Suyanto, S., G. Applegate, R. P. Permana, N. Khususiyah, and I. Kurniawan. 2004. The role of fire in changing land use and livelihoods in Riau-Sumatra. Ecology and Society **9**(1): 15. [online] URL: http://www.ecologyandsociety.org/vol9/iss1/art15

Report

The Role of Fire in Changing Land Use and Livelihoods in Riau-Sumatra

S. Suyanto[1], *Grahame Applegate*, *Rizki Pandu Permana*, *Noviana Khususiyah*, and *Iwan Kurniawan*

ABSTRACT. Results from remote sensing analysis, participatory mapping, socio-economic interviews, and hotspot information that were analyzed in a geographic information system (GIS) show how fire has changed the landscape through its use in land preparation for oil palm and timber plantations and in the development of transmigration settlements. These timber and oil palm plantations have greatly altered the livelihood options of the communities, and have created conflict between communities and companies over land-use allocation and tenure. In many cases, conflict over tenure has been the motive for forest and land fires during the annual dry season. The study suggests that, where partnerships between communities and companies were established to develop oil palm and timber plantations that included a greater sharing of benefits and use of land, the incidence of fires designed to damage the planted resource was greatly reduced.

INTRODUCTION

Indonesia is an archipelago consisting of five major islands and about 30 smaller groups. The five main islands are Sumatra, Java, Kalimantan, Sulawesi, and Irian Jaya. The island of Sumatra is one of the most densely populated and fertile islands in the Indonesian archipelago and the impacts of Sumatra's land-use allocation policy and the use of fire for the establishment of oil palm and timber plantations are significant. Fire has commonly been used to prepare land for timber and oil palm plantations, transmigration sites and shifting cultivation because it is cheap and effective (Tomich et al. 1998b). In 1997–1998, 80% of the smoke and haze problem experienced by Indonesia and its neighbors was caused by burning forests to prepare land for, in particular, plantation development on peat soils (Applegate et al. 2001).

In the past, the large plantation companies used fire as a tool to proceed with land allocation. Land was often allocated without regard for the rights of local people who already occupied the land and, in some cases, cultivated that land. Fire was often used to drive local communities from the land. Conversely, it was also used by local communities to discourage plantation companies from planting areas over which they had assumed control (Tomich et al. 1998a). During the course of land tenure conflicts, local communities frequently burned young plantations established by large companies (Suyanto et al. 2000). Since the start of the political reformation period in Indonesia in mid-1998, the visible signs of land tenure conflicts between local communities and large companies have increased (Suyanto et al. 2000). There is more violence and burning of property, as companies can no longer rely on armed personnel to quell the unrest and protect resources. The perceived injustice felt by smallholders and local communities also decreases their incentive to control the spread of fire in large-scale industrial tree plantations (Suyanto et al. 2000).

The objective of the research reported here was to study the deliberate use of fire as a tool for the development of transmigration areas and industrial timber and oil palm plantations, and the use of fire as a weapon in land tenure conflicts by the communities that neighbor the timber and oil palm plantations. The research was designed to monitor livelihood changes brought about by widespread deforestation and the underlying causes of fire that destroyed assets and forest resources. Recognition of underlying causes is deemed to be essential background for finding solutions.

OVERVIEW OF TIMBER AND OIL PALM PLANTATION DEVELOPMENT

Major changes began to occur in the forested landscapes of Indonesia in the 1970s with the

[1]World Agroforestry (ICRAF)

introduction of powerful tractors for timber harvesting. The introduction of these machines paved the way for large-scale harvesting of the tropical lowland forests, which continues today in many parts of Indonesia. In the late 1960s, oil palm was introduced on a large scale into the lowlands of northern Sumatra following timber harvesting operations. It was not until the 1990s that large-scale industrial tree plantations on logged-over forests began in order to provide fiber for pulp mills planned for the northern parts of Sumatra and Kalimantan. This forest conversion continues today in an endeavor to supply Indonesia's pulp mills, which have the capacity to consume over 25 million m^3 annually of wood fiber (Barr 2001).

Development of industrial timber plantations formed part of the strategy for national development in the Five-Year Plan (Repelita IV) in 1984. The plan called for 6.2 million ha of timber plantations to be developed by the year 2000, of which 1.8 million ha was targeted for Java and 4.4 million ha in areas outside Java (Barr 2001). By 1998, approximately 5.6 million ha of land had been allocated for timber plantation establishment (Barber and Schweithelm 2000), of which approximately 47%, or 2.2 million ha, was to be established through the Reforestation Fund (Dana Reboisasi) (Barber and Schweithelm 2000; Kartodihardjo and Supriono 2000).

At present, the area of land planted with viable industrial timber plantations is small relative to the initial target. In 1999–2000, approximately 2.4 million ha, or less than 50% of total area of land allocated, had been planted with industrial tree plantations (Ministry of Forestry and Estate Crops 2000). Data from Riau Province indicate that there are approximately 1.5 million ha of land allocated to industrial tree plantation concessions, but the ownership of at least 20%, or 300 000 ha, of this land is disputed by local communities who claim prior ownership (Riau Provincial Forestry Office 2000).

Claims over the amount of land in each concession vary from 100 to 30% in the case of the large pulp and paper companies, to zero in the case of the State-owned enterprises, or Inhutani. Most of the plantation companies have ongoing tenure-based disputes with local and immigrant communities. Of the gross area allocated for timber plantations in Riau Province, approximately 420 000 ha, or 27% of the area, has been planted (World Bank 2001).

There has been a similar, rapid development of oil palm plantations in Indonesia, with the area of plantations increasing from 120 000 ha in 1969 to almost 3.0 million ha in 1999 (Casson 2000). The oil palm industry is dominated by large-scale private and State-owned enterprises, with 50% of the oil produced by the private sector. The palm oil sector is currently dominated by four Indonesian-owned cartels (Cohen and Hiebert 1997). State-owned enterprises manage 17% of the plantations, and 33% are in the possession of small landholders. The area of oil palm plantations in Sumatra is in excess of 2.3 million ha, or 75% of the total area of oil palm plantations in Indonesia, with over 600 000 ha in Riau Province (Directorate General of Estate Crops 2000).

Based on the development plans for industrial timber and oil palm plantations, over 9.2 million ha of forest in Indonesia is slated for conversion to some form of plantation crop. Based on development plans for Riau Province, more than 2.5 million ha of forest is in concessions allocated to plantation developments.

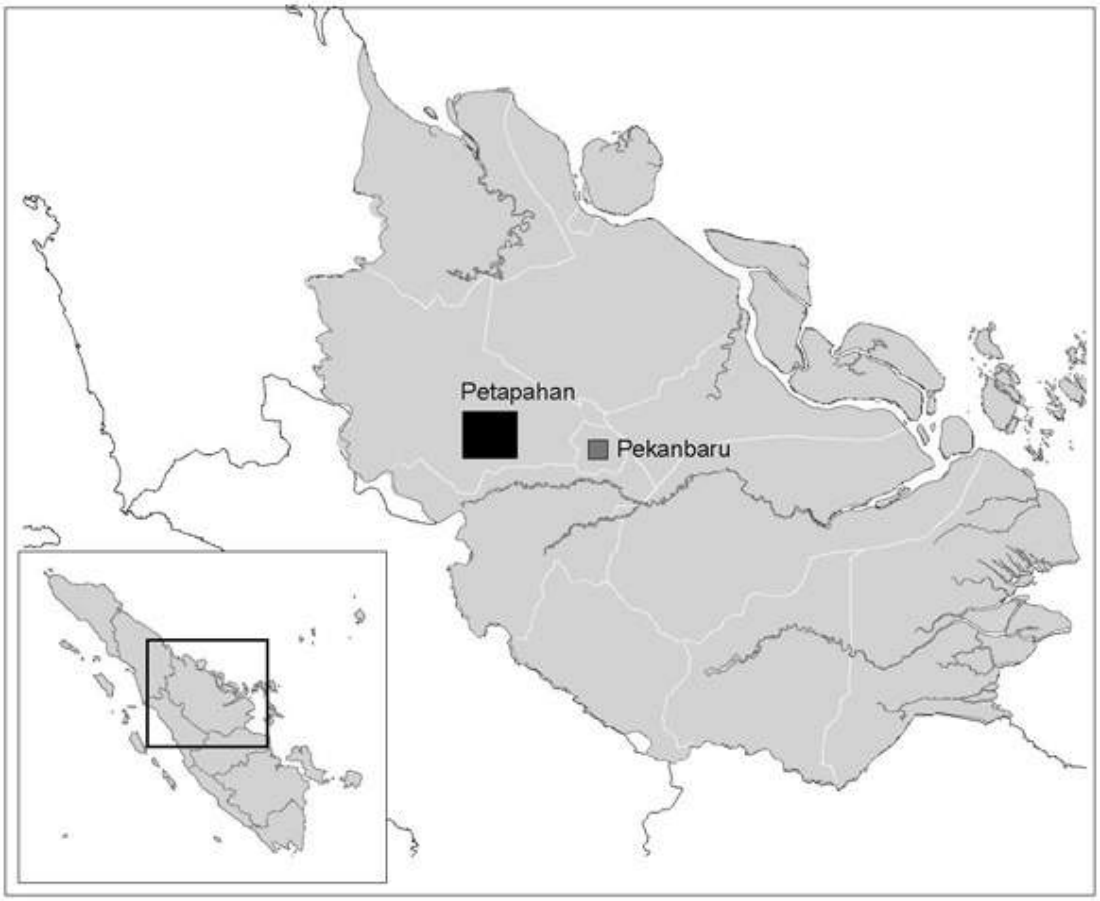
METHODS

This study applies two main levels of spatial analysis: landscape level and site-specific level. The landscape-level (Landsat TM-level) assessment focuses on general land-cover type and land-use change over time and compares this pattern with the site-level findings. At the site-specific level, the focus is on investigating the relationship between fire and land-cover change, with the information on fire location derived from hotspot analysis, participatory mapping, interviews, and field checking. A general level analysis of the hotspot data was also carried out to compare the whole of Sumatra with the data for the province and for the site.

In order to improve the analysis and understanding of the role of fire and its underlying causes, a methodology was developed that integrated the results of the socio-economic research with the results of the remote sensing-based land-cover mapping and change analysis. A geographic information system (GIS) was used for this integration. Petapahan was chosen as a study site for the site-level analysis, which integrated local people's narratives and the participatory sketch maps. The sketch maps provided additional land-cover data that could not be obtained accurately by remote sensing because of its limited spatial resolution. Using the functionality of the GIS, it was possible to calculate the area of land-use types and to determine

more accurately the size of land-cover changes within the study area rather than merely undertaking an individual analysis with remote sensing or social research. In addition, local people's narratives were added to the land-cover change results to provide insight into how and why these changes occurred.

Fig. 1. Location map of Petapahan in Riau Province, Indonesia.



Site Description

The Petapahan study site is located in the Tapung Sub District, Kampar District, Riau Province, Sumatra and is approximately 25 km from Bangkinang City, as shown in Fig. 1. The site demonstrates land-use change patterns characteristic of those in Riau Province, as well as different livelihood trends associated with these changes in land use. The site has a tropical climate, with an average annual rainfall of 3045 mm and average temperatures ranging from 26 to 32°C (Riau Provincial Forestry Office 2000).

Local communities in the area have practiced shifting cultivation for many years. Most Petapahan communities cultivate areas along the Tapung Kiri River and have established upland rice fields, but others have obtained private land and have planted tree crops (mostly rubber trees). Traditional access to the area is via the Tapung Kiri River. In the 1970s, logging companies improved accessibility by constructing roads to support their logging activities, which continued up until the mid-1990s. The area of logged forest covered 350 000 ha. In 1996, PT Akasia, received a 31 415-ha concession to develop timber plantations in this area. They have planted approximately 13 000 ha to date. However, the local community occupies about one third of the concession and the company has been forced to reduce the concession area to 19 095 ha. Unlike many of the oil palm development schemes, no partnership schemes were developed with villagers in this area. To compound the problem, only 5% of the workforce in the plantation came from the local community.

The development of transmigration schemes in the 1980s has changed the ethnic composition of the area and supplied manpower for developing plantations. The transmigrants, mostly Javanese and Sundanese, work as partners under the Koperasi Kredit Primer untuk Anggota (KKPA or Primary Co-operative Credit Members Scheme), or as laborers. Javanese and Sundanese have become the major ethnic groups in this area. In addition, there was spontaneous migration from northern Sumatra (Batak). Both groups have increased in size since the 1990s, as access was greatly facilitated by a road developed by the CALTEX Company.

Land-cover and Land-use Changes

Until 1970, there was very little change in forest cover; tall Dipterocarp forests dominated 95% of the landscape of Petapahan. Timber harvesting began in the 1970s and with it began the change, as five companies were granted logging concessions on 350 000 ha.

The second major change on this site occurred in 1982, with the establishment of transmigration settlements. From 1982 to 1987, five transmigration settlements were established with 1896 households. Development of oil palm and timber plantations was the third major land-use change. Since 1991, approximately 21 000 ha of land has been planted, under different schemes, with oil palm. Timber plantations began to be developed in 1996, and 13 000 ha of acacia plantation were established by 1999.

To illustrate the large changes in land cover and land use in the Province, a part of the study site was selected to provide a quantitative assessment of landscale-level land-cover change between 1992 and 2000 (Fig. 2). During this period, there were considerable changes in the area and quality of the forest. The total loss of natural forest over this 8-year period was 92%, or 13% each year, for high-density tall forests and 33%, or 4% each year, for low-density forests (Table 1). Analysis of a change trajectory matrix indicates that 29% of the high-density forests in 1992 and 35% of low-density forests had become oil palm plantations by 2000. Over the same period, 20% of the natural forest was logged and converted to industrial tree plantations, with most of this commencing in 1998.

Fig. 2. Land-cover change between 1992 and 2000, Riau Province, Indonesia (source: land-cover map from the unsupervised classification of Landsat imagery path 127, row 60).

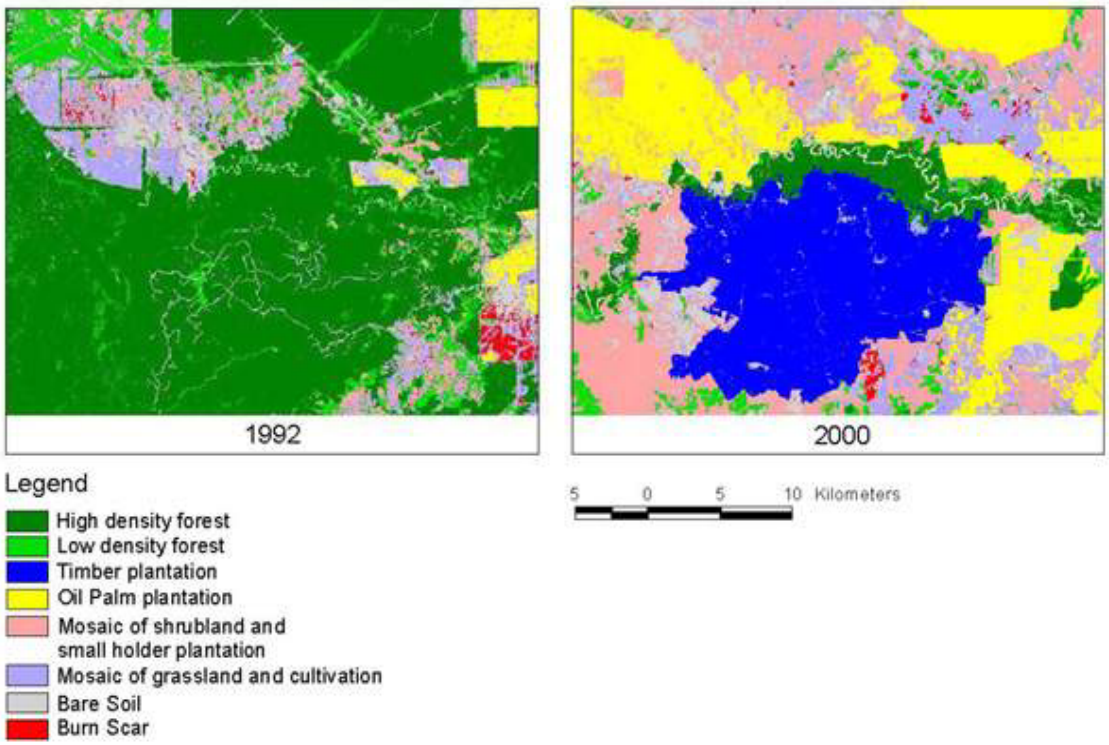


Table 1 shows that there was a 242% increase in the area of oil palm plantations in this period. The analysis also shows a 548% increase in the area of burn scars (+10 557ha) from 1992 to 1998, but this decreased to 1000 ha in 2000. Analysis of the change matrix shows that 42% of the area converted to oil palm plantation in 2000 was forest in 1992 and only 26% were converted from areas that were non-forested in 1992.

Timber plantations were initiated in 1984 and by 2000 covered 6800 ha or 1.5% of the study area. Field observations and ground-truthing of the change analysis indicate that most of the "mosaic of shrub land and smallholder plantation" and the "grassland and cultivation" mosaic can be attributed to transmigration areas, local village use, and unmanaged areas covered primarily by shrubs and alang-alang (*Imperata cylindrica*). In 1992, both mosaics combined covered 15% of the study area; by 2000, this had increased to 22%.

Table 1. Cumulative land-cover change estimates 1992–2000, landscape level

Class name	Year 1992		Year 2000	
	Ha	%	Ha	%
High density forest	86 690	50	7 249	4
Low density forest	27 344	16	18 330	10
Timber plantations	0	0	6 863	4
Oil palm plantations	23 475	13	80 197	46
Mosaic of shrub land and smallholder plantations	14 082	8	12 142	7
Mosaic of grassland and cultivation	12 411	7	35 442	20
Burn scar	1 925	1	1 046	1
Bare soil	6 795	4	12 981	7
Water and no data	2 269	1	742	1
TOTAL	**174 994**	**100**	**174 994**	**100**

Fire Hotspot Analysis

Compared with other areas of Sumatra, Riau Province displayed a high number of fire hotspots during the 1997 fire event in Indonesia. The total number of hotspots for Riau Province was 5870 or 23% of the total number of hotspots recorded in Sumatra. At the landscape level, there were 462 hotspots detected in 1997. The overlay of the 1997 hotspot data on the 1998 land-cover map (see Table 2 and Fig. 3) shows 34% of the total hotspots were located in oil palm plantations and 20% in the mosaic of grassland and cultivation. Most of the hotspots that covered both areas occurred in May, June, and July, at the beginning of the long dry season in 1997.

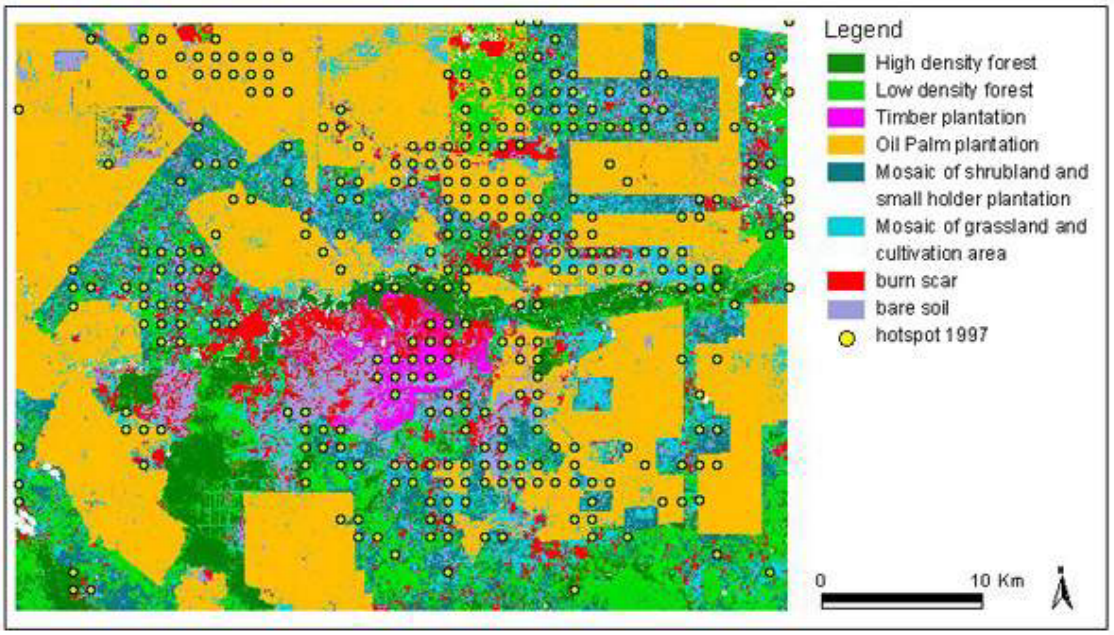
The highest hotspot density occurred on the mosaics of grassland and cultivation areas (0.51 km^{-2}). These areas are known to burn readily. The hotspot density on oil palm plantations, timber plantations, and smallholder plantations ranged from 0.22 to -0.31 km^{-2}. This result also suggests that fire is more controllable in plantations than in grassland and cultivated areas.

FIRE AS A TOOL IN LAND PREPARATION FOR OIL PALM AND INDUSTRIAL PLANTATIONS

The results from the socio-economic surveys indicated that, until 1998, most burning in Petapahan was to clear land to establish timber and oil palm plantations.

Approximately 98% of the 20 000 ha of oil palm plantations were planted between 1991 and 1998. The remaining area of oil palm plantation (2%) was planted after 1998. According to officials from a number of companies, mechanical techniques were used for land preparation, rather than fire, in accordance with the Government of Indonesia's ban on the use of fire for large-scale land preparation. However, some companies involved in nucleus plantations still used fire for plantation establishment. Many of the companies indicated that after 1998, fire was not used for land preparation. Despite this claim of zero burning, most companies that used mechanical systems for land preparation still used fire to burn off the rows of debris (gawangan) to facilitate planting.

Fig. 3. Hotspot 1997 overlaid on 1998 land-cover map (sources: land-cover map from the unsupervised classification of Landsat imagery path 127, row 60, and hot spot 1997 from Forest Fire Prevention and Control Project, EU-FFPCP 8).



One of the most common reasons for using fire in land preparation is economics. The cost of mechanical techniques, as currently practiced by many contractors, is higher than using fire to remove the residual organic debris. Table 3 shows that land preparation using fire is 300 000 Rupiah/ha cheaper than using mechanical techniques, so there is little incentive to implement zero burning techniques in land preparation. Because this is an important issue, greater use should be made of existing knowledge of cost-effective tree harvesting and mechanical/manual site preparation methods.

The second major cause of fire on this site was to prepare land for timber plantation establishment. The total planted area of timber plantations on this site is almost 13 000 ha, most of which was established between 1997 and 1999. Similar to the establishment of oil palm plantations, the cost of using mechanical techniques for site preparation is higher than using fire. Table 4 shows a cost comparison between burning and mechanical techniques for land preparation in 1997. The cost of mechanized land preparation per hectare is almost 200 000 Rupiah/ha higher than the cost of using fire to prepare the site for planting.

USE OF FIRE BY SMALLHOLDERS

Smallholders, including both local and migrant communities, also use fire for land preparation. This is the third major cause of fire. Migrants play an important role in the production of fire and smoke in this area. Migration has increased markedly since 1990, with the development of transmigration schemes and oil palm plantations. Most of the migration occurred between 1996 and 1998, with most people settling on land purchased from local Petapahan communities along the CALTEX road.

Table 2. Results from overlaying the 1997 hotspot on the 1998 land-cover map

Land Cover 1998	Area (km^2)	Hotspot Number	%	Hotspot Density (/100 km^2)
High density forest	121	19	4	16
Low density forest	233	65	14	28
Timber plantations	26	8	2	31
Oil palm plantations	726	157	34	22
Mosaic of shrub land and smallholder plantations	201	50	11	25
Mosaic of grassland and cultivation area	177	91	20	51
Burn scar	125	42	9	34
Bare soil	119	30	6	25
TOTAL	**1 728**	**462**	**100**	**27**

Table 3. Cost comparison of land preparation techniques for oil palm plantations in Riau Province, Indonesia

Activity	Using Fire[1] (Rupiah/ha)	Mechanical System[2] (Rupiah/ha)[3]
Slash	148 500	108 000
Cut	396 000	156 000
Slice	148 500	117 000
Burn	33 000	0
Mechanical Prone	0	663 000
TOTAL	**726 000**	**1 044 000**

Sources: Cost of land preparation of PT Sawit 1
[1] Based on price and physical unit in 1997
[2] Based on price in 1997 and physical unit in 2000
[3] Average exchange rate of approximately US$1: 4650 rupiah in 1997

Local farmers have the highest average area of land holding per household (8 ha), and the average land holding per household of spontaneous migrant farmers and transmigrant farmers is 3.6 ha and 2.4 ha, respectively. None of these three types of farmers have wet rice fields. The major land use here is tree cropping, especially oil palm, with more than 64% of the farmers involved in oil palm production and the remainder farming upland fields and living off secondary forests.

Almost all farmers have experience with fire in land preparation. Seventy-two percent reported that the main reason fire is used for land preparation is because

it is a cheap, easy-to-use tool. However, 12% of respondents stated that improving land fertility is the main reason for using fire in land preparation. Most farmers (more than 76%) stated that they knew that sanctions would be imposed if fire spread from their fields and destroyed a neighbor's field. The sanctions, however, are not rigid, with the amount of compensation to be paid open to negotiation. Most local farmers (92%) and spontaneous migrants (80%) did not agree with the Government's ban on fire for land preparation and did not agree with the Government imposing alternative techniques for land clearing and site preparation.

LAND TENURE CONFLICTS

The two examples strongly suggest that clear land ownership is the most important variable in reducing the conflict between communities and companies. They also show the importance of an open and transparent system of land-use allocation and compensation for expropriated land.

OPEN AND TRANSPARENT LAND-USE ALLOCATION AND COMPENSATION

The study found that, even when no partnership exists between farmers and companies for oil palm production, there is less conflict over land when the status of land ownership is clearly understood by both parties. Although the local communities surrounding the oil palm concession had already taken back and cultivated more than 90% of the area, the company was willing to compensate the community for land taken previously.

A transparent mechanism was developed to ensure all appropriate farmers received compensation, thus avoiding further conflict. In a nearby area, a timber plantation company in similar circumstances, has a serious problem because it has not compensated the local communities for land taken in the past. The communities believe that all of the concession area belongs to them (ulayat) under adat law. In addition, some land has been encroached on by migrants. As a result, numerous conflicts have arisen, and new plantings have ceased.

Table 4. Cost comparison of land preparation techniques for timber plantations in Riau Province, Indonesia

Activity	Used (Rupiah/ha)	Fire[1]	Mechanical (Rupiah/ha)[3]	System[2]
Slash	75 000		75 000	
Cut	105 000		105 000	
Slice	40 000		40 000	
Burn	45 000		0	
Mechanical Spreading	0		230 000	
TOTAL	**265 000**		**450 000**	

Source: Cost of land preparation of PT Acacia
[1] Based on price and physical unit in 1997
[2] Based on price in 1997 and physical unit in 2000
[3] Average exchange rate of US$1: 4650 rupiah in 1997

EQUITABLE PARTNERSHIPS

Developing a sound partnership between communities and companies when developing timber or oil palm plantations is a key factor in the successful management of these resources. The survey shows that there was a very weak incentive for communities to assist in suppressing fire in a plantation, when no partnership scheme existed between the company and the community. On the other hand, the willingness to

fight fires in plantations where a viable partnership scheme is in place is high. This survey found that only 4% of farmers are willing to suppress fire in timber plantations (with no partnerships), although 68–92% are willing to fight fire if it occurs in oil palm plantations (with partnership). The partnership scheme not only provides security of land and tree tenure but also enhances the source of income for the community. In contrast, all of the farmers are willing to assist if fire invades a farmer's field. The reasons for this are the social relationships and the desire to prevent the fire spreading to their own fields. The survey found that the willingness of local farmers to fight fire in forested areas is higher than the willingness of spontaneous migrants and transmigrants. This indicates that local smallholders have a higher affinity with the forest and place a higher value on it than do spontaneous migrants and transmigrants.

UNDERLYING CAUSES OF FIRE

In the study site, as is the case with many other areas in Riau Province, most fires were set deliberately to prepare land for the establishment of large-scale timber and oil palm plantations, as well as for government-sponsored transmigration schemes. The allocation of huge areas for conversion, without the development or training in appropriate cost-effective and environmentally sound land-clearing procedures and techniques, is an underlying cause of most of the large area fires. The policy of establishing large transmigration settlements through nucleus estate schemes has facilitated an increase in the area of oil palm plantations and, therefore, significantly contributrf to the fire and smoke problem in Indonesia, particularly in Riau and neighboring provinces. Smallholders also use fire to prepare land oil palm plantations and other crops. The economic incentive to use fire for land clearing is very high, as it is cheaper than using mechanical or manual methods.

The establishment of timber and oil palm plantations on land that was often obtained by force, or through a less than transparent process at the local level, has resulted in conflict over tenure with communities surrounding the plantations. In many cases, tenure conflict between companies and communities, resulting from past government policies and practices, is often the motive behind forest and land fires, and is triggered by the frustrations involved in getting satisfactory representation to have claims heard in a fair and transparent judicial system. The nature of the partnership between communities and companies in land-use development is also a very important factor influencing the incidence and suppression of fire.

POLICY IMPLICATIONS

The study suggests that the problems of land-tenure conflict should be addressed by more open and accountable land-use planning and resource allocation. A moratorium on the burning practices of many land managers would also reduce the amount of smoke and haze that is causing increased health problems among local people, as well as those in adjoining provinces and countries. Based on the analysis of the underlying causes of fire in the Petapahan site, some policy issues for both the national and provincial levels are outlined:

Zero Burning Policy

A total ban on the use of fire for land preparation for plantation development is currently impractical and unnecessary in many situations. As an alternative, intermediate-level regulations and policy change appear to be more feasible, such as:

- A total ban on the use of fire in land clearing during El Niño years, or at other critical times. Fire for land clearing may still be permitted in normal years.
- An evaluation of readily available methods and procedures for treating flammable organic fuels to ensure they dry and burn with a hot flame and produce little smoke and haze.
- Applied and adaptive research on zero or reduced burning technologies for use by communities and plantation managers in remote areas.

Reduce the Amount of Timber (Biomass) Burned

Some of the many ways to reduce the need to burn or to reduce the quantity of biomass to be burned are to:

- Develop policies and institutional mechanisms that facilitate the sale of residual timber both from large- and small-scale logging operations to medium-density fiberboard (MDF) mills, pulp and paper mills, and sawmills.
- Explore the response to removing all policy barriers (taxes and levies) at national and regional levels in marketing timber residue.

- Analyze the provincial demand for wood residue and how it might be better utilized.
- Investigate the use of different timber harvesting procedures and practices that reduce the amount of residue left after logging and clearcutting and, thus, eliminate the need to burn an area before it is planted with oil palm or timber-crop seedlings.

Forest Fire Management

In many regions, there is a need to improve the skills of forest workers, communities, and land managers in all aspects of fire management. It may be necessary to investigate the feasibility of:

- Working in cooperation with large-scale plantation operations to develop and implement suitable forest and fire management plans. These efforts should include setting up facilities and establishing practices to prevent and suppress accidental or escaped fires in plantations, or in other valuable resources.
- Developing the capacity of communities to manage the forest land under their control, by assisting with inputs to improve fire management, prevention, and suppression through the use of local materials and institutions and by being cognizant of the conditions under which many remote forest communities live.
- Investigating the introduction of a rewards system for stakeholders who maintain environmental values by the judicious use of fire in land preparation.
- Reviewing and strengthening law-enforcement mechanisms to curb land and forest fires, and delegating management of forest land to the district level.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/vol9/iss1/art15/responses/index.html

---

Acknowledgments:

The support of the European Union (EU) through a research grant to determine the underlying causes and impacts of fire in Indonesia is gratefully acknowledged. The scientists at CIFOR and ICRAF would like to thank the Tropical Research Information Center, Michigan State University, and, in Indonesia, NOAA and LAPAN for facilitating the purchase of the necessary satellite imagery used in the research. Thanks go to the EU-funded Forest Fire Prevention and Control Project in Palembang for providing fire hotspot data. We thank M. Harir Khodari and Pedi Nopialdi for their excellent assistance in the field, along with staff from oil palm and timber plantation companies and Forestry officials in Riau for their cooperation during our interviews. We are grateful to our respondents in all villages in Petapahan for their cooperation and patience during our interviews.

LITERATURE CITED

Applegate, G. B., R. Smith, J. Fox, A. Mitchell, D. Packham, N. Tapper, and G. Baines. 2001. Forest fires in Indonesia: impacts and solutions. Pages 293–308 *in* C. J. Colfer Pierce and I. Pradnja Resosudarmo, editors. *Which way forward?* RFF Press, Washington, D.C., USA.

Barber, C. V., and J. Schweithelm. 2000. *Trial by fire. Forest fire and forestry policy in Indonesia's era of crisis and reform.* World Resources Institute, in collaboration with WWF Indonesia and Telapak Indonesia Foundation.

Barr, C. 2001. *Banking on sustainability: structural adjustment and forestry reform in post-Suharto Indonesia.* Macroeconomics for Sustainable Development Program Office, WWF, Washington, D.C., USA.

Casson, A. 2000. *The hesitant boom: Indonesia's oil palm sub-sector in an era of economic crisis and political change.* Occasional Paper No. 29. Center for International Forestry Research (CIFOR), Bogor, Indonesia.

Cohen, M., and M. Hiebert. 1997. Where there's smoke... spread of Indonesia's oil palm plantations fuels the haze. Pages 28–29 *in* Far Eastern Economics Review, October 2, 1997.

Directorate General of Estate Crops. 2000. *Statistik Perkebunan Indonesia: oil palm.* Jakarta, Indonesia.

Kartodihardjo, H., and A. Supriono. 2000. *The impacts of sectoral development on natural forest conversion and degradation: the case of timber and tree crop plantations in Indonesia.* Occasional Paper No. 26 (E). Center for International Forestry Research (CIFOR). Bogor, Indonesia.

Ministry of Forestry and Estate Crops. 1992. *Statistik Pengusahaan Hutan Tahun 1991–1992.* Departemen

Kehutanan (Ministry of Forestry). Jakarta, Indonesia.

Ministry of Forestry and Estate Crops. 2000. *Statistik Pengelolaan Hutan Tahun 1999–2000.* Departemen Kehutanan dan Perkebunan (Ministry of Forestry and Estate Corps). Jakarta, Indonesia

Riau Provincial Forestry Office. 2000. *Pembangunan Hutan Tanaman Industri.* Pekanbaru, Indonesia. Indonesia. Suyanto, S., Y. Ruchiat, F. Stolle, and G. Applegate. 2000. *The underlying causes and impacts of fires in Southeast Asia. Site 3. Tanah Tumbuh, Jambi, Indonesia. Site Report.* CIFOR, ICRAF, USAID, and USFS. Bogor, Indonesia.

Tomich, T. P., M. van Noordwijk, S. Budidarsono, A. Gillison, T. Kusumanto, D. Murdiyarso, F. Stolle, and A. M. Fagi. 1998a. *Alternative to slash and burn in Indonesia, summary report and synthesis of phase II.* ASB-Indonesia Report No. 8. ICRAF, Bogor, Indonesia.

Tomich, T. P., A. M. Fagi, H. de Foresta, G. Michon, D. Murdiyarso, F. Stolle, and M. van Noordwijk. 1998b. Indonesia's fires: smoke as a problem, smoke as a symptom. *Agroforestry Today* **10**(1):4–7.

World Bank. 2001. Indonesia environments and natural resource management in a time of transition. World Bank, Washington, D.C., USA.