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

Site 1. Sekincau, Lampung Province, Indonesia

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Site Report

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Cover photo: Deforestation in the Sido Makmur subsite, Sekincau

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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 ands 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	Meter
NOAA	National Oceanic and Atmospheric Administration
Stakeholders	People or groups of people interested in or responsible for forest management. Includes landowners, local communities, industry and government organizations.
SPOT	Système Probatoire pour l'Observation de la Terre. A French commericial satellite program designed to collect high resolution imagery (resolution of 20 x 20 m).
Talang	a temporary settlement near coffee gardens

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SUMMARY

This report identifies the underlying causes of fire in the area near and within the *Bukit Barisan Selatan* National Park in the Sekincau District of Lampung Province, Indonesia. In addition, the report also outlines the methodology of how the remote sensing and social science research undertaken at the landscape level can be linked by a Geographic Information System to provide valuable insights into determining the underlying causes of fire and associated land cover changes. This study identifies that the main causes of problem fires on this site are small holders establishing coffee gardens in the forest frontier. The problem is further exacerbated by illegal logging of the forest thus making the forest prone to burning during the dry season. The increased knowledge of the profitability of coffee production and the perceived “access” to land in the National Park by the local population brings new migrants to the area. This influx of new comers exacerbates the law enforcement and monitoring problems faced by the authorities in the National Park who are ill-equipped institutionally and without the capacity and resources to deal with the encroachment and sound management of the Park.

1. INTRODUCTION

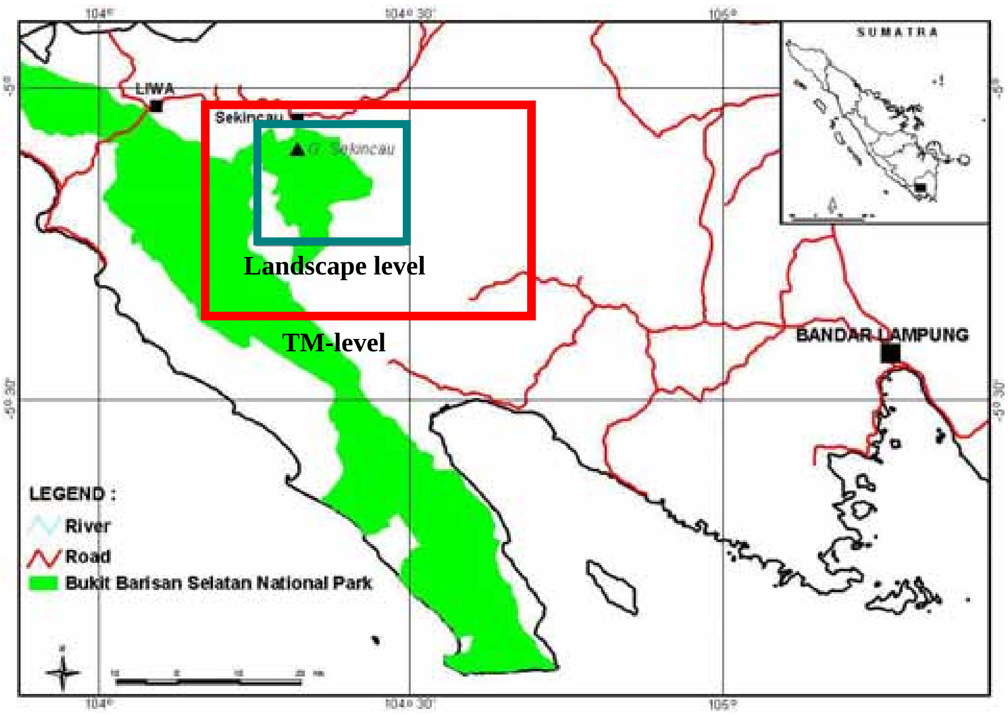
The focus of this report is Sekincau located in Lampung Province, Sumatra. The site represents a case study of fires in and around a National Park, aiming to understand the relationship between fire and deforestation. It is expected that as the human population in an area increases, pressures to convert natural forest will also increase. The population of Lampung has risen dramatically since the 1970s. In 1971, the population was 2.8 million with a density of 78 person per km^2, while in 1997, the population and population density of Lampung had increased to 6.9 million people and 209 person per km^2 respectively (BPS, 1998). According to RePPProT (1988), 50 % of the migrants who went to Sumatra since the beginning of the 20^{th} century settled in Lampung. As the population increased, forest cover in Lampung declined. Forest cover in Lampung in 1982 was only 18 % (Fraser, 1998).

The question now arises to what extent the deforestation process has been accompanied by fire. To investigate this, the hypotheses of the causes of fires, as developed by Tomich *et al*. (1998), was examined. According to the authors, there are three sources of fires: fires used as a tool to clear land; fires that accidentally go out of control; and fires as a weapon in social conflict. To investigate what role each of the above processes has played in Sekincau a multi-disciplinary research approach was used. This aimed 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 remote sensing imagery from satellites to in-depth field investigations at the landscape level. When used in combination, a more complete picture of the 1997 fires can be developed. For example, images from satellites provide information on the location, extent, and the type of land cover burned. 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.

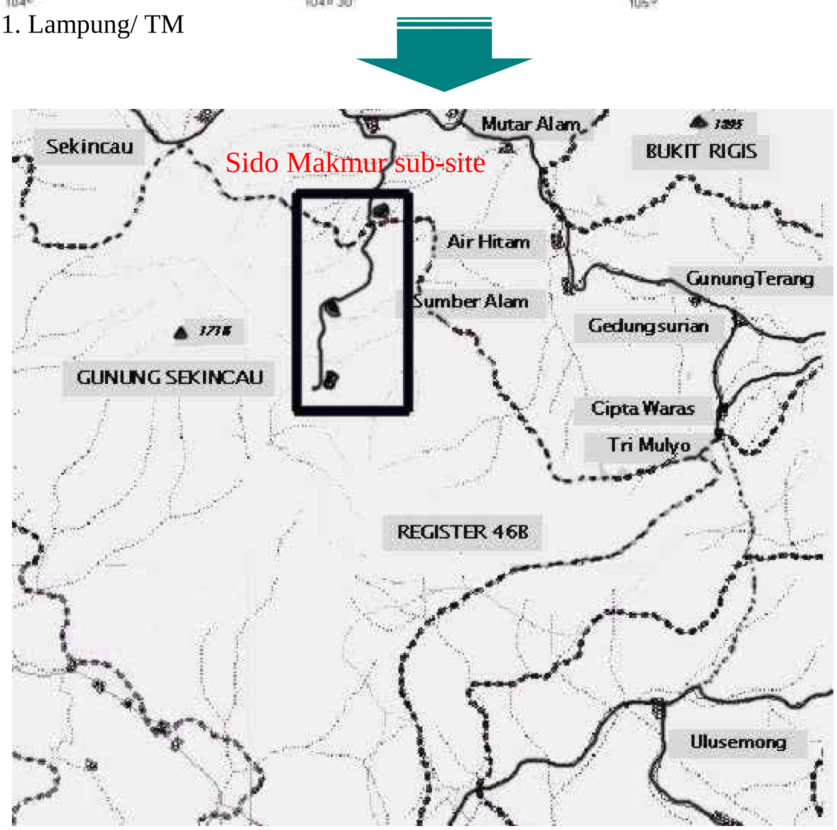
2. SITE DESCRIPTION

The Sekincau site is located on the north-eastern fringes of the Bukit Barisan National Park in the province of Lampung, in southern Sumatra. Since three levels (scales) of information were gathered for the site, there are subsequently three study area extents. The first and most general level is the entire province of Lampung (3,386,715 ha). At this level, broad scale information (1 km spatial resolution) about the occurrence and location of fire since 1992 was analyzed for the entire Lampung Province. The second, more detailed information level is a satellite-image wide area surrounding Sekincau (500,000 ha). Here satellite images (60 m and 30 m spatial resolution) from 1985, 1994, and 1997 were used to map burn scars and land cover changes. Finally, the third and most detailed level of information is the Sekincau landscape area, covering approximately 26 km by 23 km and totaling 58,500 ha. Information collected at this level included results from interviewing local people, field mapping, and satellite image interpretation. More information has been gathered over this portion of the study area compared to the other two scales, and consequently the scale provided the most detailed information for determining the causes and effects of fire. Findings from this level of analysis are extrapolated to larger areas and checked against the broader levels of information.

The Sekincau site is shown in Figure 2-1. The area is mountainous with an average elevation of between 800 and 1,200 meters. The highest peak is Mount Sekincau with a height of 1,718 m. Natural montane forest still occurs in parts of the site but the dominant land cover is coffee plantations of varying ages, covering almost 75 % of the site.



Level 1. Lampung/ TM



Level 2. Landscape level/sub-site Sido Makmur

Figure 2-1 Location of study site

Population pressure surrounding the National Park is very high and many communities are located on the edge or inside the Park (Figure 2-2). These communities, which have been expanding recently, are not comprised of indigenous people. Most of them are migrants who came from other parts of Lampung and from the adjacent island of Java. There are two types of communities: permanent and temporary migrants. Temporary migrants stay in the village for a short time for the purpose of establishing, tending and harvesting (June to August) the coffee. Their permanent homes are elsewhere in Lampung, or even Java. Permanent migrants have settled on site and do not have dwellings outside the coffee growing area.

Figure 2-2 A new migrant settlement within the National Park

3. METHODOLOGY

A combination of remote sensing/GIS and social-science research techniques were used for the study. Three different sources of remote sensing data were used, each of which provided data on a different geographic scale. First, National Oceanic Atmospheric Administration (NOAA) hot spots collected on a daily basis since 1992 provide a fire history and fire frequency for Lampung Province. This information provides a means of comparing Sekincau with other study sites in Sumatra and other parts of Indonesia. Landsat Thematic Mapper (TM) and Multi Spectral Scanner (MSS) imagery covering an area the size of a full satellite image (185 km x 185 km) provided the second source of remote sensing information. Information derived from satellite images acquired in 1985, 1994, and 1997, allows for determination of general land cover changes including the extent of natural forest and burn scars. Comparisons between the Sekincau site and surrounding areas within the extent of the satellite image are made using this level of information. Hypotheses are developed as to whether similar situations to the detailed study site exist. Finally, detailed land cover maps of the Sekincau landscape were created from a more thorough analysis of satellite imagery, field investigations, and village level participatory mapping. These maps showed specific land cover changes such as type of land use (eg. coffee plantations). This detailed information provided insights into the village-level interactions between fire and forest and provided the foundation of the analysis for this project. The methods used for collecting each level of information are outlined.

3.1 Socio-economic Study Methods

This part of the study was conducted in two stages. In the first stage, participatory mapping and group interviews were used to collect general information about the histories of *Talang* (a local name for temporary settlements near coffee gardens), and village characteristics at the landscape level. Also, village sketch maps were produced. The data we obtained was largely qualitative. Formal and informal leaders of villages attended a number of meetings where questions were asked. Following that, rapid rural appraisals with some key informants were conducted by visiting the village areas, and the initial meeting sketch maps were revised. Interviews were also conducted with Bukit Barisan Selatan National Park officers, as well as with Ministry of Forestry and Estate Crop officers in Lampung.

Since the data obtained through this approach provide mostly general information, extensive community surveys at sub-*Talang* unit were undertaken to obtain more specific data. Some formal and informal leaders in all sub-*Talang* were interviewed. All the households in each sub-*Talang* were listed and household members were asked about demography, migration and land ownership. Details about slash-and-burn practices and fires in 1997/1998 were also determined during such group interviews.

A community survey of 19 communities/sub-*Talang* (in 5 big *Talang*) located in the western part of Register 46 B[1] was conducted. The focus was on this area, because fires occurred in there in 1997/1998. Because of the complexity of the village areas, villages as a unit were not used in the analysis. Initially the *Talang* consist of temporary housing near coffee gardens. Some of these *Talangs*, however, have developed like a village. In the administrative sense, each of these *Talangs* must be part of the administrative unit (*desa*); these are mostly located along the main road. However, there is no rule that a *Talang* should be part of the nearest village. Therefore, many *Talangs* are not part of contiguous spatial units with their home villages. The total sample size consisted of 19 sub-*Talangs*, of which 84 % are located inside and 16 % outside or on the border of the National Park. Figure 3-1 is the landscape level map.

[1] Registers delineate state forest and date back to the times of Dutch administration

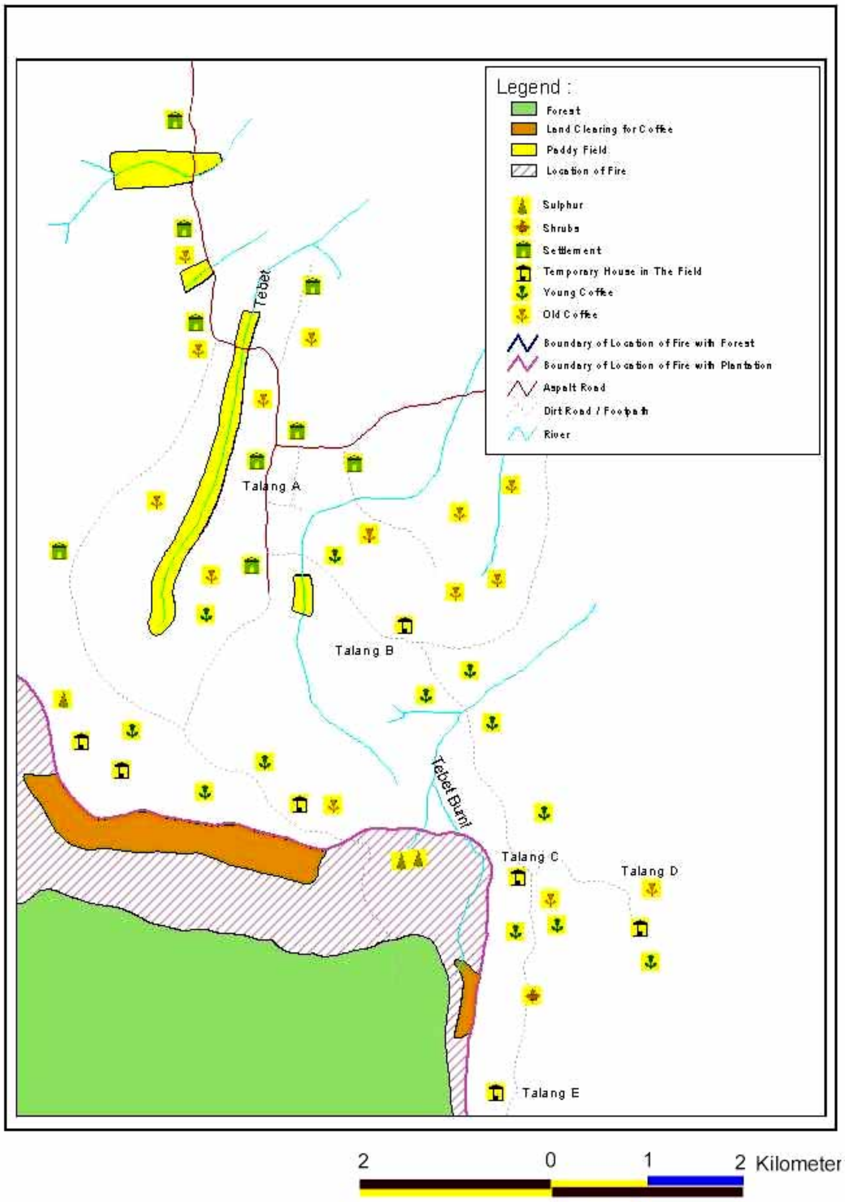


Figure 3-1 Sketch map of Sido Makmur sub-site

3.2 Remote Sensing and GIS

3.2.1 Site-wide methodology

Through remote sensing and use of GIS, the historic and current patterns of land cover and land use change were analyzed. For the Sekincau site, three dates were selected for the change analysis based on satellite imagery as seen in Table 3-1.

Date	Sensor	Scene (path/row)
1 May 1985	Landsat MSS	124/63
4 September 1994	Landsat TM	124/64
14 October 1997	Landsat TM	124/64

Table 3-1 Satellite imagery used for the land cover change analysis

All three images were of good quality and showed little cloud cover (see Figure 3-1). The Landsat TM images for 1994 and 1997 were of particularly good quality. SPOT multi-spectral image dated 22 October 1997 was also used. This image showed active fires in the southern part of the site. This image was not used in the change analysis because of the closeness in date to the Landsat TM image. Landsat TM was the preferred source for land cover classification. However, the SPOT imagery was used as a guide in interpretation of the 1997 Landsat TM.

Once the imagery was selected for classification it was geo-referenced using 1:50,000 base maps. The 1997 Landsat TM was used as the base for geo-referencing and the 1985 and 1994 images were subsequently co-registered to it. Prior to classification, all images were spectrally enhanced and various band combinations were assessed. The band combination of the original photo-print was 4, 3, 2 for the 1985 image (Landsat MSS). For the Landsat TM, bands 4, 5 and 7 highlighted vegetation as well as recent burn scars. The next stage was classification of the imagery using on-screen digitizing. Classification was first carried out on the 1994 image and the resulting file was then overlaid on the 1985 and 1997 imagery and changes drawn. For each image, land cover and burn scars were identified.

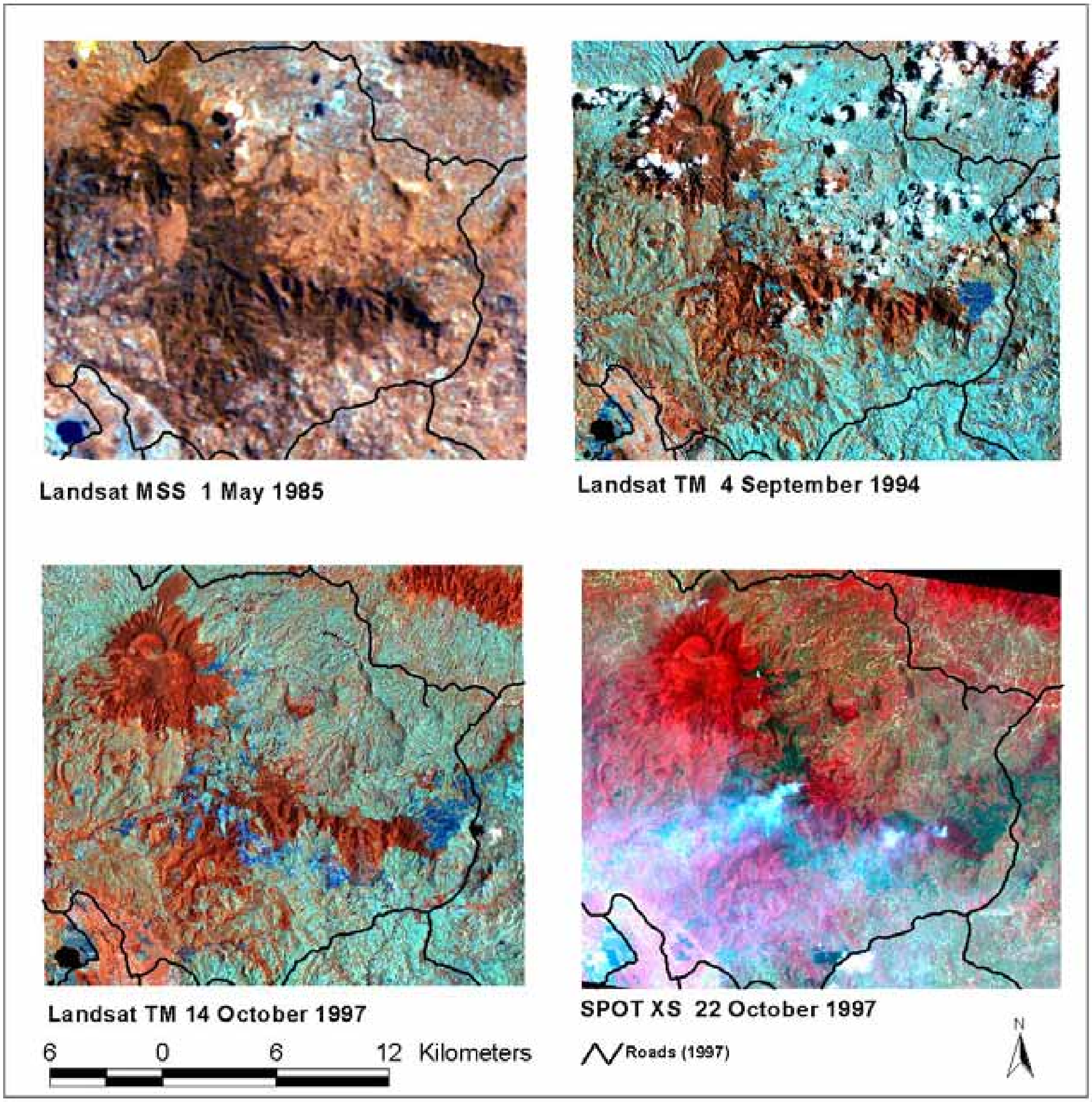


Figure 3-2 Images selected for the Sekincau Site

3.2.2 TM image level

The next level of information, the satellite image-wide analysis, was completed using Landsat TM and MSS satellite imagery. Full scenes of imagery (185 km x 185 km) were mapped according to six land cover categories, as shown in Table 3-2. Land cover was mapped from three dates of satellite images covering the Sekincau area: 1985, 1994, and 1997. These were the same images discussed in the detailed landscape level analysis (see 3.2.1). Traditional multi-spectral, unsupervised classifications were performed on each date of imagery. Six image bands were used (the thermal band was eliminated) for 1994 and 1997 TM imagery and four image bands were used to classify the 1985 MSS image. The Isodata (ERDAS, 1991) clustering algorithm with a nearest neighbor classifier was used to classify all images. Using this method, sixty spectral classes were derived from each image and, based upon analyst interpretation, each assigned to one of the six land cover classes. Maps were edited in areas of smoke, haze, cloud, and cloud shadow to more accurately reflect land cover. Additionally, checks were made between dates of imagery so that unreasonable errors could not occur. For example, natural forest existing on the 1997 image was cross-referenced with the 1994 and 1985 maps to ensure that it was classed as natural forest as well.

Land cover classes for satellite image-wide analysis
loud/shadow
Water
Agriculture/bare/other
Other forest
Natural forest
Burn Scar

Table 3-2 Simple land cover classification used in the satellite image-wide analysis of the Sekincau site

Once the land cover maps were finalized, map overlay analysis techniques using a GIS were applied to determine 1) where land cover changes occurred between the dates of imagery and 2) what relationship these changes had to the burn scars in 1997. For example, what type of land cover existed in 1994 and 1985 for areas burned in 1997? The land cover change maps and burn scars from 1997 were then assessed using a combination of visual and computer analysis to highlight other areas within the satellite image area having characteristics similar to the Sekincau landscape area. Based upon analysis completed for the Sekincau site, assumptions about other areas having similar characteristics were then possible.

3.2.3 Derivation of fire hot spots

Hot-spots data from NOAA-AVHRR imagery were available from various sources and covered 13 periods between 1992 to 1999 (for more detail refer to Appendix I).

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 are likely to vary slightly. For the Sekincau site, the focus was on integrating local people's narratives and sketch maps with land cover change maps and burn scar maps. Using the functionality of the GIS, it was possible to calculate the types and size of land cover changes. In addition, local people's narrative could be added to the 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.

4. RESULTS

Results will be discussed starting with the detailed landscape analysis and ending with the province/satellite image-wide analysis. Only by explaining the causes of fire at the most detailed level can we begin to make conjectures about fires occurring in the areas outside the Sekincau landscape area.

4.1 Fires

4.1.1 Landscape level

In Sido Makmur, a sub-site for the social-economic survey, fire occurred in October 1997 and destroyed 100 ha of natural forest (District Forestry Administration, Lampung). Our respondents, however, estimated that forest fires actually burned approximately 500 ha. This estimation is based on their observation and involvement in fire fighting. During that time, people from around the Park cut vegetation along 3 km of forest as a fire break to avoid the spread of fire.

Fire first occurred in areas near Talang E and Talang D. It then spread to the eastern part of Sekincau. Forestry officers blamed the fire on slash-and-burn methods in land clearing by farmers around the forest. The likelihood of fire from land clearing by farmers escaping to forest during an El Niño year is high because the areas of young coffee gardens are generally located near forests. On the other hand, no evidence was obtained, however, to show that fires spread out to neighboring farmer's gardens. Assuming the reliability of this lack of evidence, this suggest that fire community management system works properly. The communal (*adat*) law has a system of penalties that are imposed on farmers who mismanage fire and destroy their neighbours' field. On the other hand, there is no incentive for farmers to control the spread of fire into natural forest, which is in this case the National Park. In fact, farmers gain from the forest fire. The fire facilitates the establishment of coffee garden in the areas of post forest fire. Farmers, however, denied that their activity in land clearing was a cause of fire. Farmers argued that they are very careful in managing fire in land clearing activities. Most of the survey respondents believed that the forest fires in the site occurred as a result of accidents. They blamed the activities of illegal logging workers who make campfires and discard cigarette butts as the main source of the forest fires.

Farmers traditionally use fire in land clearing. Data on distribution of coffee areas by different tree age was used to estimate area and year of burning. The burned areas in 1997-1998 covered 310 ha. Approximately 77 % of the total land cleared with the use of fire in 1997-1998 was located in Talang E. These data suggest two things. Firstly, it seems that there is a strong relationship between fire and deforestation on this site. The establishment of coffee gardens (using fire in land clearing) is most active in the areas where natural forest is still relatively abundant. Secondly, it is most likely that fire spread from land clearing activities to natural forest because the location of burned forest areas is close to young coffee gardens. The analyses therefore suggest that there are two types of fires in this area; those that are controlled and those that are uncontrolled. Controlled fires come from the activities of smallholders for land clearing. Uncontrolled fires occurred in natural forest that could come both from the spread of fire from land clearing and from illegal logging activities inside the National Park.

4.1.2 Burn scars

Recent burn scars were mapped from satellite imagery. Through ground checking of the imagery, it was found that recent (within a few months of the imagery) burn scars showed a very distinctive spectral reflectance. Based on field observations of recent burn scars, it was determined that this may be due to the spectral reflectance of charred vegetation with some young, vigorous growth of pioneer species, such as grasses.

Visual analysis of the imagery identified three main zones of burning characterized by a distinctive burn scar pattern. In Zone 1 (see Table 4-1 and Figure 4-1), burn scars are small, 3 ha on average, widely scattered and only account for 1 % of that zone. Overlaying the 1997 burn scar map with the land cover maps for 1985 and 1994, shows that much of this forests area was already converted (coffee gardens) in 1985. From field observations in this area, it was found that fire is regularly used on a small scale to clear land for cultivation.

Burn Scar Zone	**1**	**2**	**3**
Size of zone (ha)	13,371 ha	6,548 ha	3,286 ha
Number of burn scars	48	48	11
Total area of burn scars (ha)	142 ha	1,358 ha	960 ha
% area of burn scars in zone	1 %	21 %	29 %
Average size of burn scar (ha)	3 ha	28 ha	87 ha

Table 4-1 Burn Scar Statistics

Burn scars in Zone 2, which covers part of the sub-site, are large with an average size of 28 ha and account for as much as 21 % of the zone. The majority are located near or adjacent to primary forest. Using the GIS, it was shown that much of the area covered by the 1997 burn scars in this zone was still natural forest in 1994.

The third zone exhibits very large burn scars. Although the number of burn scars is less than in other zones, the average size is much larger (87 ha) and accounts for 29 % of that zone. Historical imagery shows that this area has burned numerous times since 1994, and probably in earlier years. In 1985, this area was already cultivated. Interviews with local people in 1999 identified that this site is located in a Protection Forest in which a tenure conflict between local people and the Forestry Department has arisen. Since 1975, villagers who live around this area have planted coffee. However, in 1983, 1991, 1993 and 1996, the Forestry Department implemented a reforestation programme by cutting down all of the coffee trees and planting Caliandra (*Sesbania glandiflora*). Due to the resulting conflict, and related revenge burning by the villagers, the area has become unproductive grassland (*Imperata cylindrica*) and very prone to annual fires.

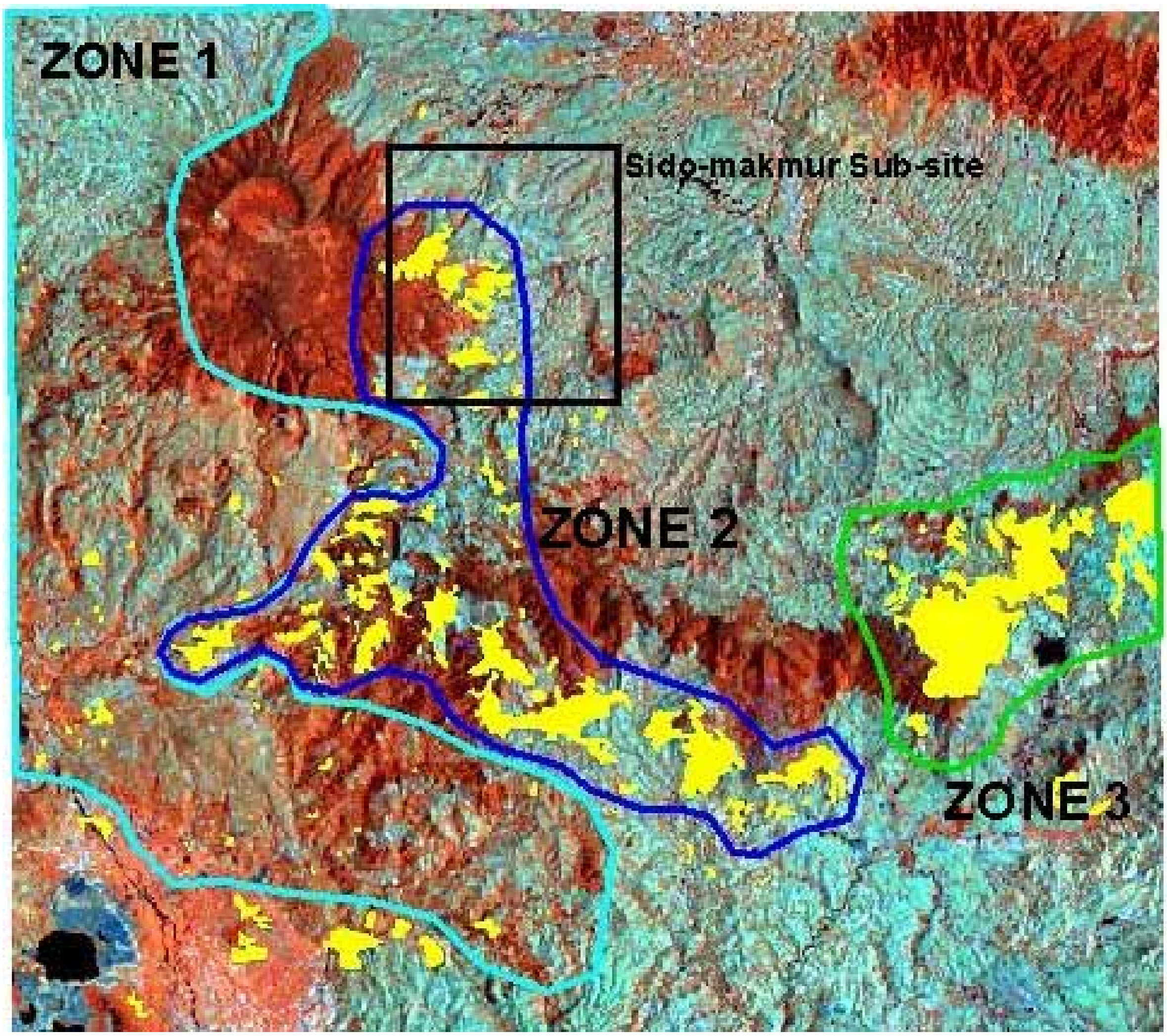


Figure 4-1 Burn scar zonation

The burn scar analysis shows that different patterns of burning can be identified and related to land use issues. For example, it appears that small burn scars are directly associated with stable agricultural areas, whereas larger burn scars are associated with forest clearing. On this site, very large burn scars were associated with areas known to be subject to conflicts over land use and between land users. These results show that there is potential to use burn scar mapping to classify fire use or fire problems.

From the satellite image-wide map surrounding the Sekincau area in Figure 4-2, information can be derived about where the burn scars are located, what potentially burned (based on change detection analysis), and which other areas surrounding Sekincau show similar burn scar patterns. Within the satellite image-wide study area, approximately three percent of the area was mapped as burn scar in 1997. This does not mean that three percent of the area burned in 1997, but rather it is a snapshot of burn scars at the time the image was taken. This percentage is less than the 4.6 percent of burn scars in the detailed landscape analysis. Most large fires mapped within the extent of the satellite image burned in and around the Sekincau site. Since there is more natural forest near the Sekincau site, it follows that more burn scars should exist here than in other areas of the image.

Further analysis of the areas mapped as burn scar in 1997 show that approximately 30 percent were classified as natural forest in 1994. Burn scars mapped as primary forest (un-logged) in 1994 are highlighted in red in Figure 4-2. Since imagery spanning the time period between 1994 and 1997 was not analyzed, the assumption is made here that this subset of 1997 fires burned in natural forest. This is consistent with the detailed landscape level assessment which determined that fire did not occur in coffee gardens, but rather in natural forests. Burn scars highlighted in orange show fires in areas other than natural forest in 1994. By reviewing patterns revealed from the different coloration of burn scars a similar pattern to that of the Sekincau site is indicated. These areas, delineated by red circles on Figure 4-2 show that land clearing for coffee growing is likely to be occurring along natural forest edges within the National Park and along the edges of forest inside forest protection areas.

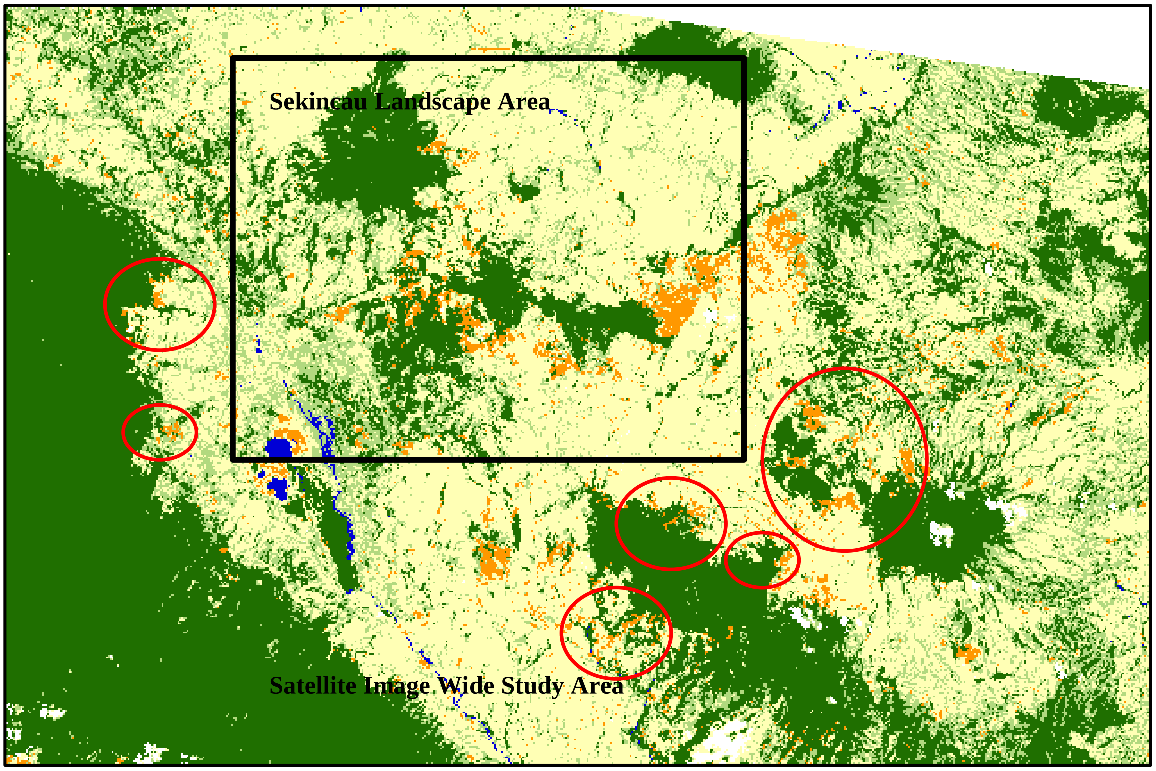
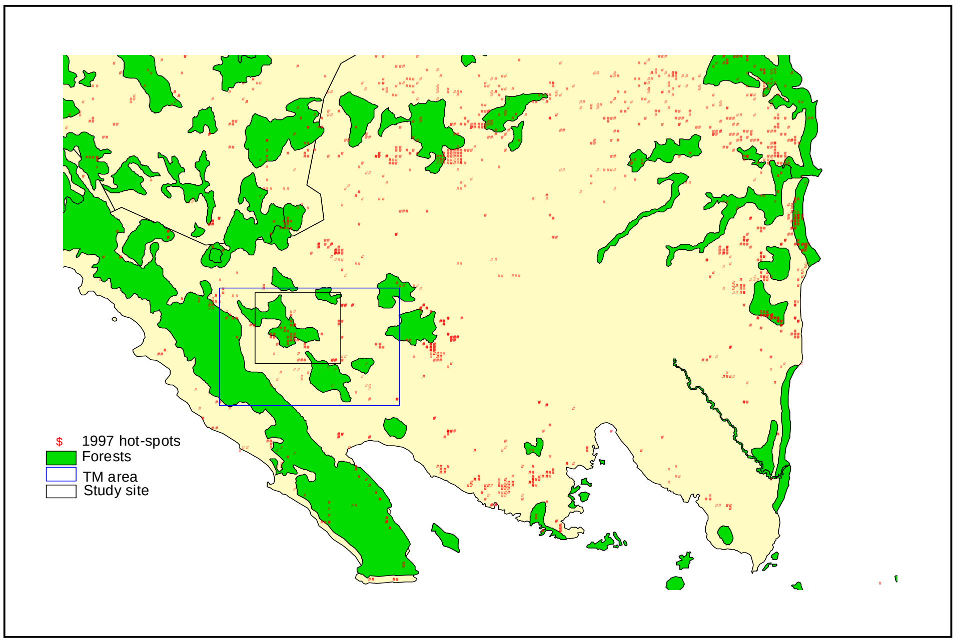


Figure 4-2 Satellite-wide study area showing land cover mapped after the 1997 fires

4.1.3 Hot-spots

Relative to other areas of Sumatra, Lampung Province did not display a high number of fire hot-spots during the 1997 fire event in Indonesia (see Figure 4-3). The total number of hot-spots detected in the time period of study was 2,839, with a density of 8.5 hot-spots/km^2. Compared to other provinces this is a low to medium number and density of hot-spots. While this would indicate that fires in Lampung Province did not contribute significantly to the overall fire situation in Indonesia, during this period, the analysis does contribute to determining the underlying causes of those fires, by investigating their distribution over time.

1997 was an exceptional hot-spot year, with more than 3 times as many hot-spots than other years. In 1992/93 and 1996, most hot-spots were detected in grasslands dominated by *Imperata cylindrica*. This, however, changed in 1997 and 1999, when most hot-spots were detected within the borders of National Parks. In the satellite image-wide study area there were 103 hot-spots detected in 1997, which gives a hot-spot density of 4.6 per km^2. In the area there are no large-scale logging or plantation companies. The hot-spots distribution in 1997 is as follows: 40 % in 'non-forest land', 25 % non-forest land in unlogged forest, and 22 % in logged forest and timber plantations. Almost all hot-spots were located near or in the National Park. The hot-spot data, therefore, support the other analyses that much of the



fire (25 %) resulted from expansion of agricultural land for coffee production.

Figure 4-3 Total number of hot-spots in Lampung Province in 1997

4.2 Land Cover/Use Changes

4.2.1 Qualitative landscape level changes

To better understand the relationship between fire and deforestation, this section addresses the causes of deforestation in Lampung. According to the head of the District Forestry Administration in Lampung, the total forest area in Lampung is 1,083,749 ha or 32 % of the entire areas of Lampung Province. The condition of the forest, however, has been degraded in most areas. The level of deforestation reached 62 % in Protection Forest, 41 % in National Parks and 76 % in Production Forest (Koridor news paper, edition 14 1/1-7 July 1999).

The development of coffee gardens, and the related increasing migration and illegal logging activities appear to be the main causes of deforestation in the National Park on the study site, with deforestation being defined as the situation where natural forest cover has been converted to other land use classification (Sunderlin and Resosudarmo, 1996). The farmers in the site argue that they do not directly open the natural forest for growing coffee. Most of them cultivated the shrub land or *Imperata* grasslands, or logged forest that had already been used under a shifting cultivation system by the indigenous Semendo people. In more recent years, however, non-Semendo peoples also developed coffee gardens by direct conversion of natural forest. There is a tendency, however, for farmers who opened natural forest to shift the blame to local Semendo people.

The second source of the coffee land is in areas of previously illegally logged forest. Recently, coffee growers have cultivated areas that were formerly natural forest through the use of fire. They argue that this land is empty land or covered in shrub, and is no longer natural forest. Therefore, they cultivate that land for coffee. Whatever the justification, in fact most of natural forest within the National Park has already been converted to coffee gardens and the rate of deforestation in this site is very high (see Figure 4-4).

Figure 4-4 Mosaic of coffee gardens, newly cleared forest and natural forest

The distribution of the areas of coffee garden is shown in Table 4-2. The total areas of coffee garden is 1,273 ha. The ownership patterns is as follows: Talang A (19 %), Talang B (4 %), Talang C (9 %), Talang D (17 %) and Talang E (51 %). The age of coffee gardens on the site is relatively young, with 75 % being below 10 years and only 11 % being more than 15 years old. The oldest coffee gardens (> 11 year) are located largely in Talang A and the youngest (< 4 years) largely in Talang E. Coffee gardens with ages between 5 and 10 years are located largely in Talang B, C and D. The data show that the oldest coffee gardens are mostly located in the Talang that is nearest to the main road, while the youngest coffee gardens are mostly located in the Talang that is furthest from the main road. This result is expected, because it is more costly and, so less profitable to cultivate distant plots, as argued by Angelsen (1996). Moreover, the effect of distance to the main road in the study site seems consistent with the finding of Chomitz and Gray (1994). Using Belize data, Chomitz and Gray found a significant positive correlation between the development of rural roads and deforestation.

4.2.2 Quantitative landscape level changes

Quantitative assessments of land cover/use change at the landscape level were carried out for the years 1985 – 1994 –1997 by classifications derived from satellite imagery, as shown in Figure 4-5.

The level of detail visible on the imagery dictated the classes chosen for the classification. As can be seen in Figure 4-5, the number of classes in the 1985 classification is less than in 1994 and 1997. This is due to the different spatial and spectral resolution of the imagery. The main difference to note between the Landsat MSS classification and the Landsat TM classification (1994 and 1997) is the number of agricultural classes, such as the coffee classes discriminated for 1994 and 1997, but not for 1985. Otherwise, most of the classes are consistent or comparable between years. For each year, cloud cover and shadow are present and affect the overall totals, the classes 'no data' 'cloud" and 'shadow' are not included in the summary tables.

A number of different types of analyses were carried out on the land cover classifications. The most basic analysis was to compare cumulative figures and percentages between years, thus giving a general picture of land cover changes, as seen in Figure 4-5. Analysis of the types, or trajectories, of changes occurring in the site was also carried out. This gave an insight into the predominant land cover change processes. Change matrices were calculated for 1985 – 1994, 1985 – 1997 and 1994 – 1997 for the Sekincau site and the Sido Makmur sub-site. These matrices can be consulted in Appendix II and III.

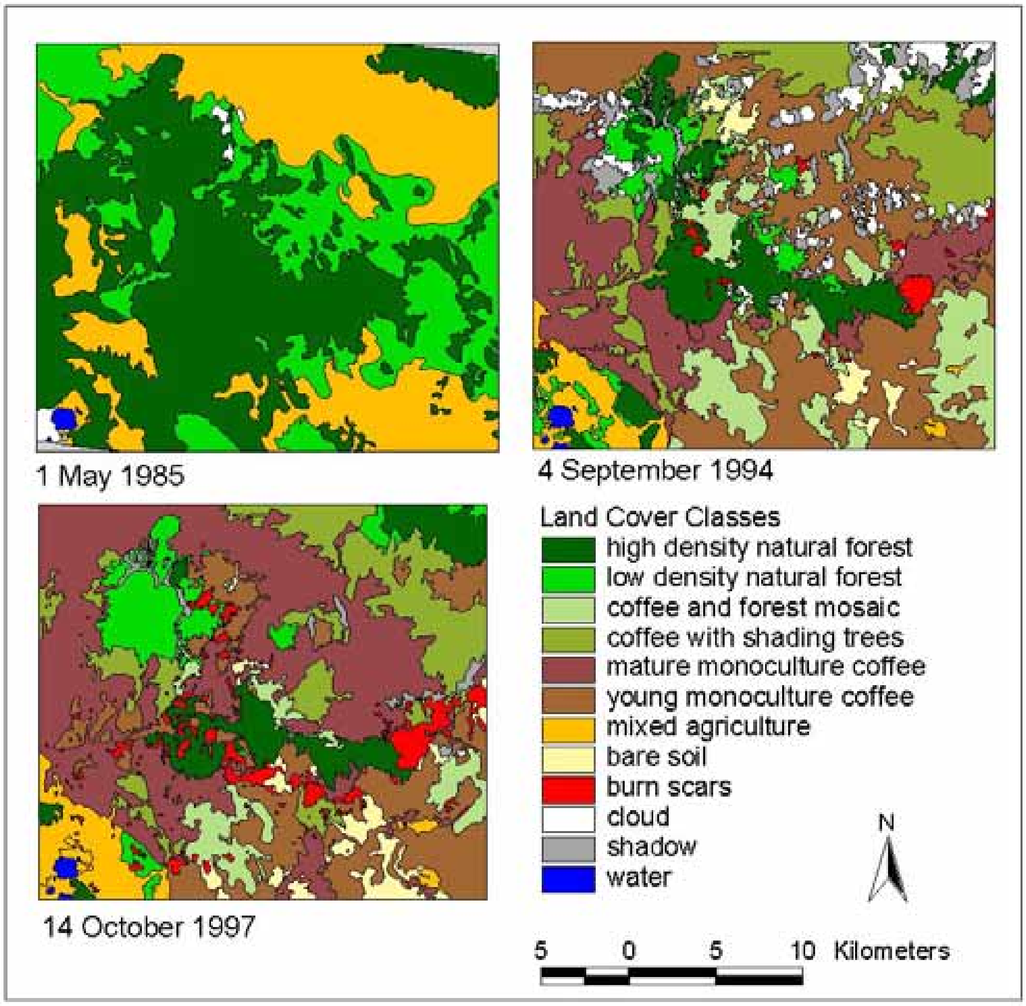


Figure 4-5 Land Cover Classification 1985, 1994 and 1997 derived from satellite imagery

Class name	1985 (ha)	1994 (ha)	Change 1985-1994 (%)	Annual Change 1985-1994 (%)	1997 (ha)	Change 1994 – 1997 (%)	Annual Change 1994 – 1997 (%)
Natural Forest	***34,963***	***8,346***	***-76.13***	***-8.45***	***6,315***	***-24.33***	***-8.11***
High density natural forest	22,493	5,846	-7**4**	**-8.22**	3,511	**-39.94**	**-13.31**
Low density natural forest	12,470	2,500	-7**9.95**	**-8.88**	2,804	**+12.16**	**+4.05**
Coffee/Agriculture	***16,498***	***42,457***	***+157.34***	*+**17.48***	***42,496***	***+0.09***	***+0.03***
Coffee and forest mosaic		6,717			2,839		
Coffee with shading trees		7,869			6,905		
Mature monoculture coffee		8,553			17,973	**+110.13**	**+36.71**
Young monoculture coffee		16,270			10,059		
Agriculture and coffee mosaic	16,498						
Mixed agriculture		1,968			2,663		
Bare soil		1,080			2,057		
Burn scars		***659***			***2,651***	***+302.27***	
Water	***148***	***148***			***148***		
Total	***51,609***	***51,610***			***51,610***		

Table 4-2 Cumulative Land Cover Changes 1985, 1994 and 1997

The most striking change in the Sekincau site between 1985 and 1994 is the loss of high density natural forest. Between 1985 and 1994, there was a 16,647 ha reduction in high density natural forest, this equates to a deforestation rate of 74 % between 1985 and 1994. In this period the annual deforestation rate in high density natural forests (closed forest) was 8 %. Table 4-2 also shows a similar reduction in low-density (disturbed; open forest) natural forest, with a total loss of 80 % or an annual loss of 9 %. The results of the change analysis between 1985 and 1994, show that the area of cultivation, especially coffee, has expanded 2.5-fold (16,498 ha in 1985 to 42,457 in 1994) at the expense of the natural forest.

Between 1994 and 1997, the annual rate of deforestation remained constant at around 8 %. However, the annual % loss for high density forest increased by 5 % compared to the earlier period (1985-1994). A total increase of 12 % was observed for low density natural forest. The reason for this may be that much of the remaining high density natural forest is becoming degraded through illegal logging activities thus becoming low density natural forest or being completely converted to coffee gardens. The most striking changes seen between 1994 and 1997 are related to coffee expansion. It should be expressed, as a cautionary note, that interpretation of the various coffee classes from satellite imagery is partially validated. However, some conclusions can still be drawn. There seems to be an increase in monoculture coffee between 1994 and 1997, from 8,553 ha to 17,973 ha, equal to a 110 % increase. The 1997 classification also shows a large area of bare soil which is likely to be recently planted coffee or areas newly cleared for coffee. Another large increase is in the area of burn scars, from 659 ha in September 1994 to 2,651 ha in October 1997, this equates to a 300 % increase.

Analysing the change matrices in Appendix II gives an insight into the types of changes occurring at the landscape level. The predominant change seen in 1985-1994 and 1994-1997 is the conversion of natural forest to coffee plantations. Field observations confirm this, however, the change matrices show the relative percentage of the change according to different classes.

The trend between 1994 and 1997 is similar to the earlier period (1985 – 1994). However, there are some trends requiring comment. Of the remaining 5,846 ha of high density natural forest in 1994, 60 % remains this type in 1997 but 25 % has become low density natural forest. Interviews in the area indicate that these areas are being subjected to illegal logging and are very prone to fires and eventual conversion to coffee plantations. From the change matrix 1994-1997, it can be seen that 46 % of the low density forest in 1994 has become coffee by 1997.

The land tenure conflict mentioned in Section 4.1.2 is clearly identified in the change matrix for 1994 – 1997 and corroborates the field narratives. According to the matrix, 10% of the mature monoculture coffee in the site was classified as burn scar in 1997 and this result is confirmed in the field where mature coffee plantations were cut down by the Forestry Department with the ensuing conflict with local people leading to fires.

4.2.3 Sido Makmur subsite land cover change analysis from remote sensing

Change analysis was also carried out for the Sido Makmur sub-site. The deforestation rate for high density natural forest in this sub-site was 82 % between 1985 and 1994, equivalent to an annual rate of 9 %, which is slightly greater than for the Sekincau site in general. The corresponding annual deforestation rate for low density natural forest is slightly lower than the general site, at 7 %. The results also show an accelerated loss of high density natural forest between 1994 and 1997. All of this forest type disappeared by 1997, due to a 33 % annual deforestation rate between 1994 and 1997. This coincides with a 450 % increase in burn scars and an increase in low density natural forest. Burn scars account for 12 % of the area in October 1997.

Table 4-3 shows that expansion in the coffee area between 1985 and 1994 is a significant feature of Sido Makmur. There was a 3.6-fold increase in the area planted with coffee in Sido Makmur compared to a 2.5-fold increase for Sekincau.

Class	1985 (ha)	1994 (ha)	Change 1985-1994 (%)	Annual Change 1985-1994 (%)	1997 (ha)	Change 1985-1994 (%)	Annual Change 1994-1997 (%)
Natural Forest	***1,933***	***457***	***-76***	***-8***	***352***	***-23***	***-8***
High Density Natural Forest	1,131	205	-82	-9	0	-100	-33
Low Density Natural Forest	802	252	-68	-7	352	+40	+13
Coffee/Agriculture	***539***	***1,977***	***+267***	***+30***	***1,911***	***-3***	***-1***
Agriculture And Coffee Mosaic	539	0			0		
Coffee And Forest Mosaic	0	471			0		
Coffee With Shading Trees	0	271			0		
Mature Monoculture Coffee	0	0			958		
Young Monoculture Coffee	0	879			924	+5	+2
Bare Soil	0	356			29		
Burn Scars	0	38			209	+450	
Unknown	321	321			321		
Grand Total	2,793	2,793			2,793		

Table 4-3 Cumulative Land Cover Change for the Sido Makmur Sub-site

Another significant change observed in the Sido Makmur sub-site is the increase in burn scars from 38 ha in September 1994 to 209 ha in October 1997.

The change matrices in Appendix III confirm that natural forest is being converted to coffee gardens probably through burning. A small percentage of high density natural forest changed to low density natural forest which in subsequent years was converted to coffee areas. Illegal logging is one of the main reasons for reducing high density forest, with a closes canopy, to a low density canopy cover.

4.2.4 TM image level

In this section land cover changes refer only to those areas being converted from natural forest to other land cover. Since land cover/land use changes are difficult to map at this level without a large amount of field verification, we will limit the discussion to deforestation. It is assumed that areas being deforested are being converted to other land cover/land use. Figure 4-6 is a composite map showing the extent of natural forest areas within the TM wide study site (see Figure 2-1). Natural forest from the three dates of imagery is shown in shades of green. Lightest green is the extent of natural forest in 1997. Progressively darker greens show the extent of natural forest in 1994 and 1985 respectively. The recession of natural forest is occurring in irregular shaped patterns, often following contours at the edges for natural forest areas. Table 4-4 summarises changes in natural forest between 1985 and 1997.

Image date	Hectares of natural forest	Percentage area containing natural forest	Annual decrease in natural forest since 1985
1985	23,264	45 %	NA
1994	17,080	33 %	- 1.3 %
1997	12,285	24 %	- 3.0 %

Table 4-4 Summary of changes in natural forest between 1985 and 1997

Burn scars from 1997 were overlaid on the natural forest change map to illustrate how changes in forest correlate with fire. An intersection of the burn scars with the change map of primary forest shows that while many burn scars were located in what was mapped as natural forest in 1994, very few were identified in areas that were deforested between 1985 and 1994. This indicates that fire was either not set in these areas or that it was controlled. These areas were likely already planted with coffee or other crops prior to the 1997 fires and were protected from fire. The central portion of the map shows a similar pattern. Overall, it is the combination of 1997 burn scars and maps of natural forest change that provide an interesting picture of the Sekincau area.

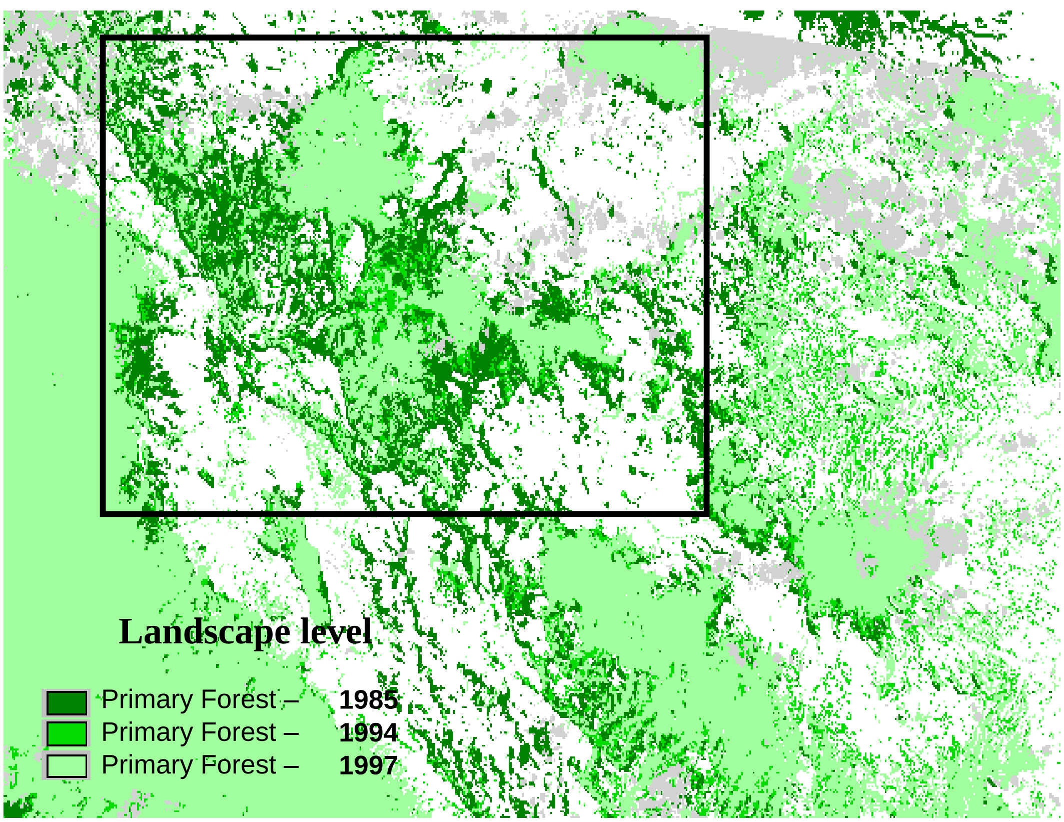


Figure 4-6 Sekincau landscape area

4.3 Migration and Land Tenure

No official population statistics are available for this site. However, based on our extensive community survey, the current total number of households is 697 and the total population is 2,599. More than 60 % of population live in *Talang* E and *Talang* D where land is still relatively abundant and close to natural forest. The population in *Talang* A is also quite large (23 %). *Talang* A is assigned for housing, school and public services. The lowest population occurred in *Talang* B. *Talang* B, however, is very near to *Talang* A. Therefore, many of *Talang* A people own coffee gardens in *Talang* B.

Almost all households work in the agriculture sector, particularly engaged in growing coffee. Less than 13 % of households worked in the non-agriculture sector such as trade, teaching, driving, house construction. The ethnic majority (between 83 %-91 %) in *Talang* A, *Talang* B and *Talang* C are Javanese, while a small proportion are Sundanese or Semendo. On the other hand, *Talang* D and *Talang* E is an ethnically mixed community. The major ethic groups are Semendo (18-38 %), Javanese (35-40 %) and Sundanese (23-26 %).

Demographic trends in our study site are heavily influenced by migration from Java and other Javanese communities from established settlements in Lampung. They migrated to the study site because of difficult lives elsewhere. They arrived when the pioneers from the family showed they were successful enough through growing coffee.

Table 4-5 shows the percentage of households by the year of their arrival in the village. This table shows the relationship between year of arrival and village settled. The majority of migrants came to the nearest *Talang* in later years and came to the furthest *Talang* in more recent years. The age of households heads in *Talang* D and E are relatively younger than in other *Talang.*

Sites	Number of Households	Year of the arrival time in the village				
		70-80	81-85	86-90	91-95	>95
Site S:	697	17	10	27	27	19
Talang A	157	49	6	17	18	10
Talang B	41	15	44	15	10	17
Talang C	71	17	24	30	23	7
Talang D	126	3	10	43	35	9
Talang E	302	6	4	27	32	31

Table 4-5 Percentage of households by year of arrival in the village

Profitability of coffee production and strengthening "informal" private land ownership attracts migrants to this area. Although land tenure security in this site is weak, because most of the coffee gardens are located inside the National Park, "private" land tenure in the park is gradually becoming more secure. Farmers feel that the government will not take their land because of the development of their community including the development of roads and other public services. The feeling of the security of land tenure has increased since the reformation period (mid-1998 to the present).

Even though none of this informally held "private" land has a government title, local society recognizes the land rights of local populations. Transferring of land right through informal sale of land and share cropping are common practices. The value of the land has been increasing rapidly. In 1985, the uncultivated land price per hectare was 250 thousand Rupiah (US$ 225; 1985 value). In 1995, the land price increased to 0.5 million Rupiah (US$ 223; 1995 value) and 1 million rupiah (US$ 128; 1999 value) in 1999 . This evidence indicates that people have confidence that security of land tenure has increased on this site and are willing to pay for land without official title.

Tenancy under sharecropping of coffee gardens is also commonly practiced. A new, young migrant initially works as a tenant under a share tenancy system. Under this system, all output and input is shared equally between informal property owner and tenant. Although security of land tenure has been increasing, it is still not fully secure, creating conditions for extraction of profit from the West Lampung coffee fields and around Bukit Barisan

National Park, for reinvestment elsewhere. We found evidence that farmers who received surplus from coffee cultivation invested their money outside the village. Some of them bought rice fields in Central Lampung, palm oil fields in Sumatra, or built houses in Java. The gardeners realize that their land could be taken back by the government at any moment. Inspection of this area by National Park officers, however, is very weak. It is a public secret that the illegal logger, or farmer who clears forest can collude with the officers, avoiding official sanctions for these illegal activities. According to the Head of Lampung's Forestry Unit, coffee farmers have contributed about 20 % of the profits of coffee production to certain officials from various government offices, including officials from the provincial forestry unit (Observer, 16 Aug 1999).

5. UNDERLYING CAUSES

Fires in 1997/1998 in the Sekincau site can be categorized as controlled fires and wild (accidental) fires. Controlled fires came from the activity of land clearing in establishment of coffee gardens by smallholders. The underlying causes of fire in Sekincau which result in deforestation, relate to a demand for coffee and its relatively high price, unclarity about land tenure and the associated migration of outsiders into the area. There are two main causes of deforestation; establishment of coffee gardens by smallholders and illegal logging activity which predispose the forest to fire. The establishment of coffee gardens greatly increased with the increase in migration and profitability of coffee production. The feeling of the security of informal land tenure in the park has increased in recent years, thus attracting more migration to the study site. Approximately half of the migrants are temporary migrants who extract profit from the coffee fields inside Bukit Barisan National Park.

During drought periods, such as El Niño, fire from land clearing and illegal-logging activities easily spreads to burn natural forest and become uncontrolled forest fires. The amount of land burned and the impacts of uncontrolled fires are much greater than controlled fires started by smallholders.

6. POLICY IMPLICATIONS

Developing policy suggestions based on a single site can often lead to misleading recommendations. In the study, some implications for both the national and provincial level are outlined.

Some of these implication are as follows:

1. The hot-spot analysis has indicated that the wave of development is moving from south to north in Sumatra, as indicated by the reduction in hot-spot numbers in Lampung over time in areas where development can take place. As indicated in this study, fire in this location will be confined to converting forest in hilly areas (mostly in National Parks) for other purposes.
2. Fire is a symptom of poor land use policies, practices and poor enforcement. It is not the problem in itself in this situation, but a tool of the developers. Fire will be reduced if the demand for coffee decreases and the subsequent demand for 'unused' forest land for conversion will also decrease.
3. External influences, in this case, the world and domestic demand price for coffee is driving the deforestation and land use change.
4. Lack of institutional capacity and support for National Park management and corruption of its system, enable illegal logging to take place within the Park. This provides the catalyst for the environmental degradation spiral to begin. The illegal logger enables fire to occur either by direct lighting, or by predisposing the forest to fire prone species by opening up canopy. The resultant environment, following burning, is then conducive for coffee production.
5. Uncontrolled and unplanned migration of people into the area, exacerbates the situation.
6. Need to improve agricultural extension systems to improve productivity of coffee, and develop sound land preparation practices.

7. REFERENCES

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APPENDICES

APPENDIX I

Source	Dates	Analytic technique
EU-Palembang station	1997: 11 Sep – 31 Dec 1998: 18 Jan – 20 Oct 1999: 26 Mar – 26 Oct	see below [1.]
EU-JRC	1996: 19 Jan – 28 Dec 1997: 2 Feb – 15 Oct	processed by a contextual algorithm
ESRIN	1993: 3 Jan – 3 Dec	processed by a contextual algorithm; day time images
CNRM	1992: 26 Apr – 31 Dec 1993: 1 Jan – 28 Mar	processed with same contextual algorithm as EU-JRC data
ATSR	1996: 1 Nov – 31 Dec 1997: 1 Jan – 31 Dec 1998: 1 Jan – 31 Dec 1999: 1 Jan – 31 Dec	background value of 308 Kelvin used; night time data
DMSP	1997: 1 Jun – 31 Dec	various extraction methods

[1.] These hot-spot data were hand processed. Both night and daytime images were used. Initially, several objects that might be fire were calibrated to establish background temperatures, after which fire locations were extracted. Subsequently, limited tests were carried out to check data and consistency.

APPENDIX II

Change matrices for Sekincau Site

in hectare and percent	1994											
1985	high density natural forest	low density natural forest	Coffee and forest mosaic	coffee with shading trees	mature monoculture coffee	young monoculture coffee	mixed agriculture	bare soil	burn scars	water	unknown	Grand Total
high density natural forest	5,846 (26)	1,961 (9)	3,968 (18)	1,057 (5)	6,258 (28)	2,092 (9)	998 (4)	47 ()	267 (1)	0 ()	0 ()	22,493 (38)
low density natural forest	0 ()	538 (4)	1,505 (12)	1,661 (13)	1,011 (8)	7,113 (57)	37 ()	225 (2)	381 (3)	0 ()	0 ()	12,470 (21)
agriculture and coffee mosaic	0 ()	0 ()	1,244 (8)	5,151 (31)	1,284 (8)	7,065 (43)	933 (6)	808 (5)	12 ()	0 ()	0 ()	16,498 (28)
water	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	148 (100)	0 ()	148 ()
unknown	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	6,857 (100)	6,857 (12)
Grand Total	5,846 (10)	2,500 (4)	6,717 (11)	7,869 (13)	8,553 (15)	16,270 (28)	1,968 (3)	1,080 (2)	659 (1)	148 ()	6,857 (12)	58,466 (100)

in hectare and percent	1997											
1985	high density natural forest	low density natural forest	Coffee and forest mosaic	coffee with shading trees	mature monoculture coffee	young monoculture coffee	mixed agriculture	bare soil	burn scars	water	unknown	Grand Total
high density natural forest	3,511 (16)	2,569 (11)	2,106 (9)	802 (4)	7,399 (33)	2,614 (12)	1,603 (7)	296 (1)	1,594 (7)	0 ()	0 ()	22,493 (38)
low density natural forest	0 ()	235 (2)	634 (5)	1,825 (15)	4,775 (38)	3,384 (27)	7 ()	662 (5)	949 (8)	0 ()	0 ()	12,470 (21)
agriculture and coffee mosaic	0 ()	0 ()	98 (1)	4,278 (26)	5,799 (35)	4,061 (25)	1,054 (6)	1,100 (7)	108 (1)	0 ()	0 ()	16,498 (28)
water	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	148 (100)	0 ()	148 ()
unknown	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	6,857 (100)	6,857 (12)
Grand Total	3,511 (6)	2,804 (5)	2,839 (5)	6,905 (12)	17,973 (31)	10,059 (17)	2,663 (5)	2,057 (4)	2,651 (5)	148 ()	6,857 (12)	58,466 (100)

in hectare and percent	1997											
1994	high density natural forest	low density natural forest	Coffee and forest mosaic	coffee with shading trees	mature monoculture coffee	young monoculture coffee	mixed agriculture	bare soil	burn scars	water	unknown	Grand Total
high density natural forest	3,510 (60)	1,461 (25)	71 (1)	33 (1)	102 (2)	175 (3)	59 (1)	5 ()	430 (7)	0 ()	0 ()	5,846 (10)
low density natural forest	0 ()	1,342 (54)	431 (17)	80 (3)	59 (2)	50 (2)	453 (18)	6 ()	78 (3)	0 ()	0 ()	2,500 (4)
coffee and forest mosaic	0 ()	0 ()	2,336 (35)	371 (6)	1,740 (26)	1,771 (26)	69 (1)	77 (1)	353 (5)	0 ()	0 ()	6,717 (11)
coffee with shading trees	0 ()	0 ()	0 ()	5,094 (65)	1,225 (16)	1,250 (16)	0 ()	64 (1)	236 (3)	0 ()	0 ()	7,869 (13)
mature monoculture coffee	0 ()	0 ()	0 ()	391 (5)	6,721 (79)	447 (5)	102 (1)	37 ()	854 (10)	0 ()	0 ()	8,553 (15)
young monoculture coffee	0 ()	0 ()	0 ()	879 (5)	7,836 (48)	5,939 (37)	64 ()	1,286 (8)	265 (2)	0 ()	0 ()	16,270 (28)
mixed agriculture	0 ()	0 ()	0 ()	0 ()	39 (2)	6 ()	1,894 (96)	0 ()	29 (1)	0 ()	0 ()	1,968 (3)
bare soil	0 ()	0 ()	0 ()	0 ()	152 (14)	327 (30)	2 ()	573 (53)	24 (2)	0 ()	0 ()	1,080 (2)
burn scars	0 ()	0 ()	0 ()	57 (9)	99 (15)	94 (14)	21 (3)	7 (1)	381 (58)	0 ()	0 ()	659 (1)
water	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	148 (100)	0 ()	148 ()
unknown	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	6,857 (100)	6,857 (12)
Grand Total	3,511 (6)	2,804 (5)	2,839 (5)	6,905 (12)	17,973 (31)	10,059 (17)	2,663 5	2,057 (4)	2,651 (5)	148 ()	6,857 (12)	58,466 (100)

APPENDIX III

Change Matrices for Sido Makmur Sub-Site

in hectare and percent	1994								
1985	High density natural forest	low density natural forest	Coffee and forest mosaic	coffee with shading trees	young monoculture coffee	bare soil	burn scars	unknown	Grand Total
high density natural forest	205 (18)	227 (20)	346 (31)	166 (15)	102 (9)	47 (4)	37 (3)	0 ()	1,131 (40)
low density natural forest	0 ()	25 (3)	111 (14)	103 (13)	399 (50)	163 (20)	1 ()	0 ()	802 (29)
agriculture and coffee mosaic	0 ()	0 ()	14 (3)	2 ()	378 (70)	146 (27)	0 ()	0 ()	539 (19)
unknown	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	321 (100)	321 (11)
Grand Total	205 (7)	252 (9)	471 (17)	271 (10)	879 (31)	356 (13)	38 (1)	321 (11)	2,793 (100)

in hectare and percent	1997							
1994	low density natural forest	coffee and forest mosaic	mature monoculture coffee	young monocultur e coffee	bare soil	burn scars	unknown	Grand Total
high density natural forest	167 (81)	0 ()	0 ()	0 ()	0 ()	38 (19)	0 ()	205 (7)
low density natural forest	185 (73)	0 ()	0 ()	31 (12)	0 ()	36 (14)	0 ()	252 (9)
coffee and forest mosaic	0 ()	0 ()	356 (76)	73 (16)	0 ()	42 (9)	0 ()	471 (17)
coffee with shading trees	0 ()	0 ()	25 (9)	170 (63)	0 ()	76 (28)	0 ()	271 (10)
young monoculture coffee	0 ()	0 ()	501 (57)	371 (42)	0 ()	7 (1)	0 ()	879 (31)
bare soil	0 ()	0 ()	64 (18)	263 (74)	29 (8)	0 ()	0 ()	356 (13)
burn scars	0 ()	0 ()	12 (31)	17 (43)	0 ()	10 (25)	0 ()	38 (1)
unknown	0 ()	0 ()	0 ()	0 ()	0 ()	0 ()	321 (100)	321 (11)
Grand Total	352 (13)	0 ()	958 (34)	924 (33)	29 (1)	209 (7)	321 (11)	2,793 (100)