Box 3

El Niño-Southern Oscillation

The El Niño-Southern Oscillation (ENSO) is the result of a cyclic warming and cooling of the surface of the eastern Pacific. This region of the ocean is normally cooler than its equatorial location would suggest, mainly due to the influence of north easterly trade winds, a cold ocean current flowing up the coast of Chile, and the upwelling of cold deep water off Peru.

At times, the influence of these cold waters wane, causing the surface of the eastern and central Pacific to warm up. This is called an El Niño event. ENSOs also affect the Earth's trade wind patterns, which in turn influence sea surface temperatures (SSTs) over vast areas of the Pacific. These changes can produce extreme weather throughout the tropics and have been linked to severe droughts in Indonesia and Australia, and heavy rainfall in South America.

At other times, the injection of cold water becomes more intense than usual, causing the surface of the eastern Pacific to cool. This is called a La Niña event, and results in heavy rainfall in Australia and Indonesia, and droughts in South America. An El Niño event is usually followed by a La Niña event.

Source: http://www.vision.net.au/daly/elnino.html

There have been twenty ENSOs in the 120 years since 1877. There is now much debate that the frequency and intensity of ENSOs is increasing, and there is some evidence that this has been the trend in the past twenty years[10].

Shown here, change of currents, warm water and clouds associated with El Niño conditions. (*a*) and (*b*) Pattern of wind and ocean currents, water temperatures and clouds in a 'normal year', (*c*) and (*d*) Pattern of wind and ocean currents, water temperatures and cloud cover across the equatorial Pacific during an El Niño event. Profile diagrams (*b*) and (*d*) after Gribbin and Gribbin (1999)[11].

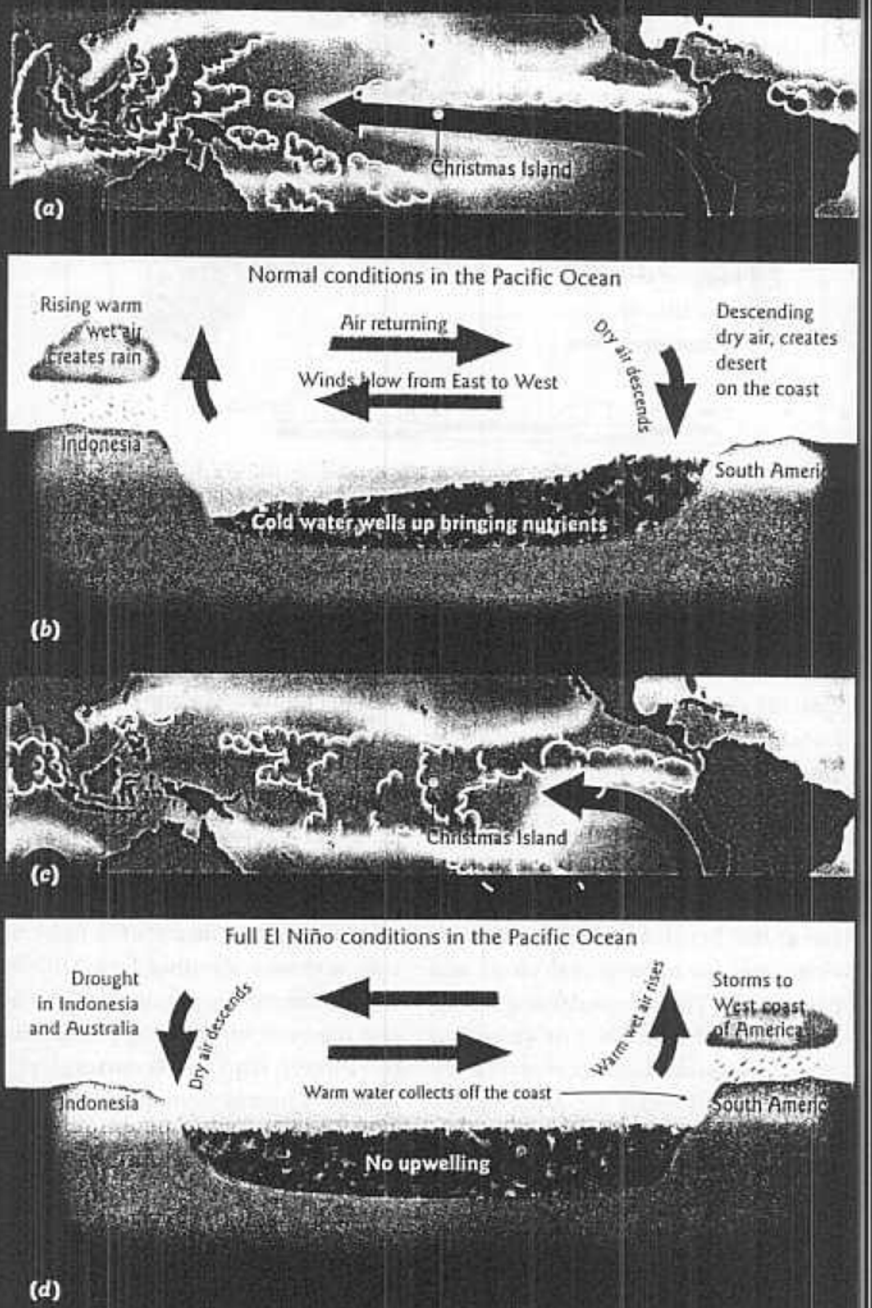
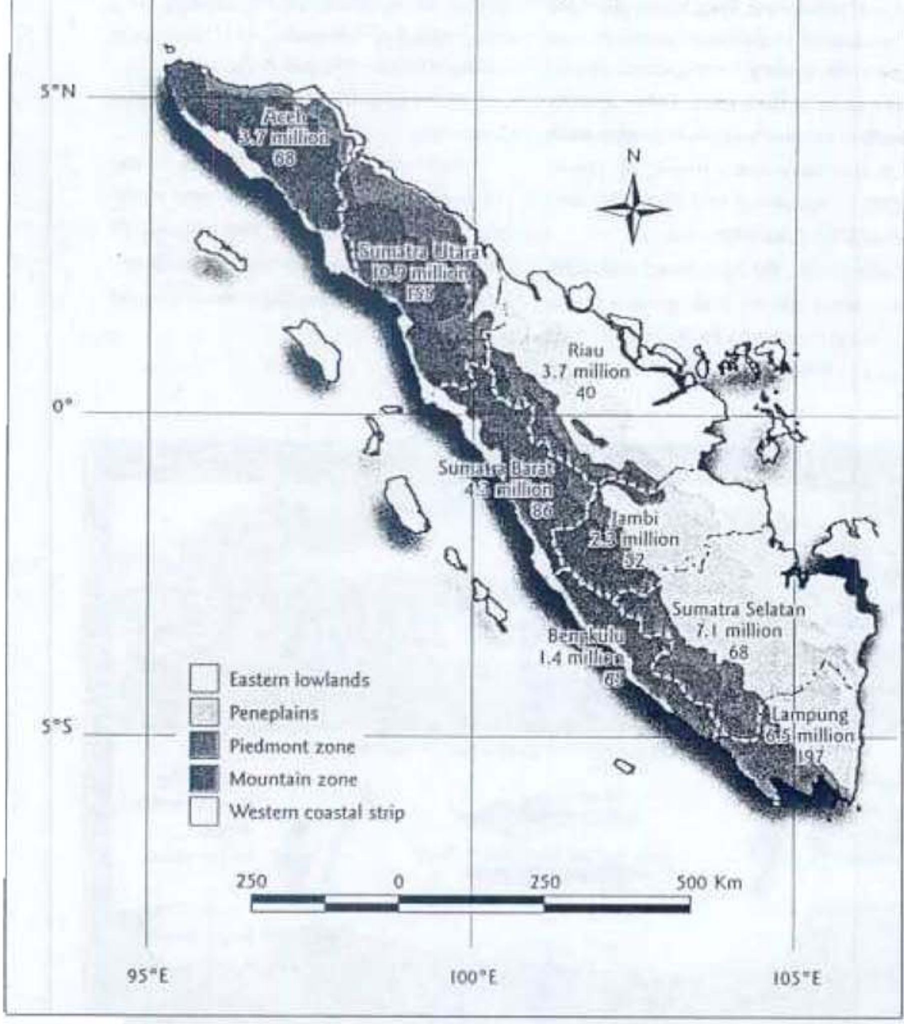


Figure 2. Agro-ecological zones of Sumatra, with populations of the eight provinces in 1994 given in millions and population density in persons km^{-2}. Source: BPS, Statistik Lingkungan Hidup, 1994.



Evidence that fire was used by man in Indonesia date back more than 10,000 years[13]. Fire is often the only option for clearing the land, especially for small farmers. Every year the dry season (from May to October) provides ideal conditions to clear land by fire. It is therefore an integral part of land use systems in Sumatra. More recently, fire has been used by large landholders over the entire Southeast Asian region to clear land for agricultural crops and plantations. The area under tree estates for pulp, timber, rubber, oil-palm and other products has increased very rapidly in Indonesia. Oil-palm estates alone have increased by 2.4 million ha in a recent three-year-period[14].

The extension of tree-crop land and concessions is often associated with transmigration, a process which was already underway early in the twentieth century and which is continuing today. The process involves the resettlement of people from the populated islands of Java and Bali to less populated areas, such as Kalimantan and Sumatra. The government transmigration programme has so far resettled 220,000 families (around 1 million people) to Sumatra. With each family receiving 2 ha of land, the total land use change directly attributable to the influx of transmigrants represents 6% of Sumatra's land area. Another factor driving land conversion is population increase and the need for growing populations to convert land for securing livelihoods. The resident population in Sumatra increased from 28 million in the 1970s to over 40 million in the 1990s.

Logging is another important factor that influences fire behaviour. The impact is two-fold. First, logged forest is more fire-prone than intact forest. A logged-over forest has increased amounts of wood residues on the ground, which easily dry out and which provide a readily ignitable fuel for the start of extensive fire. Another impact of logging and land use change relates to the fragmentation of landscapes. With forest fragmentation, the ecotone between forest and non-forest becomes larger. This itself is already a threat to the spread of fire into forest. In addition, along the forest edge, there will be change of temperature, humidity and wind regimes that modify the microclimate of the remaining forest, making it even more susceptible to fire[15].

All these various processes and factors have had major repercussions on Indonesia's historical abundance of land, with forest being rapidly converted to other uses. This pressure on land and the changes[16] that have occurred in recent decades have given a complete new setting to the 1997 fires. This new setting includes differences in social and economic as well as bio-physical and political context.

General description of Sumatra

The island of Sumatra has a wet tropical climate, and consists of four major ecological zones[17]: the lowlands of western Sumatra, a mountain range, and the footslopes and lowlands of eastern Sumatra (Figure 2). In 1994, the population of Sumatra was 40 million with an average population density of 77 persons km^{-2}. The lowlands of eastern Sumatra (Lampung, Sumatra Selatan, Jambi and Riau) have recently been subjected to considerable land use

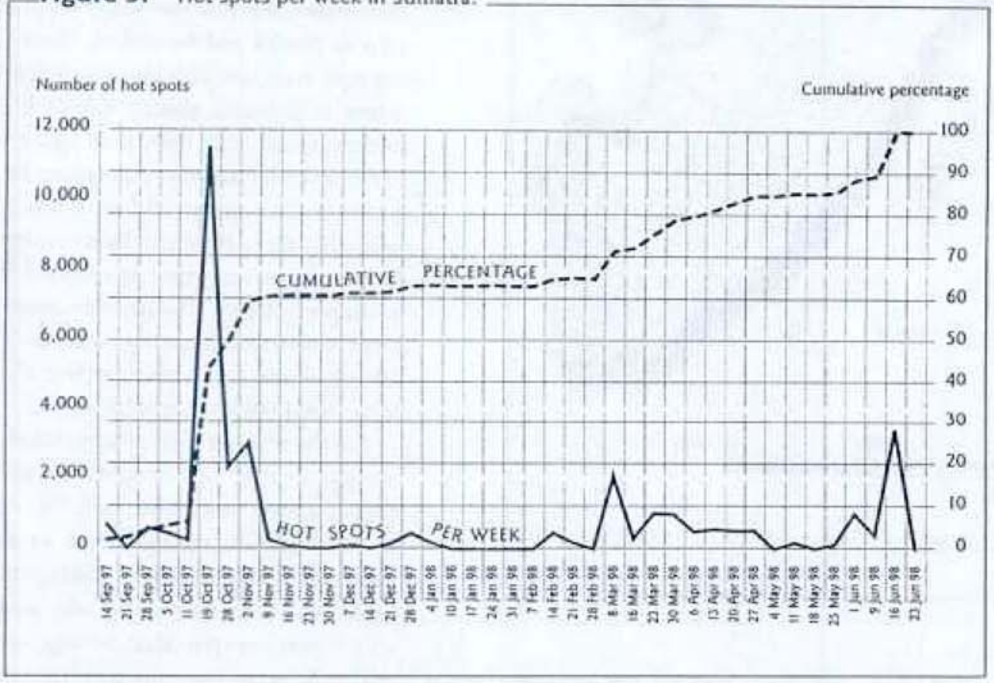
change, with many new plantations and significant increases of population. Logging concessions were already active in these locations in the mid-1970s, and in the Sumatra lowlands, commercial logging reached its peak in the 1980s. For the whole area of Sumatra, more than 15 million ha (30% of the total land area) is or was under logging concession.

To study the impact of fires on the vegetation, several maps were used. None of these maps can be considered very accurate, since the last island-wide vegetation survey dates from 1986. Since then, considerable changes have occurred[18]. Consequently, desktop mapping with this coarse dataset does not give accurate information on exact locations and areas, but it does provide insights on where the fires were most serious.

Tools and approaches

Remote sensing through satellite imagery combined with geographical information systems (GIS) provide the main means for studying the fires and for assessing what fires took place, where and when, in the archipelago. With satellite images, fires can be detected and monitored over a large area on a daily basis as so-called 'hot spots', while more detailed images provide information of the area burned, so-called 'burn scars'. Combined with digital maps, this information gives a rapid overview of what happened during the fire episode.

Figure 3. Hot spots per week in Sumatra.



The satellite used in the present study was the NOAA-AVHRR satellite (US National Oceanic and Atmospheric Administration – Advanced Very High Resolution Radiometer). This satellite can cover in one image a ground area of 1,000 by 1,000 km. It has an infrared sensor onboard which can measure the average temperature on the ground over an area of 1 km^2. This generates the so-called 'hot spot'. Hot spots do, however, have some serious drawbacks.

The NOAA satellite was developed for weather and oceanic purposes, and so the sensor sensitivity is optimized for temperatures below 40°C. In contrast, fires generally have a temperature above 60°C. This discrepancy gives rise to errors in the recognition of hot spots. Another drawback is the relatively large size of the ground cell of 1 km^2. A hot fire of 50 by 50 m can give the full cell an average temperature above 60°C, and so the entire cell is recorded as a hot spot[19]. On the other hand, a large ground fire of several hectares of sparse or low vegetation will not give an intense, hot fire and so might not be recorded as a hot spot. Therefore, areal calculation is very difficult or indeed impossible if only hot spot information is used.

Misclassification can also occur during daytime, where areas under grasslands or bare soil reach temperatures above 60°C, while fires under thick haze or smoke cover cannot be detected, as the sensor cannot penetrate haze, smoke or cloud. Furthermore, the accuracy of the ground position measurement has an error of 3 km. Consequently the exact position of the hot spot cannot be known precisely. All these drawbacks mean that mistakes can readily be made in the classification of hot spots, and that the resulting misclassifications can be large.

This said, the NOAA-AVHRR sensor is still widely used for hot spot detection, because of its daily updates. The sensor covers all parts of the Earth at least twice daily. The images can be directly downloaded from the satellite with relatively inexpensive equipment. Fires can thus be monitored daily, facilitating study of their pattern and distribution. For these several reasons, in this study hot spots have been used as a main tool for tracking the fire situation in Sumatra.

Distribution of fires

During a period of one year, almost