



# Impact of oil palm plantations on peatland conversion in Sarawak 2005-2010



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Cover image credit: ALOS satellite (left) ©EORC/JAXA, Aerial photo (right) ©Anthony Sebastian

**Scope** - *This document briefly reports on the results of project activities providing maps and associated statistics on the impact of oil palm plantations on forest and peatland conversion in Sarawak during the period 2005-2010. This work is supported by DOEN Foundation, Wetlands International, Solidaridad, and the Netherlands Space Office on behalf of the Netherlands Ministry of Environment.*

## **1. Background**

Wetlands International commissioned SarVision to prepare this report within the framework of the Wetlands and Livelihoods Project Seed Funds program. The report aims to provide sequenced maps and statistics on the area of peatlands converted for oil palm plantations in Sarawak from 2005-2010. It builds on forest cover change and plantation concession boundary mapping results from the ongoing project 'Transparent Mapping for Sustainable Oil Palm Plantation Development', which is funded by DOEN Foundation, Solidaridad and the Netherlands Space Office on behalf of the Netherlands Ministry of Environment. This project is carried out by SarVision with support from Wageningen University, Aidenvironment Asia, the Sarawak Dayak Iban Association (SADIA) and anonyx consultancy.

## **2. Assignment objectives**

For this report SarVision will provide robust data and analysis of the area of forest and peatlands in Sarawak that have been converted for oil palm plantations between 2005 and 2010.

## **3. Description of the work**

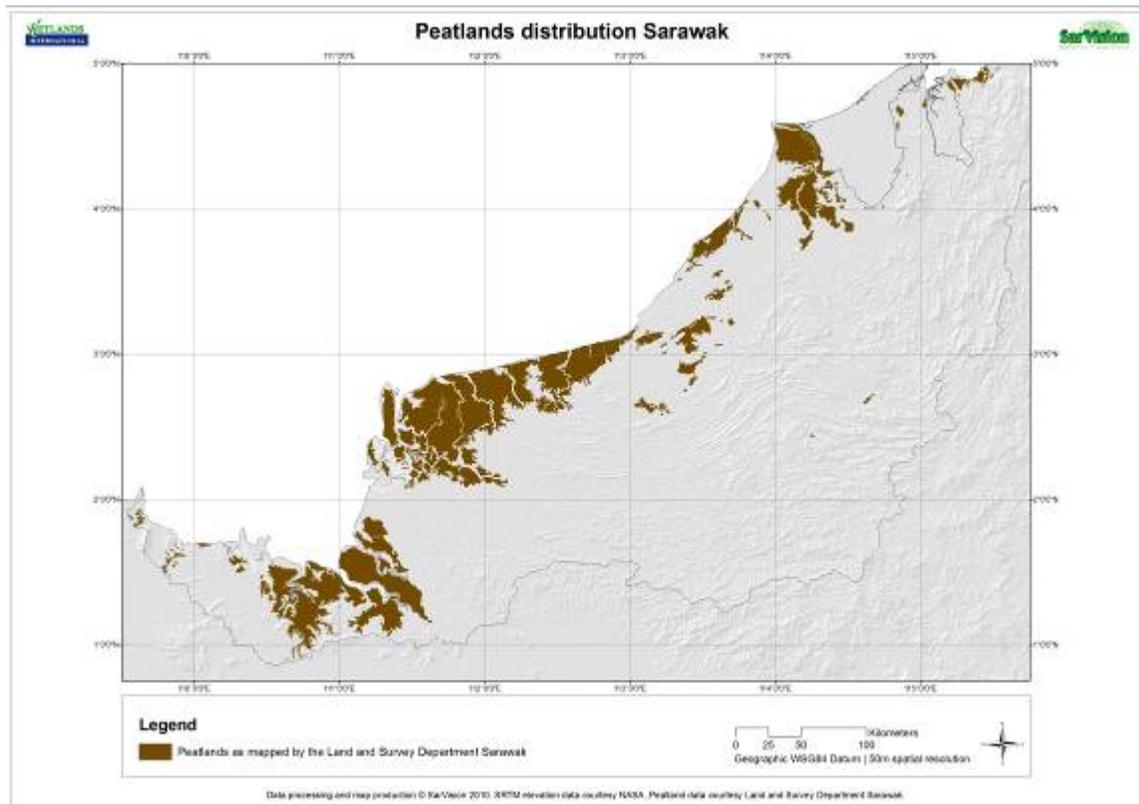
SarVision was asked to use computer-based satellite image classification approaches to map deforestation at 50m spatial resolution. A combination of Landsat and ALOS PALSAR radar satellite imagery covering entire Sarawak from 2005-2010 was proposed. Resulting agreed thematic map classes include forest, non forest, deforestation and water. The project aimed to overlay resulting deforestation maps for 2005-2007, 2007-2009 and 2009-2010 with available peat distribution data and calculate conversion statistics. Assessment of the accuracy of deforestation detection were to be supported by very high resolution satellite imagery in Google Earth and ground truth from local partner SADIA and others.



## 4. Assignment outputs

### 1. Compilation of peat distribution digital information for Sarawak

A peatland map produced by the Sarawak Land and Survey department was obtained from local sources by Aidenvironment Asia. The file was received in Google Earth kml format and converted into ArcGIS shapefile format. Spatial data inconsistencies were edited and the result stored in raster format at 50m spatial resolution (conform to the spatial resolution of the satellite imagery used). The final result is shown in *figure 1* below.



*Figure 1. Peatland distribution digital information for Sarawak, based on data from the Sarawak Land and Survey department.*

### 2. Analysis of satellite data – forest conversion to oil palm plantations overlaid on peatlands



First a baseline forest cover map for the year 2005 was developed. For the purpose of this study, forest cover is defined as an area of land greater than 1 hectare, with more than 30% tree canopy cover and a minimum tree height of 5 metres.

Note that forest cover as mapped includes mangroves, significantly degraded (peat swamp) forests, forest regrowth and industrial tree plantations (e.g. *Acacia mangium*). *Acacia mangium*, however, is mostly planted on mineral soils in Sarawak.

Peat swamp forest was defined as all forest within the boundaries of the peatland map produced by the Sarawak Land and Survey Department. We noticed this erroneously includes some significant area of mangrove north of Sibü.

The forest cover baseline map is developed using all available Landsat 7 and Landsat 5 images for 2005 covering Sarawak. Images were downloaded from USGS GLOVIS. In addition, some extra images have been downloaded from late 2004 and early 2006 to complement the 2005 series in areas with extreme cloud cover and to better fill the no-data gaps present in Landsat 7 images since 2003. All Landsat scenes were calibrated, applying terrain and illumination correction and removal of consistent sensor-based deviations.

Almost all available Landsat images contain significant clouds and haze due to the wet-tropical character of the Sarawak climate. A processing algorithm developed in-house was applied to create a cloud- and no data gap-reduced composite image by stacking many overlapping scenes and selecting the pixel values from the scenes with least cloud and haze for each location. The result is a sufficiently cloud- and haze-reduced Landsat-like image that is suitable for automatic classification and interpretation. This resulting 2005 Landsat composite image has been run through an automatic ('unsupervised') image classification algorithm, resulting in a classification with hundred classes. These classes were manually labelled by an experienced image interpreter and merged into the final forest and non-forest baseline result. A majority filter was run on the classified forest – non-forest – water result to remove remaining noise. Finally, (small clusters of) forest pixels smaller than 1 hectare were removed.

ALOS PALSAR imagery covering Sarawak was processed to map deforestation for the periods 2005-2007, 2007-2009, and 2009-2010. All Fine Beam Single polarised and Fine Beam Dual polarised radar imagery for the years 2007, 2008 and 2009 was acquired from the Japanese space agency JAXA within the ALOS Kyoto and Carbon Initiative. Imagery was calibrated, orthorectified, slope-corrected and stacked (see *figure 2*).



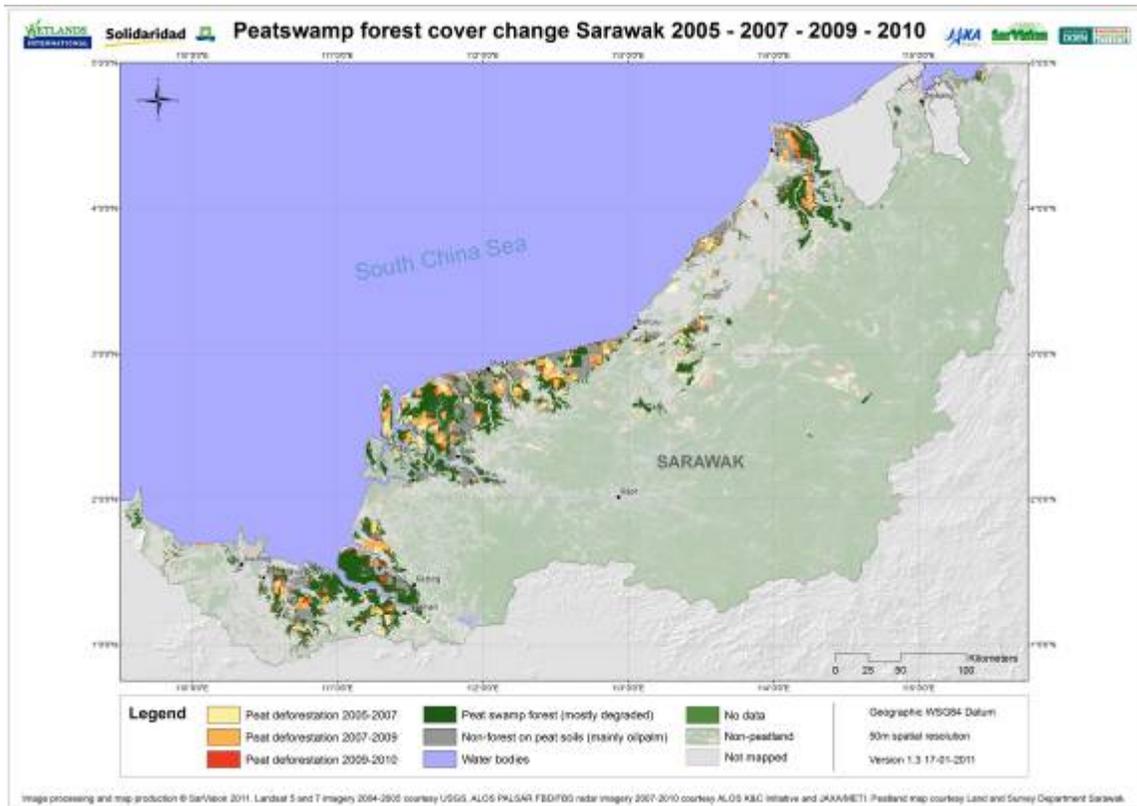


Figure 3. Final peat swamp forest cover change map for Sarawak 2005-2007-2009-2010.

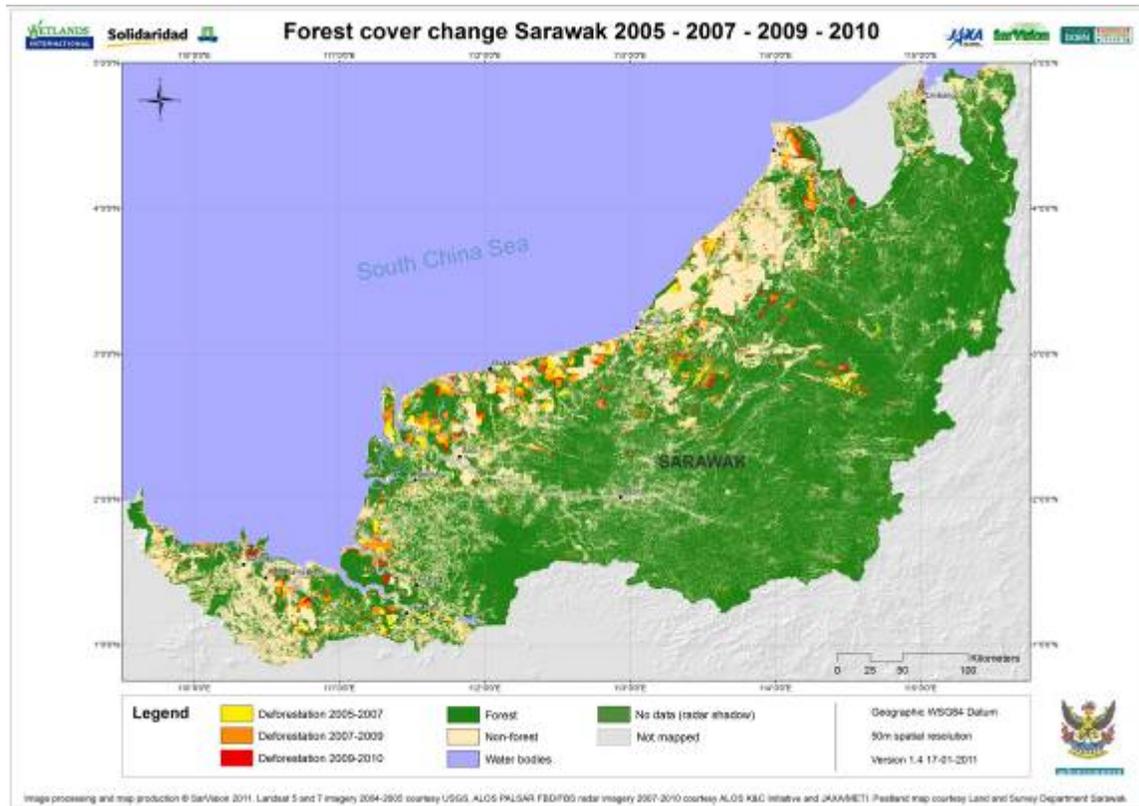


Figure 4. Total forest cover change map for Sarawak 2005-2007-2009-2010.

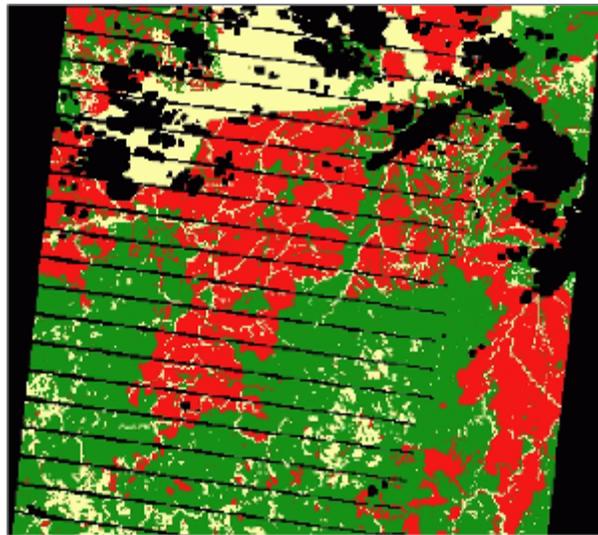
## Accuracy assessment

Both qualitative and (basic) quantitative accuracy assessment were carried out.

A qualitative assessment has been carried out using a reference dataset with 3 samples over Sarawak developed by leading remote sensing specialists working on the quantification of global Hansen *et al* 2010<sup>2</sup>. Note that forest in this reference dataset is defined as greater than 25% tree canopy cover, whereas for our study 30% is used.

Visual inspection shows that our 2005 forest non-forest map result and the reference dataset showing 2000-2005 forest status are in very good agreement, see *figure 5*.

<sup>2</sup> Hansen M., Stehman S., Potapov P. (2010) Quantification of global gross forest cover loss. Proceedings of the National Academy of Sciences of the U.S.A.  
<http://globalmonitoring.sdstate.edu/projects/gfm/>



*Figure 5. Qualitative comparison of forest cover results. Top: Hansen et al 2010 sample forest status showing non-forest 2000 (sand), forest 2005 (green), deforested 2000-2005 (red), no data stripes and clouds (black). Bottom: SarVision result for the same area showing non-forest 2005 (white), forest 2005 (green).*

We quantitatively assessed the accuracy of forest, non-forest and deforested areas using a reference data set produced from visual interpretation of 11 very high resolution images available in GoogleEarth (see for example Buchanan *et al* 2008<sup>3</sup>). These images from Ikonos, Quickbird and GeoEye sensors have a resolution of 0.6-1m, and enable observation of individual trees.

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<sup>3</sup> Buchanan, G.M., S.H.M. Butchart, G. Dutson, J.D. Pilgrim, M.K. Steininger, K.D. Bishop, P. Mayaux, 2008. Using remote sensing to inform conservation status assessment: Estimates of



We randomly selected terrestrial points in the imagery, which were labeled as forest, non-forest, or deforested area (after 2005) by an image analyst. Only points located farther than 100 m of a forest edge or road, or those that fell on a forest or non-forest patch larger than 2 ha. These account for the potential locational error of the ortho-rectified Landsat and ALOS PALSAR images and the minimum mapping unit of the final filtered map (Buchanan *et al* 2008).

Results indicate that the map result has an estimated accuracy of over 90%.

	correct	incorrect (# pixels)	percent point correct
Forest	: 3678	229	0.94
Non-forest	: 3518	60	0.98
Clearing	: 553	61	0.89

It is noted that the validation dataset is biased toward larger forest and non-forest cover areas and clearings. Future accuracy assessment should account for relatively small patches as well (i.e. between 1 and 5 hectares). In addition, more data for the verification of clearings should become available, currently the number of very high resolution images over the same area for 2 dates (e.g. 2005 and 2010) is still very limited.

Furthermore, known issues include:

- Cloud, haze and SLC-off artefacts could not be removed in a number of places due to a lack of good quality pixels. Forest is misclassified as non-forest in such places;
- Despite topographic correction, relatively short steep slopes could not entirely be corrected. This is because the Landsat imagery used has a spatial resolution of 30-50m, whereas the SRTM elevation dataset used for correction has a resolution of 90m. This inevitably results in certain small slopes in non-forest areas being misclassified as forest;
- Hydrological dynamics in mangrove areas result in false deforestation alarms, better tuning of the ALOS PALSAR classification algorithms is required.

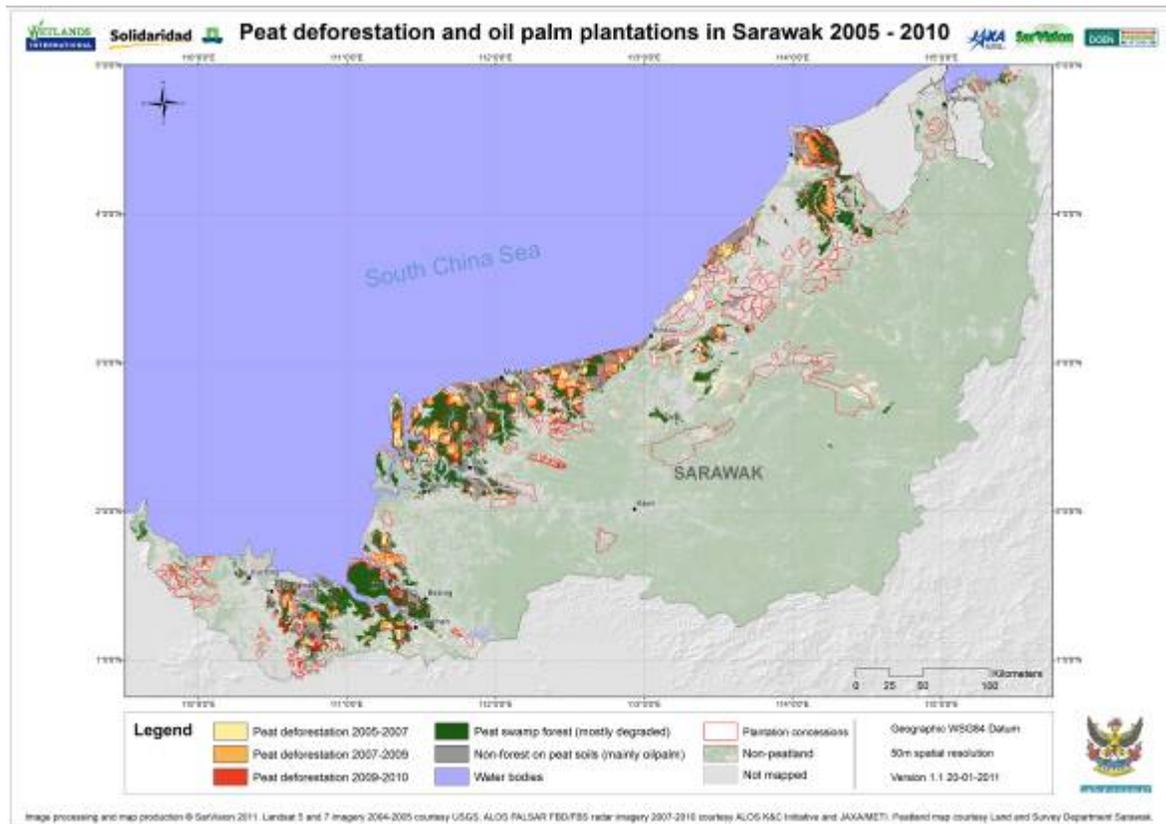
In addition to the peatland and forest cover change mapping, oil palm plantation concession boundaries obtained from publicly available Environmental Impact Assessment (EIA) reports were scanned and digitized by local mapping experts from SADIA and AidEnvironment Asia.

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recent deforestation rates on New Britain and the impacts upon endemic birds. *Biological Conservation* 141 pp. 56–66



The digitization of plantation concession boundaries is still ongoing; hence the dataset is incomplete at the time of writing. *Figure 6* shows the oil palm plantation concession boundaries mapped as of November 2010 and used for further analysis in this report.



*Figure 6. Oil palm plantation concessions digitized from Environmental Impact Assessment reports overlaid on peat swamp forest cover change map for Sarawak 2005-2007-2009-2010. Concession data collected by SADIA and Aidenvironment Asia.*



Based on the mapping results we produced the following statistics:

1. Deforestation statistics all forest Sarawak

Table 1. Yearly deforestation Sarawak (interpolated when necessary).

year	forest area (ha)	forest area change (ha)	percent change
2005	8,984,450.7	No data	No data
2006	8,814,801.7	-169,648.9	-1.89%
2007	8,645,152.8	-169,648.9	-1.92%
2008	8,470,649.8	-174,503.0	-2.02%
2009	8,296,146.8	-174,503.0	-2.06%
2010	8,118,614.4	-177,532.4	-2.14%

Table 2. Exponential forest decay/year for each interval for deforestation in Sarawak.

interval	yearly decay
2005-2007	0.019248
2007-2009	0.020604
2009-2010	0.021632

2. Deforestation statistics peat swamp forest Sarawak

Table 3. Yearly deforestation of peatland Sarawak (interpolated when necessary).

Year	forest area (ha)	forest area change (ha)	percent change
2005	1,055,896.7	No data	No data
2006	990,437.6	-65,459.1	-6.20%
2007	924,978.5	-65,459.1	-6.61%
2008	847,256.4	-77,722.1	-8.40%
2009	769,534.3	-77,722.1	-9.17%
2010	702,966.7	-66,567.5	-8.65%



Table 4. Exponential forest decay/year for each interval for deforestation of peatland in Sarawak.

interval	yearly decay
2005-2007	0.066188
2007-2009	0.091993
2009-2010	0.090476

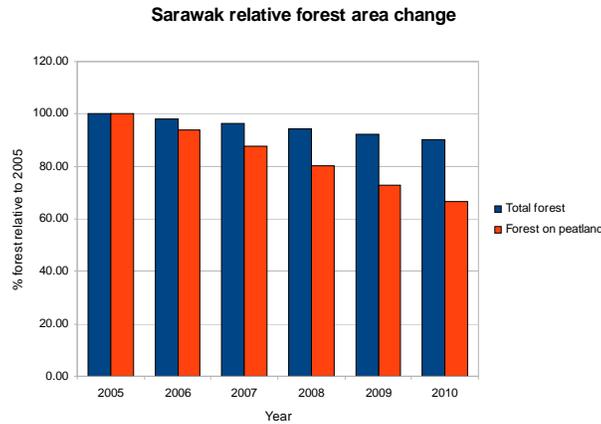


Figure 7. Relative forest area change for peat swamp forest versus all forest in Sarawak during 2005-2010.

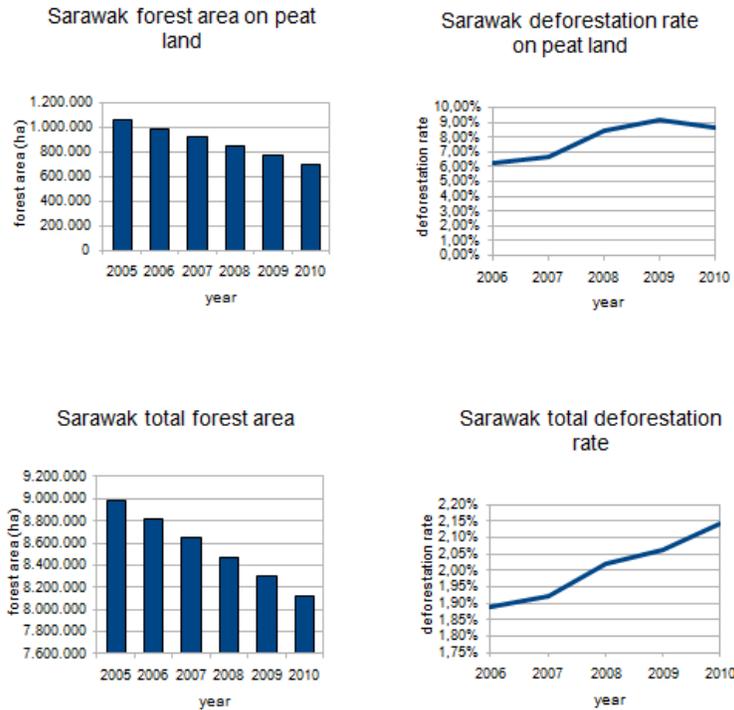




Figure 8. Comparison of absolute forest area and deforestation rate trends for peat swamp forest (top) and all forest in Sarawak including peat swamp forest (bottom) during 2005-2010.

Based on the resulting maps and figures we draw the following conclusions:

- The deforestation rate (in percent of annually remaining forest) over entire Sarawak shows a constant increasing trend for the period 2005-2010. In the period 2005-2007 1.89% of the total forest cover was cleared, while in the period 2009-2010 this increased to 2.14%;
- The deforestation rate of peat swamp forest in Sarawak shows a similar increase, an average increase in rate of 0.5%. The period of 2009-2010 however is an exception, showing a slight decrease;
- Figures show that deforestation of peatland in Sarawak is occurring at much faster speeds compared to deforestation of all forest cover: on average 8% of the peat swamp forest area has been cleared annually, compared to 2% on average for all forest in Sarawak;
- To put these figures in perspective: total forest loss for entire Asia for the period 2000-2005 was 2.8%, according to the best available recent statistics of forest cover loss (Hansen *et al*, 2010). Our results over the 5-year period 2005-2010 for Sarawak show that 9.6% of the total forest area and 33.4% of peat swamp forest area existing in 2005 has been cleared;
- Total deforestation in Sarawak is 3.5 times as much as that for entire Asia, while deforestation of peat swamp forest is 11.7 times as much, if we compare Sarawak 2005-2010 to the latest results for Asia from 2000-2005 in Hansen *et al* 2010;
- A forthcoming study by the National University of Singapore using lower resolution 250m MODIS imagery confirms the extremely high deforestation rates on peatland in Sarawak, calculating that on average 7.7% has been cleared annually during the period 2000-2010 (Miettinen *et al* 2011)<sup>4</sup>.

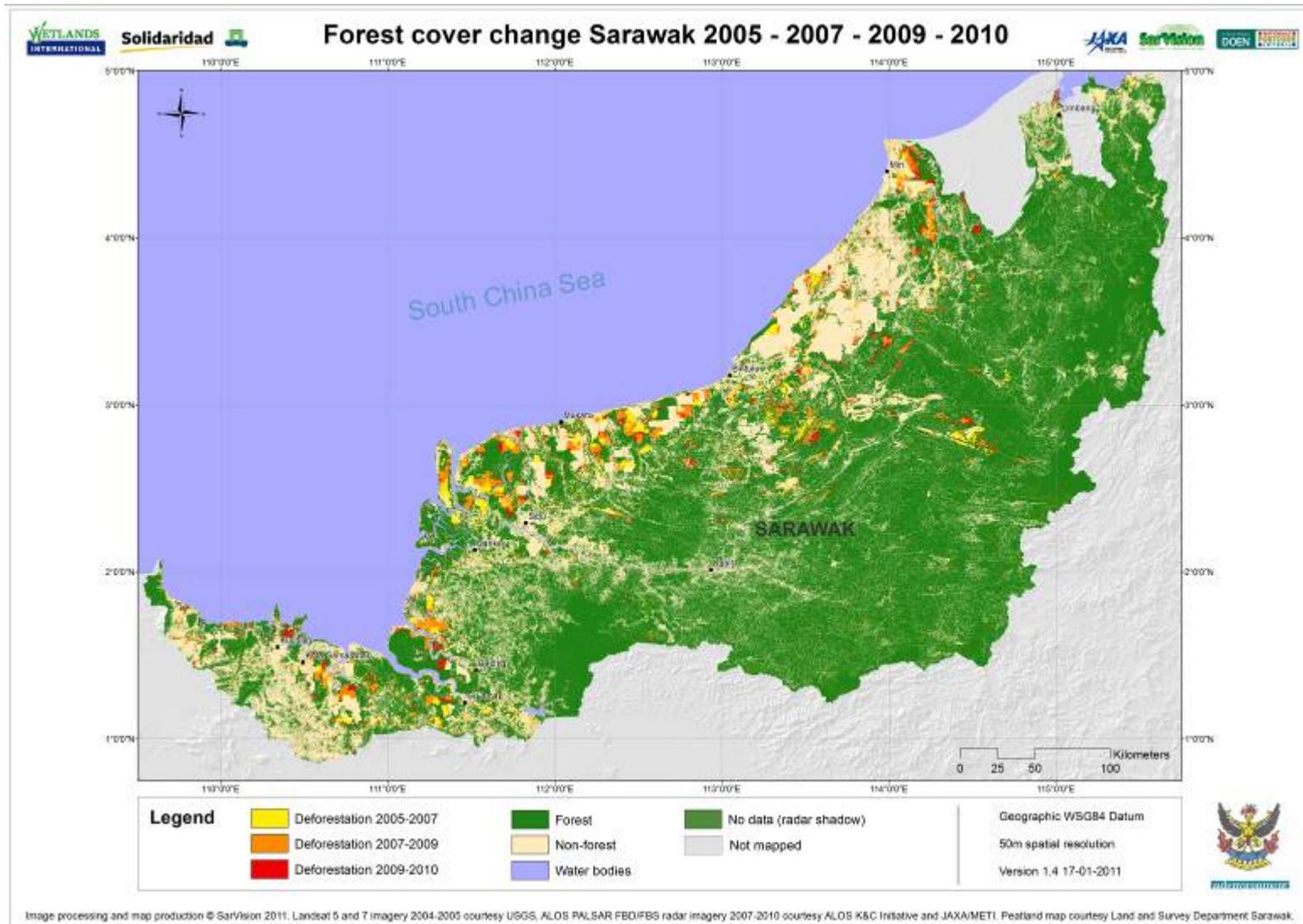
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<sup>4</sup> Miettinen, J., C. Shi, S.C. Liew, *Accepted article*. Deforestation rates in insular Southeast Asia between 2000 and 2010. *Global Change Biology*.



Additional calculations using the forest cover change, peatland, and oil palm concession boundary data show that:

- Of all the oil palm plantation areas in Sarawak we mapped so far, 44% are on peatland and 56% on other soils;
- Of all peatland area in Sarawak, 41% is covered by oil palm plantations;
- Of the oil palm plantation area we mapped located on peatlands, circa 171,000 hectare (27%) is still under (often degraded) forest cover, while the remainder has been cleared during 2005-2010 (36%) or was non-forest (37%). The non-forest class on peatland includes significant areas of oil palm plantation established before 2005;
- Of the deforestation on peat during 2005-2010, at least 65% could be attributed to the establishment of oil palm plantations (i.e. deforestation within the boundaries of known oil palm concessions available from EIA reports). This is a conservative figure as not all concession boundaries have been collected yet at the time of writing, and visual inspection shows more deforestation can be attributed to oil palm expansion.



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