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Toasted Forests – Evergreen Rain Forests of Tropical Asia under Drought Stress

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Abstract

This paper has been written to make an enormous threat known to the public. We all know about the forest fires that raged in Indonesia and parts of Malaysia in 1997, and about the noxious haze covering the whole region, but only a few experts are aware of the threat of extinction of the last rain forest areas in Southeast Asia. As this paper will show, droughts have always been a part of these ecosystems, which normally receive plenty of rain. Mild droughts can be regarded as slight or medium disturbances, which can even have a stimulating effect according to the Intermediate Disturbance Hypothesis. However, severe droughts and fires have a destructive effect, which will only be overcome in successional stages.

Logging and forest fragmentation reduce the ability of forests to overcome severe droughts. Forest fires rage in selectively logged forests, whereas they are extremely rare in undisturbed rain forests. Forest regeneration in fragmented forests is disturbed, so that we have to expect a total degradation of even effectively protected forest areas. Due to drought and fire, the remnant rain forest areas are being roasted like slices of toast . New research is also revealing that rain forests under drought stress consume more oxygen than they produce. The “green lung” and carbon sink are thus out of function. Furthermore, severe ENSO-(El Niño/Southern Oscillation)-droughts have been increasing in recent years.

The consequences both for development of the region and for the whole atmosphere are imminent. Forest fires during ENSO droughts have caused extensive damage to forests and plantations, and noxious haze clouds in the whole region. Awareness about ENSO and droughts exists and is growing within the local population. Strict regulations, drought and fire alerts, and law enforcement can reduce at least the effects of drought. A logging ban, also including selective logging, may have to be considered.

While this paper covers the whole of tropical Asia, it focuses on Sumatra, Borneo and the Malay Peninsula, which are the main evergreen rain forest areas. Other areas in the region have either seasonal vegetation, which is more drought adapted, or only small pockets of evergreen rain forest depending on local rain exposure – or the lowland forests have disappeared. The paper concentrates on Western Indonesia, Malaysia and the very south of Thailand.

Kurzfassung

Diese Studie soll auf eine beträchtliche Umweltgefahr aufmerksam machen. Die Waldbrände in Indonesien und Teilen Malaysias 1997 und der gesundheitsschädliche Smog („haze“), der eine ganze Region einhüllte, sind uns noch in Erinnerung. Aber nur wenige Experten sind sich der Tatsache bewusst, dass die noch verbliebenen immergrünen Regenwälder von Südost-Asien in ihrem Fortbestand bedroht sind. Es wird aufgezeigt, dass kurze Trockenperioden als nur leichte oder mittlere Störungen des Ökosystems anzusehen sind, die entsprechend der „Intermediate Disturbance Hypothesis“ sogar einen stimulierenden Effekt haben können. Starke und lang anhaltende Dürren und Feuer wirken sich zerstörerisch aus, und die Schäden werden nur langsam über Sukzessionsstadien ausgeglichen.

Holzeinschlag und Waldfragmentierung verringern die Chancen, dass durch starke Dürren geschädigte Wälder regenerieren. In Waldflächen, in denen selektiver Holzeinschlag betrieben wurde, breiten sich Waldbrände aus, die in ungestörten Regenwäldern höchst selten und in schwächerer Auswirkung auftreten. In den Restwäldern wurde eine mangelnde Waldregeneration festgestellt, so dass eine völlige Degradierung selbst erfolgreich geschützter Waldgebiete befürchtet werden muss. Die verbliebenen Regenwaldreste werden durch Dürren und Waldbrände gleichsam wie Toastscheiben geröstet. Neue Untersuchungen haben ergeben, dass Regenwälder unter Trockenstress mehr Sauerstoff verbrauchen als sie produzieren. Damit ist die „Grüne Lunge“ und Kohlenstoffsenke außer Funktion. Starke ENSO-Dürren haben in den vergangenen Jahrzehnten zugenommen.

Die Folgen für die Entwicklung der Region und für die gesamte Erdatmosphäre sind beträchtlich. Waldbrände während ENSO-Dürren haben bereits Schäden von vielen Milliarden Euro an Wäldern und Plantagen verursacht. Eine giftige Smogwolke (Haze) in der Region war eine weitere Folge. Das Bewusstsein für ENSO-Dürren ist in der lokalen Bevölkerung vorhanden und nimmt zu. Strenge Bestimmungen, ein Alarmplan für Dürren und Waldbrände, und Durchsetzung des geltenden Rechts können die Dürrefolgen zumindest verringern. Ein Einschlagverbot, auch für selektives Holzfällen, sollte erwogen werden.

Diese Studie umfasst zwar gesamt Süd- und Südost-Asien, konzentriert sich aber auf Sumatra, Borneo und die Malayische Halbinsel, da dort das Hauptgebiet der immergrünen Regenwälder zu finden ist. Andere Gebiete ringsum haben entweder saisonale und laubwerfende Vegetation, die an Trockenheit angepasst ist, oder kleine Regenwaldflächen, die durch lokales Klima an niederschlagsreichen Standorten gekennzeichnet sind. Die Studie behandelt daher vor allem West-Indonesien, Malaysia and das südlichste Thailand.

1 Introduction

Tropical rain forests are particular ecosystems with extremely high biodiversity, organic mass and fast growth based on high temperatures and availability of water. Nutrients and light are scarce, and there is a constant struggle for both. Without cooler temperatures and seasons, plants produce flowers and fruits all year around, and exchange their leaves after several years twig by twig, or a whole tree may be leafless for a couple of days. In the humid and warm environment, dead leaves and other plant material are decomposed within a short time, and their nutrients again become available to the living plant mass. The fruits of rain forest trees germinate within few days, but if their roots do not reach the forest soil they die. Young trees stand in a waiting position for many years until the older trees die and make room and allow light to penetrate the canopy. In these highly diverse systems, hundreds of tree species exist in one specific location. Individuals of the same species may sometimes form clusters, but others may be distributed over a larger area. Many of them are dioecious, and pollination is no longer possible if one of the last two individuals of different sexes is cut down or dies.

Over 100 years ago, the German plant geographer A.F.W. Schimper coined the term *Regenwald* for these forests, which has been translated into English as rain forest. This name is still widely debated, as many botanists and foresters are not happy with it. Most forests of the world depend on rain. Schimper certainly wished to express that this type of forest receives plenty of rain during the whole year. Therefore, this paper discusses drought in an environment that, by definition, should be free of droughts.

Tropical evergreen lowland rain forests need more than 2,000 mm of rainfall more or less evenly distributed throughout the year. Average rainfall of 2,500 to 3,800 mm is common, up to 5,000 mm is possible. Once we climb up the hills in such rain forest areas, we will note that, although some species disappear above 150 m altitude, the forest ecosystem remains more or less the same up to 900 m altitude. Above this line, which is often marked as the lower limit of frequent clouds, another ecosystem begins. This is the lower montane rain forest, which has somewhat smaller stems in steep terrain and a different species composition. These are still evergreen forests without seasons. Although lower montane rain forests should be part of this study, we can neglect them, as there are almost no reports on drought effects within these forests.

Above 1,500 m we encounter yet another forest type, the upper montane rain forests or cloud forests. These have a completely different set of species, stunted growth and umbrella-shaped tree crowns and receive a considerable portion of water through fog stripping. We will discuss this forest type later.

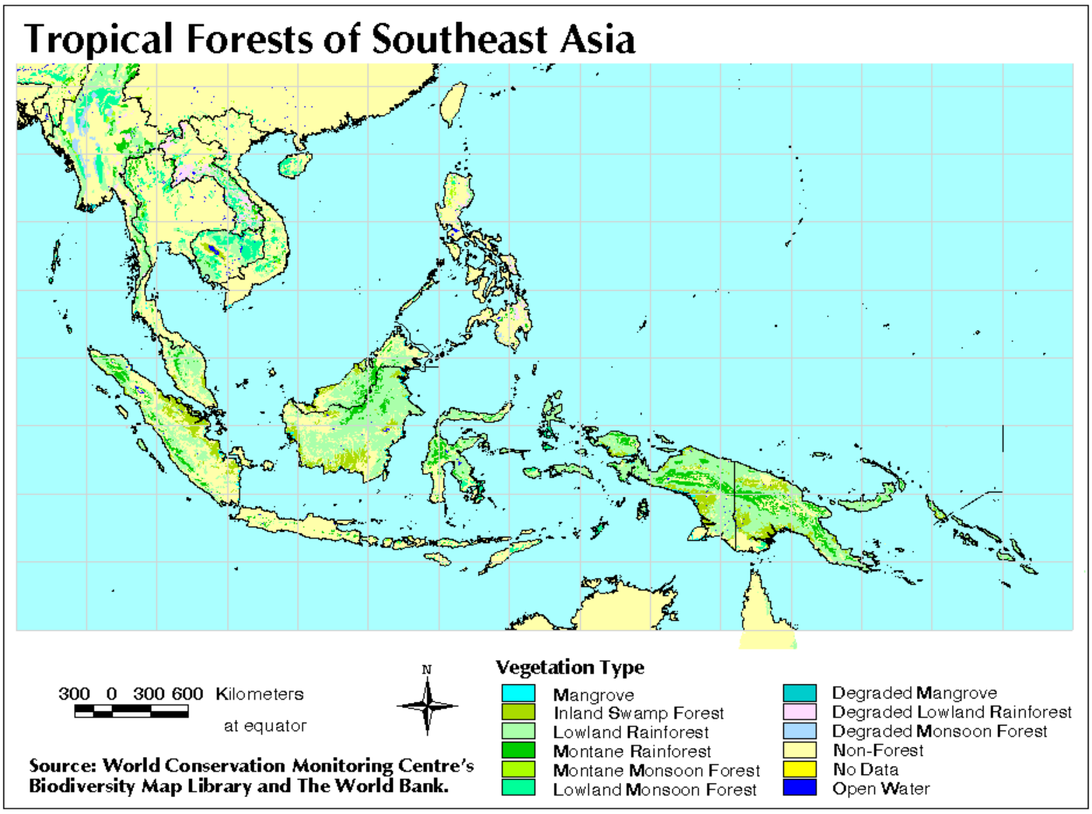
If a rain forest area experiences a pronounced drought period of about one month every year, but annual rainfall is still well above 2,000 mm, it can adapt to this drought stress. Species composition differs from that of the ever-wet rain forest and biodiversity is lower. The more drought tolerant trees are still evergreen, but leaf change will be predominant during the short drought period, and the largest emergent trees tend to be leafless for a short period. Flowering also occurs during the drier period, and fruits will germinate with the next rains. This forest type is called "seasonal rain forest" and is the typical rain forest type of continental Southeast Asia.

These seasonal rain forests are not part of the present study, as they are more or less drought adapted. Deciduous forests, like teak forests or dry deciduous dipterocarp forests of Myanmar, Thailand, Laos and Vietnam are even more drought adapted and used to annual fires. Some of these forests are often confused with rain forests, but they are completely different ecosystems. We can assume that they spread, while evergreen rain forests retreated, as a result of climate change. This is one of the explanations for the Sri Lanka – Sumatra/Borneo disjunction.

The dominant tree family of the rain forests of Southeast Asia is Dipterocarpaceae. With their huge, straight stems they constitute the best timber trees of the area. Their center of diversity is Borneo with 155 species; in the southern Malay Peninsula 127 species and in Sumatra 95 species are to be found. Beyond that area, the number of dipterocarp species sharply declines. Mindanao has only 24 species, Java and Sulawesi only 5. Within the Malay Peninsula the northern boundary is the Kra ecotone comprising the southernmost provinces of Thailand. All other rain forests of Thailand belong to the seasonal type.

The following map combines evergreen and seasonal lowland rain forests. Inland swamp forests (peat forests) are visible. These have been the main source of haze in 1997, when many of the drained peat layers were burning. The map also shows the non-forest areas. While the situation for Java or Mindanao seems to be quite accurate, much of the forest cover of East Kalimantan has meanwhile disappeared.

Figure 1: Forest Map of Southeast Asia



Source: http://forests.org/asia/

Figure 2: Satellite Image of Southeast Asia

Source: NEA, Singapore

Note: Figure 2 clearly shows that Borneo is no longer as green as on the forest map above. Green color on the image does not necessarily stand for forest. Rubber plantations or rice fields with young rice can also appear green. Brown colors stand for dry grassland, deciduous forest without leaves or harvested fields.

Figure 3: Examples for Dipterocarps

Pictures: Werner

Figure 3 left: *Dipterocarpus obtusifolius* is a deciduous species of north and northeast Thailand. It nevertheless shows the typical fruits of the genus Dipterocarpus. Such fruits are produced in huge quantities by the dipterocarps during mast years.

Figure 3 right: *Anisoptera costata* (Dipterocarpaceae) in the seasonal rain forest of Taksin Maharat National Park, Thailand, 750 m a.s.l. Trees of the same genus grow in the evergreen forests of Sumatra, Malay Peninsula and Borneo. This picture is shown as an example of the tree architecture of dipterocarps, which belong to the best timber trees of the world. The tree has a girth of 16 meters and a height of more than 60 meters. Imagine the carbon fixed in one stem of that size.

This paper summarizes research done in earlier years (s. Werner, 1988, 1990, 1992) and fieldwork in Mindanao 1996. A journey to Palawan and Singapore in August 2003 provided some additional data.

Literature has been compiled over several years, particularly in the last four years. Correspondence and discussions with experts from various institutions provided further information. Recent satellite data on fire hot spots and haze could be retrieved from the Internet.

2 Drought Stress in Rain Forests of SE Asia

2.1 Natural Disturbances in Tropical Rain Forests

Over the past years it has become evident in rain forest research that this vegetation type has not been stable since the Tertiary, counter to earlier widespread opinion. Especially during the Quaternary, ever-wet rain forest areas shrunk to small core areas, while deciduous forests spread under dry conditions. Altitudinal limits shifted up and down during warm and cold periods. Evergreen tropical rain forests of Asia must have stretched from Sri Lanka to Sundaland for some time before the Quaternary, as close relatives of plant and animal taxa prove. The area covered by them over the last 10,000 years must have expanded and shrunk several times.

Several natural disturbances are known to occur in rain forests of tropical Asia. While destruction by volcanic eruptions and mudflows is mostly restricted to mountain vegetation, and destructive floods of tsunamis may predominantly hit beach forests and mangroves, both can sometimes also destroy rain forest areas. The Intermediate Disturbance Hypothesis (Connell, 1978) about the stimulating effect of slight disturbances in an ecosystem supports the idea that these communities can cope with short droughts, which may even trigger phenology and regeneration.

The most common natural disturbance to rain forests is storm break by typhoons (cyclones), but these are less frequent in equatorial latitudes and more common towards the tropics. Windbreak has considerable effects on forest ecology. Falling or breaking trees damage other trees and undergrowth, especially when tied together by lianas. Storms may carry heavy fruits of dipterocarps and others for several kilometers, whereas normally these fruits just drop down close to the parent trees. In the open gaps created by storms much more light can penetrate to the ground, thus enabling younger trees to grow fast. Open gaps provide light and space for the younger trees in waiting position. On the other hand, heat and drier conditions may kill the mesic undergrowth, and only secondary vegetation composed of pioneer trees can fill the gaps. Direct regeneration of primary forest or succession through secondary vegetation depends on a critical size of the forest gap formed by a storm.

Landslides can occur on very steep slopes following extremely high rainfall. Such landslides in undisturbed forest are rather to be expected in mountain vegetation, as I observed in Khao Luang, Nakhon Si Thamarat Province in Thailand after the heavy rains in November 1988. Other observations are from Gunung Mulu in Sarawak. Nevertheless, landslides are a rare phenomenon in tropical rain forests.

Slight droughts may occur almost every year during one month at least. Rainfall of less than 50 or even less than 100 mm already cause slight drought stress to an environment used to receiving 200 mm and more. Such a slight drought stress may be a reason for the drop and change of leaves that otherwise would have persisted for another year or so. Development of flowers and fruits is also triggered by droughts. Such droughts do not cause any real damage, but a seasonal phenology can be influenced by unusual weather conditions. As stated above, annual and regular droughts are typical for seasonal rain forests, and are the first step to deciduous vegetation.

2.2 Severe Droughts in Tropical Rain Forests

Drought periods of several months up to half a year with no or very little rainfall are disasters, which severely affect the rain forest ecosystem. These droughts have several effects on the ecosystem:

- Plants react to water deficit with retarded growth and reduction of carbon assimilation.
- Stomatal closure reduces transpiration. CO_2 production is below consumption.
- Flowering and consecutive fruiting are triggered (mast years).
- Leaves start to wilt and drop.
- Dry dead leaves accumulate on the forest floor as in a dry deciduous forest.
- Cryptogams are dry and dying.
- Tree mortality increases considerably.
- Forest animals react by reducing their activities or migrating to other areas.
- Fire threat is drastically increased.

These effects will be discussed in detail, using references of existing fieldwork.

As long as 20 years ago, McClure published a paper "The wilted forest". His first sentences describe the situation somewhat poetically:

> *"I looked along the path ahead of me, my feet rustling through the mat of dry leaves on the forest floor. Burning sunlight streamed through the wilted canopy of drooping tree crowns to sear the already wilted and dying shrubs about me. Orchid plants were hanging and shrivelled, epiphytes along the tree limbs and trunks brown and dead, ferns and mosses dry and brittle. It was deathly quiet. No bird sang, no squirrel chattered from nearby trees, no evidence of life other than an occasional butterfly flitting over the dry leaf litter. This was the tropical rain forest of Southeast Asia?"* (McClure, 1983, p. 76).

The author of this early paper on droughts in a rain forest already refers to El Niño as a cause of the droughts, but also sees forest fragmentation as a reason for changing rainfall patterns. An even earlier paper describing drought in wet evergreen vegetation is that of Lowry et al. (1973) on Mount Kinabalu. They found 50% of the rock-face vegetation in the summit region killed by drought.

In one of the most recent papers, Potts (2003) found overall tree mortality in Lambir Hill National Park, Sarawak, increased by 5% compared to years before the 1998 drought. Potts' sites belong to the wetter parts of Borneo, which are less exposed to ENSO droughts (Ashton, pers. comm. June 2003). This fact may explain the relatively low tree mortality during that drought. No significant effects were found on seedling mortality or among vertebrate seed dispersers. Nakagawa et al. (2000), who worked on the same severe drought, obtained similar data, but found mortality of dominant dipterocarp trees 12-30 times higher than usual. Walsh (1996, p. 401) refers to data from East Kalimantan, where 37-71 % of the canopy trees on steep slope and ridge sites and 11 % in a (moister) valley bottom were killed during a drought in 1983. Walsh and Newbery (1999, s. also Newbery et al., 1999) regard droughts as a normal and natural disturbance to which rainforests are adapted. Increased mortality of trees must be seen in the right time frame, and forest communities will have enough buffer capacity to overcome such a disturbance. The two plots of Newbery and his team are in Danum Valley, Sabah. Measurements were taken in 1986 and 1996, i.e., after the severe 1982 and before the 1997 drought. The 1997 drought, which hit the region hard, was not that strong in Danum Valley (Newbery, pers. comm.). As mentioned above, we have a variety of local climates in the region concerned. Therefore, drought damage and fire will not hit all rain forests of a region in the same way.

Aiba and Kitayama (2002) collected data at Mt. Kinabalu from various altitudes, thus including lower and upper montane rain forests into their drought stress research. The authors had established nine permanent plots in altitudes of 700, 1,700, 2,700 and 3,100 meters. The lowest plots were still in lowland rain forest, but already within the 600-900 m ecotone to lower montane forest. The plots at 1700 m altitude were within the lower montane rain forest with a dominance of Myrtaceae and Lauraceae. The plots between 2,700 and 3,100 m were within the upper montane rain or cloud forest, which is rich in southern conifers like *Dacrycarpus* and *Dacrydium* (Podocarpaceae). The summit area over 4,000 m altitude is open rock with *Leptospermum* bushes.

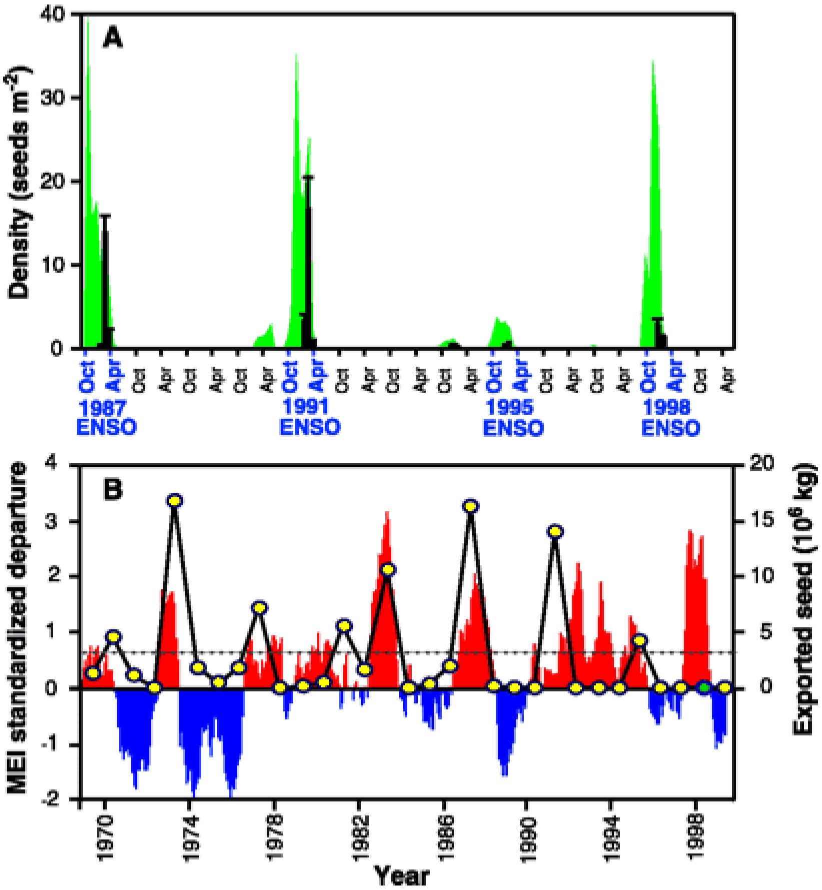
Aiba and Kitayama found that the vegetation had been substantially damaged by the 1997-98 ENSO drought, which had been the most severe ever recorded in northwestern Sabah. Within 30 years, three major droughts had hit the vegetation on Mt. Kinabalu. While the growth rate was reduced only in some tree species, mortality increased significantly, especially within the smaller trees. Some species, e.g., *Drimys piperita* and *Daphniphyllum glaucescens*, had a mortality of 31 and even 56%. Overall mortality was again around 5% and increased with increasing altitude. But exceptions existed on ultrabasic soils, where trees are probably more adapted to drought. Plants respond to nutrient and water stress with similar morphological and physiological attributes.

The trees of the dipterocarp family, which dominate the rain forests of SE Asia and contribute up to 85% of Indonesia's timber exports, have the habit of mast fruiting. This is known in other families of these forests and in temperate Fagaceae like oak and beech. Trees of one species start flowering at the same time in a whole region and produce fruits during the following months. For several years thereafter no or only few flowers will be produced. During these mast years the whole ecosystem is affected. Pollinating insects multiply excessively and provide food for other forest animals. Seed predators, both insects and vertebrates like large frugivorous birds and mammals, have plenty of food and multiply and migrate through the area.

It is evident that these mast years in SE Asia are closely linked to ENSO droughts (Ashton, Givnish and Appanah, 1988). Wich and van Schaik (2000) found correlations only in Borneo and the eastern Malay Peninsular, whereas there was no real correlation in Sumatra and the West Coast of the Malay Peninsular. Nevertheless, some ENSO droughts triggered mast fruiting there, too, especially during the strong 1997-98 event. Curran et al. (1999) discuss the impact of both El Niño and logging on canopy tree recruitment in Borneo. They show a strong correlation of ENSO and mast/export seed for the years 1987, 1991 and 1998. Only for the 1995 ENSO has an unusually low fruit production been recorded. According to the authors, uncontrolled logging has destroyed most reproductive dipterocarps in harvested stands, fragmented a once contiguous expanse of dipterocarp forest and thus disrupted regional reproductive response during mast events. Protected forest areas nowadays are like islands of high seed density and are heavily used by fruit predators, thus reducing the chance of germination or seedling survival.

Seed exports failed totally in 1998 although there was tremendous fruit fall. While seedling regeneration is failing in selectively logged areas, it has also not been successful since 1991 in the last large area of non-degraded lowland rain forest in Gunung Palung. Regeneration and thus survival of these forests is under threat by a combination of ENSO droughts, selective logging and plantation conversion.

Figure 4: Dipterocarp Fruit fall and ENSO Events



Source: Curran et al., 1999, p. 2185

Dipterocarp fruitfall and ENSO events. (A) Total monthly fruit fall (green) of all seed with viable or undamaged ripe seed (black) per square meter (mean 6 SEM) arriving in traps (73.4 m^2) monitored over 150 months. ENSO years are indicated in blue. Viable seed (26 dipterocarp spp; five genera) was present during 40 (6.2%) of the 644 weeks. (B) Regional dipterocarp seed exports were correlated with the Multivariate ENSO Index (MEI). Red bars indicate ENSO years, blue bars indicate La Niña events, and yellow circles depict seed export levels (hatched line is mean seed production for all years). Dipterocarp seed export records were compiled from forestry archives. Differences between ENSO (5.06 x 10^6 kg) and non-ENSO (0.72 x 10^6 kg) mean seed production levels were significant (P 5 0.007 in 10,000 permutations). ENSO years are counted conservatively as both years in a sequence. Seed production greater than the mean across all 31 years (>2.96 x 10^6 kg) occurred in 8 years, of which 7 years were associated with ENSO events. The 1998 value (green circle) is excluded from MEI calculations because the seed market crashed (0.16 x 10^6 kg).

During drought conditions, most plants close their stomata in order to reduce transpiration. While desert plants have developed mechanisms to tackle this problem, rain forest trees just reduce their photosynthetic activities. It has been observed that rain forests are "less green" during drought conditions (s. Odenwald, 2003). Dust and dried epiphyllous algae and moss may cause this effect. Most striking is the shift in O_2/CO_2 ratio. Rain forests are regarded large carbon sinks, but they have been found to produce more CO_2 during drought conditions than they photosynthesize. As temperatures rise during ENSO droughts, tree growth is reduced and less carbon is fixed in the wood. Oxygen-consuming recycling processes in the forest floor can cause net production of oxygen to be low in rain forests. Closed stomata and associated stunted growth, and wilted and dead leaves can make the net production even negative. Thus, tropical rain forests are not always large carbon sinks that help to reduce global warming.

3 Role of Fire in Forests of Tropical Asia

3.1 Fire in Adapted Biota

Vegetation on earth has always been exposed to fire. Some vegetation types can even only survive with fire; natural successions will change their composition. Apart from human impact, fires can be created by lightning or spontaneous ignition of dry plant material and the burning-glass effect of minerals. Since prehistoric times, man has created fires for several reasons, and as a result vegetation types may have degraded from moister to drier forests and even grasslands.

Dry deciduous and monsoon forests of tropical Asia are well adapted to fire. In fact, dipterocarp and pine-dipterocarp forests would even convert to moister monsoon or teak forests if fire were to be eliminated for many years (s. Stott, 1988; Stott et al.; 1990; Werner, 1993). Fire in a dry deciduous dipterocarp forest does not burn the living trees, which are well protected by their thick barks. Relatively small flames burn only dry leaf litter or grass and dead wood on the forest floor. A fire with temperatures around 1,000 ºC kills the leaves of shrubs and tree seedlings. Large trees would have dropped their leaves anyway during the dry season or do so shortly after the fire. The flames consume the thick layer of dead leaves, which otherwise would cover the soil and prevent tree fruits from germination, while in the open soil, the small roots can develop. Fire is thus part of the natural cycle. Only when there has been no fire for several years, has enough combustible material accumulated for the flames to reach high temperatures and set the whole forest ablaze. Teak forests as one special association of monsoon forests are also well adapted to fire. Annual droughts lasting several months and fires are normal for these forests, but the situation is aggravated by ENSO droughts. However, reduced rainfall during the wet season more affects farmers' fields than forest ecology.

3.2 Fire in Moist Forests

Moist forests normally do not burn, as the plant material is too wet for ignition. For shifting cultivation, trees have to be cut first and left for some time to dry after which the dead plant material can be burnt. As fire is an absolutely exceptional disturbance, these moist forests are not adapted to it. Only exceptional droughts allow the plant material to desiccate sufficiently so that it will burn. This has always happened occasionally in the past, but forests recovered after a number of years.

As in dry deciduous forests, fires in moist forests can be relatively small and confined to the dead plant material on the forest floor. The flames create some post-fire mortality of some trees, which seemed to survive the fire unburned. However, once an evergreen rain forest burns during a severe drought, such a rain forest is heavily disturbed and will easily burn again. Repeated fire will lead to total degradation of the forest according to the "Fire Ecology Research Group" in Freiburg, Germany (Goldammer, 1999) Heavy smoke is produced which contributes to the haze problem.

Figure 5: Sequence of Forest Degradation caused by Fire

Source: Goldammer, 1999, pp.1782-3.
1) Undisturbed tropical rain forest; 2) Litter fire following selective logging; 3) Same forest three years later; 4) Degradation after one decade; 5) Results of second fire; 6) Result of forest degradation: Savannah with low biodiversity.

Most fires in the rain forests of Malaysia and Indonesia are set for conversion of forest to plantation land. In East Kalimantan, subsurface coal fires are exacerbating the situation as they are slowly burning through the forest area, easily creating forest fires during dry years. These forest fires together with those in peat swamp forests accounted for most of the haze problems in 1997. According to CIFOR, large-scale land clearing for plantations of fast growing trees for pulpwood and oil palm were the major causes for these fires (Tacconi and Yayat, 2002). Forest fires produce a lot of white smoke, so that planes may be unable to land on airfields within the area. Very thick smoke is generated by fires in peat swamp forests when the peat layer of several meters starts burning. This again is only possible in very dry years or on drained land, as the peat layer is normally waterlogged.

Fire hotspots can be traced on satellite images. The Singapore Meteorological Service is offering such images for free download. During droughts such spots can be seen in many areas of Sumatra and Kalimantan. Most of these hot spots have been linked with forest concessions or large plantations. While the Indonesian government had previously blamed shifting cultivators, it is now evident that executives of forest concessions and plantations are responsible. Necessary steps will be discussed below in the relevant chapter.

The damage by the 1997/98 fires in East Kalimantan, Indonesia, is summarized below. About 72% of all forest plantations and 51% of the oil palm plantations were burned. The total damage in forest concessions was estimated to USD 2 billion.

Table 1: Vegetation and other Areas affected by the 1997-98 Fires

Vegetation Type	Area [ha]	Burnt [ha]	Burnt %
Grassland (*Pyramidata (Imperata) cylindrica*), scrub	368,860	292,569	79.3
Lowland dipterocarp forest	5,379,562	2,177,880	40.5
Mangrove	1,042,127	91,729	17.5
Swamp/peat forest	426,051	311,098	73.0
Secondary forest, plantations, agricultural land	2,283431	1,723,401	75.5
Wetlands	358,750	290,432	81.0
Montane forests	3,551,826	213,194	6.0
Total	**13,410,607**	**5,100,303**	**48.63**

Source: adapted from original table in http://www.zebris.com

During the 1982/83 drought, 3.6 million hectares of forest burned in East Kalimantan. About 800,000 hectares were lowland dipterocarp forest, 550,000 hectares peat forest, 750,000 hectares secondary forest and agricultural land, and 1,600,000 hectares were logged-over dipterocarp forest. Sabah experienced severe droughts in 1983 and 1998, which left one million hectares in 1983 and 130,000 hectares in 1998 burned by forest fires.

4 Canopy Dieback in Cloud Forests

Canopy dieback in tropical/subtropical forests was first reported from Hawaii and later from the North Island of New Zealand (Auclair, 1993). Werner (1988) reported canopy dieback from cloud forests of Sri Lanka and linked this with unusual drought conditions. It should be noted that drought conditions in Sri Lanka; as seen on the graph below, are not El Niño droughts, but occur rather in La Niña years. That means that rainfall conditions are opposite to those in Southeast Asia, but they are nevertheless linked with the Southern Oscillation.

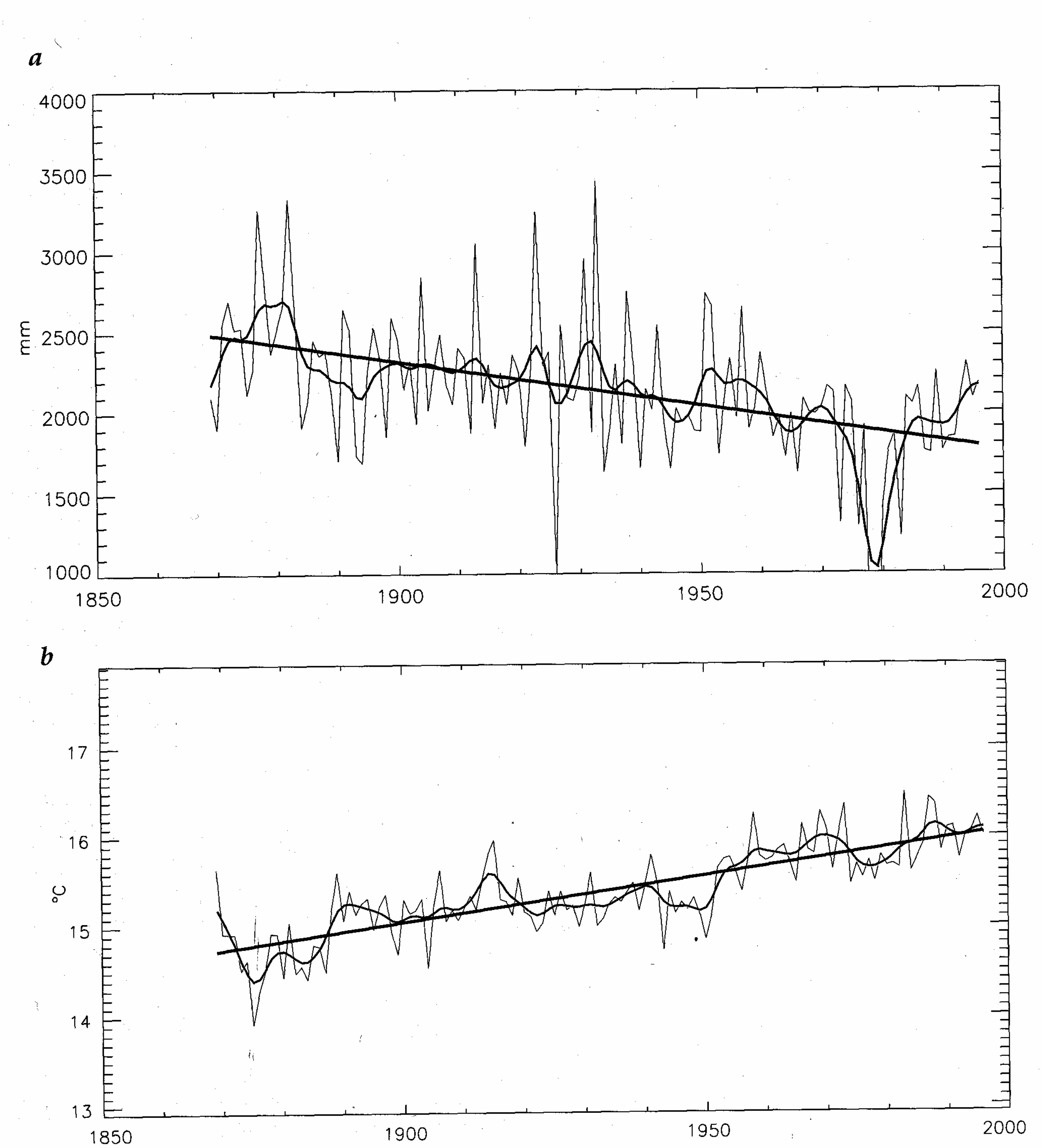
In 1996, Werner observed another canopy dieback area in a cloud forest of the highest mountain of the Philippines, Mt. Apo, Mindanao, which had been caused by ENSO droughts (Madulit, pers. comm.). The dieback area on Mt. Apo is totally overgrown by tall *Saccharum* grass and dead trees are the only trace of the former forests. Nobody knows if this forest will ever regenerate. Without regeneration, this area will convert to savannah land. Lowry et al. (1973) have described considerable drought damage within the *Leptospermum*-scrub of the peak vegetation of Kinabalu, but not canopy dieback in cloud forest. Aiba and Kitayama (2002) found drought damage within the forest of Kinabalu increasing with altitude, except on ultrabasic rocks, where vegetation seemed to be already drought adapted. While they found high mortality within some species, this cannot be considered canopy dieback. It is not yet understood why there is no dieback in the cloud forest of the Malay Peninsula, which also suffered from ENSO droughts. A colleague in the area claimed that severe dieback occurs in the cloud forest of the Malay Peninsula, especially in the Cameron Highlands.

Canopy dieback in cloud forests is a complete breakdown of whole forest patches. Death of single emergent trees can also occur, but this is not conspicuous as it looks like the normal life cycle of a tree. As these stunted forests are single-storied with few saplings in the undergrowth, death of the whole canopy means a collapse of the forest patch. Grass, which is normally absent in the undergrowth, will subsequently invade. Night frost and fire may kill the last surviving saplings, which could survive the competition from the unusual grass cover. It is not yet understood how cloud forest will be able to regenerate. It is true that severe droughts had occurred previously, but there was no report of canopy dieback. Research in these forests is new and we have no record of canopy dieback in earlier centuries.

In Sri Lanka, air pollution from drastically increased car traffic has been seen as another cause of canopy dieback. This view has been supported by measurements of higher SO_2 content in the air. However, Werner (1988) showed in a climate diagram unusual droughts in 1976, probably triggering dieback that was first observed in 1978. On the other hand, he found some regeneration and profuse epiphytic growth after high rainfall from mid 1983 until 1986. Canopy dieback had been restricted to wind-exposed slopes facing west with shallow soil cover, where strong winds had a desiccating effect. It is striking that only patches of forest were affected by dieback and not the whole forest area. If the dieback had been caused by air pollution, this would not explain patch occurrence. A combination of soil conditions, availability of water, and age plus health condition of trees may be an additional factor. Canopy dieback is still continuing in Sri Lanka and is considered an environmental disaster.

Recent observations indicate that tropical cloud forests are threatened through reduced cloud cover. Global warming is made responsible for this effect, which is both reducing the cloud forests' water supply from fog-stripping and increasing evapo-transpiration. Fog-stripping can supply considerable amounts of water in addition to rainfall (s. http://www.gened.arizona.edu/nats101gc/cloud_forest.htm). The disappearance of the cloud forest with its fog stripping will have a considerable effect on the availability of water for the lowlands, as there will be no more spring water during droughts. According to Bruijnzeel (2001), cloud water deposition rates are 1-2 mm per day on average and range from 0.2 to 4 mm per day. Rates of even 6 mm per day have been measured, but are seen as unrealistic. Some fog gauges do not distinguish between fog precipitation and horizontal rain in windy weather. Nevertheless, an annual loss of water amounting roughly to 350-700 liter per square meter in tropical catchment areas is a tragedy for the water supply of the lowland especially as this is slowly released water and not flashflood from torrential monsoon rains.

Figure 6: Annual Rainfall and Temperature at Nuwara Eliya 1870-1998



Source: Dr. Dirk Schaefer with kind permission by the author.

Nuwara Eliya is close to the dieback area on Horton Plains in Sri Lanka, and also within the range of cloud forests. Since this "hill station" had been established already before 1820, long-term rainfall data exist. Note the constant decrease of rainfall since records started, and the drought conditions at the end of the 1970ies. (a) Time of first report of canopy dieback. A severe drought in the 1920ies was much shorter than in the 1970ies. Note that drought years are El Niña years, and very wet years are el Niño years. Amount of rainfall fluctuated considerably, but the long-term tendency is clear. A temperature graph (b) of the same station and same time interval shows in contrast a constantly increasing temperature.

5 Forest Fires and Canopy Dieback in Tropical Asia in Comparison to Climatic Data and ENSO Droughts

5.1. Climatic Records

The central questions of this paper focuses on to which extent drought stress within evergreen rain forests, fire and canopy dieback are linked with ENSO droughts, and whether these droughts have increased in recent years. The concluding question is whether the rain forests of Southeast Asia will be lost, as they are under a multiple attack: logging, fragmentation, fire, and drought stress. Even a national park of several thousand square kilometers is only a fragment compared to the former extent of the forests.

The “normal conditions” with low pressure in northern Australia and New Guinea and high pressure in the eastern Pacific are inverted during ENSO years. This “Southern Oscillation” results in less rainfall in Southeast Asia, while in India and East Africa wetter conditions with floods may prevail. An ENSO drought does not necessarily imply that it is dry everywhere in the region. Even on individual islands like Sumatra, Borneo or Java various climatic regions exist. The northern tip of Sumatra is much drier than the rest of the island; Eastern Java has a seasonal climate with completely different vegetation to that in the west; Borneo also has various rainfall regimes. Eastern and southern Kalimantan are the drier parts with the central ridge receiving more rainfall. The same is true for the Philippines with more than 13 climatic zones, or continental Thailand and the Malay Peninsula. Thus, ENSO droughts have a different impact in various regions, so that research results from a national park in central Kalimantan or Sabah may be different from those in Sumatra. Moreover, not every ENSO drought will have an effect everywhere, and droughts without a linkage to ENSO also exist.

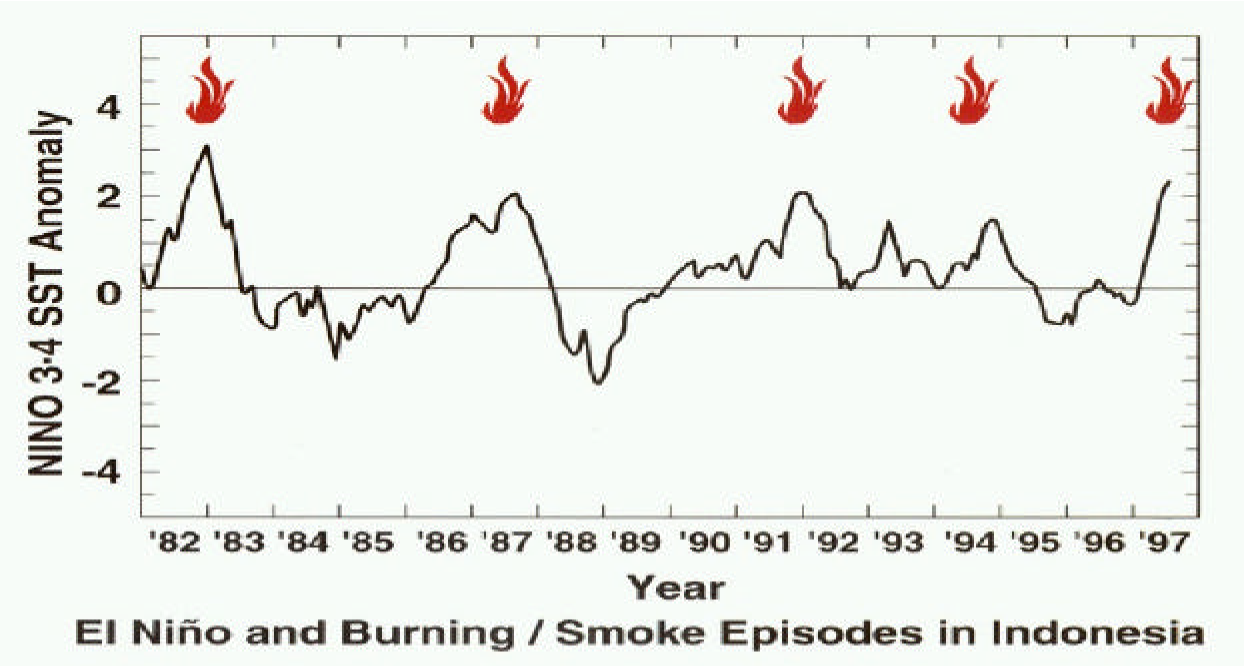
Walsh and Newbery (1999) placed the ecoclimate of Danum on Sabah in a context of other rainforest areas around the world. There is evidence that drought and fire occurred both in Borneo (Goldammer and Seibert, 1989) and the Amazon (Uhl, 1998) as early as the Pleistocene and early Holocene. However, ENSO events shortened from 15-year intervals during 15000 to 7000 before present to 2- to 8.5-year intervals 5000 years ago. The present pattern is thus already quite old, but Walsh and Newbery (1999) stress the fact that *“drought intensity and frequency is currently increasing at most stations in Sabah”.* In the absence of human activities, such droughts would be part of a natural system, but today the forests may not survive this additional stress.

Walsh (1996) published an earlier paper presenting an overview of drought incidents in Borneo since the late nineteenth century. Brookfield et al. (1995) give an even more detailed view. The El Niño of 1877/78 was a major event during the colonial time. After a drought of nine months, one third of the forest trees had died in the middle Mahakam area; fires raged in Borneo. Droughts occurred again in 1885, 1888, 1891 and 1902. The worst drought event between 1877 and 1982 was in 1914. From that year we still have clear evidence of forest fires in Borneo, with burnt forest patches that have not recovered since. Areas of thin-stemmed forests with low diversity have been found there and even some *Imperata* grasslands give evidence of that fire, as the forest could not regenerate there. The Sook plain south of Kinabalu is given as a further example. Forest fires covering the whole coastal area of Borneo were reported in 1915. The fire was said to produce severe haze causing pain to the eyes, and pieces of burning grass fell on the decks of passing ships. During 1914, only 904 mm of rain was recorded at one station, the drought lasting nine months. Another drought during the colonial era occurred during the Japanese invasion in 1942.

The Straits Times of 14 October 1972 reported extensive forest fires over South Kalimantan at the time of the 1972 drought. Further events are known from 1982/83, 1991/92 and again 1997/98. The last (moderate) ENSO drought occurred in just in 2002/03, and only the monsoon rains in July brought relief. All these droughts were linked with extensive forest fires. Goldammer (2001) presents a graph, which strikingly demonstrates the link of recent ENSO droughts and forest fires in Indonesia (Figure 7). Although ENSO droughts used to occur before, the frequency and severity of droughts has increased substantially in the past three decades, and this may be the result of global warming. According to Harrison (2001, p.63):

> *"The impacts of the 1998 drought at Lambir Hills National Park suggest that, should this trend continue, a substantial alteration of habitats and overall loss of biodiversity can be expected in Borneo".*

Figure 7: ENSO Droughts and Forest Fires in Indonesia



Source: Goldammer, 2002: http://www.fire.uni-freiburg.de/inventory/gvfi/DEKLIM-NOV-2002-2.pdf

Rainfall data of Singapore, which exist continuously from 1869 to date, prove a drastic increase of drought years. If we count the years with less than 2,000 mm rainfall within 40 years, we have four drought years from 1880 to 1920, six from 1920 to 1960 and fourteen from 1960 to 2000. The year 1997 was the driest ever recorded with only 1,119 mm of rainfall, while the average is 2,343 mm. Between 1890 and 1920 there were merely two drought years. Only the 1880ies were an exception with three drought years.

5.2 Perception/Awareness in Local Communities

Indonesia

In Indonesia, the local population is quite aware of the ENSO droughts, which affect their lives in various ways. Lack of water, failing crops, forest fires and haze are evident. While eastern Indonesia with its seasonal climate is used to droughts, this is not the case for "Sundaland" (Sumatra and Borneo and western Java). Western Java may be ignored, as the lowland forests have disappeared anyway. Knowledge about ENSO connections are so widespread among educated Indonesians, that a plantation manager can use his laptop to receive the latest ENSO index in order to determine the best time to set fire to the forest as a method of land clearing (Goldammer, pers. comm.).

For the villagers and forest dwellers of Sumatra and Kalimantan, the ENSO drought 1991 had been the most severe of the century until another even worse drought hit the area in 1997/98. The perception of the local population is that of an increase in such droughts in the last decade. But historical records show that there have been frequent droughts before. Local people of Danau Sentarum, West Kalimantan noticed an increase in fires in particular from 1991 onwards, and found this trend to be related to the increasing population density and the influence of seasonal migrants (Applegate et al., 2001). However, there was no word about increasing intensity of droughts, which was only raised by the authors themselves. In East Kalimantan they had a study site at a timber concession area with a village:

> *"Huge areas of PT Satu's concession burned in the 1997/1998 fires, the official estimate being 70,000 ha. There was no evidence or perception that the logging company was responsible for any of the burning."* (Ibid. p.42)

Drought, fire and haze are well monitored from satellite images. Anybody with Internet access can obtain excellent information; e.g., at the site of the Singapore Meteorological Service Division within the National Environment Agency (www.nea.gov.sg/metsin, the former Singapore Meteorological Service) which provides the latest satellite images of the region and haze-monitoring maps including fire hot spots. ENSO development is discussed. Another site, http://www.haze-online.or.id, is an Indonesian/ASEAN website, which provides press clippings and the latest fire warning maps. One example is given in Chapter 7.

Philippines

According to a case study in Philippines on "Impacts and Responses to the 1997/98 El Niño Event" (http://www.esig.ucar.edu/un/summ1#summ1) the situation before the 1997/8 ENSO was that:

> *"To most Filipinos, a severe drought scenario seemed improbable. Thus, actions were taken only when clear and obvious manifestations of drought already prevailed."*

But after the drought, a Presidential Task Force was established. There was more damage to agriculture than to forests. The only fire damage reported was in Palawan, where 9,400 hectares of secondary or logged-over forest burned. No virgin forest was affected by the drought according to the above-mentioned report. Palawan is the only area where rain forest drought should be expected. The remnant evergreen rain forests of Mindanao and Luzon are so exposed to the winds from the Pacific that they always receive enough rain.

Thailand

According to Absornsuda Siripong, Chulalongkorn University, Bangkok, (http://www.start.or.th/pub.htm), the climate has changed in the south of Thailand (Surat Thani Province). Rainfall is decreasing by 8.5 mm/year. The air temperature is increasing by 0.037ºC/year. No records of awareness among the village people were available.

Malaysia

Sarawak and Sabah have to be discussed along with Kalimantan. However, it is known that various local climates with different rainfall regimes exist within Borneo. There is a growing awareness about ENSO droughts, and climate change is obvious to the population with higher education. Reports about awareness in the village population are rare. This would be an interesting subject for a research project.

6 Constraints to Development through Drought in Rain Forests

6.1 Drought and Fire

Indonesia

There is no doubt that the severe ENSO droughts of recent years and their related forest fires and haze had negative effects on development of the countries affected. Estimates exist of these losses, but they do not separate between agriculture and forests. According to the WRI, the 1997-98 fires damaged 10 million hectares of land in Indonesia, contributed to the death of more than 500 people, and cost an estimated USD 9 billion (Runyan C., 2003). More than 500,000 hectares were burned in East Kalimantan alone. The total area of burned forest is estimated by CIFOR to amount to 9.7 million hectares for Indonesia. Luca Tacconi of CIFOR estimates an even higher figure of 11.7 million hectares. According to UNEP estimations, the CO_2 release from these fires was as much as the annual output of all of Europe.

The 1982-83 fires burned 3,5 million hectares of forest in East Kalimantan and an additional 1 million hectares in Sabah according to Salafsky (1994). However, this only became evident to the world community after the damage had been noted on satellite pictures nine months later. Salafsky (1994) attempted to estimate the economic loss caused by the 1991 drought in Benawai Agung, a village close to Gunung Palung National Park in South Kalimantan. His figures were in Rupiah, but as the value of this currency has meanwhile dropped considerably, they were computed in USD (1 USD = 2,000 Irp). The highest loss is through durian harvest from wild trees in the forest; a loss of about 50-75% of the durian fruits and 30-50% of the forest products were recorded (Table 2). Coffee losses were appreciable, though the total area under coffee was not mentioned. Estimated costs for delayed rice crop and increased water labor have not been included in Table 2; the figure is similar to the financial loss of burned coffee garden.

Table 2: Estimated Loss Caused by the 1991 Drought in Benawai Agung

Cost Parameter	Minimum Estimate (USD)	Maximum Estimate (USD)
Lost durian fruit harvest	62,140	88,000
Burned coffee garden	3,200	19,000
Lost forest product wages	3,350	11,180

Revisiting the site in 1995, Salafsky found that the damage for the local population resulting from the 1994 drought was as high as from that in 1991 (Salafsky, 1998).

Brookfield, Potter and Byron (1995) conclude that the indigenous population of Borneo is somehow adapted to droughts. But the “modern” population is not able to handle the impact of severe droughts.

The Orang Utan population of Borneo suffered a 33% decline in its population due to the 1997-98 forest fires (s. Secretariat of the Convention on Biological Diversity 2001).

Applegate, Chokkalingam and Suyanto (2001, p. 50) stated that in Indonesia over one million hectares are logged annually. If timber harvesting techniques are not improved and disturbed forests are not protected from fire, much of the logged-over forest will be reduced by fire to shrubland or grassland.

Malaysia / Sabah

During severe droughts in 1983 and 1998 in Sabah, one million hectares in 1983 and 130,000 hectares of forest in 1998 were affected by fires (s. Daily Express News in Appendix). The worst fires raged in 1983, whereas the 1997-98 fires were worse in Kalimantan.

> *"Sabah was perhaps the most affected state by the 1998 drought. All the Divisions suffered extremely high rainfall deficits (some as low as 90% of long term mean) for a period ranging from 4 to 9 months, affecting more than 2,797 km² and 170,000 people. About 1580 km² was engulfed in wild fire, of which more than 100 km² were agricultural lands. More than 7,200 farmers were affected with an estimated loss of about RM 7 million. A number of districts had to go for water rationing to ease off the situation. In few villages, their hill padi crops were totally wiped out prompting the authority to send in food supply to the affected areas. Similar situation was experienced in the North Eastern part of Sarawak near Miri region. The prolonged and extremely dry spells had resulted in rampant wild fire that had destroyed a sizable area of agricultural crops.*

Source: Droughts in Malaysia (http://www.water-drainage.com/images/download/low%20koon%20sing%20(a).pdf)

Philippines

According to a case study, the effects and impacts of the 1997-98 El Niño were significant in the areas of physical environment (including water supply and forest/bush fires), health, and on economic aspects (reduced productivity and revenue for agriculture, reduced hydroelectric power). A total of 9,400 hectares of second growth and/or logged-over forest burned in 1997-98, including 70 pockets of forest fires in Palawan province. The estimated cost of damage was Philippine Pesos 150 million. No virgin forests were affected.
Source: http://www.esig.ucar.edu/un/philippines.html

According to Palawan Tropical Forestry Conservation Program data, about 20,000 hectares of forest burned during the 1997-98 drought (Linda Bacosa, pers. comm.). Severe damage by canopy dieback was caused in the dry forest on serpentine rocks in Central Palawan, but these forests are recovering now by regrowth. It is interesting to note that forests on the serpentine soils at Kinabalu could stand the drought better than those on other soils (Aiba and Kitayama, 2002).

6.2 Haze

The thick haze in 1997, which originated mainly from peat swamp and forest fires in Sumatra and Kalimantan, covered an area as large as half of the United States. Concentrations of SO_2, CO, CH_4 and CO_2 were considerably elevated; relative humidity was increased. About 20 million people had to be treated for symptoms like asthma, bronchitis, eye irritations and heart problems. The number of casualties caused by these haze-triggered symptoms is unknown. Haze was responsible for at least one ship collision in the Malacca Strait and an Airbus crash in Sumatra, which took 234 lives. Kita et al. (2000) found “significant increases of total ozone” during the forest fires in 1994 and 1997 in Indonesia. The haze cloud is not only harmful for human health and dangerous for all kinds of traffic; research by Davies and Unam (1999) revealed that also photosynthesis of trees was significantly reduced during the 1997 haze.

The 1997 peat swamp fires were the severest ever experienced in the region. From the peat layers, which are up to 1.5 meters deep, between 750 million to one billion tonnes of carbon were released to the atmosphere (Asian Development Bank, 1999). According to research by Page et al. (2002, p. 61) the amount of released carbon was even higher (810 million to 2.57 billion tons). However, this included both peat and vegetation on peat land. They also reported peat layers as thick as 20 meters. This was the largest increase in atmospheric CO_2 content detected since records began in 1957, and it was equivalent to 13-40% of the mean annual global carbon emissions from fossil fuels.

During 2002/3, the latest ENSO event again caused thick haze. In the Borneo Bulletin of May 22, 2003, we read (s. also Appendix):

> *"Thick haze has returned to shroud Malaysian skies in a yearly occurrence brought on by dry weather as well as increased fires in the Indonesian island of Sumatra…".*

Another article in the Jakarta Post from 7 June 2003 reported on the thick haze in Riau, Aceh and Kalimantan. The fires were also raging in so-called "protected forest".

> *"Government officials and local residents say there was no haze problem in the 1980s, at least not a major one. A major haze event took place during the 1992 drought, followed by another one in 1994, which was also a drought year. But the thickest haze occurred in 1997 - a strong El Nino year - just after the beginning of land clearing for the PLG in 1996. The area was ablaze with flames and dense smoke reached as far as Malaysia and Thailand. Residents say this year's haze is almost mild compared to the 1997 event., nevertheless the haze continues to affect Indonesia's neighbours."*

Source: CIFOR website

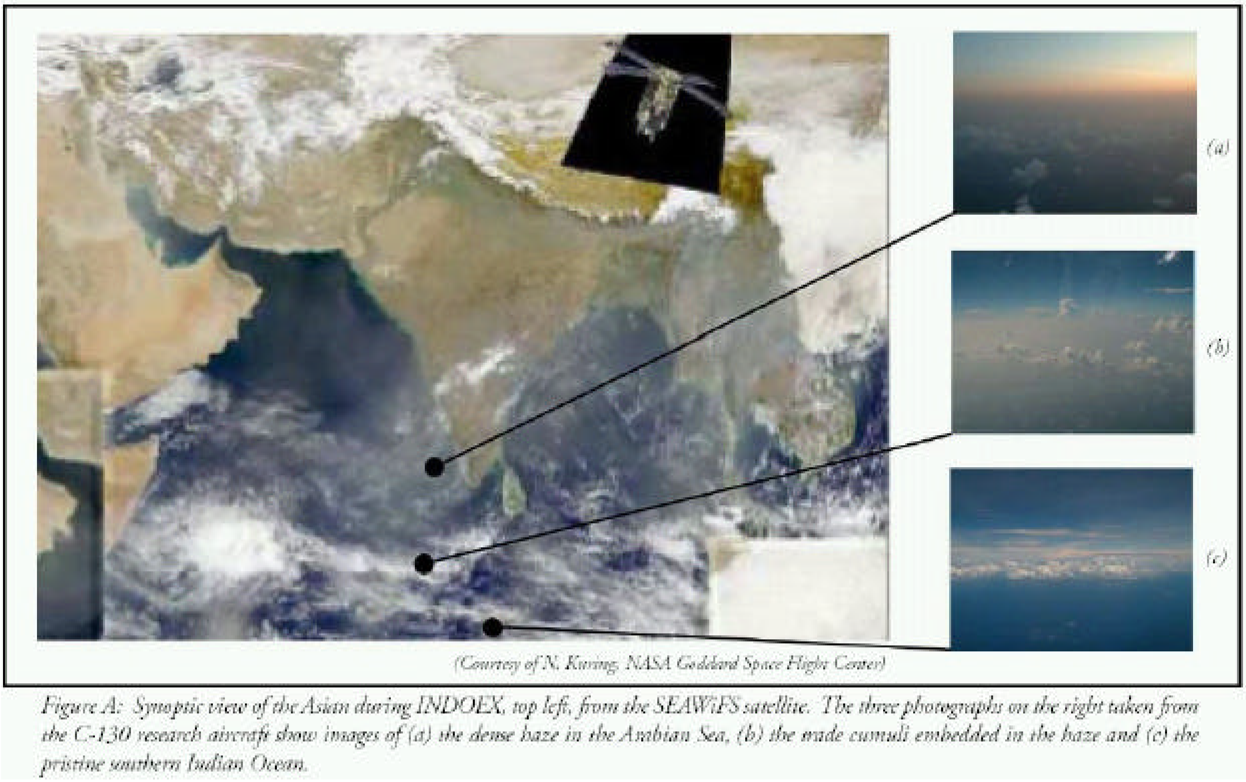
Figure 8: Haze in Central Kalimantan, September 2002

> *"Some people wear makeshift masks but often these are unable to screen out the tiny lung damaging smoke particles"*

Source: CIFOR Website http://www.cifor.cgiar.org/fire-project/index.htm

Whereas the noxious haze cloud is a temporary phenomenon, the Asian Brown Cloud over South Asia has become a permanent problem during the dry season from December to April (UNEP and C4, 2002). This cloud of smoke particles originates from industry and forest fires, but mainly from kitchen fires in India and neighboring countries. It is reducing solar radiation and size of raindrops, and thus affecting temperatures and harvests. This environmental problem deserves being mentioned here as the Asian Brown Cloud reaches mainland Southeast Asia, combining with the haze cloud to a kind of horror scenario of air pollution.

Figure 9: Asian Brown Cloud Stretching from Arab Sea to Thailand and South China



Source: UNEP and C4, 2002, p. 1.
Note: The haze cloud is temporarily situated in the right lower corner of the image, at the site of the white rectangle.

6.3. Local and Global Effects of Climate Change

The fires in Indonesia and Malaysia contribute substantially to the global carbon increase in the atmosphere. This again is accelerating the greenhouse effect. Moreover, during drought conditions, the tropical rainforest is no longer effective as a carbon sink. According to Timmermann et al. (1999), the ENSO droughts may become more frequent or even "normal" due to greenhouse warming. The variability of rainfall will increase with more extreme records. A Global Climate Model (GCM) simulation by Zhang et al. (2001) in Australia looked at the joint effect of rain forest removal and greenhouse-warmed climate. According to their results, (p. 309):

> *"… joint climate changes over tropical rainforest regions comprise large reductions in surface evapotranspiration (by about –180 mmyr-1) and precipitation (by about –312 mmyr-1) over the Amazon Basin, along with an increase of surface temperature by +3.0 K. Over Southeast Asia, similar but weaker changes are found in this study. Precipitation is decreased by –172 mm yr-1, together with the surface warming of 2.1 K. Over tropical Africa, changes in regional climate is much weaker…"*

In Southeast Asia, greenhouse warming without deforestation would result in a stronger summer monsoon, an increase in surface temperature of 2.4 K, an increase in precipitation by 1.6 mm per month, and an increase in evapotranspiration of 2.5 mm per month. However, combined with the impact of deforestation, a reduction in annually averaged surface evapotranspiration by 11.9 mm per month will be the result. Total precipitation will decrease in most months by 10 to 50 mm. Annual total precipitation will be reduced by 16.8 mm per month on average. During the summer monsoon (May–June–July) a considerable reduction in precipitation of 40 mm per month may occur.

Whereas the largest greenhouse-induced warming in most GCM simulations occur over continental regions in the middle and high latitudes, statistically significant responses occur in the large-scale atmospheric circulation such as changes in the velocity potential and vertically integrated kinetic and potential energy fields (Zhang et al., 2001, p. 309, 327). Weather in Central and Northern Europe will thus not only become warmer, but also quite windy. Already now we experience warmer summers, milder winters and an increase of strong winds in Europe (various sources). With the destruction of tropical rainforests in the Amazon and Southeast Asia, climate change will become even more marked – not only in tropical countries, but also in the north. (Zhang et al., 2001)

7 Recommendations for Risk Reduction

Recommendations have already been given throughout the text but will be summarized here again. In order to cope with increased drought and forest fires and to prevent forests from extinction it is necessary to develop the following counteractive measures:

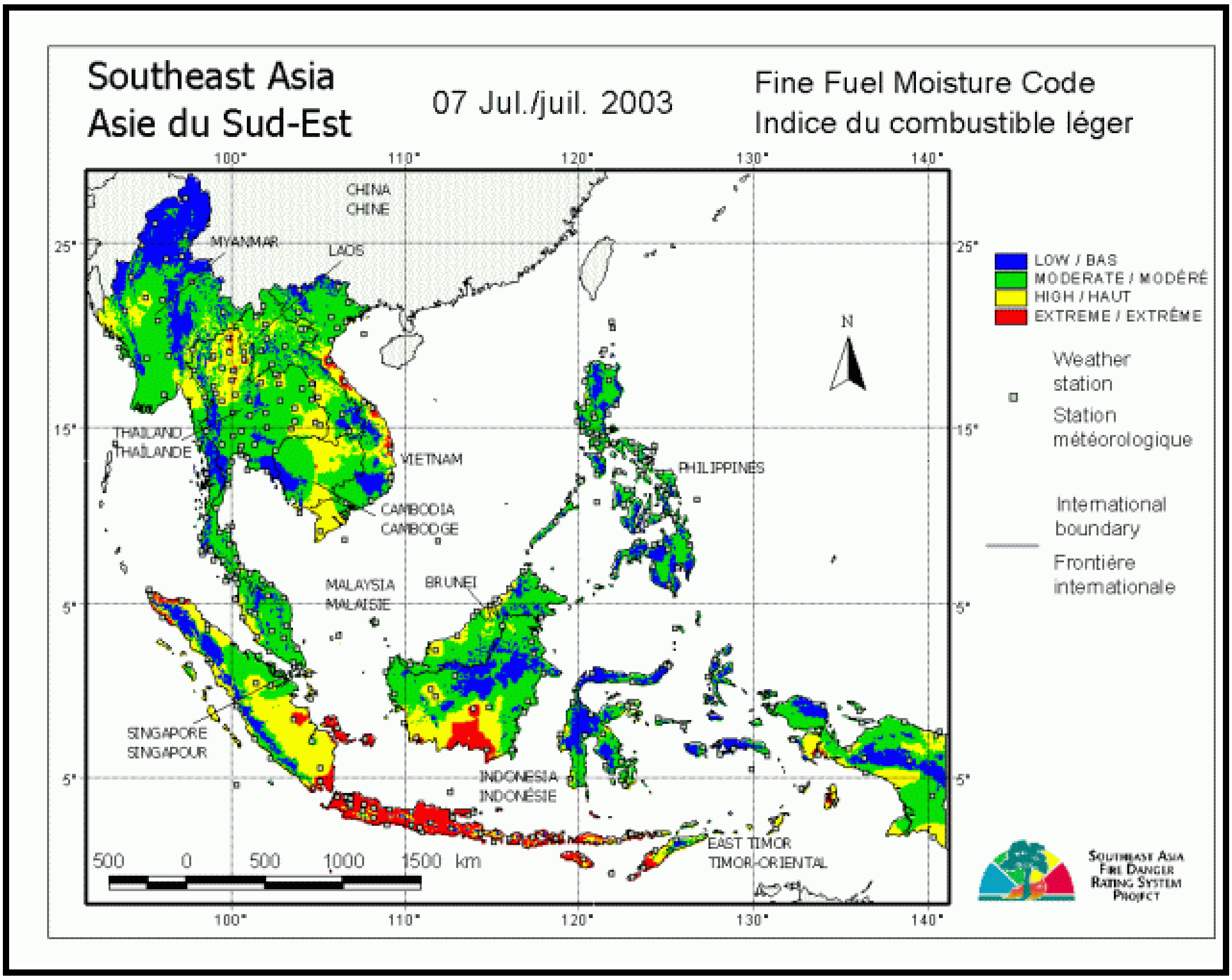
- Early warning system for droughts
- Fire risk maps for the whole region
- Satellite surveillance of forest areas
- Fire combat squads in the forest regions
- Awareness raising, e.g., through government-funded television spots about the risks of forest fires for the livelihood of the local population
- Strict law enforcement and prosecution of those setting fire to vegetation
- Incentives for local communities to control unwanted fire on land which is not their own
- Rehabilitation of peatland

These activities are immediate risk reduction measures. The following should help in the long term:

- The suitability of selective logging should be reconsidered
- All remaining rain forests should be effectively protected
- Foresters should start supervision programs for the natural regeneration of dipterocarp seedlings, as successful germination has been disturbed by forest fragmentation
- New forest plantations on land where the rain forest has been cut or burned should eventually supply new timber
- The introduction of agroforestry systems should be fostered, as they can serve as effective buffer zones around remnant forests and even link forest patches

The Sabah Forestry Department intends to establish a “Fire Danger Rating System” (FDRS) aimed at strengthening its forest fire prevention capacity. The British Colombia Forest Service is helping as consultant (s. Appendix). The imminent danger of forest fires can already easily be retrieved from the Internet. Regional offices only have to implement their alert procedure, once danger of fire is high. An example is given in the next illustration (Figure 10):

Figure 10: Recent Map of Fire Threat



Source: http://www.haze-online.or.id/fdrs.php?SHOWMAP=ffmc
Fire Danger Today, showing Ignition Potential Map. This information is made available through collaborative arrangements between the ASEAN Secretariat's CSU and SEA FDRS Project.

Malaysia is conducting a "pilot project on fire prevention and rehabilitation of peat land as part of Asean's plan to fight transboundary haze" (s. Appendix). If the project is successful, it could be a model for other Asean countries. The peat areas, which had been drained in order to obtain land for agriculture, are flooded using the draining canals. Once the peat is waterlogged again, it will no longer burn. Southeast Asia contains about 60 % of the tropical peat land; Indonesia alone has 85 % of that area, and contributed most to the haze problem in 1997, as the majority of smoke came from burning peat (s. New Strait Times in Appendix).

Selective logging of rain forests has been proved to increase drought mortality of trees and fire threats. This logging method was meant as a compromise to allow extraction of timber, where regeneration should allow a sustainable use. But unfortunately, this system does not work with the impact of drought and fire. Under these circumstances, suitability of selective logging should be reconsidered. All remaining rain forests should be effectively protected. Foresters should even supervise the natural regeneration of dipterocarp seedlings, as successful germination has been disturbed by forest fragmentation. New forest plantations on land where the rain forest has been cut or burned, should eventually supply new timber. Agroforestry systems can be effective buffer zones around remnant forests and even link forest patches together. These systems can contain indigenous rain forest tree species and enable their regeneration. Such a system has been successfully demonstrated by the “rainforestation” project in Leyte, Philippines (Margraf and Milan, 1996).

8 Summary and Concluding Discussion

Droughts are natural disturbances in tropical rain forests. Whereas slight droughts can even have a stimulating effect, severe droughts damage whole forest areas through increased tree mortality caused by water deficit and fire. Fire cannot spread in rain forest during normal wet conditions, and even under drought conditions only minor surface fires will occur in undisturbed rain forest. But in logged-over or otherwise disturbed forests, fire can spread in a devastating way.

Drought and fire damage could be repaired through natural regeneration within the rain forest areas. Forest fires occurred already in the Pleistocene and have been recorded for the last two centuries. But in recent years, severe droughts have been increasing, and the rain forests are getting less opportunity for regeneration. Forest fragmentation is exacerbating the situation , and new research has shown that natural regeneration of Dipterocarpaceae, the dominant tree species, is at risk in some regions.

From these observations we have to conclude that the remnant rain forests in Southeast Asia may degenerate and disappear even in national parks and other reserves. The only chance for a survival will be a promotion of natural forest regeneration by forestry activities, which will, however, be very cost intensive. The need of effective fire prevention within rain forests during droughts is self-evident, although there is still a long way to go. Further fragmentation of rain forests should be stopped immediately. But this will not be enough. Existing fragments should be re-linked by afforestation with indigenous tree species and by agroforestry systems.

This paper is meant to create awareness about the impending threat of increasing droughts in the rain forest environment, with manifold disadvantages for development, both locally and globally. Besides accelerating the greenhouse effect, smoke and haze are noxious for human health and deter foreign tourists. The direct financial loss through drought and fires is enormous, and can only be roughly estimated.

One side effect of drought in rain forests is that during drought stress these ecosystems do not act as carbon sinks. Fires in forests and agricultural areas further increase the production of carbon dioxide as a greenhouse gas. Scientists are presently discussing the idea that tropical deforestation has become a self-enforcing effect of the Southern Oscillation. Furthermore, stem-growth of trees is retarded during droughts. With the increase in severe droughts, as has been shown above, wood growth and carbon fixation in trees is retarded. Slower growth of trees, including those in forest plantations, is reducing the income from forestry. Slower carbon fixation is aggravating the greenhouse problem.

Awareness about drought and ENSO exists and is growing among the academic elite, decision makers and the rural population. The following activities could reduce the fire risk:

- Early warning system for droughts.
- Fire risk maps for the whole region.
- Satellite surveillance of forest areas.
- Fire combat squads in the forest regions.
- Awareness raising among the local population.
- Strict law enforcement and prosecution of those setting vegetation to fire.
- Incentives for local communities to control unwanted fire on land which is not their own.
- Rehabilitation of peatland.

These activities should help in the long term:

- The suitability of selective logging should be reconsidered
- All remaining rain forests should be effectively protected
- Foresters should start supervision programs for the natural regeneration of dipterocarp seedlings, as successful germination has been disturbed by forest fragmentation.
- New forest plantations on land where the rain forest has been cut or burned, should eventually supply new timber.
- The introduction of agroforestry systems should be fostered as they can serve as effective buffer zones around remnant forests and even link forest patches together.

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Appendix

Examples for recent texts in local newspapers

Thick haze threatens Riau, Aceh, Kalimantan

Source: The Jakarta Post, June 07, 2003

The annual choking haze has reached alert levels on mainland Riau, including the provincial capital of Pekanbaru, with authorities warning residents to stay indoors as much as possible.

The reappearance of the haze, which has occurred annually for the past decade due to the burning of rainforests on Sumatra and Kalimantan, has been met with the same authorities calling for action to be taken -- but little is ever done against the military dominated forestry companies. Riau health office deputy chief Ekmal Rusdi said on Friday that the thick smoke had reached alarming levels. "We call on the people to stay indoors as much as possible, especially at nights. The conditions can cause respiratory problems and lung diseases," he was quoted by the Antara news agency as saying.

Many residents in Pekanbaru were observed wearing cloth around their faces for protection as they traveled in the open. The thick smoke covers several regencies in the province following fires in supposedly protected rainforests in Dumai, Minas and Kampar and in forest areas in the regencies of Rokan Hulu and Rokan Hilir. "A fire is still burning in the conservation forest along the Dumai River and in the Bukit Rimbang and Bukit Baling conservation forests in Kampar and Minas regencies," Natural Resources Conservation Unit (BKSDA) chief in Riau Jhon Kenedie said.

Jhon called on relevant authorities to take action against individuals and companies using fire to clear land for farm and plantations because besides having triggered the chocking haze, the fire had spread to protected forests, home to thousands of rare species. With the help of the National Oceanic Atmospheric Administration (NOAA) in Singapore, the provincial administration has detected a large number of hot spots throughout the province.

The Environmental Management Agency (Bapedalda) said NOAA satellite imagery had located 10 major fire areas in forests owned by timber companies PT Sumatra Sinar Plywood, PT Rokan Permai Timber and PT Arara Abadi. Authorities at the Sultan Syarih Hasyim airport said the haze had not yet affected air operations in the province.

The haze is also threatening to hit the war-torn province of Aceh on the northern tip of Sumatra island, due to fires in the regencies of Aceh Singkil and Central Aceh. The haze has begun to affect motorists in the provincial capital of Banda Aceh and Aceh Besar regency. The Meteorology and Geophysics Agency (BMG) in Banda Aceh said the haze covered parts of the city but had yet to affect airport operations.

Meanwhile, authorities in Kalimantan repeated warnings that the haze covering parts of the island could affect the people's health and daily activities unless the burnings stopped. The South Kalimantan administration has put in place heavy penalties for individuals and companies using fires to clear land for farms and plantations. Local forestry office deputy chief Basuniansyah said it had detected 73 hot spots in 14 regencies in the province. Most were located near and inside company owned forests. "Our team is still in the field investigating," he claimed.

West Kalimantan Governor Usman Ja'far warned plantation companies and forest concession holders against setting fires, saying any violators of environmental and forestry laws should be taken to court. He said all regents and mayors in the province should be aggressive in preventing the fires that had plagued the province.

Haze returns as fires rage in Sumatra

Source: Borneo Bulletin, May 22, 2003 KUALA LUMPUR (dpa)

Thick haze has returned to shroud Malaysian skies in a yearly occurrence brought on by dry weather as well as increased fires in the Indonesian island of Sumatra, environmental officers said Wednesday. The Department of Environment reported that satellite images on Tuesday detected 49 hot spots - areas showing high levels of heat caused by burning - in Sumatra, which were believed to be forest fires. "The air problem we are facing now is caused by the burnings in Sumatra, but the dry spell is not helping as well," the department spokesman said. She said a total of 34 air quality stations, mostly located in the central Klang valley and the country's west coast nearing Sumatra, reportedly had moderate Air Pollutant Index (API) readings, while 16 others were classified as good. "There is an undeniable deterioration in air quality in those areas. It's still under control, but we want to alert the public to take precautions and refrain from carrying out any open burnings which would worsen the problem," she said.

DAILY EXPRESS NEWS

Forestry Dept to implement fire system 06 March, 2002

Sandakan: The State Forestry Department will be implementing a Fire Danger Rating System (FDRS) aimed at strengthening its forest fire prevention capacity.

Developing FDRS could provide advance warning of potential fire occurrence throughout the State, with funds provided by the Canadian International Development Agency (CIDA) for the development of expertise required for the purpose.

Disclosing this , Sabah Forestry Deputy Director Herman Anjin said several fire risk areas had been identified, zoned and mapped.

Some Forest Management Units are within a high risk zone and thus require effective fire management plans.

He said this while expressing his overview of the problem of forest fires in Sabah, at a recent seminar on FDRS held at the Forest Research Centre, Sepilok, jointly organised by the Forestry Department and the Canadian Forest Service.

The objective of the seminar was to raise awareness among forest managers, Sustainable Forest Management Licence holders and related government agencies on the importance of fire danger rating in forest fire prevention.

The seminar involved 90 participants representing several government agencies and Sustainable Forest Management Licence holders.

According to Herman, Sabah experienced severe droughts in 1983 and 1998, which had affected one million hectares and 130,000 hectares of forest fires, respectively.

Most, if not all, of forest fire cases were caused by human activities, especially shifting cultivation, hunting, arson and, to a certain extent, land clearing for agriculture development, he said.

Lacking in experience and appropriate equipment had been contributing factors affecting the department's ability to contain forest fires effectively.

"This is compounded by the abundance of fuel in logged-over areas, lack of access and absence of strategic water sources," he added.

He pointed out that the Forestry Department initiated the development of fire prevention and control capability in 1995, with the Protection Branch of British Colombia Forest Service appointed as consultant.

Rehabilitating peat land to fight haze
July 05, 2003 - New Strait Times - Deborah Loh - PUTRAJAYA:

Malaysia is conducting a pilot project on fire prevention and rehabilitation of peat land as part of Asean's plan to fight transboundary haze.

If successful, the project will be a model for other Asean countries to adopt in preventing peat fires, which are difficult to extinguish and are a major cause of the haze that Southeast Asia experiences annually.

The Global Environment Centre (GEC) said 123 hectares of peat land in Batang Berjuntai, Selangor, was the site of the pilot project where attempts to re-flood the soil (healthy peat is water-logged) was now under way.

GEC manager Chee Tong Yiew said canals which had initially been used to drain the area were being "blocked" to re-flood the peat soil.

"It appears successful so far. Trees have started to grow again. We will continue testing this method to see if it is effective and if it works, it will be a demonstration project for the rest of Asean to follow," he said at a forum on the "Asean Peatland Management Initiative (APMI)" here, yesterday.

Various government agencies are involved in the project, with the Science, Technology and Environment Ministry as the focal point.

The APMI is a programme that promotes sustainable management of peat lands in the region and is part of the Asean Agreement on Transboundary Haze Pollution and the Asean Regional Haze Action Plan.

The APMI has been adopted by all Asean members. The GEC was appointed by the Asean secretariat to be the programme's technical and operations support agency.

Under the APMI, member countries share information on their respective experiences in peat land management, predict peat fire hazard areas and monitor fire outbreaks.

Chee said all Asean members had identified the need to increase their capacity and knowledge about peat management, as Southeast Asia contained 60 per cent, or 25 million hectares, of the world's tropical peatlands.

Indonesia alone has 85 per cent of peat in the region, and had contributed 95 per cent of peat fires and haze during the haze crisis of 1997 and 1998, GEC director Faizal Parish said.

Dry peat soil is highly combustible due to its organic content. Peat fires burn underground and emit huge amounts of smoke, causing haze.

Peat is normally drained to use the land for agriculture, a practice which became widespread in Indonesia during the 1990s.

Source: http://www.haze-online.or.id/news.php?ID=20030707100517

ASEAN Haze Agreement to Enter into Force on 25 November, 2003

ASEAN Secretariat, September 26, 2003
Jakarta

The ASEAN Agreement on Transboundary Haze Pollution will enter into force on 25 November 2003. This follows the deposit of the sixth instrument of ratification by the Government of Thailand with the Secretary General of ASEAN on 26 September, 2003. The Agreement provides for its entry into force sixty days after the deposit of the sixth instrument of ratification. Brunei Darussalam, Malaysia, Myanmar, Singapore, and Viet Nam had earlier deposited their instrument of ratification/approval.

The Agreement, signed by the ten member countries of ASEAN on 10 June 2002 in Kuala Lumpur during the World Conference and Exhibition on Land and Forest Fire Hazards, is the first such regional arrangement in the world that binds a group of contiguous states to tackle transboundary haze pollution resulting from land and forest fires. The Agreement contains provisions on monitoring, assessment and prevention, technical cooperation and scientific research, mechanisms for coordination, lines of communication, and simplified customs and immigration procedures for disaster relief. The Agreement provides for the establishment of an ASEAN Coordinating Centre for Transboundary Haze Pollution Control to undertake the various activities required under the Agreement.

Parties of the Agreement are required to cooperate in developing and implementing measures to prevent and monitor transboundary haze pollution, and control sources of fires by developing early warning systems, exchange information and technology, and provide mutual assistance. The Agreement also requires the Parties to respond promptly to a request for relevant information sought by a state or states affected by such transboundary haze pollution, when the transboundary haze pollution originates from within their territories. The Parties are required to take legal, administrative and/ or other measures to implement their obligations under the Agreement.

Since the signing of the Agreement in June 2002, the ASEAN Environment Ministers have consistently expressed their commitment to ensure the early entry into force of the Agreement. This speedy adoption and early entry into force of the Agreement bears testimony to ASEAN’s resolve to tackle land and forest fires and transboundary haze pollution comprehensively.

The Association of Southeast Asian Nations is composed of Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Viet Nam.

The following papers have been published so far:

No. 1	Ulrike Grote, Arnab Basu, Diana Weinhold	Child Labor and the International Policy Debate Zentrum für Entwicklungsforschung (ZEF), Bonn, September 1998, pp. 47.
No. 2	Patrick Webb, Maria Iskandarani	Water Insecurity and the Poor: Issues and Research Needs Zentrum für Entwicklungsforschung (ZEF), Bonn, Oktober 1998, pp. 66.
No. 3	Matin Qaim, Joachim von Braun	Crop Biotechnology in Developing Countries: A Conceptual Framework for Ex Ante Economic Analyses Zentrum für Entwicklungsforschung (ZEF), Bonn, November 1998, pp. 24.
No. 4	Sabine Seibel, Romeo Bertolini, Dietrich Müller-Falcke	Informations- und Kommunikationstechnologien in Entwicklungsländern Zentrum für Entwicklungsforschung (ZEF), Bonn, January 1999, pp. 50.
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No. 6	Mingzhi Sheng	Lebensmittelhandel und Kosumtrends in China Zentrum für Entwicklungsforschung (ZEF), Bonn, May 1999, pp. 57.
No. 7	Arjun Bedi	The Role of Information and Communication Technologies in Economic Development – A Partial Survey Zentrum für Entwicklungsforschung (ZEF), Bonn, May 1999, pp. 42.
No. 8	Abdul Bayes, Joachim von Braun, Rasheda Akhter	Village Pay Phones and Poverty Reduction: Insights from a Grameen Bank Initiative in Bangladesh Zentrum für Entwicklungsforschung (ZEF), Bonn, June 1999, pp. 47.
No. 9	Johannes Jütting	Strengthening Social Security Systems in Rural Areas of Developing Countries Zentrum für Entwicklungsforschung (ZEF), Bonn, June 1999, pp. 44.
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No. 17	Arnulf Heuermann	Die Bedeutung von Telekommunikationsdiensten für wirtschaftliches Wachstum Zentrum für Entwicklungsforschung (ZEF), Bonn, September 1999, pp. 33.
No. 18	Ulrike Grote, Arnab Basu, Nancy Chau	The International Debate and Economic Consequences of Eco-Labeling Zentrum für Entwicklungsforschung (ZEF), Bonn, September 1999, pp. 37.
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