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Community fire use, resource change, and livelihood impacts: The downward spiral in the wetlands of southern Sumatra

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Abstract Fire is an important community wetland management tool in Indonesia, but its increasing use in the wetlands of southern Sumatra is degrading the landscape and diminishing household incomes and livelihood options. We studied evolving community land and fire use, resource and livelihood impacts on two sites of roughly 250 km^2 each using satellite image analysis and biological and socio-economic surveys. Uncontrolled fire use expanded over time in relation to *sonor* or swamp rice cultivation, logging, fishing, grazing, and annual cropping on drained wetlands. As a result, most of the landscape has been subject to repeated fires of varying intensities, more extensive in El Niño years. Direct burning by companies played a smaller transitory role in fire ignition over the two decades. But company activities and other large-scale developments contributed to expanding community fire-based land use by bringing in more people, improving access to remote wetlands or making them more flammable. Widespread, repeated fires have transformed the landscape from mature high swamp forests to uniform stands of fire-resistant *Gelam* (*Melaleuca cajuputi*) forests and thickets, open savannas and grasslands. These new types of land cover are also degrading. Local communities have rapidly adapted to the changing resources and new opportunities. Logging and fishing declined in importance, and *sonor* and harvesting of *Gelam* expanded. But resource depletion has led to falling incomes and fewer livelihood options. The impacts extend beyond local areas as workers migrate into neighbouring forests to extract resources. Large-scale developments, community fire-based management practices and landscape transformation are spreading from accessible to formerly more remote wetlands.

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1. Introduction

Large-scale fires have increasingly ravaged Indonesia's rainforests over the past 20 years, causing significant ecological, social, and economic losses in Indonesia and in neighbouring countries (Bompard and Guizol 1999; Barber and Schweithelm 2000; Siegert et al. 2001). Wetlands have featured disproportionately in the losses (Anderson and Bowen 2000; Siegert et al. 2001; Page et al. 2002). In the 1997/98 fires, it is estimated that wetlands totalled 2.1 million ha, or 18% of the total area burnt in Indonesia (Tacconi 2003), but accounted for 60% of the acrid haze produced (ADB/BAPPENAS 1999). Carbon emissions from burning peat and vegetation in that year made up an estimated 13%–40% of the mean annual global carbon emissions from fossil fuels, making Indonesia one of the largest polluters in the world (Page et al. 2002).

Southern Sumatra's wetlands have burnt extensively in recent years, and these fires have contributed substantially to the smoke haze blanketing the region. The fires have been associated with development activities such as commercial logging, draining of wetlands, establishing plantations, transmigration (resettlement), and agricultural projects (Anderson and Bowen 2000). Community practices may play an important role, however. Fire is a long-standing management tool in many areas, but intensifying and expanding its use—particularly through *sonor,* or swamp rice cultivation—may be transforming the landscape on a large scale.

The wetlands of southern Sumatra are part of the continuous east coast wetland system stretching from North Sumatra to Lampung. Unlike North Sumatra and Riau, which have an equatorial climate and relatively high rainfall throughout the year, southern Sumatra has a pronounced dry season with several consecutive months of less than 100 mm rainfall between June and October (Geophysics and Meteorology Agency; Oldeman et al. 1979; Holmes 1998). Extended droughts are more likely in southern Sumatra. *Sonor,* a traditional system of rice cultivation, is practised in years with droughts lasting five to six months (Bompard and Guizol 1999). As wetlands dry out, surface vegetation is burnt and rice seeds broadcast on the ash-enriched soil. As water levels rise, the rice grows and is eventually harvested using boats. *Sonor* is a low-cost, low-maintenance activity with little demand for labour. Farmers simply spread the seeds and return six months later to harvest the crop. *Sonor* is becoming more common as droughts become more frequent. Fire is also commonly used to open access to fishing grounds, wood, and other resources.

Information about the exact nature and sustainability of community fire-based management is limited, but it is essential that the ecological and livelihood impacts and contribution to widespread fires be better understood. Peat and other freshwater wetlands cover 19 million hectares, or 10% of the Indonesian landmass as a whole, the percentage rising to around 39% in West Papua, 33% in Sumatra, and 27% in Kalimantan (RePPProT 1990). Many people rely on the resources of these areas. Wetlands also provide invaluable environmental services in terms of carbon storage, biodiversity conservation, and hydrological regulation. Large-scale developments and intensification of community fire-based management may be endangering these benefits offered, while contributing significantly to global air pollution.

In this paper, we explore the evolution of community fire-based management and its links to large-scale developments, widespread fires, ecological resources, and livelihoods, as revealed in our study of two sites in the wetlands of southern Sumatra. We discuss the implications of these findings for sustainable community wetland management in greater Sumatra and Indonesia. We finally suggest management and policy options for a) already degraded wetlands of southern Sumatra and b) remaining remote forested wetlands of Indonesia.

2. Study area

The study sites, Mesuji and Sugihan, represent the southern and the northern sections of southern Sumatra's wetland system (Figure 1). Both sites are relatively accessible but represent different stages of intensifying land use and development, as well as different demographic, socio-economic, institutional, and site conditions (Table 1). A third site, Pampangan, which was included in the study (Suyanto et al. unpublished report) and showed similar local wetland use patterns and impacts, is excluded here.

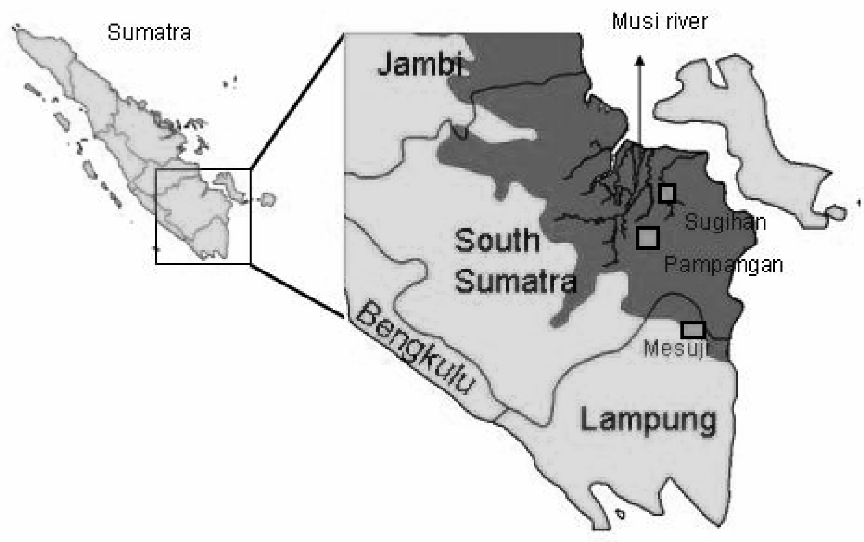


Figure 1. Location of the Sugihan, Pampangan and Mesuji study sites in southern Sumatra. Darker shade is wetland.

Table 1. Socio-economic and physical characteristics of the study sites

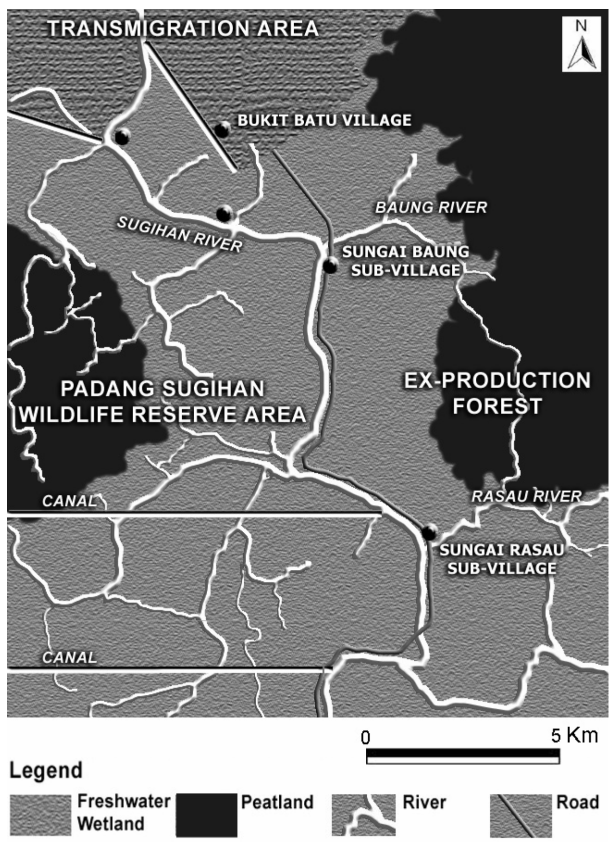
Variable	Mesuji	Sugihan
Landforms	• Peneplain, 69 km^2 • Wetland (alluvial and peat), 166 km^2	Wetland (alluvial and peat), 280 km^2
Local Settlement	1800s	1960s–70s
Population density (year 2000)	25 people per km^2 (Mesuji subdistrict) (BPS Tulang Bawang 2001)	12 people per km^2 (Air Sugihan subdistrict) (BPS OKI 2000)
Period of commercial logging in the original mature high forests	Before 1955 to late 1980s	Early 1970s to 1991
Land use in the site and its vicinity	Oil palm, coconut, and timber plantations; local and transmigrant settlements; *sonor*	Local and transmigration settlements, *sonor*
Land cover	Plantations, settlements, secondary vegetation	Transmigrant settlement, secondary vegetation
Land tenure	• Communal village land, evolving to more secure private land • Private land: company and transmigrants • Conflict areas: local village, company, and transmigrants	State land (wildlife reserve and ex-production forest) with informal local use

The Sugihan site measures 280 km^2 and is located around the Sugihan river and its tributaries in Air Sugihan subdistrict, Ogan Komering Ilir district, South Sumatra province (Figure 2). The site is dominated by flat alluvial wetland, which covers roughly 64% of the area in broad bands along the rivers, and peat further inland to a maximum depth of 95 cm in surveyed areas. It ranges in altitude from sea level to 20 m. Long-term residents moved into the area in the 1960s–70s, and now live in four subvillages along the Sugihan river. The population rose then fell with the onset and decline of commercial logging in the 1970s–80s (Suyanto et al. unpublished report).

The Mesuji site measures 235 km^2 and is located around the Buaya river in Mesuji subdistrict, Tulang Bawang district, Lampung province (Figure 3). Landforms include alluvial wetlands along the rivers, peat further inland and 69 km^2 of peneplains to a maximum of 50 m above sea level. The maximum peat depth recorded was 3.7 m. Average rainfalls during the July to October dry seasons in 1993 and 1995 were 53 and 59 mm per month, respectively, but only 5–6 mm per month in the drought years of 1994 and 1997 (Agricultural Extension Office, Menggala). Long-term inhabitants have lived in three villages along the Buaya river since moving into the area in the 1800s. Spontaneous and government-sponsored immigration caused a population explosion in the 1990s (Suyanto et al. unpublished report).

Mesuji is further along the path of exploitation and degradation than Sugihan. Mesuji was settled and logged out much earlier, and subject to substantial development including large

Figure 2. Key features and land tenure on the Sugihan site, 2002. Sources: Dinas Kehutanan Palembang and this study.



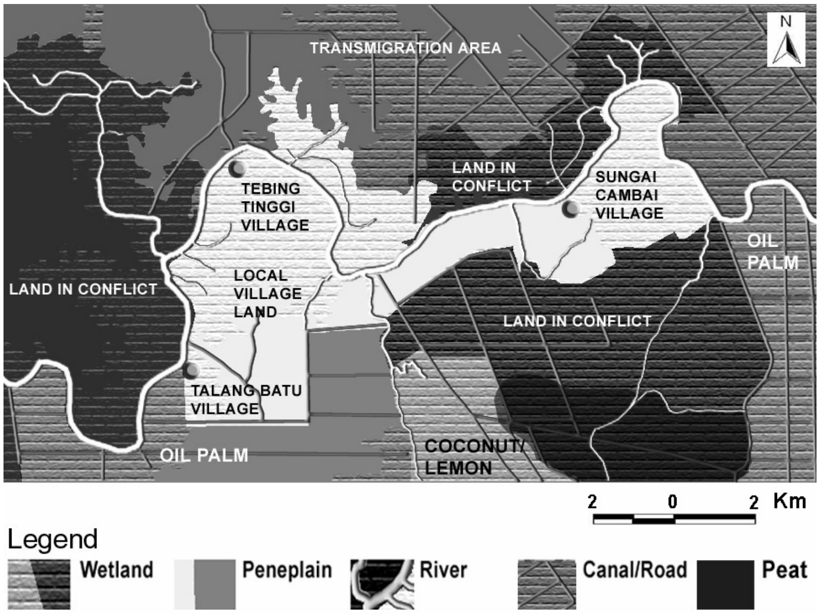


Figure 3. Key features and land tenure on the Mesuji site, 2002. Source: this study.

transmigration and plantation projects on peneplains and drained wetlands. Sugihan is still largely in secondary vegetation, with just one transmigration site developed to the north. In general, intensive land use is spreading from readily accessible into remote wetlands.

Undeveloped wetlands of Mesuji are owned or claimed by the local villages (Figure 3). In Sugihan, undeveloped wetlands are government-owned protection or ex-production forest with informal community access and use (Figure 2). Despite tenure differences, land cover, and use of the undeveloped wetland areas are currently quite similar.

3. Methods

3.1. Village socio-economic surveys

Participatory and rapid rural appraisals (PRAs and RRAs) were used to gather information on land management practices, fire patterns, demography, land tenure, major development or commercial activities, the condition of ecological resources, and livelihoods. PRAs were conducted in the Bukit Batu transmigrant village and all four local subvillages in Sugihan. In Mesuji, PRAs were conducted in the two local villages of Sungai Cambai and Talang Batu, and RRAs in the two transmigrant villages closest to the swamps, Wonosari and Dwi Karya Mustika. Participants in the group discussions were asked to list the chief livelihood sources in five-year periods from 1955 to the present, and the relative importance of each on a scale of 1 to 5.

3.2. Land cover and ecological resource change

Best recent single scene LANDSAT images were chosen for each site—Path/Row 124/062 from July 2001 for Sugihan and Path/Row 123/063 from April 2000 for Mesuji. Unsupervised classifications were performed on the wetland areas in these images, the maximum number of classes set at 30. Laumonier (1997) used similar LANDSAT image classifications with careful ground checking for identifying several successional vegetation stages in Sumatra.

Field data, including photos and vegetation and hydrological measurements, were used to define and refine the classifications. Thirty classes of land cover were narrowed down to roughly 10 distinct classes identifiable on the ground. In the final field surveys, two patches (of three plots each) within each class were sampled on each site. Classes were regrouped and accuracy of the final classifications checked again in the field to produce the final land cover maps (Figures 4 and 5). The classes largely differed in canopy or vegetation cover density as well as the wetness of the area.

Land cover was also classified for earlier years, and crosschecked for consistency with the most recent ground-checked classifications from 2000/01. These included June 1978, June 1986, June 1992 and January 1998 for Sugihan; and March 1984 and August 1996 for Mesuji. Land cover change across the time series was characterized for each site.

Field surveys identified resources in terms of accessibility, wood density and size, site suitability for *sonor* (soil types, fuel conditions), and fish conditions (water levels, presence of pools). Changes were extrapolated back through the time series of LANDSAT imagery. Information obtained from village and field-based social surveys underpinned the interpretation.

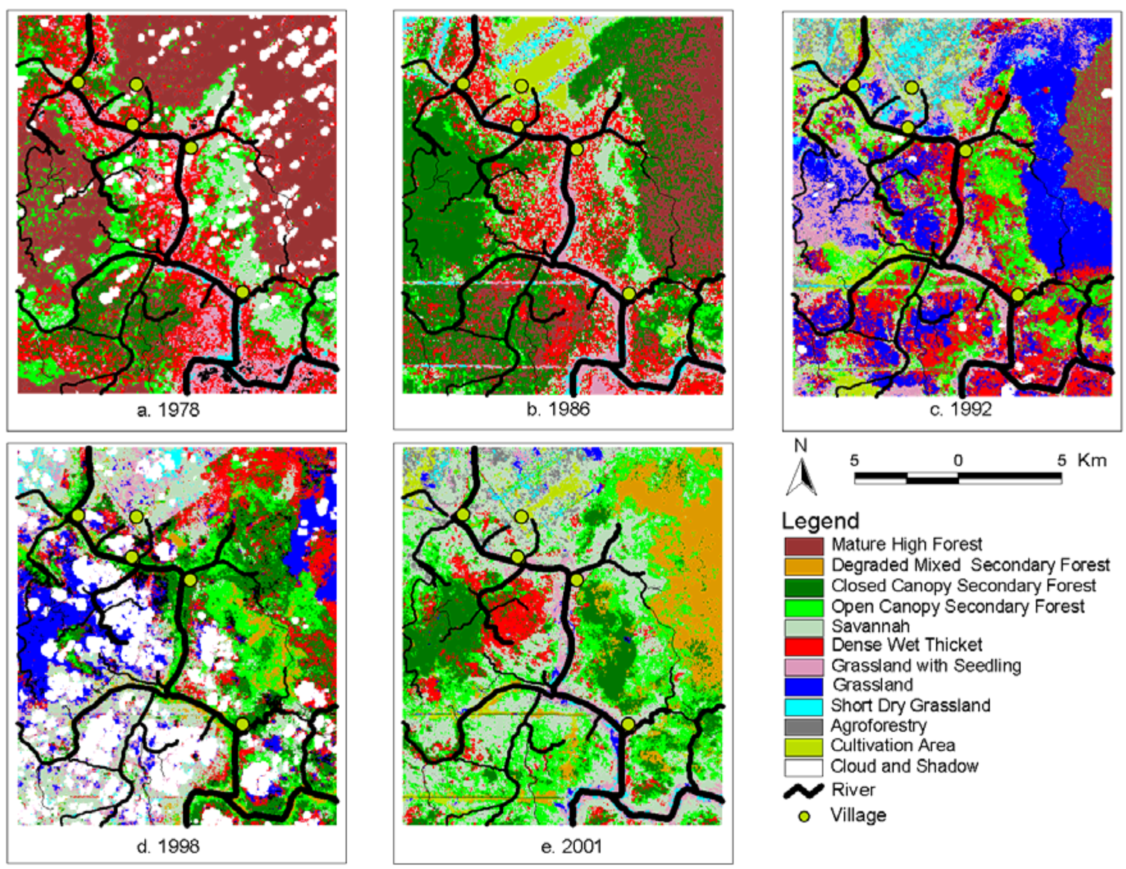


Figure 4. Land cover classifications of the Sugihan site in years 1978, 1986, 1992, 1998, and 2001.

Resource conditions in the mature high forest type could not be sampled because no patches remain on the study sites. Some extrapolation was possible, however, using earlier surveys from mature high forests in southern Sumatra (Laumonier et al. 1983; Brady 1989, 1997; Laumonier 1997).

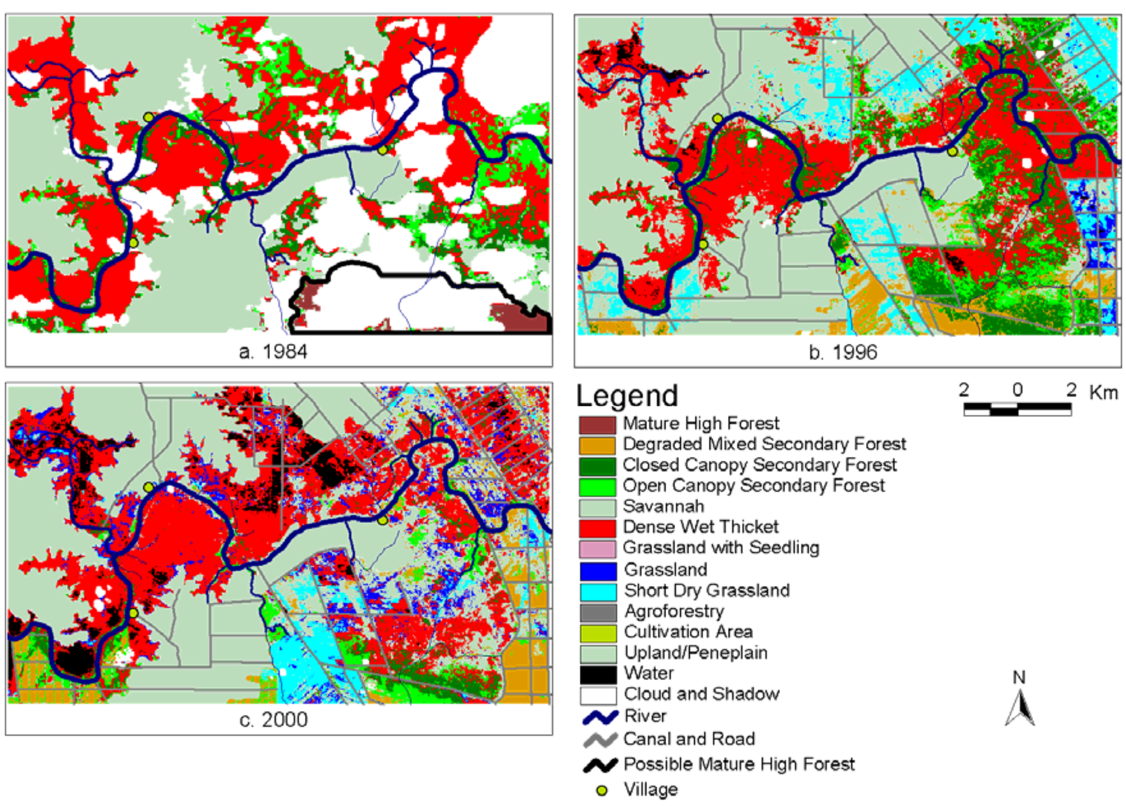


Figure 5. Wetland cover classifications of the Mesuji site in years 1984, 1996, and 2000.

3.3. Field ecological surveys and analyses

Field surveys were performed during the dry season within two relatively large, accessible and homogenous patches of each common land cover class spread out over the landscape. Attention was also paid to potential topographic, hydrological, and soil differences. Within each patch, sampling was done around three sample points located at 200 m distances along a 600 m transect. After subsequent refinement of classifications, some sample points were shifted to other classes.

A nested plot design was used for sampling trees (> 5 cm diameter at breast height, or dbh, 10 m × 10 m plots), saplings (> 2 m height to ≤ 5 cm dbh, 5 m × 5 m plots), seedlings (< 2 m height), and herbs (three 2 m × 1 m plots). Density, basal area, and volume of trees, density of seedlings and saplings, and percent cover of herbs and lianas were obtained by species. Soil layering and characteristics, and wet and dry season (standing water) water levels were recorded near each sample point. The ecological data were averaged across plots of a single land cover type on each patch.

3.4. Land and fire use mapping

Two residents familiar with the area's history and ecology were interviewed at each sample point on land use practices and users in that area and its vicinity. The questionnaire considered the nature of activities; timing, season, and frequency of use; suitability of the site; management methods including fire use and control; identity of the users; and changes over time.

3.5. Fire patterns

Maps of the area burnt over time were created from the land cover change analysis. The incidence of fires was detected by identifying areas recently burnt or, in a more degraded vegetation type, between adjacent land cover classifications in the time series (as in Jakubauskas et al. 1990). Field information was used to determine whether the type of land cover change could be attributed to fire. Information on fire frequency, intensity, timing, and purpose was obtained at each sample point by assessing the structure and composition of vegetation; charcoal marks on wood; charcoal, ash, and burnt soil in the soil profile; and field interviews. LANDSAT imagery yielded supplementary information in the intervening periods. Additional images were available for the years 1994, 1997, and 2000 for Sugihan, and 1999 for Mesuji. Links between land use and fires were gleaned from village surveys and field interviews. The location, extent, timing, and frequency of fires were assessed through overlay and spatial analyses of the burn areas over the time series.

4. Results

4.1. Community wetland and fire management practices

Land use practices vary over time and space depending among other things on ecological characteristics and the resources available in the landscape. Land cover types arising from the classifications and field surveys include mature high forests, closed and open canopy secondary forests, degraded mixed secondary forests (of mixed species and structure), savannahs (grassland with scattered trees), dense wet thickets (tall seedling and herbaceous regrowth), and three grassland types (Figures 4 and 5). Different ecological conditions and resources were associated with the various land cover types, indicating their usefulness for the major activities of *sonor*, fishing, and harvesting of *Gelam (Melaleuca cajuputi)* (Table 2).

Table 2. Average ecological conditions and resources in different land cover classes. Standard deviations in brackets.

		Melaleuca cajuputi (Gelam)											
Vegetation Class	**N**	**Tree density/ha**	**Tree basal area m2/ha**	**Tree volume m3/ha**	**Sapling density/ha**	**Mean tree dbh, cm (maximum)**	**Other tree species density/ ha**	**Seedling density/ ha, live+ dead**	**%cover herbs, live+dead**	**Litter depth, cm**	**Access-ibility**	**Flood water level, cm**	**Early dry season water level, cm**
Sugihan													
Degraded mixed secondary forest	3	247 (143)	2.76 (1.46)	1.19 (1.38)	89 (154)	25; 14; 6 (40)	567 (603)	139444 (241525)	66 (25)	19.4 (19)	Variable	52.0	2.8 (3.1)
Closed canopy secondary forest	3	2856 (2671)	9.24 (6.36)	0.78 (0.44)	22667 (15451)	6; 12; 6 (15)	156 (269)	64074 (58347)	67 (20)	6.9 (7.3)	Very low	44.4 (11.7)	5.0 (1)
Open canopy secondary forest	4	479 (253)	1.91 (1.24)	0.13 (0.11)	11700 (11921)	7; 6; 9; 6 (20)	98 (116)	43194 (32868)	51 (2)	5.7 (1.4)	Low	32.2 (10.0)	3.3 (2.0)
Savanna	4	354 (289)	2.04 (1.90)	0.30 (0.40)	2400 (2091)	5; 7; 6; 13 (26)	42 (83)	5694 (3187)	57 (14)	32.0 (14.8)	Medium	19.6 (6.0)	1.9 (1.0)
Dense wet thicket	2	117 (165)	0.31 (0.44)	0.02 (0.03)	36800 (27719)	6; 6 (8)	0 (0)	66389 (30248)	55 (20)	8.9 (9.6)	High	33.8 (21.0)	4.3 (0.5)
Grassland with seedlings	2	267 (377)	1.10 (1.56)	0.06 (0.09)	1200 (1131)	7; 7 (12)	4 (5.9)	9444 (0)	56 (5.2)	20.8 (20.3)	High	21.1 (9.3)	2.3 (1.9)
Grassland	1	0	0	0	0	.	0	556	61	23.4	Variable	31.5	2.7
Short dry grassland	1	0	0	0	0	.	0	1667	101	2.2	High	.	1.0
Mesuji													
Closed canopy secondary forest	2	683 (731)	2.58 (2.85)	0.21 (0.23)	42800 (19422)	7; 6 (10)	0	102222 (8642)	27.5 (2.1)	27.6 (7.8)	Low	28.5 (1.2)	
Open canopy secondary forest	2	483 (684)	2.37 (3.35)	0.18 (0.25)	22933 (7731)	8; 8 (15)	0	14722 (9035)	26.3 (14.4)	34.3 (0.2)	Low	13.8 (1.2)	
Savanna	2	371 (194)	2.22 (1.98)	0.24 (0.28)	8467 (8391)	7; 10 (21)	0	22500 (14535)	64.3 (12.0)	56.9 (17.5)	Medium	18.0 (8.0)	
Dense wet thicket	3	189 (327)	1.54 (2.67)	0.13 (0.22)	2400 (3075)	10; 10; 10 (15)	0	72778 (69764)	80.8 (27.0)	30.8 (8.2)	High	31.2 (6.4)	
Grassland	1	0	0	0	0		0	0	75.5	32.2	High		

Sonor dominated land use in long-drought years in both study sites. *Gelam* harvesting and processing, and fishing were common in other years. Fire is integral to all these activities. Fires are lit in the dry season to burn off the vegetation, to make it easier to walk through the wetlands, and to access timber areas or pools with fish. Fire is used to ward off the cold, insects, and other discomforts in the uncongenial swamps, besides for cooking. Annual burning also keeps riverbanks and areas around villages free of vegetation and wildlife, and generates fresh grass for cattle. There is no attempt to control the area burnt, and fires can easily spread into nearby degraded forests, particularly in long-drought years.

4.1.1. *Sonor*

Ideal *sonor* sites have abundant, continuous biomass that burns well. They are also close to rivers and villages for transport and protection. Savannahs and dense wet thickets fit the bill (Figures 4 and 5, Table 2). The savannahs in particular are very flammable, having a substantial dead herb and litter layer and scattered *Gelam* saplings and poles. Low water levels also make savannah areas prone to attempted *sonor* in shorter dry spells.

Open to closed canopy secondary forests with higher *Gelam* densities are highly flammable and have substantial biomass to burn, yet their remoteness makes them unsuitable for *sonor*. Grasslands are highly flammable, but typically low in biomass so do not provide substantial ash inputs for *sonor*. Also, where grazing has taken place, soils tend to be quite compacted. Degraded mixed secondary forests with mixed species, heterogenous structure, and higher water levels are reputedly less flammable than *Gelam* forests. Besides, these forests are relatively inaccessible and have less suitable peaty soils.

Land is cleared and prepared in late September to late October of the long-drought year. Vegetation not consumed in the first burn is slashed and burnt again. Seeds are broadcast in early November. Local paddy varieties that can be harvested within five to six months are usually used, such as *Sawah Kemang, Sawah Putih*, and *Padi Ampay*. Some farmers, especially migrants, also try to use the high-yielding varieties IR 42 and IR 64. Families prepare and plant the land, but hire labour from transmigration areas to help with harvesting.

The community surveys found that the average production from *sonor* is almost equivalent to that of upland paddy, but lower than that of intensive wetland paddy cultivation (Table 3). *Sonor* contributed significantly to the total rice production for the Air Sugihan subdistrict in 1998, increasing by 67,609 tons, or 350%, in this El Niño period (Central Statistics Bureau). Mostly long-term residents practice *sonor*. In Mesuji, the *sonor* land has belonged to the local community for a long time and land tenure is now evolving into a more private system. In Sugihan, the land is in the state forest zone, but local people have cultivated it since 1981. S*onor* is crucially important for household consumption. Wetland communities are highly dependent on it because there are few alternate locations for growing rice and upland rice cultivation is also difficult in long-drought years.

Table 3. The relative productivity of paddy under different cultivation systems

Site	Average productivity over 5 years from 1996-2000 (tonnes/ha)		Productivity in 1997/98 *sonor* (tonnes/ha)	
	Wetland Paddy[1] (BPS)	Upland Paddy[1] (BPS)	*Sonor* paddy[2] (BPS)	*Sonor* paddy[3] (PRA survey)
Air Sugihan	3.0	0.0	2.1	1.6
Mesuji	4.4	2.6	n.a.	2.2

[1] Data for Air Sugihan (BPS OKI 1996-2000). Data for Mesuji (BPS Tulang Bawang 1997-2001).

[2] Data for Air Sugihan (BPS OKI 1998). Data for Mesuji (BPS Tulang Bawang 1999).

[3] Participatory Rural Appraisal in this study.

4.1.2. Timber extraction

Communities were engaged in intensive commercial logging in the original mature high forests on both sites on a formal or informal basis, as in virtually all forested areas of Indonesia. They used concession logging roads and canals, and catered to existing markets.

Following logging and burning out of the original mature high forests, the dominant woody species on these wetlands is *Gelam*. *Gelam* is a fast-growing, rapidly fruiting timber species that grows in waterlogged, acidic, and brackish soils and responds positively to repeated disturbance (Boland et al. 1984). Fires cause *Gelam* to drop its seeds. When moisture levels increase, the seeds germinate readily and grow rapidly on the ashy beds where the competing seed and litter layers have been destroyed. Trees are fire resistant once they reach three to four metres in height.

Local communities widely exploit *Gelam* for commercial purposes. It is used for construction poles, firewood, pulp, and sawn timber. The few available *Gelam* poles are cut in the readily accessible savannahs and dense wet thickets (Figures 4 and 5, Table 2). *Gelam* is scarce in the relatively inaccessible open canopy secondary forests and degraded mixed forests. Closed canopy secondary forests contain dense patches of *Gelam,* but these are remote and so harvesting is restricted to more accessible sites along streams.

Gelam is usually collected by groups of four to six people using a boat called *Klotok* that can hold up to 100 poles. Usually *Gelam* is cut in the wet season, when it can be transported down rivers. Timber cutters walk up to half a kilometre into forests from rivers and canals. Poles are carried by foot along the same routes in the dry season.

4.1.3. Charcoal production

Charcoal is an alternative source of income in Mesuji and is sold both in domestic and international markets. It is made from *Gelam* wood residue and twisted poles. Charcoal is produced by burning the wood for two days in pits on site.

4.1.4. Fisheries

Fishing has played a significant role in both study sites. Fisheries in rivers, floodplain lakes (*lebak*), and wetlands in southern Sumatra are allocated under an auction system (Sistem Lelang Lebak Lebung). The Fisheries Service (Dinas Perikanan) and local government (PEMDA) manage the system. The government sets rates and grants rights for harvesting, distributing, and marketing fish in a particular area to the highest bidder for one year (Koeshendrajana and Cacho 2001). In some cases, the area is subsequently leased to up to a dozen sublessees. Local people harvest fish for contractors and home consumption (Giesen and Sukotjo 1991).

Rivers and floodplain lakes contain water all year, while the wetlands tend to dry out in the dry season. Water levels are usually high from December to January, recede from March to May, are low from June to August, and rise again in September to November (Koeshendrajana and Cacho 2001). Fish harvests follow the seasonal cycle. In the dry season, fish are trapped in pools in the wetlands as water levels drop, and are easy to catch. During that time, catches reach up to 20 kg per day. In the rainy season, catches drop to about 5 kg per day. Fishing peaks between June and September (Giesen and Sukotjo 1991). Incomes from fishing can reach Rp. 300,000 per month during the wet season, and twice or thrice as much in the dry season (Noor et al. 1994). High yields in the dry season may also result from spawning and breeding occurring in the early wet season, followed by rapid growth during the mid and late wet season (Zieren et al. 1999).

In the wetlands, good fishing conditions may be found in the accessible sections of degraded mixed and closed canopy secondary forest patches with their high water levels and/or pools arising from peat and vegetation burning (Table 2). Dense wet thickets close to rivers may also yield fish. Fish can also be found in grasslands inundated during floods.

4.2. Evolving local land use, fire regimes, and resource shifts

Sonor, along with some *Gelam* harvesting and fishing, dominates land use in both study sites. These practices have evolved and changed following large-scale logging and/or conversion of the original mature high forest, repeated fires, and changing resources.

4.2.1. Sugihan

Until 1978. Seasonal migrants came to the area for fishing before settling permanently in the 1960s to 1970s. The area to the east of the Sugihan river was declared a production forest in 1970 and land allocated to various logging concessions (Figure 2). Local people and concessionaires began logging the more accessible mature high forests beyond the rivers and the population increased as loggers moved into the area. Local people began to practice some *sonor* in the disturbed wetlands alongside rivers during droughts in 1972/73 and 1977 (Figure 4a).

The riverbanks and areas around the villages were also burnt annually to keep them clear of vegetation and wildlife and to open access into the forest for logging and fishing. The alluvial or shallow peat areas beyond the narrow strip of grasslands up to 3 m from the Sugihan river appear to have been burnt at some time, possibly in the course of *sonor,* logging, or fishing (Figure 4a). Fire could also have spread from riverbank burning.

In 1978, most of the site further away from the rivers was still under mature high forest (37% of the area; Figure 4a, Table 4) containing valuable timber species such as Meranti (*Shorea* sp.), Terantang (*Campnosperma* sp.) and Pulai (*Alstonia pneumataphora*) on alluvial and peat soils, and Ramin (*Gonystylus bancanus*) on peat soils (Laumonier et al. 1983; Brady 1989, 1997; Laumonier 1997).

Annual burning along the riverbanks and areas around the villages created grasslands (9.2% of the area), probably with some *Gelam* seedlings as on the present landscape. Beyond the narrow strip of grasslands to up to 3 m from the Sugihan river, the land cover was reduced to a mix of savannahs, open and closed canopy secondary forests, or dense wet seedling thickets. Secondary forests in alluvial or shallow peat areas with low disturbance would have had a mixed composition with *Gelam, Macaranga pruinosa, Alstonia pneumatophora, Campnosperma* sp., *Ilex cymosa, Ploiarium alternifolium,* and *Dyera* lowii (Brady 1989; Laumonier 1997). In cleared and repeatedly burnt areas (perhaps the savannah and dense wet thicket types covering 26% of the area) *Gelam* was probably the dominant woody species along with sedges and grasses, as on the current landscape (Laumonier et al. 1983; Giesen and Sukotjo 1991; Laumonier 1997).

1978–86. In the early 1980s, most of the mature high forest to the east of the site was being commercially logged using logging rails (Figure 4b). The mature high forest in the northern part was cleared to establish the Air Sugihan transmigration area (Figure 2). The locale has a system of canals and permanent agriculture supported by annual burning for fertilizing and weed control. Two canals were also established to the west of the Sugihan river for another transmigration development but the project was abandoned in 1983 when the area was redesignated as the Padang Sugihan Wildlife Reserve for elephants herded in from adjacent transmigration sites (Brady 1989). The canals provided increased access for local people, however, and the new reserve continued to be subject to logging and other activities, perhaps including some burning.

Table 4. Percent area in different land cover classes in Sugihan from 1978 to 2001

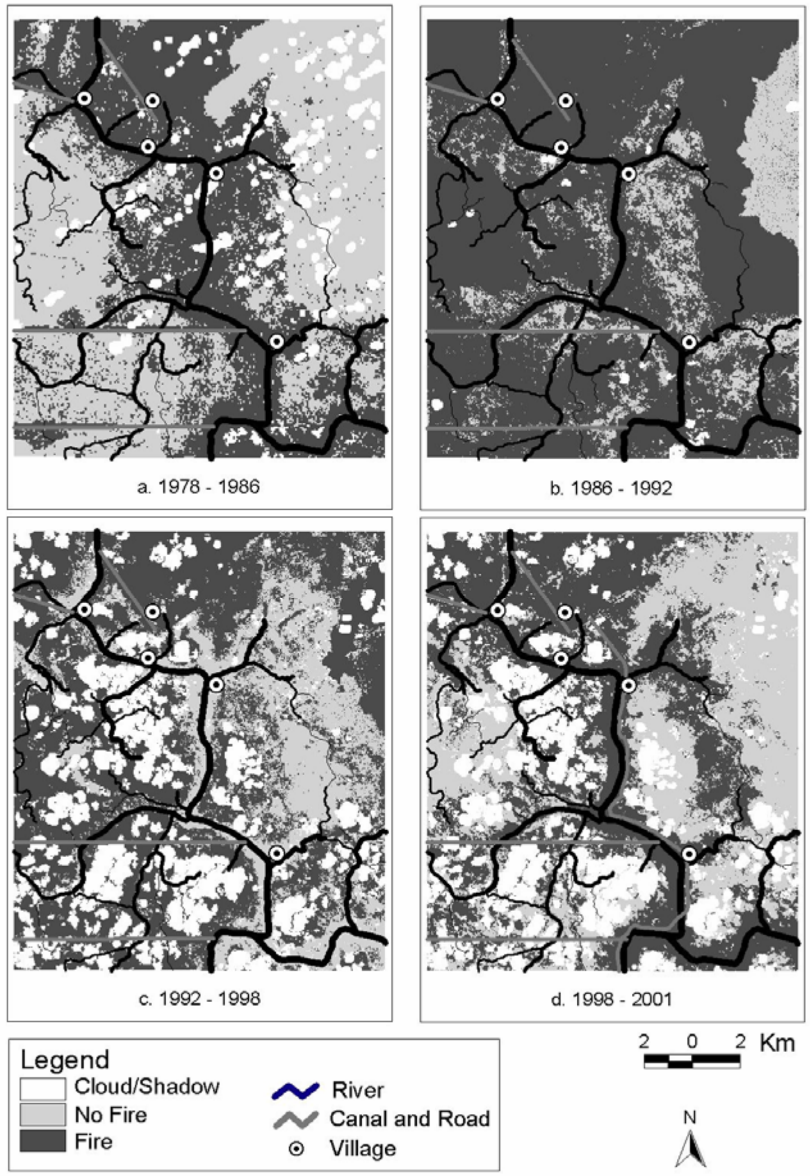
Land cover class	1978	1986	1992	1998	2001
Mature high forest	37.0	17.4	6.0	0.0	0.0
Secondary forests	26.4	51.6	24.8	47.8	81.1
Degraded mixed secondary forest	0.0	0.0	0.0	3.0	13.7
Closed canopy secondary forest	6.7	33.0	0.0	15.0	13.2
Open canopy secondary forest	11.1	5.1	10.9	11.6	22.2
Savannah	8.7	13.5	13.9	18.2	32.0
Young secondary regrowth	26.3	24.8	31.7	16.3	10.7
Dense wet thicket	17.9	18.2	19.5	10.8	6.3
Grassland with seedlings	8.4	6.6	12.2	5.5	4.4
Pure grassland	0.8	2.3	27.9	11.3	2.7
Water	1.2	0.3	0.6	3.1	0.7
Agriculture/agroforesty	0.0	3.5	8.2	0.0	4.8
Cloud	8.3	0.1	0.9	21.4	0.0
Total	100.0	100.0	100.0	100.0	100.0

Local people continued to cut timber in previously disturbed areas beyond the rivers. They also practised some *sonor* in the 1982 El Niño, and burnt the area along the rivers yearly. This practice resulted in strips of up to 1.5 km wide from the rivers (32% of the area) being repeatedly burnt at varying frequencies, which allowed for differential regrowth (Figure 6a).

Commercial logging and transmigration development led to a large 52% decline in the area under mature high forest (Table 4, Figure 4b). Intensively logged areas in the wildlife reserve and edges of the production forest to the east had changed to logged-over and secondary forest types by 1986. There was also some regrowth to higher density secondary forest in the previously disturbed areas beyond the rivers. This change amounted to a 95% increase in degraded and secondary forests, which now covered at least 52% of the landscape.

Species composition was probably made up of mixed pioneers, if subject to less disturbance, and almost pure *Gelam* in areas cleared and burnt repeatedly. Repeatedly burnt areas adjacent to the rivers were still in young secondary regrowth—probably *Gelam* dominated—covering about 25% of the landscape. The annually burnt narrow strip along the rivers was still in pure grass-sedgeland.

Figure 6. Area affected by fire between 1978-86, 1986-92, 1992-98 and 1998-01 in Sugihan.



1986–92. Commercial logging continued and intensified in the remaining mature high forests to the east until the El Niño year of 1991. *Sonor* was practiced again in the drought years of 1987 and 1991 in the previously burnt broad strip adjacent to the rivers and villages, where *Gelam* regrowth burnt well to create an ash bed. *Sonor* was more widespread in 1991, practised by both original inhabitants and transmigrants. Transmigrants took to *sonor* after crops in the reclaimed wetlands declined or failed after 10 years of nutrient depletion through burning, development of acid sulphate soils, and difficulties with managing water.

Eighty-two per cent of the site was burnt between 1986 and 1992, the largest areas in the El Niño years of 1987 and 1991 (Figure 6b). The large fires could be attributed to forest degradation through logging and draining, particularly in the reserve (Brady 1989), incidental human activities in logging areas, burning for *sonor*, annual grassland burning, and escaped fires.

Continued commercial logging removed valuable remnant timber and further degraded the mature high forests. The large fires devastated the degraded landscape, leaving just the easternmost section, amounting to 6% of the study area, under partially logged-over mature high forest and burning down all the closed canopy secondary forest (Figure 4c, Table 4). Grassland types increased from 9% to 40% of the area. There was regrowth to open canopy secondary forest in the unburnt section to the east. There was a significant decline in wood resources during this period, both primary and secondary forest types.

1992–98. Local people continued to log the remnant mature high forest after the 1991 fires (6% of the area) and searched for buried burnt wood elsewhere. As commercial timber declined, they also began to harvest the new resource, *Gelam*, in the older regrowth stands following fires.

In the subsequent El Niño periods of 1994 and 1997/98, local communities practiced *sonor* again. Larger areas were burnt and cultivated in 1997/98, as delineated in Figure 7a. In the 1997/98 fires, the last remnant logged-over patches were burnt along with most of the rest of the landscape, except alongside the rivers, including the regrown forest patches. Between 1992 and 1998, 48% to 73% of the area was burnt with fires arising from activities within already degraded forests or spreading from *sonor* and annual grassland burns (Figure 6c).

Secondary forest cover increased from 25% to 48%, particularly closed canopy forest from 0% to 15% (Figure 4d, Table 4), as a result of regrowth in the remote production forest area to the east, including areas burnt before 1986 and in 1991. *Gelam* probably dominated the cleared and repeatedly burnt secondary forest, whereas the recently logged-over burnt peat forest to the east had a more mixed composition of pioneer species. The 1991 fires reduced the area of young secondary regrowth and grasslands from 59% to 28%. Dense wet thickets declined from covering 18% to 19% of the landscape to 11%. Thickets largely disappeared from original locations next to the Sugihan river, with regrowth into savannahs and open canopy secondary forests.

Repeated burning also evened out depressions in the wetland soils, resulting in the loss of dry season fish pools near local villages. However, local people attribute the decline in fish since 1991 primarily to peat forest fires, which acidified the water seeping into the river. This hypothesis remains to be verified.

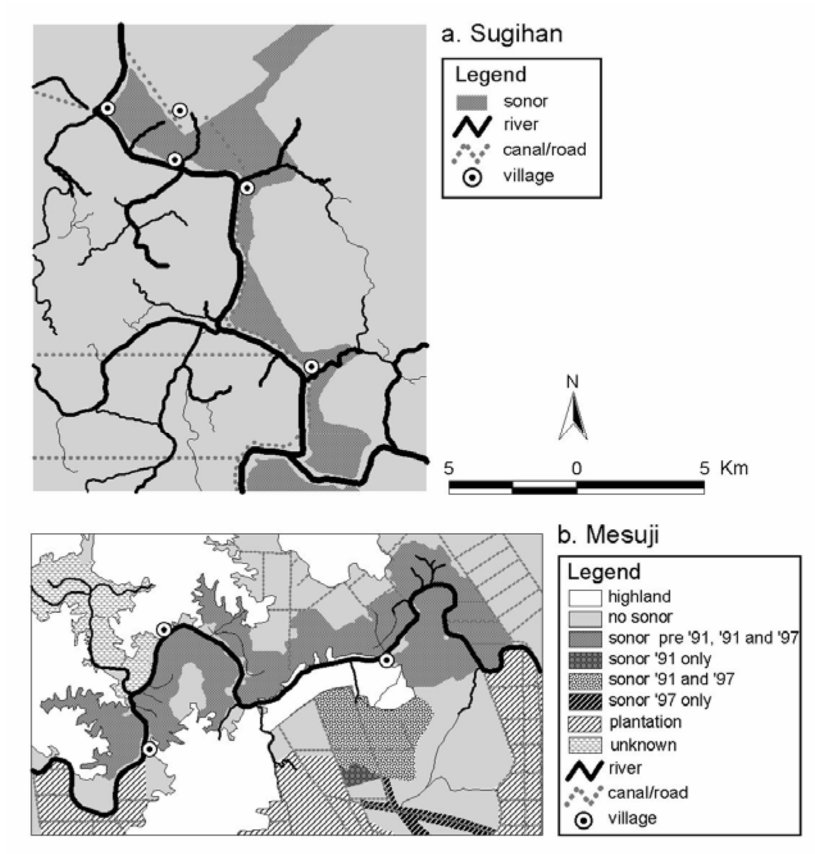


Figure 7. a) Sonor area on the Sugihan site, and b) Expansion of sonor area from before 1991 to 1991 and 1997 in Mesuji.

1998–2001. By 2001, the more accessible areas—transmigration area and strips along the rivers—were burnt again (41% of the area), probably repeatedly, while the remote areas continued to regrow (Figure 6d). There were attempts to burn for *sonor* whenever there was a slightly long dry season, which practice increased the frequency of fires. There was increased extraction of accessible *Gelam* poles and larger trees for construction and pulp, taking advantage of increased demand and available trees. In 2000, the government began building a new road linking the transmigration settlement with Riding village in Pampangan subdistrict. The road could affect local land use practices by opening up markets and bringing new developments like plantations into the study site.

The landscape in 2001 was dominated to 67% by young *Gelam* forest regrowth of varying densities (Figure 4e, Table 4). Grasslands occurred near the rivers and covered 7% of the area, 4% of which had scattered *Gelam* seedlings. Degraded secondary forests of mixed structure and composition of pioneer woody species and substantial liana cover on peat soil, occupied 14% of the area, mainly in the more recently logged-over burnt area to the east.

4.2.2. Mesuji

Until 1984. Local people began logging commercial timber in the original mature high forests in the 1950s. By 1984, most of Mesuji—both peneplain and wetland areas—was logged over. Wetland areas beyond the rivers had been frequently burnt for *sonor* starting in the 1950s (Figure 7b). Social surveys suggest that *sonor* occurred during the long-drought years of 1955, 1957, 1961, 1967, 1972/73, 1977, and 1982 in the disturbed forest areas. Dense wet thickets of tall herbs and young *Gelam* regrowth dominated the roughly 6000 ha (62% of the visible wetland area free of cloud cover) of cleared and repeatedly burnt areas adjacent to the rivers (Laumonier et al. 1983, extrapolation from this study; Figure 5a, Table 5). These flammable accessible areas are reputedly ideal for *sonor* cultivation.

Table 5. Area (ha) in different land cover classes in Mesuji from 1984 to 2000

	Year		
Wetland cover class	1984	1996	2000
Mature high forest	**307+**	**0**	**0**
Degraded mixed secondary forest			
(or some oil palm in Mesuji)	**0**	**1,119**	**1,192**
Secondary forest of mostly *Gelam*	**3,424**	**7,818**	**5,209**
Closed canopy secondary forest	1,264	2,665	533
Open canopy secondary forest	1,161	1,154	1,016
Savannah	999	3,999	3,661
Dense wet thicket	**6,076**	**5,356**	**7,138**
Grassland	**0**	**1,955**	**1,893**
Grassland	0	239	1,001
Short dry grassland	0	1,716	892
Water	**0**	**250**	**1,050**
Cloud/shadow	**6,850**	**158**	**174**
Total wetland	16,657	16,657	16,657

In 1984, there was only one potential area of around 1200 ha of mature high forest in the peat soils to the southeast, as suggested by land cover classifications (Laumonier et al. 1983 and this study; Figure 5a), the large remnant stumps and logs still present in 2002, and field interviews. *Nypa fruticans* dominated the open to closed canopy forest fringe along the rivers, while *Gelam* trees, in varying densities following clearing and repeated burning, dominated the few other small patches scattered over the landscape. Starting from the early 1980s, larger *Gelam* trees and poles were harvested where available as an alternative commercial timber. Fishing was also common.

1985–96. From 1985 to 1987, communities logged out remnants of the original swamp forest species in the community-designated lands up to 2 km from the river (Figure 3). Large-scale concessions logged out the remaining areas to the south including the mature high peat forest (Figure 5a). Thereafter large-scale oil palm, hybrid coconut, and lemon plantations were established on the southern part of the site, and a transmigration development in the northern section followed in 1993 (Figure 3). Roughly half the transmigration and plantation land is drained wetland reclaimed since the mid-1980s. Land preparation included the use of fire, which tended to escape into the adjacent degraded landscape.

Sonor was practised more widely in the El Niño year of 1991, expanded along the new canals into contested land to the south (Figures 3 and 7b). The social surveys revealed *sonor* was also practised in 1987 and 1994, but these burnings did not show up in the field interviews and may have been of lesser importance. Areas alongside the new canals were also burnt to regenerate grass for cattle, with fires spreading into the surrounding landscape.

Fire played an important role in shaping this landscape between 1984 and 1996. Most of the area was burnt (Figure 8) at least once, but more likely twice or more owing to smallholder activities such as *sonor*, grazing, wood extraction, transmigrant agriculture, and some land clearing for large-scale developments. The fire map underestimates the area burnt, as it fails to include light burns and areas that have regrown over the 12-year period.

In 1996, *Gelam* was the dominant woody species in the remaining natural wetland areas, occurring as scattered trees to dense stands (Figure 5b, Table 5). The village lands along the rivers remained largely covered in dense wet thickets of tall herbs and *Gelam* seedlings following repeated burning (Figure 5b). A large area in the south-east, whose tenure was contested between coconut plantation owner PT SACNA and Sungai Cambai village, regrew into a mix of higher density *Gelam* forests and degraded mixed forests on peat areas, after being cleared and repeatedly burnt. Elsewhere, the contested area regrew into savannas and dense wet thickets. The extraction of *Gelam* timber and poles increased in the secondary forests and dense wet thickets, excluding the peat area to the south. *Gelam* was first extracted for sawn timber with diameters above 20 cm, but rapid extraction and repeated burning for *sonor* reduced the number of large trees. People engaged in *Gelam* cutting could also have caused fires, particularly given the degraded, flammable condition of the landscape.

Village surveys suggested declines in fish yields since the 1990s owing to industrial pollution in the river and wetland reclamation. The timing also coincides with the large El Niño fires of 1991, but the existence of causal relationships is unknown.

1996–2000. Local communities practised *sonor* again in the El Niño period of 1997/98, expanding the area further south to include the drained accessible peat sections along the canals (Figure 7b). About 75% of the landscape burnt during this period, excluding the developed oil palm areas and some of the peat forest area to the south (Figure 8). There were also repeated fires in the transmigration, coconut palm plantation, and contested areas. Fires largely originated from activities such as *sonor*, wood extraction, grazing, and transmigrant agriculture.

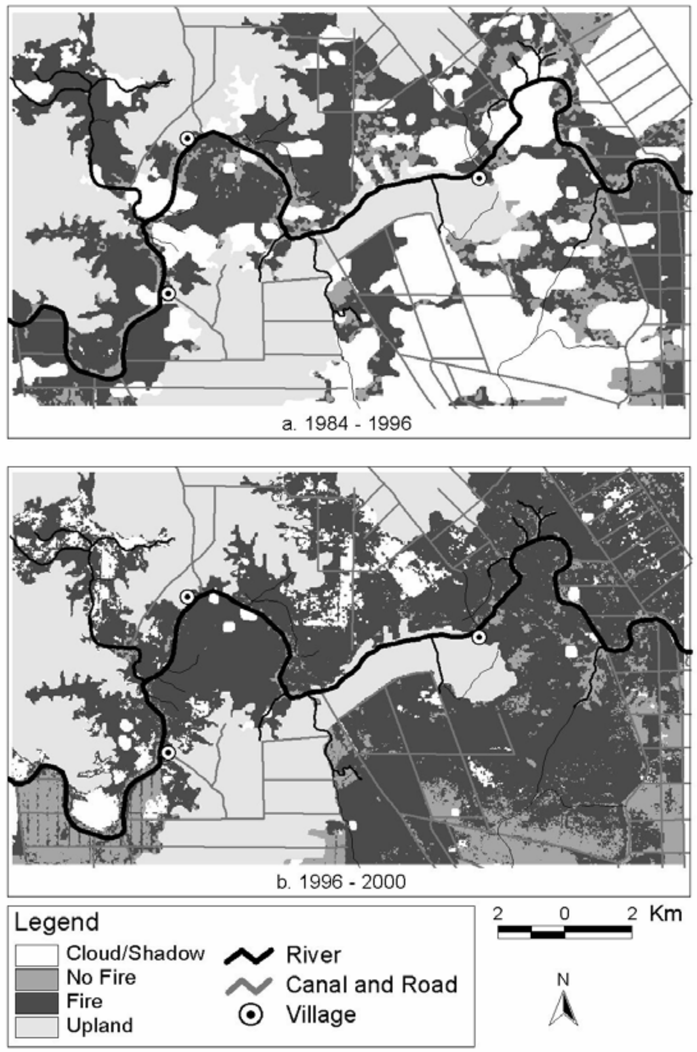


Figure 8. Wetland areas affected by fire between 1984-1996 and 1996-2000 in Mesuji.

Between 1996 and 2000, the PT SACNA–Sungai Cambai conflict area was further degraded and fragmented. Dense wet *Gelam* thickets were converted to grasslands, while open to closed canopy *Gelam* forests converted into savannas and dense wet thickets of young *Gelam* (Figure 5c). Overall, closed canopy secondary forests declined by 80% and dense wet thickets increased from 33% to 46% of the area (Table 5). There was continued *Gelam* extraction but of smaller sized trees and increasingly for charcoal.

Fish yields continued to decline. Fire was also widespread in the Mesuji wetland in the relatively long dry season of 2002, when local people and transmigrants attempted *sonor*.

4.3. Livelihood impacts and adaptations

The communities' intensifying fire-based land management triggered in part by external developments has altered the nature of the study areas' ecological resources, which in turn has led to major changes in livelihoods. People have adapted rapidly to the changing resources, opportunities, and constraints offered by the landscape transformations (Figures 9 and 10).

4.3.1. Sugihan

In Sugihan, fishing was the primary livelihood source up to 1970. Logging concessions were granted in 1970, and commercial timber extraction was the main activity until 1990. Uncontrolled logging by smallholders and concessionaires, followed by major fires in 1991, led to a rapid decline in timber and logging, followed by a decline in population. Since 1991, local people have resorted to salvaging some of the large burnt and buried timbers.

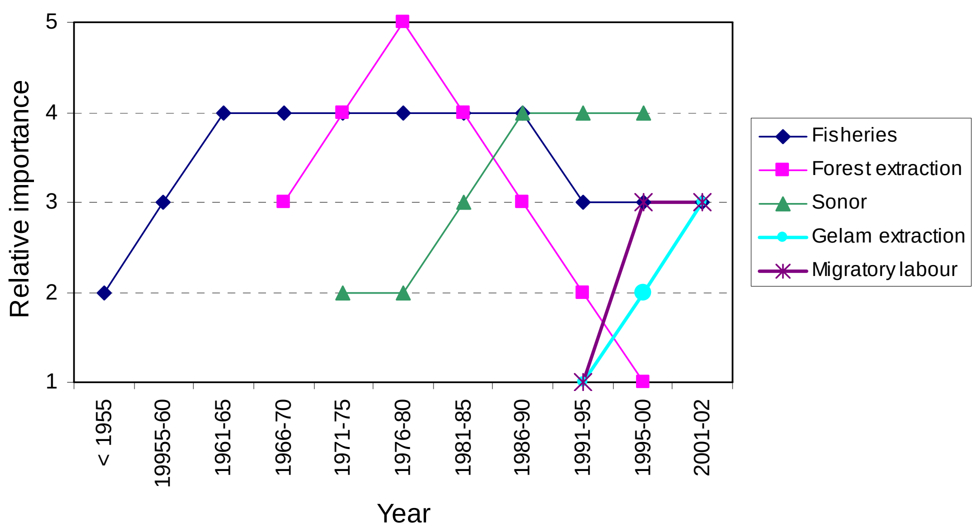


Figure 9. Trends in livelihood sources (cash income plus subsistence) of long-term residents of Sugihan. Relative importance was ranked as: (1) Very low; (2) Low; (3) Average; (4) High; and (5) Very high. Forest extraction refers to timber extracted from the original mature high forests.

Sonor appeared in the 1970s and steadily increased in importance as commercial timber resources declined and the landscape degraded. It became the main livelihood in long dry years, particularly 1987, 1991, and 1997. The importance of fishing declined in 1991 with a decline in fish yields, which coincided with the time of widespread drought and fires.

Koeshendrajana and Cacho (2001) attribute the decline in inland fisheries of South Sumatra to overfishing and environmental changes.

Gelam extraction appeared as a livelihood source in the 1990s, when the first widespread fires extirpated the remnant commercial timber stocks and left behind a landscape dominated by secondary *Gelam* forests. Since then, *Gelam* extraction has increased to become a key livelihood source in 2001/02, particularly with increased demand for construction poles and pulpwood. Demand for *Gelam* is unpredictable, however, and its value is low, making it a risky primary source of income.

Migratory labour became the second major source of income in the 1990s because of declining local natural resources and the intermittent nature of *sonor*. Local people commonly take jobs in mines on Bangka Island and logging the remaining forests of Jambi and Riau provinces.

Fishing, migratory labour and *Gelam* extraction are now the main livelihood sources in non–El Niño years, when *sonor* is not possible. Absolute income levels have been dropping since the 1980s and livelihoods are more difficult to sustain following the depletion of resources.

In the first years after arriving, the transmigrant community in Sugihan planted crops on cleared land and logged timber from forested land allocated to them. From 1984 until 1990, they planted crops on the now deforested, drained land. Prolonged flooding in 1990 and reduced soil fertility made cultivation difficult. The community also suggests that fires in the peat forest—the water catchment area—in 1991, 1994, and 1997 reduced the quality and quantity of water. Many transmigrants went home to Java or shifted into other livelihoods. The pests that have overrun their abandoned land affect neighbouring farmlands as well. Other opportunities now include *sonor* and labour in the mines on Bangka Island or logging in parts of Jambi and Riau provinces.

With the decline in timber and difficulties with permanent agriculture on wetlands, *sonor* is increasing in importance for local and transmigrant communities. *Sonor* offers high yields for household consumption and sale. It was ranked as the main livelihood in long dry seasons. The young *Gelam* forests have low value and are burnt readily for crops in *sonor* years.

4.3.2. Mesuji

Prior to 1955, fishing was the most important livelihood source in Mesuji. From 1955 to 1970, commercial logging overtook fishing in importance, but then declined through the 1980s as the forests became exhausted and converted to other types of land cover. Fishing yields declined further from 1991 until the present, a period when wetlands were drained and reclaimed for transmigration settlements and plantations, and widespread fires occurred. Fishing is now one of the least significant sources of income.

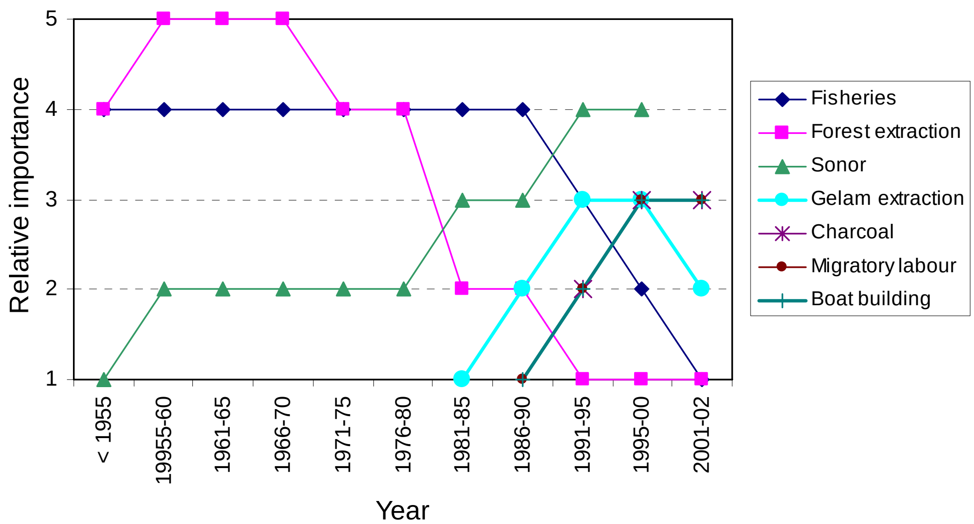


Figure 10. Trends in livelihood sources (cash income plus subsistence) of long-term residents of Mesuji. Relative importance was ranked as: (1) Very low; (2) Low; (3) Average; (4) High; and (5) Very High. Forest extraction refers to timber extracted from the original mature high forests.

Sonor has become the dominant source of income in drought years. The area in *sonor* has expanded to include more distant reclaimed areas and even area on peat soils. Resource change with commercial logging, draining and land conversion, and repeated burning for *sonor* has not only changed the relative importance of livelihood types, but also created new sources of income. During the 1980s, secondary regrowth of *Gelam* was cut for sawn timber, but this production shifted to lesser products such as construction poles following overlogging of mature trees and repeated burning. The importance of this new source of income continued to fall in 2001/02 as the resource declined further.

Charcoal production started in 1994. Sawmill offcuts were used at first, but now charcoal is made from *Gelam* offcuts and twisted poles. The production of charcoal is currently one of the three major livelihood sources in non–El Niño years. The second is migratory labour, as in Sugihan. The third and surprising source developed in the late 1980s and involves building boats using remnant timber from the last small patch of riparian forest near Sungai Sidang.

As in Sugihan, transmigrants living in the Mesuji wetlands had limited success with permanent agriculture and took to *sonor* and migratory labour instead. Both local people and transmigrants ranked *sonor* as their main source of income in a long dry season.

5. Discussion

5.1. Community wetland use and fires

Fire is an integral tool for managing wetlands on both study sites, regardless of the land tenure. Burning was uncontrolled. *Sonor* and other fire-based activities were perceived as the best use of these lands. The low value of secondary forest resources like *Gelam* discouraged conservation. Swamp fires were difficult to control, and there was no perceived need to do so.

Local community use of fire increased over time with intensification of *sonor*, logging, fishing, and grazing. Accessible areas such as near rivers were burnt frequently. Logged-over forests were susceptible to extensive burning in long-drought years, arising from activities within these areas and fire escaped from *sonor* and riverside burns. As a result, most of the landscape on both sites has been subject to repeated fire of varying intensities, more extensive in El Niño years.

Large-scale developments contributed to expanding community fire-based land use by bringing in more people, improving access to remote wetlands, or making them more flammable. The more accessible community-owned wetlands of Pampangan in South Sumatra had already been degraded and used by local people since the 1950s (Suyanto et al. unpublished report). Also in Mesuji, the accessible wetlands had already been burnt for *sonor* since the 1950s. Commercial logging from the 1970s improved access to more remote areas on all sites by opening up tracks and degrading the forests, making them fire prone and thus more suitable for *sonor*. Canals for establishing plantations or transmigration areas give access to new areas for logging, fishing, *sonor,* and grazing. Transmigration development led to annual burning of well-drained sites for cultivation. In other areas, draining has allowed for burning and limited *sonor* in even shorter dry seasons. Transmigrants brought into the swamps also adopted local practices after experiencing difficulties farming reclaimed wetlands, as also suggested by Nedeco–Euroconsult (1978) and Giesen (1991) for Jambi and Lampung, respectively. Frequent droughts in recent decades have also contributed to widespread fire use, with swamps drying and more opportunities to cultivate swamp rice.

5.2. Direct burning by companies versus community-ignited fires

Logging concession staff may have been partly responsible for fire ignition within the forests during the period of commercial logging. Fires also played a direct role in large-scale plantation development, when it was used to clear land and did spread into nearby degraded areas. Once established, oil palm plantations were not sources of fires, but communities repeatedly burnt coconut palm plantation areas because of conflicts over land tenure. In general, local and transmigrant community fires were the major sources of ignition over two decades on these study sites, and direct burning by companies played a smaller transitory role. Company activities, however, contributed to expanded community fire-based land use.

5.3. Resources and livelihoods

Logging and widespread, repeated fires have transformed the landscapes on both sites and beyond. The land cover has changed from mature high swamp forests to uniform stands of fire-resistant *Gelam,* open savannas, and grasslands; and it is further degrading.

There is a strong feedback loop between local wetland and fire use, changing ecological resources and the ways in which people adapt. Local communities have adapted rapidly to take advantage of new opportunities as the resource base changed. Commercial logging declined as timber was exhausted. Fishing declined after 1991 on both sites, coinciding with widespread drought and fires. Declining fish yields are attributed variously to industrial pollution, wetland reclamation, acidification of the water, and the loss of dry season fish habitats near local villages as a result of repeated burning and changes in land cover. Giesen and Sukotjo (1991) and Giesen (1991) cited similar reasons for fish decline elsewhere in southern Sumatra.

Sonor and *Gelam* extraction arose and expanded following logging, burning, and transformation of the mature high forest landscape to secondary *Gelam* forests and thickets. The *Gelam* regrew rapidly, burnt well, and provided favourable conditions for rice crops. *Sonor,* which produces bumper crops with low labour and cash investments, became very attractive, particularly given the lack of suitable permanent rice cultivation sites in the wetlands, failure of crops in the uplands during long droughts, and limited alternative livelihoods. Recently there were increased attempts to burn for *sonor* whenever there was a slightly long dry season, a practice that increased the frequency of fires.

On both sites, but Mesuji in particular, accessible *Gelam* trees have also been declining in abundance and size as a result of overcutting and repeated burning. Consequently there has been a shift from sawn timber to lesser *Gelam* products such as construction poles and charcoal.

Despite rapid adaptations and making use of new opportunities by local people, their income levels, subsistence sources, and livelihood options overall are declining in line with repeated burning and depletion of resources. The adaptations have extended impacts beyond the local area, as migratory labour has moved into neighbouring forests to exploit resources. The situation can only be expected to worsen as land cover increasingly changes into younger *Gelam* regrowth and grasslands. It is possible that repeated burning and further degradation of this secondary vegetation could eventually affect the intermittent *sonor* production as well.

Proximate and denser *Gelam* forests that burn well are preferred for *sonor* compared with grassier areas. Grasslands are used for *sonor* if there is still paddy seed left.

These resource changes and adaptations took place earlier on the southern Mesuji site, which is a relatively small wetland strip along the Buaya river surrounded by uplands or peneplains. The northern Sugihan site is located in an extensive section of remote wetland. In general, intensified wetland use and transformation appear to be spreading from long accessible areas into more remote sites, and large-scale developments facilitate this change.

Drought years appear to be economically critical periods, given the possibility of *sonor*, bumper rice crops, and higher incomes in a resource-poor environment. Ironically, any reduction in the frequency of droughts could further intensify economic hardships.

5.4. Implications for sustainable community wetland and fire management

Most of the wetlands of Sumatra and Kalimantan do not seem to be subject to any long-term sustainable management practices for forest and plant resources of value (Giesen 1991; Abe 1997; Bompard and Guizol 1999; this study). Important exceptions have been cited for parts of West (Giesen and Aglionby 2000) and Central Kalimantan (Jauhiainen personal communication), where the traditional users of wetlands are communities of Dayak origin who still maintain strong links to the forests, harvesting timber, and minor forest products. For the most part, people appear to have initially moved into wetlands for fishing, and this is the main activity in most areas (Giesen and Sukotjo 1991; MacKinnon et al. 1996). Alternative, sustainable options are very limited. There appears to be more exploitative use of natural resources in wetland areas once the opportunity presents itself through markets, roads, canals, and drought events. This shift occurs irrespective of type of land tenure and duration of habitation of site. The role of fire and patterns of landscape transformation may, however, be slightly different in the wetlands with equatorial type climate such as in northern Sumatra and West Kalimantan, though draining would render them all flammable.

Uncontrolled fire is and will continue to be a major feature on the degraded wetlands of southern Sumatra. It is an important tool for local communities in a fire-prone landscape, and there is no incentive to control the burning. In El Niño periods, fires are more widespread and have more severe impacts. The fires will continue to have large regional and global environmental impacts, such as substantial carbon emissions, haze, and biodiversity losses. Natural resources will continue to degrade.

People are adapting as resources change, but their options and economic returns are deteriorating. People have come to depend on frequent droughts to profit from *sonor*. Once the landscape is modified and economic pressures persist, further degradation seems inevitable. Such developments are expanding into remaining intact wetlands with slated development plans and/or migrating populations in search of livelihood options.

5.5. Management and policy options

For the already degraded wetlands of southern Sumatra, a multifaceted management and policy strategy is needed to control fires, arrest environmental degradation, and halt the spread of unsustainable practices, while improving livelihoods.

a) Given the critical importance of fire for local wetland use, it is probably unfeasible to prevent burning in the broad strips along waterways, both in the annual burn areas and long dry season *sonor* areas. The technical and socio-economic feasibility of controlled burning for *sonor* and other local wetland use should be examined, however, particularly in long drought years, so that fires are contained.

b) Beyond the broad strips along waterways, much of the degraded wetlands of southern Sumatra should be rehabilitated and conserved to prevent further large-scale fires, haze, carbon emissions, and environmental degradation. Inappropriate canals should be closed and community activities within these areas restrained. But conservation contributes little to local livelihoods. There is a need to identify viable livelihood options that will significantly improve local economic conditions and reduce the fire and degradation problem.
   - Oil palm plantation development in limited selected areas as a way to enhance local livelihoods, and prevent widespread fires and emigration, needs further investigation. Established oil palm plantations in Mesuji appear to be quite resistant to fire, but they do not contribute much to local livelihoods. Perhaps they could, but high investments on wetlands and economies of scale may demand large areas for development and partnerships with major companies. The long-term sustainability of oil palm on drained wetlands also needs to be examined.
   - Provision of livelihood options outside the swamps in long drought periods could help reduce the risk of widespread fires. Given the importance of migratory labour to Bangka, ways should be explored to improve this migratory labour system and to pull people away from wetlands to more sustainable options in Bangka and elsewhere.

c) On established transmigration sites, there is interest in shifting from annual to estate crops or agroforestry in partnership with companies to improve livelihoods and avoid annual burning (Suyanto et al. 2004). There is planned smallholder oil palm development on transmigration sites in Sugihan with local investment, results of which remain to be seen. Appropriate tree crops need to be chosen and promising options supported by local government and rural development projects. Canal and water management need improvement. Fire use for annual cultivation should be regulated to avoid destructive fires.

d) Any rural development projects aimed at improving livelihoods need to be accompanied by negotiations and agreements to control burning and to help protect and restore the larger wetland areas beyond the annually burnt strips. Adoption of any recommended practices will require the provision of incentives, clarification of tenure, community education, and formation of local institutions and regulations to support and implement such measures. Communities may also need to be financially rewarded for protecting environmental services. Long-term impacts on fisheries and local water quality could potentially be used to drive local interest in peat forest conservation and management.

For currently remote, sparsely inhabited forested wetlands of Indonesia, development policies and plans need to be reconsidered to avoid the downward spiral of environmental degradation and declining economic returns. It may be better to avoid altering the site conditions, improving access, and increasing the population in these marginal areas. Livelihood pressures and degradation could drive the sensitive wetland ecosystems and the communities forced to depend on them beyond the brink, creating major, fire-prone environmental disasters.

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