Further, the smoldering organic fires may persist and be reactivated as an ignition source in the next dry spell (Goldammer and Seibert 1989).

In the past 20 years, the incidence of major fires in the peatswamp forests of Southeast Asia has been increasing. In East Kalimantan, a fire that started in September 1982 lasted for 10 months and affected more than 35,000 ha. The fire followed an almost unprecedented period of drought in the region, associated with an *El Niño*.

The contribution of tropical peatlands to the global carbon cycle is higher than in most temperate zones. It is estimated that 15 percent of the global peatland carbon resides in tropical peatlands. Peatswamp fire emission contains, like other biomass-burning emissions, large amounts of carbon dioxide, carbon monoxide, particulate matter, oxides of nitrogen and sulfur, and a variety of volatile and semivolatile compounds. However, peat vegetation has a higher biomass density and burns predominantly under smoldering combustion. This results in higher emissions of all pollutants per hectare burned.

At the annual meeting of the standing committee of the Convention on Wetlands, better known as the Ramsar Convention, 27 countries and four global NGOs gathered in Switzerland on 2 October 1997. They expressed their concern at the forest fires in Indonesia. Louise Lakos, chairperson of the committee, noted: "The members of this international conservation body drew attention to the fact that a large proportion of the area burning is peatswamp forest, which constitutes an important global wetland type, which we cannot afford to lose. Time is short and action is needed urgently."

Source: *Down to Earth*, Vol. 6 No. 11, 31 October 1997.

> The haze-affected countries have borne much of the cost of the region's recent fires, though they have had little control over their magnitude, frequency, or duration

across borders, impact on water quality and fish resources in international waters, and—most important—transboundary atmospheric pollution and other haze effects. This last mentioned impact was highly evident in the wake of the 1997-1998 fires in the ASEAN region. As Ramon and Wall (1998) observed, "whereas the impact of fires concerns mainly foresters and conservationists, it is the smoke that causes politicians and economists to react."

Fires cause smoke, the smoke mixes with the atmosphere and drifts around, causing transboundary atmospheric pollution and related problems. The haze-affected countries have borne much of the cost of the region's recent fires, though they have had little control over their magnitude, frequency, or duration. Emissions from wildfires are thus a regional problem, even though the fires themselves may occur well within the national boundaries of individual AMCs.

Haze Formation and Dispersion

Forest fires and other vegetation fires produce gaseous and particle emissions that have impacts on the composition and functioning of the global atmosphere (Crutzen and Goldammer 1993; Levine 1991, 1996; Van Wilgen et al. 1997). These emissions interact with those from fossil-fuel burning and other technological sources, which are the major cause of atmospheric pollution and human-caused climate changes.

Open burning to dispose of biomass residue of land conversion involves stacking it into large heaps and leaving it undisturbed until it is dry enough to burn. It is then set alight. The result is typically a low-temperature fire that only partially burns the material to be disposed of. A relatively large quantity of partially-combusted material therefore remains, much of it being light enough to be carried into the air by the heat generated by fire. A similar process also happens when wildfire enters a forest.

Once released into the atmosphere, the partially-combusted material tends to remain stationary, unless there is sufficient wind to mix it with fresh air free of particulate matter. If enough mixing takes place, the partially-combusted material from the fires becomes so dispersed that it is relatively benign, and for the most part, unnoticeable. This is ordinarily the case in ASEAN countries where land conversion is in progress. In these areas, land-clearing fires occur continuously, on a year-round basis, and often the production of emission materials and local formation of haze remains unnoticed.

However, when a large enough number of land-clearing fires occurs at the same time in a limited area, or when the fires in a particular area reach a large enough scale, so much emission material is released at the same time that the atmosphere is incapable of fully diluting it. If the resulting buildup of atmospheric debris becomes sufficiently concentrated, winds ultimately transport the cloud of haze into the airspace of recipient countries before it can be adequately diluted. Transboundary haze is born.

Therefore, haze pollution can be said to be "transboundary" only if its density and extent is so great at source that it remains at measurable levels after crossing into another country's air space. Reducing transboundary haze pollution in the region, therefore, ultimately requires limiting the amount of emissions from open burning that each member country allows to enter the atmosphere during any particular time. The aim of limiting the emissions (and their release into the atmosphere) should be to control pollution both within boundaries and at a transboundary level.

Most particle processes in the atmosphere, such as atmospheric deposition rate and residence time, light scattering properties and visibility, deposition pattern within the human lungs, and health impacts depend on particle size.[15] While coarse particles flush out of the atmosphere within several hours up to a day, fine particles have the longest residence time (up to weeks) in the atmosphere and travel extensive distances (hundreds to thousands of kilometers). Their elimination out of the atmosphere is mainly due to rain.

Factors Affecting Haze Dispersion

The haze problem suffered by Indonesia and its neighbors, due to the 1997-1998 wildfires, was a result of a combination of factors—the volume of smoke, humidity, and the level of wind speed and rain.

The distribution of haze away from the biomass fires in Indonesia is primarily controlled by wind and vertical mixing. The most significant large-scale influence on winds in the region is the position of the intertropical convergence zone (ITCZ), which exerts control over the broad-scale wind speed and direction.

By September 1997 many large and uncontrolled fires were burning in the peat areas of East-Central Sumatra, much of South Sumatra, and Central and West Kalimantan. During the September-October period, thick haze blanketed these regions in particular. In late September-early October the haze was carried out of these regions, particularly to the north and west under the influence of relatively strong trade wind flow. It was during this time that peninsular Malaysia and Singapore were especially hit by haze. This was a period during which the ITCZ was lying well north over the Mekong area countries and the Philippines, with the trade winds to the south of the ITCZ having a strong north-south component. As the ITCZ moved south later in October, the airflow developed more of an east-west component,

The haze problem suffered by Indonesia and its neighbors, due to the 1997-1998 wildfires, was a result of a combination of factors—the volume of smoke, humidity, and the level of wind speed and rain

Haze from fires in peatland is estimated to contribute 60 percent and converted forests 18 percent of the total smoke and haze produced

pushing most of the haze away from the fire zones, toward the west and into the Indian Ocean.

The fires of February-April 1998 were largely confined to Borneo, and in particular to East Kalimantan province. Haze became thick again during March and April 1998, but was largely confined to Borneo, especially in the south. The presence of a broad area of low-level convergence over Borneo at this time resulted in light low-level winds (or lack of strong winds), which limited the haze movement off the island.

Magnitude of Dispersion

Fires do not respect national (in some cases, even natural) boundaries. During the 1982-1983 East Kalimantan fires, the haze also reached as far as peninsular Malaysia and Singapore, lasting an entire month and covered an area of about 35 million ha. In 1997, haze covered about 100 million ha of land and water and lasted as long as six months. From September to November 1997, the dense haze from the Indonesian fires spread over an area the size of Western Europe, affecting some 70 million people in the region, directly or indirectly. This haze was, probably, the worst on record. The 1998 fires in Indonesia did not affect mainland Asia as much as in 1997. The haze covered the source area of East Kalimantan and spread over to West Kalimantan, southeastern Sarawak, and parts of peninsular Malaysia.

Critical Sources of Haze

Haze from fires in peatland is estimated to contribute 60 percent and converted forests 18 percent of the total smoke and haze produced. Instead of stray individual fires, 80 percent of the haze was produced by seven clusters of fires in and around peat forests in Kalimantan and Sumatra. Shifting cultivation accounted for only 1.5 percent of the haze. The thickest haze came from an extensive fire in a 1 million ha area of peat being drained by the Government for a massive rice planting project, known as the Grand Million Hectare Peatland Project *(Projek Sejuta Hectare Lahan Gambut)*. During the 1997-1998 fires, more than 700 million mt of carbon dioxide were released into the atmosphere from the burning of the peat[16] (Levine 1998).

Adverse Impacts of Haze

Air Pollution

At the peak of the haze, the Air Pollution Index (API) reached unprecedented levels in the region. An API count exceeding 100 but below 200 is considered unhealthy; between 200 and 300 is very unhealthy; and between 300 and 500 is considered hazardous. API readings remained in the hazardous range for long periods in September and October 1997 in Sarawak, with a high of 849 recorded. A reading of 1,000 was recorded in the interior of East Kalimantan in mid-April 1998, a level that is probably not unusual in areas close to the fires. Malaysians and Singaporeans were informed when air pollution reached unsafe levels, and were warned to take appropriate protective measures.

In Miri, as the API continued to hover above the 500 mark in April 1998, the Sarawak Natural Disaster Relief Committee declared a host of emergency mitigation measures, including closing of schools and kindergartens, advising residents to wear protective masks and to refrain from using private motor vehicles, and advising polluting industries (mainly in the quarry, mining, cement-mixing, asphalt, saw-milling, and transport sectors) to scale down operations in order to reduce the volume of pollutants being emitted into the atmosphere (Abraham 1998).

Most Indonesians were, however, unaware of the level of health hazard they faced. Some areas were affected by the haze from July to December 1997, and it started again in February 1998. Exposure to acute air pollution elevates the probability of premature death in vulnerable groups such as asthmatics, people with chronic lung or heart disease, and young and old pneumonia patients.

Health Hazards

According to the Economic and Environment Program in Southeast Asia (EEP-SEA) and WWF (1998 b, c), the haze of 1997 cost the people of Southeast Asia some $1.4 billion, mostly in short-term health costs. More than 40,000 persons were hospitalized for respiratory and other haze-related ailments. The long-term impacts on health of exposed children and elderly are as yet unknown. In Kuching, Sarawak, Malaysia, at one stage, the Government came within a hairsbreadth of evacuating the city's 400,000 inhabitants. In Indonesia alone, health officials estimated that 20 million people suffered from health problems related to the haze.

Impairment of Visibility

The effect of haze on light and visibility has an impact on economic production (manufacturing and agricultural), transport, tourism, etc., while haze-caused accidents result

BOX 8

Air Pollution and Health Effects

Air Pollutant Standard Index (PSI)	Health Category	Health Effects	Preventive Measures
Up to 50	Good	None	None
51–100	Moderate	None or limited for the general population	Not necessary
101–199	Unhealthy	Moderate symptoms for sensitive individuals, followed by irritation in healthy population	Individuals with light heart and respiratory problems have to reduce physical movement and outdoor activities
200–299	Very unhealthy	Significant symptoms as well as drop in tolerated body movement or exercise in heart and lung patients; general symptoms among healthy population	Aged and sick individuals have to stay indoors and reduce physical exercise; the public has to avoid excessive outdoor activity
300–higher	Hazardous	Appearance of certain early diseases in addition to clear and significant problems as well as decrease in tolerated body movement or exercise for healthy population; index of more than 400 could potentially cause premature death for sick people and the aged if not treated properly; healthy individuals will have symptoms that restrict normal activity	Aged and sick individuals have to stay indoors and avoid physical activity; at Index levels of more than 400, people have to avoid physical outdoor activities; everybody has to stay indoors, close all windows and doors, and limit physical activity

Source: World Health Organization.

The 1997 haze was so thick at times that visibility was reduced to less than 10 m, making land, sea, and air travel hazardous

in loss of lives. Several gaseous compounds in the haze are likely to affect global environment and climate. Quantitative evaluation of impacts was, however, limited due to the fragmentary particle measurement data and methodological problems.

Particulate matter scatters the light and causes severe reduction of visibility. Analysis of freshly emitted biomass burning particles generally have two size distributions, consisting of fine particles smaller than 2.5 microns in diameter ($PM_{2.5}$) and coarse particles ranging from more than 2.5 microns diameter to about 10 microns (PM_{10}). In biomass emissions, the fine particles represent up to 90 percent of the total mass of particles emitted (Ward 1998). The size distributions of partially aged biomass burning particles found in Indonesia, Malaysia, and Singapore indicate that the ratio of $PM_{2.5}$ to PM_{10} is about 80 percent. This ratio includes the urban particle background, whose fine particle fraction generally contributes about 50 percent of PM_{10}. These results indicate that the fine particle fraction in haze conditions is much higher than in urban background aerosols (Dieterle and Heil 1998).

During the 1994 fires, haze pollution in Sumatra reduced the average daily minimum horizontal visibility to less than 2 km. At the end of September of that year, visibility in Singapore dropped to less than 500 meters (m), while in Malaysia it dropped to 1 km or less in some parts of the country. Haze disrupted land, sea, and air transportation.

The 1997 haze was so thick at times that visibility was reduced to less than 10 m, making land, sea, and air travel hazardous (see Box 9). In some areas, visibility fell to only a few meters for several months. In one Indonesian town, school children were reported to have been tied to a rope to prevent them from becoming lost in the haze on their way to school. On 11 April 1998 the Sultan of Brunei's palace became almost invisible behind a thick curtain of haze (Associated Press, 11 April 1998), as were Kuala Lumpur's tallest-in-the-world twin towers in September and October 1997, and again in April 1998.

Disruption to Transport

Transport was also severely disrupted. Closures of airports and cancellations of flights were common in the region. River transport in Borneo and marine traffic in the Strait of Malacca were also disrupted. Economic losses from such disruptions, and aircraft and maritime accidents were compounded by steep declines in tourist arrivals.

Similar problems have been recorded during virtually every major outbreak of fires and haze in the region since 1982-1983. Following each of these instances, several AMCs have resolved

BOX 9 The Toll of Haze

The smog arising out of the 1997 fires spread to Brunei Darussalam, Indonesia, Malaysia, Philippines, Singapore, and Thailand, affecting a population of 70 million.

- On September 26, all 234 people on board a jetliner died when it crashed before landing in northwest Indonesia. Visibility was poor due to the haze.
- An Indian cargo ship collided with a Panamanian vessel in the Strait of Malacca, killing 29 people. Reason: poor visibility.
- Seven boat accidents were reported in Kalimantan's Mahakam River. In one, nine students were killed.

Doctors point out that the smog (haze) can cause a range of ailments from heart and lung diseases to damage to the nervous system, blood, and kidneys.

Experts predict that the impact of the forest fires in Indonesia is potentially more dangerous than that of the oil fires in Kuwait during the 1990 Gulf War.

Source: *Down to Earth*, 31 October 1997.

to prevent any recurrence. But despite such resolve, disasters due to fires and haze have occurred repeatedly in the AMCs.

Global Warming

Most of the gases present in haze play direct or indirect roles in regulating the atmosphere of the earth (Wirawan 1993). Their release during large-scale burning leads to an increase in the concentration of greenhouse gases, thereby contributing to global warming. Burning peat is especially detrimental because it releases carbon into the atmosphere that has been in storage for thousands of years, and smoke from peat fires contain high levels of sulfur oxides (see Box 7). British peat specialist Jack Rieley estimated that the peat fires in Indonesia in 1997-1998 could have released more carbon dioxide than the annual contribution from cars and power stations in western Europe (WWF 1997). Efforts are continuing to quantify the amount of biomass that was burned in the 1997 fires, in order to estimate the amount of carbon dioxide released from the burning of above-ground vegetation (Liew et al. 1998, Ramon and Wall 1998). The haze also has effects on the world's climate (see Box 10).

Ozone Concentration

Nitrogen oxides in haze can be quickly converted into nitric acid, causing acid rain. (Rain falling in Sabah in 1997 was highly acidic, registering pH3.85, a level of acidity that damages plants and aquatic life.) Haze can also undergo a photochemical reaction that greatly increases the ground level concentration of ozone (Abraham 1998, Crutzen and Andreae 1990). Ozone causes eye irritation, impairs lung function in humans, and reduces crop production by damaging plants (Wirawan 1993).

Economic Costs

Economic costs of the fires were high and they had profound impacts. Some of them were highly visible. The fires burned villages, caused losses of property, and injury and harm to people. Many lost their means of livelihood. All those who lived in haze-affected areas suffered discomfort.

The fires burned villages, caused losses of property, and injury and harm to people. Many lost their means of livelihood

BOX 10 Effects of Haze on World's Climate

Scientists studying the effects of forest fires have, so far, focused on the cooling that occurs when smoke blocks sunlight. It was reported that smoke particles help in forming water droplets. However, it was not certain how this would affect rainfall. Now Daniel Rosenfeld, an atmospheric scientist at the Hebrew University of Jerusalem, Israel, has shown that smoke from forest fires can, in fact, stop clouds forming raindrops. In other words, smoke tends to prevent rainfall.

Rosenfeld studied simultaneous visual, infrared, and radar observations from the National Aeronautics and Space Administration's (NASA's) Tropical Rainfall Measuring Mission (TRMM) satellite as it passed over Borneo in March 1998, when half of the island was covered with smog. He found that dense smoke completely turned off normal tropical rain. The smoke filled the clouds with tiny particles that made water vapor condense. However, the moisture was divided among so many droplets that they were too small to fall as rain. At the same time, smoke-free clouds over the other half of the island produced ample rainfall (*New Scientist*, Vol. 164, No. 2208).

Rosenfeld believes forest fires are at least partly responsible for the decline in rainfall in the tropics over the past century. "For certain types of clouds, heavy smoke blocks precipitation altogether," he says, adding that smoky tropical clouds can yield some rain only if they rise high enough for water to freeze.

Experts warn that this may lead to disastrous effects on the world's climate. Similar effects seem to be occurring elsewhere, says Christian Kummerow, a project scientist at Goddard Space Flight Center, near Washington, DC.

Anything that affects the rainfall pattern is important. According to Hans Graf of the Max Planck Institute for Meteorology in Hamburg, Germany, about two thirds of the energy that powers the planet's weather depends on the formation and fallout of raindrops.

Source: *Down to Earth*, 15 January 2000. p. 24.

Direct economic impacts of the fires and haze included loss of forest and land resource capital; loss of timber and nontimber forest crops and stocks; damage to infrastructural assets; agricultural crop losses, productivity loss, and falling yields; falls in tourism arrivals and revenue; disruption in commerce; and disarray in transport systems, unplanned cost of fire suppression efforts, health care, and rehabilitation.

Plant growth may also have been affected by the reduction in solar energy as a result of the sun's rays being partially blocked by haze. Photosynthesis may have been further reduced by the deposition of soot particles on leaves. A drop in aquaculture and fisheries productivity also results from a reduction in available solar energy.

More than 40,000 people have sought medical help and hospitalization in Indonesia and Malaysia for smog-related respiratory ailments

Fire affected the marine environment and its biological resources, resulting in increased sediment from burned water catchments. This resulted in a reduction of primary aquatic productivity through light suppression and by imposing stress on filter feeding organisms. The haze also reduced solar radiation and productivity of all species with food chain links to the mangrove ecosystem. Details about the economic impacts of the fires on specific subsectors of the economy can be found in various reports (BAPPENAS 1999, MOE-UNDP 1998, EEP-SEA and WWF 1998b).

Social Costs

Health-related Costs

During the haze, the health of some 40 million people in the region was directly affected. (Some sources estimate the total number of people affected directly and indirectly to be about 70 million.) More than 40,000 people have sought medical help and hospitalization in Indonesia and Malaysia for smog-related respiratory ailments (BAPPENAS 1999).

A rapid survey by the Japan Medical Team for Disaster Relief in October 1997[17] assessed the effects of haze pollution on human health in the Province of Jambi, Sumatra. The survey indicated that 98.7 percent of the people complained of at least one symptom and 91.1 percent of the people complained of at least one respiratory symptom after the haze. A physical examination revealed that 33.3 percent of tested people suffered from conjunctivitis, 8.9 percent stridor, and 2.9 percent rale (Obayashi 1998).

The United Nations Disaster Assessment and Coordination (UNDAC) Mission on Forest Fires conducted assessments of land and forest fires in several countries, including Brunei Darussalam, Indonesia, Malaysia, Philippines, Singapore, and Thailand, in September-October 1997. The team reported that 11 people died and 23,000 people suffered from respiratory diseases in Central Kalimantan. In Jambi, 35,368 cases of upper respiratory tract infections were reported, while in West Sumatra the number was even higher (47,565 cases). South Sumatra also recorded a number of diarrhea cases during the haze.

The Indonesian Ministry of Health estimated after the 1997-1998 fires that the haze-related health problems affected 240,000 people in the country. The total number of deaths, severe asthma cases, bronchitis, and acute respiratory infection cases in eight provinces of Kalimantan and Sumatra was about 2,000. These numbers reflect the health problems caused by PM_{10} and do not include effects associated with other pollutants.

A study on asthma attacks among children revealed that a high concentration of fire-generated carbon monoxide, nitrogen dioxide, and inhalable suspended particulate matter (PM_{10}) was responsible for the health problems (ASEAN 1998a).

Other Social Costs

Other social impacts of forest and landfires have included damage to heritage sites, graveyards, tribal houses, and shelters in the rice fields.

Environmental Costs

Environmental costs include those resulting from ecological and related impacts of fires on plant, wildlife, soil, air, water, biodiversity, and global climate, and a diminution of the environmental services of the forests.

Ecological impacts of wildfire of 1997-1998 included adverse ecological changes affecting terrestrial, aquatic, marine, and agricultural ecosystems; reduction in ecosystem functioning and landscape stability; damage to wildlife, wildlife habitat, and protected areas; loss of sequestered carbon, emission of greenhouse gases and contribution to global warming; microclimatic changes; air pollution; water quality changes, reduction in water yield; increased soil erosion, loss of soil nutrients and fall in productivity; plant mortality, loss of forest growing stock, damage to regeneration, spread of *alang alang*, and forest degradation/ deforestation; erosion of biodiversity affecting ecosystem, species, and genetic variability; and loss of environmental heritage—all affecting the potential sustainability of development.

Biodiversity Loss

There has been loss of biodiversity as a result of the 1997-1998 fires, which caused increased degradation of globally important protected areas such as Kutai National Park. The 1997-1998 fires destroyed most of East Kalimantan's Kutai National Park and Bukit Suharto Nature Reserve. Some 85 percent of Wanareset (research forest) was also burned. Severe damage was not limited to natural biodiversity, but also included agricultural ecosystems. A great deal of the forest burned was secondary, resulting in depleted biodiversity.

In Iriyan Jaya, Kalimantan, and Sumatra, a particularly dangerous ecological impact has been the degradation of large areas of peat soils through fire. Extensive fire damage to the peat soils of the swamp forest ecosystem is also expected to accelerate the changes brought about by draining of these swamps for agricultural expansion, and drastically alter the role of this ecosystem in water storage to sustain regional forest, agricultural, and aquatic ecosystems.

Wildlife Decline

The fires affected not only humans but also wildlife. A drop in the numbers of rare and endangered animal species caused directly by fires has been compounded by the hunting of disoriented animals for food and for sale.

WWF Indonesia in a news release of 17 December 1998 claimed a decrease in the population of orangutans (*Pongo pygmaeus*) as a result of forest fires in 1997-1998 in Indonesia and Malaysia. In Borneo and Sumatra, orangutans were forced to flee the forests due to the heat and smoke. Hunger, too, drove them out of the forests as the fires destroyed the fruits on which the orangutans feed.

The Kalimantan fires have reduced the orangutan habitats by some 40 percent, worsening a decline estimated by WWF (1998) at 80 percent in the 1970s and 1980s. Destruction occurred not only to the orangutans' habitat but also to the habitats of other flora and fauna. Efforts must be made urgently to protect these important habitats.

A drop in the numbers of rare and endangered animal species caused directly by fires has been compounded by the hunting of disoriented animals for food and for sale

Estimated Value of Total Costs

There have been several attempts to estimate the value of all the losses caused by the fires and haze. Insufficient data and the differences in the methods adopted have caused considerable variation. Nevertheless, the economic costs have been significant, irrespective of the methodology. Some details of 1982-1983 and 1997-1998 fires in Indonesia are provided, as an illustration.

Fires of 1982-1983

Economic losses due to the 1982-1983 fires are estimated at $9 billion (Table 4). This amount is three times the total annual revenue from the forestry sector in 1980, which totaled $3 billion (MOE-UNDP 1998).

In addition to the opportunity costs incurred by the State, local communities also experienced significant losses. Mayer (1989) reported that food, water, and forest supplies were diminished, access to remote communities was blocked, and income was reduced. According to Mackie (1984), damage to pepper crops alone amounted to $2 billion.

Thus, the estimate of losses, while significant, is only partial as the socioeconomic costs have not been fully accounted for.

Fires of 1997–1998

Since the fire season of 1997-1998 continued in two sequences over two calendar years, there are several valuations of losses—preliminary, detailed, by individual years, and by individual sectors of economy; covering host and recipient countries of haze impact; and more comprehensive ones covering all the fires.

One of the more comprehensive estimates was prepared by the Asian Development Bank (ADB). It includes losses covering forestland (timber, NWFPs, reduced/impaired growth), biodiversity, spiritual and cultural values, indirect benefits, carbon sequestered, plantations, estate crops, agricultural crops, and tourism, as well as additional costs incurred for treating haze-related ailments and firefighting.

This valuation builds on previous estimates but includes the cost of the 1998 fires. A modeling approach was used so that the estimates can be updated when more data become available. The approach to valuing the losses has been to sum the value of the individual components, each of which uses the most appropriate technique.

The total losses resulting from the 1997-1998 fires and haze have been estimated at between $8.8 billion and $9.7 billion, with an average of $9.3 billion. A summary of these costs is given in Table 5. With all their negative impacts, and heavy socioeconomic and environmental costs, the fires exposed the weaknesses of government policies in Indonesia.

The reform package introduced by the Government in April 1998 to the International Monetary Fund and further described in the Memorandum of Economic and Financial Policies of 29 July 1998 reflects the measures and targets set to correct the situation. The fires also elicited spontaneous responses regionally, nationally, and internationally in the form of concrete support and action.

TABLE 4 Losses Resulting from Forest Fires in East Kalimantan, 1982–1983

Source of Loss	Value ($ billion)
Timber from Natural Forest	7,981
Timber from Swamp Forest	348
Nonwood Forest Products	373
Rehabilitation Expenses	352
Total	**9,054**

Source: Schindler et al. 1989a, b.

TABLE 5 Summary of Costs of the 1997–1998 Fires in Indonesia

	Estimated Economic Losses ($ million)		
Sector	**Minimum**	**Maximum**	**Mean**
Agriculture			
Farm Crops	2,431	2,431	2,431
Plantation Crops	319	319	319
Forestry			
Timber from Natural Forest (logged and unlogged)	1,461	2,165	1,813
Lost Growth in Natural Forest	256	377	316
Timber from Plantations	94	94	94
Nonwood Forest Products	586	586	586
Flood Protection	404	404	404
Erosion and Siltation	1,586	1,586	1,586
Carbon Sink	1,446	1,446	1,446
Health	145	145	145
Transmigration, Buildings, and Property	1	1	1
Transportation	18	49	33
Tourism	111	111	111
Firefighting Costs	12	11	12
Total	**8,870**	**9,726**	**9,298**

Source: Final Report, ADTA INO 2999: *Planning for Fire Prevention and Drought Management* (BAPPENAS 1999).

Notes

[6] Member countries of ASEAN are Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Viet Nam.

[7] For definition see Glossary in Appendix 1.

[8] For definition see Glossary in Appendix 1.

[9] Several reports and papers including the WWF discussion papers "The Year the World Caught Fire" (WWF 1997) and "The Fire This Time" (Schweithelm 1998a) contain an overview of the Indonesian wildfires in 1997 and 1998.

[10] Ground surveys made by Lennertz and Panzer (Panzer 1989) in timber concessions throughout the burned area have provided proof that damage was generally heavier in logged-over than in primary forests.

[11] The situation has been the same for several years. A seminar on Forest Fire and Satellite Data Utilization held in Jakarta in September 1987 revealed that the Ministry of Forestry had been unable to deal comprehensively with forest fires due to shortage of funds (GOI/FAO 1990b). Investigations indicated that the country's multimillion dollar reforestation fund, collected on timber produced, had not been used to fight fires or set up antifire defenses.

[12] The Indonesian Government has been somewhat late in reacting to fire warnings; data on hot spots were available during January/May 1997, and yet there was no timely proactive initiative. Even after news releases were made of an impending ENSO, land preparation burnings continued as usual in August 1997.

[13] In Indonesia, during the 1997-1998 fires and haze, intersectoral coordination at the central level was not effective due to inadequate institutions, including unclear assignment of tasks, authority, and responsibilities among the relevant institutions, especially in the mobilization of personnel, equipment, and financial resources, as well as reporting and information dissemination. These problems were also seen at provincial and district levels. Donor assistance does not come from a single source using a clearly defined mechanism. Some is received directly by MOFEC, some through the BAKORNAS PB, and others go directly to the provinces. Exchange of information is not well organized, which complicates monitoring of the assistance (BAPPENAS/JICA/ITTO 1999).

[14] ADTA INO 2999: *Planning for Fire Prevention and Drought Management*.

[15] Apart from the impact of particulate matter on health, it could also affect the long-term global temperature balance by disturbing the evaporation-condensation cycle.

[16] ADB under its ADTA INO 2999 estimated that a total of 757 million mt of carbon dioxide were produced during the 1997 and 1998 fires (more than 85 percent of this was as a result of the combustion of peat). The total cost of the carbon released into the atmosphere (based on $7/mt) was calculated to be $1.446 billion. This figure is conservative; other estimates have put the amount of carbon dioxide produced at 3.7 billion mt, or nearly five times the level estimated by the technical assistance.

[17] Within about two to three months of the forest fires and haze.