The Underlying Causes and Impacts of Fires in South-east Asia

Site 5. Danau Sentarum, West Kalimantan Province, Indonesia

by

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Site Report

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by

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Cover photo: Burnt swamp forest, Danau Sumbuk, Danau Sentarum National Park

by Andi Erman

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ABBREVIATIONS AND TERMS

Adat rights	Traditional ownership or use rights recognized by local law
GIS	Geographic Information System
ha	Hectare
km	Kilometer
Kanwil	*Kantor Wilayah* (Provincial Office)
Landsat MSS	Landsat Multispectural Scanner. An imaging system found on the first five Landsat satellites. The system collects multispectral data in four nonthermal radiation bands with a spatial resolution of 79 x 79 m.
Landsat TM	Landsat Thematic Mapper. A multispectral scanner imaging system on board the Landsat 4 and 5 satelllites. The imaging system collects mulltispectral data in seven bands (six nonthermal bands have a spatial resolution of 30x30 m, whereas the thermal band has a spatial resolution of 120 x 120 m. The temporal resolution is 16 days.
m	meters
MOFEC	Ministry of Forestry and Estate Crops
RePPProT	Regional Physical Planning Programme for Transmigration
Stakeholders	People or groups of people interested or responsible for forest management. Includes landowners, community, industry and government organisations
Spot XS	SPOT multispectral scanner imaging system with a spatial resolution of 20 m x 20 m.
TREES	Tropical Ecosystem Environment Observations by Satellite

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SUMMARY

Within the framework of the CIFOR/ICRAF/USFS project on underlying causes and impacts of fires in South-east Asia, 8 sites were studied in detail by linking spatial data with socio-economic information, to provide a solid basis for a scientific study of the causes and impacts of vegetation fires. This report provides the results of an analysis of the causes and impacts of vegetation fires in the Danau Sentarum area in West Kalimantan, Indonesia. The 250,000 ha site is an area of open lakes and seasonally flooded swamp forests surrounded by low hills. Most of the site (197,000 ha) falls within the Danau Sentarum National Park. Two general fire regimes are present in the study area. One is seen in the upland areas and along the larger rivers, where fire has been used for centuries as part of the swidden agriculture system. The other is seen in the low-lying swamp forests in and around the lakes where fire has been present for centuries, but not for any apparent use such as cultivation.

The methodology adopted for this site varies slightly from others in the study. Similar to other sites landscape level analysis was the basis, but within the site, 5 villages were selected for more detailed analysis. This applied to both the socio-economic as well as the remote sensing/GIS analysis. This approach enabled a deeper understanding of the complex issues surrounding the relationship between local communities and fires in the swamp forest.

The research confirmed the locally held view that swamp forest fires have been worsening since the early 1990s. Satellite imagery showed that burn scars in swamp areas increased from 5,483 ha in 1973 to 18,905 ha in 1997. The reasons for fires in the swamp forest were clear. In broad terms, the results of the village interviews indicated that there are three main reasons for fires: resource extraction; increased population and greater access; and climatic conditions conducive to fire. However, the underlying causes were less obvious. Villages with apparently similar characteristics showed different experiences with fire. It was concluded that factors associated with community structure and organization, strength of customary laws, perceived value of the forest and inter-village relationships, play a crucial role in the absence or presence of fires.

1. INTRODUCTION

Large-scale fires and associated smoke are an increasing problem in Indonesia and surrounding countries. For instance, major fires occurring in the El Niño years 1982/1983, 1987, 1991, 1994, and 1997/1998 (Dennis, 1999) devastated large areas of forest and caused significant economic losses, both in Indonesia where most fires occurred and in neighboring countries. The economic costs of the 1997/98 fires in Indonesia have been estimated to exceed US$ 9 billion with carbon emissions high enough to elevate Indonesia to one of the largest polluters in the world (Asian Development Bank, 1999; Barber and Schweithelm, 2000). The major causes of these fires are, however, still largely unclear. Some have blamed small-scale farmers, others large-scale estates for causing fires, suggesting that these actors deliberately set fires to forest to open up land for plantations or agriculture. In 1994, the Indonesian government blamed slash-and-burn activity by smallholders as the major cause of fire, and they estimated that these people were responsible for more than 85 % of the 5,000,000 ha burned (Jakarta Post, 7 October 1994). Environmental NGOs, however, blamed activities by forest concessionaires and plantation owners as the major cause of fires (Jakarta Post, 3 October 1994). In contrast, taking advantage of data obtained from fire hot-spot information and satellite imagery, all institutions including government agencies believe that large-scale land clearing for plantations of fast growing trees for pulpwood and oil palm were the major causes of fire in 1997 and 1998. Yet, fires occurred at multiple scales and for many reasons, and impacts on local communities and forest had a variety of complex causes.

In this report, the Center for International Forestry Research (CIFOR), the International Centre for Research in Agroforestry (ICRAF), and the United States Forest Service (USFS) provide a study of the underlying causes and impacts of vegetation fires in Indonesia. The aim is to answer questions about the reasons (why), nature (what), perpetrators (who), and locations (where) that were associated with the fires. Several methods of information gathering were used, ranging from satellite-derived remote sensing imagery at the landscape level to in-depth field investigations at the village level. When used in combination, a more complete picture of fire can be developed. However, only through extensive interviews with local people combined with on-the-ground participatory mapping, can an answer be found to whom was responsible for the fires and what were their underlying reasons. From the field

investigations and the use of a Geographic Information System (GIS), a more accurate estimate of what burned can be determined at the landscape level.

This study will apply two levels of spatial analysis: landscape and village. At the site-specific level, the study focuses on the relationship between fire and land cover/land use change through analysis of satellite imagery. At the village level the relationship between fire and land cover/land use change and the village community was investigated by integrating the results of village interviews with an analysis of satellite imagery.

The Danau Sentarum site was chosen for a number of reasons. Fire is and has been part of the Danau Sentarum landscape for a long time. The analysis of pollen and charcoal records carried out recently by Anshari *et al*. (2000), provides a picture of changing vegetation over the past 30,000 years and charcoal is present throughout the record. In addition, a wealth of written evidence is available from the early 19th century through to the present day. Two general fire regimes appear to be present in the area. One is seen in the upland areas and along the larger rivers, where fire has been used for centuries as part of the swidden agriculture system. The other is seen in the low-lying swamp forests in and around the lakes where fire has been present for centuries but not for any apparent use such as cultivation. The causes and impacts of the swamp forest fires are still poorly understood and the aim of the research in this site is to understand these underlying causes more fully.

2. SITE DESCRIPTION

2.1 Biophysical

The study site covers an area of 254,731 ha in the Danau (Lake) Sentarum area in the upper reaches of the Kapuas River in West Kalimantan. A substantial part of the site is occupied by the Danau Sentarum National Park which covers 198,000 ha (see Figure 2-1).

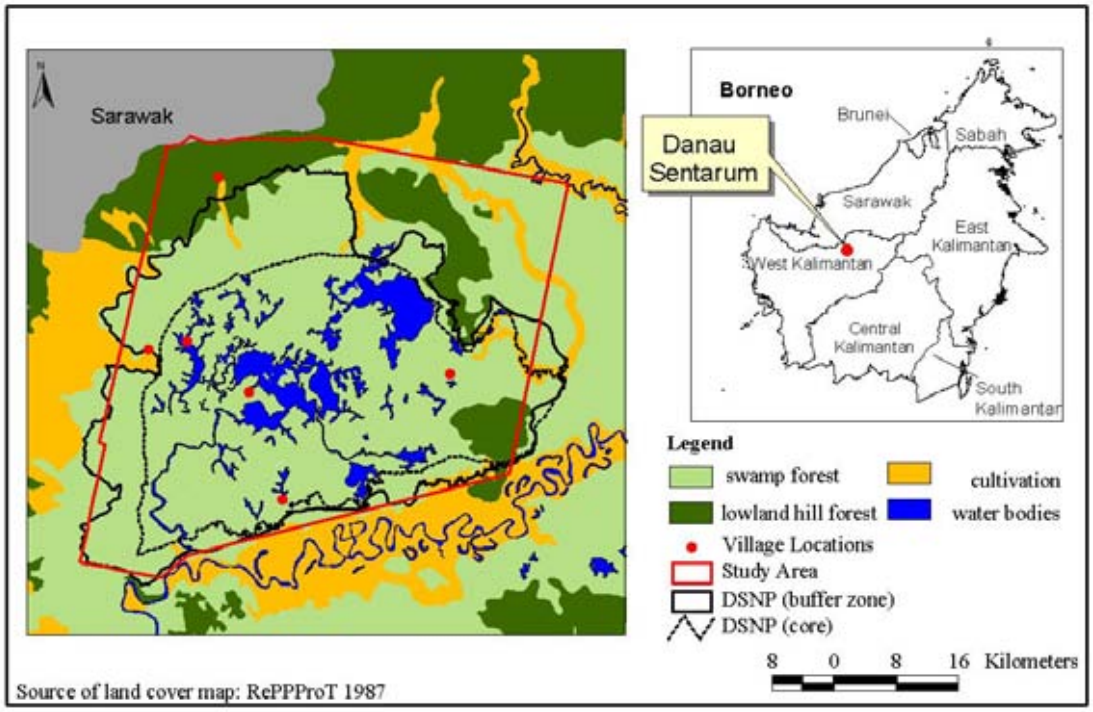


Figure 2-1 Location of study site

Danau Sentarum is an area of open lakes, seasonally flooded peat and freshwater swamp forest, and lowland hill forest (see Figure 2-1). Agriculture, both semi-permanent and swidden dominate in the north and south of the study area. The elevation rises from an average of 35 m in the lakes-basin to about 750 m on the surrounding hills. This unique environment is located in the floodplain of the middle section of the River Kapuas, some 700 km upstream from the estuary. Within the study area the area of open water covers approximately 30,000 ha of intricate waterways and open lakes. The variation between high and low water level reaches 12 m or more. In extreme dry years, such as El Niño events, the lakes dry out completely

leaving fish stranded in small pools and channels (see Figures 2-2 and 2-3). The wetland area plays a very important role in buffering floods on the nearby River Kapuas.

Quaternary sediments of clays, fine sands, and peat dominate the geology of the study area. In addition there are rock outcrops in the swamps and in the ranges to the north. Tertiary arkosic sandstone outcroppings are the most common formation in around the swamps (Giesen, 1987). This parent material is notoriously deficient in nutrients and this infertility is obvious from the associated sandy soils and the stunted pole-like vegetation that develops on it. Soils of the area can be grouped into two main classes: fine sediments and organosols of the plains, and sands and loams of the hills. The clay soils are acidic, heavy clays, and generally very infertile. The peat soils developed in this area are topographic peat, developing in areas between rivers and at the base of hills. The peat in this area is moderately deep 0.5-2 m.

2.2 Vegetation

There are two broad forest types in the study area: swamp forests and dryland forests. Swamp forests extend over 149,333 ha (1997 estimates) and dryland forest extends over 25,438 ha (1997 estimates) (Dennis and Kuriawan, 2000). Swamp forests extend over 58 % of the study area, varying from 5–8 m tall vegetation, along the lake-edge, to 35 m tall peat swamp forest. In his vegetation study Giesen (1996) identified four broad swamp forest types: 1) dwarf swamp forest, 2) stunted swamp forest (see Figure 2-2 and 2-3), 3) tall swamp forest, and 4) riparian forest. A full description of species composition of all forest classes can be obtained in Giesen (1996).

Figure 2-2 Stunted swamp forest during high water (same view as Figure 2-3)

Figure 2-3 Stunted swamp forest and lakes during the 1994 dry season

The second main forest type in the area is dryland forest accounting for 10 % of the study area. Dryland forest generally occurs on the hills, which range in height from 140 to 750 m, and on the undulating uplands in the northern part of the study area. Apart from secondary vegetation, two dryland vegetation types occur in the area, namely hill forest and heath forest.

The remaining type of forest encountered in the study area is secondary forest, or forest re-growth. This occurs on abandoned sites of shifting cultivation (*ladang*), areas cleared for habitation, some burnt areas and in areas opened up/disturbed by logging. Ferns, shrubs and trees such as *Macaranga sp.,* and a hill variety of *Fagraea fragrans* generally dominate re-growth areas.

2.3 Land use

There are three main land use types within the study area; forest, water and agriculture. Forest covers the largest part of the area, followed by water and agriculture. All land and water in the area is simultaneously owned by the State and claimed by local communities. Therefore the area exhibits two layers of management; official Government management through, for example, logging concessions, and local communities' unofficial management of natural resources such as fish, and through cultivation of crops.

Most of the land within the study area is officially designated as State forestland, including wetland areas. Up until the mid-1990s a large proportion of the study area was managed by licensed forest logging concessions, approximately 172,443 ha (67 %) divided amongst 7 private companies. Danau Sentarum National Park (DSNP) occupies the remaining 132,000 ha of state forestland in the study area. The areas allocated for licensed logging in this area are found in two distinct areas: the lowland peat/freshwater swamps and the hill forests. In the swamp forest areas, field observations and interpretation of satellite imagery show that most of the logging activities were carried out selectively and much of the forest remains intact but disturbed. In contrast, logging activities in the hill forest areas have had a greater impact and some clear felling is observed. Dense patterns of logging roads often appear and most of these roads remain after the logging has ceased. Some of these roads even become public roads and are used by local people or outsiders to access the forest.

Since 1997, with the cessation of many of the legal logging concessions illegal logging has increased rapidly. This is seen particularly in the swamp forests to the north and east of the lakes. The logging is on quite a large scale with small sawmills springing up 'over night'. Field reports indicate that these logging activities are well organised mainly by one or two entrepeneurs. The cut logs and planks are transported illegally over the border into Sarawak

where they are sold (Jakarta Post, 23 May 2000). In the swamp forest the illegal loggers often use the remains of old tracks created by the legal logging to gain access to the forest.

The study area managed to escape the eye of plantation developers until 1995–1996 when discussions and plans started for the establishment of oil palm plantations in this area. Maps released, in 1996, by the National Land Agency, showed that approximately 47,000 ha of the study area were proposed for oil palm development. Most of the oil palm plantations proposed in the study area fall within the boundaries of former logging concessions. A field visits in 2000 found that only one of the plantations, north of the DSNP had started operations.

2.4 Danau Sentarum National Park

The core of the study area is the Danau Sentarum National Park (DSNP). The area was first proposed as a Nature Reserve in 1981. In 1982, the Reserve was legally gazetted with an area of 80,000 ha and the status was changed to Wildlife Reserve. In April 1994, the Reserve was declared Indonesia's second Ramsar site[1]. In 1996, the boundary was extended to 132,000 ha to include some of the surrounding hills. In February 1999, the Reserve was declared a National Park with a core area of 132,000 ha and a buffer zone which has not yet been officially defined. However, at least one year after the area became a National Park, management by the Department of Conservation remains minimal with only two rangers occasionally stationed in the area. The local communities who live in the Park remain the *de facto* managers of the area. The Park is important for many species of wildlife, such as the orangutan (*Pongo pygmaeus*), proboscis monkey (*Nasalis larvatus*), Storm's stork (*Ciconia stormi*), several species of crocodile, and as many 266 species of fish (Jeanes and Meijaard, In press).

[1] Ramsar sites are assigned under the 1971 Ramsar Convention. This is an international treaty that provides a framework for the co-ordinated designation and conservation of internationally important habitats. As of 1994, 654 Ramsar sites had been designated covering an area of over 43 million ha (Navid, 1994 in UNEP, 1995).

2.5 Socio-economy

The area is home to two distinct ethnic groups both with quite different settlement and resource use patterns. The Melayu fisher people who make up the majority of the population live along the rivers and around the lakes (see Figure 2-4). The Iban Dayak cultivators and hunters live primarily in traditional longhouses in the hilly area north and north-east of the lakes. Each community within the study area has a defined area over which it claims customary or traditional rights to use and manage the resources found within that area. These rights do not mean that a village legally owns the resources, simply that it controls their use through a system of locally decided regulations which are referred to as fishing regulations or customary law (*hukum adat*[2]). In addition to fishing the regulations concern resources such as wood, honey, rattan, and problems such as forest burning (Harwell, 1997; Heri, 1996). The regulatory power is vested in the head fisherman in the case of the fishing villages and the head of the longhouse/tribal leader in the case of the Iban villages.

Figure 2-4 Typical Melayu fishing village at Danau Sentarum

[2] *Hukum adat* is generally translated as 'customary law' although some regard this as rather simplistic. This translation does not convey the deeper spiritual meaning of the term and the link between people, their ancestors, and the environment.

There are good population data for DSNP, thanks to data collection by a donor project[3], but in other parts of the study area data are less complete. According to 1997 population estimates some 8,480[4] permanent residents live in DSNP, with an additional 2,400 during the dry season when seasonal fishing migrants move into the area. In the absence of total population estimates, some data is available on population density for the study area. Within the lake-basin a density of 5.4 to 7.6 persons/km^2 is calculated by Jeanes (1997), including the swamps around DSNP the density falls to 3.8–5.22 persons/km². These figures are in line with the official district-wide population density of 5 persons/km². Population density in the uplands populated by the Dayak communities is much lower than in the Melayu fishing areas at 3–4 persons/km².

Population growth rates within the area are high relative to the province as a whole. Within DSNP, Aglionby (1996) recorded a 41 % increase over the past ten years for the central lake-basin. Giesen (1987) also noted large population increases (20–50 %) in the lake-basin villages over the earlier period 1980–1986. These figures are much greater than the official average 1988 population growth rate of 1.69 % for the administrative district (*kabupaten*) as a whole.

The socio-economy of the study area can be divided into two physical areas: the northern uplands populated by Iban Dayak and the lake-basin and associated rivers to the south populated by Melayu fisherpeople.

The most important livelihood activities for the Iban are subsistance hill rice cultivation and agroforestry. Swidden agriculture is still practised by many Iban communities although some former areas of shifting cultivation have become more permanent. In recent years black pepper cultivation has increased because of favourable prices (see Figure 2-5). Collection of non-timber forest products such as honey and rattan is also important, as is cultivation of tree crops such as fruit and rubber; furthermore there is some fishing and hunting. In general, commercial activity is limited and restricted to the sale of pepper, salted or caged fish and rubber. In contrast to the Dayaks, the Melayu are almost solely dependent on the income from

[3] Conservation Project of the DFID funded Indonesia-UK Tropical Forest Management Programme 1992–1997.
[4] Population estimates (1996) are from socio-economic surveys carried out by the DFID Project. Population estimates for 1997 are from Erman (1998). A population figure is obtained by multiplying the number of families by 5.

wild and caged fish. Secondary sources of Melayu income include honey harvesting, rattan and timber. On the larger river levees such as the Kapuas, rice, rubber and vegetables are grown in a semi-permanent agricultural system. Cattle are also reared in small numbers and sold for meat.

Figure 2-5 Black pepper cultivation by Dayak farmers

2.6 Infrastructure

Water transport is very important in the study area. The numerous lakes and rivers provide the main means of access to many of the towns and villages in the swamp areas and along the Kapuas River. It is only in the northern, upland part of the study area where road transport assumes importance. There is one main public road in the area and it stretches from the Malaysian border eastwards and links to the main district town of Putussibau; 80 km of this road cuts across the study area. This road was constructed in 1991–1992 and paved in 1994–1997. However, during the wet season damaged parts of the road become impassable, and at other times poorly made bridges cause bottlenecks. Recent reports suggest that the heavy volume of illegal logging traffic is severely damaging this road.

2.7 Fires

Fire is and has been part of the Danau Sentarum landscape for a long time. The oldest evidence of fires at Danau Sentarum comes from the analysis of pollen and charcoal records carried out recently by Anshari et al.(2000). The record provides a picture of changing vegetation over the past 30,000 years and charcoal is present throughout the record. The analysis identified increased burning levels and indicators of forest disturbance during the past 1,400 years (Anshari, *et al.* 2000).

Providing a more recent description of fire, from the mid-19th century up until present time there are many written accounts of visits to the Danau Sentarum area that provide a wealth of fire descriptions. One of the first explorers to mention the evidence of swamp forest fires at Danau Sentarum was Pfeiffer (1856) who visited the area in January 1852. She described extensive areas of burnt standing trees in the swamps to the north-west of the lakes. Gerlach (1881) visited the area in March 1881 and commented on both drought and fires. He mentions the pronounced drought of 1877; a year that is now known to have exhibited a strong El Niño Southern Oscillation (Harger, 1995a; Harger, 1995b; Trenberth and Hoar, 1997). In 1877, the lakes were almost completely dry with only small trickles of water in the channels, and one could walk for miles on the dry lake bed (Gerlach, 1881). As to the cause of the fires, Gerlach blamed the Dayaks for setting fire to the forests during the dry season for sheer enjoyment. Further visits by Bock (1882), Molengraaff (1900) and Enthoven (1903) provide interesting, albeit somewhat anecdotal descriptions of fires in Danau Sentarum around the turn of the 19th century, suggesting that fire was common, although the underlying reasons for its existence remained unclear. Helbig (1937) who described much burned land in the northern hills of the Danau Sentarum area confirmed this picture.

Some visitors to the lakes did not encounter evidence of fires. Polak (1949) did not report any traces of burnt forests, even though she looked for them. Vaas (1952) who accompanied Polak suggested that the lack of fires was due to the absence of fishing activities during the Second World War.

Much of the more recent analysis of fires in Danau Sentarum was carried out during the DFID-funded Conservation Project (1992–1997). During his initial study of Danau Sentarum

in 1986, Giesen described extensive tracts of burnt swamp forest in the north, along the Sumpa River, and also an active fire near the village of Nanga Leboyan in the east of the Park (Giesen, 1987). He found that fires were fairly common in the dwarf and stunted swamp forest types where large amounts of litter and an open canopy, increase fire risk during dry conditions (Giesen, 1996). Giesen (1987) postulated that an increase in commercial logging and the activities of fishermen were the main underlying causes of fires at Danau Sentarum. It was found in some areas that fishermen clear swamp forest with fire to increase the area of open water for placing fixed gill-nets (Giesen, 1987). Giesen also hypothesised that much of the dwarf and stunted forest at Danau Sentarum is induced and maintained by fire.

In 1994, Luttrell (1994) carried out the first study specifically on fires in Danau Sentarum. The outcome of this research was that the underlying causes of burning were complex and results of the fieldwork were inconclusive. In general, it was found that local people attributed fires to neglect (of cigarettes, campfires, and fish-drying fires) or jealousy over resources. Blaming another ethnic group (Melayu or Iban) or outsiders (loggers) was also common. One new cause, not mentioned by previous observers, was that fires were ignited to facilitate the capture of the red-phase *Arowana* fish (*Scleropages formosus*), a valuable, and now rare, ornamental fish. Burning created open waters at the forest edge, where the *Arowana* could be lured into shallow waters at night by lamps and scooped up by nets (Luttrell, 1994).

Giesen (1996) carried out vegetation studies in 27 recently burnt areas in June 1994. These showed that the species that most often survive fire are: *Shorea balangeran* (*kawi*) (in 80 % of fires), *Crudia teysmannia* (*timba tawang*) (65 %), *Mesua hexapetalum* (*kamsia*) (51 %) and *Syzygium* sp. (*tengelam*) (51 %). This does not mean that many trees survive a fire: for a given fire this may vary between 0–25 % of all trees. On average, however, about 1–3 percent of all trees appear to survive a typical fire. Survival is important for recruitment, and relatively fire-tolerant species such as the aforementioned four are most likely to form an important element in the recovering vegetation. Of these four species, *kawi* survives in the greatest numbers. A second important element in areas recovering from fire are the pioneer species; i.e. those species that newly establish themselves from propagules (seeds, fruit). The most important pioneer species observed at burnt sites at DSNP are shrubs *Croton* cf. *ensifolius* (*melayak*), *Ixora mentanggis* (*mentangis*), *Timonius salicifolius* (*kerminit*), and the herbs *Polygon* sp. *lembung* and *kumpai* (various grasses). For more detail on the vegetation characteristics of

burned areas in Danau Sentarum refer to Giesen (In press).

Since 1992, fires in the Danau Sentarum have also been studied using remote sensing and Geographic Information System (GIS) techniques. Dennis and colleagues (Dennis *et al.*, In press; Dennis *et al.*, 1998) conducted a forest cover change study in three village territories for the period 1973–1990–1994. The study showed that fire had affected all three areas to varying extent with the impact being most severe in swamp forest. However, the results showed that within this small sample there was great variability in the pattern of fires. Two of the sites were fishing villages located within swamp forest with similar characteristics. However, one of the areas, located in the middle of the Park had experienced little fire damage between 1973 and 1994, whereas the other had experienced a 5-fold increase in fires over the same period. Interviews in 1996 with this community about the causes of these fires focused on motivations of jealousy or revenge and on inadvertent wildfire caused by insufficiently extinguished cooking fires. Another possible source, reported to Dennis in 1997, was the burning of water-hyacinth (*Eichhornia crassipes*), which cause problems for navigation by small boats. Apparently, people thought that by burning this plant in dry season they would prevent its re-growth when the area became inundated again. Overall, the researchers remained dissatisfied with these explanations, despite considerable efforts on several occasions to understand the picture more fully. What the study did show was the potential of combining remote sensing/GIS with socio-economic and ethnographic data for understanding the causes and impacts of burning.

Based on the above sources of information, two general fire regimes appear to be present in the area. One is seen in the upland areas and along the larger rivers, where fire has been used for centuries as part of the swidden agriculture system. The other is seen in the low-lying swamp forests in and around the lakes where fire has been present for centuries but not for any apparent use like cultivation. The causes and impacts of these swamp forest fires are still poorly understood. This report describes how remote sensing and GIS techniques and social research were used to contribute to an understanding of the trends and patterns of swamp forest fires within the Danau Sentarum area.

3. METHODOLOGY

In order to research the underlying causes and impacts of fire in this site two levels of analysis were used; landscape and village. This is the only site, of the eight sites researched in the Underlying Causes of Fire in South-East Asia Project, in which village-level analysis was carried out.

3.1 Socio-Economic Study Methods

From about sixty villages in the study site, six villages were chosen for this study (see Table 3-1). The villages were chosen on the basis of forest cover type (see Figure 3-1), land use, ethnic group, and fires. In order to preserve confidentiality of the informants, the actual name of the village will not be used in this report.

Location	Village A	Village B	Village C	Village D	Village E	Village F
No. of families in 2000 and (1986)	47 (25)	16 (15)	72 (45)	135 (80)	25 (10)	9 (17 in 1996)
Ethnic group	Melayu	Melayu	Melayu	Melayu and Iban	Iban	Iban
Size of village work area (ha)	2,541	2,157	2,918	17,650	6,432	10,334
Main activity	Fishing	Fishing	Agriculture/ Fishing	Fishing	Agriculture	Agriculture
Land use	National Park, Vegetable gardens, Logging concession (closed), Rubber gardens	National Park, Pepper gardens,	National Park, Rubber and pepper gardens, fish ponds, oil palm plantation, and logging concession (closed)	National Park, Logging concession (former)	National Park, Rubber gardens, Rice, Logging concession (closed)	Oil palm plantation, Rubber and pepper gardens, logging concession (closed), Illegal logging
Land users	Community and outsiders	Commu-nity	Community	Commu-nity and outsiders	Commu-nity and outsiders	Commu-nity and outsiders

Table 3-1 General data for the six villages

The techniques used to study the socio-economy at the village-level comprised participatory rural appraisal (PRA), sketch mapping, and rapid rural appraisal (RRA). These activities were conducted between March and April 2000 by staff from Yayasan Dian Tama (YDT) and Andi Erman from CIFOR. In the village, semi-structured interviews were conducted in large meetings with village leaders and a broad cross-section of the community (see Figure 3-2).

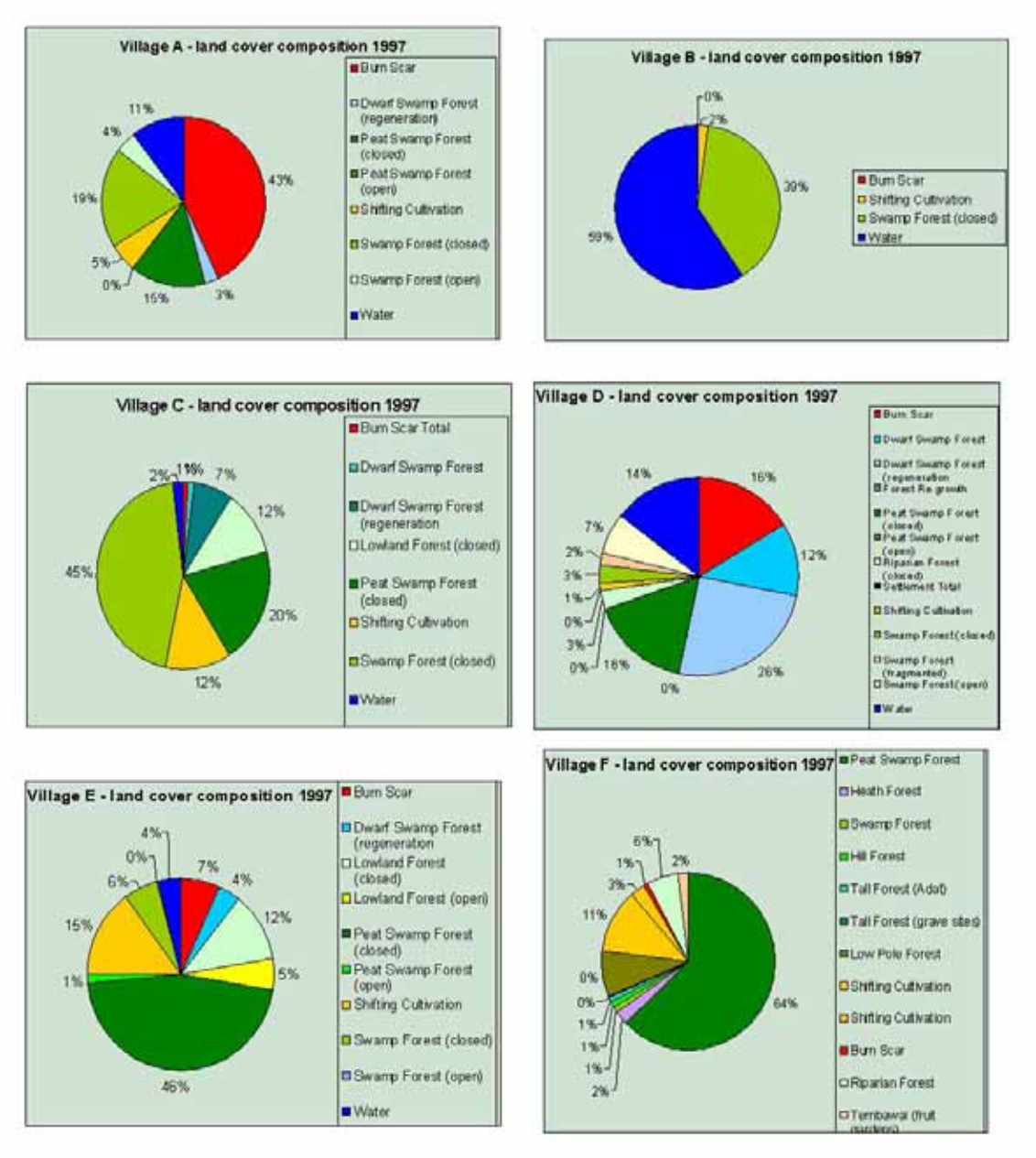


Figure 3-1 1997 Land cover composition by village

Initially, general information was collected such as population size, history of the village, and

livelihood strategies. Sketch mapping was used as a means of discussing land use, land cover, land tenure, and changes and associated changes. The work area (*wilayah kerja*) was used as the largest unit for the discussion and its boundary drawn on the sketch map[5]. Once the community felt comfortable with the team, discussions regarding fires followed.

Figure 3-2 Participatory Rural Appraisal in Village A

In addition to the village interviews, an RRA was carried out in the village territory. The sketch map and satellite image printouts were used as the basis for identifying features of interest. One or two people from the village accompanied the YDT/CIFOR team in the field. A global positioning system (GPS) was used to record the location of burn scars. Information about the cause of the fire was obtained from discussion with people from the village.

At the landscape-level, a sketch map (see Figure 3-3) was developed based on the 1:50,000 topographic base maps and the Province land use planning map (*peta Paduserasi*) dated 1999, at a scale 1:250,000, issued by the Provincial Office of the Department of Forestry (*Kanwil Kehutanan*). Land cover and land use information at the landscape level was collected from

[5] Village boundary maps were available form the DFID Conservation Project, see Dennis and Erman (1997).

reports and from satellite image analysis. Also, the first author of this report has 10 years experience in the site, and the second author comes from the site.

3.2 Remote Sensing and GIS

3.2.1 Site-wide methodology

By using remote sensing and a Geographic Information System (GIS), burn scar size and distribution were determined, and the historic and current patterns of land cover and land use change were analyzed at both the village and landscape level. The imagery used in this analysis were provided from previous studies of the area (see Table 3-2). Imagery used for the change analysis in the Danau Sentarum site covers the period July 1973 through to May–July 1997 (see Table 3-2 and Figure 3-4). This is the longest time period for change analysis in any of the eight sites. Unfortunately the 1997 imagery is pre-1997 fire, however the 2000 sketch mapping and hot-spot analysis helped to complete the picture.

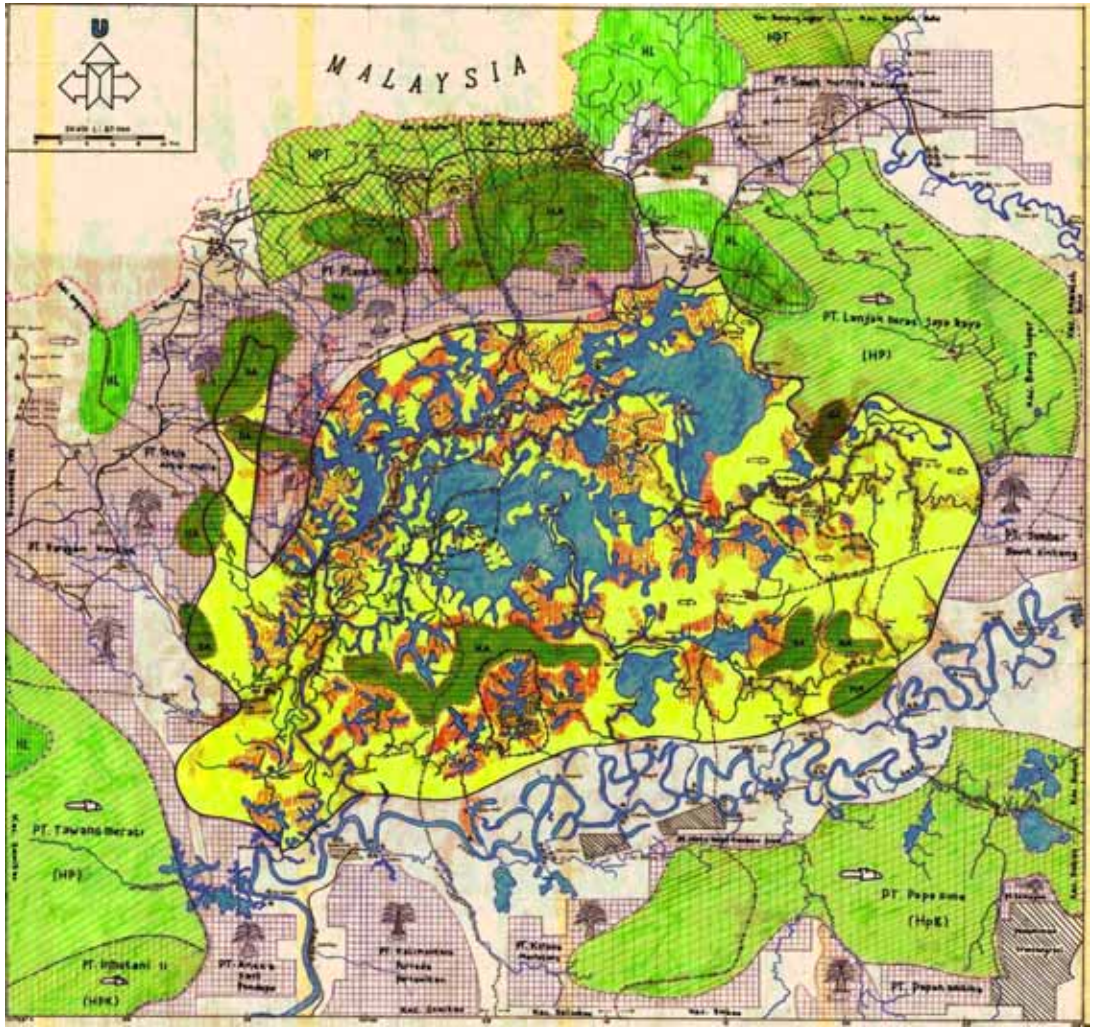
Date	Sensor	Scene (path/row)	Image Source
14 July 1973	Landsat MSS	129/59-60	DFID Project
28 August 1990	Landsat TM	120/59	DFID Project
31 May/11 June/12 July 1997	SPOT XS	292/348, 292/349	TREES Project

Table 3-2 Imagery used in the change analysis

Figure 3-3 Landscape Level Sketch Map of Danau Sentarum Site

Sketch Map of Danau Sentarum Site

Danau Sentarum, West Kalimantan Province, Indonesia



LEGEND

- River
- Lake
- Main road
- Unpaved Road
- Village
- Transmigration Area
- Country Boundary
- Sub District Boundary
- Village Boundary
- HPH Boundary
- National Park Boundary
- Communal Land Boundary
- Protection Forest Boundary
- Protection Forest
- National Park Area
- Communal Land
- Production Forest
- Conversion Forest
- Limited Production Forest
- Plantation Area
- Rubber Garden
- Fire Area
- Logging Activity

Figure 3-3 Landscape level sketch map of Danau Sentarum site.

The earliest image in the sequence is Landsat MSS dated 14 July 1973. This is one of the first images in the Landsat programme that started in 1972. The quality of the image is fair considering the age of the data. Scattered clouds were a problem in some parts of the image. The second image in the sequence is dated 28 August 1990. This image is virtually cloud-free. Three SPOT XS images were available for 1997, all pre-fire; 31 May, 11 June and 12 July. The images dated 31 May and 11 June (scene 292/348) cover most of the study area. However cloud covers precludes using the scenes in their entirety. For the interpretation, the eastern portion of the 31 May image and the western portion of the 11 June image were used. The southern part of the study site is covered by scene 292/349 and the image is dated 12 July 1997.

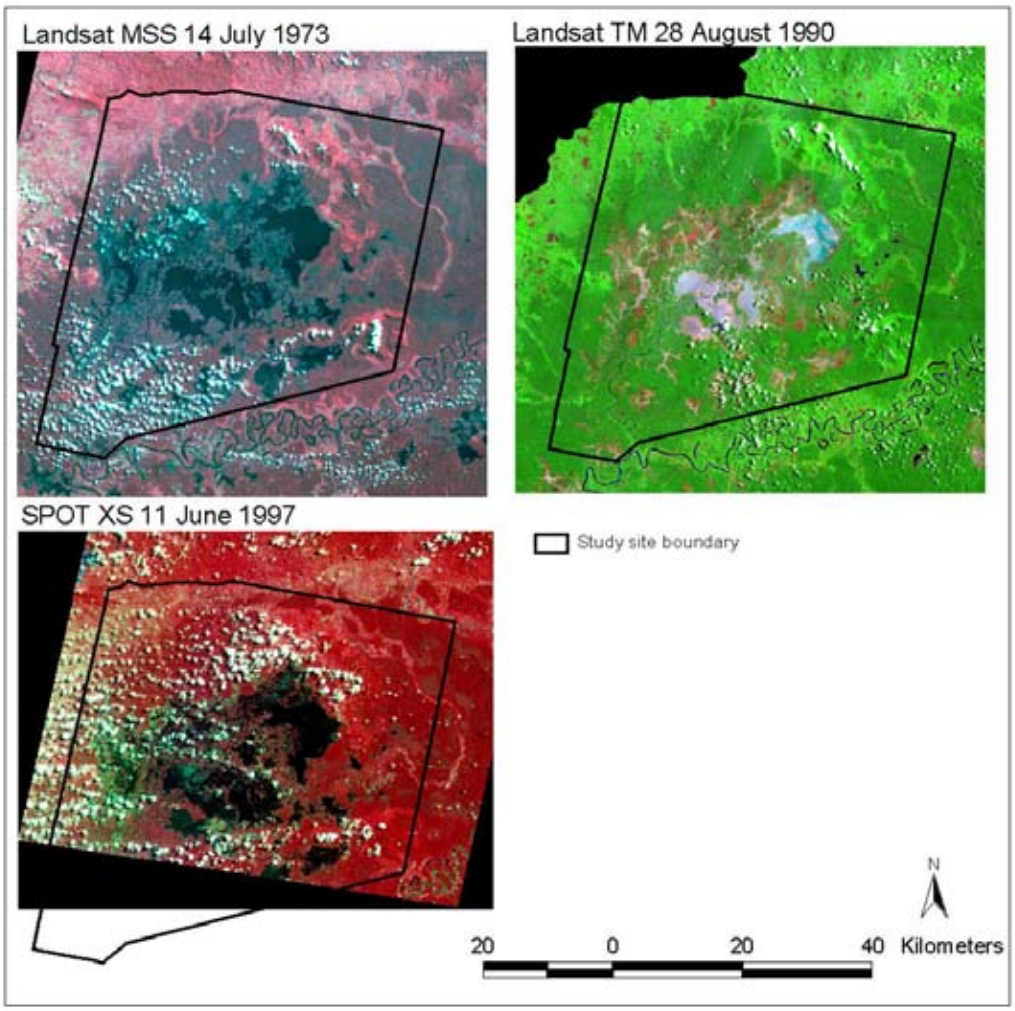


Figure 3-4 Satellite imagery selected for the Danau Sentarum site

It was not necessary to carry out pre-processing of the imagery as all were already ge-referenced though the DFID and TREES Projects. In addition, part of the land cover classification for the site had already been carried out under the TREES Project (Dennis and Kurniawan, 2000).

The remote sensing analysis for this site provided some challenges. This is the only site in which we compared imagery from three different sensors, Landsat MSS, TM and SPOT. In addition to the differences in sensors and spatial resolution, the seasonal variability within the dataset added to the difficulties of maintaining a consistent level of interpretation. Danau Sentarum is a seasonally flooded forest area with a complex and fluctuating hydrological cycle (Giesen, 1996; Klepper, 1994). From week to week, the water levels fluctuate, submerging or exposing vegetation in the process. The Landsat MSS imagery is dated July 1973 and shows high flood levels, thus much of the dwarf swamp forest and burnt swamp areas were submerged. This contrasted sharply with the Landsat TM imagery dated August 1990, which was at the height of the dry season, clearly showing areas of dwarf swamp forest and recent swamp forest burning. The SPOT imagery covers 3 dates (May, June and July) in 1997 just as water levels are beginning to fall. The SPOT imagery pre-dates the extremely dry conditions of the 1997 El Niño.

All image processing was carried out using PC ER Mapper. Classifications and subsequent spatial analyses were achieved with PC ARCVIEW. On-screen digitizing, using the digitizing methodology developed by TREES (Dennis and Kurniawan, 2000; Feldkoetter, 1999), was chosen as the method of forest cover classification for the Landsat MSS, Landsat TM, and SPOT.

Despite the great amount of user interaction in the classification process, problems were still encountered. The Landsat MSS image is one of the early products of the Landsat mission and the quality of the image, even after image restoration, was not good. The limited number of spectral bands (four: green, red and two near-infrared) also meant that the results of the classification were variable. The inclusion of a mid-infrared band is generally favored for discrimination of natural vegetation types. Inaccurate classification was particularly apparent in areas of heterogeneous vegetation and areas of steep topography. By comparison, the classifications of the Landsat TM and SPOT were easier because of the excellent quality of

the image and higher spatial and spectral resolution of the image than the MSS.

Mapping of burn scars was a complicated process. In the swamps, flooding is the norm, and apart from during the dry season, burn scars remain unvegetated or eventually develop a sparse cover of shrubs. On the Landsat MSS imagery, burn scars were not easily identified because the area was flooded. Areas that showed a sparse covering of shrub vegetation or appeared to show remnants of woody vegetation were considered burn scars. Experience of comparing recent imagery with field observations supports this assumption. On the TM and SPOT, there is quite a broad range of spectral values for this class, ranging from highly reflective (no woody vegetation), as in Figure 3-5, to less reflective with a mixture of burnt/woody and non-woody vegetation. Ground checking improved interpretation of this class.

Figure 3-5 Burnt area in the swamps of Danau Sentarum, August 1999

3.2.2 Derivation of fire hot spots

For this area, the 1997, 1998 and 1999 hot-spot data from the Japanese International Co-operation Agency (JICA) – Ministry of Forestry and Estate Crops (MOFEC) fire project based in Bogor, Indonesia were used. Unfortunately, from this source there are no 1996 data available. The data used in this study also included hot-spots from 1992 and 1993. To get a better idea of the vulnerability of this study to fire, hot-spot densities in Danau Sentarum were compared to hot-spot densities in the entire West Kalimantan Province, the swamps of West Kalimantan, National Parks in West Kalimantan and logging concessions in West Kalimantan. Furthermore, hot-spot maps were overlaid onto the land cover and land use maps of the study site to investigate which areas were most prone to fire.

3.3 Integration of Social Science and Remote Sensing

In order to improve the analysis of underlying causes of fire, a methodology was developed that integrates some of the results of the socio-economic research with the results of the remote sensing-based change analysis. A GIS was used for this integration. Not all outputs from the socio-economic research are compatible with a GIS and from site to site, the types of outputs vary slightly. For the Danau Sentarum site, the focus was on integrating local people's narratives and sketch maps with land cover change maps and burn scar maps at the village level. At the landscape level, land cover change and burn scar analysis was carried out. The results from the village and landscape level were then compared. Using the functionality of the GIS, it was possible to calculate the types and size of land cover changes in relation to the territory claimed by a village. In addition, local people's narrative could be added to these land cover change results to provide an insight into how and why these changes occurred. For the 1997 fires, sketch maps were overlaid with the burn scar maps and compared to provide both a quantitative and qualitative assessment of the fires. Digital air photos were also used to enhance the interpretation of satellite imagery.

4. RESULTS AND DISCUSSION

The results and discussions will be separated into two spatial scales. Fires were assessed at both the village and the landscape level. Using the results of the village-level interviews and the land cover change analysis, a picture of the causes and impacts of fire was constructed in each of the six villages. At the landscape level, a picture of the impact of fire on the landscape over the past 30 years was constructed. Information from these different levels was then was brought together.

4.1 Fires and land cover change at the village-level

The village-level results comprise data both from interviews and observations in the village, and land cover change analysis from remote sensing and GIS activities. For each village different aspects of the results will be presented. Some of the villages show quite a severe fire problem whereas other do not. In the case of Village A, where fire is a problem, we will present the results of the village interviews as well as land cover change maps and tables. Village B does not have a problem with fires and this is evidenced by both the interviews and the land cover change analysis, in this case we do not feel it is important to show the change maps and tables.

4.1.1 Village A

Village A is situated on the southern boarder of the DSNP along the River Tengkidap. Results of the interviews indicate that the village was permanently established in 1955 with 13 families. Before this, people from the nearby town of Selimbau on the River Kapuas, would live here on a seasonal basis to harvest fish. The population by 2000 was 47 families. These people are Muslim Melayu fisher folk who depend heavily on the excellent fisheries of the area. In addition, they also cultivate some small areas for vegetables, and harvest honey from the forests. The area claimed by the community covers approximately 2540 ha of lakes, rivers and forest.

When the protected area was first proposed in 1982, this village was outside the Reserve boundary. At that time it lay within a logging concession. Logging stopped here in the mid-

1980s with little visible impact on the forest, now 20 years later. This village is close to the River Kapuas, 2 hours by small canoe. However, during the dry season the village becomes cut-off by water routes, as all rivers leading to the village dry out.

This village experienced severe fires in the 1990s, so much so that by August 2000, most of the tall swamp forest in the village territory had burned. The land use history of the village, which dates back to the 1950s, shows that up until 1991 most of the burning in this village area was associated with small areas of shifting cultivation along the rivers. The land cover classification of the 1973 imagery shows some burn scars around the village, and in one instance on the edge of the lake (see Figure 4-1). Small areas of shifting cultivation mentioned in the village interviews are too small to be picked up on the low resolution Landsat MSS imagery.

Year Land cover class	July 1973	August 1990	***1973 – 1990 change***	***% change***	July 1997	**1990-1997 change**	***% change***
Peat swamp forest (closed)	478	477	***-1***	***-0.2 %***	384	**-93**	***-19 %***
Peat swamp forest (open)	-	-	**-**	**-**	1	**-**	**-**
Swamp forest (closed)	1,530	1,074	***-456***	***-30 %***	524	**-550**	***-51 %***
Swamp forest (open)	173	240	***+67***	***39 %***	108	**-132**	***-55 %***
Dwarf swamp forest	12	-	***-12***	***-100 %***	-	**-**	
Dwarf swamp forest (regeneration)	-	39	***+39***	**-**	69	**+30**	***+77 %***
Burn scar	73	210	***+137***	***+188 %***	1053	**+843**	***+401 %***
Cultivation	-	226	***+226***	**-**	127	**+99**	***-44%***
Water	273	273	**-**	**-**	273	**-**	**-**
Total	2,539	2,539	**-**	**-**	2,539	**-**	**-**

All areas in hectares

Table 4-1 Land cover change statistics for Village A, 1973-1990-1997

By 1990, we see an increase in burnt areas compared to 1973 (see Figure 4-1). According to the change analysis there was a 188 % increase in burn scars and also a 226 % in cultivation (see table 4-1). Analysis shows that the forest type most severely affected by fires was the stunted swamp forest. To the villagers, this type of forest is the important for placing honey boards (*tikung*) to attract bees. During the wet season, when water levels are high, people in this community harvest honey from these *tiking.* Honey is and important secondary source of income to many of the communities in the Danau Sentarum area. In 1991, the local people began to notice a drop in the production of honey and thought that there was a link with the fires. By 1999, the number of *tikung* had fallen, from over 2000 before 1991, to less than 500.

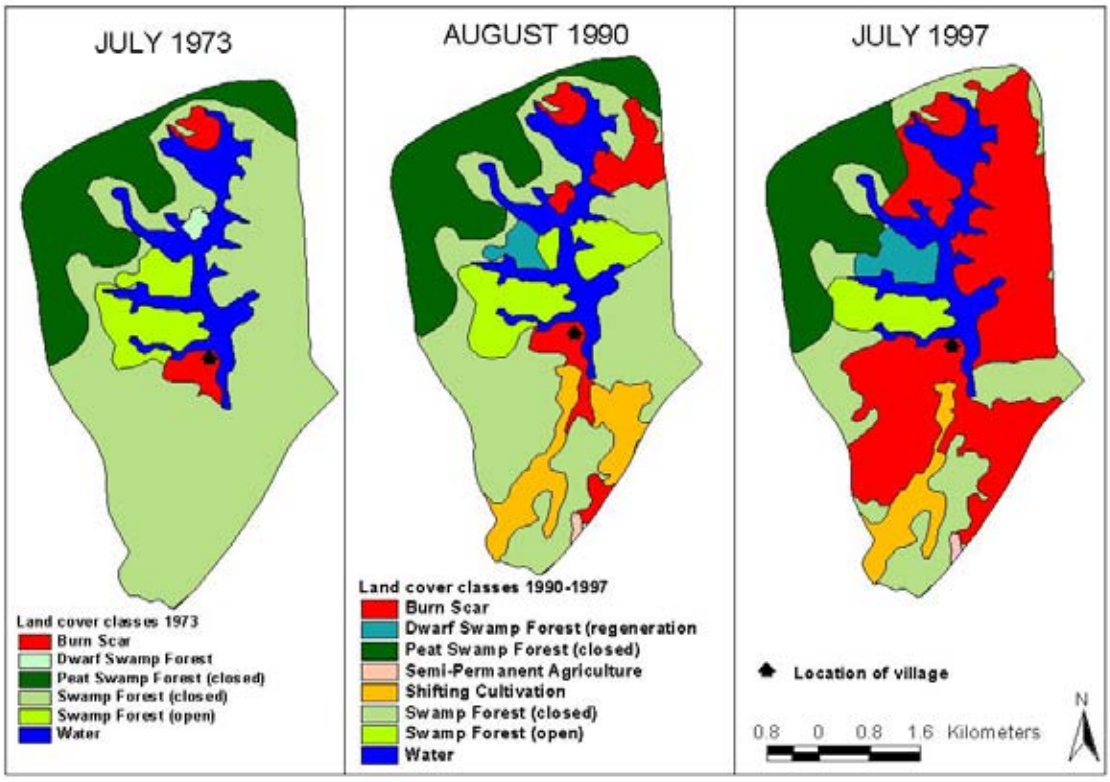


Figure 4-1 Land cover change maps, Village A 1973-1990-1997

The change analysis for the period 1990-1997 confirms the results from the field research that fires have been very bad since 1991.Unfortunately we only have two points in time for the 1990s change analysis. In this period there were two El Niños, one in 1991 and one in 1997 (although the 1997 imagery pre-dates the El Niño drought). In addition, there was a prolonged dry season in 1992. Satellite image analysis shows that burn scars increased by 401% from

210 ha in 1990, to 1053 ha by mid-1997, see Table 4-1. This means that 46 % of the land area of the village territory is now burned. Similar to the earlier period 1973-1990, stunted swamp forest has been most severely affected experiencing a reduction of 52% (see Table 4-1). Visual analysis of some newly acquired Landsat ETM imagery, dated 26 August 2000, confirms that fires were bad during the El Niño of 1997. The image shows that all of the stunted swamp forest has burned, and all that remains in terms of tall forest is a small area of peat swamp forest in the northern part of the village territory.

In the past decade, fires have greatly impacted the landscape of Village A. This is borne out by the image analysis and the interviews. The results of the research into the underlying causes for this village help us to understand why these fires have taken place. The community gave five main reasons for fires; these are as follows;

1. **Land clearing for vegetable plots**. Since the early 1990s, the women of the village have started to grow vegetables along the river levees. During the dry season, the rivers dry out and fishing and access can be difficult. To supplement diets and income it was decided, as seen by success in other villages, that vegetable growing was a worthwhile activity. Areas are cleared by fire during the dry season. These areas are usually near to the village or in former shifting cultivation sites along the river levees.

2. **Clean/burn water hyacinth** (***Eichhornia crassipes***) **that blocks waterways**. Apparently, because of its proximity to the large River Kapuas, water hyacinth from this river easily and prolifically colonises the River Tengkidap. The main water access to Village A is along the River Tengkidap, and water hyacinth can cause severe problems for access and fishing, see Figure 4-2. During the dry season, when the rivers and lakes are dry, the villagers gather the plant and burn it. It is dead at this time anyway (Giesen, pers comm.). They tend to just leave the plant to burn and said that often these fires can spread to other areas. Dennis and Erman (in press) and Dennis *et al*. (1998) have also found water hyacinth burning in other villages to the south of the main lakes area. Unfortunately, the burning does not have much impact on the return of water hyacinth, as new plants float in during the wet season.

Figure 4-2 Water hyacinth (*Eichhornia crassipes)* **causing transportation problems in Village A**

3. **Careless discarding of cigarettes** by outsiders travelling through the area. Grassland is most vulnerable to fire and these fires can spread into the nearby forest.

4. **Clearing of short-cuts** (*pintas*) for canoes and boats to cross through the swamp vegetation. This is common in the swamps of the entire study area. Many of these were originally created during former times and old Dutch literature refers to them (Enthoven, 1903). The clearing is carried out during the dry season when fire risk is also high. Often these fires go out of control and burn swamp forest. The image analyse shows burn scars in areas of these short-cuts.

5. **Influx of fisher folk during the dry season**. During the dry season or long droughts fishing is at a premium throughout much of the swamps and dried up lakes. What remains of water during these times are small pools or shallow channels into which fish are concentrated. The pickings are usually abundant and easily acquired. People from outlying areas temporarily migrate to the area and often set up small camps in or near the swamp forests. Here they cook food and smoke fish, both activities using fire (see Figure 4-3).

Quite often when the people move on to the next campfires are not properly extinguished and, sometimes, due to the dry conditions, the fires spread into the forest.

Figure 4-3 Cooking fish on a campfire in the dry swamp forest, August 1999

The above reasons for fires are, in the main, all associated with resource use strategies. There was no apparent connection between fire and conflict over land use. However, it is readily apparent that there seems little incentive to prevent fires in the swamp forest in this particular village territory. Activities such as clearing land for crops, clearing water hyacinth and clearing access routes are all carried out at times when the risk of fires going out of control is high. For all most 36 years, even with a steadily rising population that fires happened but not with dramatic consequences. However, in the early 1990s the situation changed dramatically, and by 2000 almost all the swamp forest areas had burned. The picture is very similar for the immediate neighbours of Village A. Changes in land use at this time included an expansion of vegetable gardens and this possibly accounts for fires in the southern part of the site. However, north of the village, where no vegetables grow, is also badly burned. As this is a primarily a fishing community, one could draw the conclusion that the forest areas are not considered as important as the areas of lakes and rivers. Hence the reason why fires near

forests may not be carefully controlled. Some researchers have noted that fishermen sometimes burn areas of forest or low scrub at the edge of lakes to increase the area of open water (Giesen, 1987, Luttrell, 1994). However, the fact that honey collection in the tall swamp forests is important casts some doubt on this hypothesis. In some of the other villages in this study we found that fishing and honey gathering communities protected their forests from fire.

4.1.2 Village B

Village B is situated in the middle of the DSNP, where the River Tawang enters the main system of lakes. The village was established in about 1963 by five families. Since the establishment of the Danau Sentarum Wildlife Reserve in the early 1980s, this village has fallen completely within the protected area. By 1986, the population had reached 15 families, and 16 families by 2000. These people are Muslim Melayu fisherfolk who depend largely on fisheries both wild and caged. In addition they also harvest honey from the forest, and cultivate crops on higher ground. Data gathered from the 2000 interviews indicated that the average yearly harvest of honey in this village is about 1,5 tonnes. The number of honey boards (*tikung*), (see Figure 4-4), is between 1000-1500. The area claimed by the village covers approximately 2,157 ha of lakes and swamp forest. During the dry season, when the lakes dry out, limited access to the village is maintained along the shallow channel of the River Tawang.

Figure 4-4 Honey board (burned) in swamp forest

Village B has experienced little, large-scale land cover change. In 1963, when the village was first established, forest was cleared on the small hill (42 ha) that lies within the village territory. Since that time the hill has been continuously cultivated to a lesser or greater extent with rubber gardens, and now pepper. This cultivation was never very extensive at any one time but little original forest remains on the hill. Throughout the image sequence 1973-1990-1997, the hill is classified as shifting cultivation. Other than this hill, the swamp forest, which accounts for 95 % of the land area, has changed little. Between 1973 and 1990 there was no change in the swamp forest, but between 1990 and 1997, 2 ha burned. Dennis *et al.* (1998) carried out a land cover change study in an adjacent village and found a similar story. In that village, swamp forest was reduced by only 0.7% over the period 1973-1990.

Fires have never severely impacted this village. People remember quite accurately most of the years that were bad for fires. In 1982-83, they remember a very long dry season (this was an El Niño), and there was a very small fire in the swamp forest, caused by, they say, natural factors. This burned area was not detected on the 1990 imagery. In 1994, which another El Niño, there were two small fires in the swamp forest (see Figure 4-5). These burn scars were detected on the 1990 imagery, with a total size of 2 ha.

Figure 4-5 View from hill in Village B towards swamp forest. Note remnants of forest burned in

1994.

The El Niño of 1997 still figures prominently in the memory of the villagers. However, despite the very dry conditions, no fires occurred in this area. The community said that they were very careful not to start fires and they made a concerted effort to protect the honey trees which are located in the surrounding swamp forest. Analysis of the August 2000 Landsat TM imagery confirms that there were no fires in 1997. The community gave two main reasons for uncontrolled fires; these are as follows;

1. **Natural factors, such as lightening** caused fires in the drought years;

2. **Clearing of short-cuts** (*pintas*) for canoes and boats to cross through the swamp vegetation. This is common in the swamps of the entire study area. The clearing is carried out during the dry season when fire risk is also high.

4.1.3 Village C

Village C is situated in the eastern part of the DSNP, on the River Leboyan which flows south, from the high mountains on the boarder with Sarawak, into the main system of lakes. Before the extension of DSNP in 1996, this area was outside the Park and partially fell within the boundaries of a logging concession. This concession is still operational in some places but since 1999, there has been an upsurge in illegal logging.

There is a long history of settlement in this area but the village became established in its current position in about 1944 with 11 families. By 1986, the population had reached 45 families, and has risen steadily to 72 families by 2000. The area claimed by Village C covers an area of 2,918 ha of tall swamp forest (including peat swamp), lowland hill forest, shifting and semi-permanent cultivation as well as areas of water. The community is composed of Muslim Melayu people whose livelihood depends largely on agriculture and fishing. Since 1994, agriculture has started to play an increasingly important role. Cultivation occurs on the river levees and on hill slopes (see Figure 4-6). Rice and pepper are the main crops and small rubber and fruit gardens are located on the slopes of the hill. Hill areas are shared with a neighbouring community.

Figure 4-6 Clearing forest for cultivation

Fire is and has been used frequently in Village C for land clearing for cultivation. The results of the land cover change analysis show this increase in the area of cultivation. In 1973, the area of cultivation was approximately 193 ha, mainly on river levees (see Figure 4-3). By mid-1997, the area of cultivation had reached 368 ha. This cultivation has expanded at the expense of tall swamp forest. Areas of burning occurring outside the areas of cultivation are confined to the lake edges (see Figure 4-3).

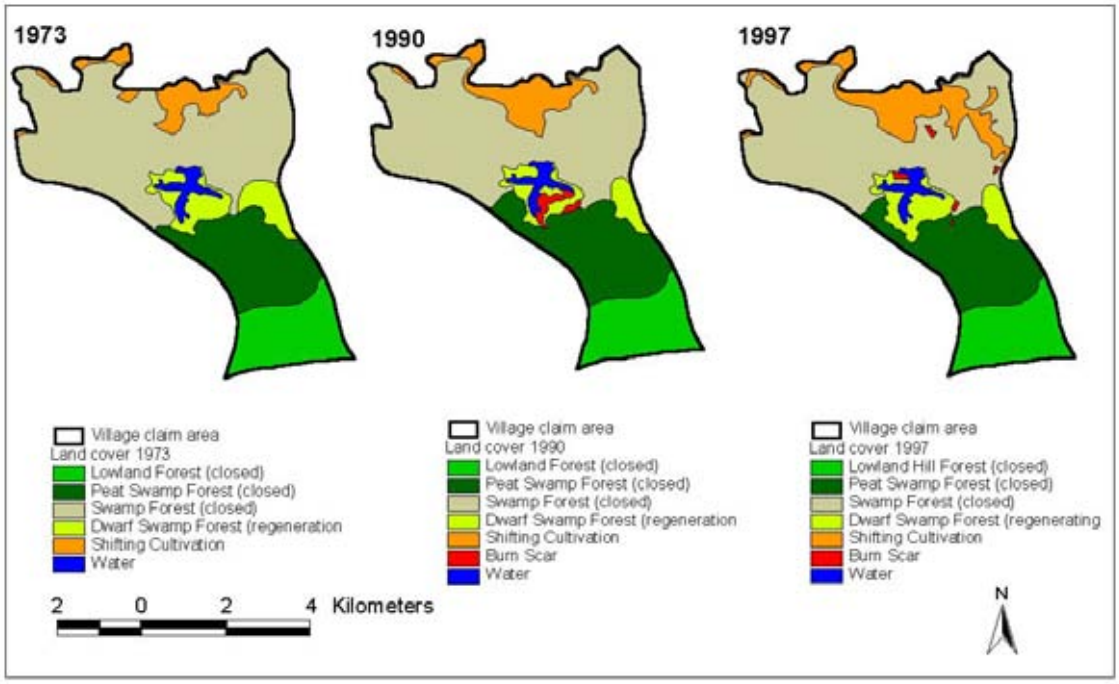


Figure 4-7 Village C - land cover change 1973-1990-1997

Unintentional or accidental fires were mentioned in the village interviews but none of these fires seemed to have had a large impact on the forest. Many of these fires were in areas close to the small lake and have been associated with fishing or hunting activities. Hunting for crocodiles or deer was also another reason for fires in areas close to the lakes. However, before 1997, in general, fires did not frequently go out of control and this is substantiated by evidence from the satellite imagery. Honey harvesting is also important in this village and they cited this as the main reason why they were careful with fire during the dry season. In 1997, some fires for land clearing fires did get out of control because people underestimated the dry conditions. As many as 250 honey boards were accidentally destroyed.

Visual analysis of the August 2000 confirms many of the findings in the field. The area of cultivation along the rivers had expanded into new areas and there has been a substantial increase in cultivation on the hill slopes. Around the lake there has also been some new burning. Evidence of illegal logging is clearly seen in the peat swamp forest areas.

The community gave two main reasons for uncontrolled fires; these are as follows;

1. Careless discarding of cigarettes; and

2. Fishing, and hunting in the swamp forest.

4.1.4 Village D

In terms of population and area, Village D is the largest in this study. The village lies on the western fringe of the National Park, and has been inside the boundary of the protected area since 1982. The tall swamp forest in the north is within a logging concession which ceased operations in 1999. This village is the longest established in the lakes area. As far back the early 1800s, the Dutch army used it as base for maintaining security in this border region (Enthoven, 1903).

The population of the village in 2000 was 135 families, mainly Muslim Melayu people. The population increase has been high, in 1986 the population was 80 families. Livelihoods depend largely on fishing but agriculture is also important. Due to its relative proximity to the boarder with Malaysia, many people are also involved in trading various products; fresh fish, smoked or salted fish, honey, pepper, rattan, and wood.

The area claimed by this community covers 17,650 ha of swamp forest, lakes and rivers. The majority of the area is used solely by Village D, but some hill areas are shared with Village E for shifting cultivation. In the swamp forests, on its eastern boundary, there is an area of conflict with an adjacent village. This conflict has its roots in the time (in the 1950s) when new administrative boundaries (*kecamatan*) were established by the local government. These boundaries did not coincide with the sultanate (*kerajaan*). The area of mismatch has now become and area of conflict.

It is possible to look at the historic land cover changes in Village D through the many written reports from the mid-19th century. These reports show that fire has been a part of this landscape for at least two hundred years. One of the first explorers to mention the evidence of swamp forest fires near Village D was Pfeiffer (1856) who visited the area in January 1852. She described extensive areas of burnt standing trees in the swamps. Gerlach (1881) visited the area in March 1881 and commented on both drought and fires. He mentions the pronounced drought of 1877; a year that is now known to have exhibited a strong El Niño Southern Oscillation. In 1877, the lakes were almost completely dry with only small trickles of water in the channels, and one could walk for miles on the dry lake bed (Gerlach, 1881). As

to the cause of the fires, Gerlach blamed the Dayaks for setting fire to the forests during the dry season for sheer enjoyment. The interviews carried out through this project also provide some additional historic evidence of fires. From 1940 up until present day there have been many deliberate as well as accidental fires in the area.

Figure 4-8 Manmade shortcut (*pintas*) through dwarf swamp forest

The results of the image analysis confirm that this is an area very badly affected by fires. Between 1973 and 1990, there was a 360 % increase in burn scars, from 444 ha to 2,043 ha. This area increased to 2,636 ha by mid-1997. Tall swamp forest has been most severely affected by these fires. Between 1973 and 1997, this type of forest has decreased by 94 %, from 1,502 ha to 90 ha (see Figure 4-5). Fortunately the tall peat swamp forest has not been so badly affected, decreasing by only 12 %, 3,815 ha to 3,333 ha, between 1973 and 1997.

This area is dominated by dwarf swamp forest (see Figure 4-8), much of which regenerates after fire (see Figure 4-5). The change analysis shows that the amount of this cover type stays fairly much in equilibrium as areas re-grow and burn again. This finding conforms well with Giesen's observation that dwarf and stunted swamp forest at Danau Sentarum are particularly vulnerable to fires (Giesen, 1996). There is also a strong likelihood that much of the dwarf swamp forest in the area has previously burned. This is evidenced by the fact that areas that at one point in the analysis were regenerating swamp forest became dwarf swamp forest in the next time period and then in the subsequent period burned again, repeating the cycle. Further analysis of the time series would be valuable in testing Giesen's hypothesis that much of the dwarf and stunted forest at Danau Sentarum is fire-induced (Giesen 1996). Giesen (pers. comm.) remarks that species composition of dwarf swamp forest, which is dominated by *Timonius salicifolius* (*kerminit)*, *Croton* cf. *ensifolius* (*melayak)* and *Ixora mentanggis* (*mentangis),* also supports this hypothesis: A few fires would lead to dominance by fire tolerant species such as *Shorea balangeran (kawi),* while repeated fires would lead to a dominance of pioneer species, such as *mentangis, melayak* and *kerminit*.

Fires have been and still are a big problem in this village area. A long history of fires in the area has made it more vulnerable to fires during the dry season as the predominant vegetation type, dwarf swamp forest, burns easily. In addition, during the dry season, there is a large influx of fisherpeople and hunters from communities outside this village. These people set up temporary camps in the swamp forest and carry out activities such as cooking which can lead to uncontrolled fires. The size of the area claimed by Village D is large and it is difficult for them to monitor all activities taking place there. Conflicts over boundaries have also lead to deliberate burning of the swamp forest.

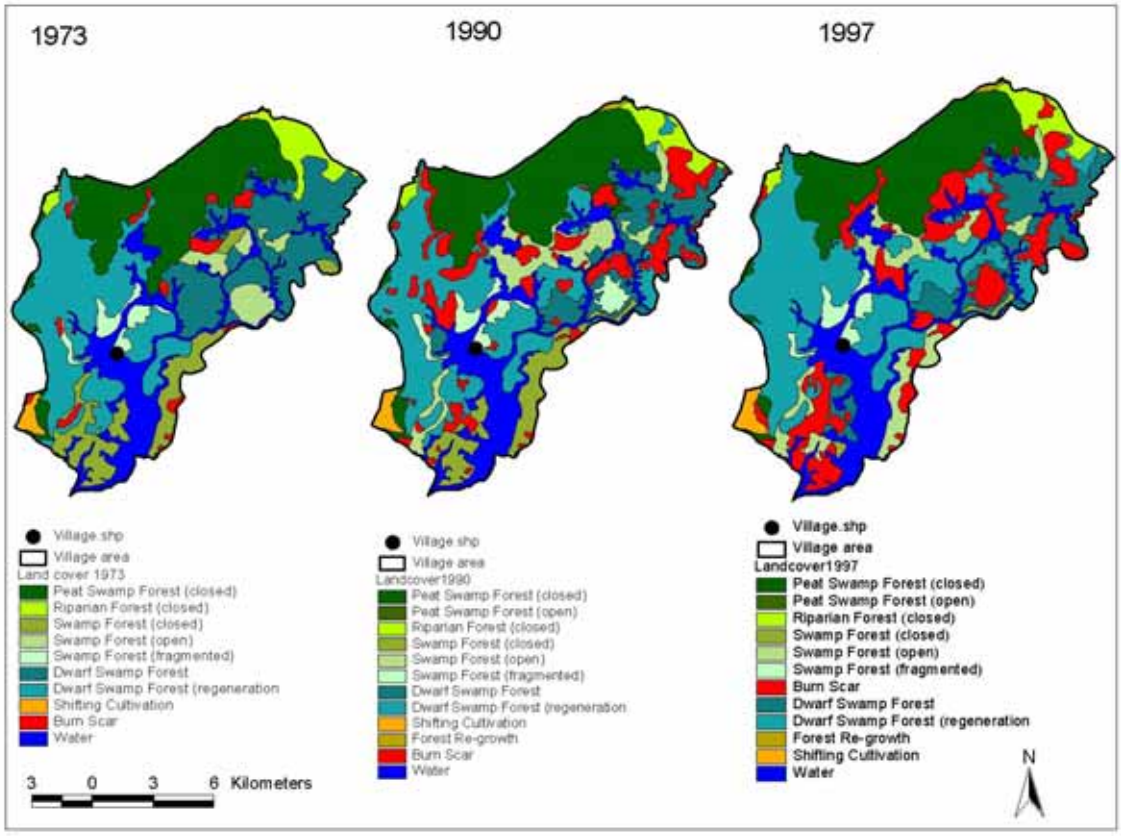


Figure 4-9 Village D - land cover change 1973-1990-1997

The community gave four main reasons for uncontrolled fires; these are as follows;

1. **Villagers and outsiders fishing, and hunting (deer, soft-shelled turtles) often use fire in the process**. For example, deer are lured to areas of new grass which are created by burning an area a few months before hunting. Figure 4-10 shows people transporting deer traps for a hunting expedition. During the dry season, as mentioned earlier, fishing is at a premium and many people move into the area and set up temporary camps and use fire for cooking. Many of the people who set up these camps are not from the village but from outside.

Figure 4-10 Returning from a deer-hunting trip. The men are carrying the traps made from rattan.

2. **During the 1980s, some fires in swamp forest were deliberately set in order to find the valuable, aquarium fish, the red arowana (*Schleropages formosus*)** (Luttrell, 1994). The price ranged from Rp.500.000 to Rp1.000.000 (1986 – 1992 prices) for a 10cm long fish. Fire was used to clear forest at the edge of lakes so that it was easier to find the fish. The fish were caught at night by flashlight. This fish is now extremely rare and people no longer burn forest to look for this fish.

3. **Clearing of short-cuts** (*pintas*) for canoes and boats to cross through the swamp vegetation (see Figure 4-8). This is common in the swamps of the entire study area. Many of these were originally created during former times and old Dutch literature refers to them (Enthoven, 1903). The clearing is carried out during the dry season when fire risk is also high. Often these fires go out of control and burn swamp forest. The image analyse shows burn scars in areas of these short-cuts.

4. **Conflict over village boundaries.** As discussed earlier in this section, there is conflicting territory claim with an adjacent village. Almost every dry season this area is deliberately burned by one or other of the villages. People tend to burn the parts which are rich in resources such as rattan, honey trees and areas plentiful in supplies of fish. On a number

of occasions the communities involved have tried to resolve this conflict with help from the local government officials. However, the situation is still unresolved and burning continues.

4.1.5 Village E

Village E is an Iban Dayak village (officially part of Village D) located just outside the western National Park boundary, although its resource use areas cross the boundary. Wadley (1999b) reports that this area has been continuously farmed since at least the mid-1850s. In 1990, the Village E longhouse contained 71 people in 13 "doors" or households (1990 Indonesian Census). By 2000, the number of families had risen to 25. Half are Protestant, half are Catholic. These Iban practise an "integral" form of shifting cultivation, which includes dry land and swamp rice farming, hunting, fishing, cultivation of a wide variety of cash and secondary subsistence crops, as well as extensive use of nearby forests for other products. Village E lays claim to one exclusive use zone (*wilayah kerja kampung*), four zones shared with other villages (*wilayah kerjasama*), and two traditionally protected forest areas (*hutan adat*) [6]. The claim area is within the boundaries of two logging concessions and also part of the National Park. The main logging concession was activated in 1986 and its activities were still evident in 1992-93 (Colfer *et al*. 1997b). In June 1996, a new logging camp was established in the south by a second logging concessionaire and this was still active a year later.

This village claims approximately 6,386 ha of hill forest, swamp forest and water (see Table 4-2). Between 1973 and 1997 a number of interesting land use patterns emerge. Swamp forest covers the largest area of any forest type in the territory of Village E. The decrease in the area of non-peat swamp forest was 478 ha (-15 %) between 1973 and 1997, (see Table 4-2). However, the area of peat swamp forest did not change as dramatically, falling just under 2 %. The predominant cause of change in the swamp forest is burning (see Figure 4-11). Burnt swamp forest significantly increased in the areas around the lakes in the southern part of the village E territory, from approximately 90 ha in 1973 to 422 ha in 1997, almost a fivefold increase. The annual increase in burning of swamp forest was greater between 1990 and 1997

[6] These represent the Indonesian classification system, and do not exactly reflect Iban forest management. *Hutan adat*, for instance, covers a wide range of Iban forest categories, both sacred and non-sacred (Wadley,

than during the first time period (9 % as opposed to 28 %). The most probable reasons for this increase include a growth in population from a nearby village using the area for fishing and the presence of a new logging camp. Local people report that timber company employees resort to burning as a way of encouraging deer who come to feed on new re-growth (also seen in other places in Borneo), to enhance hunting success. Another interpretation involves the presence in the early 1990s of Arowana, a valuable fish. It was reported burning made it easier to catch them. The areas most affected by fire also coincide with shared claim areas where tenure is likely to be less secure. It can be hypothesised that less secure tenure in these areas may encourage burning, or discourages fire prevention.

Year Land cover class	July 1973	August 1990	***1973 – 1990 change***	***% change***	July 1997	***1990-1997 change***	***% change***
Hill forest	1,193	1,000	***-193***	***-16***	1,000	***0***	***0***
Peat swamp forest	3,157	3,120	***-37***	***-1***	3,103	***-17***	***<1***
Swamp forest	863	553	***-310***	***36***	385	***-168***	***-30***
Dwarf swamp forest (regeneration)	0	263	***NA***	***NA***	259	***-4***	***-1%***
Burn scar	90	223	***+133***	***+147***	422	***+199***	***+89***
Cultivation	826	970	***+144***	***+17***	960	***-10***	***1***
Water	257	257	***NA***	***NA***	257	***NA***	***NA***
Total	6,386	6,386	***NA***	***NA***	6,386	***NA***	***NA***

Areas in hectares

Table 4-2 Village E – land cover change 1973-1990-1997

pers. comm., 1 October 1999).

Figure 4-11 Flooded, burnt tall swamp forest

The other main forest types that have decreased in area over the past 24 years are hill and lowland forest (see Table 4-2). These forests are found in the areas most favourable for swidden agriculture. Based on our historical interviews which suggest that the village territory has not changed very dramatically, we conclude that there were approximately 1,193 hectares of hill forest within the Village E claim area in 1973.[7] By mid-1990, this was reduced by 16 % to 1,000 hectares. The general areas chosen for cultivation have varied little, with large areas of hill forest remaining intact. During the course of the village sketch mapping sessions we found that much of the remaining hill forest areas contained village burial sites and as such may not be disturbed. The remaining decline in hill forest can be accounted for by a greater percentage of areas that are a mosaic of swidden agriculture and secondary forest. Between 1973 and 1990, 89% of the hill forest remained intact, with 131 ha cleared for swidden agriculture. There was a slight annual decrease (-0.6% to -0.4%) in the conversion of hill forest to agriculture from 1990 to 1997. Over the period 1973–1997, a

[7] In 1989, Village E became officially part of Village D with which borders are shared; and since then our impression is that there has been increasing use of Village E's land by Village D community members (for small-scale food crop agriculture and, to a lesser extent, for a rubber planting project) in the southeastern portion of Village E's territory. Village E's willingness to cooperate in this derives partially from gratitude to Village D residents for their help in 1986 when Village E's longhouse burned to the ground, leaving its inhabitants destitute.

mosaic of small areas reverted to forest (43 ha) as they were left fallow (see Figure 4-12). Based on our change analyses estimates, we would suggest that the amount of clearing was not dramatic in the past and probably was at appropriate levels for this swidden cultivation system. However, the more recent increase in the rate of change, particularly for lowland forest, indicates that the remaining forest will be gone in a ver short time.

Figure 4-12 Fallow areas and forest re-growth

The impression gathered from the village interviews is that fires have not greatly impacted this village. This is partially borne out by the image analysis. Fire is predominantly used by this community in the process of clearing land for cultivation. According to the community fires rarely burned beyond the area of intention. From the satellite image analysis, we did not identify any areas where fires had escaped and caused damage to natural unlogged forest areas. The results of the research into the underlying causes for this village help us to understand why these fires have taken place. The community gave two main reasons for fires; these are as follows;

1. **Preparation of land for cultivation** (shifting cultivation). These fires rarely burn beyond

the area of intention because the community strongly protects their forest areas through traditional laws (*hukum adat*).

2. **Land tenure conflict in the 1990s with a logging concession**. The logging concession cut trees in an area of sanctuary forest (*hutan adat*) claimed by Village E. In retaliation the community burned down the logging company's base camp. After this, the company stopped logging in this forest.

4.1.6 Village F

Village E is located in the northern part of the study site. The village area lies entirely within an oil palm concession which began in 1999. Before 1999, the area fell completely within the Army logging concession. Part of Village F may fall within the buffer zone of DSNP but this boundary has not yet been delineated or demarcated on the ground. The people who live in this village are Christian Iban Dayak. The current population (1999) is 9 families, but in 1994, 17 families lived there. Families moved from this village to areas nearer the main road which was completed in 1996.

The area claimed by this community covers 10,334 ha of peat swamp forest and shifting cultivation/forest re-growth mosaic. Agriculture is the main activity of the community. In addition they collect products, such as rattan, and hunt mammals in the forests. In addition to rice, one of the main crops is pepper (black and white) which fetches good prices across the border in Sarawak (Malaysia). Fruit gardens (*tembawai*) provide valuable fruits such as durian. Erman and Dennis (2000) provide a detailed description of prices fetched by these various commodities.

The land cover change analysis for this village shows very little change in forest cover between 1973 and 1997. The predominant forest cover type is peat swamp forest, this covers 63 % of the area claimed by the village. Although this forest has been logged selectively, the logging has now stopped and much of the forest is in good condition (see Figure 4-13). There are also other types of forest such as, dry land (tall) forest, heath, swamp, riparian and hill. Some of the tall forest is protected by community for religious reasons, see Figure 4-13. The area of shifting cultivation has remained stable during the period of the analysis and in fact has reduced slightly from 1,560 ha in 1973 to 1,365 ha in 1997. However, this difference may

be more due to interpretation difficulties. Areas of re-growth could not be distinguished on the lower resolution Landsat MSS, whereas they were easier to discriminate on the higher resolution SPOT imagery.

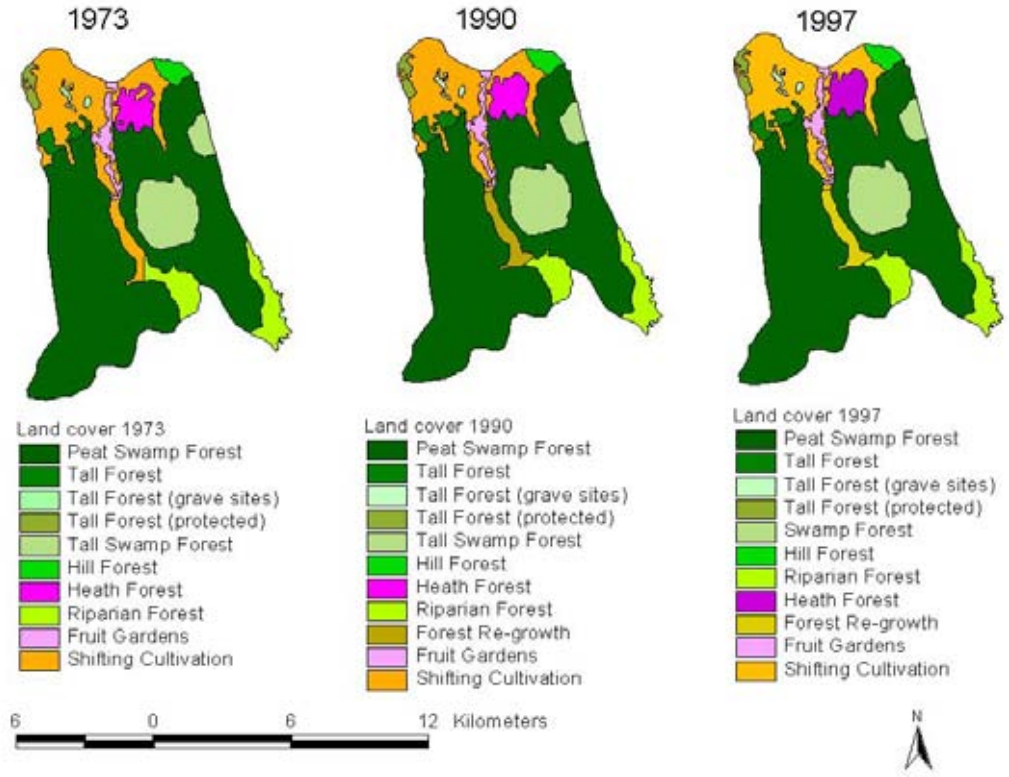


Figure 4-13 Village E - land cover change 1973-1997

Fire has not impacted this village. When interviewed, people said that when fire was used to clear land for cultivation a very strict control was kept on the fire. They had no experience of fires going out of control and burning areas of forest. The laws of the village are very strictly adhered to and people who damage important areas such as forest are sanctioned. The villagers remember the long drought of 1997 and said that they were very cautious about using fire to clear land, for hunting, and any other activity that involved fire. During this time they also remember strong winds which further increased fire risk. They also heard stories from outsiders about the fires in other parts of the region and experienced the smoke that was obscuring the skies for many weeks.

Up until now this village has not been worried about uncontrolled fires in their area. However,

with the recent activities associated with the oil palm company and illegal logging, they have now become concerned that fire may soon become a problem for them. In late 1999, the oil palm company struck deal with the village to plant 3,000 ha of oil palm in the forest claimed by Village E. The company started building an access road through the peat forests in August 1999, see Figure 4-14. Now the village thinks that the company only wants to remove the timber and has no serious plans to plant oil palm because the soil is not suitable. Opening up of the peat swamp forest is likely to lead to drying out of the peat forest and indeed increasing the risk of fires during dry conditions. The village has also heard from other parts of West Kalimantan how oil palm companies use fire to clear huge areas of land for planting. They are worried this will happen in their area and that fires will escape into their special forests and shifting cultivation areas.

Figure 4-14 Access road built through the peat forest by the oil palm company

4.2 Fires and land cover change at the landscape level

Two general fire regimes are present in the study area. One is seen in the upland areas and along the larger rivers, where fire has been used for centuries as part of the swidden agriculture system. The other is seen in the low-lying swamp forests in and around the lakes where fire has been present for centuries but not for any apparent use, like cultivation. The following sections discuss the fires in the swamp forests as these fires present a serious problem in the area as seen by the results from the village studies. Village A and D showed the most serious problems with uncontrolled fires and they are both located in the swamps. Fires associated with shifting cultivation do not appear to cause problems in the site, as evidenced by the village studies of Village C, E and F. Any uncontrolled fires in these villages were located in swamp areas. The following analysis comes partly from a recent study by the authors (Dennis et al., In press, b). This study includes data from the interpretation of 1994 aerial photography that was not used in the current study (Dennis et al., In press, a)

4.2.1 Cumulative change in burn scars

The results of the burn scar analysis show that there was a significant increase in the area of burnt swamp forest in Danau Sentarum between 1973 and 1997 (see Figure 4-15). Within the study area, the area classified from satellite imagery as burn scars in swamp areas increased from 5,483 ha in 1973 to 18,905 ha in 1997, this equates to a 245 % increase (see Table 4-3).

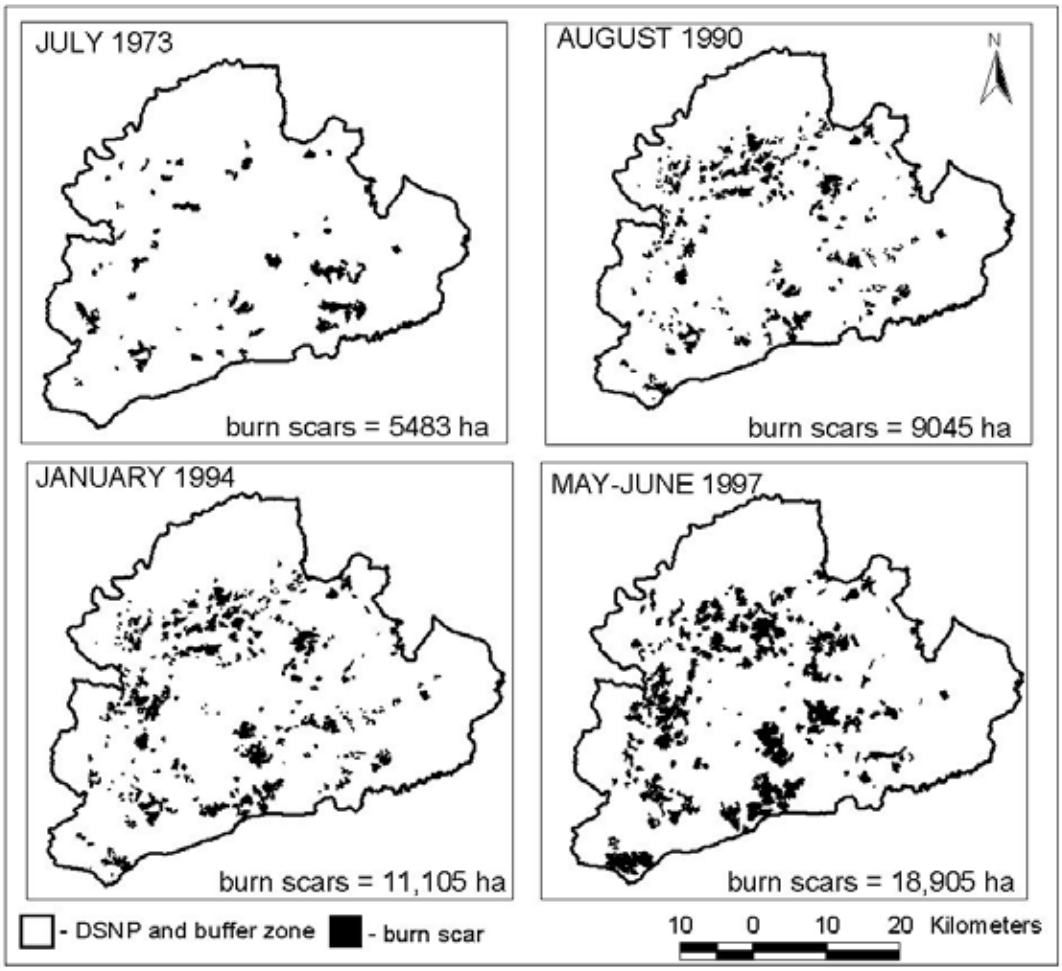


Figure 4-15 Burn scar distributions 1973-1990-1994-1997

	July 1973	Aug. 1990	Burnt area increase 1973–1990	Jan. 1994	Burnt area increase 1990–1994	May-July 1997	Burnt area increase 1994–1997
Burn scars in swamp forest (ha)	5,483	9,045	+ 3,562 (+ 64.9 %)	11,105	+2,060 (+22.7 %)	18,905	+7,800 (+ 70.2 %)
Burn scars as % of total land area	3.3	5.6	-	6.8	-	11.7	-
Area of swidden agriculture (ha)	5,910	7,751	-	5,890	-	7,658	-

Areas in hectares

Size of swamp area in the study site: 197,000 ha; size of total land area: 162,000 ha

Table 4-3 Burn scar area 1973–1997

The area classified by field work as swidden agriculture, a system which uses fires, did not change greatly over the period 1973–1997 with an increase of only 1,748 ha or about 30 % (see Table 4-3). The following results only deal with burnt swamp areas not associated with swidden agriculture.

The increase in burning can be analyzed for 3 time periods 1973–1990, 1990–1993, and 1993–1997. Between 1973 and 1990, the area of burn scars increased by 3,562 ha (+ 64.9 %) from 5,483 ha to 9,045 ha (see Table 4-3). An annual increase was not calculated because burning did not occur every year. During this 17-year period there were three El Niño events—1977, 1982, and 1987—one every 5.6 years, which produced prolonged dry periods. In addition there were approximately 5 dry years—1975, 1976, 1979, 1986, and 1989—in which fires could also occur. Assuming there were only 8 years in which the swamps were dry enough for fires to take place, the annual increase in burnt area, allowing a correction for years in which no burning occurred, was 8.1 %.

Between 1990 and early 1994, the area of burning increased by 2,060 ha or 22.7 %. During this three-year period there was one El Niño event in 1991 (Trenberth and Hoar, 1997), and two dry years (1990 and 1992). Based on this data the annual corrected increase in burning is 7.5 %, which is slightly lower than during the 1973–1990 study period.

The final period in the study is mid-1994 until mid-1997. During this period the burnt area increased from 11,105 ha to 18,905 ha, equating to an increase of 70.2 %. One El Niño (in 1994) and no other dry years were observed during this period; the 1997 El Niño occurred after the 1997 image date and was not included in this analysis. Therefore, assuming one fire year the annual corrected increase in burnt area is 70.2 %.

4.2.2 Forest change and burn scars

Using the GIS, it was possible to look at the forest types being burned. Between 1973 and 1990, freshwater swamp forest and dwarf swamp forest are affected most, with respectively 2,240 ha and 3,075 ha being completely destroyed by fire (see Table 4-4). 27.5 % of the burn scars remained unchanged or burned again during the 17-year period. Regenerating dwarf swamp forest was also badly burned, accounting for 11.9 % of the pre-fire composition.

	Composition of 1990 burn scars in 1973 (ha)	**Composition of 1997 burn scars in 1990 (ha)**
Burn Scar	2,489	6,389
Dwarf swamp forest	3,075	2,206
Dwarf swamp forest (regeneration)	1,082	2,005
Peat Swamp Forest	139	1,332
Riparian Forest	20	74
Swamp Forest	2,240	6,761
Cultivation	-	138
Total	**9,045**	**18,905**

Table 4-4 Burn scar forest cover composition pre-fire

Between 1990 and 1997, the areas most affected by fires were again tall swamp forest, dwarf swamp forest, and regenerating dwarf swamp forest, but there was also an increase in the area of peat swamp forest burned. In this period, the area of swamp forest burned was 6,761 ha or 37 % of the total area burned. Seven percent of the burn scars was previously tall peat swamp forest, which is a significant increase over the earlier period. Thirty-two percent of the burn scars remained burnt or burned again between 1990 and 1997. The amount of burnt dwarf swamp forest as a percentage of the total burn scar area dropped from 46 % in the earlier period to 22 % in the second period.

4.2.3 Burn scar dimensions

Analysis of the size of burn scars between 1973 and 1997 shows an interesting pattern. In 1973, only 60 distinct burn scars were identified in the study area, the mean size of the burn scars was 91 ha, with the largest being 581 ha and the smallest being < 1 ha. By 1990, the number of burn scars had increased to 248 with the mean size dropping to 36 ha. However, the range in size was much greater, with the largest burn scar being 453 ha and the smallest being 1 ha. The burn scar statistics for 1994 did not differ much from 1990, but 1997 saw a large change. Although the number of burn scars did not change greatly, 174 compared to 248 in 1990, the mean size of burn scars increased from 36 ha to 108 ha and the maximum size increased dramatically from 453 ha to 1,339 ha.

4.3 Hot-spots

Figure 4-16 shows the location of the study site and the distribution of 1997 fire hot-spots in West, Central and most of East Kalimantan Provinces. From the 151 hot-spots that were detected in the study area between 1992 and 1999, 50 % were detected in 1997. The highest hot-spot density was recorded in 1997 in the National Park area (see Table 4-5). The logging concessions in the study site have relative low hot-spot densities compared to the logging concessions in the entire province. This is not surprising as most logging is in swamp forests and consequently not heavily logged. Also, hot-spot densities in wetland and National Park areas in Danau Sentarum are on average lower than for the whole province, except in 1998. In this year, hot-spot densities in all land use categories in Danau Sentarum are higher than those in the entire province, suggesting that 1998 was a relatively serious fire year for the study site

compared to other areas in West Kalimantan Province. However, this was not substantiated from fieldwork in 2000.

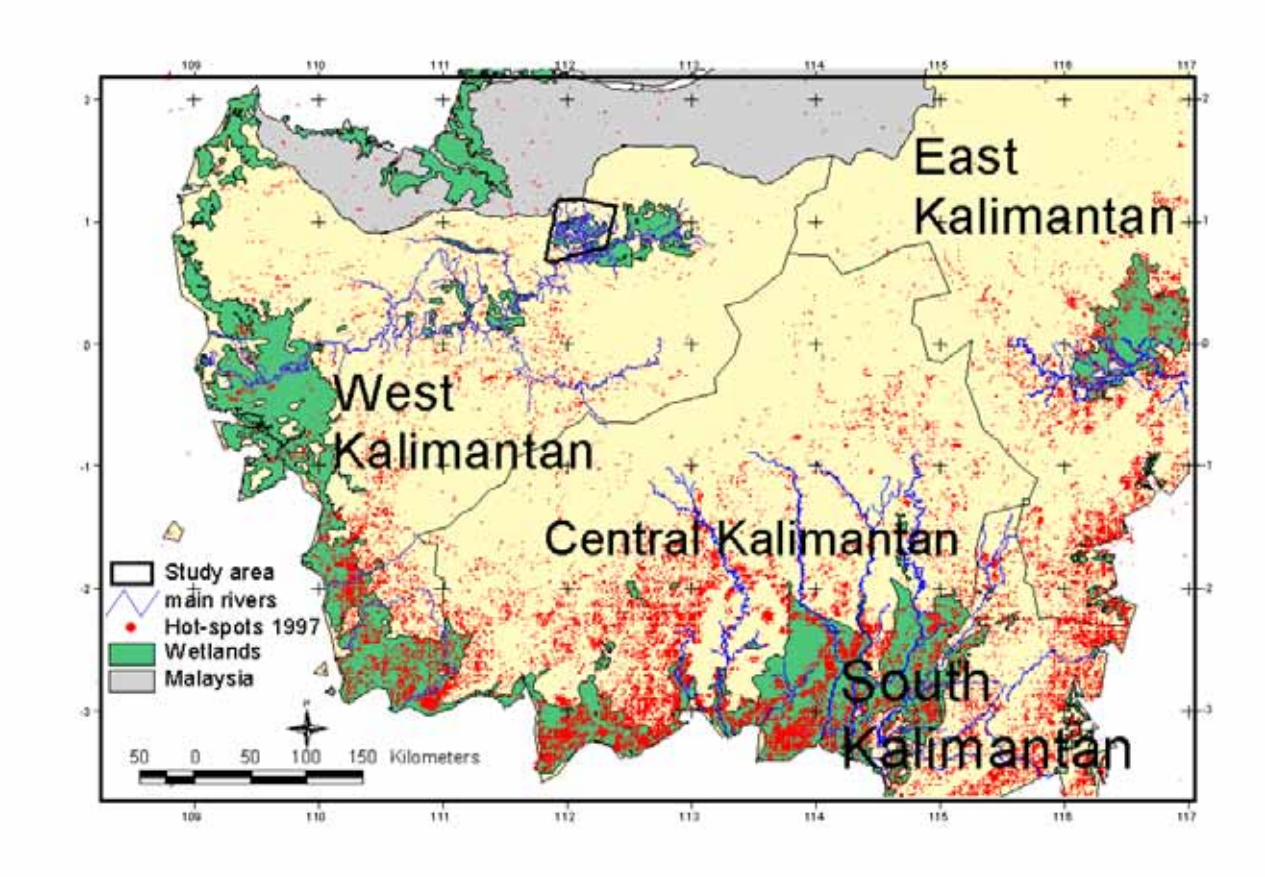
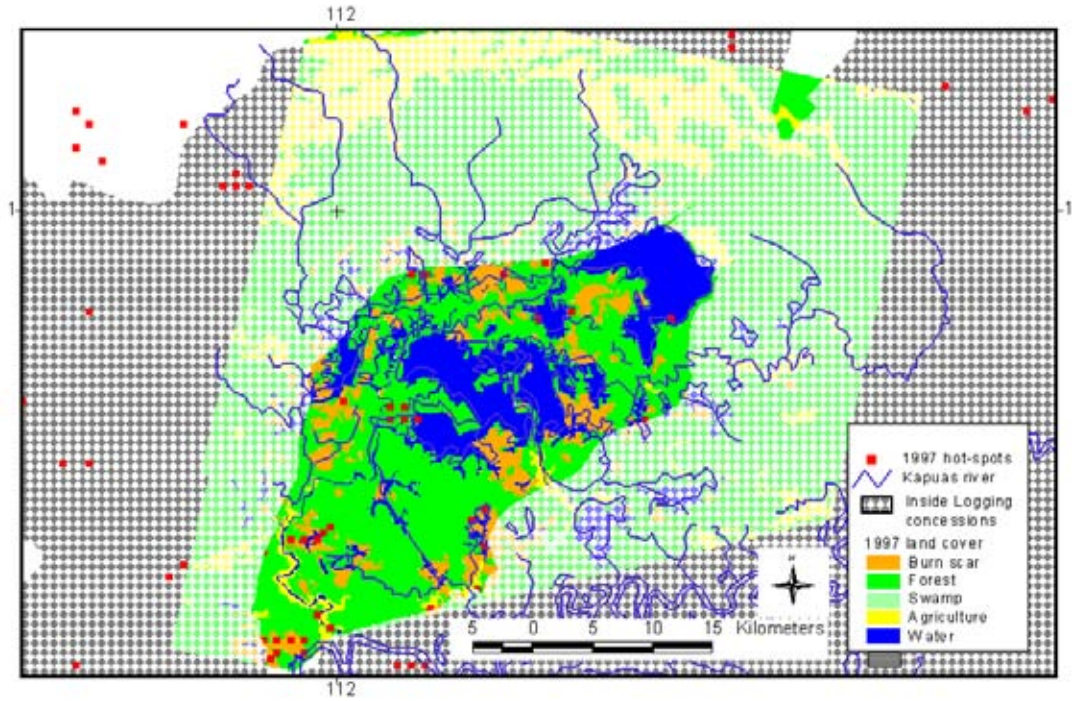


Figure 4-16 The Danau Sentarum study site in relation to the distribution of 1997 fire hot-spots in Kalimantan

	West Kalimantan				Danau Sentarum			
year	Nat. Park	Logging concession	Wetland	Province	Nat. Park	Logging concession	Wetland	Study site
1992	0.3	0.7	0.8	0.9	0.2	0.7	0.7	0.5
1993	0.2	0.2	0.7	0.3	0.0	0.0	0.0	0.0
1997	2.2	6.7	18.5	6.2	4.6	1.8	3.1	2.7
1998	0.1	1.0	1.6	1.2	1.9	1.3	4.2	1.5
1999	0.4	3.3	3.6	4.0	0.7	1.3	1.4	1.1

Table 4-5 Hot-spot densities in various land use types in West Kalimantan and Danau Sentarum

Table 4-5, further shows that 1997 has the highest hot-spot densities, both for the study site and the whole province. Although the highest number of hot-spots and hot-spot densities were seen in 1997, these are low compared to the average for the whole province (except for the National Park area). These data indicate that burning in Danau Sentarum occurs most years, while possibly being less dependent on extreme droughts like similar to that which occurred in 1997 compared to the rest of the province. A possible explanation may be that burning in Danau Sentarum is habitually done by local people, while there is less activity and burning by large companies.



Note: Brighter colours delineate the area in the immediate vicinity of Danau Sentarum not included in logging concessions.

Figure 4-17 1997 hot-spot distribution in the Danau Sentarum study site

The hot-spot occurrence in the different land cover types in 1997 shows that 40 % of the hot-spots are in burn scar areas (Figure 4-17 and Table 4-6). The other hot-spots are mainly in closed forest (40 % of total). This fits the previous observation that the National Park area suffered the most from fires.

Thirty-one percent of the 1997 burn scars were already burn scars in 1990, while 45 % was closed forest, indication that fires in Danau Sentarum are partly started in areas already burned and partly in areas that had not yet been burned before. This is corroborated by the detailed remote sensing analysis and fieldwork, see Section 4.1 and 4.2.

Land cover 1998	Area in km^2	Number of hot-spots	Density per 100 km^2
Burn Scar	180	29	16.1
Dwarf Swamp Forest	173	6	3.5
Dwarf Swamp Forest (regeneration	79	2	2.5
Forest Re-growth	92	4	4.3
Heath Forest	6	0	0.0
Lowland Forest (closed)	92	1	1.1
Lowland Forest (fragmented)	36	0	0.0
Lowland Forest (open)	31	0	0.0
Peat Swamp Forest (closed)	653	9	1.4
Peat Swamp Forest (fragmented)	19	0	0.0
Peat Swamp Forest (open)	136	0	0.0
Riparian Forest (closed)	29	0	0.0
Semi-permanent Agriculture	31	0	0.0
Settlement	1	0	0.0
Shifting Cultivation	300	3	1.0
Swamp Forest (closed)	340	12	3.5
Swamp Forest (fragmented)	17	0	0.0
Swamp Forest (open)	52	0	0.0
Swamp Grass	2	0	0.0
Water	287	4	1.4
Total	**2,556**	**70**	**2.7**

Table 4-6 Danau Sentarum land cover (1997) in relation to 1997 hot-spots

5. UNDERLYING CAUSES

Unique conditions prevail in the swamp forests of Danau Sentarum which make it prone to fires. There is no evidence to suggest that fires are a problem in the swidden agriculture areas on the higher ground surrounding the swamps. Hence, the following discussion focuses on the swamp forest areas. The results of the analysis show a clear and increasing trend in the total area and size of burn scars between 1973 and 1997. There is a substantial increase in the total burnt area from 5,483 ha in 1973 to 18,905 ha in 1997, with a steady increase in the intervening years. In parallel with a total increase in burnt area is an increase in the overall size of individual burnt areas. Delving deeper into these changes shows that the impact of fires has been worsening in recent years. In the first time period studied, 1973–1990, the main types of vegetation affected are dwarf swamp forest and stunted swamp forest. In the second time period, 1990–1997, there is a shift away from dwarf swamp forest being the main victim of fire to stunted swamp forest, and more worryingly, tall peat swamp forest. This indicates that new types of forest are being burned in addition to areas that have historically burned such as the fire-prone scrub-like dwarf swamp forest.

Having analyzed the trends and processes of fire in Danau Sentarum, some insight can be gained into the underlying causes. Evidence from interviews and field observation show that fires in the swamps of Danau Sentarum can be either **deliberate** or **accidental** and during El Niño years the number of fires increases considerably due to prolonged dry conditions. Identifying the underlying causes has proved difficult as evidenced by the earlier work of Giesen (1996) and Luttrell (1994). Their hypotheses on the main causes of fire, i.e. forest resource exploitation and fishing, however, still apply today. This doesn't, however, answer why there is an increasing trend in fires. Here we can now speculate based on the findings of the six village studies.

Field analysis, including detailed interviews in six villages, show that for each village area there is a specific set of reasons why certain areas burned. In broad terms, the results of the village interviews showed that there are **three main causes of fires:**

1) Factors related to natural resource extraction;

2) **Increased population and greater access and influence from outside the village areas;**

3) **Presence of a fire-prone landscape particularly during El Niño years;** and

4) In addition there were less frequent causes, or particular cases, related to **boundary conflicts and problems associated with invasive species such as water hyacinth.**

Firstly, fires connected with resource extraction from both forest and water areas have been cited as a cause since the first reports of fires in the 1800s. Many interviewees did not admit to deliberately using fire as a tool in improving fishing areas as cited by both Giesen (1996) and Luttrell (1994). However, interviewees would blame others for such practices, which leads one to believe that there is some truth in this cause. Carelessness with cooking fires in the swamps during the dry season was often cited. Direct observations by the authors in 1994, 1997 and 1999, proved that fires can start from cooking fires which have not been properly extinguished.

Over time, certain resources have played a more important role than others. One interesting example was the valuable *Arowana* fish, which was extensively sought during the 1980s, until it almost disappeared. As described by Luttrell (1994) fire was used in the search for the fish and many of the fires in the 1980s may have been due to a high demand for *Arowana*. Indeed the fish was so valuable that the authors were told that it was worth burning down forest just to find one. People also remember times when fire was used to encourage a flush of grass that would lure deer out of the surrounding forests. However, deer are now very rare in the forests surrounding the lakes and hunting of the deer in this way is rarely practiced now. It has further been reported that Iban use fire when hunting for turtles, while honey collecting is also a possible cause of fires: harvesting involves smoking the bees out of a hive with smoldering torches, and under dry circumstances fires could easily spread out of control.

Resource extraction can also afford protection from fire. For example, villages where honey extraction is an important source of income in addition to fish appeared to protect forest areas important for honey harvesting. Strong customary laws helped to ensure that people were careful with fire in these forests. Such was the case in two fishing (Melayu) communities in this study. In addition, in the Dayak communities, it was found that forest areas which locally classified as customary or sanctuary forest for resource or religious reasons appeared to be

better protected from fire. Such was the case in both the Dayak villages in this study.

Secondly, there is an increasing human population and increasing accessibility in the Danau Sentarum area, both because of improved transportation and an increased demand on resources. This is linked to a population increase. Jeanes (1997) reports that the human population in the Danau Sentarum area has been on the increase, and in 1997, the total population of the Park had reached 8,480 permanent residents, with an additional 2,400 that migrate to the area during the dry season for seasonal fishing (Erman, 1998). A positive correlation between human population and burning is expected. Many of the villages in the study said that they now have much less control on people entering their territories, particularly when they are large and very accessible.

Thirdly, there may be natural reasons for an increase in burning. There is a possible trend of an increased frequency of the El Niño phenomenon, which is generally accompanied by very dry conditions in the Danau Sentarum area. Local people noticed a big increase in fires from 1991 onwards, especially in 1991, 1994, and 1997, all of which are known El Niño years. Furthermore, the ongoing deforestation in the upper Kapuas area is possibly leading to greater fluctuations in river level. In 1986, floods were already more pronounced than in the decades before, and this trend will continue if changes in land cover continue (W. Giesen, pers. comm; pers. obs.). Whether this increased flooding frequency is counter-balanced by more frequent drying out of the lakes' area is yet unknown, but as the lakes area connected with the river, such trends are possible. A final natural reason for increased fires may be the increasing amount of combustible material that is left behind after logging which increases the intensity of any fire in the area, assisting in its spread.

In addition to the three main factors it was also found that there were causes of fires associated with particular situations. Conflicting claims to fishing areas was a cause of deliberate fires in one of the villages studied. Dennis *et al*. (1998) also found this in other areas at Danau Sentarum. The only other admitted deliberated fire was the burning of a logging company base camp.

These three main factors interact in different ways that are difficult to predict because most are very site-specific. For instance, two villages may have conflicting ideas about ownership or use rights of a certain resource use area (see e.g. Dennis, *et al.*, 1998). Increasing resource

extraction by, for instance, improved market access, may go hand in hand with increased conflict risks, because of higher population pressure, which, in very dry times, may lead to many fires. However, on the other hand, the potential threat of a conflict may be counteracted by an agreement between villages and the expected fires might not occur.

6. POLICY IMPLICATIONS

Based on the analysis of the underlying causes of fire in the Danau Sentarum site, some policy implications for both the provincial/district level and village level are outlined below.

1) The provision of increased resources to local institutions, in particular the Agency for Conservation of Natural Resources, for education, awareness and for community participation in fire prevention and suppression. This will lead to an increased understanding of the implications of fires in a landscape that has, in recent years, become heavily impacted by people from outside to the detriment of the local communities.

2) By establishing multi-stakeholder participatory management for the Danau Sentarum National Park, there may be a chance to avoid further degradation of the swamp forests and natural resources. This will need to be carried out at the district level, with support from the Province. This report will be key in providing information to outline the serious problem that is arising.

3) A review of the land allocation policies in swamp areas, particularly those on forested peat areas, including restricting or reducing the allocation of swamp forest for the establishment of oil palm plantations. This will need to be undertaken at the district level with Provincial government support. The importance of the swamp forests remaining in tact needs to be understood as further degradation of the ecosystem has both local and serious downstream impacts for the River Kapuas catchment.

4) As the delineation and demarcation on the ground of the National Park and its buffer zone are inadequate, confusion over resource use is further exacerbated. It is imperative that under decentralisation, due to start in January 2001, that the relevant institutions undertake this activity. It should be followed-up with some village-level presentation to outline and explain the process and reason for the boundary marking, and to outline the various users permitted.

5) If the pattern of burning and ecosystem degradation continues it will have severe consequences for the integrity of the Park and for the people and their environment downstream. These developments and associated impacts of increased burning,

conversion of forest to oil palm will have implications for the district in terms of changes to the economy and natural resource degradation, livelihood changes and perhaps an increase in land use conflicts.

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