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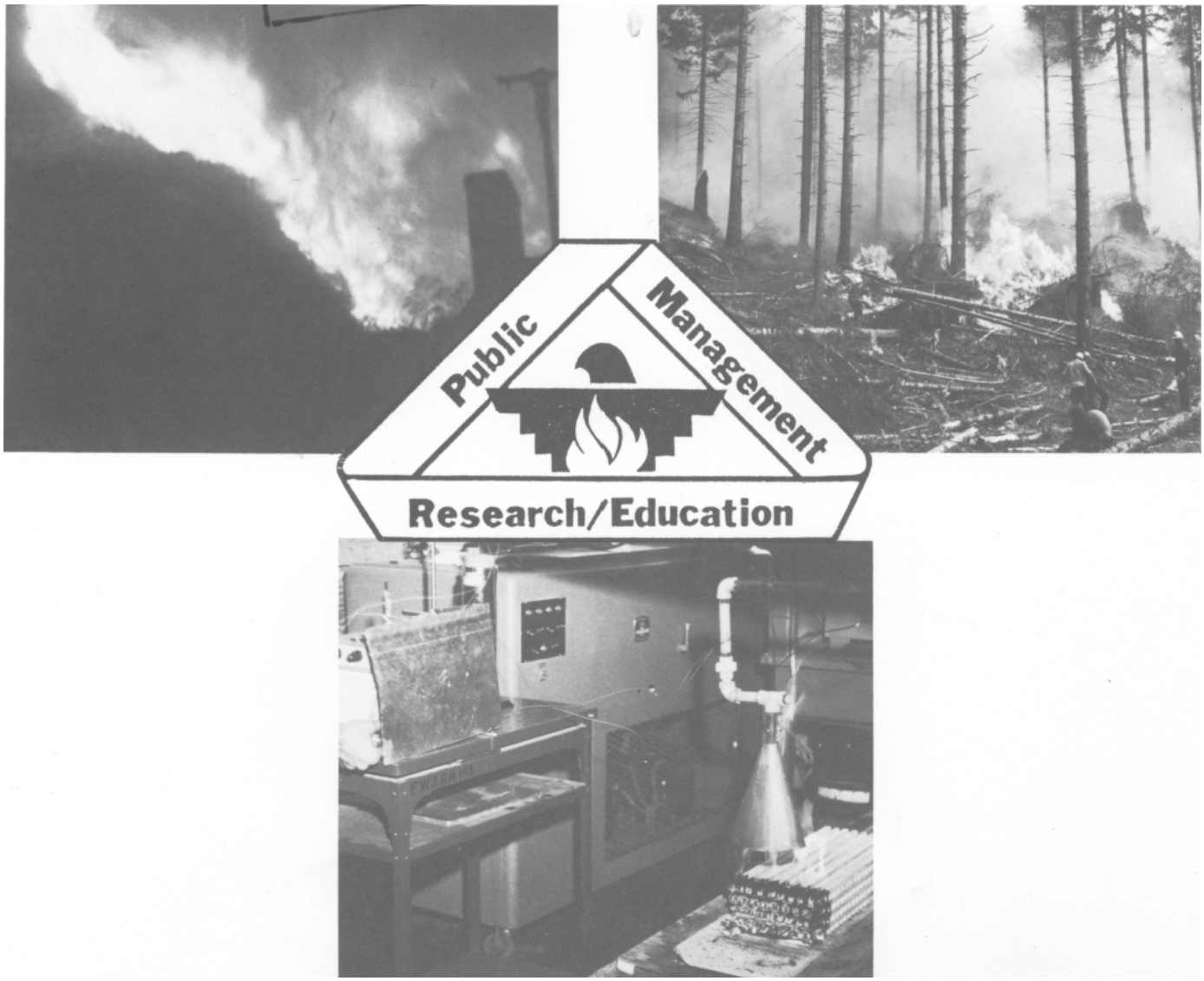

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Wildfires and Forest Development in Tropical and Subtropical Asia: Outlook for the Year 2000[1]

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Abstract: Growing population and enhanced demand for fuelwood, timber and agricultural land are causing a rapid deforestation process throughout the tropics and subtropics. This pressure on the forest land is being accompanied by increasing occurrence of human-caused wildfires. In most cases the fires are following in the wake of the exploitation of natural forests and the slash-and-burn shifting agriculture, or they are set deliberately by graziers, hunters and collectors of minor forest products. It is estimated that each year wildfires affect more than 50 million hectares of forested land and about 600 million hectares of savannah and bush land within the tropical and subtropical regions of the world. An increasing tendency towards wildfire occurrence can be expected during the next decades. The collective scenario in the remaining noncommercial forest land will therefore be characterized by degraded and open formations, and the overall development of many forest communities will lead to an extended transformation into highly flammable fire climax savannas. Examples of this process are given by describing the development of the most prevailing forest types in tropical and subtropical Asia. Relevant concepts of future wildland fire management and research need to be oriented towards this future scenario.

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The tropical forests of the Americas, Africa and Asia in 1980 covered about 1,935 x 10^6 ha of which 61,200 x 10^6 ha were closed forest and 735 x 10^6 ha were open tree formations. In addition, fallow forest land accounted for 410 x 10^6 ha (FAO 1985). In most countries of the humid and dry tropics, forests are being cleared or degraded at a rapid rate, mainly to satisfy the basic subsistence needs of poor rural communities.

In this zone live 2 billion people, and the population is increasing at a net annual average rate of 2.6 percent. The increasing population is exerting pressure for the use of forest land for agricultural and settlement purposes. According to the estimates of the Food and Agriculture Organization of the United Nations (FAO 1985) the deforestation rate of closed tropical forests and open tree formations has been estimated at 11.3 x 10^6 ha per year during the early 1980's, mostly due to transfer of forest land to agricultural use.

Official statistics of deforestation in tropical Asia show an average deforestation of 1.8 x 10^6 ha per year during the 1976-80 period (FAO/UNEP 1981). The deforestation within Insular Southeast Asia alone (Indonesia, Malaysia, The Philippines) amounts to 0.8 x 10^6 ha per year, and is expected to reach 1.0 x 10^6 ha per year during the 1981-85 period.

A great part of this forest depletion is due to shifting agriculture (slash-and-burn techniques) and the long-term effects of repeated and uncontrolled wildfires which accompany fuelwood collection, grazing and the harvest of minor forest products. The high frequency of wildfires in degraded vegetation types (savannas, bush and grasslands) is a major impediment to the restoration of former forest types or the development of climax forest (Goldammer 1986a). It has been estimated that the total area burned or cleared (all ecosystems worldwide) amounts to 630-690 x 10^6 ha per year (Crutzen and others. 1979; Seiler and Crutzen 1980). More than 98 percent of the burned and cleared area is in the tropics and subtropics. The total forested area cleared and burned annually for agricultural purposes in the 6 tropics covers about 30-80 x 10^6 ha. with an average of about 50 x 10^6 ha. The burning of savanna and bushland amounts to approximately 600 x 10^6 ha per year. Major single wildfires recently reported within the tropics sometimes exceed 3-5 x 10^6 ha (Malingreau and others 1985; Goldammer 1986).

SOCIOECONOMIC AND CULTURAL BACKGROUND

The vast majority of wildfires follows in the wake of traditional agricultural practices and other deep-rooted burning habits of the rural population. Goldammer (1986c) classified five broad causes of wildfires within the tropics:

Shifting Cultivation--Slash-and-burn agriculture is variously known as swidden, shag, kaingin, jhum, chena, podu, etc. in various parts of the world. It involves the clearing of woody vegetation by girdling and felling trees at the beginning of the dry season, and the burning of the dried biomass at the end of the dry season. The spread of the fires into the surrounding forest land is usually not controlled by the peasant forest cultivators. With increasing population pressure and due to shortening of fallow period, abandoned slash-and-burn areas are increasingly converted into sterile bush or stretches of grassland.

Grazing--Intentional grassland burning is an old cultural tool for stimulation of grass growth during the dry season, the control of parasites that carry and transmit stock diseases, control of undesirable plants, and driving of game. The scarcity of grassland available for grazing and a heavy reliance on grazing in forest areas results in extended uncontrolled silvopastoral practices, thus increasing the penetration and spread of grazing fires within the forested land.

Harvest and Collection of Nonwood Forest Products--Nonwood forest products have an increasing economic and social significance in many tropical countries. They include grasses, fruits, leaves, honey, wax, resin_ etc. The collection of this produce is very often facilitated by setting fire to the forest land. The permanent presence of people travelling through the forested land also provokes a high probability of accidental wildfires.

Migration and Land-Settlement Programs--The last undisturbed reserves of lowland tropical rain forests become more and more influenced by spontaneous migration and organized (public) land settlement projects. The ecological condition of the forests is altered by logging, fuelwood collections, and invasion of grasses, thus making the rain forest vulnerable to wildfires.

Wildland-Settlement Interface--The mutual influence of wildland and village/urban fires is considerably higher compared with that in industrialized countries outside the tropics. This is due to fuel characteristics, materials used for house construction, and burning habits of rural populations.

The role of natural (lightning) fires, which are considered a major factor in maintaining balance in the tree-bush-grass composition patterns of tropical savannas, becomes relatively less important compared with the increasing pressure of human-caused wildfires.

THE PRESENT SITUATION IN THE ASIAN THEATER

In accordance with the systematics of the FAO Asia Tropical Forest Resources Assessment (AFAO/UNEP 1981) this paper summarizes the wildfire information available for the whole of Asia south of China, from Pakistan to the west, to the island of New Guinea to the east, with the exception of the Maledives and Singapore (fig. 1). More than half of the land area of these countries is located within the tropical belt, except Bhutan, Nepal, and Pakistan, which are entirely above the Tropic of Cancer. They have been included because they are part of the same subcontinent and are presenting similar features as the neighboring regions of India. Moreover, tropical and subtropical climatic influences are perceptible quite north of the

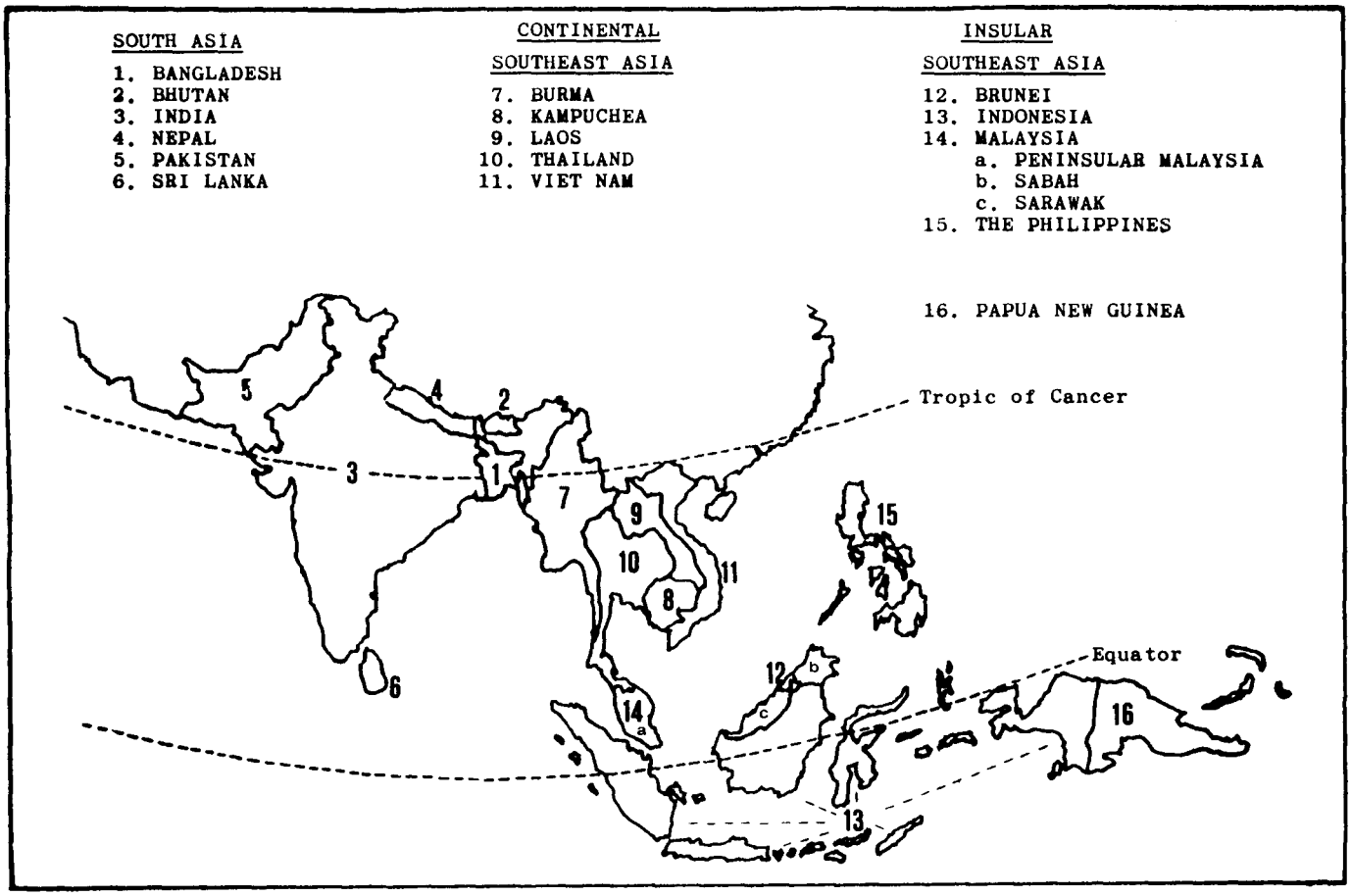

Figure 1--Sixteen countries were studied in tropical Asia.

Tropic of Cancer. Papua New Guinea, although generally considered an Oceanian country, has been included because of its relatively large area within the tropical belt and the fact that it shares with Indonesia the island of New Guinea.

The forest types regularly affected by fire are shown in table 1. Most of the field information was collected by the author. Information that was lacking has been taken from country reports or personal communication. In none of the countries reliable forest fire statistics exist. In most cases fire reports highly underestimate the real number, size, and damage of forest fires.

Some estimates may demonstrate the regional dimension of the forested area annually affected by fire. In India, Srivastava (1985) reports that almost one third of the Sal forest (Shorea robusta). one half of the hill pine forests (Pinus roxburghii) and one half of other forest ("miscellaneous") are burnt every year. Goldammer (1986) estimates that the annual area burnt in Burma may exceed 3.5 to 6.5 x 10^6 ha. Major single wildfires recently reported in Indonesia and Malaysia amounted to 2 to 3.5 x 10^6 ha. Altogether it is estimated that within tropical Asia more than 10 x 10^6 ha of forested land (closed and open broadleaved forests, and coniferous forests) are burnt over every year, in addition to the average deforestation rate of nearly 2 x 10^6 ha per year.

WILDFIRE REGIMES IN THE MAIN FOREST TYPES

The wildfire regime in tropical and subtropical forests is mainly determined by the degree and history of disturbance and degradation processes. The feature of a type of fire regime may be the same in different natural vegetation types. A broad classification of fire regimes in tropical and subtropical Asia

Table 1--Main forest types of tropical Asia regularly affected by wildfires. Bamboo forests and the different grass and brush savanna types are not listed because of regular fire occurrence throughout the whole region.

Country	Forest type regularly affected by wildfire[1]
Bangladesh	CBF 1,2.3: Dipterocarp forests in the Chittagong Hill Tracts. CBF 4: Shorea robusta forests ("inland Sal forest").
Bhutan	CBF 4: Shorea robusta, associated with Schima Walichii, Lagerstroemai, Terminalia spp. through the Sub-Himalayan tract, including lower slopes of the Himalayas. CF: Pinus roxburghii forest on Himalaya slopes between 1000 and 1500 m. associated with Rhododendron, Quercus and Castanopsis spp.
Brunei	Similar to Indonesia
Burma	CBF 4: Mixed deciduous forest with tea (Tectona grandis) Moist and dry mixed deciduous forest associated with bamboos (Bambusa, Dendrocalamus spp.) CBF 7: "Indaing" and "Semi-Indaing" forest with Dipterocarpus tuberculatus. CF 1: Subtropical hill forests with Pinus khesiya (1200 to 2400 m) and P. merkusii in lower elevations.
India	CBF 4: Tropical moist and dry Sal forests (Shorea robusta) and dry tropical teak forest ((T. grandis). CBF 9: Hill broadleaved forests with Quercus spp., being replaced by bamboos. OBF: With teak, sal, Terminalia, Anogeisus etc. CF 1: Pinus roxburghii (Western Himalayas), P. khesiya (eastern Himalyas). CF 2: Occasionally in higher elevations in Pinus wallichiana, Abies, Picea, Cedrus spp.
Indonesia	CBF: On periodically water-logged lands. CBF 6: Swamp and peat-swamp forest during extreme droughts. CBF 5: Dipterocarpaceae. CBF 1: With Shorea, Hopea, Dipterocarpus spp. OBF: Natural savannas with Melaleuca and Eucalyptus spp. in Nusatenggara and Irian Java. CF 1: Pinus merkusii in northern Sumatra (around Toba Lake).
Kampuchea	CBF: Melaleuca leucadendron forests. OBF: Mixed open forest with Shorea, Dipterocarpus, Terminalia spp. east of Mekong north of the lakes. CF 1: Hill pine forest west of Mekong (Pinus merkusii).
Laos	CBF 9: Broadleaved hill forest between 800 and 1000 m, with Fagaceae and Lauraceae. OBF 7: Dry deciduous forest in the Mekong lowlands, with Pentacme, Terminalia, Dipterocarpus, Shorea spp. In higher elevations Castanopsis, Quercus spp. CF: Pinus merkusii until 800 m, followed by P. khesiya.

Malaysia	Similar to Indonesia
Nepal	CBF 4: Sal forests (Shorea robusta) in the Terai lowlands. CF 1: Pinus roxburghii. CF 2: Occasionally in Abies, Picea and Tsuga stands.
Pakistan	CF1: Pinus roxburghii stands between 900 and 1650 m.
Papua New Guinea	OBF: Eucalyptus and Melaleuca savannas in south-central and southwest of the island.
The Philippines	CF 1: P. khesiya forest lands in the Central Cordillera of North Luzon. CBF: Occasionally in dipterocarp forests. Fire climax tree/grass savannas in the foothills of the Cordillera.
Sri Lanka	OBF: Mainly in monsoon grasslands and savannas.
Thailand	CBF 9: Extensive areas up to 1000 m elevation with Dipterocarpus, Shorea, Hopea, Anisoptera, Dalbergia and Lagerstroemia spp. CBF 4: Mixed deciduous forests with Tectona grandis. CBF 7/OBF 7/CF 1: Similar to Burma.
Viet Nam	OBF 7: Similar to Laos and Burma, especially in elevations above 500 m.

[1]Forest classification simplified on the base of Champion and Seth (1968) and FAO/UNEP (1981).

CBF = Closed broadleaved forest
OBF = Open broadleaved forest

1 = Tropical wet evergreen forest
2 = Tropical submontane or montane evergreen forest
3 = Tropical semi-evergreen forest
4 = Tropical moist deciduous forest
5 = Heath forest edaphic subtype
6 = Peat-swamp forest of moist forest
7 = Tropical dry deciduous forest
8 = Tropical dry evergreen forest
9 = Subtropical broadleaved hill forest
9CF = Coniferous forest
1 = Subtropical pine forest
2 = Himalayan moist temperate forest

therefore embraces different forest types of the classical forest distinction of Champion and Seth (1968) and the description by FAO/UNEP (1981). South Asia is represented by examples of India and Nepal. Continental Southeast Asia by Burma, and Insular Southeast Asia by Indonesia and the Philippines.

Tropical Wet Evergreen Forests

The tropical wet evergreen forests are found in regions with average temperature above 20°C and annual rainfall between 1,500 and 2,500 mm. The dry season does not extend beyond 2 to 4 months with less than 50 mm rainfall each. The forests occur mainly in Insular Southeast Asia. The dense overstory and the intermediate tree layer prohibit the entrance of sunlight and the establishment of an herb-shrub layer. Decomposition and nutrient cycling is rapid due to the humid climatic conditions. The tropical rain forest trees in general are fire sensitive due to the thin bark.

Under undisturbed conditions, these factors altogether characterized a nonflammable forest ecosystem. After being disturbed by logging operations, forest road construction and shifting cultivation, however, this forest type tends to become flammable due to increased sunlight and wind penetration, logging residues and understory formation (fig. 2). Pioneer plants which are often introduced from outside the region invade the forest land after serious disturbance of the rain forest. They form highly flammable vegetation covers (e.g. Eupatorium, Lantana and Imperata spp.).

An extreme and prolonged dry season may create conditions favorable to spread of extensive wildfires within this forest type. A striking example of this kind is the wildfire occurrence in the dipterocarp rain forest of Indonesia. Malaysia and the Philippines during the 1982-83 "El Niño" drought. After the 1982-83 fire season more than 3.5 x 10^6 ha of land was burnt in East Kalimantan/Indonesia, about the same area in Sabah and Sarawak/Malaysia, and about 20,000 ha in Mindanao/ Philippines (fig. 3). Even the peat-swamp forest, an edaphic subtype of tropical moist forests, were affected. The turflike accumulation of peat, which may be up to 20 m deep, was dried to a depth exceeding 0.5 m and carried ground fires causing the most severe and lasting damage of the rain forest (see also Lennertz and Panzeer 1984).

Such extreme environmental conditions usually occur only at long intervals. The fire

Figure 2--Slash-and-burn agriculture is one of the major fire causes within the tropical rain forest lands. Under extreme drought conditions the rain forest may become extremely flammable.

Figure 3--A burnt rain forest site south of Samarinda (East Kalimantan/Indonesia), 18 months after the 1982-83 wildfire.

occurrence in the moist tropical rain forests may therefore be restricted to such occasional events. However, increasing land-use pressure on the remaining closed rain forest areas in Asia will also increase the probability of coincidence of the factors mentioned causing such catastrophic wildfire situations.

Tropical Semi-Evergreen and Deciduous Forest

With longer dry periods, the evergreen forests are replaced by semi-evergreen and mixed deciduous forests. The shedding of leaves during the dry season favors the spread of surface fires within these forest types which are found throughout tropical Asia (fig. 4). Large expanses occur in Burma.

Fire presumably has played a major role in the successional development of the teak-bearing (Tectona grandis) mixed deciduous forests of Burma (fig. 5). None of the teak-bearing forests of Burma are primeval forest (Kermode 1964; Goldammer 1986d . All of them have been affected to some extent by wildfire. These fires usually burn as surface fires of moderate intensity. The main fuel components are the dry leaves of the fire-tolerant teak and other deciduous trees and the bamboos. A great part of the teak-bearing mixed deciduous forests has the characteristic properties of a fire climax forest (Goldammer 1986d). Exclusion of fire leads to a striking absence of reproduction of teak (U KYAW ZAN 1953; Goldammer 1986d).

The most important types of the deciduous dipterocarp forests are the "Indaing High Forest" and the "Semi-Indaing Forest" (fig. 6). They are also exposed to frequent and almost annual wildfires. The characteristic species are Dipterocarpus tuberculatus and Pentacme siamensis, which show the same fire-related surviving mechanisms as does teak. The long-term influence of these frequent fires is resulting in a slow process of site degradation and erosion. The total annually burnt area of forested land in Burma has been estimated at 3.5 to 6.5 x 10 ha (Goldammer 1986d).

In the northern part of the subcontinent of India the main deciduous forest type frequently exposed to wildfires is the "Terai" forest, predominantly consisting of almost pure or mixed stands of Shorea robusta ("Sal"). This dry dipterocarp forest association stretches south

Figure 4--Southern Tropical Dry Deciduous Forest, Chandrapur. Maharashtra/India. The degraded form of this forest type is characterized by wide-spaced fire tolerant species, e.g. teak (Tectona grandis).

Figure 5--Teak (Tectona grandis) a forestation near Haldwani (Uttar Pradsh/India). Surface fires generally occur during the end of the dry season and expose the mineral soil. The first monsoon rains hit the top soil layer before protective crown cover or herbaceous layer have been developed. This stand has lost approximately 2,000 m^3 of topsoil since stand establishment 30 years ago.

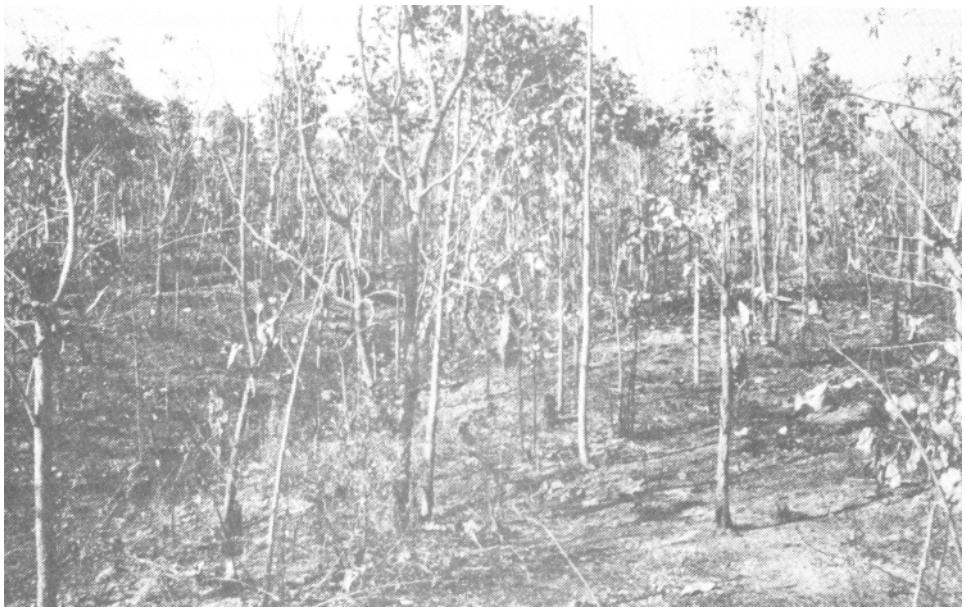

Figure 6--Lowland "Indaing" forest near Yezin, Burma. This forest type is subjected to annual fires, extensive grazing and fuelwood cutting. It represents a common feature of degraded deciduous forests within tropical South and continental Southeast Asia.

of the Himalayan foothills and is found in India, Nepal. and Bhutan. The frequent fires do not cause damage to the old Sal trees because of its thick and heat-insulating bark. Regeneration, however, is usually killed back. Since the rootstock is generally not affected by the low-intensity surface fires, new and vigorous shoots appear after the fire. These coppices are palatable for the local cattle, and the fires therefore are set deliberately.

A single fire will not harm this "fire tolerant" forest association. Frequent or annual fires, however, affect the age class distribution by widening the gap between the mature overstory and the regeneration process. Therefore, apparently overmature and decadent Sal forest completely lacking young trees occur in large areas (Goldammer 1986e).

The overall development of deciduous forests subjected to frequent wildfires, grazing and uncontrolled logging generally leads to degraded formations; the schematic development and the management implications are shown in figure 7.

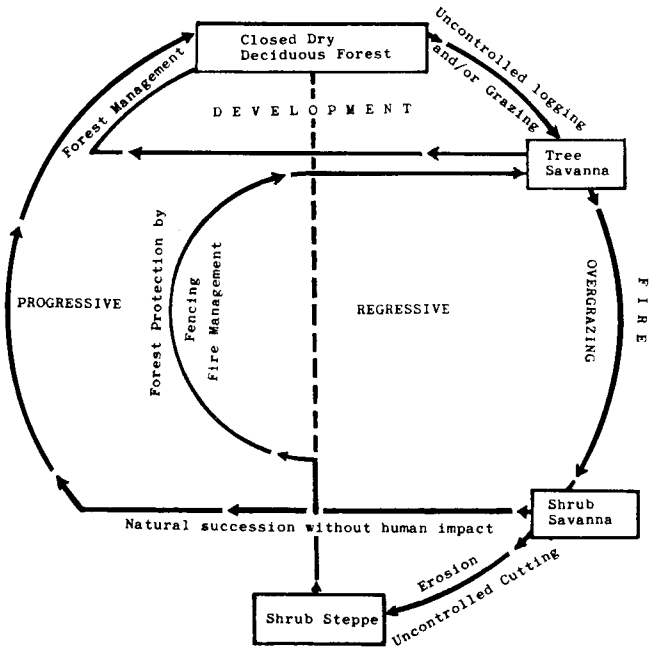

Figure 7--Schematic development and management implications of dry deciduous forest influenced by wildfires and grazing. (Modified after Verma 1972).

Broadleaved and Coniferous Hill and Montane Forests

Wildfire effects become increasingly visible throughout the submontane and montane forests of tropical Asia and the Himalayas. In mountainous regions where pines occur naturally (Pinus khesiya and P. merkusii in continental and insular Southeast Asia; P. roxburghii and P. wallichiana in the Himalayas), many of the broadleaved forests (e.g., dipterocarp forests in lower elevations and oak-chestnut associations in higher elevations) are replaced by fire-climax pine forests.

A striking example of this kind of forest development is found in the island of Luzon, the Philippines (KOWAL 1966; Goldammer 1985, 1987). Within the Central Cordillera the forest land has been influenced by human-caused fires for centuries. P. khesiya forms extensive, more or less even-aged stands which, at higher elevations above 1,500 m, maybe densely stocked but which become more open at lower altitudes (fig. 8). In most of the forests there are only two strata, the pine layer and the herbaceous layer dominated by fire tolerant grasses (Themeda triandra, Imperata cylindrica, Miscanthus sinensis) and bracken fern (Pteridium aquilinum). Fire exclusion leads to the reestablishment of fire sensitive understory and the replacement of a great part of the pines by dipterocarps (expanding from lower elevations) or oak associations ("mossy forest," descending from higher altitudes); under undisturbed conditions pure pine stands are usually restricted to dry sites and extremely poor soils, mainly on ridges and steep slopes.

Similar fire regimes and forest dynamics are observed within the whole natural range of Pinus khesiya (India, Burma, Thailand, Laos, Viet Nam). The same refers to Pinus merkusii, which occurs at lower elevations in both continental and insular Southeast Asia. Due to fire adaptation of P. merkusii the actual occurrence of this species has been greatly expanded compared with its natural (undisturbed) range (Lamprecht. 1986).

The stability of serial fire climax pine forests depends on a variety of factors (topography, fire frequency, distribution of precipitation, grazing/trampling effects, etc.). Steep slopes are generally exposed to erosion and long-term degradation whereas properly fire-managed stands may be maintained as steady-state pyroclimax forests.

Figure 8--Open and parklike Pinus kesiya hill forest stand in Burma. This type of fire-climax pine forest occurs throughout the whole range of Asian pine species.

Savannas and Other Forest Types

With increasing influence of uncontrolled logging, grazing and wildfires, most tropical forest types tend to follow the degradation scheme shown in figure 7. The overall development leads to wide-spaced vegetation covers, mostly referred to as tree, bush or grass savannas. Regardless of the primary origin of many of the diverse savanna types throughout the tropics, natural and anthropogenetic fires have long been recognized as the major factor in creating and maintaining tree-bush-grass composition patterns of tropical savannas (e.g., open dipterocarp woodlands throughout tropical Asia, or the temporarily inundated "Padang" heath forests of Indonesia).

Some of the pioneer plants occupying the forest land repeatedly cleared and burned (short rotation shifting agriculture) tend to form pure and highly flammable vegetation covers. The most aggressive invading grass species is Imperata cylindrica which forms extensive fields and most unsuitable habitats for germination and seedling growth of forested plants. These Imperata fields ("Cogonales" in the Philippines, "Alang-alang" in Indonesia) in 1970 covered more than 20 percent of the land area in the Philippines (6×10^6 ha). According to the latest data available, Imperata fields cover more than 16×10^6 ha in Indonesia, and 4×10^6 ha in Thailand and Papua New Guinea respectively (FAO/UNEP 1981), converting former forest land into almost sterile and unproductive waste land.

Frequently burnt forest sites may also develop into almost pure stands of broadleaved trees. Typical pyrogenetic forests are particularly common in Indonesia and New Guinea (Irian Java and Papua New Guinea). In Java gregariously growing Tectona grandis and Albizia lophanta stands are found. In New Guinea fire-induced Eucalyptus and Melaleuca savannas are common on sites exposed to seasonal inundation and extreme drought (fig. 9).

DESIGN OF A HOLISTIC SCENARIO

According to a report of The Population Institute the world's population has reached the 5 billion mark recently. It can be expected that the world's population will be growing to 6.2 billion by the year 2000 (Associated Press 1987). The countries facing the most serious growth by the end of this century are mainly

Figure 9--Industrial plantations within the tropics and the subtropics are mainly based on fast growing introduced species, e.g., Pinus and Eucalyptus spp. Stand development is characterized by extreme fuel build-up and wildfire hazard. Prescribed burning techniques need to be introduced into plantation management. Photo shows prescribed burning in 9-year old Slash pine (Pinus elliottii) plantation in Paraná/Brazil.

within the tropics and include Bangladesh, Brazil, Burma, China, Egypt, India, Indonesia, Iran, Kenya, South Korea, Mexico. Nigeria, Pakistan, the Philippines Tanzania, Thailand, Turkey, Viet Nam and Zaire.

This population growth will exert increasing pressure on the forest resources, causing the most serious changes within the tropical rain forest lands. Mabberley (1983) estimated that by 1990 there will be little of the rain forest left in Australia, Bangladesh, India, Sumatra and Sulawesi. peninsular Malaysia, Melanesia, the Philippines, Sri Lanka, Thailand, Viet Nam, Central America, Madagascar, and East and West Africa through the depredations of timber extraction, cattle ranching and transmigration schemes.

By the year 2000, it can be estimated that a great part of the forests within the tropics (except some of the remote and wet rain forest lands of Brazil's western Amazonia, the Guineas and the Zaire basin) will be degraded to secondary open forest land or converted to other land-use systems. In general the open forest lands will become more flammable, and the fire regimes will change accordingly. Forest and wildland dynamics and fire regimes will be characterized by increasing wildfire occurrence and increasing size of single fires. More frequent fires will lead to an overall selection of fire tolerant/resistant species, thus resulting in the loss of diversity in much of the previously closed forest land.

Rural land-use systems will be characterized by uncontrolled agroforestry techniques (agrosilviculture, silvopastoral techniques). The mutual interactions of fires spreading from agricultural land and villages into the wildland and vice-versa will increase the threat to human life and properties.

The direct local impact of wildfires on soil stability and erosion will have considerable

downstream effects. Large-scale erosion, flooding, siltation and desertification will be more common. The forest denudation within the largest watershed of the world, the Himalayas, and its impact on the lowland south Asian countries may be a striking example of this kind of development (Koshoo 1986).

Furthermore the impact of biomass burning has a considerable potential in contributing to global changes of biogeochemical regimes and the atmosphere (see Crutzen and others 1979; Crutzen and Seiler 1980; National Research Council 1986; Palmer 1987).

IMPLICATIONS FOR MANAGEMENT AND RESEARCH

The lack of awareness of the wildfire problem within the tropics is mainly due to nonexisting or incomplete information about the extent and impact of wildfires. The existing reporting systems generally underestimate size and damage of the fires. Most information available is restricted to plantations.

In most tropical countries integrated forest/wildland fire management concepts need to be developed. These approaches will be extremely different from systems existing within the industrialized, mainly nontropical countries, because they will deal with a complete different socio-cultural, economic, and political background.

The need for tropical fire research is obvious. In Asia present activities are casual, and the research institutions and universities pay only small attention to the environmental impact of wildfires. However, some first programs were stimulated by FAD in the Philippines and in Burma (Goldammer 1986d, 1987). FAD has also initiated a series of local and national fire management programs in India, Indonesia, Burma and the Philippines. The next step should be a regional project within tropical Asia to stimulate and coordinate fire management activities.

If more information on fire ecology in tropical biota will be available, it presumably will be recognized that the overall tropical fire regime represents a threat to local and global natural resources, comparable to the emission-caused forest dieback within the industrialized countries of the northern hemisphere.

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