FRAGMENTATION IN PROTECTED WETLAND

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1. **INTRODUCTION**

Tropical deforestation is occurring at an unprecedented pace to the point of threatening the biodiversity and sustainability of forest ecosystem. Deforestation is removal of forest that contributes to the increase of carbon emissions. Deforestation also causes forest fragmentation. Fragmentation is a process of dividing a large and intact forest cover into smaller and less connected pieces. As defined by Coops et al. (2004), fragmentation is breaking up of habitat or continuous large cover type into smaller, disconnected parcels. Fragmentation is a dangerous threat to tropical rainforest especially the biodiversity of the ecosystem (Goparaju *et al*., 2005: Abdullah and Nakagoshi, 2007). According to MacArthur and Wilson (2001), small sized islands will have high extinction and species turnover rates. Fragmentation in long term contributes to changes in terms of edge effects, migratory corridors and loss of connectivity to the natural communities in the ecosystem. In return, species replace each other and do not commonly lead to long term dominance of any species (Bazzaz, 2000).

It is important to understand the problem of fragmentation for land use planning. Spatial and temporal information about landscape patch size, the dispersal or aggregation of activities, edge densities, and connectivity in landscape is required for the planning (Apan *et al*., 2000). The spatial and temporal information can be quantitatively measured using landscape indices that describe ecological and environmental processes. Landscape indices are crucial in detecting the pattern of change and disconnected patches that are not readily visible to the human eye or easily detectable by human analyst.

2.WETLANDS IN THE TROPICS

Tropical regions around the world are currently facing an ongoing threat of fragmentation. This undergoing threat will in long-term create a large scale of deforestation in the forest cover. The Food and Agriculture Organization of the United Nations (FAO), estimated that within a decade more than 2.4 million ha of tropical forests were lost each year in Southeast Asian countries (FAO, 2006). It is also known that Southeast Asia has more wetland compared to other parts of the world. According to Safford and Maltby (1998), the worlds wetland covers 6% of the earth and peatland makes up more than half of that. Peat swamp forest is one of the most distinctive wetland types found in Southeast Asia. About 10% to 12% of the worlds peatland area are mainly found in tropical countries covering about 30 to 45 million ha and three quarters of the world tropical peatland located in Southeast Asia which are mainly found in Indonesia and Malaysia (Mansor, 2004; Immirzi and Maltby, 1999). It is estimated that the peat swamp forest occupies 21 million ha in Indonesia and Malaysia (Dent, 2000). The huge expanses of peat swamp forest can be found associated with other wetland types such as sago, melacuca, nipah palm and mangrove (Hooijer, 2005).

In Malaysia peat swamp forest is well distributed both in Borneo and Peninsula Malaysia. The peat swamp forest covers extensively in both areas (Voglmayr and Yule, 2006). It is recorded that in the early 90's, the total peat swamp forest area in Malaysia was 2.7 million ha as shown in Table 1 (Wong, 1991). About 1 million ha are distributed in

Peninsular Malaysia and another 1.7 million ha in East Malaysia (Ambak and Melling, 2000). However, compared to the recent data the area had decreased to 1.5 million ha (UNDP/GEF, 2006). This means more than half of the peat swamp forests in Malaysia were destroyed within a decade. It is estimated that the peat swamp forest areas cover about 70% in Sarawak, less than 20% in Peninsula Malaysia and the rest in Sabah (UNDP/GEF, 2006).

Table 1: Estimate of undisturbed peatland area in Southeast Asia

Country	Area (ha x 10^6)
Brunei	0.01
Indonesia	17.00-27.00
Malaysia	2.25-2.73
Papua New Guinea	0.50-2.89
Philippines	0.10-0.24
Thailand	0.07
Total	19.93-32.94

Source: Rieley (2004)

For mangrove, it is estimated that 15.2 million ha existed as of 2005 down from 18.8 million ha in 1980 (FAO, 2007). According to FAO (2006), Asia is the lowest forest cover in terms of land area where the largest extend of mangrove is about 6 million ha. Mangrove ecosystem covers 146,530 km of the tropical shorelines of the world out of 198,000 km in 1980. This represents 2.6% losses of the mangrove in 20% (FAO, 2006). The documented losses include combine losses in Philippines, Thailand, Vietnam and Malaysia totalling an area of 7445 km^2 (Spalding, 2005).

3. CAUSES OF WETLAND FRAGMENTATION

In the past, wetland was considered as wasteland. Negative images were used to describe wetlands. Wetland was seen as the source of disease and noxious (Dahl, 2007). Prior to that, in the mid 1970's, the drainage and destruction of wetlands were accepted by government policies (Mitsch and Gosselink, 2007). The wetland was extensively replaced by agricultural, commercial and residential development. History of environmental changes had long been occurring in the history of early human before civilizations. Anthropogenic activities such as settlement and agriculture during interval ca 9000-5500 cal BP time in Central Europe and various cultural periods have been discovered on the basis of archeological findings (Kalis *et al*., 2002). The first enormous amount of human impact on natural ecosystem resulted from the Neolithic way of life where clearance of dense forest was requirement for arable farming. During the last decade human intervention had depleted the wetlands of Southeast Asia in particular (Richards, 1993).

Fire is the most periodic threat to the wetland environment especially in the peat swamp forest. According to Aiken (2004), the forest in Kalimantan, Borneo has extensively been fragmented and degraded due to the ravages of fire. Peat swamp forests are more prone to fire than other forest type because of the soil type that has limited water-holding capacity. Drought can easily cause the water level to drop and dry out producing an organically rich surface layer of peat which can easily catch fire (Akaakara, 2002). When the remaining trees are killed, canopy cover is reduced and grasses will quickly colonize the burned area.

Repeated fires can cause a complete destruction of the forest and replace it with scrub and grassland (Cochrane, 2003). Although some fires were started by burning coal seams, the majority of the fires resulted from human activities (Aiken, 2004).

Ecosystem management needs a better understanding of how the human disturbances influence ecosystem dynamics and how focal ecosystem interacts with adjacent areas (Liu *et al*., 1999). Therefore, most of the forest fires reported occurred in degraded or logged-over peat swamp forest, both in the east and west coasts of Peninsula Malaysia and the coasts of Sabah and Sarawak (Wan Mohd Shukri, 2001). The rapid population growth would also increase the pressure of land. The outcome would be the reclamation of peat swamp forest for agriculture which is causing the area to be fragmented (Wösten *et al*., 1997). In Sabah, the largest piece of peat swamp forest in Klias Peninsula was severely fragmented and degraded by fire related to agricultural activities during the El-Niño-Southern Oscillation (ENSO) events (Kamlisa, 2008). Even though certain fire was started by burning coal, the majority of fires resulted from human activities especially the use of fire to clear and prepare land for oil palm plantation (Aiken, 2004). It is reported that after the 1960s, Malaysia's economic development depended on the agricultural sector (Abdullah and Nakagoshi, 2006). During this time most of the forest areas were converted to agricultural activities, especially for the oil palm and rubber tree plantation. However, according to Chuvieco *et al*. (2009), the distance to roads is also considered as the cause of fire occurrence due to human social activities following negligence handling and giving accessibility to the forest area. Wetland locations near to settlements also prove to be more prone to fire because of the cultural practices of the community which can lead to accidental fire (Jaiswal *et al*., 2002).

4. MEASURING FRAGMENTATION WITH LANDSCAPE INDICES

The problems created by fragmentation are important to be understood for resource management and land use planning. Therefore, spatial and temporal information for decision-making about landscape patch size, the dispersal or aggregation of activities, edge densities, and connectivity in landscape are required (Apan *et al*., 2000). Landscape indices are the quantitative measurements used in the field of landscape ecology to link ecological and environmental processes with patterns found on landscape. Landscape indices are employed to create quantitative measures of spatial patterns found on a map or remote sensing image (Frohn, 1998). Landscape indices are very important to detect the pattern of change that is not readily visible to the human eye or easily detectable by human analyst. Many analyses of landscape pattern are conducted on land cover data that are stored within a GIS (Turner *et al*, 2001). There are a large number of metrics have been developed to identify the landscape composition and configuration on categorical maps (Mcgarigal and Marks, 1995).

Measurements of landscape fragmentation analysis were conducted by Apan *et al*. (2000) using landscape structure calculations. This approach is used to quantify landscape fragmentation and its change over time using metrics that can describe landscape structure. ArcView Spatial Analyst with extension patch analysis developed using Avenue Code and an interface to FRAGSTAT was used to generate landscape indices. The description of landscape indices that is generally used to quantify fragmentation is explained in Table 2. A suite of selected metrics is very useful in interpreting landscape change. No single landscape indices could capture all aspects of fragmentation whereby the common approach is to calculate a set of metrics that captures a range of fragmentation landscape (Hong *et al*., 2004).

Table 2: Description of landscape indices from FRAGSTAT software

Index	Formula	Description
Class Area (CA) (ha)	$CA = \sum_{j=1}^{n} a_{ij}\left(\frac{1}{10,000}\right)$	*Class area* is a measure of landscape composition; specifically, how much of the landscape is comprised of a particular patch type.
Percent of Landscape (PLAND) (%)	$PLAND = P_i = \frac{\sum_{j=1}^{n} a_{ij}}{A}(100)$	PLAND equals the sum of the areas (m^2) of all patches of the corresponding patch type, divided by total landscape area (m^2), multiplied by 100 (to convert to a percentage); in other words, PLAND equals the percentage the landscape comprised of the corresponding patch type. Note, total landscape area (A) includes any internal background present.
Number of Patches (NP)	$NP = n_i$	NP equals the number of patches of the corresponding patch type (class). When the NP increases indicating that the area is highly fragmented
Patch Density (#/100/ha)	$PD = \frac{n_i}{A}(10,000)(100)$	PD equals the number of patches of the corresponding patch type divided by total landscape area (m^2), multiplied by 10,000 and 100 (to convert to 100 hectares).
Mean Patch Size (MPS) (ha)	$MN = \frac{\sum_{j=1}^{n} x_{ij}}{n_i}$	MN (Mean) equals the sum, across all patches of the corresponding patch type, of the corresponding patch metric values, divided by the number of patches of the same type. MN is given in the same units as the corresponding patch metric.
Largest Patch Index (%)	$LPI = \frac{\max(a_{ij})}{A}(100)$	LPI equals the area (m^2) of the largest patch in the landscape divided by total landscape area (m^2), multiplied by 100 (to convert to a percentage); in other words, LPI equals the percent of the landscape that the largest patch comprises.

Source: McGarigal and Marks, 1995)

5. CASE STUDY: FRAGMENTATION OF WETLANDS IN THE KLIAS PENINSULA

The Klias Peninsula is an extensive wetland located in Beaufort area of approximately 130,000 ha. In the Klias Peninsula, there are seven forest reserves (FR) with a total area of 31,409 ha. Types of wetland forest reserve classes are shown in Table 3. The Binsuluk Forest Reserve (BFR) and Klias Forest Reserve (KFR) are the most protected and highly utilized PSF for research purposes. Both FR are the remaining pristine good peat swamp forest (PSF) which were gazetted as Class 1 FR in 1984. The KFR consist of 3,630 ha and BFR is 12,106 ha (UNDP/GEF, 2005). Species like *Dryobalanops rappa* (Kapur paya), *Dactylocdalus stenostachys* (Jongkong), *Shorea platycarpa* (Seraya paya) *and Gonystylus bancanus*

(Ramin) can easily be found here (Sabah Forestry Department, 2005). The upper canopy of this forest reserve is dominated by *Dryobalanops rappa*. However, fire has brutally degraded the neighbouring BFR, leaving only the KFR relatively intact. The entire Klias peat swamp deposit is evaluated to be at least 7400 ha and only 3600 ha are protected within the KFR. Much of the adjacent area are lost and became highly fragmented within the forest boundary because of fire during the El-Niño events in 1983, 1991, 1998 and 2003 (March-April). Due to the poor remaining stands of peat swamp forest especially in BFR, there are tremendous pressure for its conversion to agricultural uses by the adjacent local society in the area (Sabah Forestry Department, 2005).

Table 3: Forest reserves in the Klias Peninsula

Forest Reserve	Gazetted	Area (ha)	Class	Main Habitat
Klias FR	1984	3,630	L (Protection)	Mainly PSF
Klias Commercial FR	1972	3,630	ll (Commercial)	Mainly PSF
Binsuluk FR	1984	12,106	L (Protection)	Mainly PSF
Padas Damit Amenity FR	1984	9,027	lV (Amenity)	Mixed Swamp Forest and Mangroves
Kg. Hindian Amenity FR	1932	580	lV (Amenity)	Mangrove and PSF
Nabahan Amenity FR	1932	356	IV (Amenity)	Mangrove and PSF
Menumbok Mangrove FR	1984	5,710	V (Mangrove)	Mangrove
TOTAL		31,409		

Source: UNDP/GEF (2006)

A study was conducted to evaluate the deforestation and fragmentation by vegetation type in the Klias Peninsula. Landsat MSS of 1985 and Landsat TM of 2003 were used to analyze the pattern of vegetation fragmentation in the Klias Peninsula. With a supervised classification approach; the two images were classified into ten land cover types, which include good peat swamp forest, mangrove, shrubland, grassland, bareland, palm oil, rubber, cloud, shadow and water. Based on the classification results, the fragmentation analysis was conducted on the good peat swamp forest class using landscape indices. Evaluation of fragmentation needs more than one metric to describe the landscape pattern. This study focuses on the good PSF class and the indices include area metrics, shape metrics, patch density, patch size, variability metrics, nearest neighbour metrics, diversity metrics and contagion and interspersion metrics. The FRAGSTATS spatial pattern analysis program version 3.3 (McGarigal and Marks, 1995) was used to calculate the landscape indices. The good PSF from land cover of 1985 and 2003 were used in deriving the landscape indices using the FRAGSTATS.

Results from supervised classification approach indicate that the total area of the peat swamp forest which occupied 25,158 ha in 1985 decreased to 5,459 ha in 2003 due to the extensive El-Niňo fires that occurred in 1998 and in 2003. Resulting the increase of grassland almost four times in size, from 17,918 ha in 1985 to 45,660 ha in 2003. In Figure 1 and 2, the land cover image of 2003 shows that bareland covers almost 50% of Binsuluk Forest Reserve. Bareland has significantly increased three times in size, from 10,647 ha in 1985 to 33,143 ha in 2003.

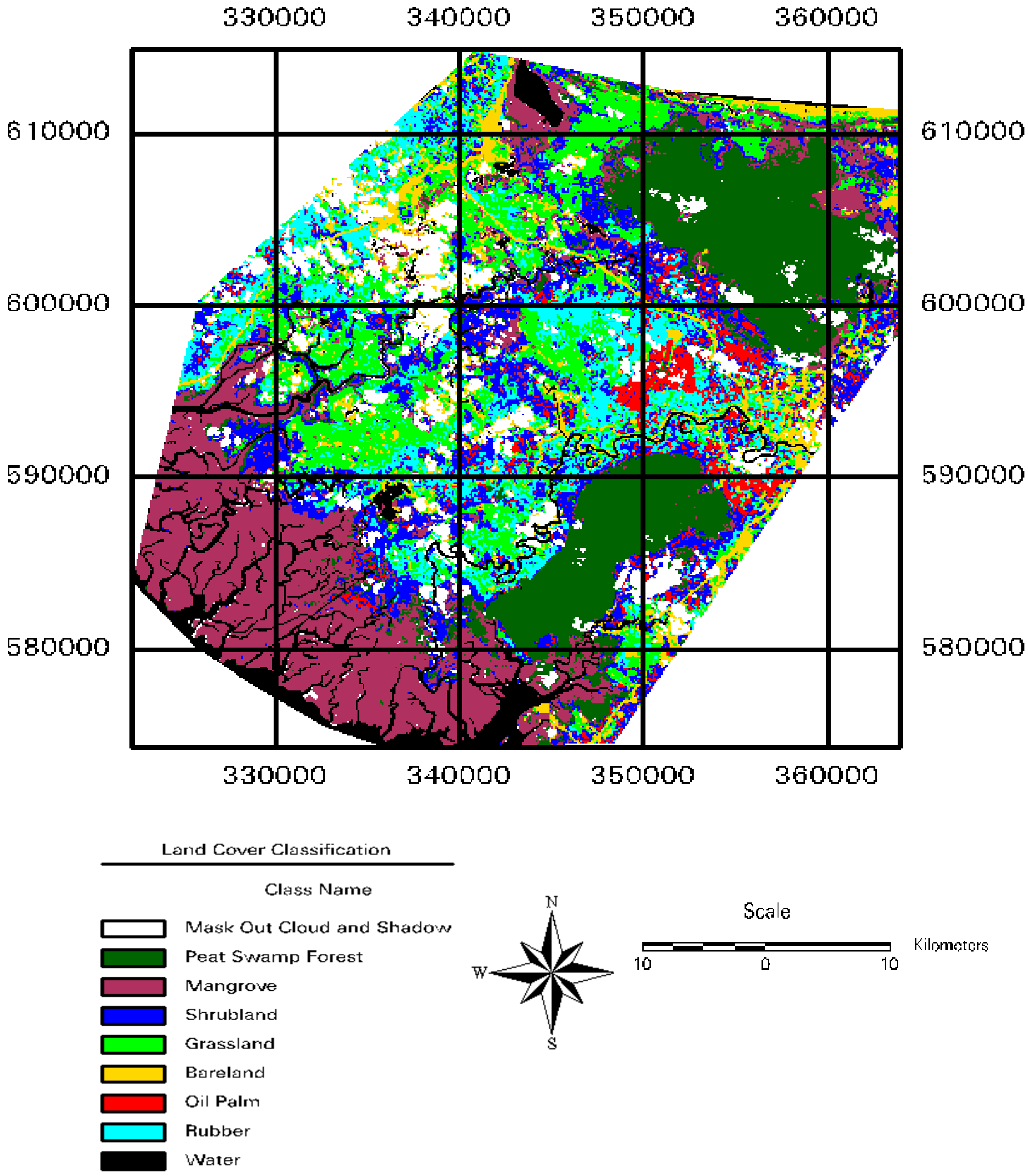

Figure 1: Land Cover Maps of the Klias Peninsula in 1985

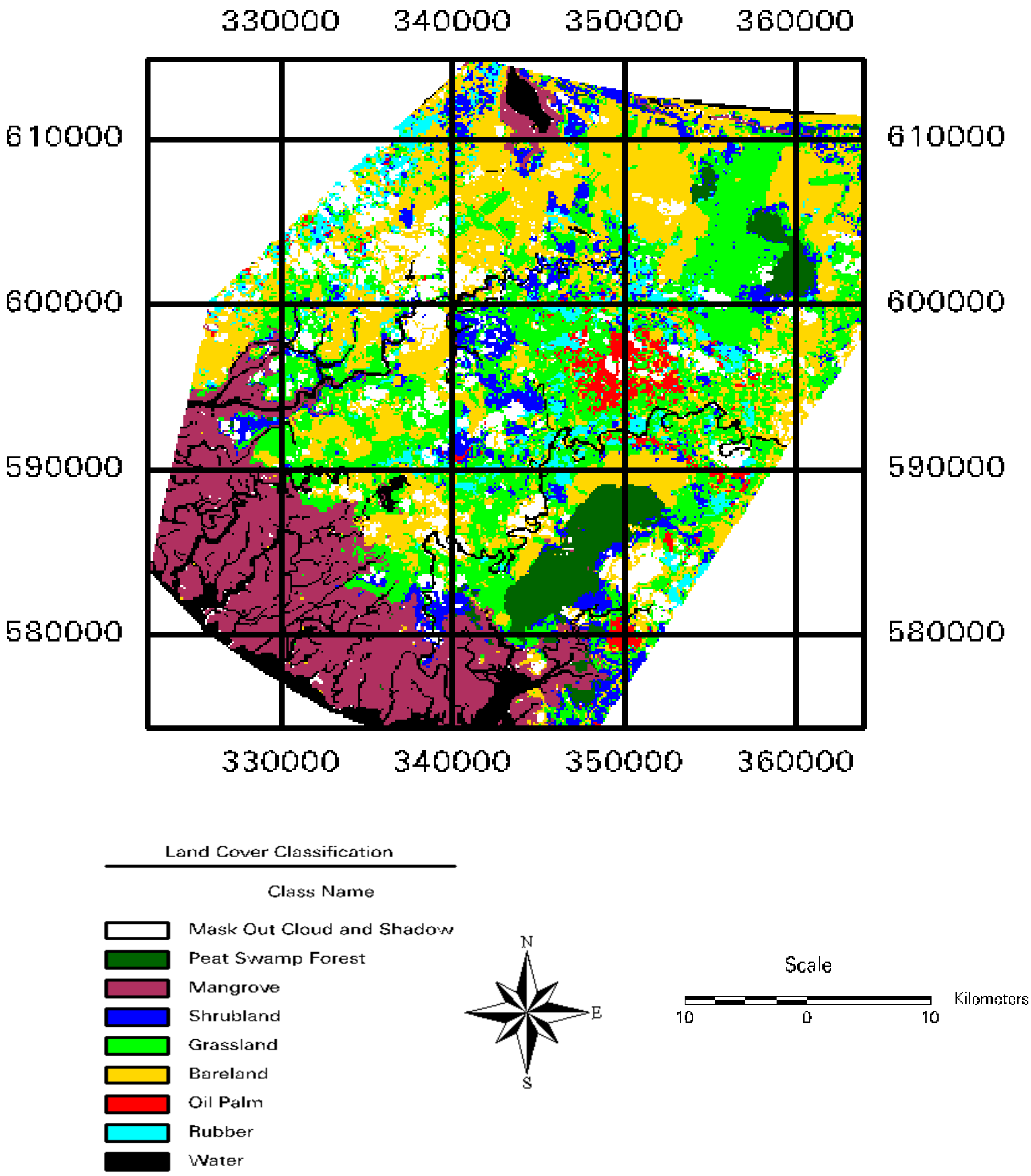

Figure 2: Land Cover Maps of the Klias Peninsula in 2003

Based on the fragmentation analysis, it is indicated that in Table 4 the patch density, patch size and largest patch index have clearly shown that the Good PSF in the Klias Peninsula has undergone drastic fragmentation during 1985 to 2003. Number of patches have increased and this means the breaking up of the Good PSF into smaller patches from 1,714 to 8,254 patches. The mean patch size also shows that the fragmentation has decreased significantly from 1.9 to 0.63. Supported by the result from largest patch index indicating that the sGood PSF patch has drastically decreased from 0.95% to 0.39%.

Table 4: Landscape indices for Good PSF in the Klias Peninsula for 1985 and 2003

Indices	Year	
Class Level: Good Peat Swamp Forest	1985	2003
Class Area (ha)	3333	5200
Percent of Landscape (%)	1.7	2.62
Number of Patches	1714	8254
Patch Density (#/100/ha)	0.86	4.15
Mean Patch Size (ha)	1.9	0.63
Largest Patch Index (%)	0.95	0.39

As a conclusion, the PSF has significantly decreased due to land conversion and fires occurred during El-Niño events in 1985 and 2003. More than 70% of the areas are transformed to bareland and grassland due to the destruction on the two remaining patches of PSF. Similar supportive findings by the fragmentation analysis show the number of patches have significantly increased from 1985 to 2003. Without proper control of unsustainable land use practices, deforestation leading to further fragmentation will destroy the remnants of the PSF in the Klias Peninsula.

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