Land Cover Assessment in Rimba Raya Restoration Concession Central Kalimantan, Indonesia

Technical Report submitted to Infinite Earth
February 5, 2010

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1. Executive Summary

A land cover assessment of Rimba Raya Restoration Concession was conducted January 2010 in order to provide baseline data for the project and to support the carbon assessment for the Project Design Document (PDD). A new classification scheme of 18 land use / land cover types was developed for Rimba Raya based on Ministry of Forestry classification but expanded to include more detailed and accurate types specific to Rimba Raya. Land cover mapping was accomplished following a two-part approach including remote sensing image classification techniques followed by image interpretation in GIS. In the first phase, pixel-based image classification was conducted to make use of spectral information in Landsat7 ETM+ bands that are sensitive to vegetation. The results of this classification provided important verification of broad land cover types such as forest, shrub and herb cover. In the second phase, land cover was interpreted and digitized using classified and original Landsat data in a GIS. Interpretation was therefore able to incorporate key ancillary data including aerial photos, survey data and other GIS data compiled for Rimba Raya, which substantially improved the classification.

Major findings of this land cover assessment are:

- Summarizing all forest classes, 41.2% of Rimba Raya remains forested with 33% total in peat swamp forest, dominated by the central contiguous forest block delineated in this and previous maps

- 25.8% of the Rimba Raya concession area consists of cleared land and oil palm plantation. Most of this conversion occurred between 2003 and 2008 and included areas of peat and kerangas vegetation types.

- Open sand-kerangas complexes, locally known as “padang” cover 17.2% of Rimba Raya and are prominent in the south and north. These areas include remnant kerangas forest but are mostly sparsely vegetated scrublands. These were misclassified by Ministry of Forestry’s regional mapping and have been updated

- In the northwest along the border between Rimba Raya and Tanjung Puting National Park, an estimated 4,294 ha of lowland forest still persists. This type is important for its high biodiversity. More than half of this has been degraded since 2003 as nearby areas were burned and cleared.

- Satellite image analysis indicates all Rimba Raya peat swamp forests have been degraded, especially by selective logging. Logging damage is visibly heavy in smaller patches of forest adjacent to open areas and oil palm plantation. In larger, more inaccessible forest blocks, light to moderate degradation varies unevenly.

- While human impact has had a massive impact on land cover in Rimba Raya, most subsistence activity is concentrated along the Seruyan River near villages. Only 2.4% of Rimba Raya land is in active or abandoned cultivation.

2. Introduction

Land use/land cover mapping provides the basis for land planning, assessment and management in a variety of contexts. Developed as a spatial database, land use/land cover maps provide information that can be easily analyzed, displayed and layered with other data in a Geographic Information System (GIS). The objective of this project is to develop a GIS-based land cover map that provides baseline information for the Rimba Raya Restoration Concession, Central Kalimantan, Indonesia.

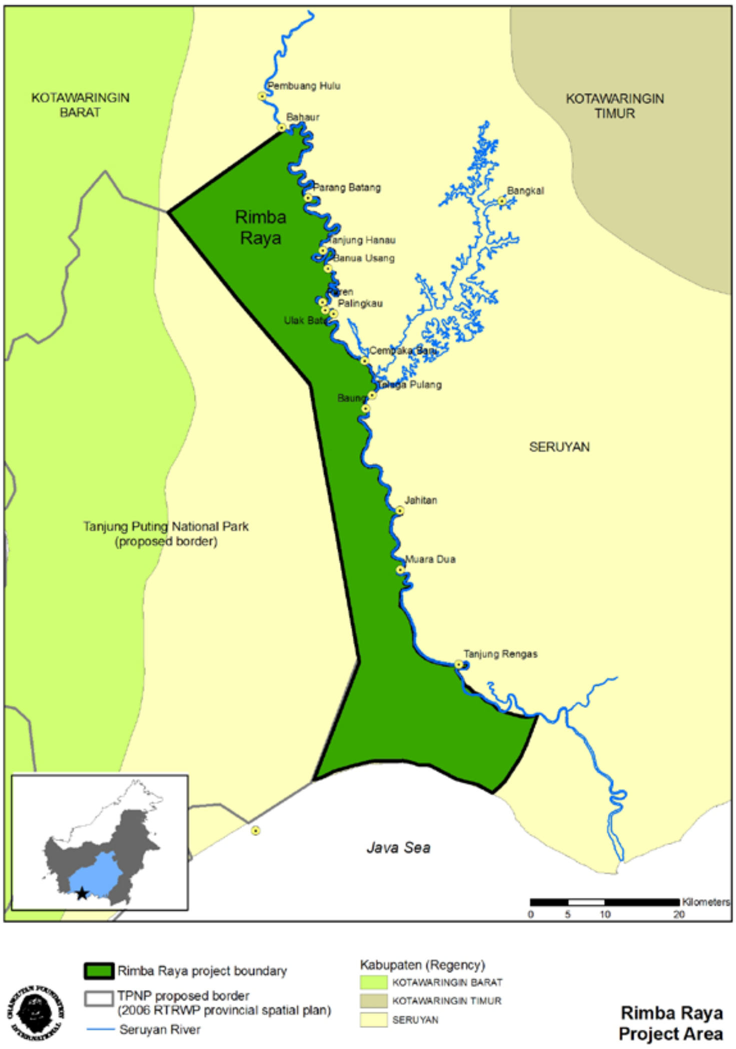
The Rimba Raya project, led by InfiniteEARTH, aims to protect forests and orangutans, mitigate climate change by protecting rich carbon stocks in Rimba Raya's peatlands, and provide new economic opportunities and community development in villages on the project border. The Rimba Raya climate, community and biodiversity (CCB) project represents an innovative approach in the emerging field of Reductions in Emissions from Deforestation and Degradation (REDD).

Land use/land cover mapping provides an essential component of project development, analysis, planning, communication and implementation. Land cover mapping was first conducted for Rimba Raya by Orangutan Foundation International (OFI), Forest Carbon Consultants and Sonokeling Forestry Consultants. These unpublished maps provided project participants with an initial understanding of the Rimba Raya area. Prior to these efforts, Rimba Raya land use/land cover was represented on publicly available maps compiled by the Ministry of Forestry at the regional scale for all of Indonesia.

Since the start of the Rimba Raya project, new survey and aerial data have been collected and land cover classification has been conducted to support project development. This land cover mapping project aims to make use of existing data to develop a more complete, accurate and useful land use/land cover map and spatial database for the Rimba Raya project. The current mapping effort is especially aimed at providing spatial land cover data for the Project Design Document (PDD) carbon assessment.

3. Study Area

The Rimba Raya proposed Restoration Concession covers an expanse of 101,000 hectares of tropical peatlands adjacent to Tanjung Puting National Park on the southern coast of Central Kalimantan (Figure 1).



Rimba Raya is dominated by low-lying peat swamps situated just inland of coastal mangroves in the far south and a thin strip of riverine forest on mineral soils flanking the Seruyan River. Rimba Raya peat swamps intergrade with narrow bands of heath forest, regionally known as "kerangas" and scrublands, locally known as "padang", scrub forest on sandy hillocks formed by relict beach ridges. Peat swamp forests in the project area have been degraded by selective hand-logging and burning, with several large recent fires converting much of the area to open swamp shrublands.

The Rimba Raya project area includes 12 villages and 11 sub-villages along the Seruyan River. Residents of these villages settled the area about a century ago and make their living primarily by fishing and farming. People have modified natural landscapes along the river and throughout the Rimba Raya region, especially by burning and hand logging valuable timber in peat swamplands. Extensive networks of logging canals have been built throughout the project area and though commercial logging has stopped, these canals still provide transportation routes to interior forests.

4. Existing Land Cover Maps

4.1 Ministry of Forestry Regional Mapping

The Ministry of (MoF) conducts land cover mapping for Indonesia about every five years based on visual interpretation and digitization of Landsat7 ETM+ imagery by technicians experienced in interpreting land cover for Indonesia. These maps provide the most current official land cover mapping available from the Indonesian government.

The land cover/land use classification used by MoF provides the most-widely used classification system by land managers in Indonesia. The MoF scheme consists of 21 broad classes of forest and non-forest vegetation, agriculture and other human land use activities prevalent in the Indonesian landscape. (Table 1)

Table 1. Ministry of Forestry Land Use / Land Cover Classification Scheme

Class Name (English)	Class Name (Indonesian)	Symbol	Code
Primary dry land forest	Hutan lahan kering primer	Hp	2001
Secondary dry land forest	Hutan lahan kering sekunder	Hs	2002
Primary swamp forest	Hutan rawa primer	Hrp	2005
Secondary swamp forest	Hutan rawa sekunder	Hrs	20051
Primary mangrove forest	Hutan mangrove primer	Hmp	2004
Secondary mangrove forest	Hutan mangrove sekunder	Hms	20041
Shrubland	Semak / belukar	B	2007
Swamp shrubland	Semak / belukar rawa	Br	20071
Savannah	Savanna	S	3000
Timber plantation	HTI	Ht	2006
Crop plantation	Perkebunan	Pk	2010
Dry cultivation land	Pertanian lahan kering	Pt	20091
Dry cultivation land with shrub	Pertanian lahan kering dengan semak	Pc	20092
Transmigration area	Transmigrasi	Tr	20093
Rice land	Sawah	Sw	20093
Fish pond	Tambak	Tm	20094
Bare land	Tanah terbuka	T	2014
Mining	Pertambangan	Tb	20141
Built-up area / Housing	Permukiman	Pm	2012
Water body	Tubuh air	A	5001
Swamp	Rawa	Rw	50011
Cloud	Awan	Aw	2500

Reproduced from: Baplan Dep Hut, 2001 / National Forest Inventory, 2001

The most recent MoF land cover map, based on 2002-2003 imagery and published in 2005, was obtained for Central Kalimantan. As the Ministry of Forestry does not currently distribute this information through a data clearinghouse, land cover information was obtained through several NGOs working with Orangutan Foundation International and InfiniteEARTH. Data include the GIS shapefile of 2003 landcover, a description of MoF land cover classes and a jpeg map of land cover published by MoF which confirms the authorship and date of the GIS file and classification.

The following map shows MoF land use / land cover mapping for Rimba Raya (Figure 2). (Note the colors map to the same or similar classes in the new land cover classification shown in the results section.) Based on MoF mapping, Rimba Raya is almost entirely comprised of swamp. Most forested areas are designated secondary peat swamp forest, shrublands are swamp shrublands and deforested areas with little or no vegetation are designated as [open] swamp.

Despite misclassification, delineated boundaries in MoF mapping are consistent with those delineated by this and other landcover mapping efforts. That is, differences in broad land cover types are easy to see and digitize, but class assignments are more difficult to make and are dependent on the project-specific context of land use and land cover.

4.2 Project-level mapping efforts

In 2008, OFI extended their land cover mapping of the Greater TPNP area to include the park buffer, which was later proposed as the Rimba Raya Restoration Concession. This land cover classification was based on multi-spectral SPOT imagery, using raster-based analysis of band thresholds to differentiate forest and non-forest and unsupervised classification of forest. This provided an initial test of image classification for Rimba Raya. In this assessment, automated pixel-based analysis performed well to differentiate forest from non-forest. Forest type was accurately classified at the broad level but dry ground classes remained confused. Note that Ministry of Forestry mapping groups dry land and peat swamp forest types as these broad classes are the most easily discriminated in both visual interpretation and automatic classification of multispectral imagery.

In 2009, two project consultants for Rimba Raya, Forest Carbon Consultants and Sonokeling Forest Consultants, produced land cover maps for baseline project assessments. Both efforts relied on interpretation of available Landsat imagery, Ministry of Forestry land cover mapping and expert knowledge of land cover / land use types in Kalimantan peatlands. These independent efforts produced similar results in land cover type delineation, with most boundary variation related to the scale of analysis and differences in the level of detail in the classification system used. Differences in map attributes were related to differentiating forest and shrubland types and assigning labels to mixed land use types in human-dominated environments.

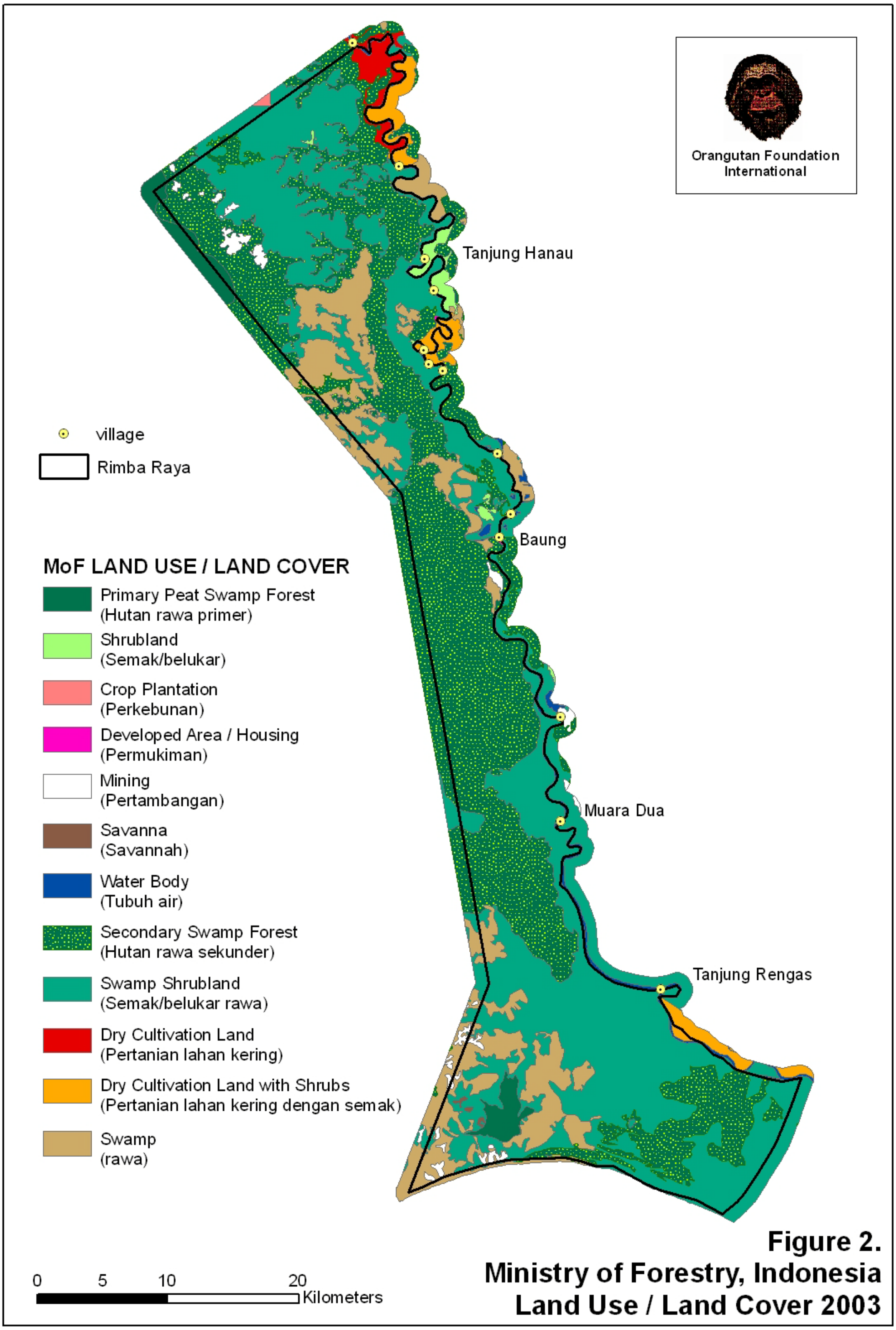


Figure 2.
Ministry of Forestry, Indonesia
Land Use / Land Cover 2003

5. Remote Sensing Analysis and Data

5.1 Satellite Image Analysis for Land Cover Mapping

Multispectral sensors, carried by a number of government and privately-operated satellites, record electromagnetic radiation (EMR) from the ground in wavelengths that are particularly well-suited to land cover mapping. EMR data are stored in bands of information for each pixel in the image. Land cover classification is typically carried out using visible, near-infrared, short-wave infrared and thermal bands which have characteristic responses to vegetation, bare soils, water and urban areas. For example plants absorb EMR in the red band wavelengths and are reflective in the near-infrared (NIR) such that calculating vegetation indices based on these bands can provide robust estimations of vegetative cover for all pixels across an image scene. This type of analysis provides the basis for land cover classification and mapping.

The main advantages of using a remote sensing approach to land cover mapping, is that this provides a fast, systematic, quantitative method for classifying land cover across broad areas. In Indonesia, where many areas are inaccessible and few sources of spatial data exist, remote sensing for land cover assessment has become an essential resource for land management agencies.

One of the main problems with optical sensor data in Indonesia and elsewhere in the tropics is that prevalent cloud-cover severely reduces data quality. Radar data collected by remote sensors is impervious to cloud clover and is becoming more widely available and readily useable. The disadvantage to using radar data is that these bands lack vegetation-specific information and visual interpretation is not as intuitive as optical band data. Radar data has recently become available for Rimba Raya and will be tested for land cover assessment in the future.

Among optical sensors, medium and high spatial resolution data can be used for land cover analysis. Spatial resolution determines the level of detail that can be captured from the ground, where image pixel size represents the sensor's instantaneous field of view (IFOV).

5.2 Satellite Image Review and Selection

Medium resolution sensors including AVHRR (1 km) and MODIS (250 and 500m) are available for download and were previously reviewed for Rimba Raya. These datasets have the advantage of being collected every 1-2 days, which increases the probability of obtaining scenes with minimal cloud and haze. However, their relatively coarse spatial scale is not suitable for more detailed land cover classification especially in the complex human-disturbed landscape of Rimba Raya, where ground features vary at a fine scale.

High-resolution sensors SPOT4/5 (20/10m) and Landsat ETM+ (30m) provide better spatial detail for project-level land cover assessments. Available data from these sensors were previously compiled and reviewed for the Rimba Raya land cover assessment.

SPOT4 2005 and SPOT5 2008 data are available for greater Tanjung Puting National Park including Rimba Raya. However, the SPOT sensor swath, or extent of ground data capture per pass, is relatively small compared to Landsat, therefore multiple scenes are needed to cover the Rimba Raya project area. The 2005 dataset was relatively cloud-free but missing a scene in the southern portion of the project area. The 2008 data set had complete coverage of the project area but four of the five scenes had significant cloud and haze cover. Poor results from a preliminary land cover classification performed using this dataset indicated that this SPOT dataset does not provide an adequate basis for land cover mapping.

The entire Landsat data archive is available for free through the U.S. Geological Survey (USGS) online clearinghouse, and Landsat scenes for 2001-2009 were selected, downloaded and processed for Rimba Raya for a previous project. A single Landsat scene covers Rimba Raya, so scene mosaicking is not required and there is full coverage of the project area. The main disadvantage of Landsat sensor data is the Scan-Line Corrector (SLC) malfunction that unexpectedly occurred in May 2003. Since that time the sensor has returned image data missing lines of pixels across imagery. These data gaps limit land cover visualization, especially on hardcopy maps, as images appear with black “no data” stripes across scenes. Post-2003 data (termed “SLC-OFF” data) still provide useful land cover information for image analysis and manual delineation of land cover within a GIS where data can be layered and view scale zoomed to improve interpretation.

For Rimba Raya, the April 2003 Landsat image provides full data coverage of the project area in a nearly cloud-free scene. Of the more current SLC-OFF datasets, the January 2008 scene provides the most cloud-free view of the ground. Given the objectives of the land cover assessment, these two images were selected for analysis and mapping.

6. Materials: Data and Software

6.1 Landsat Imagery

The April 2003 Landsat scene provided a remarkably clear view of ground conditions in Rimba Raya and provides the best basis for image classification and interpretation for the project. Because land cover change has occurred since 2003, the more recent January 2008 image provided the basis for updating 2003 land cover boundaries and attributes. Full 7-band imagery was used in pixel-based image classification. Both the full-band imagery and the classified image were saved as geotiff files for use in GIS. Bands 7, 5 and 3 of the full-band imagery were assigned to the RGB color display in the geotiff file to highlight human disturbance in natural vegetation. The classified image was saved with unique color mapping assigned to classes representing broad land cover types.

6.2 Aerial imagery

Aerial imagery was flown for a large portion of Rimba Raya by Forest Carbon Consultants July-August 2009. These geo-referenced images provide a clear and detailed view of land cover with a ground footprint of 900 x 900 meters. 130 of these aerial photos were selected across varied land cover conditions to provide ground reference data for image interpretation. A GIS shapefile of aerial photo locations was used to catalog selected photos and make them more readily accessible during the map interpretation GIS session.

6.3 Field Survey and Ancillary GIS Data

Field survey data also provided important ground reference data for image interpretation. GPS field data from OFI expeditions in 2004 and 2005 and Infinite Earth surveys in 2009, compiled as ArcGIS shapefiles were used to support map interpretation. Ancillary GIS data from OFI including locations of villages, rivers, roads, canals, logging access points and guard posts were also used.

6.4 Software

Image review, analysis and classification were performed in ENVI 4.7 software. Results of classification were saved as geotiff images for use in GIS. Land cover interpretation, delineation and attributing were performed in ArcGIS 9.3. An open ENVI window was used during edit sessions to check spectral characteristics of land cover as needed and confirm map interpretations.

7. Methods

7.1 Approach

Previous models of land cover classification were reviewed, improved and tested at the project start. Decision-tree models based on band thresholds performed well in detecting cloud, shadow, water and bare ground and in classifying remaining land cover into broad types such as forest, non-forest and cleared land. However, these models could not accurately produce more detailed class mapping such as differentiating dry ground forest types or correctly assigning classes to land cover modified by human activity. While these objects could be visually interpreted from imagery, they could not be adequately captured by pixel-based classification. Therefore land cover mapping relied first on automated classification of broad categories, then on visual interpretation for more detailed class delineation and assignment. This approach allowed more direct use of multiple data sources to make decisions about land cover classification, which produced a more accurate map than could have been obtained from a fully-automated process.

7.2 Land Cover Types in Rimba Raya

A land cover and land use classification system should be project-specific so that it provides useful and relevant information to project participants while remaining consistent with regional and national land cover classification schemes. There is no national land cover classification scheme for Indonesia, but the Ministry of Forestry’s LULC classification is widely used and broadly applicable at the project-level. The MoF scheme therefore provided a good basis for land cover classification at Rimba Raya.

The Rimba Raya land use / land cover classification (Table 2) expands on the MoF scheme to include more detailed dry land forest types and more specificity about the level of forest degradation. Forest type and level of degradation affects biomass and carbon and provides the basis for biological conservation and human resource development, which are key components of the Rimba Raya project, so these classes are important to include in the Rimba Raya classification scheme. Many class names were also modified to reflect the project context, while still retaining their relationship to MoF classes.

Table 2. Rimba Raya Land Use / Land Cover Classes

Class Name	Description
Lowland forest	Lowland dipterocarp forest on mineral soils. This is a “dry land” type and is found primarily in the northwest.
Lowland forest degraded	Lowland dipterocarp forest on mineral soils with some apparent logging damage, adjacent to lowland forest. Note that the term “degraded” is used rather than the term “secondary” which implies forest succession from clear-cutting.
Peat swamp forest degraded (light to moderate)	Peat swamp forest, locally “rawa” denoting peat substrate. All peat swamp forests in Rimba Raya appear to be lightly to moderately degraded by logging and fire.

Peat swamp forest heavily degraded	Peat swamp forest patches bordering areas of intensive human activity. Heavily degraded and at high risk of loss.
Peat shrublands	Formerly peat swamp forests, these areas were deforested by fire. Dense, shrubby growth and scattered trees, seasonally wet.
Seasonally inundated wetlands	Locally “danau” or seasonal lake, most of these areas were formerly peat swamp forests that have been logged and burned. Where these are adjacent to rivers, flooding may be semi-permanent
River and coastal forest	Narrow patches of forest along the Seruyan probably on mineral or mixed soils. One small patch of mangrove in the south was detected.
Heath forest	Rich tropical heath forest on predominantly sand soils, similar biomass to degraded peat and lowland forest. Mixed species composition including lowland, swamp and heath forest types. Small isolated patches. Perhaps more prevalent in the past but may convert to kerangas forest or open scrub when burned.
Kerangas forest	Dense scrub forest on sand soils. Air photos show even height, loose canopies lacking the broad leaves of peat and lowland forest. Visually distinct on satellite imagery, smooth in texture, but may be confused with peat swamp forest so prevalent in Rimba Raya.
Kerangas scrub	Open scrub forest, intermediate between kerangas forest and open sand scrub, seen in the south.
Open sand scrub	Open sand soils with thin scrubby vegetation, locally known as “padang”. These may be former heath or kerangas forests that have burned. Bright white sand may be apparent on imagery, or not depending on whether herb cover is present. These ancient beach areas intergrade with peatland areas in Rimba Raya.
Dry shrublands	Woody shrubs, scattered trees on dry ground, probably deforested by fire. This area is mapped in the south between kerangas and peat swamp. Its former forest (and soil) type is unknown.

Cleared land	This class is applied to currently grass-dominated areas that have been recently burned, but lie outside cultivation lands. Large areas of peat swamp forest lost in 2006 are currently classed as “cleared land” but unlike the repeatedly burned cultivated lands, former forests may begin regenerating
Cultivated land with shrubs	Repeatedly burned cultivation land, locally “lading”, often abandoned after several years of cultivation. Old lading often has woody shrubs and scattered, slow-growing trees
Cultivated land	Repeatedly burned, active cultivation land. May appear bright green on imagery from new post-fire herbaceous growth
Cultivated crop plantation	At Rimba Raya this class refers to oil palm plantation which is currently confined to the KUCC concession in the north
Bare ground	Non-vegetated area, often from recent burn in a variety of vegetation types. Also bare soil areas of open sand scrub may be classified as bare ground.
Open water	Deep water with no vegetation, especially on or near the Seruyan River and lower reaches of the Baung River

7.3 Pixel-based Image Classification

Several automated classification algorithms were tested to provide the most informative basis for land cover interpretation. The simplest algorithm (tested last) with a small number of classes specified proved to be the best at separating the most important land cover types without introducing significant misclassifications. An unsupervised classification, which classifies pixels based on their statistical separation, was performed on Landsat7 ETM+ 2003 subset to the Rimba Raya region. The isodata algorithm was used on spectral bands 5,4,3 with 8-10 classes specified. Color mapping and labels were assigned to classes and exported as a geotiff file for use in ArcGIS software. The raw image, displayed with RGB bands 7,5,3 highlighted human disturbance in vegetation and was also saved as a geotiff for use in map interpretation.

7.4 Image Interpretation and Attributing

An ArcGIS ArcMap edit session was used to display vector and raster spatial data and create the landcover map. The Ministry of Forestry data was used as the basis for polygon delineation to make use of their experience in land cover/land use mapping in Indonesia, especially map interpretations in human-dominated landscapes. In order to eliminate confusion and improve interpretation in project border areas, the Rimba Raya project boundary was buffered by 1 kilometer and used as the land cover mapping boundary. The resulting land cover classification was clipped to the Rimba Raya project boundary for subsequent analysis. The Ministry of Forestry data was subset to the buffered Rimba Raya project boundary and these landcover polygon outlines were drawn on top of image data. Ancillary spatial data were added to the map to provide orientation including rivers, villages, roads, canals, logging access points and survey transect locations. Aerial photo location point data was added so image data could be queried, added and viewed as needed. Similarly, compiled GPS data from previous field surveys were added to the project and activated as necessary to interpret landcover in some areas. A minimum mapping unit was set to 250m x 250m or 6.25 hectares (roughly 9x9 pixels) to ensure consistently detailed mapping across types throughout the project area.

Edits proceeded polygon by polygon within an area, viewing all data necessary, making an interpretation of landcover, modifying polygon boundaries as needed and assigning class types. In many cases, original polygon delineations followed my visual interpretation as MoF technicians likely used the same Landsat image for mapping. Given the more detailed classification system for this project, original polygons were often split to reflect more refined class assignments. For example MoF dry land forest was reclassed into three new types which required original polygons to be divided and new polygons created. The scale of this analysis was also somewhat finer than the regional MoF mapping, so smaller patches of landcover were delineated that did not exist in MoF mapping.

Map attributing followed digitization with land cover codes added to the attribute table for each polygon record. Image classification and ancillary data played a key role in label assignments as interpreting raw imagery alone could lead to misclassification. For example, dense green vegetation cover could appear to be shrubs rather than grasslands based on the raw image alone, but the structure of vegetation could be confirmed by classification. This was especially important in areas where recent or repeated burns had changed the character of vegetation from what might otherwise be expected in similar peatland landscapes.

Survey data and field experience were essential for interpreting even prevalent landcover types and led to several important reassignments from original MoF mapping. For example open sand scrub, locally known as "padang" is situated in a complex mosaic of peat swamp forests at Rimba Raya and was therefore misclassified by MoF mapping as swamp. Another example is the absence of lowland forest in the MoF mapping. In other Central Kalimantan peatland areas, such as Sebangau to the east, there is no lowland forest, so it follows that MoF technicians may have assumed all forest in the Rimba Raya area was peat. However, in Rimba Raya, where elevations rise slightly to the northwest there are several patches of lowland forest which lie along the border of Rimba Raya and extend into Tanjung Puting National Park. These areas were reclassified in the new land cover map.

Aerial data provided essential data for reconfirming and extending field knowledge, especially in less-familiar areas such as the far south. Here, remnant scrub forest (regionally known as "kerangas") remained in the treeless open scrub complex prevalent in northern Rimba Raya and Tanjung Puting. Given the peatland context of the region, these forest patches appearing in the Landsat image were misclassified in MoF mapping as peat swamp forest. Aerial photos confirmed sandy soils and very different canopy architecture in these southern scrub forests. Reexamination of raw imagery confirmed slight texture and color difference between these forests (which appeared smooth and olive-colored) compared to peat swamp. These slight differences were not picked up by automated classification and even with careful visual interpretation, classification would have been more difficult without aerial photos.

As new types were encountered that fell outside the original classification system, such as mangrove and riverine forest, unique values were added to the table with land cover descriptions. After the entire map was classified, these new classes were reviewed, combined and added to the classification.

7.5 Map Edits and Validation

After the 2003 mapping was completed, class boundaries and attributes were rechecked against both raw and classified image data for each polygon and adjusted as necessary. The final version of the 2003 map was then copied to a new 2008 file. This map was displayed with 2008 Landsat imagery and interpretation was repeated to search for land cover changes. Forest clearing, especially by fire, was the most prevalent change detected. In each case, polygon boundaries were modified and attributes reassigned to new land cover types. The 2008 data set had some cloud and haze cover which reduced visual interpretation somewhat but confusion was reduced substantially by having a complete classification already in place and searching only for land cover in the image that did not match delineated boundaries. Land cover change was easily detected by this process and the classification task made much simpler. This approach made the best use of excellent quality Landsat data in 2003 while producing a more current landcover map.

The second complete pass of the entire classified map using 2008 imagery enabled boundary delineation and classification to be confirmed. In some cases, questionable polygon assignments were revealed and reviewed. Final map validation was reviewed with both raw and classified image data sets. Table records were also reviewed for consistent class names and duplicate polygons. Xtools Pro was used to calculate areas (ha) for all polygons, then all polygons <6 hectares in size were examined. Some of these were "slivers" created as part of the digitizing process and were eliminated by merging each with an adjacent polygon. Others were small, but real land cover polygons on the analysis border that had been clipped from the original MoF dataset. Of these, polygons <2 hectares in size were merged with polygons in the project area.

Following fine-scale polygon rechecks and table updates, color mapping was applied to classes to provide a final broad confirmation of the land cover map classification. Checks against MoF and other land cover mapping were performed to confirm classification in large polygons, especially where class reassignments had been made.

8. Results and Discussion

8.1 Land cover map

The resulting land use / land cover map for Rimba Raya (Figure 3) shows similar delineations of major forest blocks compared to MoF and previous project mapping efforts. The following list highlights major updates in this land use / land cover classification

- The central block of peat swamp forest follows the delineation of MoF 2003 mapping except where major fires in 2006 deforested a significant area west of Tanjung Rengas. This area is now classified as “cleared”.
- The open sand-kerangas complexes in the south and north have been reclassified from MoF “swamp” classes and delineation slightly more detailed
- Peat swamp forests in the south have been reclassified as kerangas and other river and coastal forest.
- In the northwest along the Rimba Raya border, peat swamp forest was reclassified as lowland and degraded lowland forest.
- Extensive areas of MoF peat shrublands have been reclassified as “dry shrublands” where no water is present and as “cleared” where no or few shrubs are present.
- Palm oil plantation has converted all former MoF land cover classes within the KUCC concession in the north.
- Other land cover change associated with this palm oil development is additional cleared areas and degradation in the lowland forest, not seen in 2003.

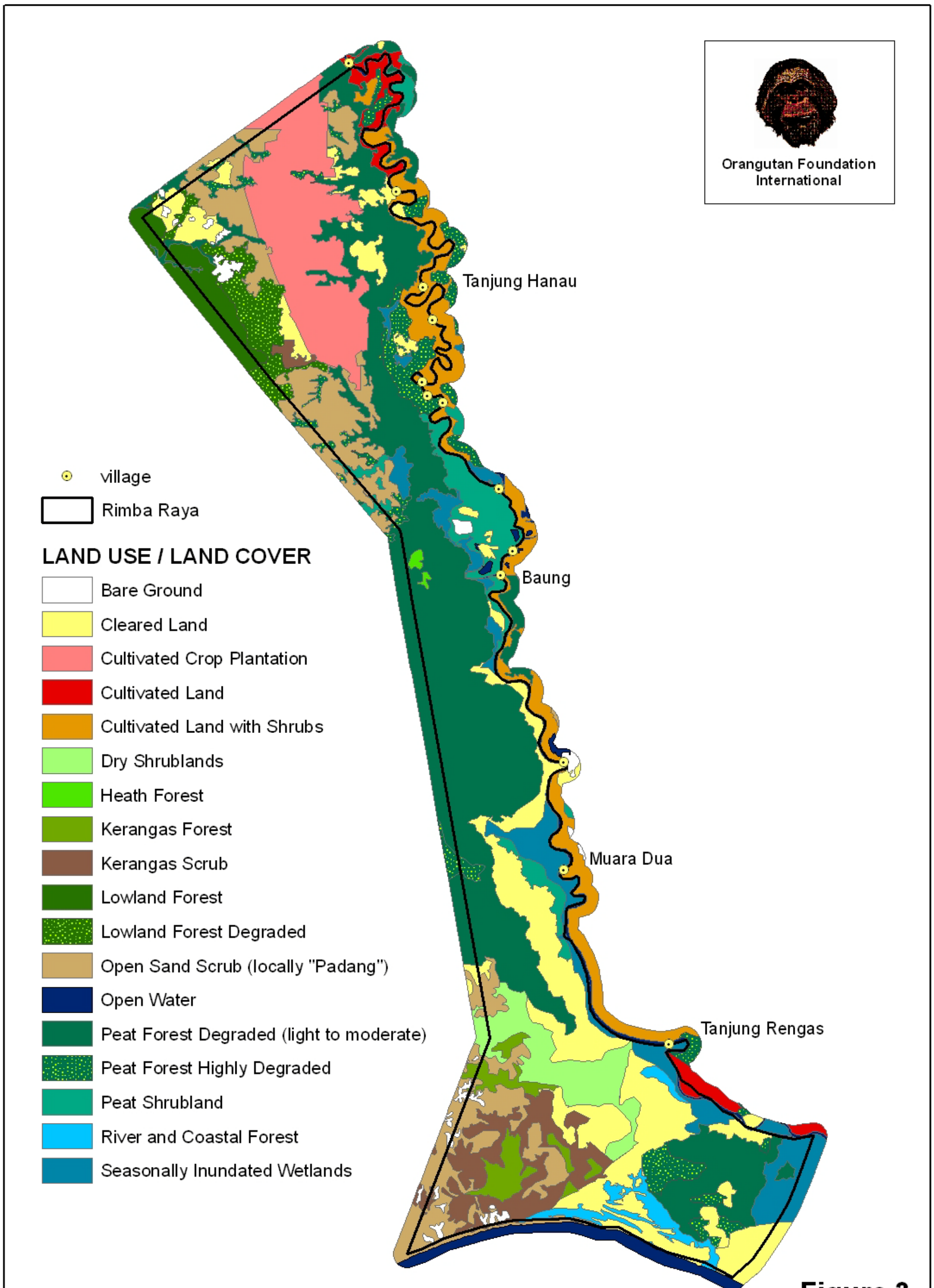


**Figure 3.
Land Use/Land Cover
Updated Mapping 2010**

8.2 Land Cover in Rimba Raya

Rimba Raya is dominated by peatland forests, shrublands and open swamps and large forest blocks remain in the central portion of the project. Most Rimba Raya peat forests have been impacted by logging activities. Extensive logging rails and canals built within the past 20 years are still clearly visible on Landsat imagery even with its 30m pixel resolution. Logging damage appears in and around these logging routes as deforested pixels but it is difficult to assess the extent of this damage or the level of logging that took place from satellite imagery alone. Field surveys for the carbon assessment recorded a range of forest biomass estimations across 14 hectares of lightly to moderately logged forest in transects distributed across the project area. Heavier logging damage and reduced biomass is likely associated with accessibility, logging duration and intensity. Currently, spatial data for logging damage do not exist for Rimba Raya so image-based map classification remains general (i.e. “lightly to moderately logged) for the entire forest area.

Biologically important lowland forest blocks remain in the northwest corner of the project bordering Tanjung Puting National Park near the Tanjung Hanau orangutan release site which is situated in peat swamp forest. Other small patches of lowland forest may exist in the northern and western areas of Rimba Raya where there is slight elevation gain, but these small patches are difficult to detect within peatland forest. The patch of lowland forest encountered during the carbon assessment survey is visible on the imagery at transect T1 but its size falls below the 6.25 hectare minimum mapping unit for this classification.

Scrub forest on sandy soils, or kerangas forest, is present in the southern part of Rimba Raya within a large complex of open scrubland. This same scrubland, dominated by sparse shrubs and small trees once dominated the northern parts of Rimba Raya, but much of this has been converted to oil palm plantation.

Human activities have given rise to a complex mosaic of non-forest land cover along the Seruyan River. Vast expanses of Rimba Raya forest, extending far beyond village boundaries, have been cleared in the recent past by deliberately set fires. These fires are set in part to clear land for agriculture and recent image analysis for the region shows these are strongly associated with rapid land conversion to palm oil in the region. In Rimba Raya the northernmost of five oil palm concessions planned for Rimba Raya, KUCC, has completely replaced more than 10,000 hectares of natural vegetation within its boundaries since 2003.

8.3 Land Cover Summary Statistics

Areas of the mapped classes were calculated in GIS and summarized in Table 3. Summarizing all forest classes, 41.2% of Rimba Raya remains forested with 33% total in peat swamp forest. An additional 9.4% of the area comprised of peat shrub and flooded areas was most likely under peat swamp forest cover some years ago. 25.8% of the Rimba Raya concession area consists of cleared land and oil palm plantation. Most of this conversion occurred between 2003 and 2008 and included areas of peat and sand vegetation types. 17.2% of land cover in Rimba Raya is part of a kerangas complex which is dominated by sparse shrubs on open sandy soils. While human impact has had a massive impact on land cover in Rimba Raya, most subsistence activity is concentrated along the Seruyan River near villages. Only 2.4% of Rimba Raya land is in active or abandoned cultivation.

Table 3. Summary of Map Classification Areas

Land Cover / Land Use Class	Hectares	Percent
Bare Ground	925.6	0.9
Cleared Land	16664.4	16.0
Cultivated Crop Plantation	10145.7	9.8
Cultivated Land	978.8	0.9
Cultivated Land with Shrubs	1553.2	1.5
Dry Shrublands	4195.1	4.0
Heath Forest	172.0	0.2
Kerangas Forest	2253.4	2.2
Kerangas Scrub	5016.6	4.8
Lowland Forest	1494.3	1.4
Lowland Forest Degraded	2800.9	2.7
Open Sand Scrub (locally "Padang")	10610.0	10.2
Open Water	1191.8	1.1
Peat Forest Degraded (light to moderate)	29669.5	28.5
Peat Forest Highly Degraded	4657.4	4.5
Peat Shrubland	3983.6	3.8
River and Coastal Forest	1844.9	1.8
Seasonally Inundated Wetlands	5827.1	5.6
Grand Total (inside GIS boundary)	103984.2	100.0

9. Conclusion

The objective of this project was to develop a GIS-based land use / land cover map that updates existing mapping and provides baseline information for Rimba Raya, especially to support analyses of the Project Design Document (PDD). In Rimba Raya seasonal flooding, a complex history of fire, logging and ongoing human activities in villages along the Seruyan and throughout Rimba Raya's interior, have created a diverse mosaic of land use and land cover. A combined remote sensing and GIS approach proved to be the most successful way to accurately interpret and map these complex features.

Accurate spatial data for land cover and land use classification is a key component for land planning, project development, implementation and management. This assessment demonstrated that project-specific mapping provides a more accurate and relevant spatial database for supporting baseline assessments for Rimba Raya compared to regional mapping. But the current mapping effort is also meant to be a starting point for future and continued land cover assessment. Land cover is dynamic, and finer-scale mapping will be required for specific work within Rimba Raya as the project develops. It is hoped that information from this mapping assessment will provide a basis for improving, updating and detailing land cover classification in Rimba Raya in the future.