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# HISTORICAL DEVELOPMENT OF INDUSTRIAL SCALE OIL PALM PLANTATION OVER PEATLAND IN RIAU AND WEST KALIMANTAN PROVINCES, INDONESIA

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## SUMMARY

Over the past three decades oil palm plantation (OPP) in Indonesia has been developed on peatland. Expansion of OPP is a large scale land use change and is having dynamics to the environments. In the perspective of national-level resource management and policy development regarding peatlands, understanding the historical expansion of OPP over peatland and explores the dynamics of above-ground biomass (AGB) during the land use changes is much needed. The study area consisted of two provinces in Indonesia, namely Riau and West Kalimantan. This study highlights the conversion of peat swamp forests (PSF) based on the status of primary or secondary forests. The study also reported on the transitions occurred in AGB in the peatlands that have been developed for OPP by distinguishing classes of peat thickness. Landsat imagerywas used to visually interpret OPP followed by intersection with peat thickness and swamp forest maps to create province-wide maps; spanning three temporal periods spanning from 1990 to 2000 to 2010 to 2013. The AGB estimates reported in the scientific literature were used to assess the AGB loss associated with each land use change. The results show that in 1990, the two provinces collectively had approximately 0.31 Mha of OPP, which expanded to 3.04 Mha by 2013. The OPP grew at an approximately constant rate (11% yr–1). Only 0.94% (29,137 ha) of the OPP had been derived directly from primary peat swamp forest (PPSF), and 21.55% (0.67 Mha) of the OPP had been established on land previously covered with secondary peat swamp forest (SPSF) within the past 23 years (1990-2013) in Riau and West Kalimantan. Higher portion of SPSF converted to wet shrublands (WSL) leading to the greatest loss of AGB (85.5 M tons). Lower loss of AGB resulted by conversion from SPSF to OPP (47.5 M tons). Similarly, the loss of AGB from the conversion of PPSF to OPP (estimated to be only 4.39 M tons) was higher than for conversions from PPSF to WSL (3.44 M tons ).

***Keywords****: land use change, oil palm, peat swamp forest, plantation, above-ground biomass*

## INTRODUCTION

During the mid-1980s, Indonesian government implemented policies to promote diversification of products outside the oil and gas sector focused on development of tree crop plantations. Original proposed development was Industrial Tree Crop Estate (*Hutan Tanaman Industri* or HTI) as a model to be established on degraded land, supposedly to reduce the demanding of natural timber. At almost the same time, there has been booming in development of oil palm plantation (OPP) from about 0.5 ha in 1984, increased to over 1.0 Mha by 1990, to approximately 2.4 Mha in 1997, and to nearly 3.0 Mha in 2000 (Pagiola, 2000). Expansion of OPP in previously swampy areas including peatlands involved the drainage of land during preparation; therefore, since the 1980s, there has been an increase in the distortion of landscapes and a loss of small segments of land held by poor landholders in the logged peatlands (Page *et al*., 2009). The drainage of land during preparation involves civil engineering work such as the development of road networks and waterways, ultimately leads to lowering the ground water level, creating aerobic conditions within the peat that accelerate oxidation, nitrogen mineralization and microbial activities (Hirano *et al.*, 2007). Such logging activity causes the humid tropical forests to be highly prone to forest fires and desiccation because of wood loss and the opened canopy (Siegert *et al.*, 2001).

Therefore, from the perspective of national-level resource management and policy development regarding peatlands, understanding the historical expansion of OPP in Indonesia allegedly drivers of deforestation and the mechanisms involved is much needed. The current study is aimed to observe the historical expansion of OPP and explores the dynamics of above-ground biomass (AGB) during land use changes in peatland ecosystems.

## MATERIALS AND METHODS

The study was conducted in Riau and West Kalimantan Indonesia. . Landsat imagery (4, 5, 7 and 8) of the study area were downloaded from the US Geological Survey website: http://glovis.usgs.gov/. Province-wide scale (1:250,000) peatland distribution maps were prepared by Wetland International (WI) in 2003/2004, followed by the Indonesian Centre for Agricultural Land Resources Research and Development (ICALRRD) in 2011. Peatland distribution data and peat thickness were obtained from ICALRRD (2011), which was used to obtain details related to peat thickness. The land use data for forest lands were acquired from the Indonesian Ministry of Forestry and used to locate swamp forests. Primary peat swamp forest (PPSF) and secondary peat swamp forest (SPSF) polygons were intersected with peat thickness polygons to obtain the locations of PSF.

Landsat imagery (4, 5, 7 and 8) was processed using ArcGIS® 9.3 software by performing on-screen analysis to locate OPP. During on-screen interpretation, multistage visual technique images were displayed as false color composites of various Landsat bands. The OPP were then identified and delineated, intersected with spatial extent and thickness of peat soils. The peat-layer thickness information was used to determine the extent of OPP above two groups of peat soil with thickness identified as being either more or less than 3 m. Similarly, the peat soil polygons were intersected with OPP and swamp forests data to circumscribe the PSF and to further distinguish between the peatlands and PSF. To extract PSF and differentiate it from swamp forests above mineral soils, the land use change data for forests was overlaid with peatland maps across each time periods of 1990-2000, 2000-2010, and 2010-2013. The primary outputs of the data analysis were land cover change matrices. The results were then compared with land cover maps and published statistics from other studies. To estimate the changes in AGB across selected land uses, the reported estimates of AGB from the scientific literature were used. The decline in biomass was estimated by multiplying the spatial change (ha) in AGB during each land use transition based on the difference of biomass.

The average time for carbon storage in standing oil palm tree excluded harvested and cut palm frond is 25 years during the rotation period. Applying the differences in the AGB carbon stocks, the C lost during each land use transition was estimated by multiplying the difference factor with the areal increase in each time period, following the time-averaged biomass stocks from this study and applied C fraction (CF = 0.50) [ton C (ton dm) 1] from IPCC (2006) for the selected land uses. The results thus show similar trends to that of biomass losses, i.e. the greatest C loss in AGB was estimated to occur in areas converted from SPSF to WSL, i.e. 42.8 M tons. This is followed by conversion from SPSF to OPP, i.e. 23.8 M tons. Whilst C loss in AGB from the conversion of PPSF to OPP was estimated to be only 2.19 M tons, and this is higher than C loss in AGB from the conversion of PPSF to WSL i.e. 1.72 M tons.

## RESULTS AND DISCUSSION

### Current and Historical Oil Palm Plantations in Peatlands

Peatlands distribution was processed from raw data obtained from ICALRRD, and the results show that the total peatland area based on peat thickness in Riau and West Kalimantan was 3.83 Mha (2.24 Mha < 3 m; 1,59 Mha > 3 m), and 1.69 Mha (1.44 Mha < 3 m; 0.25 Mha > 3 m), respectively. Table 1 summarized the OPP that have been developed over peatland in Riau and West Kalimantan since 1990 based on the peat thickness classes. Riau and West Kalimantan had 1,552,165 ha (91.60%) and 359,879 ha (80.00%) of peatland, respectively, that has been converted to OPP with legally permitted thickness (< 3 m). The results show that much of the peatlands with legally permitted thickness that are available for further development and plantations from 2013 onwards in both provinces are now greatly limited. Riau has 0.32 Mha and West Kalimantan has 0.79 Mha of remaining peatland that can be developed. Similarly, the spatial extent of peat soils supporting OPP increased from 22,992 ha (7% of total oil palm area) in 1990 to 1.3 Mha (43%) by 2013 in both provinces, of which 1.04 Mha (30%) occurs in Riau, compared with 0.26 Mha (29%) in West Kalimantan. The use of peatlands for OPP in areas with peat thickness > than 3 m (legally not permitted) increased in both provinces, from 26 ha and 0 ha (0.11% and 0%) in 1990 to 0.31 Mha and 24,796 ha (30% and 9%) in 2013 in Riau and West Kalimantan, respectively. The analysis revealed that the OPP expanded almost linearly in both provinces with a more drastic rise in Riau from 1990 to 2000, and from 2010 onwards.

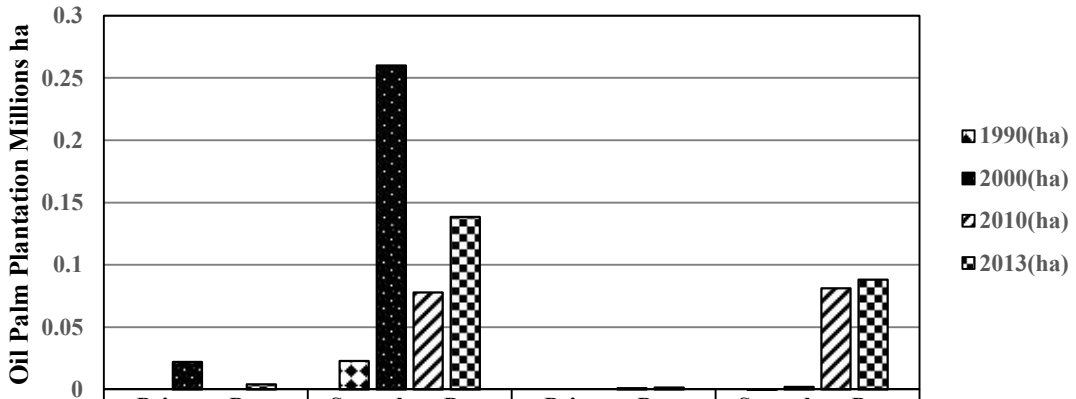
**The Conversion of Peat Swamp Forest to Oil Palm Plantations**

Table 1. Oil palm plantations in peatlands based on peat thickness in West Kalimantan and Riau, Indonesia

| Year | Land Use | Mineral soil (ha) | Oil Palm over Peat (ha) | | | | |
|---|---|---|---|---|---|---|---|
| | | | D1 | D2 | D3 | D4 | Grand Total |
| **West Kalimantan** | | | | | | | |
| **1990** | Oil Palm | 43,518 | 140 | -------- | -------- | -------- | 43,658 |
| **2000** | Oil Palm | 181,498 | 3,193 | 7,035 | 2,490 | -------- | 194,216 |
| **2010** | Oil Palm | 359,960 | 57,571 | 39,877 | 9,288 | 12,558 | 479,253 |
| **2013** | Oil Palm | 641,799 | 81,449 | 131,287 | 27,549 | 24,796 | 906,880 |
| **Riau** | | | | | | | |
| **1990** | Oil Palm | 246,402 | 4,855 | 42,37 | 13,734 | 26 | 269,255 |
| **2000** | Oil Palm | 845,340 | 59,415 | 147,643 | 130,425 | 25,718 | 1,208,541 |
| **2010** | Oil Palm | 972,696 | 61,116 | 212,804 | 187,477 | 52,791 | 1,486,884 |
| **2013** | Oil Palm | 1,087,486 | 66,364 | 268,721 | 395,374 | 310,755 | 2,128,700 |

Peat thickness classes: D1, 50–100 cm; D2, 100–200 cm; D3, 200–300 cm; D4, > 300 cm

The results show that a very minute fraction of OPP has been derived from primary peat swamp forests (PPSF); most of the OPP has been established on land previously inhabited by secondary peat swamp forests (SPSF). Our results supported the finding (Figure 1) that in both provinces the expansion took place initially using SPSF and then in the later stages (from 2010 to 2013) some portion of PPSF has also been used. This study revealed that the exploitation of PSF for OPP is indirect and that PSF is not only being converted to OPP but also to other land uses. After analyzing all regions and temporal periods in both provinces, only 0.94% (29,137 ha) of the OPP had been derived directly from PPSF; 21.55% (0.67 Mha) had been established on land previously covered with SPSF. In particular, Riau had the overall highest observed magnitude of SPSF conversion from 1990–2000, while in West Kalimantan more expansion took place from 2000–2010. An overall comparison shows that Riau had the highest spatial extent of OPP that had replaced both primary and secondary PSF, i.e. 26,424 ha and 499,782 ha compared to 2,749 ha and 171,865 ha in West Kalimantan, respectively. The research results are both similar to and distinct from study of Miettinen *et al*. (2012). Some researchers believe that the expansion of OPP in Indonesia is one of several drivers of deforestation. However, it is a misconception to allege that all OPP originate from PPSF, as described by Pagiola (2000).




| | Primary Peat Swamp Forests (Riau) | Secondary Peat Swamp Forests (Riau) | Primary Peat Swamp Forests (West Kalimantan) | Secondary Peat Swamp Forests (West Kalimantan) |
|---|---|---|---|---|
| 1990(ha) | 0 | 22852 | 0 | 140 |
| 2000(ha) | 22136 | 260202 | 0 | 2142 |
| 2010(ha) | 0 | 78026 | 1065 | 81255 |
| 2013(ha) | 4288 | 138701 | 1684 | 88329 |

Figure 1. Temporal expansion of oil palm plantations and conversion of primary and secondary peat swamp forest in Riau and West Kalimantan, Indonesia

**Loss of Above-Ground Biomass Because of Land Use Changes**

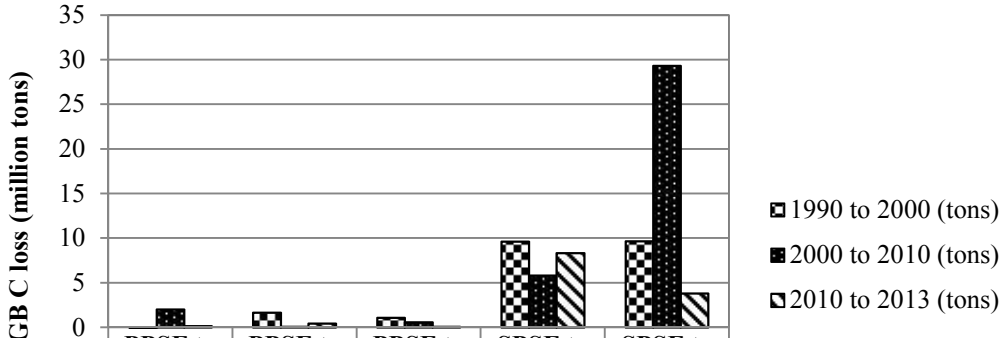
The change in AGB is an obvious outcome in various land use changes. These changes involve a change from systems such as forests with high levels of biomass stock to less densely vegetated ecosystems such as

shrublands or monocultures such as OPP. The biomass lost from 1990 to 2013 during all time periods was estimated (Table 2 and Figure 2) for each land use change category using the difference of biomass in each land use type per hectare. By totaling the AGB lost during all time periods and in both provinces, the highest amount of AGB loss was found to be a result of the conversion of SPSF to WSL (85.5 M tons); this was followed by 47.5 M tons from the conversion of SPSF to OPP. Similarly, the AGB loss from the conversion of PPSF to OPP was estimated to be only 4.39 M tons, which is higher than the 3.44 M tons lost by the conversion from PPSF to WSL. During the three periods analyzed, the greatest loss of AGB was estimated in areas converted from SPSF to WSL i.e. 19.30 M tons, 58.66 M tons and 7.59 M tons; this was followed by areas with a conversion from SPSF to OPP i.e. 19.21 M tons, 11.66 M tons and 16.62 M tons, respectively. During the same time periods, the estimated loss of AGB from conversion of PPSF to OPP was 3.32 M tons, 0.16 M tons and 0.89 M tons, which is higher than the loss of AGB from conversions of PPSF to WSL, which were 2.17 M tons, 1.13 M tons and 0.13 M tons, respectively.

Table 2. Loss of above ground biomass from primary and secondary PSF conversion to oil palm plantation and other land uses in Riau and West Kalimantan

| Time Period | Loss of above-ground biomass due to land use change (tons) | | | | |
|---|---|---|---|---|---|
| | PPSF to SPSF | PPSF to OPP | PPSF to WSL | SPSF to OPP | SPSF to WSL |
| **West Kalimantan** | | | | | |
| 1990 to 2000 | ---- | Nil | 1,774,679 | 156,889 | 6,757,022 |
| 2000 to 2010 | ---- | 160,115 | 14,881 | 5,951,580 | 9,700,927 |
| 2010 to 2013 | ---- | 253,295 | ---- | 6,469,717 | 1,436,183 |
| **Riau** | | | | | |
| 1990 to 2000 | 13,010 | 3,328,848 | 397,608 | 19,058,732 | 12,550,926 |
| 2000 to 2010 | 4,046,240 | ---- | 1,120,022 | 5,715,127 | 48,967,606 |
| 2010 to 2013 | 264,224 | 644,759 | 132,374 | 10,159,292 | 6,162,210 |

PPSF: Primary peat swamp forest; SPSF: Secondary peat swamp forest; OPP: Oil palm plantations; WSL: Wet Shrubland




| | PPSF to SPSF | PPSF to OPP | PPSF to WSL | SPSF to OPP | SPSF to WSL |
|---|---|---|---|---|---|
| **1990 to 2000 (tons)** | **6505** | **1664424** | **1086144** | **9607810** | **9653974** |
| **2000 to 2010 (tons)** | **2023120** | **80058** | **567452** | **5833353** | **29334266** |
| **2010 to 2013 (tons)** | **132112** | **449027** | **66187** | **8314504** | **3799196** |

PPSF: Primary peat swamp forest; SPSF: Secondary peat swamp forest; OPP: Oil palm plantations; WSL: Wet shrubland; AGB: Above-ground biomass; LUs: Land uses

Figure 2. Overall loss of AGB carbon from primary and secondary PSF conversion to OPP and other land uses

## CONCLUSION AND RECOMMENDATIONS

It is obvious that oil palm plantation (OPP) in Indonesia have developed extensively over time. This research revealed that OPP replaced secondary peat swamp forest (SPSF) to the extent that secondary in terms of areas. OPP that directly converted primary peat swamp forest (PPSF), in fact, only minor, less than 1% of the total OPP expansion during 1990 to 2013 in Riau and West Kalimantan. Similarly, higher area of SPSF was converted to wet shrubland (WS), leading to the greatest loss of above-ground biomass (AGB) when compared with all other types of land use change. This study does not cover the social and economic aspects of the trajectory of land use change; therefore, we recommend further studies should analyze shorter time periods and use advance remote-sensing technologies other than visual interpretation to identify the economic and social factors that drive the land use change. Special consideration should be given to exploring the causes of major and spontaneous land use changes, *e.g.* conversion of SPSF to WSL, using field surveys and the knowledge of local indigenous peoples.

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