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PROGRESSION OF PEATLAND DEGRADATION AND CONVERSION PROCESSES IN SUMATRA

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SUMMARY

In this study we used over 50 high resolution satellite images to analyse sequences and interrelations in the progression of peatland degradation and conversion processes in three study areas in Sumatra, Indonesia since the 1970s. The results demonstrated the extreme vulnerability of Southeast Asian peatlands. Forests disturbed by intensive logging were noticed to be intermediate stages towards further degradation. Fires were practically non-existent in nearly-pristine peat swamp forests but were highly concentrated in heavily degraded forest areas leading to either an extremely degraded landscape or conversion to agriculture. By 2010, large scale industrial plantations covered half of all deforested area. Nearly 70% percent of all plantations in the study area had been established since 2000. The results highlight the importance of active and tightly controlled management of peatland areas, both in conservation and development activities.

KEY WORDS: tropical peatland, logging, plantation development

INTRODUCTION

Human intervention in tropical peatlands through drainage and removal of the natural land cover directly impacts peatland hydrology and landscape morphology and leads to increase in carbon emissions (Couwenberg *et al.*, 2010; Hooijer *et al.*, 2010). Furthermore, deforestation of peatlands for agricultural purposes and degradation of peat swamp forests (e.g. by logging) endanger their ecosystem functions and jeopardize the existence of unique flora and fauna found in Southeast Asian peatlands (Rieley and Page, 2005). Disturbance in humid tropical forests also leads to higher fire vulnerability due to the drying effect of opened canopy and increased amount of dead wood debris (Siegert *et al.*, 2001).

During the past 20 years widespread logging and land clearance operations have taken place in the peat swamp forests of insular Southeast Asia and large areas of peatlands have been converted into industrial oil palm and pulp wood plantations (Miettinen and Liew, 2010). To understand where the changes taking place currently may lead in the near future, it is necessary to not only understand the rate of peatland degradation and conversion processes in this region, but to also understand the typical stages, sequences and timelines of the process.

In this study we investigated the progression of changes in three study areas in Sumatra and derived conclusions on the interrelation between logging, fire activity and plantation

establishment in order to provide basis for improved estimation of the future of peatland areas in insular Southeast Asia.

MATERIAL AND METHODS

Study areas

The three separate areas studied were located in the Provinces of North Sumatra, Riau and Jambi in Sumatra, Indonesia. The study areas ranged from 2300 to 3500 km^2. All of them were covered by peat swamp forests in the 1970s. They included varying levels of peatland degradation and conversion, as well as varying levels of legal forest protection. The borders of peatland were outlined using a peatland atlas by Wahyunto *et al.* (2003) which provided information on the extent and locations of peatland areas in Sumatra in the scale of 1:700 000.

Satellite data

Altogether 54 satellite scenes from eight different sensors were used. 32 of these images were acquired by the Satellite Pour l'Observation de la Terre (SPOT) satellites and 22 by the Landsat satellites. Together these 54 satellite images provided feasible time series of observations over the study areas since the 1970s. The base maps using images from the 1970s were followed by eight or nine subsequent observations depending on the study area.

Land cover classification

Visual image interpretation was used in this study. The delineation of land cover and degradation level polygons was done in 1:50 000 scale. The classification scheme (Table 1) was designed based on literature review (e.g. Giesen, 2004; Rieley and Page, 2005) and personal experience of the authors. The aim was to include the main phases of tropical peatland degradation and conversion process into the classification scheme while keeping it simple enough to maintain reliability of the results.

Table 1. Description of land cover types used in the classification.

Land cover	Description
1. Water/Seasonal water	Permanent water bodies and areas inundated part of the year (e.g. river flood zones).
2. Nearly-pristine PSF	Peat swamp forest with no or only minor signs of human intervention. Note that these forests may have experienced selective logging activities and may not be entirely pristine.
3. Moderately degraded PSF	Peat swamp forest with clear signs of systematic intensive logging, typically in the form of logging tracks, canals and/or open canopy.
4. Heavily degraded PSF	Peat swamp forest with only remnants of original forest cover.
5. Secondary forest	Areas covered by secondary growth typically >3 m in height.
6. Shrub	Shrubland covered by woody plants typically <3 m in height.
7. Fern/grass	Ferns and grassland
8. Cleared/burnt	Open area with no vegetation, including recently burnt areas.
9. Small-holder mosaic	Mosaic area of farms, small plantations, agricultural fields, gardens, shrub etc., used by small-holder farmers.
10. Industrial plantation	Large scale industrial oil palm and pulp wood plantations. An area is considered plantation from the point onwards when it has been fully cleared and the drainage canal structure is established.
11. Built-up area	Towns, industrial areas, transmigration settlement villages etc.

Active fire data

The ATSR 'algorithm 2' active fire detections were used from July 1996 until the end of 1999. No active fire detection data earlier than July 1996 were available for this study. Moderate Resolution Imaging Spectroradiometer (MODIS) active fire detections were used from 2000 to 2010.

RESULTS

The results revealed a drastic decline of peat swamp forest cover in the study areas during the investigation period. Forest cover at the North Sumatra study area shrunk from 92% in 1977 to 6% in 2009. Furthermore, all of the remaining forests were degraded in 2009. The forest coverage remaining in 2009 at the other two areas was 40% (Riau) and 58% (Jambi), with varying levels of degradation. Even inside Berbak National Park located in the Jambi study area, the forest cover had dropped from 99% to 77% during the study period.

Closer inspection of the progression of deforestation showed that in all of the study areas the proportion of degraded forests had remained rather constant throughout the process (Fig. 1). This was a clear sign that degraded peat swamp forests had been merely intermediate steps towards further changes. Forests degraded by intensive logging were either further developed into managed land cover types (often using fire as a clearing tool) or burnt by uncontrolled fires. In all of the study areas degraded forests were shown to have remarkably higher fire densities than nearly-pristine forests. The fire densities for all the study areas combined were 7 fires/100 km^2, 56 fires/100 km^2 and 140 fires/100 km^2 for nearly-pristine, moderately degraded and heavily degraded peat swamp forests respectively.

The high fire density in degraded forests may have been partly connected to deliberate land clearance activities. Nearly half (46%) of all fires during the study period took place on areas that were later converted to large scale industrial plantations although these areas cover only 28% of the study area. The fire density results also revealed very high concentration of fires in clearances and burnt areas 308 fires/100 km^2. The fact that burnt areas were noticed to have experienced high fire activity shows that fires had taken place repeatedly in the same areas. This type of repeated fire activity may partly be connected to the abovementioned possible plantation conversion activities, but it also shows the high fire vulnerability of extremely degraded peatland areas.

Finally, the analysis revealed a clear acceleration in the rate in which plantations had been established on peatland areas. Overall, 69% of all plantations in the study areas had been established during the past ten years. Moreover, the time gap from the first signs of forest degradation to establishment of plantation had decreased towards the end of the study period. Since the late 1990s the average time taken for conversion of nearly-pristine peat swamp forest to industrial plantation has been around six years.

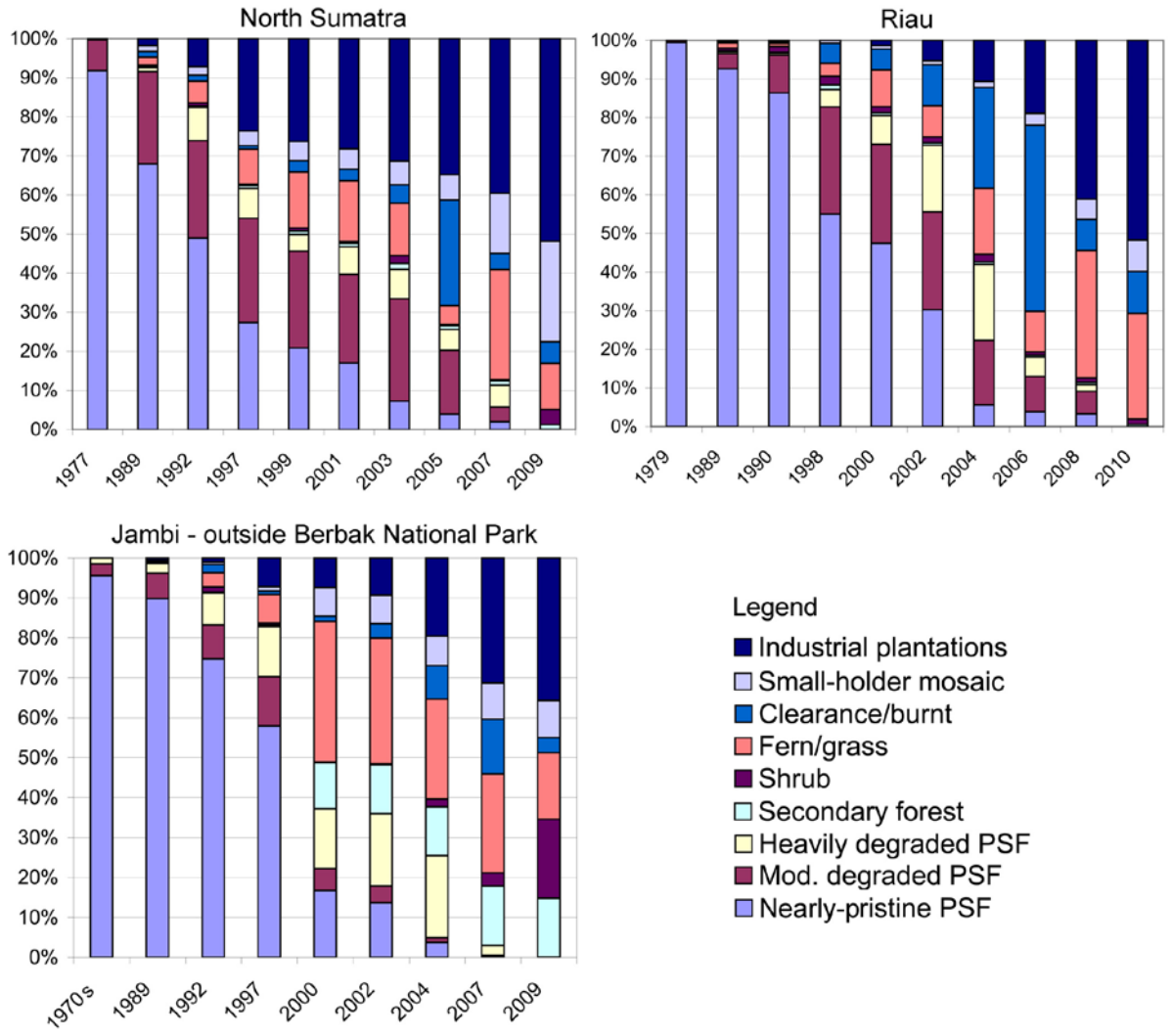

Figure 1. Progression of land cover changes in those areas that were deforested between 1970s and 2009/2010. Only overlapping valid areas of all yearly maps could be analysed (1577 km^2 in North Sumatra, 1175 km^2 in Riau and 720 km^2 in Jambi – outside Berbak).

DISCUSSION AND CONCLUSION

The results of this study not only underline the extreme vulnerability of disturbed Southeast Asian peatland ecosystems but they highlight the fast acceleration of peatland degradation and conversion in this region during the past twenty years. The percentage of forest cover in the studied peatland areas had dropped from 93% to 38% between the 1970s and 2010. Half of all deforested peatland were covered by industrial plantations at the end of the study period.

But it is important to note that plantation development is not the only form of peatland deforestation and degradation currently taking place in insular Southeast Asia. Although around half of all fire activity was shown to be potentially connected to plantation development, in other parts of the study areas fires in disturbed peat swamp forests led to destruction of the ecosystem with no indications of preparations for further development. This type of degradation process with repeated burning of degraded peatlands has also been noticed by other authors to take place elsewhere in the region (Page *et al.*, 2009).

The findings of this study underline the importance of active and tightly controlled management of peatland areas, both in conservation and development activities. Policy reviews to promote conservation, sustainable use and rehabilitation of peatland areas may be needed to change the course of current peatland degradation and conversion in Southeast Asia. The new REDD finance mechanisms rewarding carbon conservation, that may be implemented in the near future, may be able to support this.

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